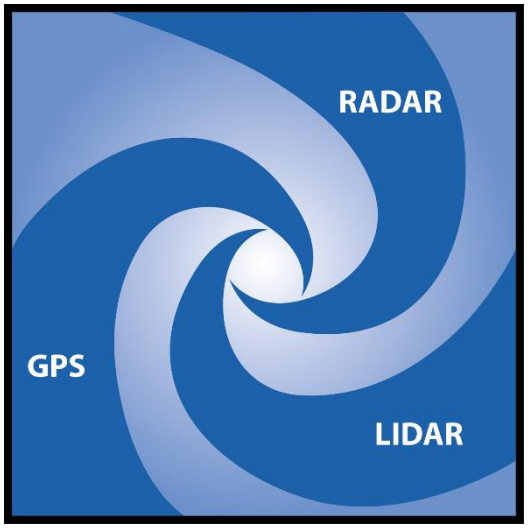
Multi-Source Sensor Fusion for Small Unmanned Aircraft Systems Using Fuzzy Logic



Brandon Cook
NASA Ames Research Center & University of Cincinnati

Dr. Kelly Cohen
University of Cincinnati

Motivation

- As small Unmanned Aircraft System (sUAS) applications proliferate we will see an increase in airspace congestion

- Must accurately estimate sUAS locations
  - Can move/maneuver quickly
  - Vulnerable to wind gusts
  - Operate beyond visual line-of-sight (BVLOS)
  - Identify/track rogue or non-conformant vehicles

http://www.profitguide.com/industry-focus/technology/is-canada-ready-for-drones-70777

- Given multiple sensor readings, which should we trust?

