Unmanned Aerial Systems (UAS) Integration into the National Airspace System (NAS)

Robert J. Shively

NASA's Unmanned Aerial Systems (UAS) integration into the National Air Space (NAS) project has been working closely with the FAA and RTCA Special Committee 228 to identify and break down barriers to UAS integration. A focus of this work is on detect and avoid (DAA) technologies. A pilot has responsibility to see and avoid other aircraft and to remain "well clear," using their best judgment (Federal Aviation Regulations (FAR) Sec. 91.113). For UAS to perform this function, the see function is replaced by sensors to detect the other aircraft. Secondly, the pilot judgment of well clear has to be replaced by a mathematical expression. For Phase 1 of this effort, a well clear violation was defined if all three of these conditions are true: a) the horizontal clearance is less than 4000 ft., and b) the vertical clearance is less than 450 ft., and c) the time to loss of well clear is less than 35 seconds. This definition was developed with a great deal of community input and testing to ensure interoperability with Air Traffic Control (ATC) and pilots of manned aircraft. Appropriate guidance, alerting and displays were developed to allow UAS, with the appropriate sensors, to effectively maintain well clear. This work contributed to FAA Technical Standard Orders: TSO-C211, Detect and Avoid and TSO-C212, ATAR for Traffic Surveillance. Phase 2 of this work extends the operational environment to include the terminal area and lesser capable aircraft that might not have the payload capability to carry the RADAR defined in Phase 1. This session reports on work from Phase 1 and initial work in Phase 2.

Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

AIAA Aviation Forum 2018

Jay Shively

Sub-Project Manager, Detect and Avoid

Full UAS Integration Vision of the Future

Manned and unmanned aircraft will be able to routinely operate through all phases of flight in the NAS, based on airspace requirements and system performance capabilities.

UAS Integration in the NAS Organizational Structure

Host Center

AFRC Director of Programs:
Joel Sitz
Deputy Director:
Laurie Grindle

Program Office

IASP Program Director
Dr. Ed Waggoner
Deputy Program Director
Lee Noble

Program External Interfaces

ExCom, RTCA Steering Committee, UAS Aviation Rulemaking Committee

Project Support

- Lead Resource Analyst – April Jungers, AFRC
- Lead Proc Officer – Rosalia Toberman, AFRC
- Scheduler – Irma Ruiz, AFRC
- Risk and Outreach Lead – Jamie Turner, AFRC
- Doc and Change Mgmt – Lexie Brown, AFRC
- Admin Support – Sarah Strahan, AFRC
- Resource Analyst – Amber Gregory, AFRC
- Resource Analyst – Warcquel Frieson, ARC
- Resource Analyst – Julie Blackett, GRC
- Resource Analyst – Pat O'Neal, LaRC

Project Office

- Project Manager (PM) – Robert Sakahara, AFRC
- Deputy PM – Davis Hackenberg, AFRC
- Associate PM – Laurie Grindle, AFRC
- Chief Engineer – William Johnson, LaRC
- Deputy Chief Engineer – Clint St. John, AFRC

- Staff Engineer – Dan Roth, Doug Wada, AFRC
- Senior Advisor for UAS Integration - Chuck Johnson
- UCAT Liaison– Jim Murphy, ARC
- SIO Technical Manager – Kurt Swieringa, LaRC

Project External Interfaces

FAA, DoD, RTCA SC-228, Industry, etc.

Aero Centers

- Brad Flick – ARD, AFRC
- Huy Tran – ARD, ARC
- Ruben Del Rosario – ARD, GRC
- George Finelli – ARD, LaRC

