

# Automatic Dependent Surveillance Broadcast: ADS-B Sense-and-Avoid System



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# Introduction to ADS-B

## Automatic Dependent Surveillance Broadcast

- Replacing radar for tracking aircraft worldwide
  - Prevent collisions
- Sharing position, altitude, velocity, etc. with air traffic control and other aircraft
  - ADS-B Out = Transmit
  - ADS-B In = Receive
- **FAA-mandate**  
**by Jan. 1, 2020**



# Operational View

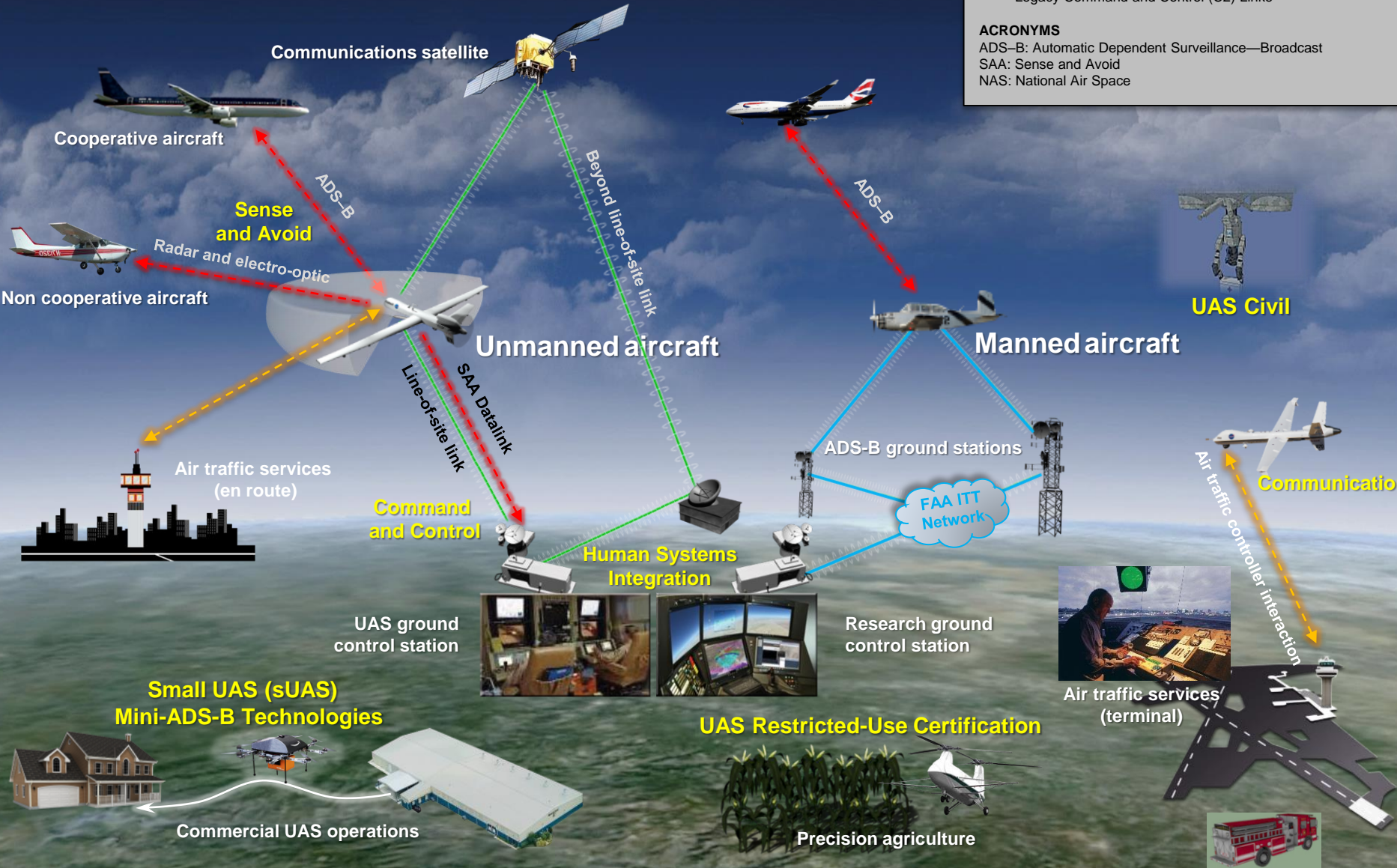


**LEGEND**

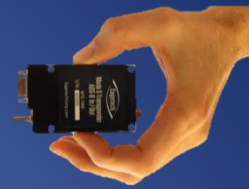
- Sense and Avoid (SAA Technologies)
- Air Traffic Services
- ADS-B Ground Stations and Network
- Legacy Command and Control (C2) Links

**ACRONYMS**

- ADS-B: Automatic Dependent Surveillance—Broadcast
- SAA: Sense and Avoid
- NAS: National Air Space



# Operational Use Cases



- Urgent need to safely integrate UAS into the National Air Space (NAS)
  - First responders and firefighters
  - Search-and-rescue missions
  - Monitoring and/or fighting forest fires
  - Package delivery (Amazon<sup>®</sup>, Domino's<sup>®</sup>, FedEx<sup>®</sup>)
  - Surveying farmland, borders, pipelines
- Consumer/Commercial demand for UAS likely to explode in the next decade
  - **30,000 drones operating by 2020 (FAA)<sup>1</sup>**
- **Market opportunity by 2020 for ADS-B equipped Unmanned Aircrafts: from \$240 to \$360 million.**



[1] <http://www.washingtontimes.com/news/2012/feb/7/coming-to-a-sky-near-you/?page=all>, accessed on October 15, 2104

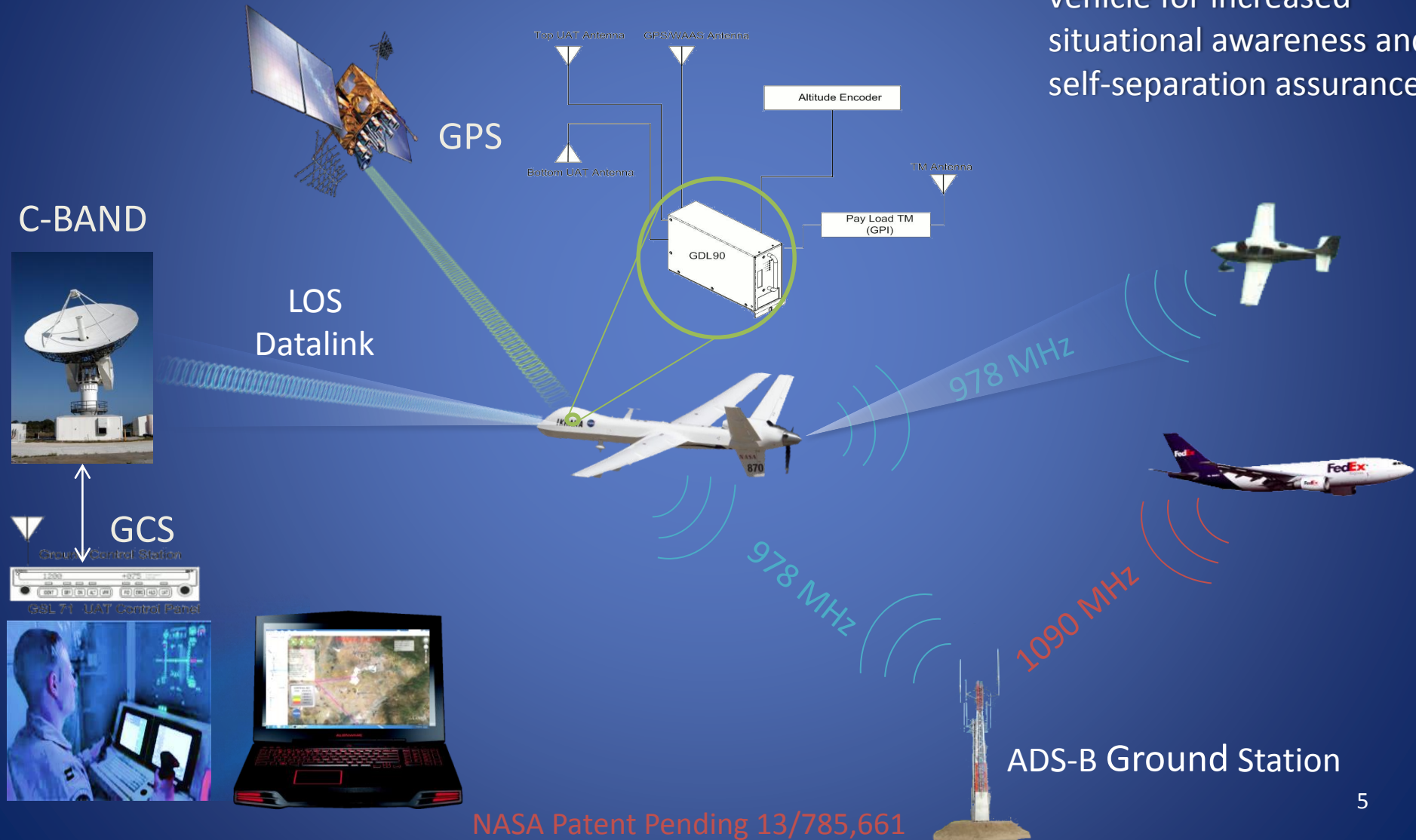
# New Technology

- ADS-B OUT
- ADS-B IN
- ADS-B Sense and Avoid

# UNMANNED ADS-B AIRCRAFT SYSTEMS



- ADS-B system coupled to an unmanned aerial vehicle for increased situational awareness and self-separation assurance



