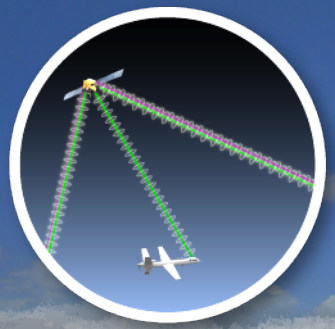

Considerations for RTCA Phase 2 Low Size, Weight, and Power (SWAP) Surveillance Requirements

Presented to RTCA SC-228 Working Group 1

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Foreword

- This briefing consists of suggested issues and problems when integrating low size, weight, and power surveillance systems onto UAS for the purposes of detect and avoid.

- Main purpose is to exchange information and get feedback.

- Desired feedback
  - What to add?
  - What to edit?
  - What to delete?

- These issues/problems become ours (working group 1).
  - Not just mine or NASA's

Outline

- Background
- Scope of this Topic White Paper
  - What Needs to be Addressed on this Topic in the Phase II MOPS?
  - What Does Not Need to be Addressed?
- Operational Environment as it Relates to Phase II and this Topic?
- Assumptions
  - Operational Assumptions
  - Technical Assumptions
- What is the Approach to Developing this Topic in the Phase II MOPS?

Background

- Most UAS platforms can't meet the Phase 1 radar requirements due to limited size, weight, and/or power (SWAP)
  - Non-cooperative sensor for smaller class of UAS, i.e. low SWAP
  - Need to update the Phase 1 DAA MOPS to incorporate the new technologies enabled by the Phase 2 MOPS for non-cooperative surveillance

- This briefing is focused on low SWAP sensor work that will lead to development of MOPS for non-cooperative sensors

What Needs to be Addressed on this Topic in the Phase II MOPS?

- Define what low SWAP means:
  - Relative to the SWAP of the Phase 1 radar system
  - Relative to conventional cooperative surveillance system (ADS-B/Transponder)
  - Upper thresholds for volume, weight, power

- High-level objective
  - Evaluate the interoperability between the performance requirements of low SWAP surveillance with DAA alerting and guidance requirements
  - Determine how to incorporate these new technologies into DAA
  - Determine if they are sufficient

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Decide Approach:
  - Top-down solution: how far can the sensor detect intruder and declare a track, and how it stacks up with issues below

  Or

  - Bottom-up solution: evaluate/tune issues below that then informs detection/declaration range requirements

- Performance requirements such as
  - Detection/declaration range
  - Field of view – elevation/azimuth
  - Max number of tracked targets
  - Update rates
  - Track report fields (track ID, range, range rate, etc.)
  - Accuracy/uncertainties
  - Special cases

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - **Detection/declaration range**
  - Field of view – elevation/azimuth
  - Max number of tracked targets
  - Update rates
  - Accuracy/uncertainties
  - Special cases

Factors with Detection/Declaration Range

Issues:

- Maneuver performance and closure speeds (Keith covered)
- New (reduced) DAA well clear parameter (Tod covering next)
  - Appropriately scaling of DAA well clear definition (DMOD and mod tau)
- Total Pilot Response Time
  - Alert times
  - ATC coordination
  - Pilot response time
- Command latencies
- Time to establish track
- Other factors
  - Impact of weather conditions