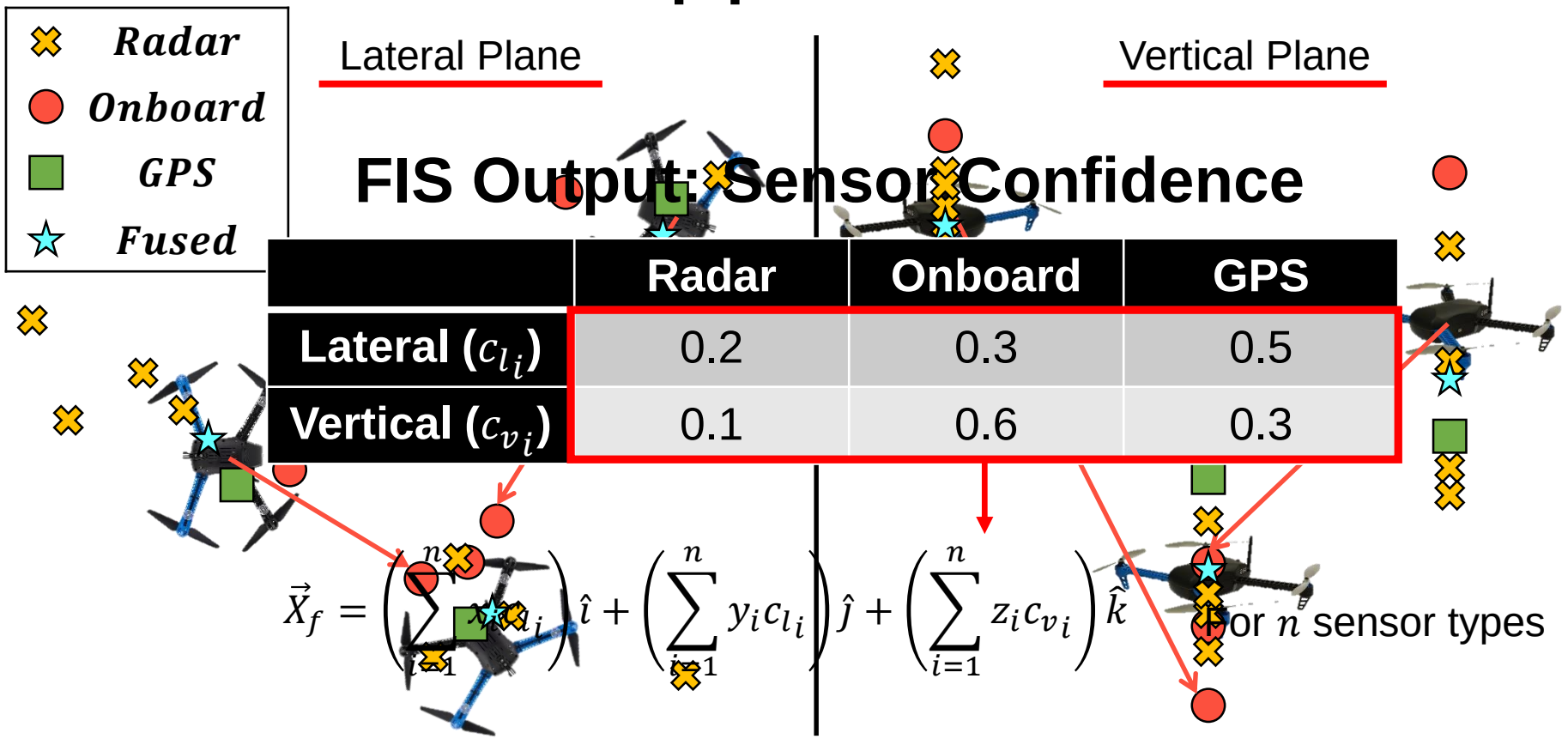
Outline

- Research Objectives
- Proposed Solution
- Testing Environment
- Results
- Conclusions
- Future Work

Research Objectives

- Develop a sensor fusion system using Fuzzy Logic and Maximum a Posteriori (MAP) estimations
  - Adaptive to available sensor types
  - Adaptive to sensor performance
- Test system using various sensor type combinations (GPS, Radar, and Onboard)
- Improve sUAS location estimation when compared to raw measurement values

Approach



FIS Output: Sensor Confidence

	Radar	Onboard	GPS
Lateral (c_{l_i})	0.2	0.3	0.5
Vertical (c_{v_i})	0.1	0.6	0.3

$$\vec{X}_f = \left(\sum_{i=1}^{n} x_i c_{l_i}\right)\hat{\imath} + \left(\sum_{i=1}^{n} y_i c_{l_i}\right)\hat{\jmath} + \left(\sum_{i=1}^{n} z_i c_{v_i}\right)\hat{k}$$