## Results

### ADS-B flight tests on Ikhana UAS



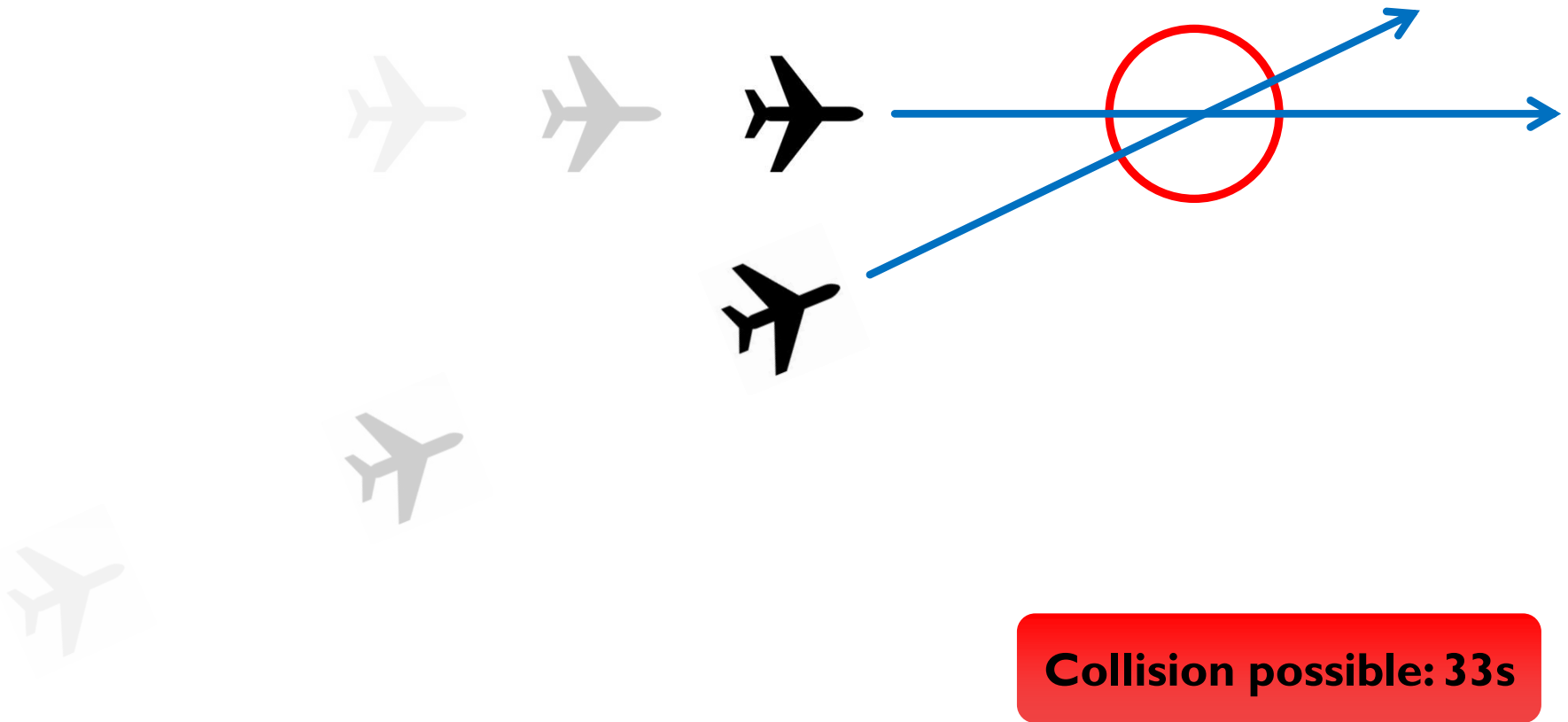
- ADS-B Out: March 2012
  - First time a UAS as large as the MQ-9 had flown equipped with ADS-B
- ADS-B In: May 2012
  - 2 Flight Tests at Dryden with successful traffic surveillance

## Benefits

- **Complies with FAA certification for ADS-B Out** (5.7 feet position accuracy, FAA independent analysis)
- **Provides backbone** technology for NextGen
- **Increases safety** by ensuring safe separation
- **Increases pilot awareness,** situational and traffic
- **Other technical benefits**
  - Provides 3D synthetic views
  - Loss link of UAS telemetry uses FAA Tech Center ADS-B data for redundancy

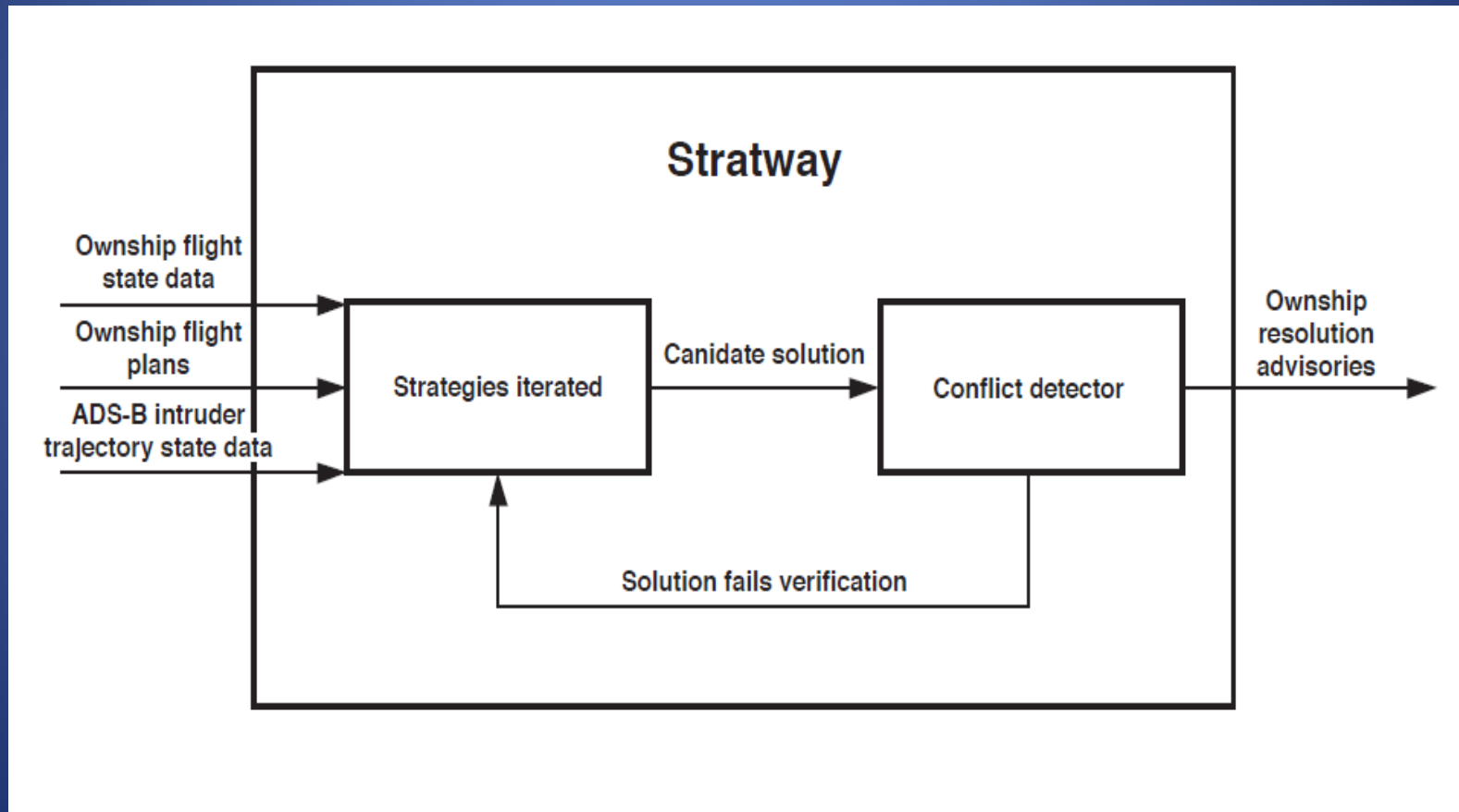
# Advanced sense-and-avoid algorithm

- ▶ Software uses ADS-B broadcast information to construct aircraft trajectories, and predict future loss of separation.



# ADS-B sense-and-avoid algorithm

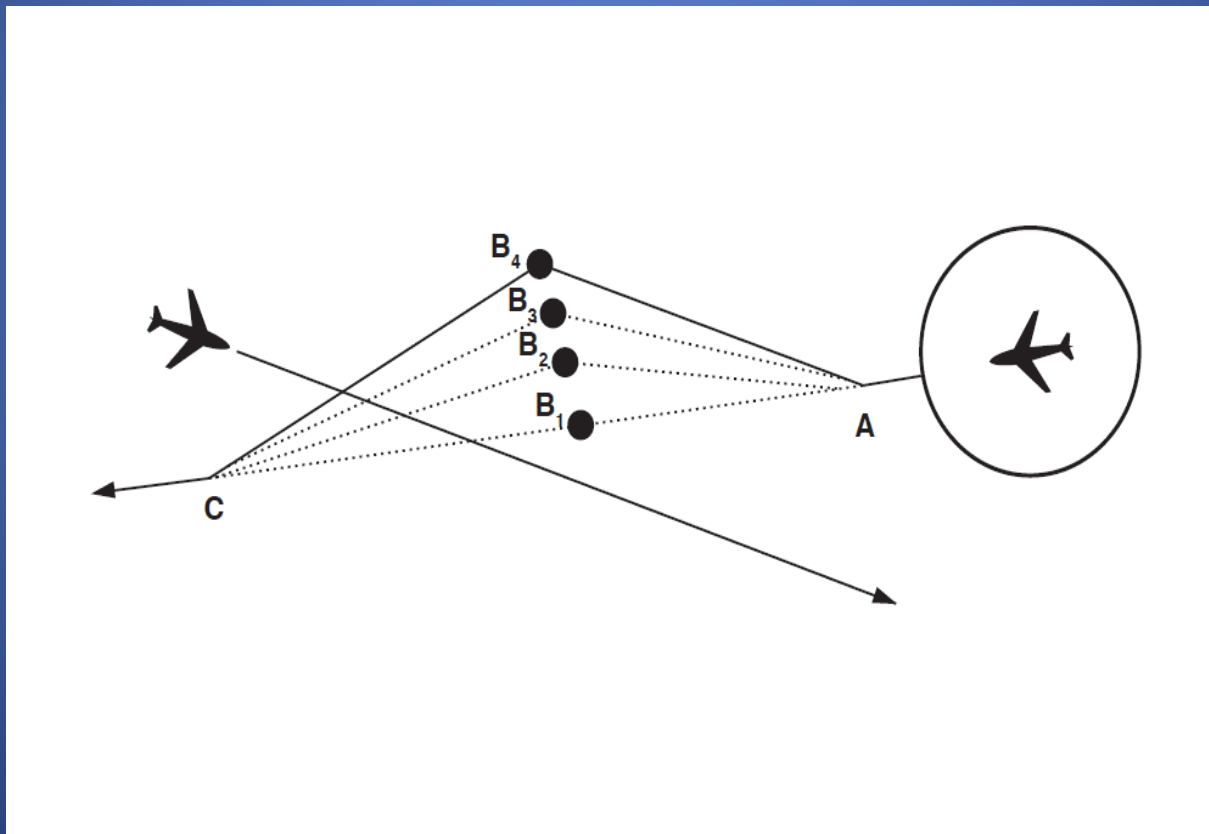
Stratway – a modular approach to safe conflict resolutions.