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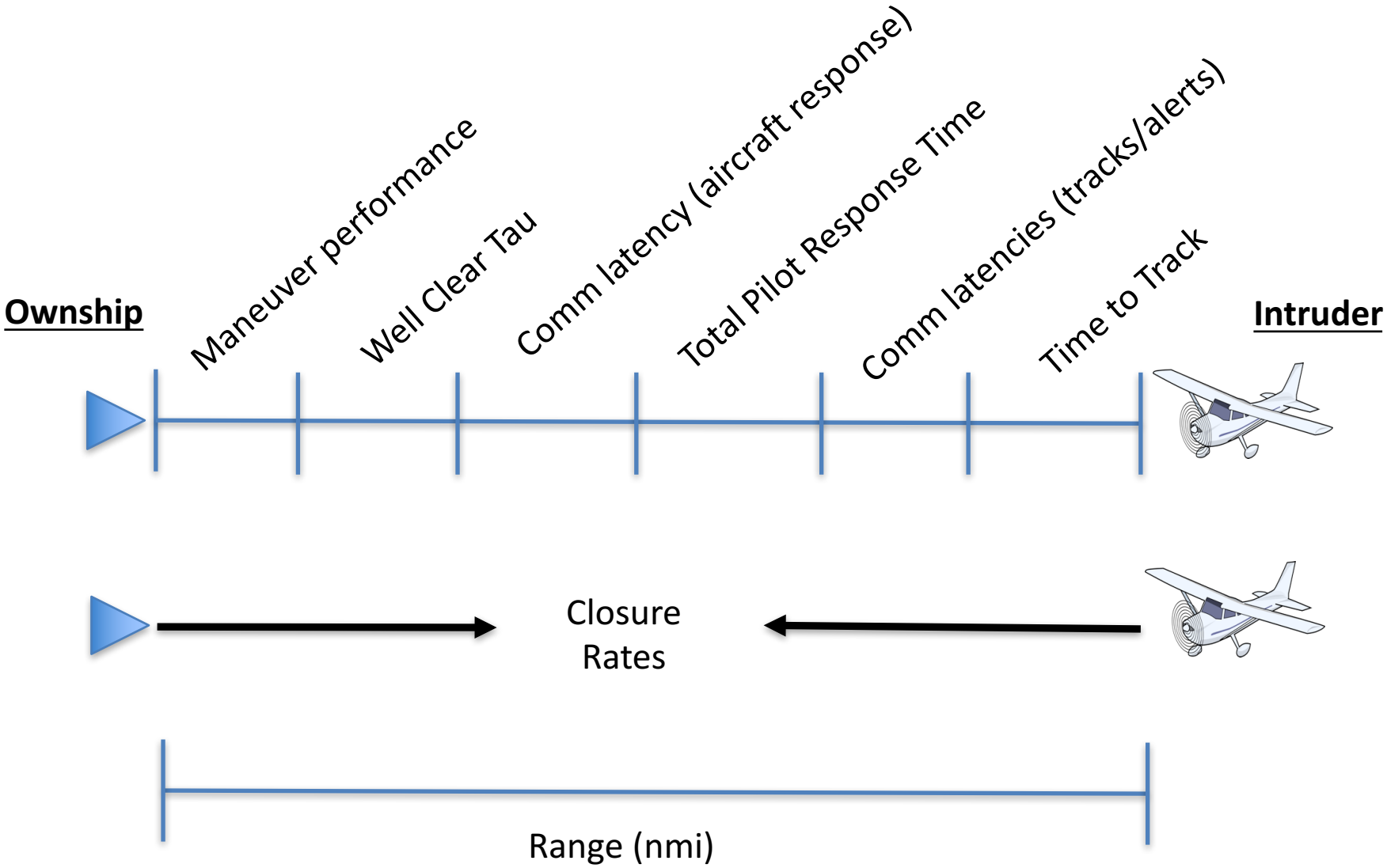
DAA Timeline



Total Pilot Response Time

- Pilot response time
  - Display work to shorten response time?
  - Pilot-on-the-loop?
  - Auto-executed maneuver?
  - To enable low SWAP sensor it may require us taking a look at HMI and reduce response times
- ATC coordination
  - Depending on what we determine as the SWAP thresholds, declaration ranges may not allow for DAA Corrective alerts
  - Evaluate how often there wasn't enough time for ATC coordination given an encounter with a non-cooperative intruder
  - Likely (hopefully) very, very low? Validate with fast-time study.
- Alert times
  - Parameters for DAA alerting requirements such as late alerts, early alert, minimum average alert time likely need updating
  - Can they be reduced to require less SWAP?

Communication Latencies

- Modeling Time Lags
  - Downlinking surveillance data from aircraft
  - Upload of commanded maneuver to aircraft responding

- Assumption is that this is already informed by the C2 MOPS

- Probably just need a simple model for this our our simulations

Time to Establish Track

- Time between detection of target and declaring a track
- Assumption is sensor MOPS will have requirements on this, and we will need to evaluate interoperability with DAA alerting and guidance
- Likely to just need a simple model for this in fast-time simulations

Other Factors for Detection

- Environmental conditions
  - Rain
  - Snow
  - Dust

- *Decide whether to include these, and if so how?*

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - Detection/declaration range
  - **Field of view – elevation/azimuth**
  - Max number of tracked targets
  - Update rates
  - Accuracy/uncertainties
  - Special cases

Azimuth/elevation

- Study the trade space to understand the encounter geometries characteristics and whether there is enough coverage to provide DAA alerts and guidance that help the pilot remain DWC (non-cooperative sensor)

- How wider field of view translates to helping the pilot remain DWC. What's the minimum?