Subprojects

Command and Control (C2) SPM
Mike Jarrell, GRC

C2 Subproject Technical Lead
Bob Kerczewski, GRC

Detect and Avoid (DAA) SPM
Jay Shively, ARC

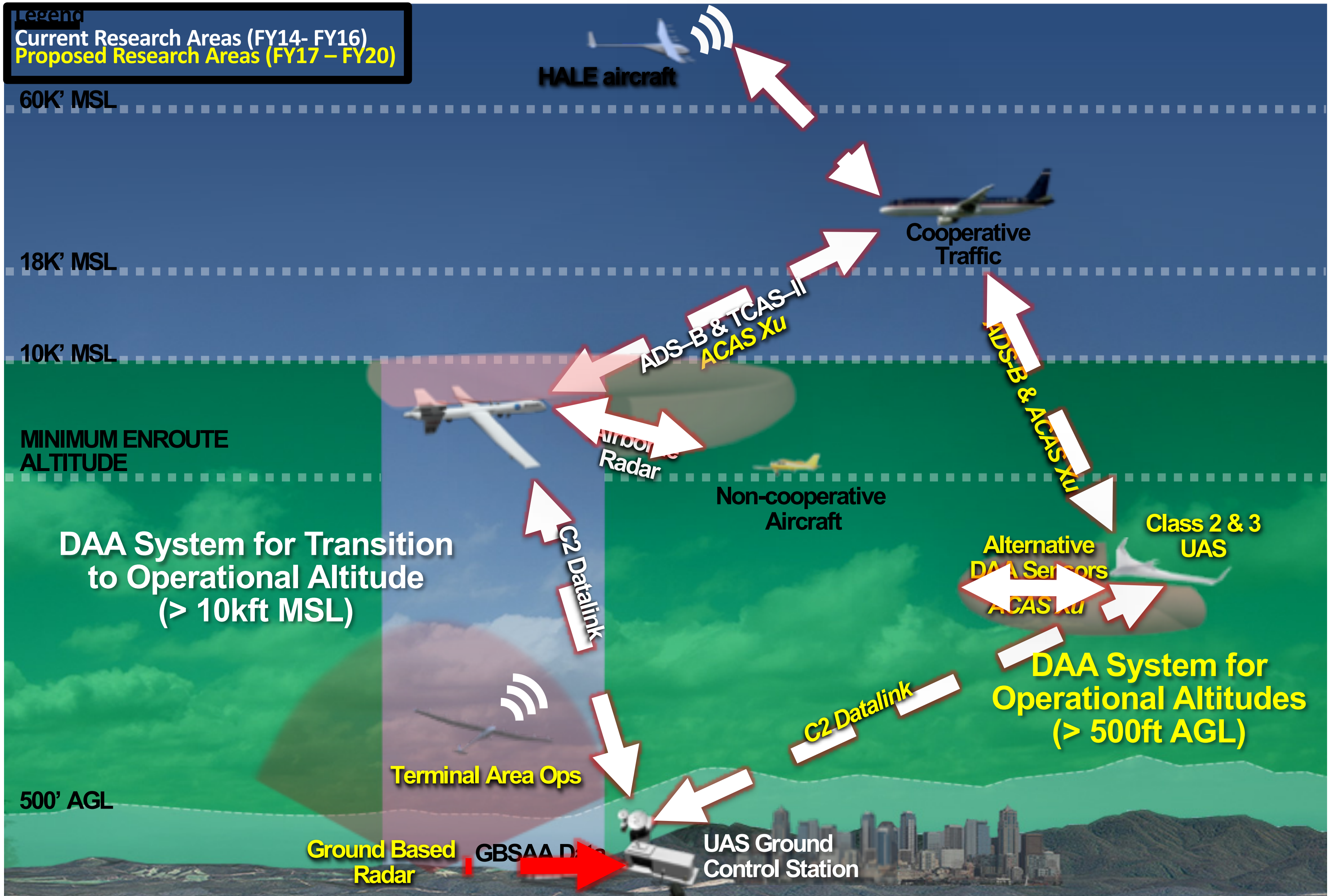
DAA Subproject Technical Leads
Gilbert Wu, ARC; *Jessica Nowinski*, ARC; Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E) SPM
Mauricio Rivas, AFRC

IT&E Subproject Technical Lead
Sam Kim, AFRC; Ty Hoang *(Acting)*, ARC

ARD: Aeronautics Research Director, PM: Project Manager, SPM: Subproject Manager, UCAT: Urban Air Mobility Coordination Assessment Team, SIO: Systems Integration and Operationalization

DAA Operational Environments



See and Avoid: FAR Sec. 91.113

General. When weather conditions permit, regardless of whether an operation is conducted under instrument flight rules or visual flight rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft. When a rule of this section gives another aircraft the right-of-way, the pilot shall give way to that aircraft and may not pass over, under, or ahead of it unless well clear.

Piloted “see and avoid” = UAS “detect and avoid”

Pilots vision replaced by sensors (on- or off- board or both)

Pilot judgment of well clear = mathematical expression of well clear

Horz Miss Distance = 4000ft; Vert Miss Distance = 450ft;
modTau = 35sec

Phase 1 Accomplishments

DO-366

Minimum Operating Performance Standards (MOPS) for Air-to Air Radar Detect and Avoid (DAA) Systems

Technical Standard Orders

TSO-C211, Detect and Avoid
TSO-C212, ATAR for Traffic Surveillance

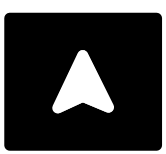
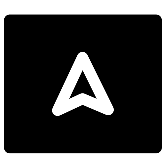
NASA DAA Team Contributions:

- Well clear definition
- Alerting
- Guidance
- Displays
- Reference algorithm
- Significant modeling and simulation