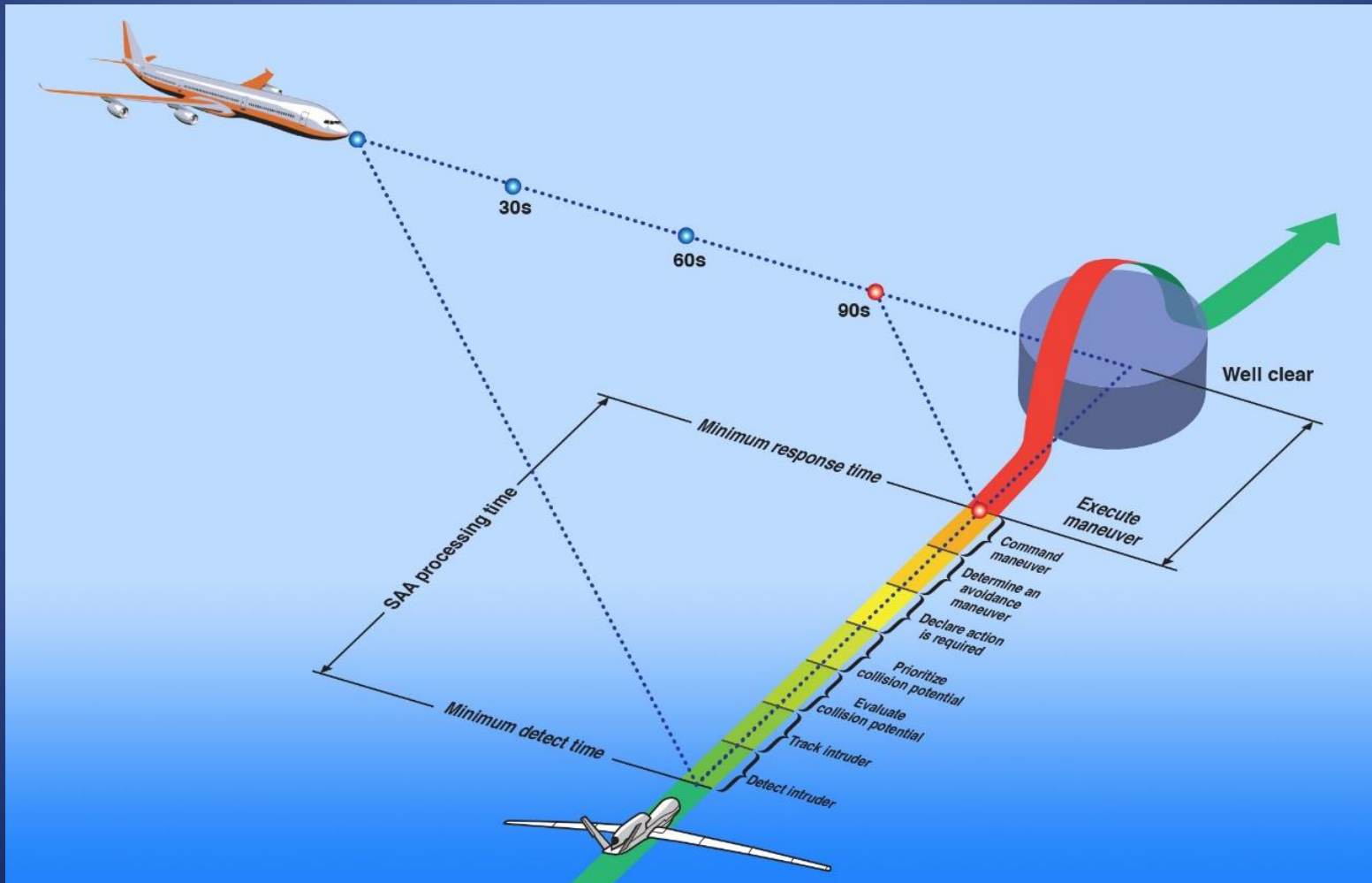
# Stratway conflict resolution algorithm

Stratway – strategies are iterated.



# Sense-and-Avoid sub-functions

NASA Sense and Avoid unique capabilities provided by the Stratway code.



