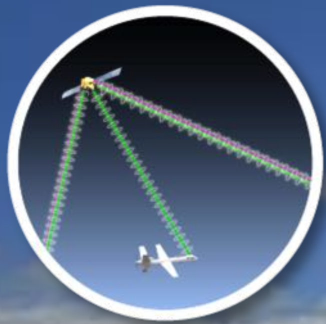


Unmanned Aircraft Systems (UAS) Integration in the National Airspace System (NAS) Project

UAS Integration in the NAS

Human Systems Integration Overview

2nd Workshop on Human-Automation Interaction Considerations for UAS Integration

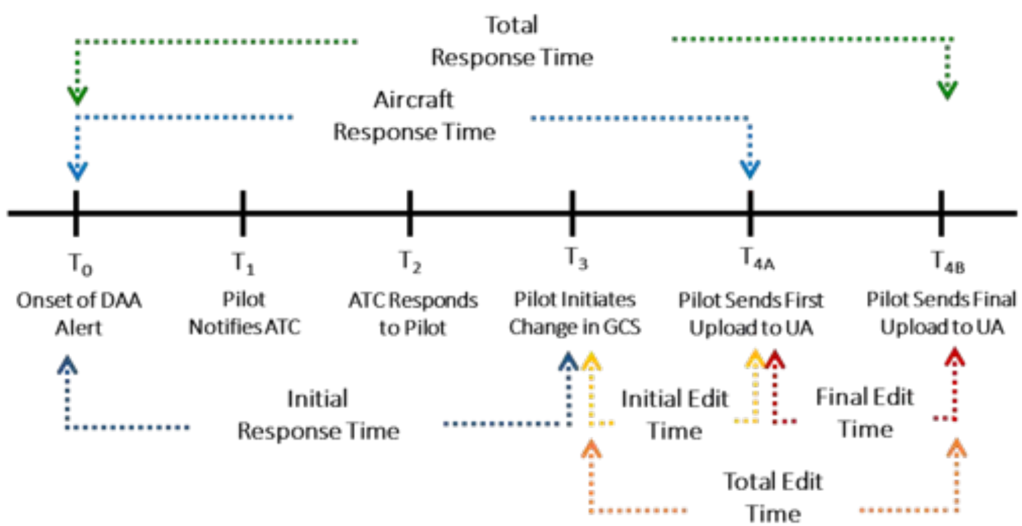
16 May 2018

Conrad Rorie
Human Systems Integration

UAS-NAS HSI Phase 1 Efforts

- 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

<u>Pilot-Air Traffic Control Interaction Timeline & Metrics</u>



Contributions to Phase 1 UAS DAA MOPS

- Suggestive DAA guidance requirements
- Alerting logic and thresholds
- Display integration
- Pilot response timeline
  - Directly influenced RADAR Requirements
- V&V of alerting, guidance and display draft MOPS

→ DAA HITL Experiments

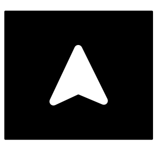
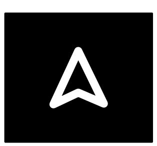
- TCAS/DAA interoperability concept
  - Requirements for DAA guidance and alerting
- Regain well clear guidance logic/display

→ DAA-TCAS Interoperability HITL

- Alerting and guidance logic for special cases
  - E.g., no altitude, no bearing
- Alerting and guidance displays for special cases