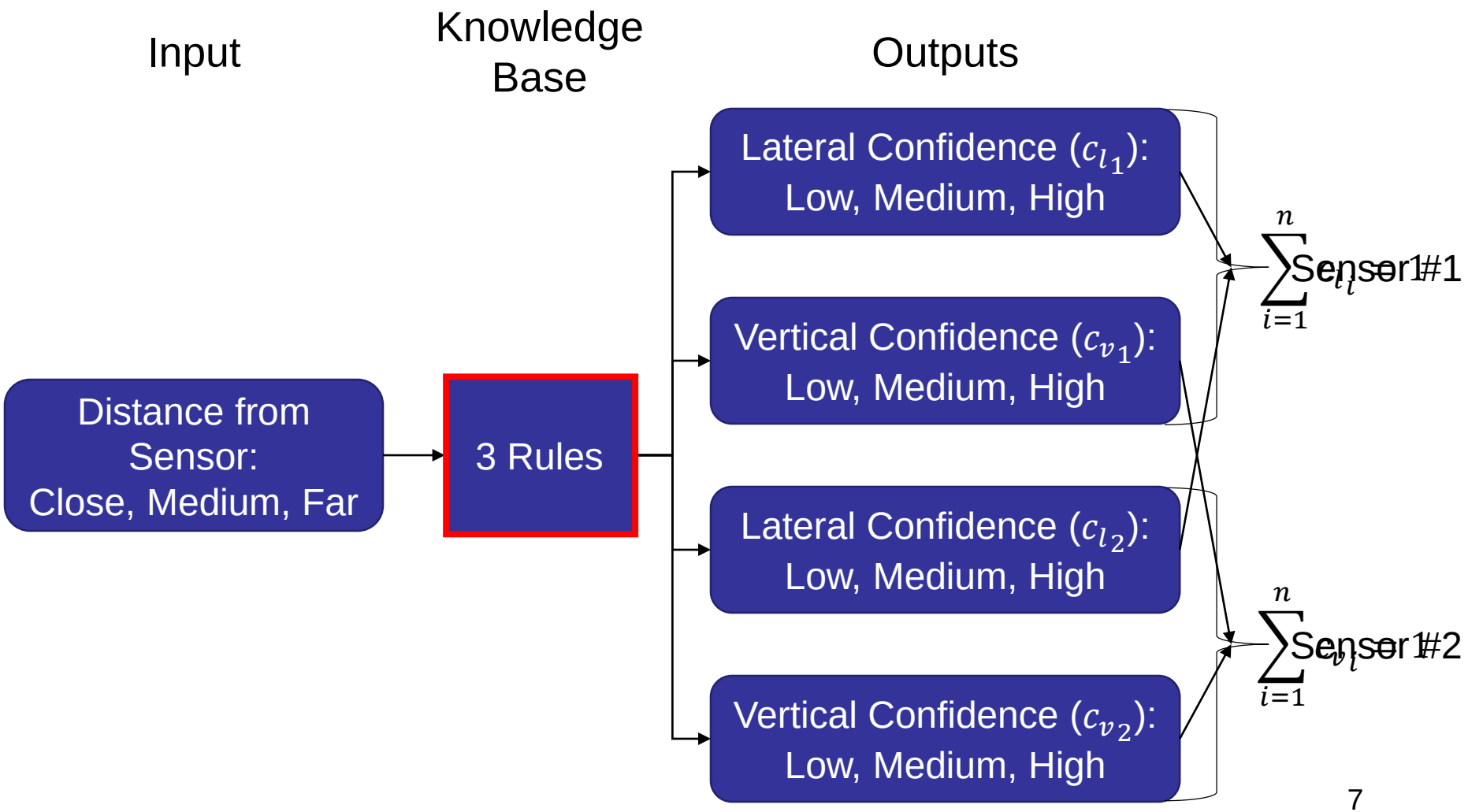
for n sensor types

1. Find MAP estimation for each vehicle for each sensor type
2. Parse 3-dimensional values into lateral and vertical planes
3. Use Fuzzy Inference System (FIS) to determine sensor type confidence for each plane
4. Calculate final position estimate using weighted average

Fuzzy Inference Systems

- 3 FISs developed for sensor type combinations:
  - Radar and GPS
  - Radar and Onboard
  - Radar, Onboard, and GPS
- FISs calculate each sensor's confidence in both lateral and vertical planes
- Single-input-four-output structure
  - Normalized inputs and outputs