Displays

- An early critical question for the Phase I MOPS for DAA systems was what, if any, level of DAA maneuver guidance would be required to support acceptable performance on maintaining well clear?
- Phase I MOPS assumptions specify that the pilot in command will execute maneuvers to remain well clear
  - i.e., No automatic/autonomous DAA capability
- Display types given level/type of maneuver guidance:
  - ***Informative***: Provides essential information of a hazard that the remote pilot may use to develop and execute an avoidance maneuver. No maneuver guidance automation or decision aiding is provided to the pilot
  - ***Suggestive***: Automation provides a range of potential resolution maneuvers to avoid a hazard with manual execution. An algorithm provides the pilot with maneuver decision aiding regarding advantageous or disadvantageous maneuvers
  - ***Directive***: Automation provides specific recommended resolution guidance to avoid a hazard with manual or automated execution. An algorithm provides the pilot with specific maneuver guidance on when and how to perform the maneuver

Alerting

Symbol	Name	Pilot Action	Buffered Well Clear Criteria	Time to Loss of Well Clear	Aural Alert Verbiage
	TCAS RA	• ***Immediate action required*** • Comply with RA sense and vertical rate • Notify ATC as soon as practicable after taking action	*DMOD = 0.55 nmi *ZTHR = 600 ft *modTau = 25 sec	0 sec (+/- 5 sec) (TCPA approximate: 25 sec)	"Climb/Descend"
	DAA Warning Alert	• ***Immediate action required*** • Notify ATC as soon as practicable after taking action	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	25 sec (TCPA approximate: 60 sec)	"Traffic, Maneuver Now" x2
	Corrective DAA Alert	• On current course, ***corrective action required*** • Coordinate with ATC to determine an appropriate maneuver	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	55 sec (TCPA approximate: 90 sec)	"Traffic, Avoid"
	Preventive DAA Alert	• On current course, corrective action **should not be required** • Monitor for intruder course changes • Talk with ATC if desired	DMOD = 0.75 nmi HMD = 1.0 nmi ZTHR = 700 ft modTau = 35 sec	55 sec (TCPA approximate: 90 sec)	"Traffic, Monitor"
	Guidance Traffic	• **No action required** • Traffic generating guidance bands outside of current course	Associated w/ bands outside current course	X	N/A
	None (Target)	• **No action required** • No coordination required	Within surveillance field of regard	X	N/A

* These values show the Protection Volume (**not well clear volume**) at MSL 5000-10000ft (TCAS Sensitivity Level 5)

Alerting and Guidance Processing Requirements

- Prototype DAA Algorithms
  - Detect and AvoID Alerting Logic for Unmanned Systems (DAIDALUS) (MOPS reference algorithm)
  - Generic Resolution Advisor and Conflict Evaluator (GRACE)
- Fast time simulations (Ames and LaRC)
  - Alerting criteria to sensor range requirement
  - Assessed the adequacy of DAA's alerting timeline by recording when and where air traffic controllers issued traffic alerts and advisories during encounters
  - Effects of sensor uncertainty (RADAR, ADS-B)
  - Relationship between aircraft performance parameters and the required maneuver initiation range

Verification and Validation

- Flight test validation
  - NASA's Ikhana own ship
  - Manned intruders of varying sizes
  - Virtual intruders through the live, virtual constructive (LVC) distributed sim environment
- No Chase COA Demo

Photo: NASA

V & V

- End to End fast time simulation
  - reference DAA implementation (DAIDALUS)
  - sensor and tracker models
  - pilot response model
  - Community agreed upon test vectors

- HITL simulation
  - DAA display requirements
  - Alerting
  - Guidance

Phase 2

- Well Clear
  - Terminal area
  - Low SWaP
- Low SWaP Sensor
- Algorithm modifications
- Guidance, displays, alerting – tuning
- ACAS-Xu/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements (for new sensors)

Development of Low Cost, Size, Weight, and Power (C-SWaP) Detect and Avoid Sensor Cooperative Agreement

- Partnership: Competed via a cooperative agreement notice; selected Honeywell
- Objective: The objective of this CA is to provide specific potential public benefits.
  - These include improved safety of UAS integration into the NAS through improved sensor technologies
  - Testing of those technologies in highly relevant simulation and operational testing environments
  - Breaking down the barriers for less-equipped, more-affordable UAS to access the NAS

NASA ARC SIERRA-B

Photo: NASA

- Schedule:
  - Flight Test 5: FY18
  - Flight Test 6: FY19

FT 5

Goal:
Characterize RADAR performance
Collect DAA for off-line analysis

Intruders (notional):
Cooperative and non-cooperative
Various RADAR cross sections

Fall, 2018

FT 6

Goals:

– Evaluate end to end DAA system performance with PIC in the loop
– Evaluate low-SWaP well clear definition
– Evaluate terminal well clear definition

Vigilant Spirit Control Station – AFRL
Photo: NASA

Fall, 2019

Summary

- Close coordination with the FAA and RTCA SC 228
- Successfully helped the community move forward with UAS Integration
- Phase 2 underway to extend and enhance earlier efforts
- Following talks discuss details of some phase 1 efforts and initial work on phase 2