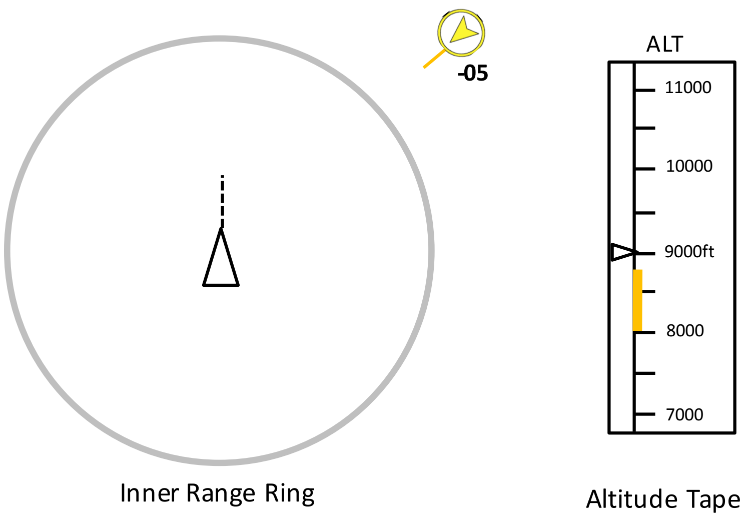
→ Special Cases Mini HITL

Phase 1 DAA Alerting Criteria

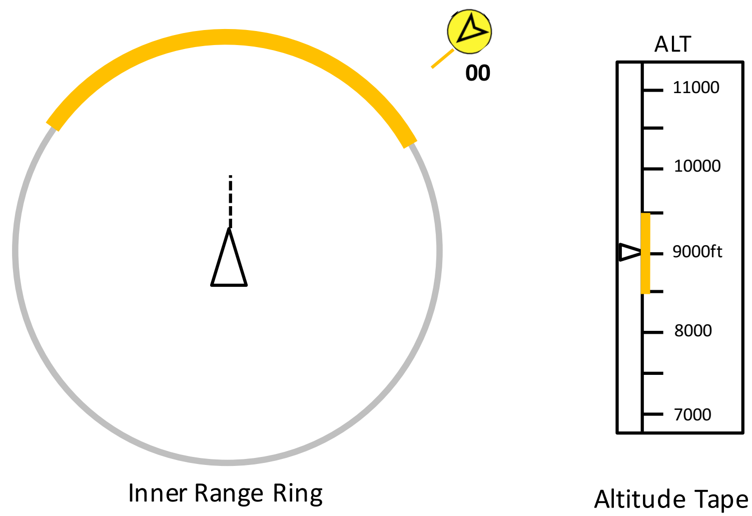
Symbol	Name	Pilot Action	DAA Well Clear Criteria	Time to Loss of DAA Well Clear	Aural Alert Verbiage
	Warning Alert	• Notify ATC as soon as practicable after taking action	DMOD = 0.66 nmi HMD = 0.66 nmi ZTHR = 450 ft modTau = 35 sec	25 sec	"Traffic, Maneuver Now" x2
	Corrective Alert	• Coordinate with 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

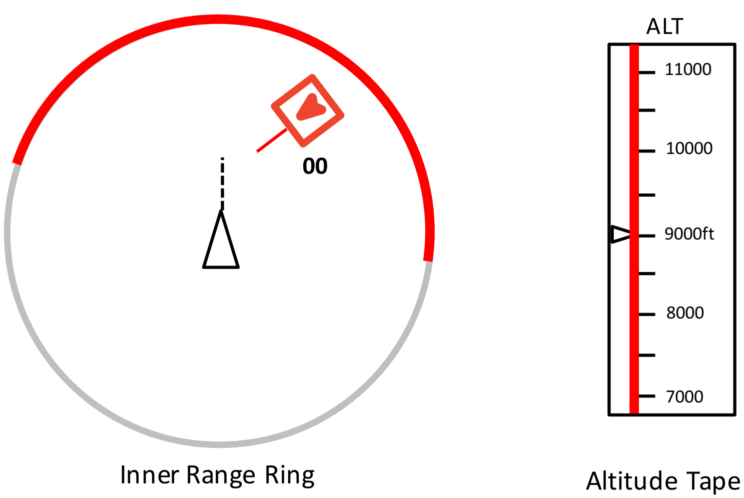
Remain DAA Well Clear Corrective Guidance



