UAS Integration in the NAS: Detect and Avoid

Conrad Rorie *for*

Jay Shively

Detect and Avoid

Sub-Project Manager

UAS-NAS Phase 2
Project Organization Structure

PROJECT OFFICE LEVEL

Project Leadership

Project Manager (PM)	Robert Sakahara, AFRC
Deputy PM	Davis Hackenberg, AFRC
Chief Engineer (CE)	William Johnson, LaRC

Project Support

Sr. Advisor AFRC	Chuck Johnsons,
Staff Engineer	Dan Roth, AFRC
Lead Resource Analyst	April Jungers, AFRC
Resource Analysts	Amber Gregory, AFRC
	Warcquel Frieson, ARC
	Julie Blackett, GRC
	Pat O'Neal, LaRC
Scheduler	Irma Ruiz, AFRC
Risk Manager/Outreach	Jamie Turner, AFRC
Change/Doc. Mgmt	Lexie Brown, AFRC
Admin Support	Sarah Strahan, AFRC

Project Systems Engineering Office

Deputy Chief Engineer	Clint St. John, AFRC
SIO Technical Manager	Kurt Swieringa, LaRC

SUBPROJECT LEVEL

Command and Control (C2)

Subproject Manager

Mike Jarrell, GRC

Subproject Technical Lead

Jim Griner, GRC

Detect and Avoid (DAA)

Subproject Manager

Jay Shively, ARC

Subproject Technical Lead

Gilbert Wu (A)/Confesor Santiago, ARC; Lisa Fern; ARC; Tod Lewis, LaRC

Integrated Test and Evaluation (IT&E)

Subproject Manager

Mauricio Rivas, AFRC / Jim Murphy, ARC

Subproject Technical Lead

Ty Hoang, ARC (A) ; Sam Kim, AFRC

(A) Acting

UAS-NAS Project Value Proposition

NASA UAS-NAS Project Activities

TC C2 — C2 Performance Standards

- Research C2 SatCom Systems
- Develop C2 Prototype Terrestrial System
- → Conduct C2 Flight Test and MS&A
  Data Link, CNPC Spectrum, CNPC Security, BVLOS/BRLOS, ATC Interoperability
- → Develop C2 Requirements

TC DAA — DAA Performance Standards

- Develop DAA Test beds
- → Conduct DAA Flight Test and MS&A
  Human Factors Performance Trade-offs, Low Cost SWaP sensors, Well Clear, Collision Avoidance
- → Develop DAA Performance & Interoperability Requirements

Integrated Test & Evaluation

- Develop DAA Prototype System
- → Live Virtual Constructive (LVC) Test Infrastructure
- → Conduct Technology and CONOPS testing
  - ACAS Xu FT2
  - No Chase COA
  - Conduct FT5 Test Scenarios
  - Conduct FT6 Test Scenarios

SIO — Systems Integration and Operationalization

- Develop Robust NASA/ Industry Partnership
- → Develop certification compliance toolkit(s)
- Integrate Essential Technologies
- → Conduct Demo

Key Products

- C2 Performance Requirements to inform C2 MOPS → RTCA Terrestrial ... MOPS
- DAA Performance Requirements to inform DAA MOPS → RTCA Non-Coop Sensor MOPS
- Re-usable Test Infrastructure → RTCA GBDAA MOPS; RTCA DAA MOPS Rev A/B
- Substantiated path → Generic Certification Compliance Toolkit(s)

Resultant Outcomes

- C2 Technical Standard Order (TSO)
- DAA Technical Standard Order (TSO)

DAA Subproject Structure for Project Phase 2

Detect and Avoid

<TC-DAA>

Subproject Manager (SPM)

Jay Shively, ARC

Subproject Technical Leads

Gilbert Wu (A), ARC; Lisa Fern; ARC; Tod Lewis, LaRC

TECHNICAL CHALLENGE/ SUBPROJECT LEVEL

Alternate Surveillance Requirements

Well Clear Alerting Requirements

ACAS Xu

External Collaborations

Integrated Events

TECHNICAL WORK PACKAGE LEVEL

DAA Performance Standards

Develop DAA Test beds

Conduct DAA Flight Test and MS&A

Human Factors
Performance Trade-offs
Interoperability
Self Separation
CONOPs
Well Clear
Collision Avoidance

