



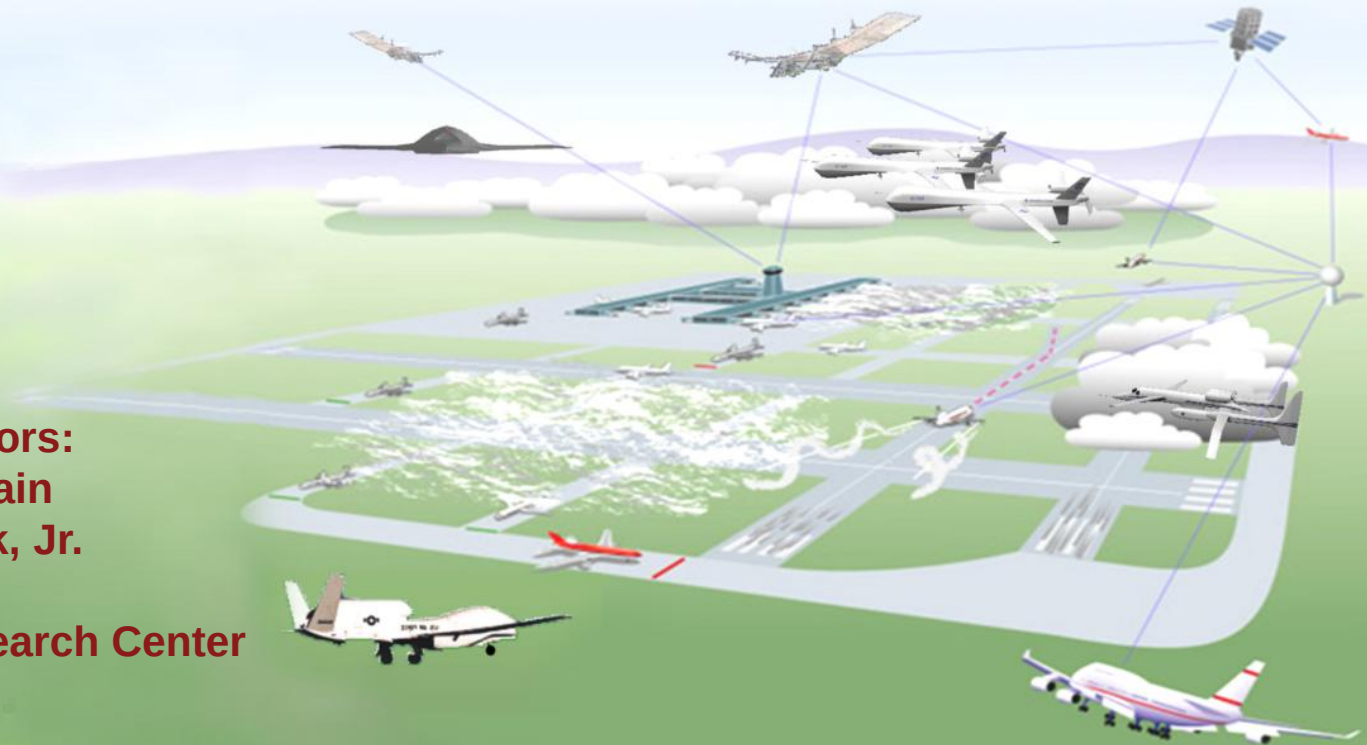
National Aeronautics and Space Administration



Unmanned Aircraft Systems (UAS) Controller Acceptability Study 1 (CAS1)

RTCA SC-228 WG-1 (DAA) Briefing
Washington, DC
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Briefing Outline



- NASA SAA Concept and how CAS1 fits into its development
- CAS1 experiment description
- CAS1 simulation overview
- Initial CAS1 results
- Initial conclusions
- Other considerations



UAS Background and CAS1



- UAS operate today under many restrictions
 - Certificate of Authorization or Waiver (COA) for public use
 - Experimental certificate for civil use
 - Goal is to move toward more routine access
- UAS span a wide range of size and performance
 - Small UAS (<55 lbs.) will be covered by separate rulemaking
 - Our research interest is in larger UAS, interacting with air traffic services in non-segregated airspace
- Routine access will require new equipage, standards, rules, procedures, etc., and supporting research for the same
 - CAS1 addresses one small subset of this research



CAS1 Assumptions for UAS

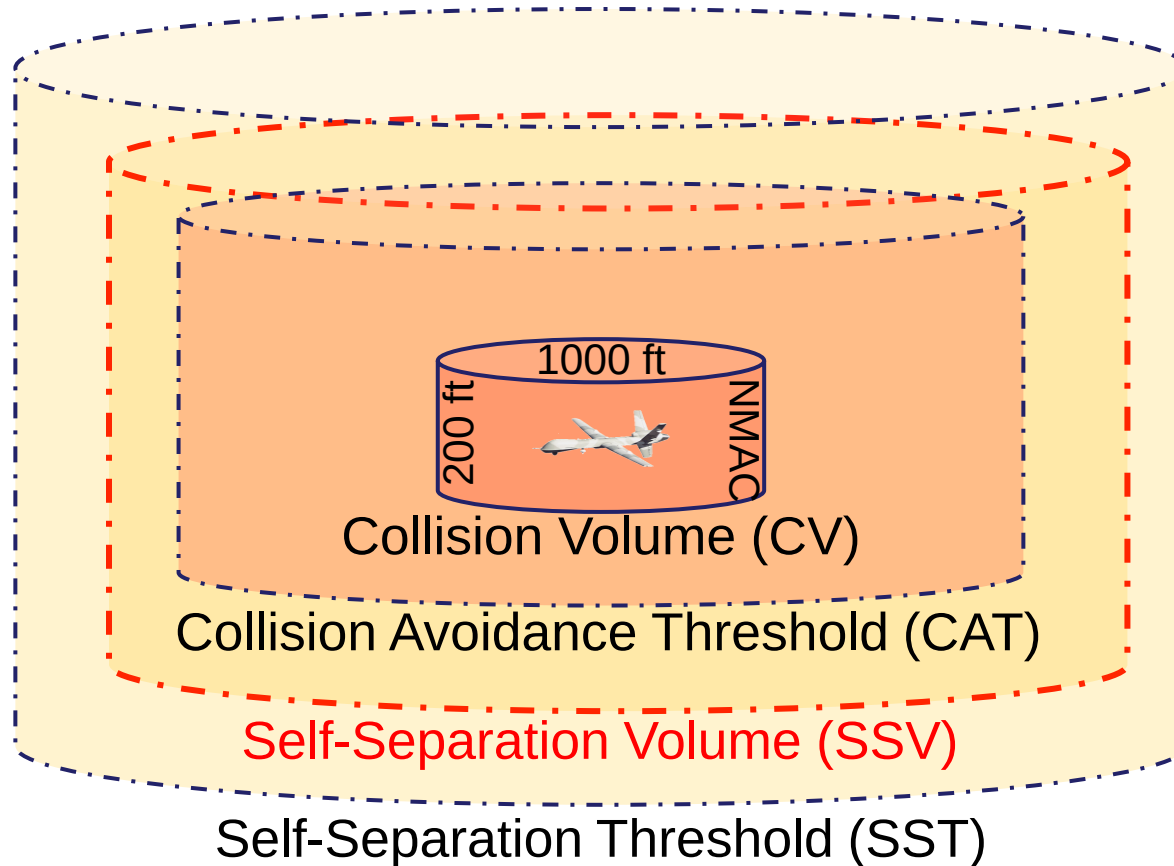


- A future environment where appropriate certified equipment, operational approvals, rules and procedures are in place to enable IFR “file and fly” access for UAS
- Today’s ATC environment and equipage with small changes to procedures and phraseology for UAS
- Nominal operations
 - No lost comm, lost command/control link, equipment failures
 - Pilot always in the loop (no autonomous operations)
 - Consistent ATC communication with minimal delays
- Trained UAS pilots with access to “sense and avoid” guidance



CV, CAT, SSV, SST and “Well Clear”

Workshop Model with NASA SAA Concept’s Self-Separation Volume (SSV):



Note: CAT, SSV and SST boundaries are notional and generally not cylindrical



Clear of Self Separation Volume (SSV) = Well Clear



- SSV size should be large enough to avoid:
 - Corrective RAs for TCAS-equipped intruders
 - Safety concerns for controllers
 - Undue concern for proximate see-and-avoid pilots
- SSV size should be small enough to avoid disruptions to traffic flow
- SSV size should vary appropriately with operational area (airport vicinity, departure, approach, en route, etc.)