# NASA ADS-B SAA Display

## LEGEND



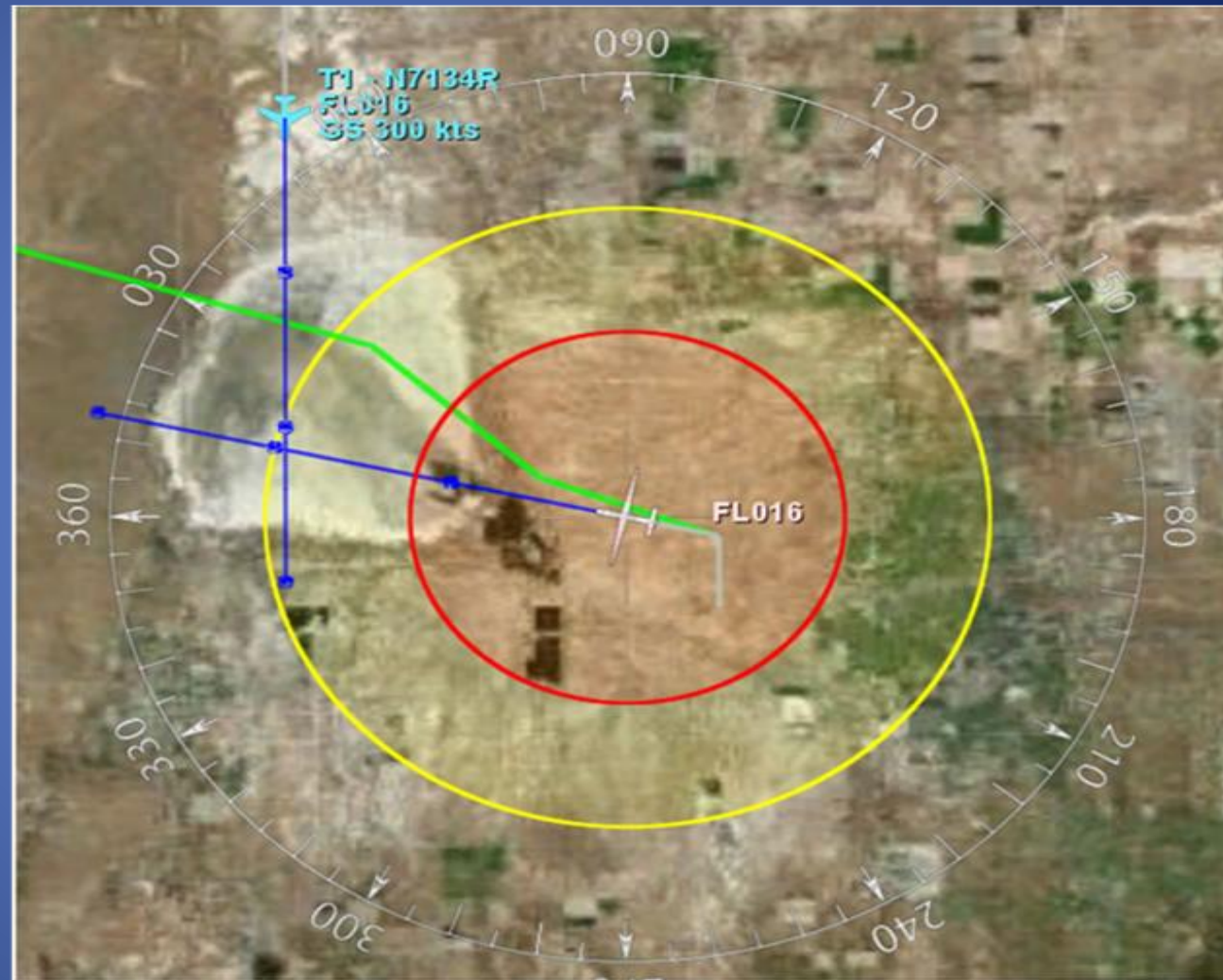
Target aircraft transmitting ADS-B

Ownship's resolution advisory

Aircraft's nominal trajectory

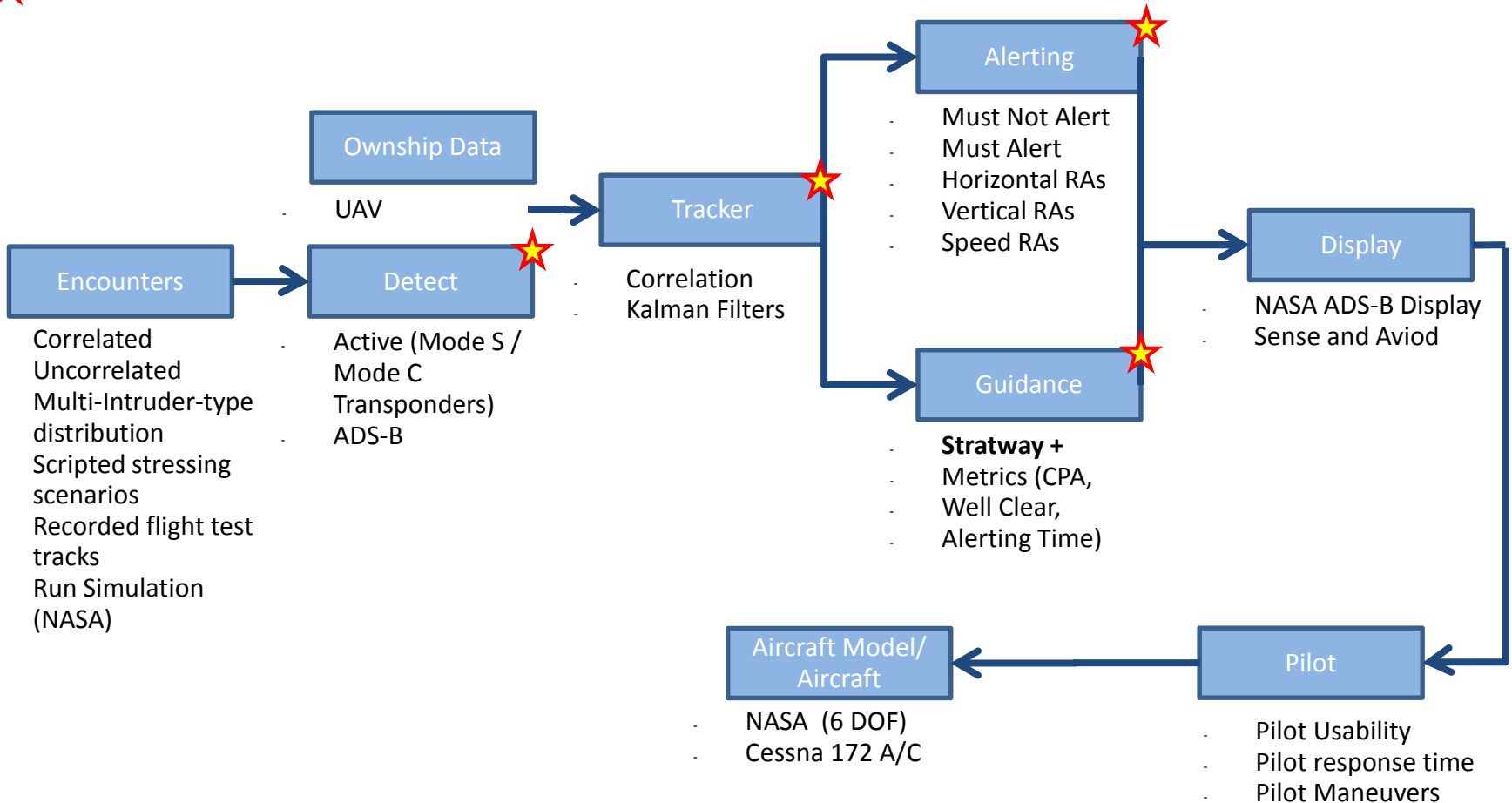
Traffic alert advisory

Traffic threat advisory



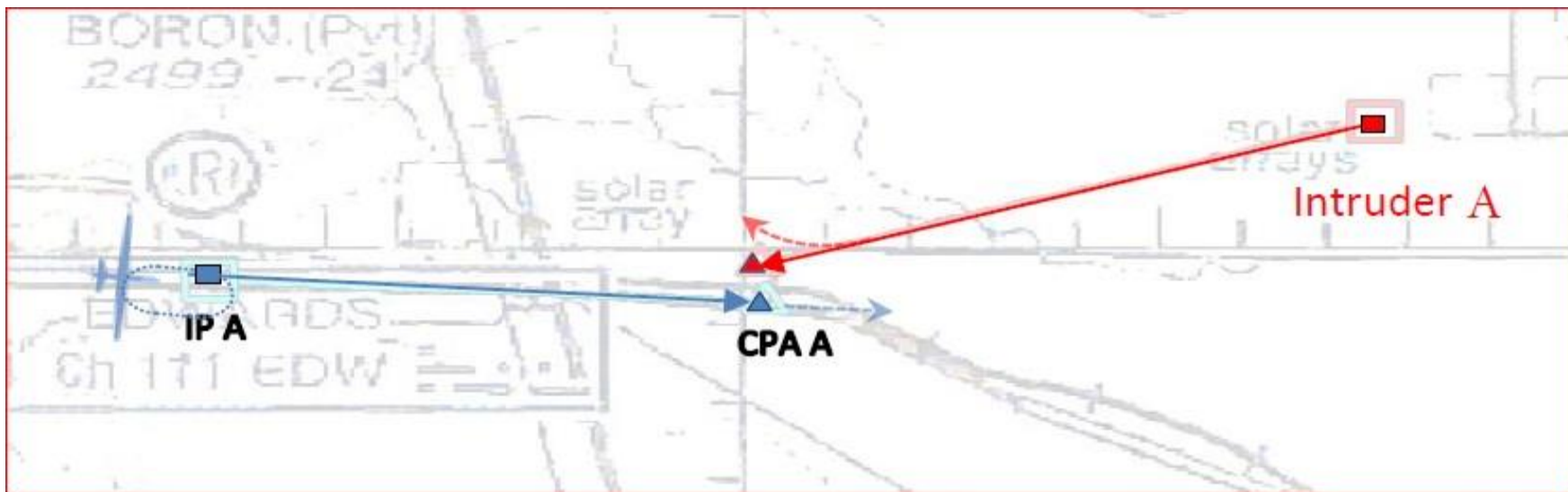
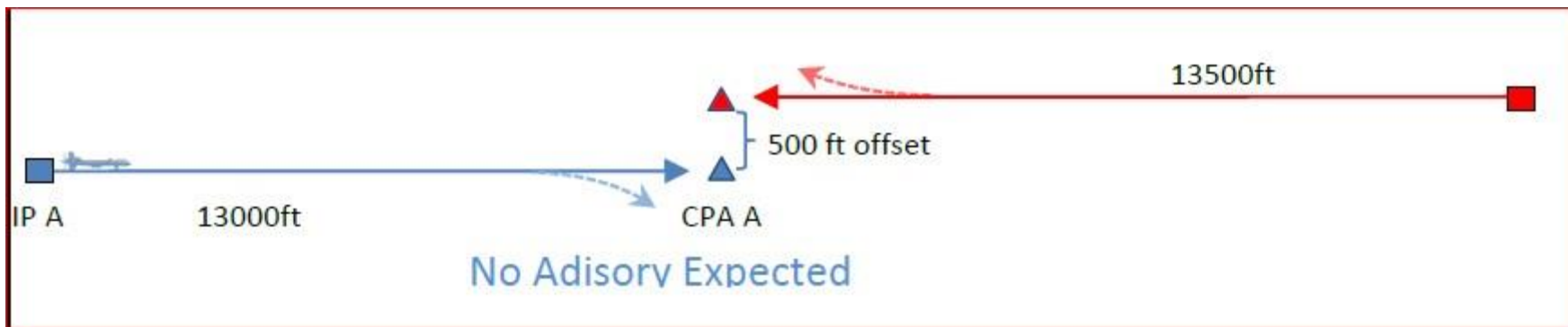
# Model Elements Used To Develop and Validate Requirements

★ SAA Requirements



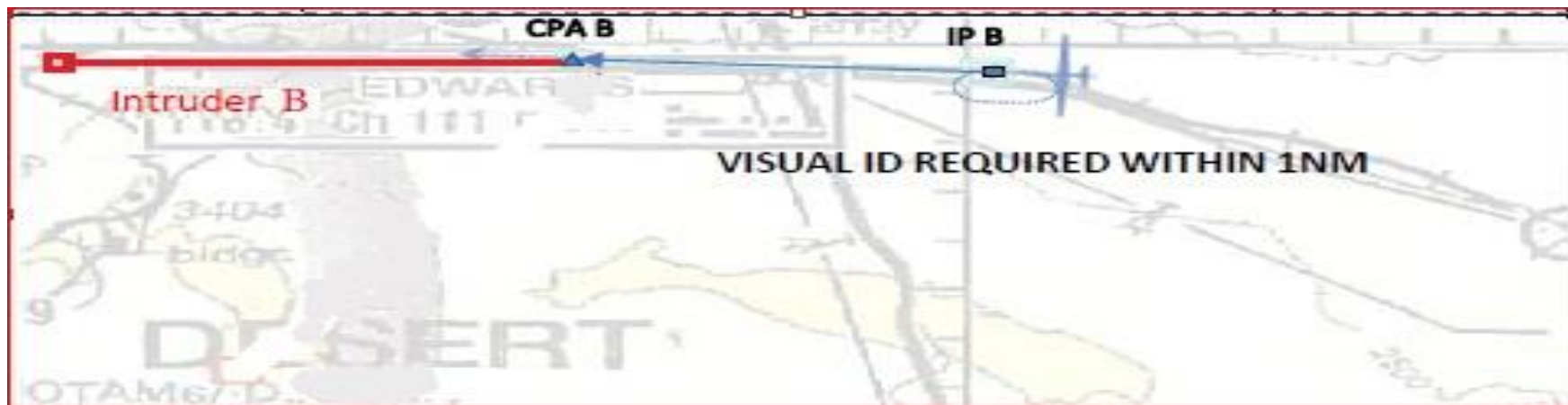
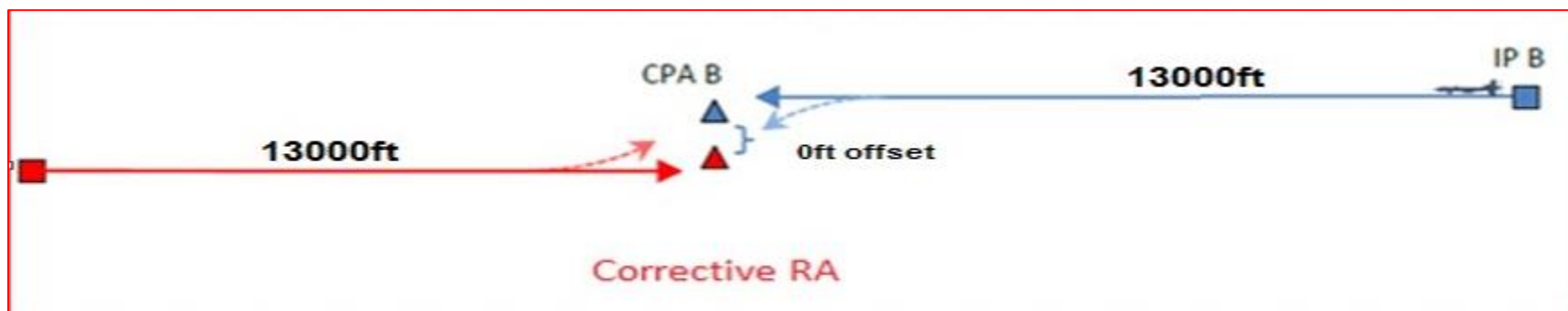
# Encounters Geometries Used To Develop and Validate Requirements

- Horizontal & Vertical Encounters
- 500, 200, 0, -200, -500 feet offsets
- Head On, Crossing, 45, 90, 180 degree.