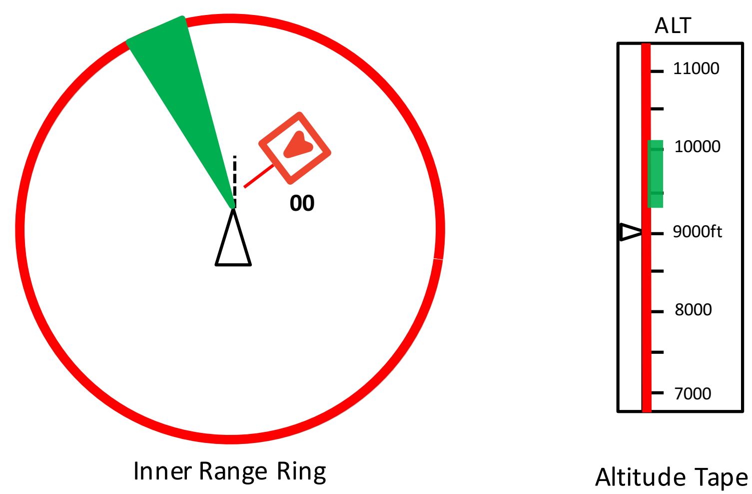
Remain DAA Well Clear Corrective Guidance



Remain DAA Well Clear Warning Guidance



Regain DAA Well Clear Guidance



UAS-NAS Phase 2 Efforts

- Focus on development of technologies and standards for enabling a broader range of UAS types and operations
  - Smaller UAS (e.g., Scan Eagles, Shadow)
  - Approach and departure operations at towered and non-towered airports
  - Automation considered an *optional* equipage
    - Phase 1 assumed a pilot-in-the-loop at all times

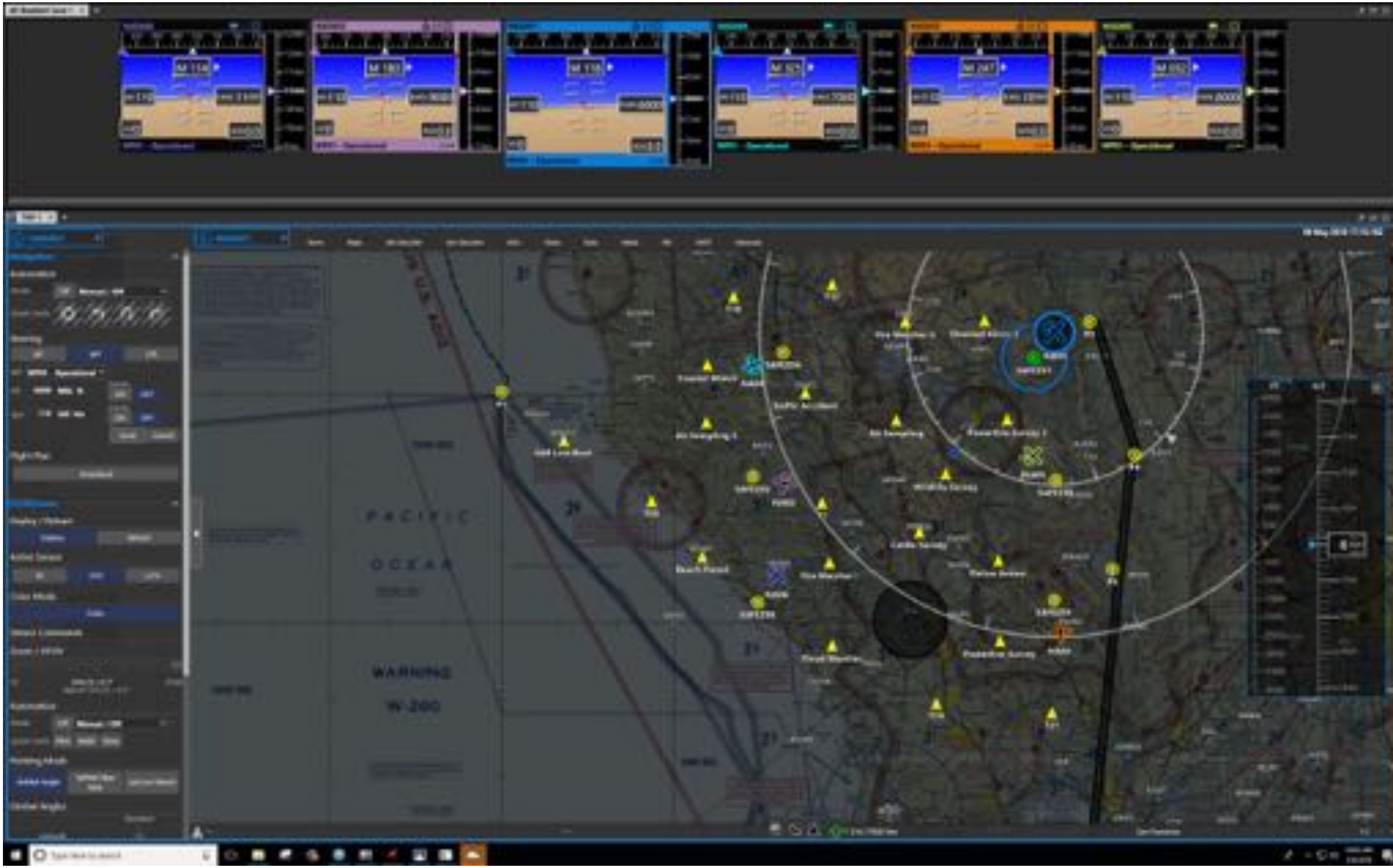
- DAA alerting and guidance will have to take into account new types of operations, such as:
  - Low cost, size, weight, and power airborne surveillance for detecting and tracking non-cooperative aircraft
  - DAA well clear definition for smaller UAS and terminal operations
  - ACAS Xu performing both ‘remain well clear’ and collision avoidance functions
  - **Automation/Autonomy**
    - Auto-Collision Avoidance (Auto-CA)
    - Multi-UAS control