Determination of minimum and maximum operationally acceptable SSV sizes will inform the design space for required SAA surveillance accuracy



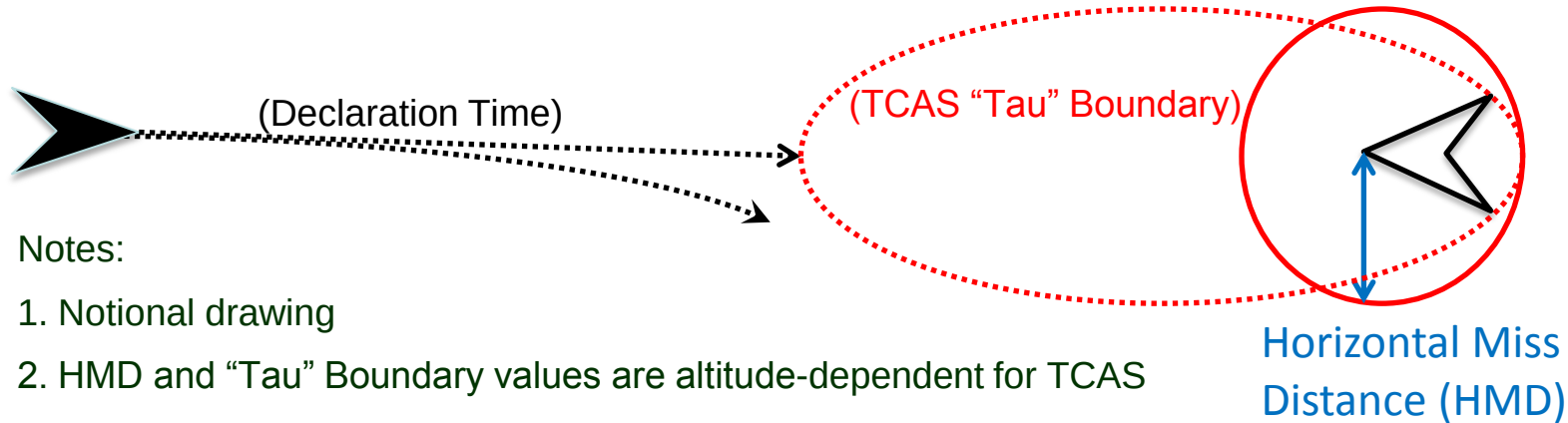
TCAS-Compatible SSV and SS Algorithm



- NASA UAS-NAS has developed a TCAS-compatible SSV and Self-Separation (SS) concept:
 - Consiglio M., Chamberlain J., Muñoz C., and Hoffler K. Concept of Integration for UAS Operations in the NAS. 28th International Congress of the Aeronautical Sciences, Brisbane, Australia, 23-28 September 2012
- NASA UAS-NAS has also developed a SS algorithm (Stratway+) to implement this SSV and concept:
 - César Muñoz, Anthony Narkawicz, and James Chamberlain, A TCAS-II Resolution Advisory Algorithm. Proceedings of the AIAA Guidance, Navigation, and Control Conference (GNC), AIAA-2013-4622, Boston, Massachusetts, August 2013
 - Anthony Narkawicz, César Muñoz, Jason Upchurch, James Chamberlain, and María Consiglio, A Well-Clear Volume Based on Time to Entry Point. Technical Memorandum, NASA/TM-2014-218155, January 2014
- Stratway+ provides a range of pilot guidance to remain well clear of other detected aircraft within a specified time



Effective Shape of TCAS CAT

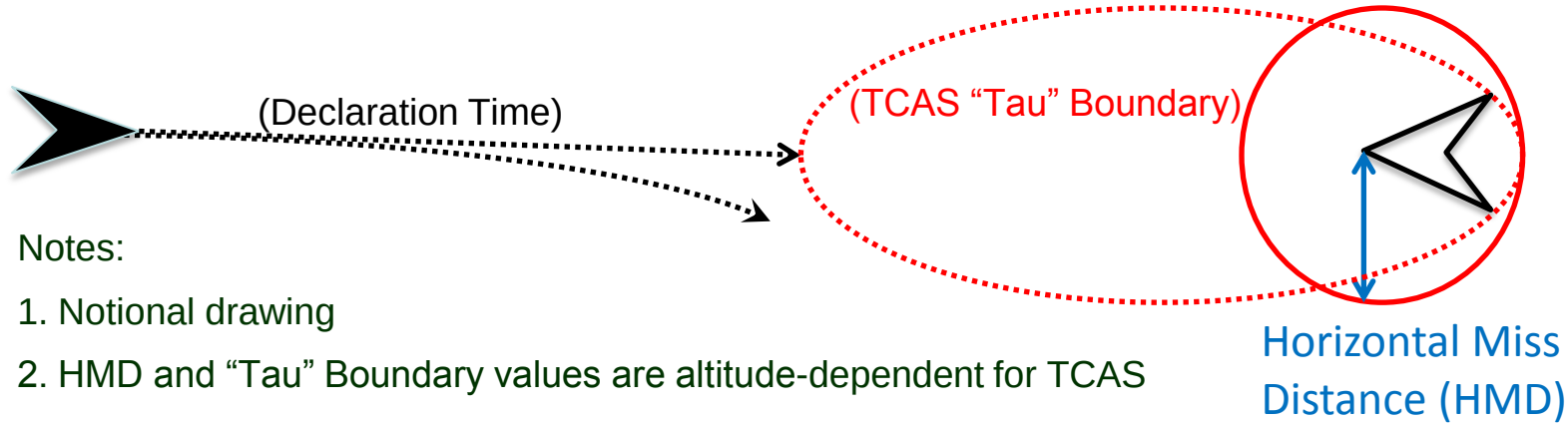


Notes:

1. Notional drawing
 2. HMD and “Tau” Boundary values are altitude-dependent for TCAS
 3. Drawing assumes insufficient vertical separation (e.g., co-altitude)
- If trajectories will pass outside of HMD (=DMOD) then no RA will occur (assuming perfect surveillance/tracker performance)
 - If trajectories will pass within HMD then RA occurs at “Tau” boundary
 - TCAS II V7 is actually behaving like a CPA/Time-to-CPA system!
 - Actually more like an “HMD-radius/time-to-HMD-radius” system



SAA “Self Separation Bands” Concept



Notes:

1. Notional drawing
2. HMD and “Tau” Boundary values are altitude-dependent for TCAS
3. Drawing assumes insufficient vertical separation (e.g., co-altitude)

If Ownship trajectory will pass within HMD laterally of intruder then

- “Self Separation Bands” will appear on Ownship trajectory when within specified declaration time of the Tau boundary
- Pilot will need to negotiate a trajectory change outside of Bands

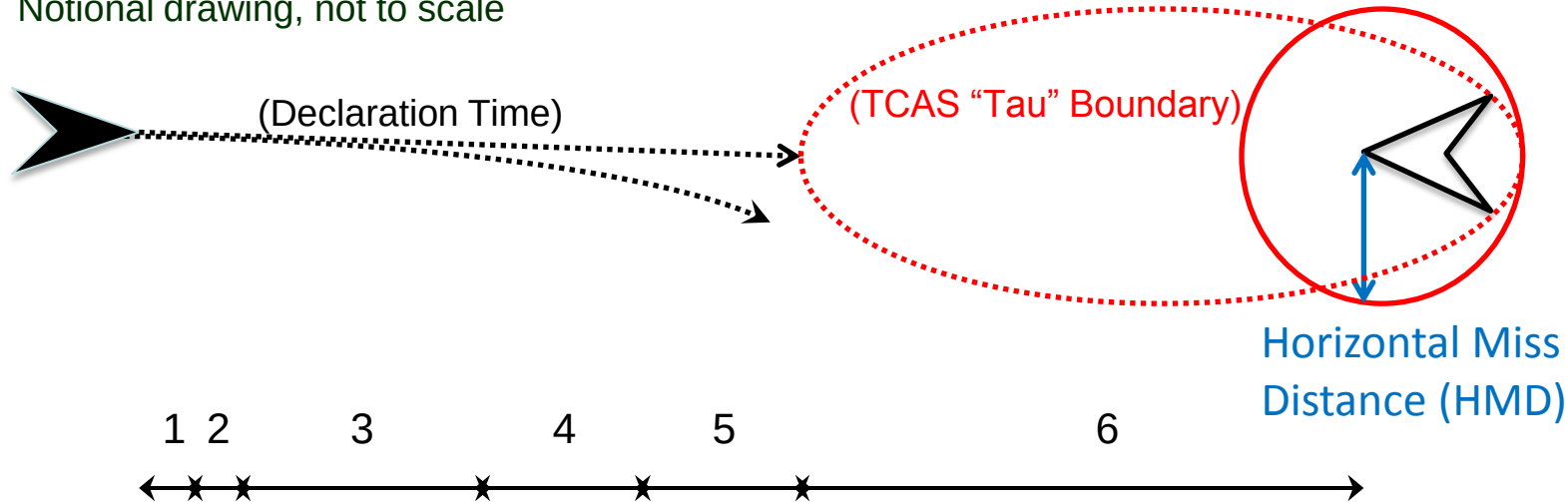
No Bands will appear on trajectory if it will pass outside of HMD