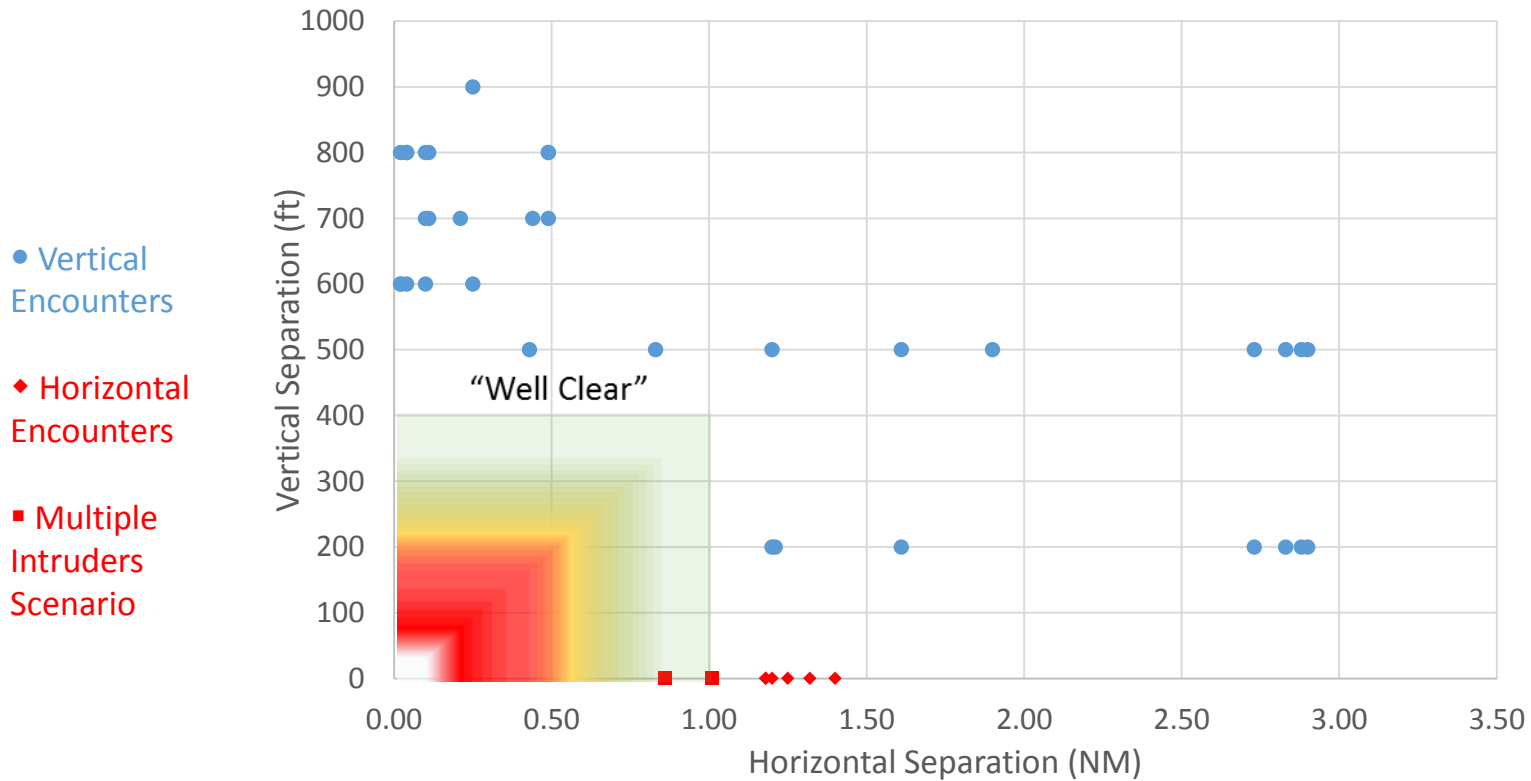


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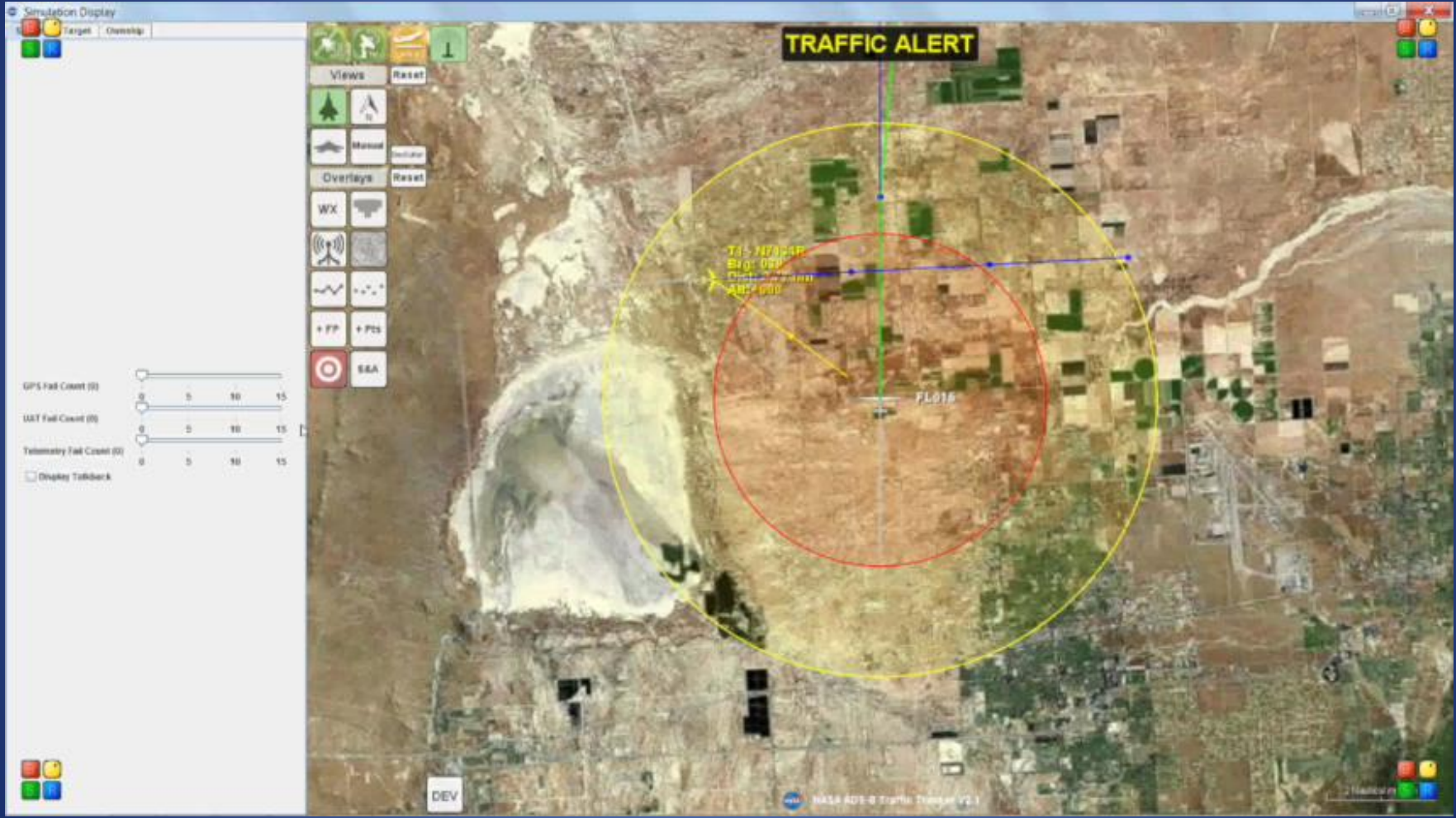
- Horizontal & Vertical Encounters
- 500, 200, 0, -200, -500 feet offsets
- Head On, Crossing, 45, 90 degree.



# SAA Algorithm Performance



# ADS-B Sense and Avoid Simulation





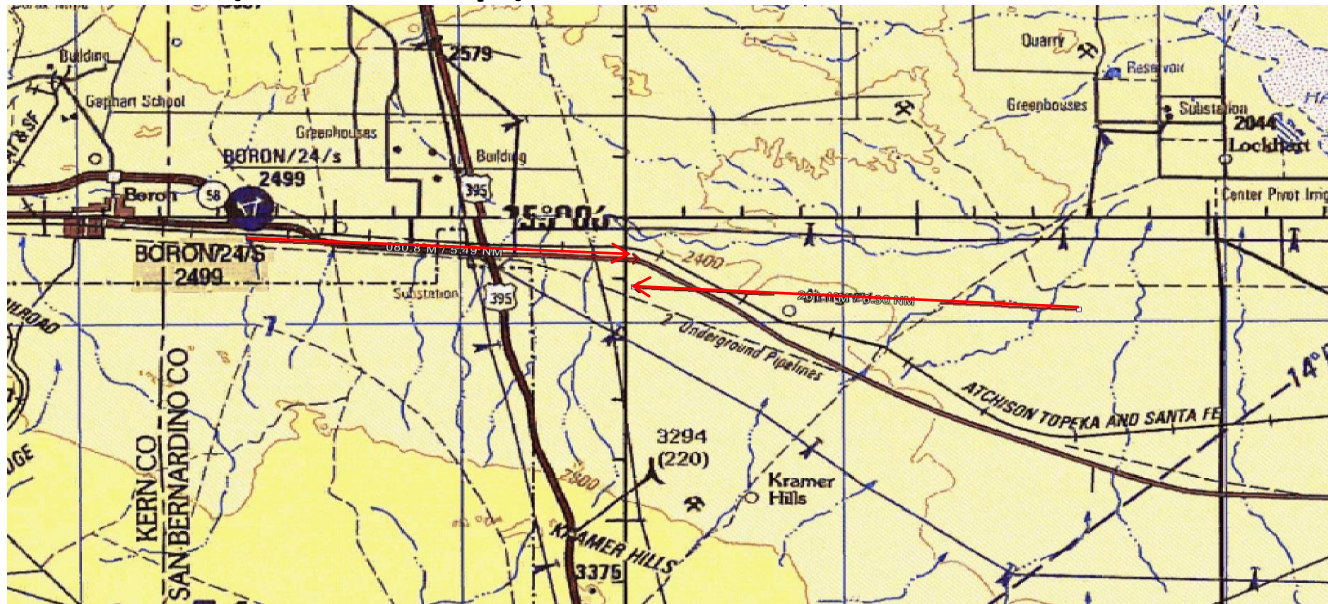
# Manned Flight Tests ADS-B SAA



▶ Test Aircraft (Ownship)



▶ Intruder



# Flight Test Validation

NASA ADS-B Traffic Tracker V2.1



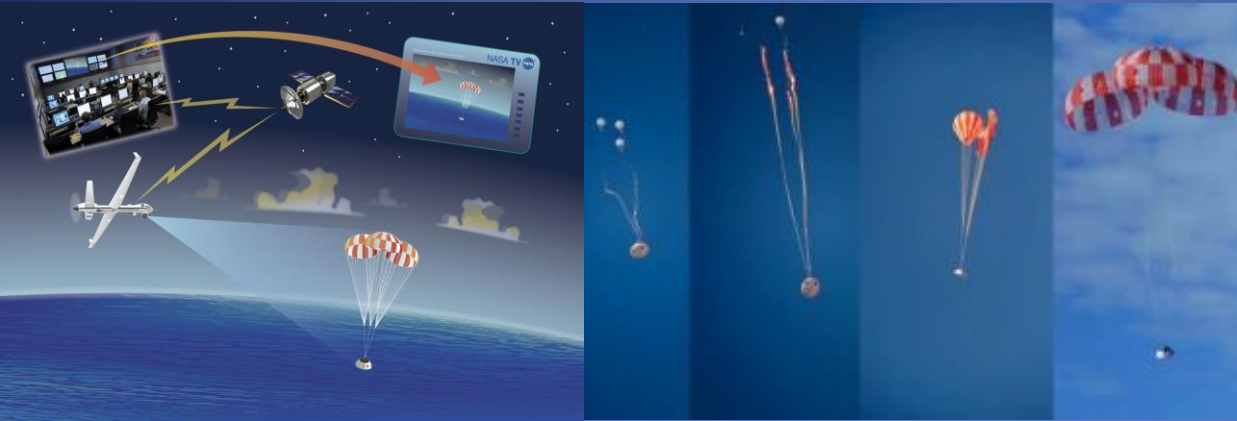
# Flight Test Lessons Learned



- Simplify, simplify, simplify, don't try to get it totally right the first time.
- Incrementally integrate the ADS-B Out and ADS-B In capability.
- Pilot Useability tests are critical for design of man-machine interface
- Flight tests can be used to validate simulations

# Future Applications and Benefits

## ADS-B on Space Craft Vehicles



*Commercial Applications both inside and outside NASA: Long Endurance 5 years Commercial space vehicles with ADS-B Systems (will likely emerge in the next decade).*

*NASA is a world class leader in cutting edge astronautics technology.*

- Complies with FAA certification for ADS-B Out
- ADS-B represents the backbone technology for NextGen.
- Provides re-entry tracking from ground station/UAS for space vehicle recovery