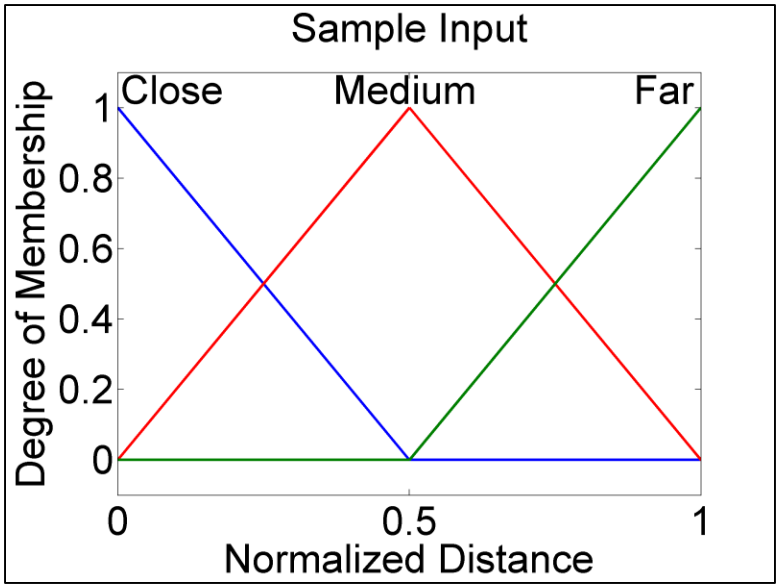
FIS Structure

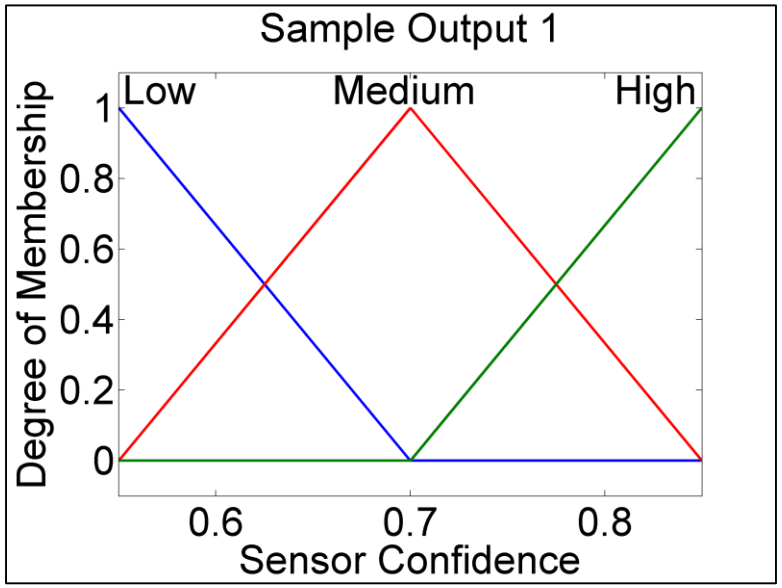


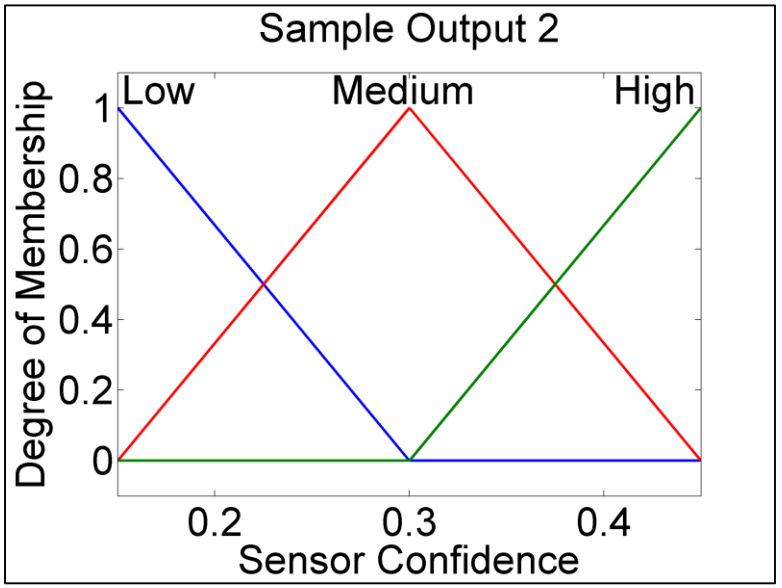
FIS Example Rule Base

	Input	Outputs			
		Lateral		Vertical	
Rule #	Distance	GPS	Radar	GPS	Radar
1	Close	Low	High	Low	High
2	Med	Med	Med	Med	Med
3	Far	High	Low	High	Low