Notional Values for Time-to-CPA



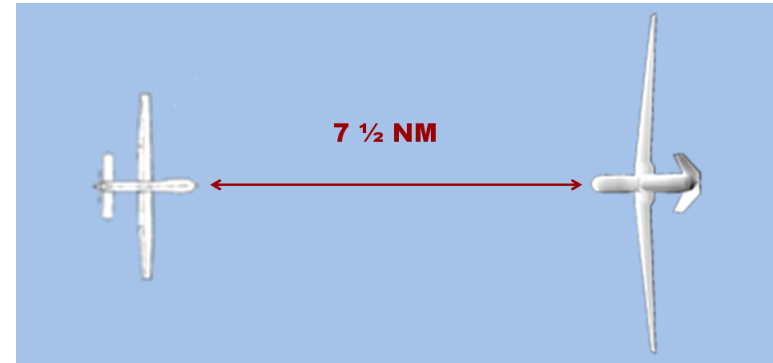
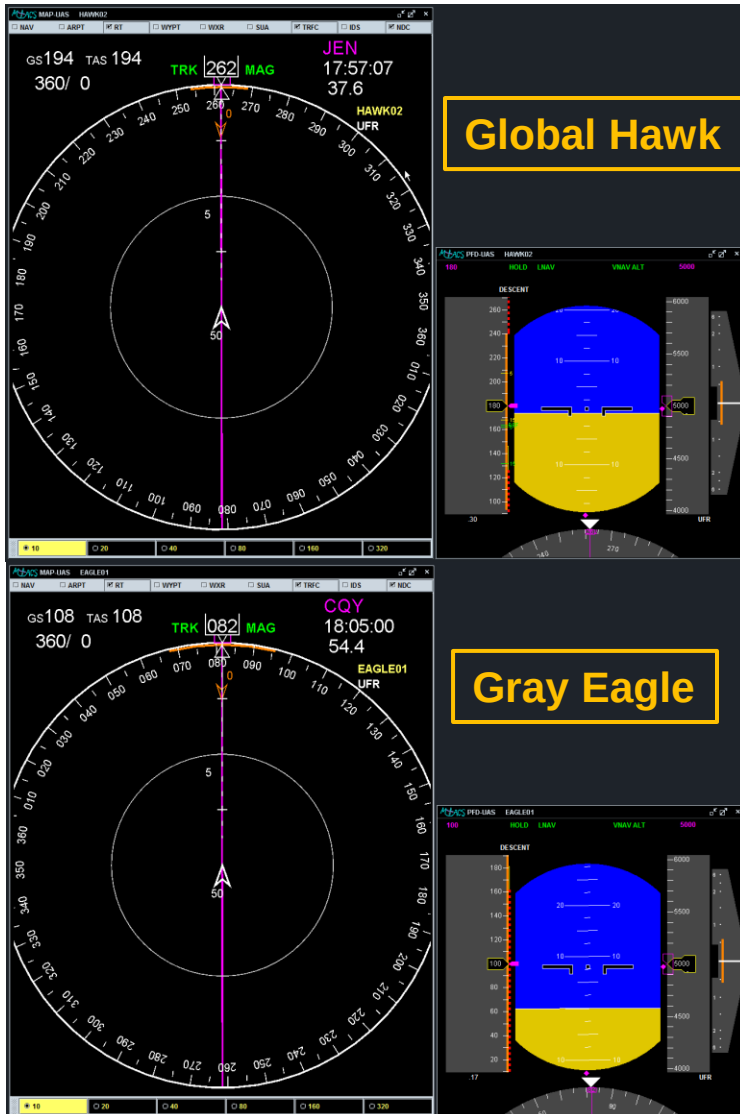
Notional drawing, not to scale



- **Example** numbers:

- | | | |
|----|---|----------------|
| 1. | Time for PIC to notice alert: | 5 secs |
| 2. | Time for PIC to determine action: | 5 secs |
| 3. | Time to query/negotiate with ATC: | 20 secs |
| 4. | Roll in/roll out time including C2 delay: | 10 secs |
| 5. | Time to turn 30 degrees at 3 deg/sec: | 10 secs |
| 6. | TCAS RA threshold: | <u>35 secs</u> |
| | Total: | 85 secs |

Self Separation Bands Example



Head-On Encounter:

- “Global Hawk” (194 kts, 3 deg/sec turn)
- “Gray Eagle” (108 kts, 1 deg/sec turn)
- ~90 seconds to collision, 70 seconds declaration time
- “TCAS Bands” (20 sec tau, .35 nmi HMD)
- Different Performance = Different Bands



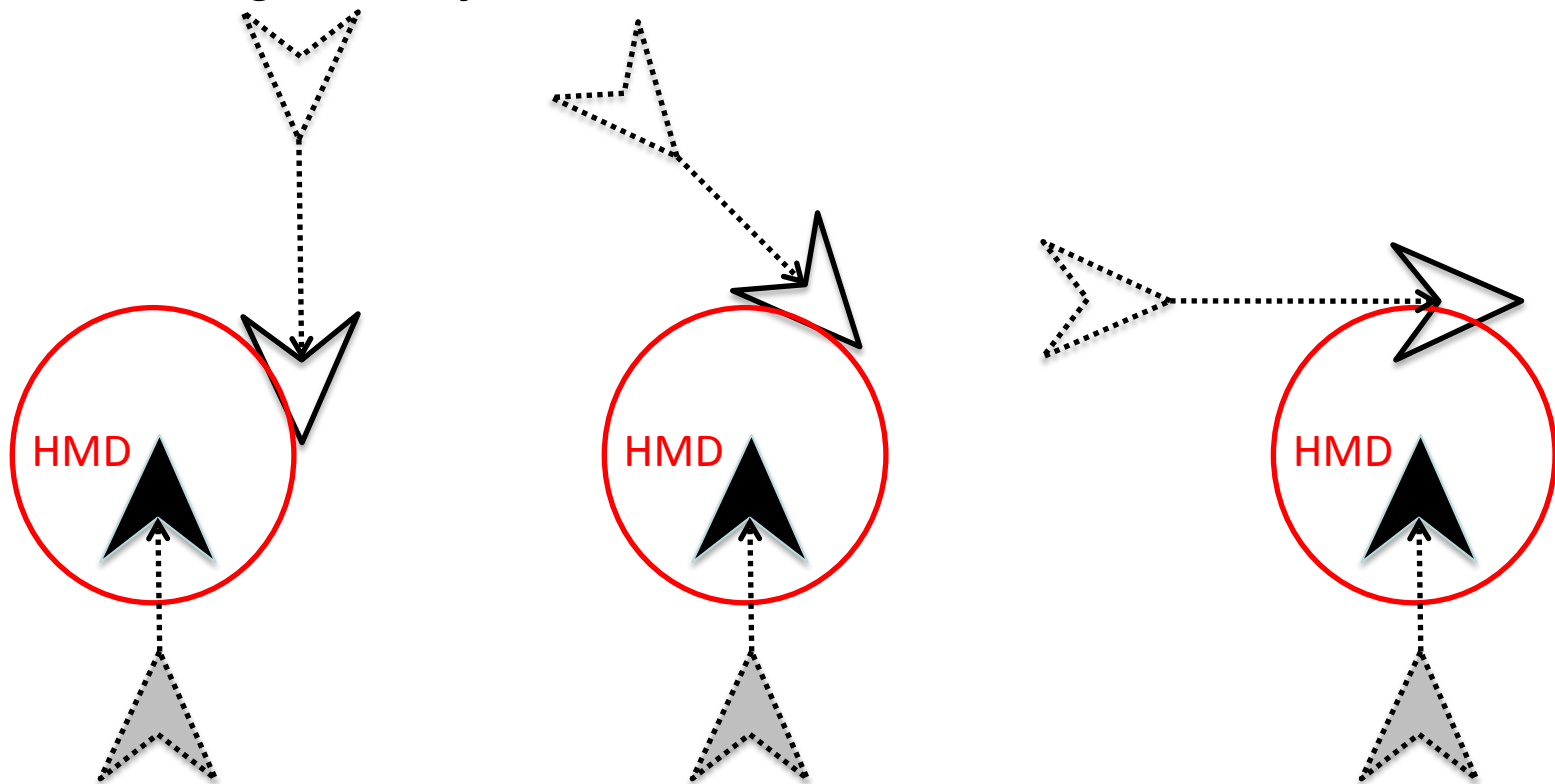
Tau and HMD for TCAS

- TCAS Tau and HMD values for RA issuance are altitude-dependent (lower values at lower altitudes):

Own Altitude (ft)	Tau (sec)	HMD (nmi)	HMD + 50%
< 1000 AGL	N/A	N/A	N/A
1000-2350 AGL	15	0.20	0.30
2350-5000	20	0.35	0.53
5000-10000	25	0.55	0.83
10000-20000	30	0.80	1.2
20000-42000	35	1.1	1.7
>42000	35	1.1	1.7

HMD versus Encounter Geometry

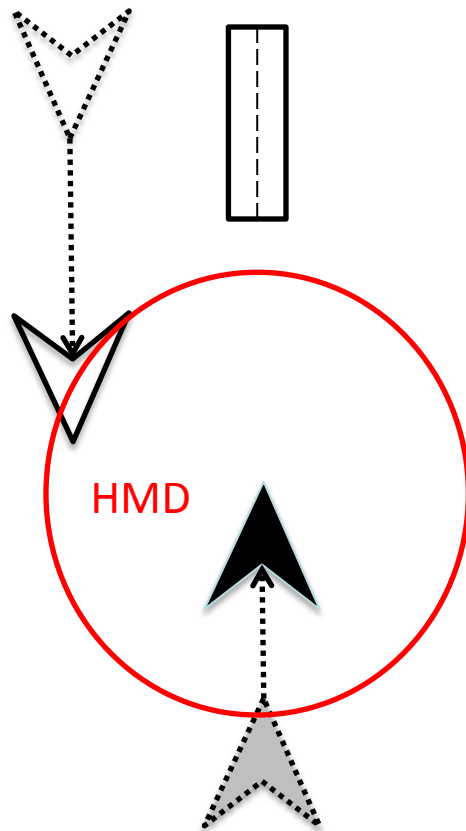
- TCAS will not activate an RA if HMD is cleared, regardless of encounter geometry:



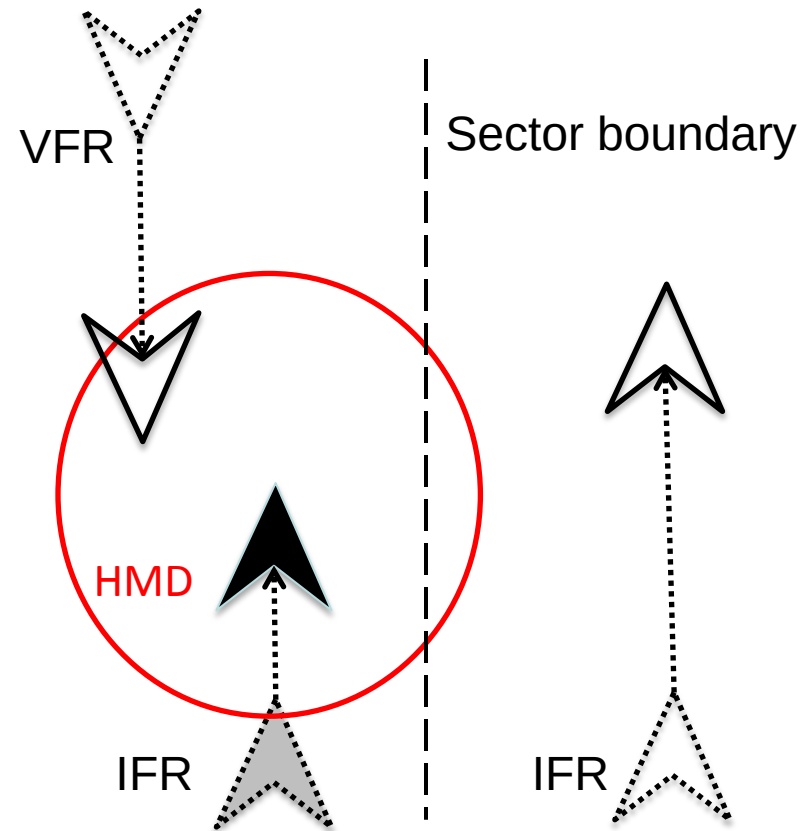
- Air traffic controllers and proximate manned aircraft pilots may desire more than TCAS HMD, especially for crossing geometries

Unacceptably Large HMD

- Excessive lateral displacements will be disruptive to traffic flow:



UAS on final approach,
intruder on downwind leg



UAS "well clear" deviation
causes secondary conflicts

HMD = Horizontal Miss Distance



CAS1 Research Questions



1. What SAA SS horizontal maneuvers are too small, resulting in issuance of traffic safety alerts or controller perceptions of unsafe conditions?
2. What SAA SS horizontal maneuvers are too large (excessive “well clear” distances), resulting in behavior the controller would not expect and/or disruptions to traffic flow?
3. Is there a range of acceptable SAA horizontal miss distances that can be applied to the development of SAA algorithms? Is this range affected by encounter geometry and/or speed differential, and if so, how?



Hypotheses



1. Controllers will find relatively small Horizontal Miss Distances (HMD) values (at or near the TCAS minimum) acceptable for non-crossing geometries, as long as the UA reports the other aircraft acquired.
2. Controllers will require/desire larger HMD values for crossing geometries with the UA passing in front of the intruder especially if the intruder is faster.
3. Controllers will find larger required SAA HMD distances to be increasingly disruptive to traffic flow in high density environments conducted in VMC.

Assumption: There will be interactions between HMD, encounter geometry and intruder speed differential for crossing geometries. Discovering these interactions is important to the refinement of quantitative SS acceptable-range definitions for self-separation functions.



CAS1 Research Approach



- Construct a set of simulated “well clear encounters”
 - Different miss distances, encounter geometries, relative speeds
- Embed these encounters into simulated background traffic scenarios representative of moderate-workload TRACON traffic (IFR and VFR) on a calm, clear-weather day
- Ask a series of ATC volunteers to “control” the simulated traffic scenarios, and measure the results
 - Direct query after each encounter
 - Workload and performance measures throughout
- Perform statistical analysis of all data afterward to assess the range(s) of acceptable horizontal miss distances



Research Design - Subjects



- Subjects:
 - Air Traffic Controllers familiar with the Dallas-Ft. Worth East side will perform traffic separation tasks for the scenarios proposed
 - Expected sample size is 12 Air Traffic Controllers, performing ATC tasks in the simulated environment one person at a time over two days of testing
 - UAS and manned aircraft will be controlled by pseudo-pilots at control stations in a different room
- Subject recruitment:
 - Retired ATC with DFW experience
 - Investigating the use of DFW active controllers



Independent Variables



- Horizontal Miss Distance (6 values: 0.5, 1.0, 1.5, 2.0, 2.5, 3.0 nmi)
- Encounter Geometry (3 values: opposite-direction, crossing, overtake)
 - Intruder opposite-direction at 180 degrees +/- 15 degrees (non-crossing)
 - Intruder to right at 90 degrees +/- 15 degrees (crossing)
 - Intruder ahead at 0 degrees +/- 15 degrees (overtaking, non-crossing)
 - All geometries without vertical separation (but may include climbing/descending trajectories)
 - Ownship passes to right of intruder for non-crossing geometries
 - Ownship passes in front of intruder for crossing geometries
- Intruder Speed Differential (5 values for crossing: 0, +/- 40, +/- 80 kts)
- 42 test conditions: 6 opposite-direction, 6 overtake, 30 crossing
- 14 encounters per hour (tested extensively)
- 6 One-hour test sessions enables a replicate for each encounter
- Not all Encounter Geometries require all Speed Differentials



Research Design - Dependent Variables



- **System Performance Metrics:**
 - Aircraft-Aircraft separation distances for each encounter
 - Operational errors and deviations, delays to aircraft in scenario, re-sequencing of arrival aircraft
 - Voice communication errors (includes transposing info, call sign errors, repeats, say again)
- **Human Operator Performance Metrics:**
 - Verbal query/recording of miss distance acceptability, and any explicit action taken (vector, traffic advisory(s), safety alert, adjacent traffic re-route, etc.) immediately after each encounter
 - Workload assessment by Air Traffic Workload Input Technique (ATWIT) methodology at fixed intervals during simulation – response scale built into display software
 - Post-scenario questionnaires (after each hour)



Experiment Matrix

Horizontal Miss Distance in Separation Algorithm

Encounter Type

	.5	1.0	1.5	2.0	2.5	3.0
Head-on	1 speed	1 speed	1 speed	1 speed	1 speed	1 speed
Overtake	1 speed	1 speed	1 speed	1 speed	1 speed	1 speed
Crossing	5 speeds	5 speeds	5 speeds	5 speeds	5 speeds	5 speeds

- Yields 42 combinations, assigned 14 per hour in hours 1, 2, and 3
- Matrix repeated (different orders) in hours 4, 5, and 6 with Horizontal Miss Distance held constant for 30 minute durations to enhance workload rating measurements
- Hours 1, 2, and 3 order randomized across subjects (e.g., 231, 312 ...)
- Hours 4, 5, and 6 order randomized across subjects (e.g., 654, 546 ...)