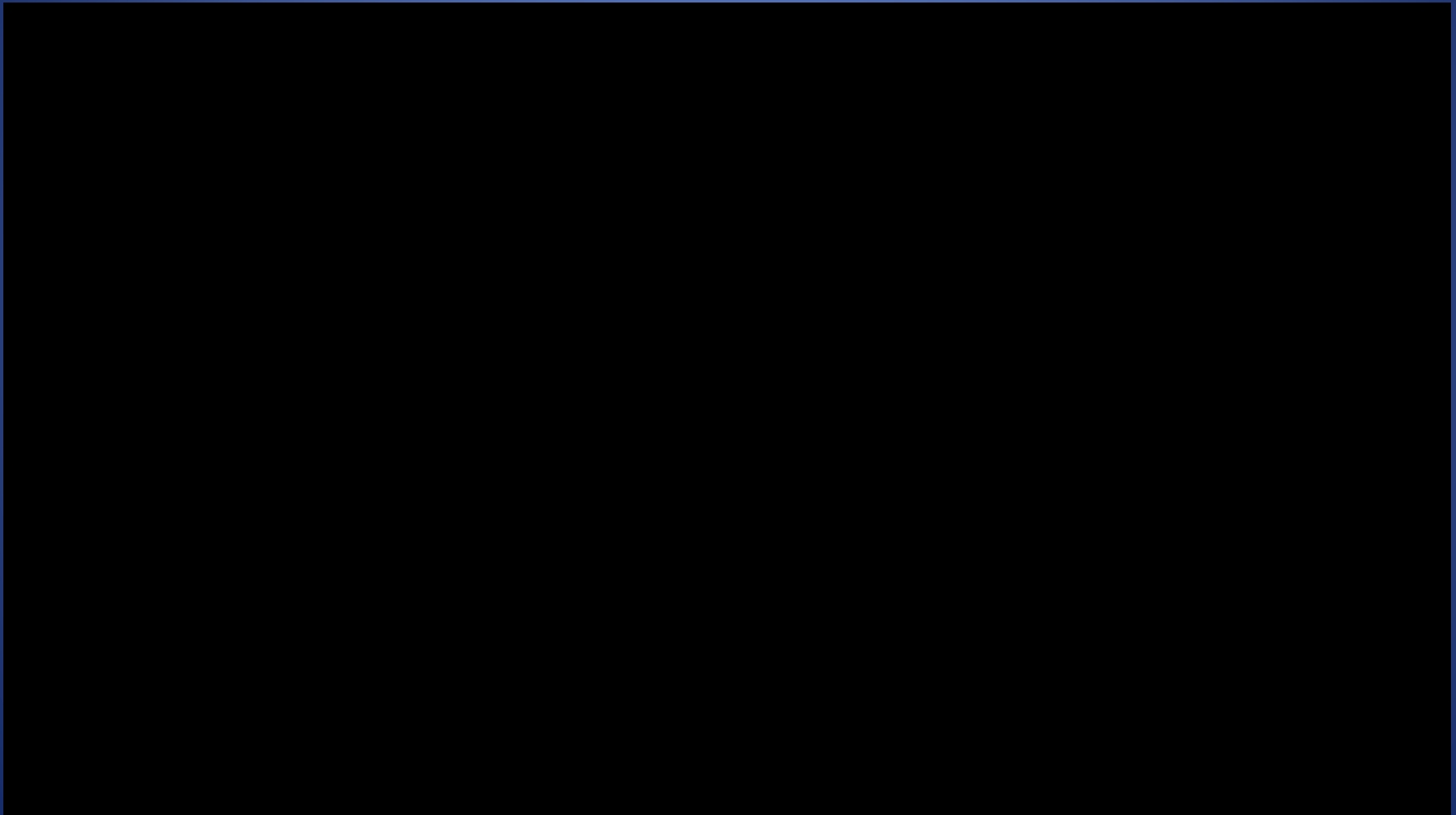


# Conclusion

- Research presented demonstrates the ADS-B SAA performance for conflict detection and conflict resolutions for unmanned and manned general aviation using accurate ADS-B velocity state information.
- Vigilant Aerospace Systems, Inc has successfully licensed the NASA ADS-B SAA technology
- NASA will conduct research on a miniaturized radar for detecting uncooperative targets and/or objects.



# ADS-B Sense and Avoid System Video



# Questions?



# Backup Slides





# NASA's Successful Flight Tests

- **Various sizes:** Ikhana, DROID, Towed Glider
- **Performance:** 5.7 ft. accuracy (304 ft. mandate)
- **Traffic surveillance:** Up to 17 real-time tracks
- **Record-setting:** First time large UAS had flown with ADS-B

Ikhana



Dryden Remotely Operated  
Integrated Drone (DROID)

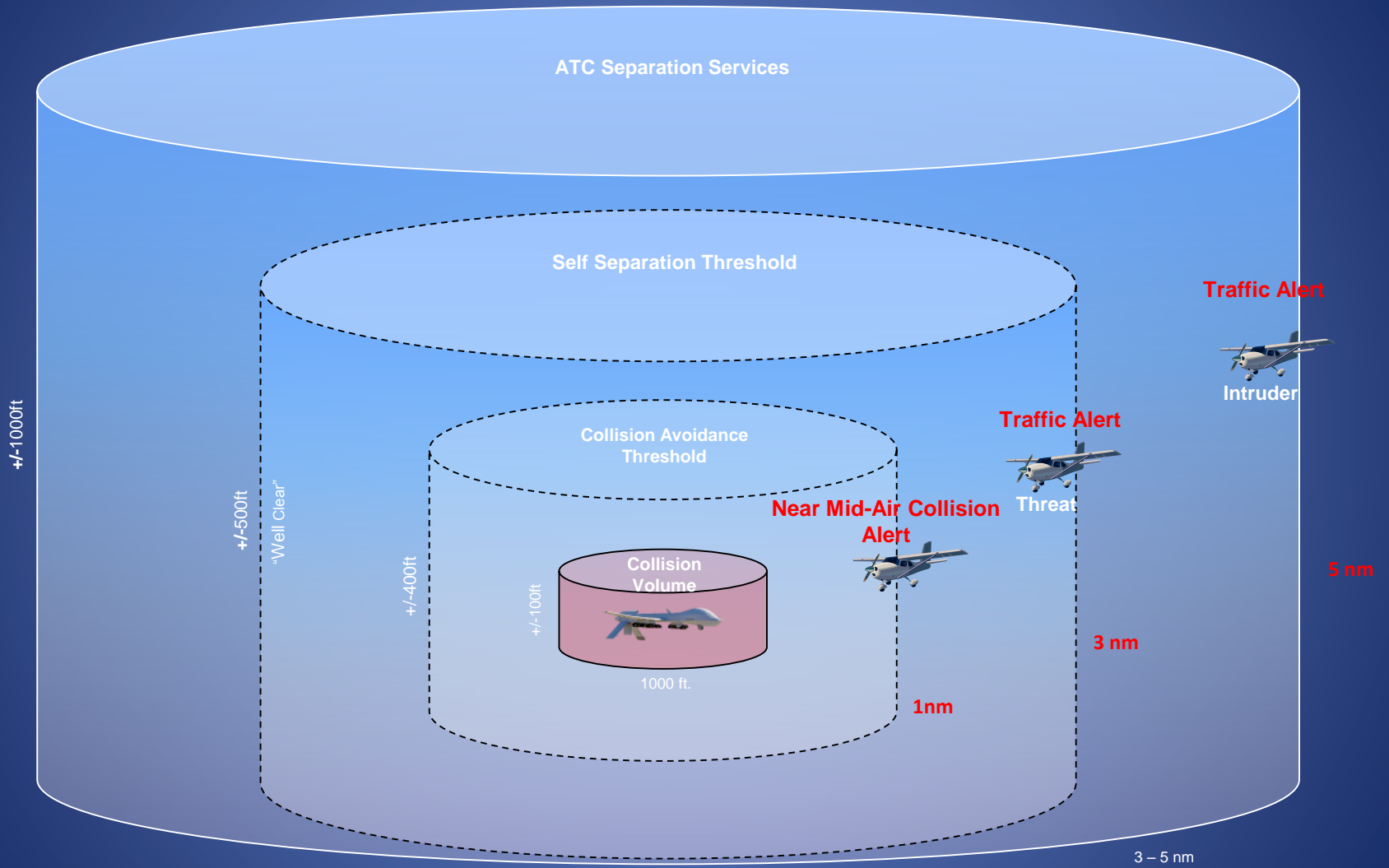


Towed glider



# Alerting Logic

## RISK Collision Volumes



# MANNED AIRCRAFT SYSTEMS



Aircraft



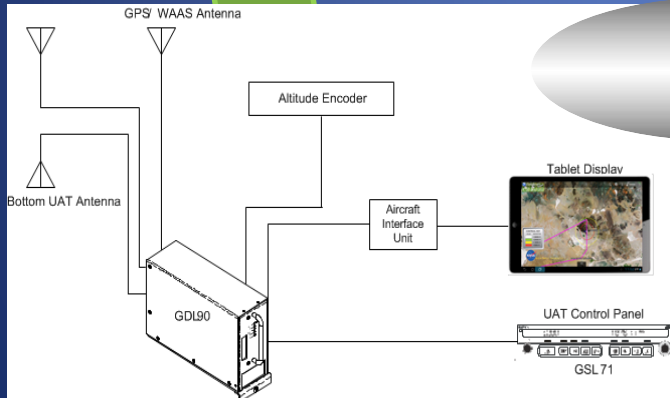
- Traffic Conflict Detection
- Integrated 2D/3D Weather
- Integrated 3D Terrain
- NASA Dryden developed capability
- ADS-B Sense and Avoid

Tablet User Interface



## Architecture

ADS-B Out & In



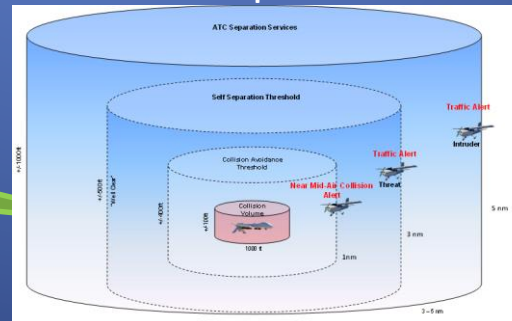
Sensors

ADS-B Data

Displays

Algorithms

Sense and Avoid Self-Separation

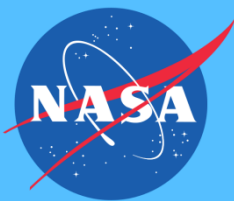


- Detects intruding aircraft in terms of increasing threat risk
- Alerts pilots of potential collisions and provides resolution advisories

- ADS-B Out Broadcasts Ownership
- ADS-B In reception of air-to-air ADS-B messages from proximate aircraft and ADS-B In traffic information.

# Simulation Scenario Demo





# NASA Armstrong Flight Research Center

## Small UAS ADS-B Sense and Avoid System for the DROID and Towed Glider



### BACKGROUND

Urgent need to **safely** integrate UAS into the National Air Space (NAS), as these systems are less expensive alternatives for:

- Search and rescue missions
- Monitoring forest fires
- Package delivery
- Surveying farmland, borders, and pipelines
- Fire Fighting missions



Dryden Remotely Operated Integrated Drone



### **What is ADS-B?**

- **ADS-B Out** is the *broadcast* of position information to other aircraft and ground stations.
- **ADS-B In** is the ability to *receive* ADS-B Out transmissions.

### **Why use ADS-B?**

- By 2020, all aircraft flying in transponder airspaces will be required to have ADS-B.
- Provides more reliable tracking of aerial vehicles and increases safety.

### OBJECTIVE

- Evaluate SAA Algorithm performance with small and mid-sized UAVs

Towed glider

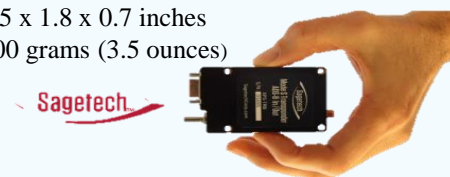


### SYSTEM

#### ADS-B Hardware

ADS-B Out transponder from Sagetech Corporation

- 3.5 x 1.8 x 0.7 inches
- 100 grams (3.5 ounces)



#### Sense & Avoid Software and Algorithms

The software package is entirely developed by NASA

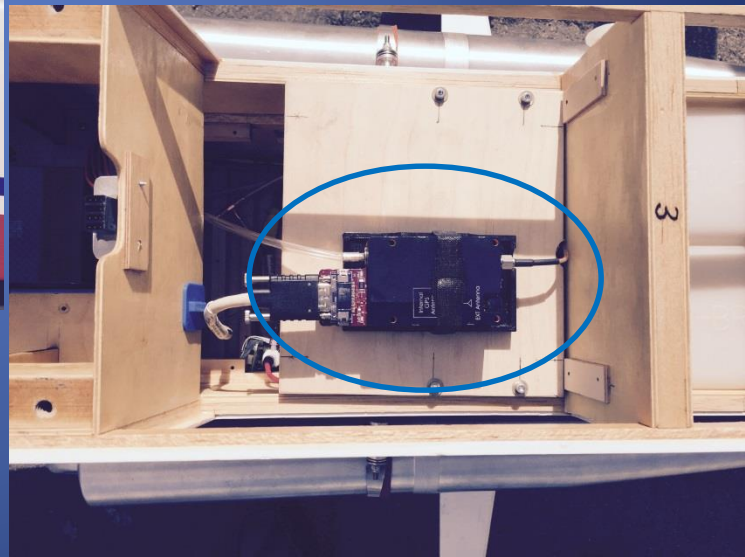
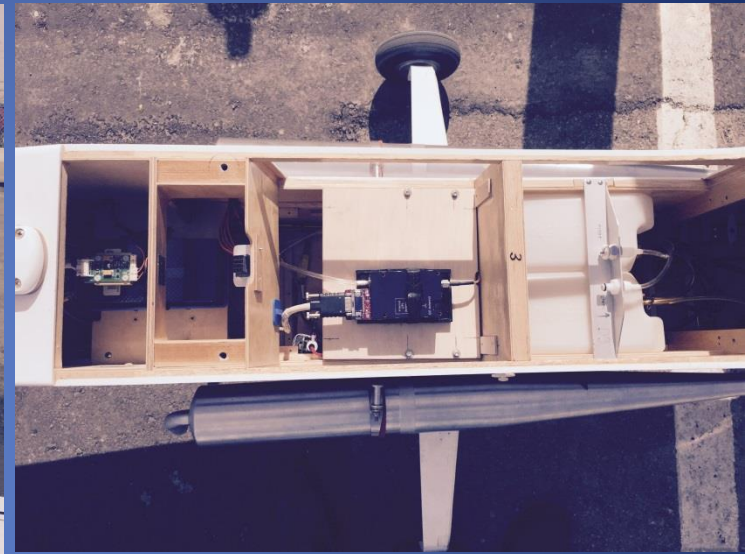
- **World Wind – 3D** Geobrowser
- **Stratway** - Strategic resolutions for aircraft conflicts
- **Sense & Avoid**–Alerts pilot of potential collisions to avoid accidents