- Some type of trade against encounter geometries and sensor field of view that show impact on DWC (non-cooperative)

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - Detection/declaration range
  - Field of view – elevation/azimuth
  - **Max number of tracked targets**
  - Update rates
  - Accuracy/uncertainties
  - Special cases

Max number of tracked targets

- Verify the interoperability between the maximum number of intruders tracked interoperates with DAA alerting and guidance and integrate into the airspace
  - How many tracked targets are required for suitable performance?

- Determine whether the number of tracked intruders the sensor can maintain at various update rates is sufficient/required

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - Detection/declaration range
  - Field of view – elevation/azimuth
  - Max number of tracked targets
  - **Update rates**
  - Accuracy/uncertainties
  - Special cases

Update rates

- Verify the interoperability between updates rates if different than 1Hz and DAA alerting and guidance requirements.
  - Maybe requirements can be traded off to accommodate the low SWAP surveillance, but still maintain acceptable safety and efficiency
  - Is it more desirable to have a large FOV that is updated less frequently (> 1 Hz), or a smaller FOV that is <= 1 Hz?

- Prioritization and lower update rates for lower priorities
  - Tradeoffs in DAA alerting and guidance performance

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - Detection/declaration range
  - Field of view – elevation/azimuth
  - Max number of tracked targets
  - Update rates
  - **Accuracy/uncertainties**
  - Special cases

Accuracy/uncertainties

- Develop requirements for interoperability with DAA alerting and guidance (hazard and non-hazard zones)
- Develop new set of accuracy requirements and test vectors
  - Determine acceptable error bounds on sensor track output
  - Incorrect alerts and missed alerts
- Get early start on passing test vectors when degraded tracks are used
  - Identify degraded tracks as soon as possible
  - Start working on surveillance uncertainty mitigations early

What Needs to be Addressed on this Topic in the Phase II MOPS? (cont.)

- Performance requirements such as
  - Detection/declaration range
  - Field of view – elevation/azimuth
  - Max number of tracked targets
  - Update rates
  - Accuracy/uncertainties
  - **Special cases**

Alerting and Guidance Special Cases

- Develop new special cases that addresses DAA interoperability challenges
  - Non-cooperative and cooperative sensors

- For example, in Phase 1, when the altitude state estimation error exceeds a threshold, there are requirements that changed how alerts are scored, i.e. alert using only horz. closure rate and horizontal miss distance estimates (not altitude)

- Airspace integration
  - Increased traffic densities will reduce total airspace volume, thus elevation capability may be more critical than in Phase 2 compared to Phase 1.

What Does Not Need to be Addressed?

- Detection of other hazards such as birds, structures, power lines, etc.

- Any feedback? What else should be added?

Operational Environment as it Relates to Phase II and this Topic?

- Assumption is operational environment is similar across all the individual white papers
  - Common operational environment for Phase 2
  - Maybe it's a little different for GBSAA compared to airborne surveillance issues cited here

- *Hope to be informed by Paul Campbell's Operational Environment briefing/white paper*

Operational Assumptions

- UAS are operating under IFR.
- Two way communication with ATC (nominal conditions following flight plan/mission)
  - However, for DAA the low SWAP timeline may not allow for mandatory ATC coordination
- Detection of non-cooperative intruders are primarily used for operation below 10,000 feet

Technical Assumptions

- Focus in this white paper/briefing is on airborne equipment
  - GBSAA will be covered by another briefing/white paper

- Surveillance system used to detect other aircraft

What is the Approach to Developing this Topic in the Phase II MOPS?

- Coordination by sensor manufacturer and DAA research organizations needs to occur
- We need encounter sets/model and traffic density values to drive testing
- Need (relatively smaller) UAS performance model (turn, climb, descent, stop/slow down) for those intending to leverage low SWAP requirements
- Need models of sensors/surveillance systems
- NAS-wide simulations will help evaluate airspace integration issues and rates of encounters/alerts for input into verifying requirements and safety risk management assessment

What is the Approach to Developing this Topic in the Phase II MOPS? (cont.)

- Human-in-the-loop simulations to verify that when low SWAP sensor requirements are integrated with DAA alerting and guidance we get acceptable pilot performance, as baselined in Phase 1 for the Phase 1 system.

- Flight test(s) to verify results collected in simulation, demonstrate the maturity of the technology integration, and validate the MOPS.

Questions???

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