UAS-CAS1 Nominal Daily Schedule



Day 1

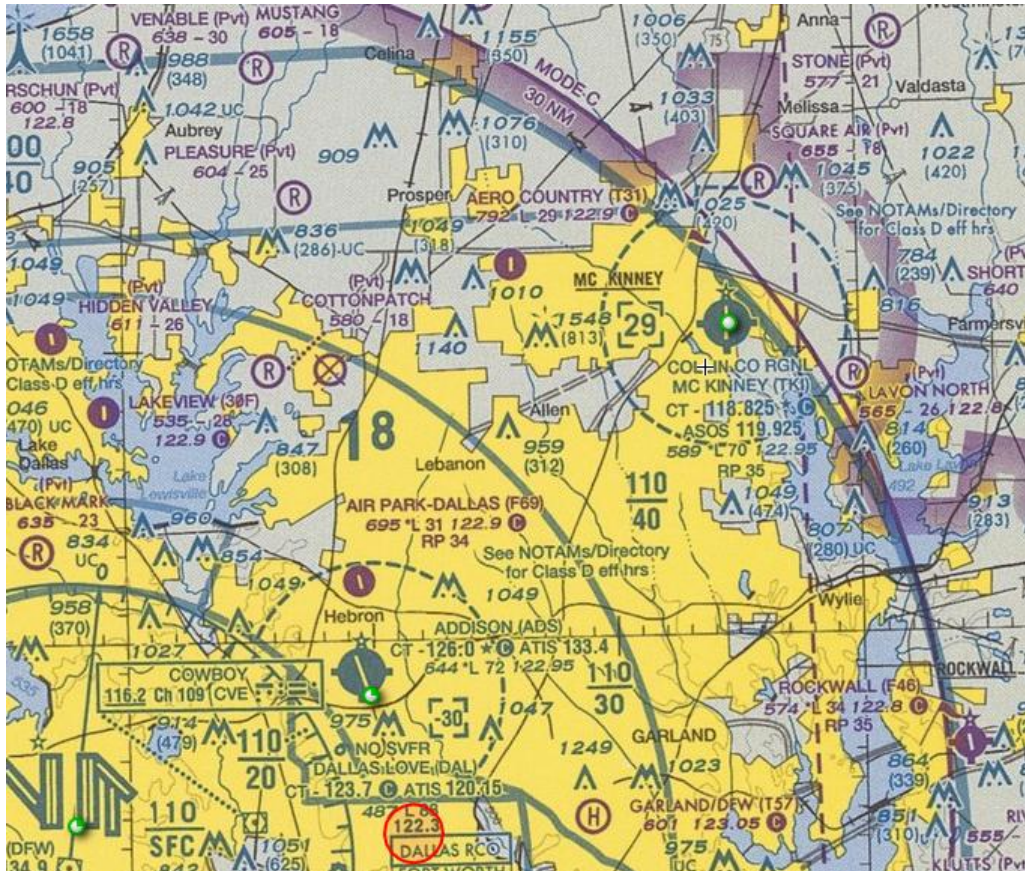
- 8:30 Arrival, Logistics, Informed Consent, Initial Questionnaire
- 9:00 “Classroom” Training
- 10:00 Break
- 10:15 Practice Sessions
- 11:15 Data Run 1, Questionnaire
- 12:30 Lunch Break
- 1:30 Data Run 2, Questionnaire
- 2:45 Break
- 3:00 Data Run 3, Questionnaire
- 4:15 Adjourn

Day 2

- 8:30 Arrival
- 8:45 Data Run 4, Questionnaire
- 10:00 Break
- 10:15 Data Run 5, Questionnaire
- 11:30 Lunch
- 12:30 Data Run 6, Questionnaire
- 1:45 Break
- 2:00 Debriefing
- 3:15 Adjourn



CAS1 Traffic Scenario Area

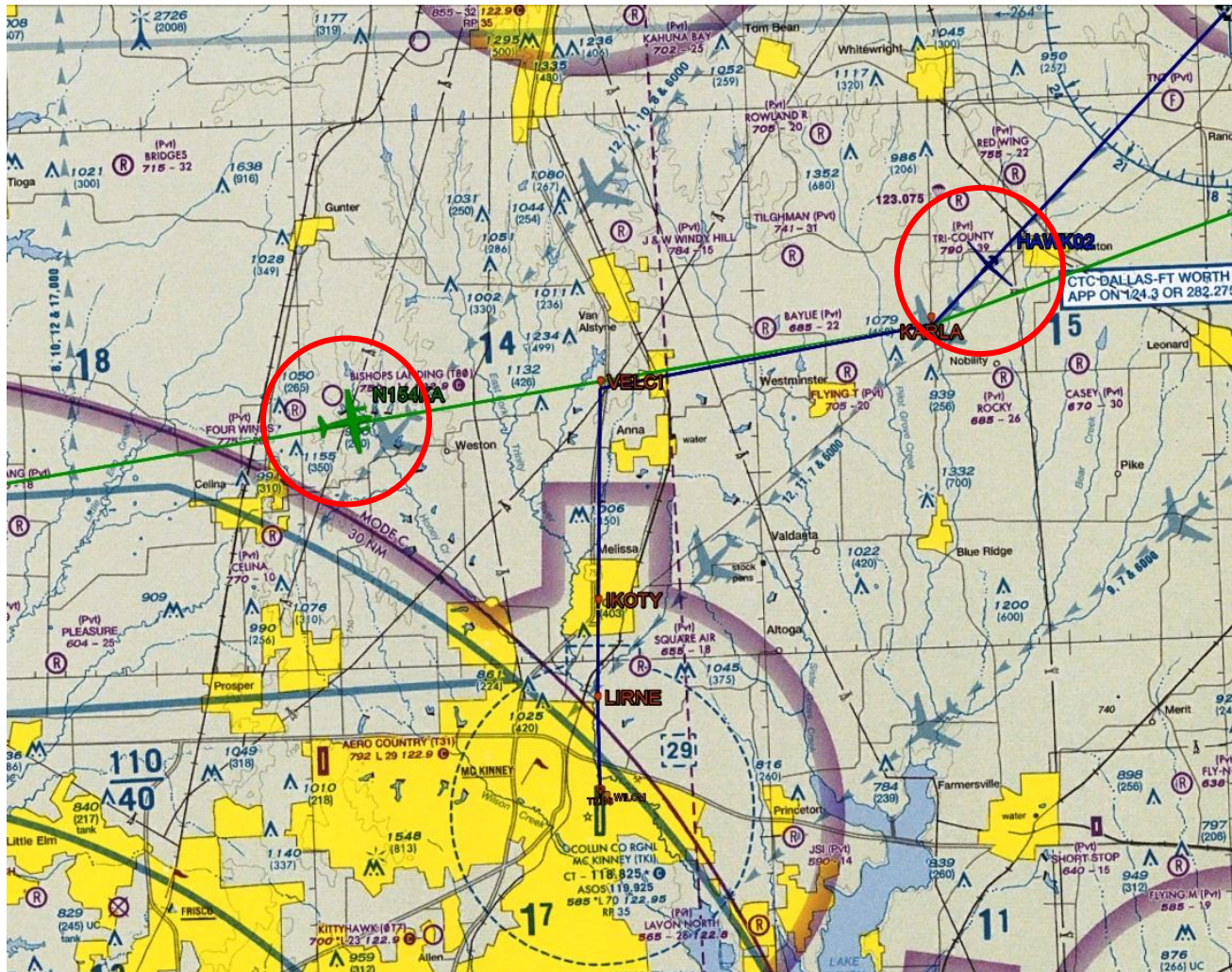


Scenarios focused on ATC sector handling arrivals to Collin County Regional (McKinney – TKI), ~28 nmi NE of DFW

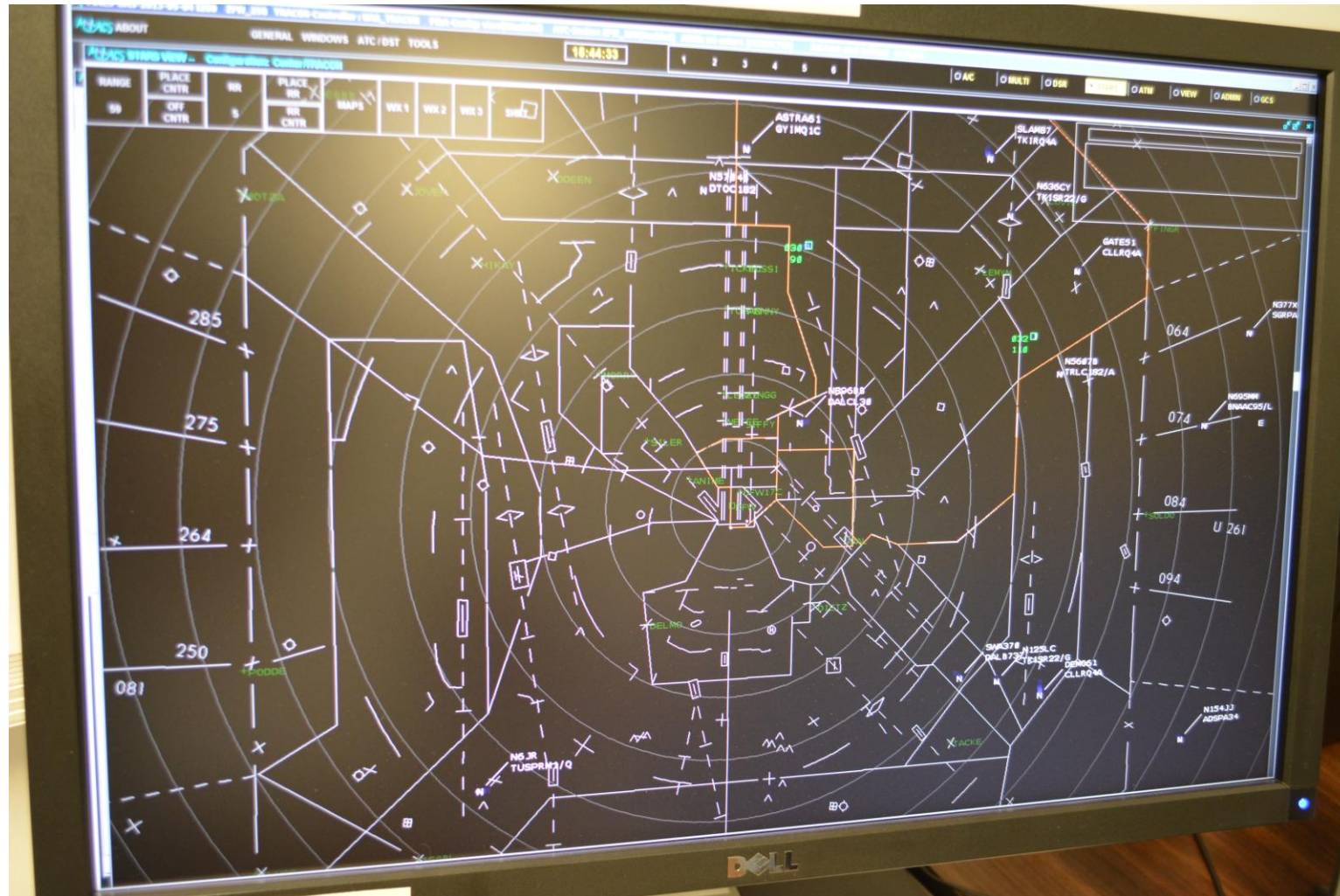
Feature-rich airspace:

- Class B, 4000-11000' above TKI
 - VFR & IFR aircraft all under positive control, all cooperative
- Class D, SFC-2900' around TKI
 - VFR & IFR cooperative aircraft receiving Class D ATC services
- ❖ Class E, 700' or 1200' up to FL180 and outside Class B and D
 - IFR aircraft
 - VFR aircraft, some receiving ATC services, some not
 - Some non-cooperative traffic outside of 30 nmi Mode C veil
- Class G, SFC to overlying airspace
- Nearby non-towered airports

Illustration of Head-on Scenario

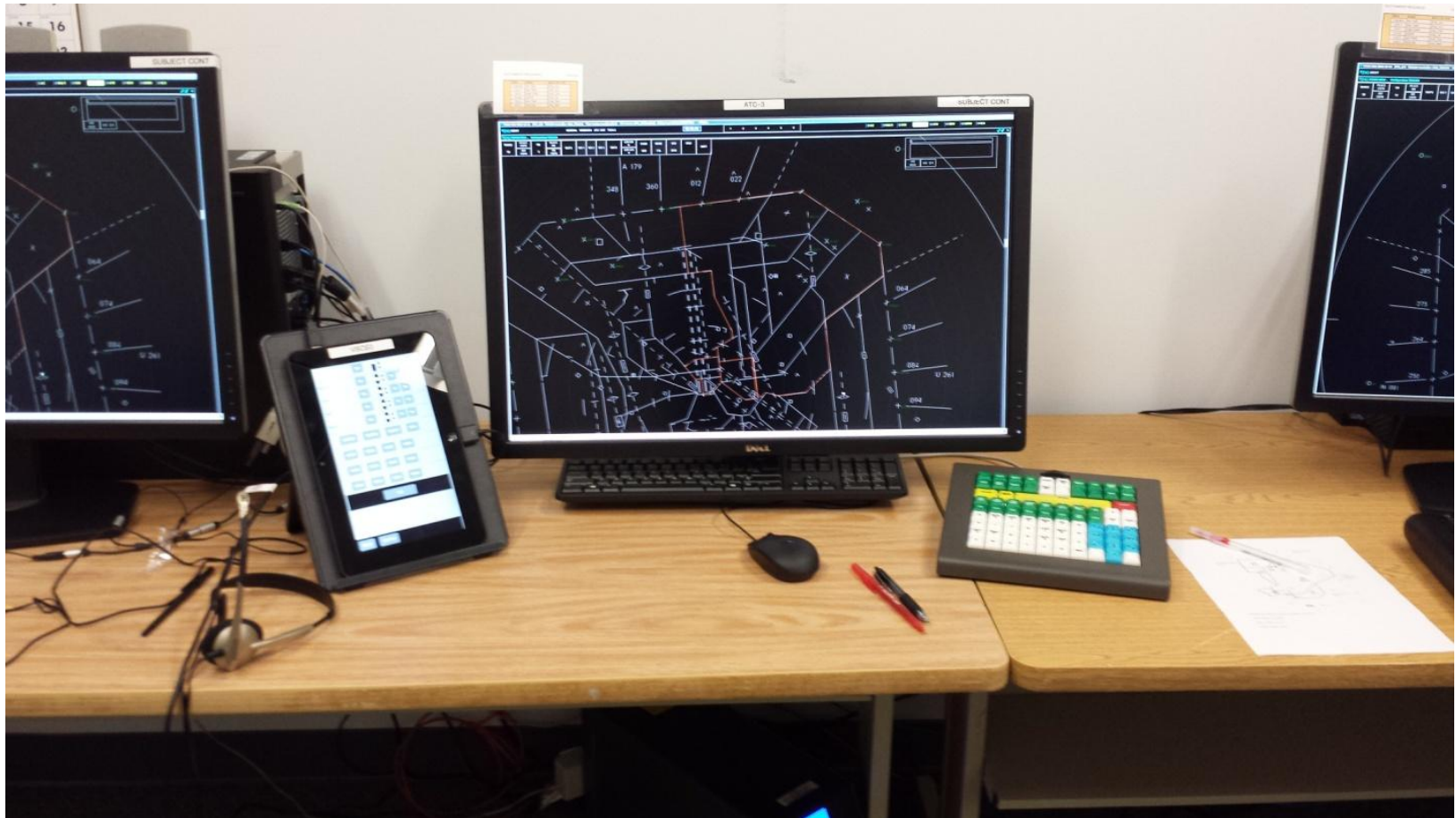


Head-on Co-Altitude Traffic While on Approach



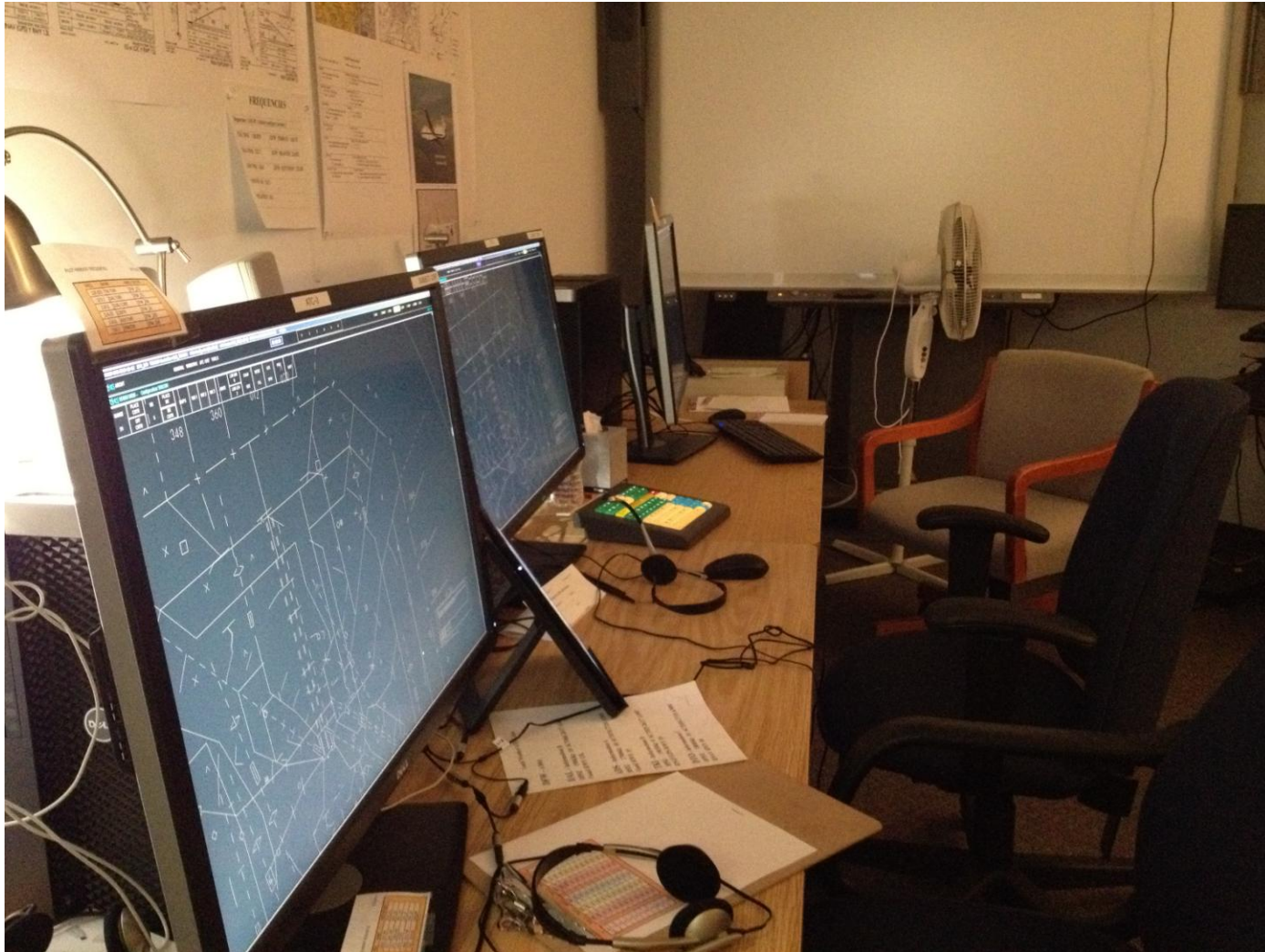


CAS1 Subject Workstation





CAS1 Subject Room View From the Doorway



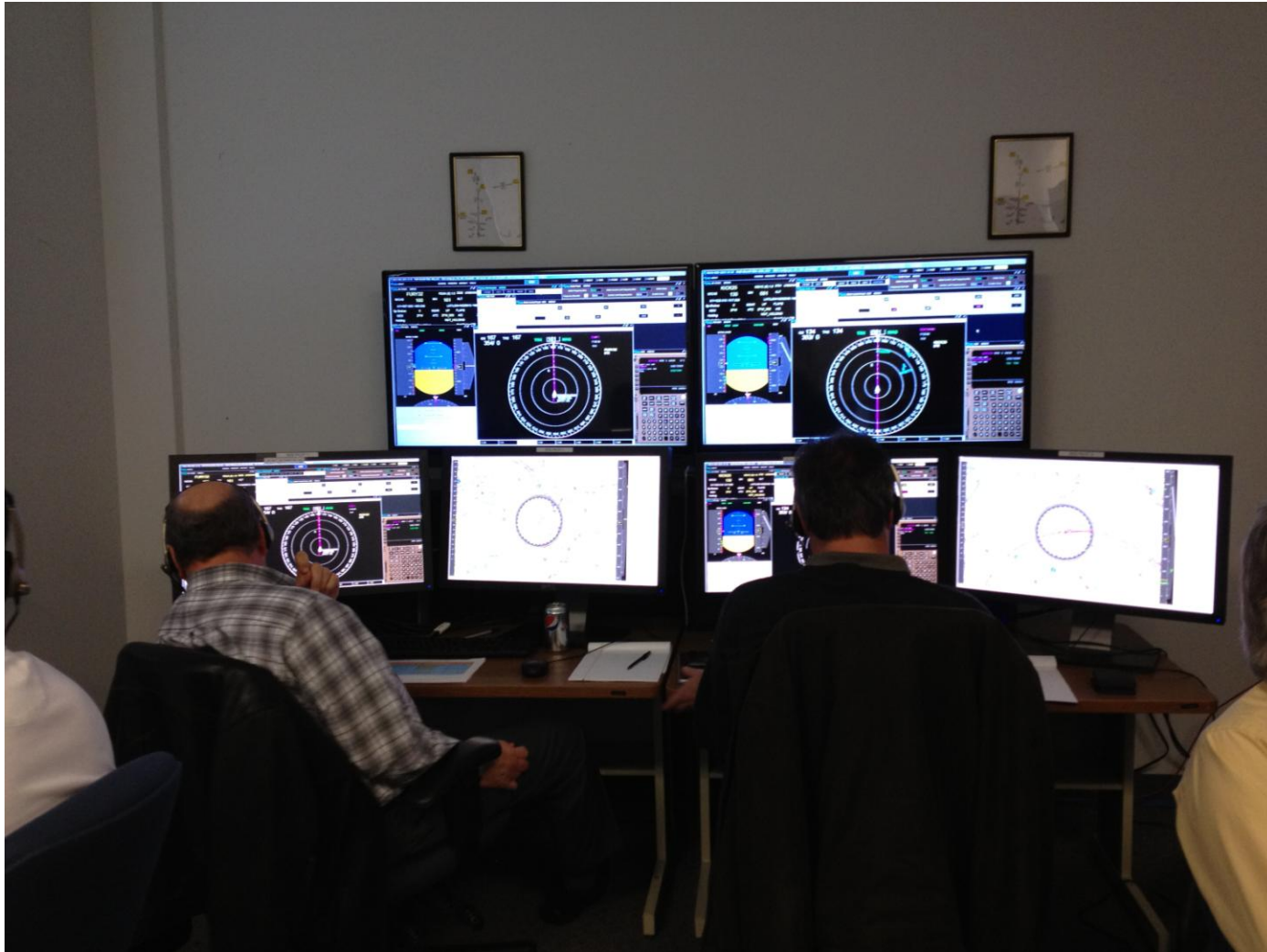


Production Lab: Background Traffic Pilots





Production Lab: UAS Pilots





Production Lab: “Ghost” Controllers





Production Lab: Sim Mgr, “Ghost” Pilots





Hour 3 Scripted Encounters: GCS 1 & 2

UA Initial Conditions
Hour 3

ALL										
#	Active (sec)	EC	CPA	HMD	UA Call Sign	UA Flight Phase	UA Filed Route	UA Altitude Profile	EC (sec)	Intruder
1	139	CR	1.5	3.0	RAGS54	DEP	TKI.SLANT.FINGR.PRX [UA CHANGES TRACK BEFORE ENCOUNTER]	1000 CLB 3000	320	N7003A
2	389	CR	1.5	2.5	LOBO64	DEP	TKI.SLR [REQT 5,000' ALT AFTER ENCTR]	1200 CLB 3000	566	N7348A