### SYNOPSIS

- **Advanced system will be needed to keep drones from colliding with manned aircraft vehicles.**
- Validating the software algorithms with flight experiments to improve safety.
- **This ADS-B Sense and Avoid product is key to safety.**



# ADS-B Equipped DRIOD

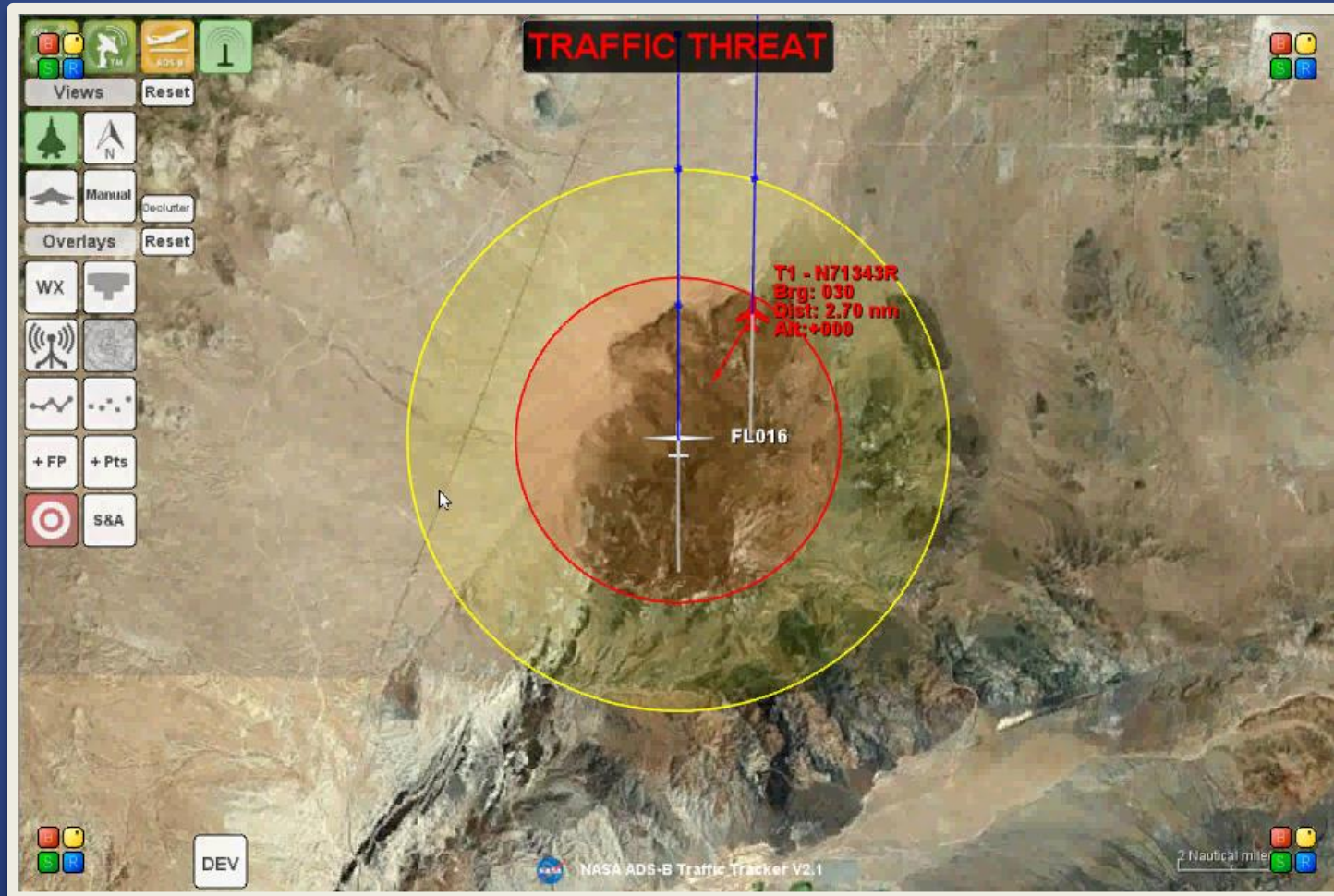




# Benefits of NASA's ADS-B Technology

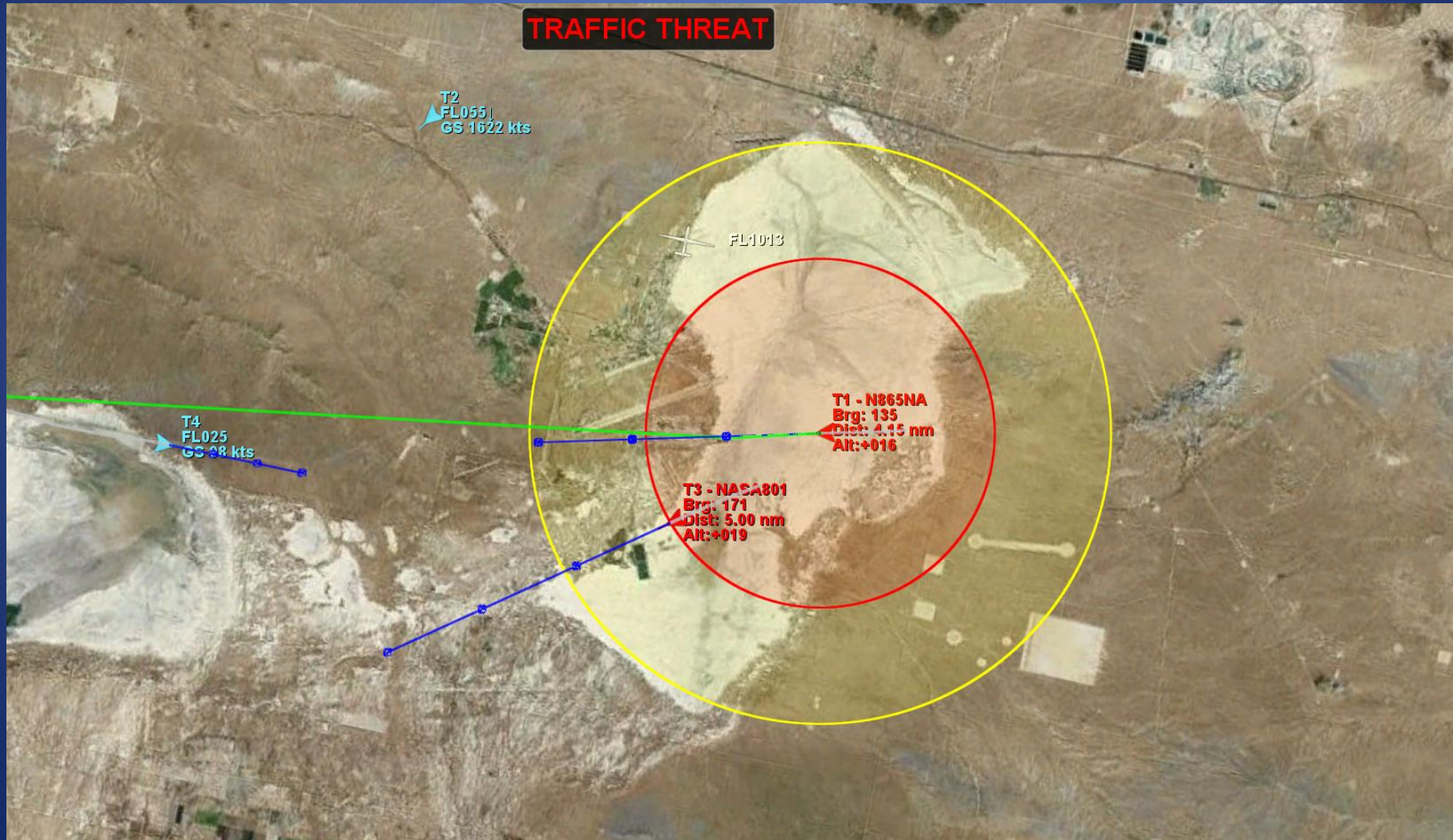
- **Complies with FAA** certification for ADS-B Out
- **Provides backbone** technology for NextGen
  - Tracking UAVs and other aircraft on tablets
- **Increases safety** by ensuring safe separation
  - ADS-B sense-and-avoid capability
- **Increases awareness**, situational and traffic
  - Preeminent attribute for successful UAS operations
- Other technical benefits
  - Provides 3D synthetic views of the UAS
  - Loss link of UAS telemetry uses FAA Tech Center ADS-B data for redundancy