Upcoming UAS-NAS Human Autonomy Teaming Research

- **Multi UAS Control – Human-in-the-Loop (HITL) Simulation**
  - When: June 2018
  - Goal: investigate the effect of multi-UAS, single-operator control on pilots' ability to maintain DAA well clear while flying in Class E airspace
  - Experimental Design:
    - *Independent Variable* – number of UAVs under single-operator control (1:1, 1:3, 1:5)
    - *Primary Task* – work through a 'mission deck' and other high-priority, high-workload sensor tasks
    - *Scripted Encounters* – conflicts will be designed to occur with UAS, varying by:
      - Whether the UAS is under "focus" – in multi-UAS conditions, the pilot can only focus on one UA at a time
      - Single vs. multi-threat encounter – in multi-UAS conditions, simultaneous conflict with 2 different UA's
  - Automation Considerations: this HITL is **not** incorporating any automation-related tools (e.g., auto-CA/RTC), however:
    - Pilot debriefs & questionnaires will elicit feedback on ways to facilitate both 1:N and M:N UAS control
    - A follow-on engineering analysis will present pilots with multi-UAS control and sharing capabilities (i.e., M:N)
      - Can incorporate architectures/concepts identified in this workshop

Upcoming UAS-NAS Human Autonomy Teaming Research

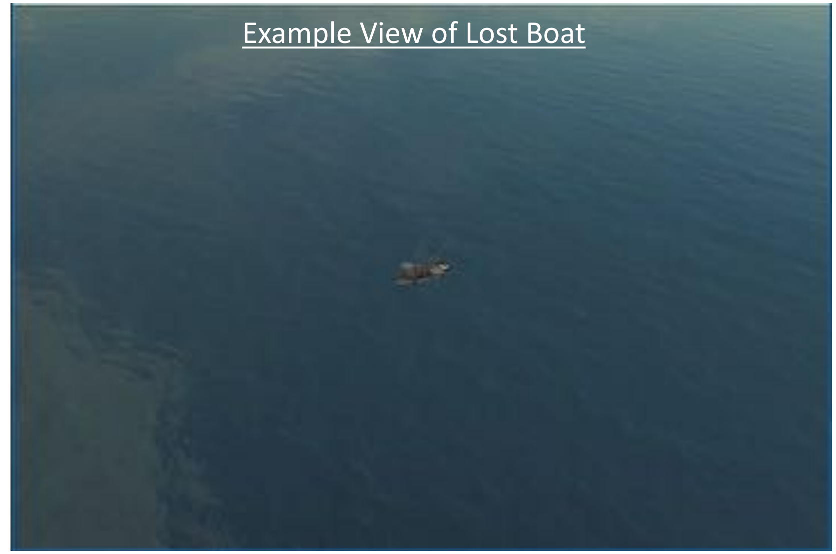
- Current M:N design



Upcoming UAS-NAS Human Autonomy Teaming Research

- Screenshots of sensor task (metaVR)