3	421	CR	2.5	2.5	CRATE52	OVFT	LUD.JOVEM.CRAFF.332422N/0965301W.DUA [INTRUDER CHANGES TRACK] [REQT 5,000' ALT AFTER ENCTR]	1200 CLB 3000	806	N351CB
4	799	HE	0.0	0.5	ARCO21	ARR	LIT.BYP.KARLA.VELCI.RNAV18.TKI	3500 DES 3000	1045	N182LB
5	1075	CR	3.0	3.0	FURY32	DEP	TKI.DUMPY.CLL [INTRUDER CHANGES TRACK] [REQT 4,000' AFTER ENCTR]	1200 CLB 3000	1280	N120PF
6	1256	CR	1.5	2.0	KICK25	OVFT	LUD.JOVEM.CRAFF.332422N/0965301W.DUA [INTRUDER CHANGES TRACK] [REQT 5,000' ALT AFTER ENCTR]	1200 CLB 3000	1523	N7077T
7	1638	CR	0.5	0.5	NACHO32	DEP	TKI.330803N/0963526W.SLR [REQT 5,000' ALT AFTER ENCTR]	1000 CLB 3000	1753	N5956A
8	1532	OV	0.0	1.5	CAMEL25	OVFT	SLR.WILBR.332400N/0963000W.332400N/0971000W.ONLY	LVL 6000	1975	N5321R
9	1846	CR	1.5	1.5	HALL52	ARR	GYI.SASIE.VELCI.RNAV18.TKI	3300 DES 3000	2252	N5457B
10	2066	OV	0.0	1.0	CAFE61	OVFT	SLR.WILBR.332400N/0963000W.332400N/0971000W.ONLY	LVL 6000	2460	N8842B
11	2471	CR	1.0	1.0	GRITS12	DEP	TKI.PERSN.ORICK.MLC.KLUBB.LIT.MEM [REQT 5,000' ALT AFTER ENCTR]	1000 CLB 3000	2709	N5653B
12	2707	CR	1.0	1.0	OXEN21	OVFT	LUD.JOVEM.CRAFF.332422N/0965301W.DUA [INTRUDER CHANGES TRACK] [REQT 5,000' ALT AFTER ENCTR]	1200 CLB 3000	2962	N6034A
13	2914	HE	0.0	2.0	BASCO12	ARR	LIT.BYP.KARLA.VELCI.RNAV18.TKI	3500 DES 3000	3160	N5590B
14	2505	CR	1.5	3.0	MIDAS62	OVFT	GVT.FINGR.331718N/0963700W.331718N/0971000W.DTO [INTRUDER CHANGES TRACK]	LVL 4000	3403	N8008B