# ADS-B SAA Display Traffic Advisory

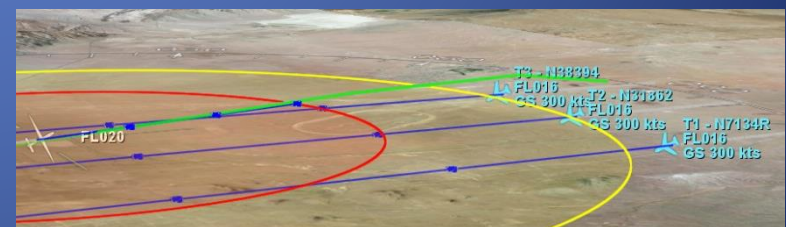
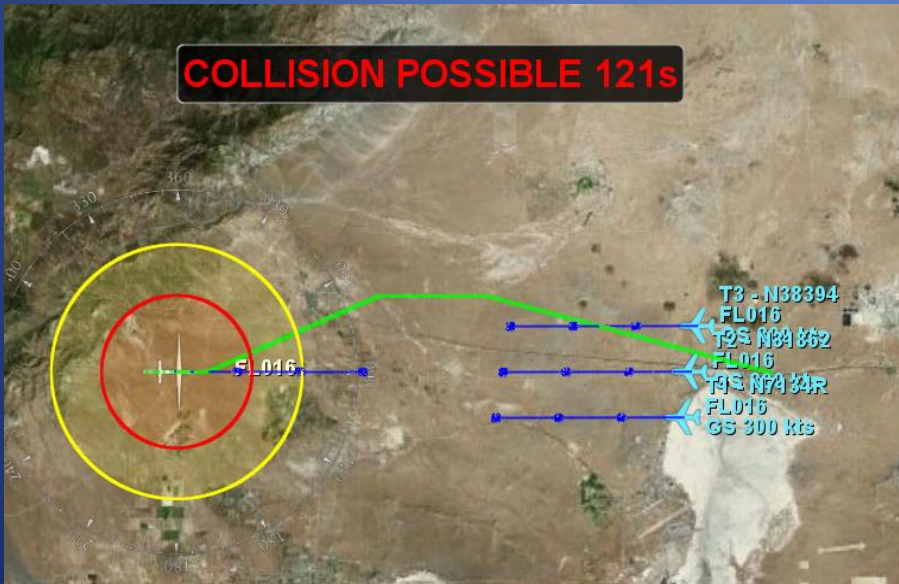
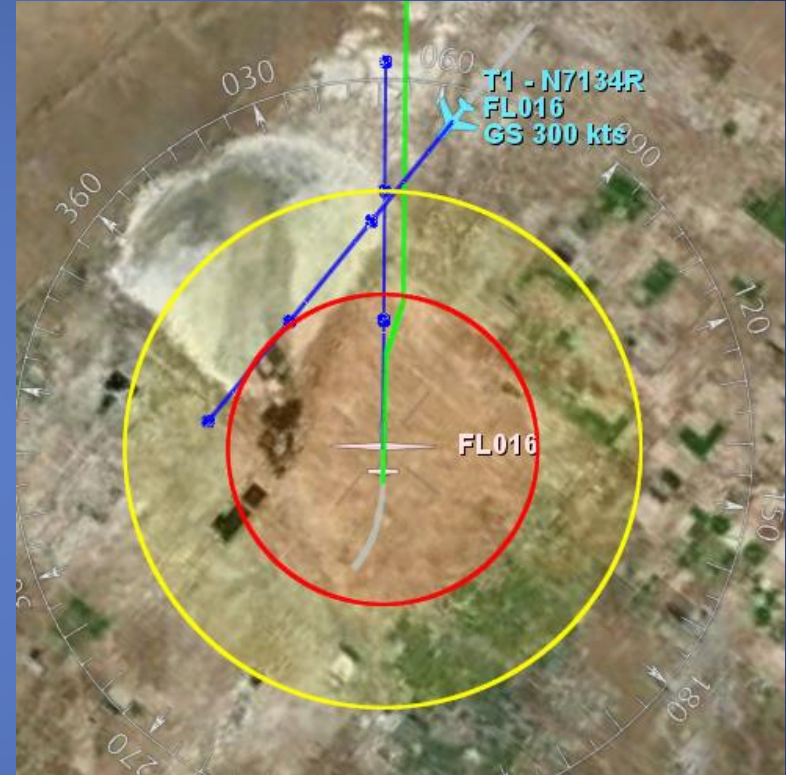
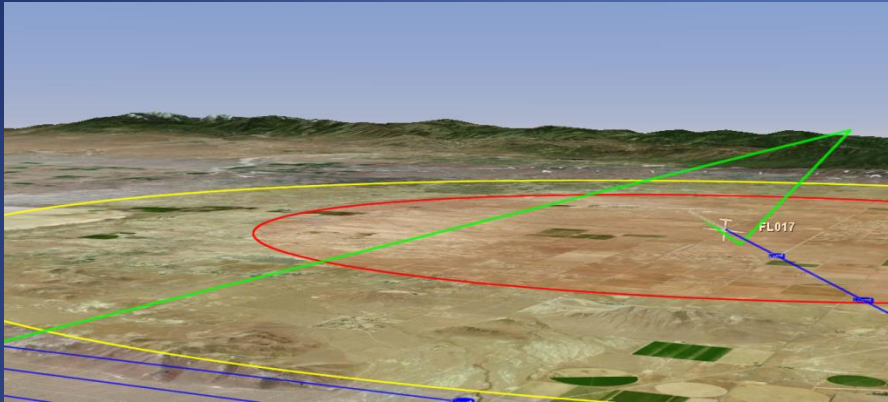




# Flight Tests ADS-B Sense and Avoid (Green Resolution Advisory)



# Conflict Detection Resolution Advisory





# NASA Pilot Usability Tests

## Human Factors

■ Conflict detection    ■ Resolution advisory



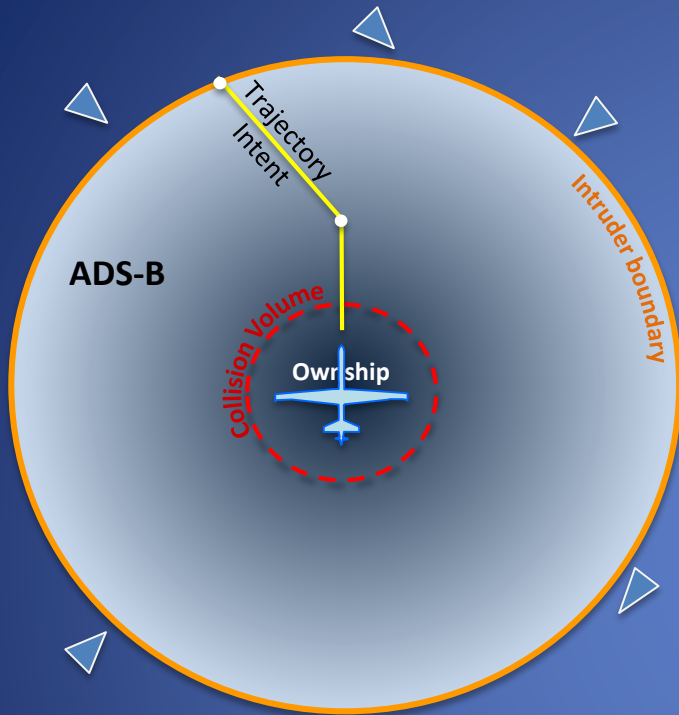
# ADS-B Situational Display

## Traffic Alerting



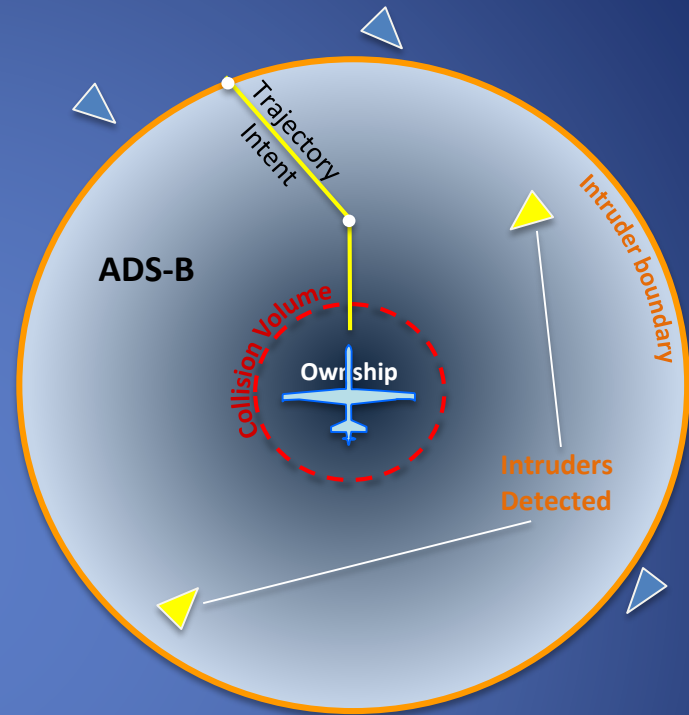
TRAFFIC THREAT INDICATORS

# ADS-B Mission Scenarios



"Baseline" case: No intruders, conflicts or collisions detected.

➤ Nominal UAS Operations

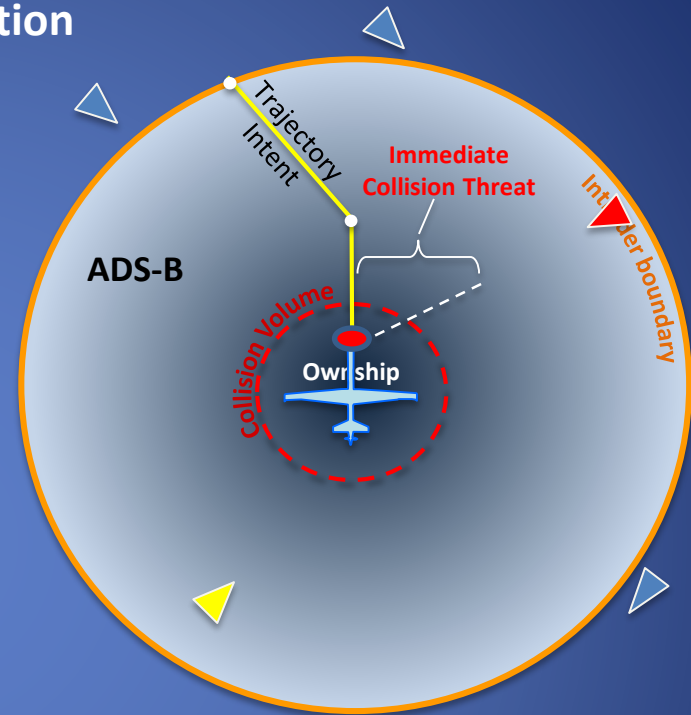
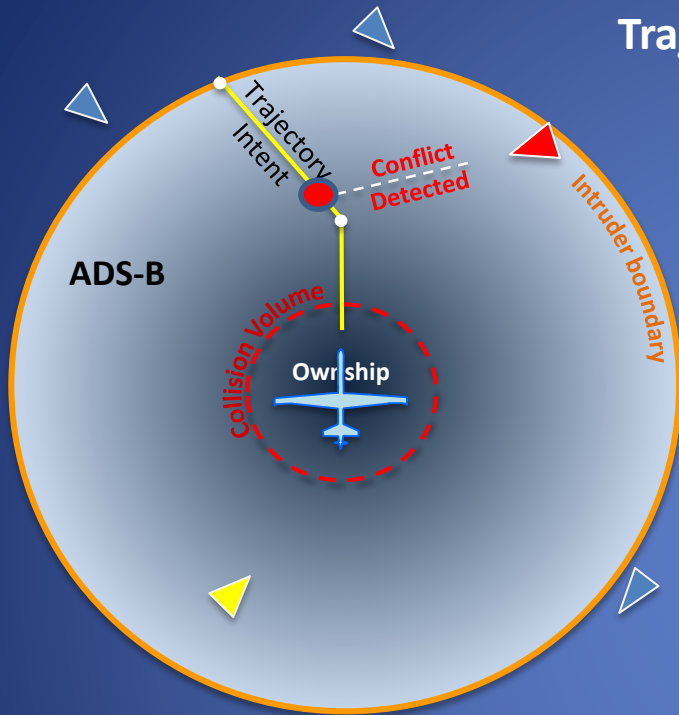


"Intruder" case: Traffic A/C crosses intruder boundary  
Traffic Alert

➤ Loss of Separation

# ADS-B Mission Scenarios

## Trajectory Estimation



**“Conflict” case:** Traffic A/C **Conflict** threat detected.

- Conflict Threat Detection
- Resolution Advisory
- Time to CPA appears at top of the display

**“Collision” case:** Traffic A/C **Collision** threat detected.

- Collision Threat Detection
- & Resolution Advisory