Develop DAA Performance & Interoperability Requirements

DAA Performance Requirements to inform DAA MOPS

RTCA Non-Coop Sensor MOPS

RTCA DAA MOPS Rev A/B

GBDAA MOPS

DAA Technical Standard Order (TSO)

SCHEDULE PACKAGE LEVEL

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”

Pilot vision => surveillance sensors (on- or off- board, or both)

Pilot judgment of well clear => mathematical expression of well clear

Phase 1 DAA well clear defined as:

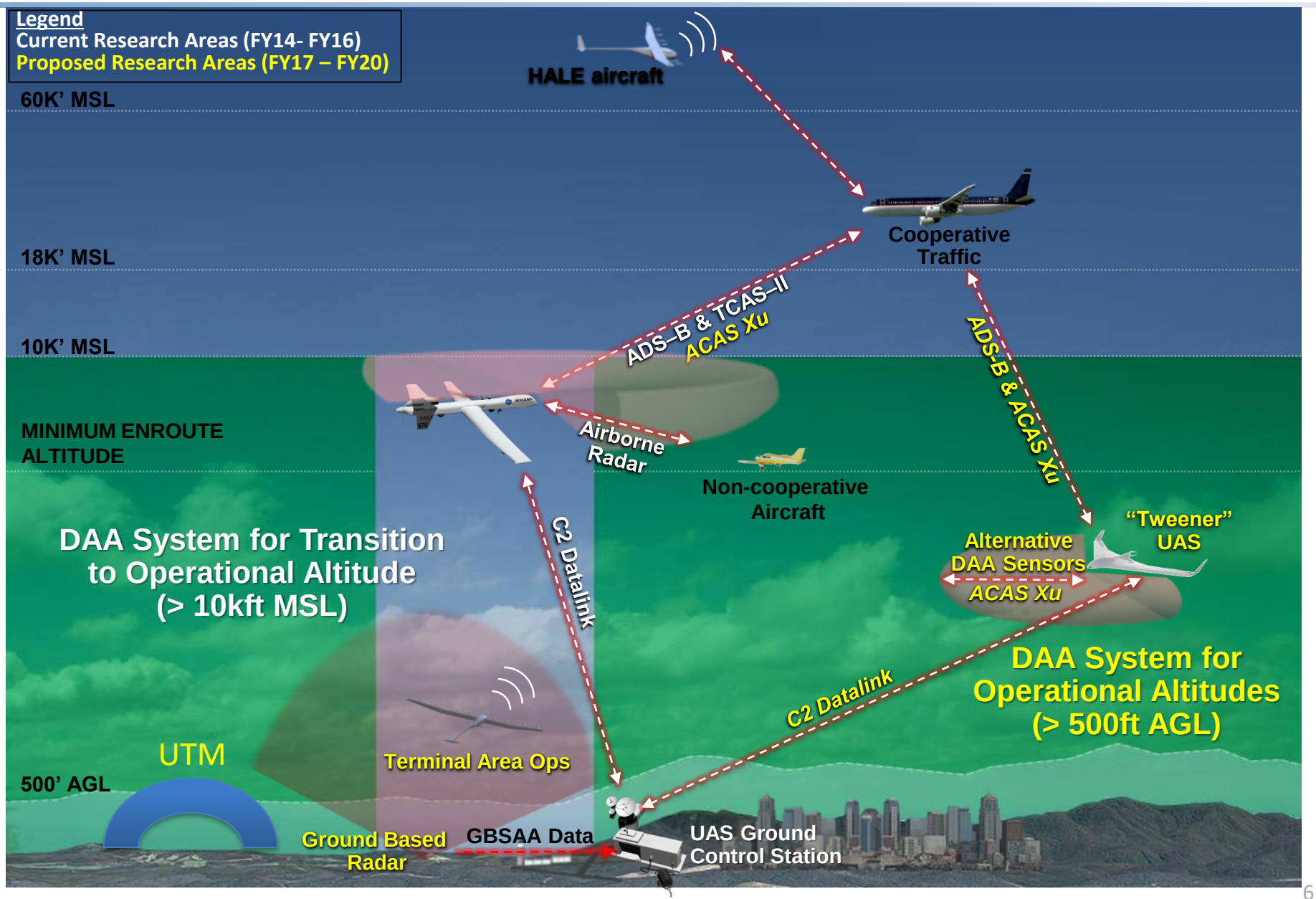
Horz Miss Distance = 4000ft

Vert Miss Distance = 450ft

modTau = 35sec

DMOD = 4000ft

DAA Operational Environments



Phase 1 Accomplishments

RTCA DO-365:

- Minimum Operating Performance Standards for **Detect and Avoid Systems**

RTCA DO-366:

- Minimum Operating Performance Standards for **Air-to Air Radar Traffic Surveillance**

FAA 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

Phase 2
FY 18 - 20

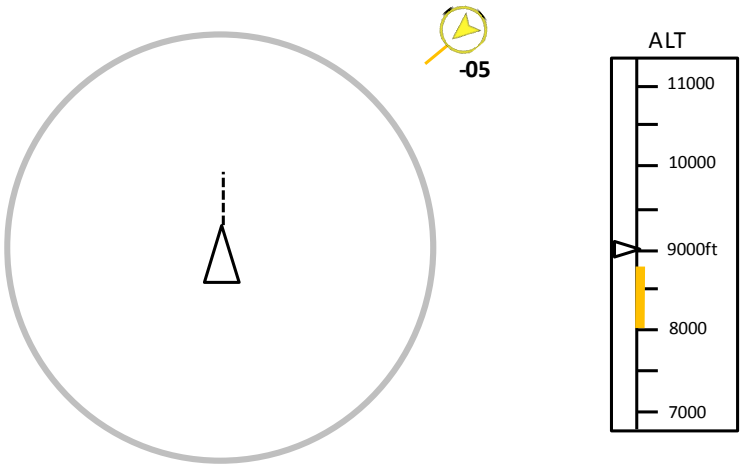
- Augmented Well Clear Definitions
  - Terminal
  - Low SWaP
- Low SwaP Sensors
  - RADAR
    - Cooperative agreement with Honeywell
- Flight Tests
  - FY 19 – Low SWaP RADAR
    - Unmitigated encounters
  - FY 20 – Pilot response to new well clear definition; use of Low SWaP RADAR

Phase 1 DAA Alerting

Symbol	Name	Pilot Action	DAA Well Clear Criteria	Time to Loss of DAA Well Clear	Aural Alert Verbiage
	Warning Alert	• Notify ATC as soon as practicable after taking action	DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 450 ft modTau = 35 sec	25 sec	“Traffic, Maneuver Now” x2
	Corrective Alert	• Coordinate with ATC to determine an appropriate maneuver	DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 450 ft modTau = 35 sec	55 sec	“Traffic, Avoid”
	Preventive Alert	• On current course, corrective action should not be required	DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 700 ft modTau = 35 sec	55 sec	“Traffic, Monitor”
	Guidance Traffic	• Traffic generating guidance bands outside of current course	Associated w/ bands outside current course	X	N/A
	Remaining Traffic	• Traffic within sensor range	Within surveillance field of regard	X	N/A

