Ground Based Sense and Avoid (GBSAA) 101 Overview

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Outline

• Background
• Bed-down Locations
• Desired Outcome
• Pieces of the Puzzle
• Architecture
• Tools
• Demonstrations
• ATC enablers
• Conclusions
Background

• Unmanned Aircraft Systems (UAS)/Remotely Piloted Aircraft (RPA) have proven themselves in combat situations
• But flying RPAs in the U.S. National Airspace System (NAS) is still a challenge
• Two means are available:
  – Fly in Restricted airspace or implement a Temporary Flight Restriction (TFR) during UAS operations
  – Fly under a Certificate of Authorization or Waiver (COA), which specifies means to safely separate and avoid traffic conflicts
    • Ground observers
    • Chase planes
• Both FAA and DoD seek a more permanent solution
  – Airborne sense and avoid capabilities are still years away
  – But ground-based sense and avoid (GBSAA) could well work now

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NextGen & RPA Challenges

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Mandate for the design and deployment of an air transportation system to “accommodate a wide range of aircraft operations, including airlines, air taxis, helicopters, general aviation, and unmanned aerial vehicles” to meet the nation’s needs by 2025 (i.e.-NextGen).

DoD NextGen Lead Service Memo (28 Dec 07)- OPR-Gordon England- Dep Sec Def

“NextGen also addresses unique DoD requirements…These include Homeland Defense policies and programs, special use airspace for training and ranges, employment of unmanned aircraft systems, and surveillance of the air and maritime domains”.

DoT -IG Report (21 Apr 10) OPR-Honorable Calvin Scovel III

“…the evolving use of UAS technology has become an important issue for FAA, DOD, DHS and other agencies. However, there are no established cross-agency requirements for UAS or a clear understanding of how they will be used in a NextGen environment”.

Need Sense & Avoid (SAA) to realize potential for “File & Fly”

GBSAA - near term solution

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USAF Ground Based Sense and Avoid Locations

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* UAS/UA aka Remotely Piloted Aircraft (RPA)

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Airspace Integration Overview
- DoD UAS Airspace Access

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Planned DoD UAS bed-down by 2013 requires:

• 113 CONUS locations

• 1.1M UAS flight hours (vs 3.3M manned aircraft hours)
  - Required for initial & continuation training
  - Small UAS (Group 1) will fly 77% of 1.1M hours in the 2013 timeframe

• 91% of the airspace UAS will need to use Class E & G airspace
  - Majority of non-cooperative traffic also operate in Class E & G
  - Presents the highest accident potential

Army       Air Force      Navy       Marines
SOCOM        State

ID’d but Post TBD

2008:
- 11 locations
- 14 units

2008: Army   Air Force   Navy   Marines
                   SOCOM  State ID’d but Post TBD

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2013:
- 113 locations
- 152 units

2013: Army   Air Force   Navy   Marines
                   SOCOM  State ID’d but Post TBD

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Enable *routine* unmanned aircraft operations in non-segregated *civil* airspace

- To satisfy Military, Federal, and *public-interest* mission and training needs
- While maintaining current level of civil airspace *safety*
- *Without adverse impacts* on civil aviation operations and efficiencies
- While also enabling growth of *commercial* UAS applications

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Considerations

- Solution needs to include:
  - Maximizing use of existing resources
  - Gap filler capabilities/technologies
  - Operational procedures development (Major variable)

- Key factors to ensure safe RPA operations
  - Performing comprehensive safety analyses
  - Defining and implementing operational procedures
  - Conclusively demonstrating a positive impact upon the overall safety of the NAS

- DoD GBSAA must prove that the GBSAA system provides safe separation of aircraft

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Pieces of the GBSAA Puzzle

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FAA Workshop May 2009

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GBSAA Architecture

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Airborne Objects / Targets

Non-cooperative Aircraft

Radars

Tracker

Display

Ground Control System (GCS)

Ground Observer

Voice Communications

Avoidance Maneuvering

UAS

Air Traffic Controller (ATC)

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CRADA is One Tool

Cooperative Research and Development Agreement (CRADA)

- Formalized arrangement - government and collaborators cooperate to develop & use shared resources
- No funds are exchanged
- Participants fund own contribution to the shared asset
- Modifies assets as needed for exercises using the shared asset
- Time limited; typically two-year duration but can be extended w/ agreement by both participants
Raytheon & ESC/HBAI CRADA

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– Leverage existing ATC systems to improve RPA access to NAS
  • Optimize tracker for GBSAA