Example View of Downed Aircraft


Example View of Lost Boat


Example View of Traffic Accident


Example View of Cattle Survey

Upcoming UAS-NAS Human Autonomy Teaming Research

- **Automatic Execution of Collision Avoidance & Return to Course – Engineering Analysis**
  - When: January 2019
  - Goal: implement and evaluate candidate architectures & HMI display concepts for auto-Collision Avoidance (CA) & Return-to-Course (RTC)
  - Task 1: *Regulatory Review* – an analysis of existing civil and military (U.S. and international) regulatory requirements and guidance addressing human-automation interaction with auto-pilots and other cockpit systems
  - Task 2: *Automation Workshop* – HF experts collaborate to identify potential human-automation architectures and HMI designs
  - Task 3: *Engineering Analysis* – four pilots will come in and fly select scenarios designed to scenarios and concepts identified by regulatory review and automation workshop
    - HMI concepts will be integrated into Vigilant Spirit Control Station
  - Automation Considerations: mode awareness, transparency, overreliance

Upcoming UAS-NAS Human Autonomy Teaming Research

- **ACAS Xu – HITL Simulation**
  - When: April 2019
  - Goal: implement and evaluate presentation of ACAS Xu alerting and guidance; namely the presentation of horizontal Resolution Advisories and blended maneuvers
  - Automation Considerations: this HITL may incorporate the optional auto-CA/RTC functionality that ACAS Xu is able to support

- **Multi-UAS Control 2 – HITL Simulation**
  - When: August 2019 (tentative)
  - Goal: investigate multi-UAS control with emphasis on display concepts that facilitate M:N operations
  - Automation Considerations: auto-CA/RTC will be implemented to support larger number of UAS; tools to allow pilots to hand-off control with safely and efficiently
    - Integrate 'playbook' type solutions to multi-UAS & DAA environment

Automation Workshop - Breakout Plan

- **Workshop goals:**
  - Apply expertise to address *specific* human-automation interaction use cases
  - Identify research gaps
    - Prioritize areas in need of further study
    - Identify people/orgs that may be able to address open items in near term
  - Produce ideas and concepts that can drive upcoming work at NASA and SARP
    - NASA's upcoming studies can leverage architectures and HMI designs identified here
      - Multi UAS engineering analysis AUG 2018
      - Auto-CA/RTC engineering analysis in JAN 2019
      - M:N HITL in AUG 2019
    - SARP can apply lessons learned from the workshop to their forthcoming Multi-UAS CONOPS

- **Breakout group deliverables:**
  - High-level 'architecture' for each use case
    - I.e., what are the human & automation roles and responsibilities?
    - How can the human-automation architecture be designed to support coordination/synchronization?
    - Functional allocation diagram – e.g., pictures of the white board/power point slide(s)
  - HMI design concepts
    - Mock up or detailed description of proposed HMI design concepts
    - List of display, control, and automation features
  - List of critical challenges that must be resolved in near-term

Breakout Groups

Breakout Group 1	Breakout Group 2
Facilitator 1: Scott Scheff *Facilitator 2*: Jay Shively	*Facilitator 1*: Kim Vu *Facilitator 2*: Ted Lester
Ellen Bass	Emilie Roth
Sherry Chappell	Michelle Yeh
Chris Miller	Maria Kuffner
Alex Kirlik	Joe Boyd
Ferne Friedman-Berg	Joe Lyons
Sean Calhoun	Mike Rayo
Asher Balkin	Adam Hendrickson
Jay Shively	Conrad Rorie
Jacob Kay	Sarah Strahan

Workshop Notes

- Need early buy-in from ATC/NATCA