Phase 1 DAA Suggestive Maneuver Guidance

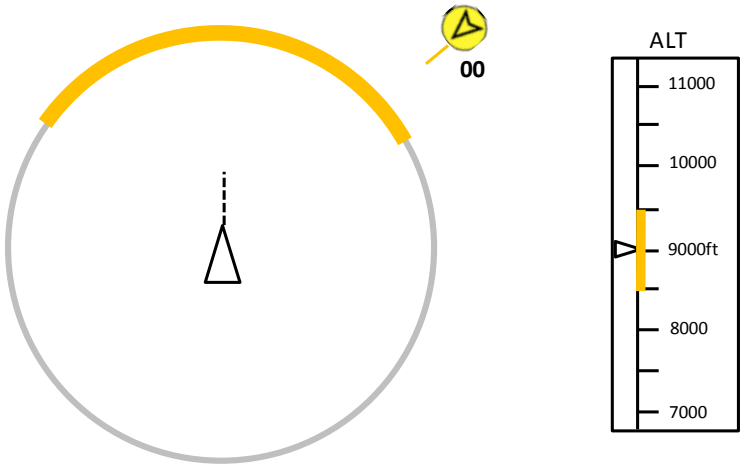
Remain DAA Well Clear Corrective Guidance



Inner Range Ring

Altitude Tape

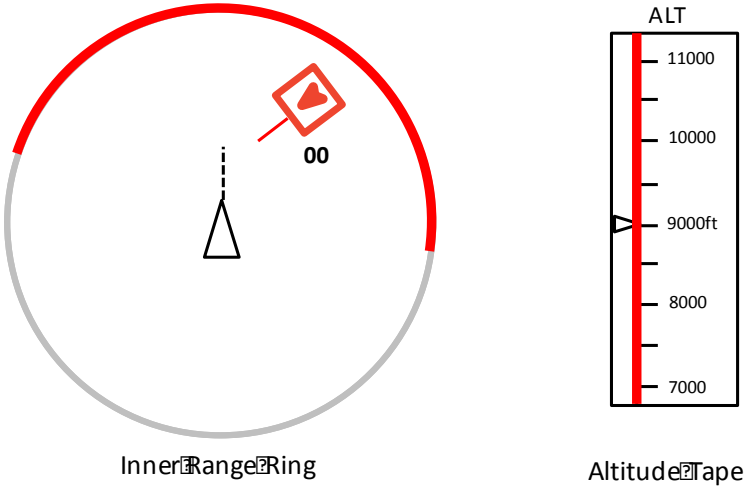
Remain DAA Well Clear Corrective Guidance



Inner Range Ring

Altitude Tape

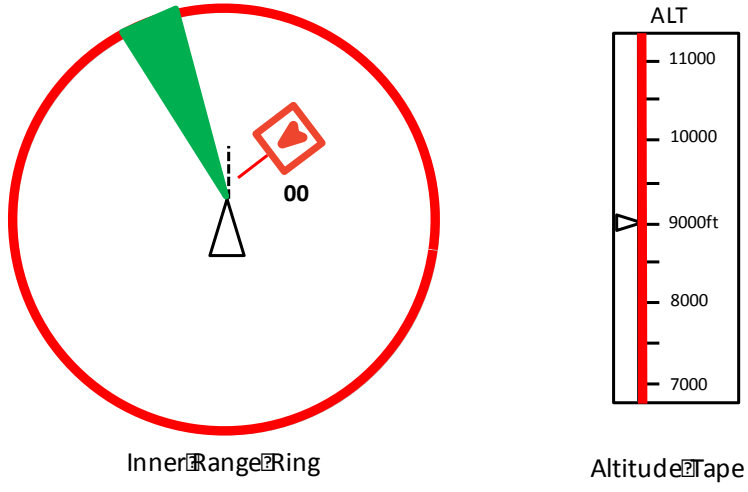
Remain DAA Well Clear Warning Guidance



Inner Range Ring

Altitude Tape

Regain DAA Well Clear Guidance



Inner Range Ring

Altitude Tape

HSI DAA Performance Metrics

- Multiple human-in-the-loop (HITL) simulations were performed to identify requirements for UAS DAA systems. The following metrics were used to assess pilot and system performance:
  - Pilot response times
  - Proportion of losses of DAA well clear
  - Severity of losses of DAA well clear
  - ATC interoperability
  - Subjective assessment & workload

Pilot-Air Traffic Control Interaction Timeline & Metrics