– Dynamic Protection Zone (DPZ) to provide pilot with traffic information to effect self-separation threshold

– Leverage future ASR-11 capability (PSR Altitude Estimation)
  • Reduce clutter, e.g. wind turbines, terrain
  • Improve Probability of detection (Pd) and positional accuracy of non-cooperative targets
  • Provide more options for maneuvering around traffic
    – Altitude on non-cooperative air vehicles
Airspace Characterization

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- Compile data from radar sensors that:
  - Includes both non-cooperative (search-only) and beacon targets
  - Has been associated into “tracks”

- Determine traffic patterns such as:
  - 3-dimensional distributions, with separate altitude and horizontal distributions
  - Velocity and climb/descend rate distributions
  - Time distributions such as day-of-the-week and hour-of-the-day
  - Correlations between altitude and velocity, altitude and hits, etc.

- Compare the results from the various sensors to determine:
  - Which targets are detected and not detected by multiple sensors
  - Which targets are likely to be noise and not real airborne targets
  - Which sensors are most viable for a ground based sense and avoid (GBSAA) system, complementing each others’ strengths and weaknesses

- Support the design for a GBSAA that will:
  - Minimize exposure to other air traffic
  - Enable safe Remotely Piloted Aircraft (RPA) operations

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M&S
Track Initiation Analysis

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- Evaluate time required to see (initiate track) on a “pop-up” intruder
- Relies on Airspace PD Coverage Modeling
  - Model considers:
    - Random intruder pop-ups in Airspace
    - PD of Radar(s) at given <Lat, Lon, Alt>
    - Radar asynchronous update rates
    - Tracking system logic (m of n criteria)
- Results
  - Distribution of track initiation times
  - Where can we fly in the airspace?
  - Minimum altitude limits for sufficient time to initiate track on intruders

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I n t e g r i t y  -  S e r v i c e  -  E x c e l l e n c e
Two Approaches for GBSAA

- **Modified Zero Conflict Airspace (ZCA)**
  - Test site is Cannon AFB
  - Geographic Display
  - Only RPA or civil aircraft in statically defined airspace at same time
  - Near term improvement to COA

- **Dynamic Protection Zone (DPZ)**
  - Test site is Gray Butte Airfield
  - Pilot centric display
  - RPA flies with civil aircraft in non-segregated airspace
Army Zero Conflict Alert Concept

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• **Army Zero Conflict Airspace Concepts:**
  – Airspace Volumes of Interest (AVOIs) can be used to support the constructs of Zero Conflict Airspace (ZCA).
  – Diagram of Army requirements for GBSAA. Our capabilities will provide for alerts based on these 3-D elements.

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Dynamic Protection Zone

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- Collaboration with USAF ESC & MITRE
  - DPZ shape and separation thresholds studied.
    - STARS constructs a DPZ around the RPA so any trajectory penetration will provide an intrusion alert in a configurable time frame
    - Shape evolved from “kidney-bean” alert zone to the current shape.

Example scenario of RPA and another target on a collision course.

Evolution of Display Capabilities

**Self Separation Threshold**
Green circle, of radius ("B") represents distance the track can travel in an adaptable time (e.g. 60 seconds) at its current ground-speed. The distance ("A") between the track and the center of the circle will be a percentage of the circle’s radius.

**Collision Avoidance Threshold**
Yellow circle, of radius ("D") represents distance (i.e. 30 sec) track can travel at its current ground-speed. The distance ("C") between the track and the center of the circle would be a percentage of the circle’s radius.

**Collision Volume**
For the RPA, the fused-track “filled blue circle” will be used. Represents an area that ‘covers’ the location of the aircraft with an 80% confidence level.
Gray Butte Concept Demonstration

• Current Gray Butte operations require chase aircraft
• Proof of Concept will be used to demonstrate the viability of GBSAA using the Dynamic Protection Zone (DPZ) approach
  – ASR-11 at Edwards will be used as well as BORON long-range radar
  – Self separation will be accomplished using DPZ
  – Raytheon CRADA leverages STARS LITE fusion tracker with DPZ development with alerting for RPA Pilot
  – Airspace characterization, NMAC probability, $P_d$, M&S, etc. all part of overall safety case
• Proof of Concept activities will be used to develop Program of Record requirements
ATC Enablers for GBSAA