FIS Example Membership Functions





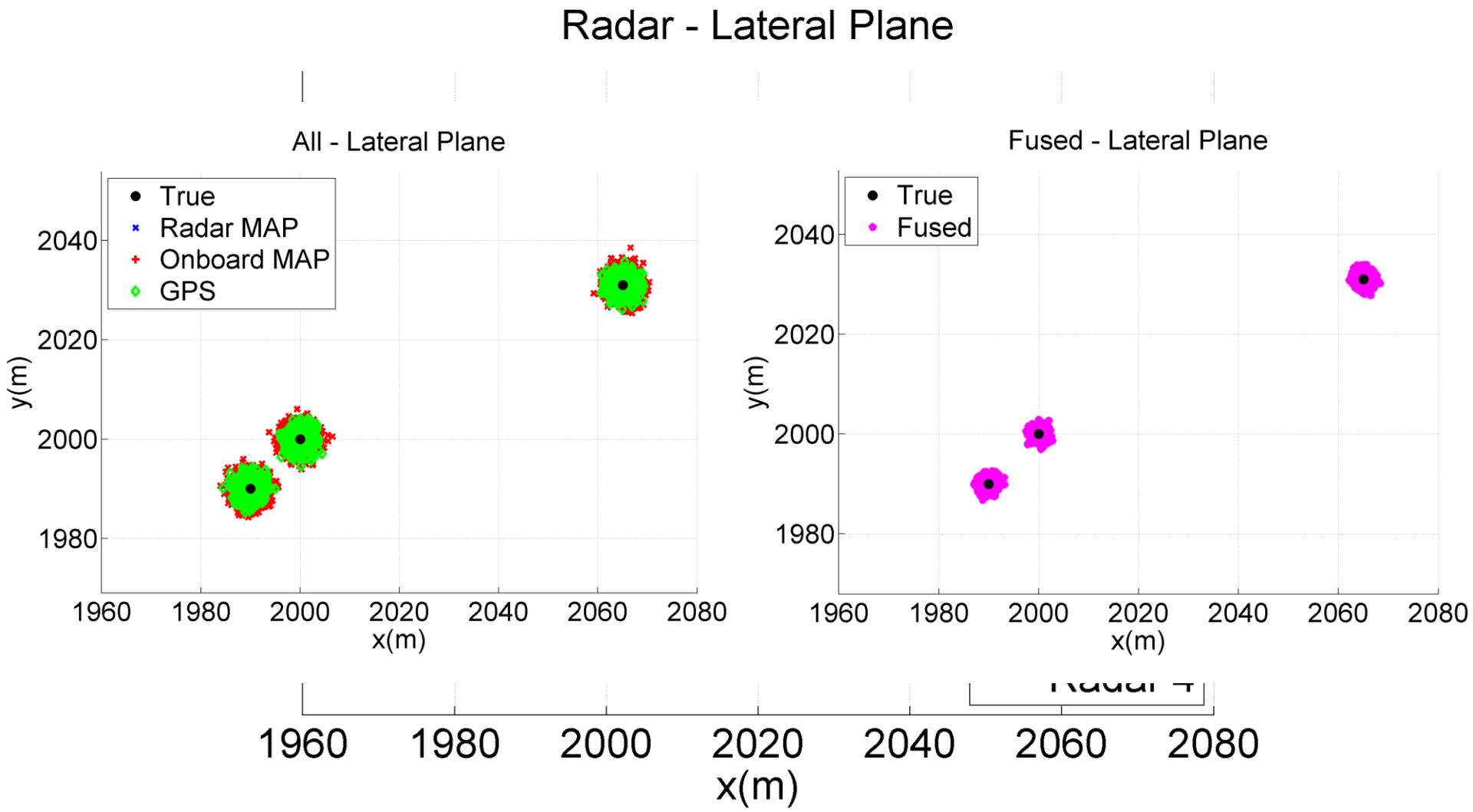


Testing Environment

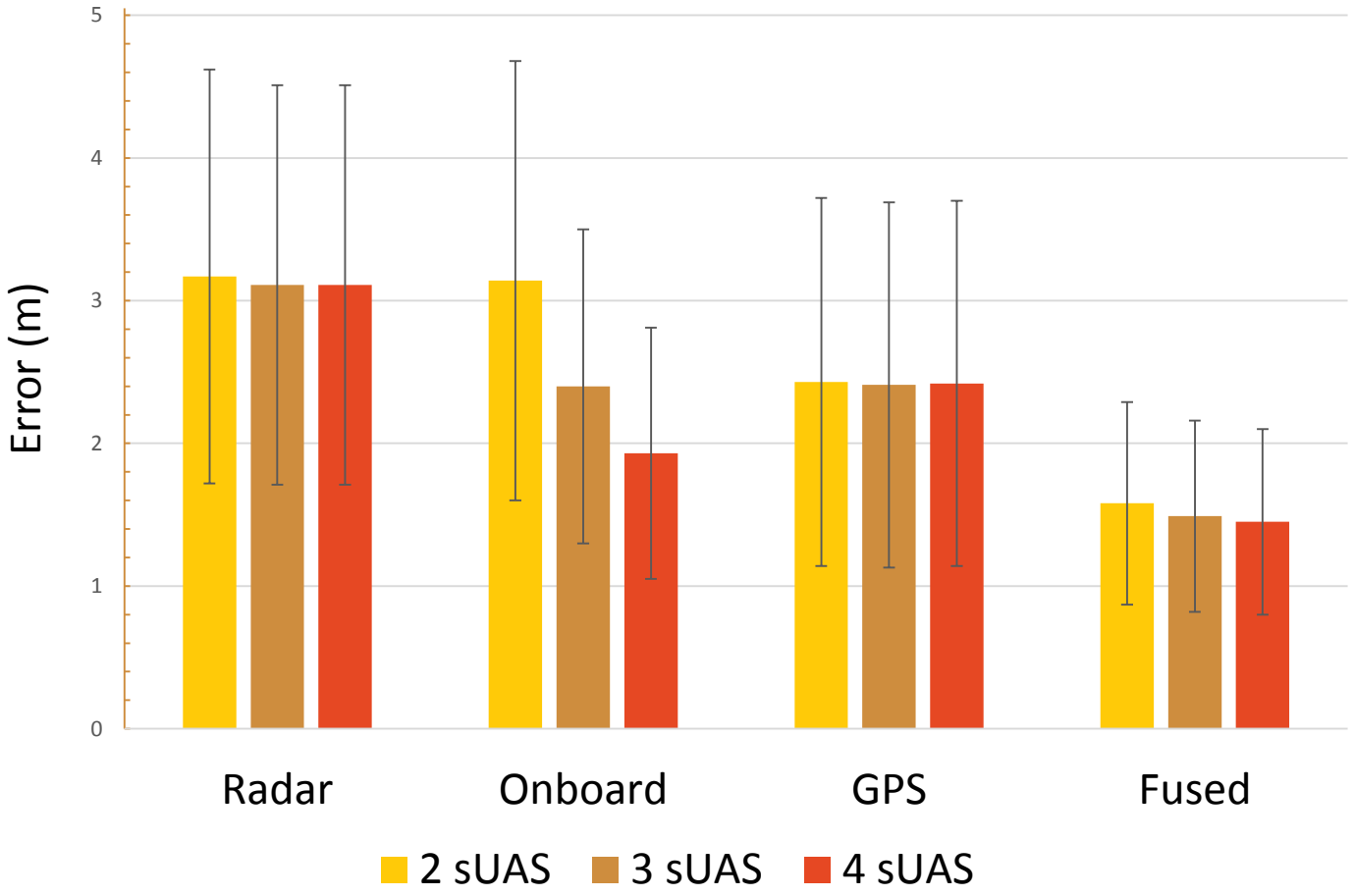
# Radars	# UAS	# Cases	Onboard	GPS On?
2	1	15	No	Yes
	2	5	Yes	Yes/No
	3	5	Yes	Yes/No
	4	5	Yes	Yes/No
3	1	15	No	Yes
	2	5	Yes	Yes/No
	3	5	Yes	Yes/No
	4	5	Yes	Yes/No
4	1	15	No	Yes
	2	5	Yes	Yes/No
	3	5	Yes	Yes/No
	4	5	Yes	Yes/No

- 135 tested cases
- 1,000 independent measurements from each sensor for each case
- Raw measurement values passed through sensor fusion system
- Error between true and estimated vehicle location was recorded

Sample Scenario



Results



Conclusions

- Demonstrated a novel approach to estimate the location of an sUAS using Fuzzy Logic
- Fusion system estimates were more accurate than raw or MAP estimates
- Can apply proposed system to any sensor type with variable reliability and performance

Future Work

- Train each FIS using advanced techniques
- Incorporate sensor fusion system into a vehicle tracker
  - Data association:
    Which data belongs to which vehicles
  - Data filtering:
    Exclude bad data points
  - State estimation:
    Speed and heading
  - Future state estimation:
    Predict vehicle location at future times

Questions?

Brandon Cook

Email: brandon.cook@nasa.gov