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• Advanced Signal Data Processor (ASDP)
  – Replaces obsolete SDP
  – FAA/DoD fielding underway for all ASR-11s
  – Raytheon Concurrent Beam Processing (CBP) for UK ATC radars w/ ASDP

• Terminal ATC radars well-placed throughout the NAS to support GBSAA mission needs

• STARS LITE
  – Smaller scale STARS workstation
  – Fusion tracker
  – Integrates up to 3 radar feeds
  – Installed @ FAA contract towers
  – Army/USAF planning to deploy @ remote towers

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ATC Radars Currently Measure only Range and Azimuth

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1. Range precision is 1/64 nmi or greater
2. Azimuth precision fixed ~2 degrees
   - Location uncertainty increases with Range
3. Probability of Detection ($P_d$) for a single modern terminal radar ~ 95%
   - Depends on the tuning/filtering
4. Weight the degree of reliance you can assign each detection depending on distance of radar from the a/c

Impact of the Tracker
1. A tracker takes sequential detections and connects them into a track that represents a single object moving through the airspace
2. Mosaic Tracker works with data from only one radar at a time
3. Fusion Trackers combine the data from multiple radars and combine them into a single track
4. Fused detections from 2 radars has $P_d$ ~ 99.75%
5. Track Initiation Criteria is important

Exaggerated Azimuth Resolutions

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Conclusions

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• Airspace characterization tool set developed
  – Input: AREPS Output, Range vs. Altitude Slices at all Azimuths
  – Output: $P_d$ as a function of <Lat, Lon, Alt>

• Explore airspace radar coverage
  – Combined coverage from multiple radars
  – Concurrent beam processing

• Track Initiation model developed
  – Dependent on $P_d$ model (discussed above)
  – Model validated and verified

• Track Initiation Time Simulation
  – Conduct simulations appropriate for determining statistically significant results
  – Initial Results for Grand Forks AFB (test case) and Edwards AFB
  – AREPS output for Cannon AFB available

• Safety case development has started with AFSC
Questions?
GBSAA Contacts

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- Mr Kevin Carey – 8194
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Backup Slides

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Target Altitude Estimation

Tests have been conducted at Stockton (2005), FAATC (2007), and Travis AFB (2008) to establish the advantages of the concurrent beams configuration versus the standard switched beam configuration.

US Patent number 4,961,075 “Two and one-half dimensional radar system”, Harold R Ward

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GBSAA CRADA Background

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- ESC/HBA GBSAA CRADA
- Signed by Raytheon (Collaborator)
  - Leverages existing ATC systems to improve RPA access to NAS
  - Demonstrate fused ASR-9/-11 (ATC) show same tracks as Sentinel (AD)
  - Use Dynamic Protection Zone (DPZ) to improve GBSAA effectiveness
  - Leverages future ASR-11 capability (PSR Altitude Estimation) to
    - Reduce clutter, e.g. wind turbines
    - Improve Probability of detection (Pd) and positional accuracy of non-cooperative targets
  - Gov’t SMEs proactively engaged w/ Raytheon technical staff
    - Radar data collected @ Edwards AFB
GBSAA CRADA

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• **Issue:** Terminal ATC radars (ASR-9/-11) can detect non-cooperative targets to support GBSAA. However, routine velocity filtering in ATC tracker discards reports for slow-moving/non-cooperative aircraft.

• **Proposal:** 2-Tracks
  
  • **Track I (Clutter Control/Tracking)**
    – Develop appropriate radar tracker configuration (using STARS LITE) to support GBSAA mission @ Gray Butte & Cannon AFB
    – Use STARS LITE tracker for detecting objects flying below the usual ATC Velocity filter
    – Use DPZ SW with STARS LITE to allow UAS operations in non segregated airspace
  
  • **Track 2 (Altitude Estimation)**
    – Use DASR w/ ASDP to validate concurrent beam processing (future DASR enhancement) to provide improved detection and positional accuracy (X,Y,Z) of non-cooperative targets
GBSAA CRADA
Operational View for Track 1

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Terminal ATC RADAR (Recorded)

Tracker for GBSAA (STARS LITE)

GBSAA-Optimized Tracks & Plots

Tracker for ATC Automation

ATC-Optimized Tracks & Plots

UAS GCS - GBSAA

RPA Observer's Display

TRACON - ATM

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ASR-10SS / DASR with ASDP (Test Configuration)

- FAA/DoD ordered ASDP retrofit kits for fielded systems
- Raytheon awarded contract to develop Concurrent Beam Processing for UK ATC radars