BLUE: GCS ONE
GREEN: GCS TWO

2/4/2014

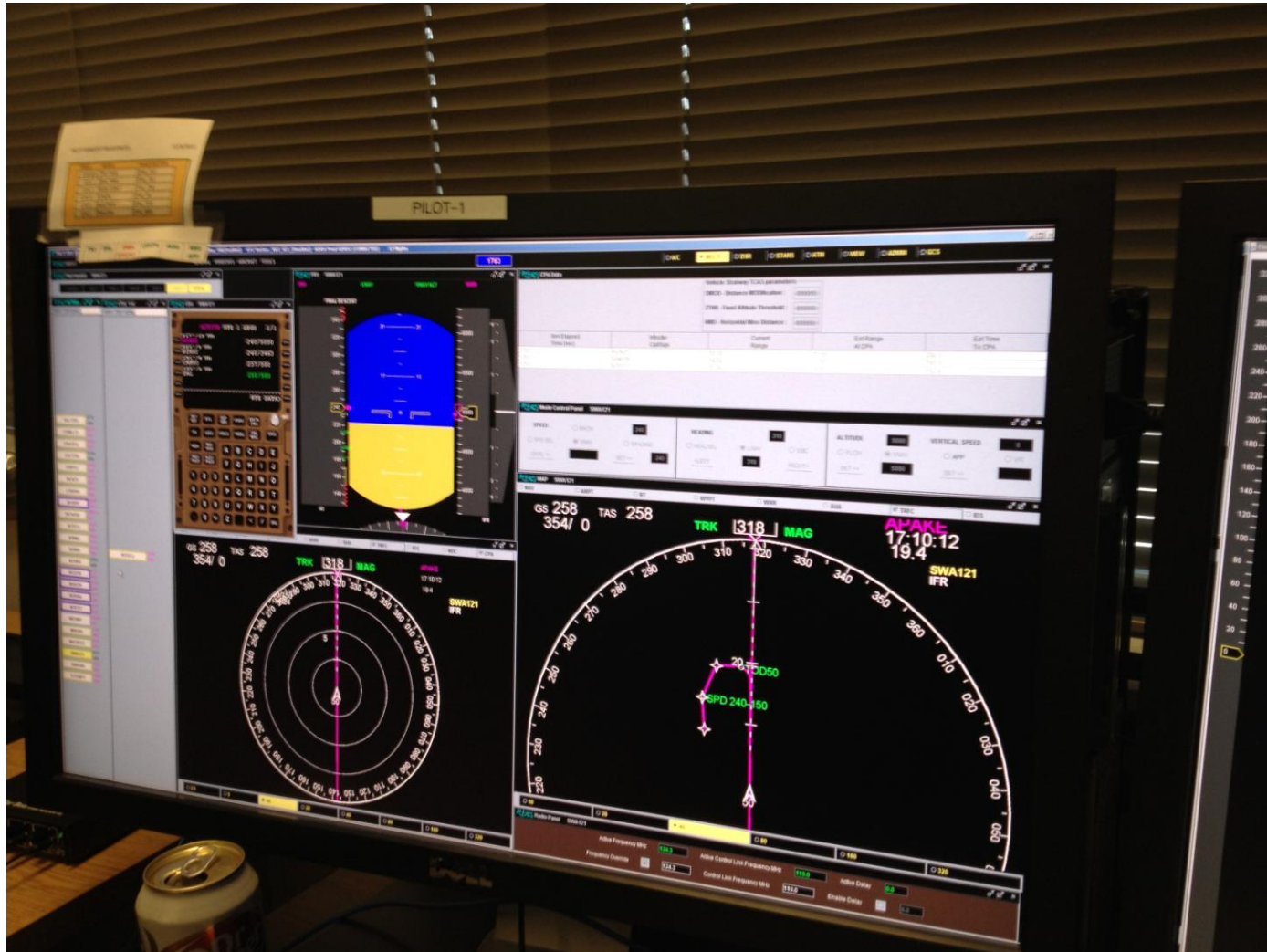


ATC Subject View of a Crossing Encounter (UA is Departing TKI)





Background Traffic Pilot Station: MACS Screen





Background Traffic Pilot Station: Control List



	BE20		
F	ARR		
	PRM1/G		
V	DEP		
	C335		
TJ	ARR		
	BE58		
NJ	OVR		
	GLF2		
RR	DEP		
	C208		
964	ARR	N335TJ	C335 ARR
	C172	SWA121	B737 ARR
21R	ARR		
	C182		
57B	ARR		
	C172		
956A	ARR		
	C172		
077T	ARR		
	PA24/G		
349P	ARR		
	C140		

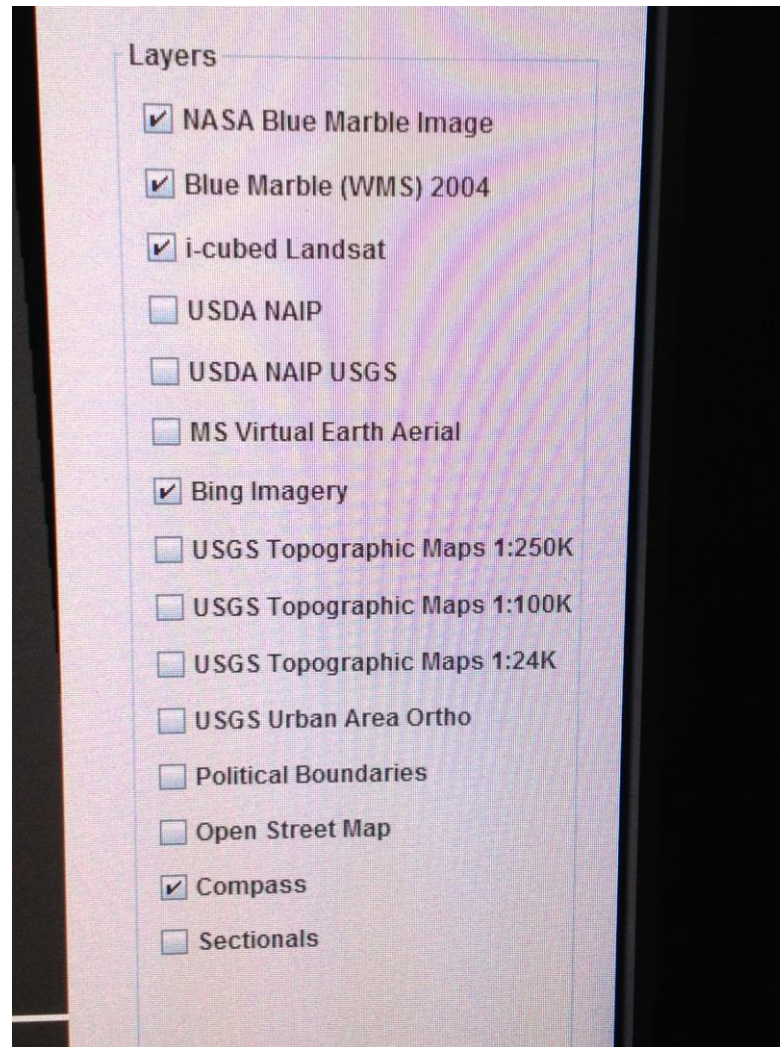


Pilot Station: Moving Map (Close-up View)



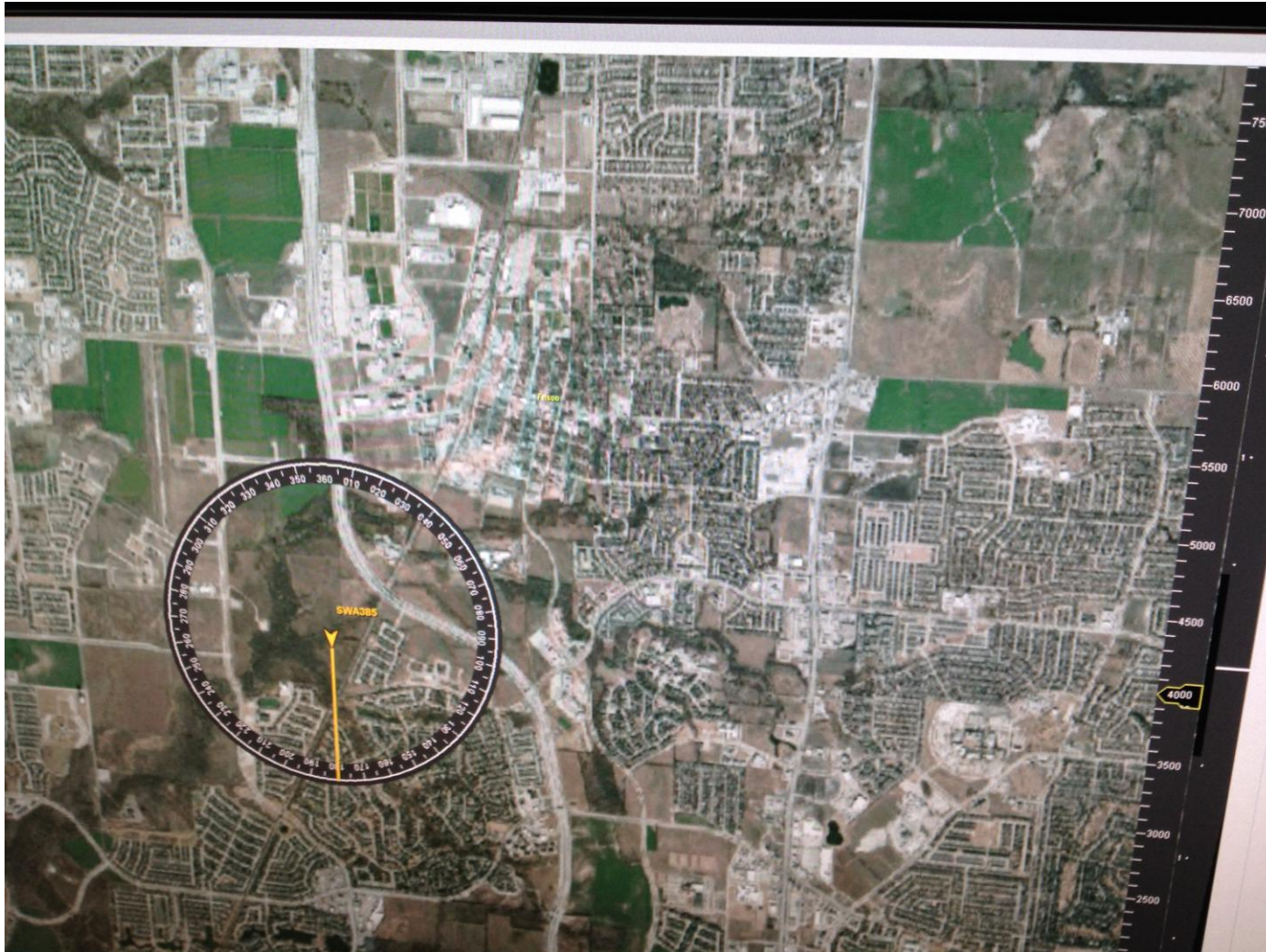


Moving Map Options





Moving Map Imagery



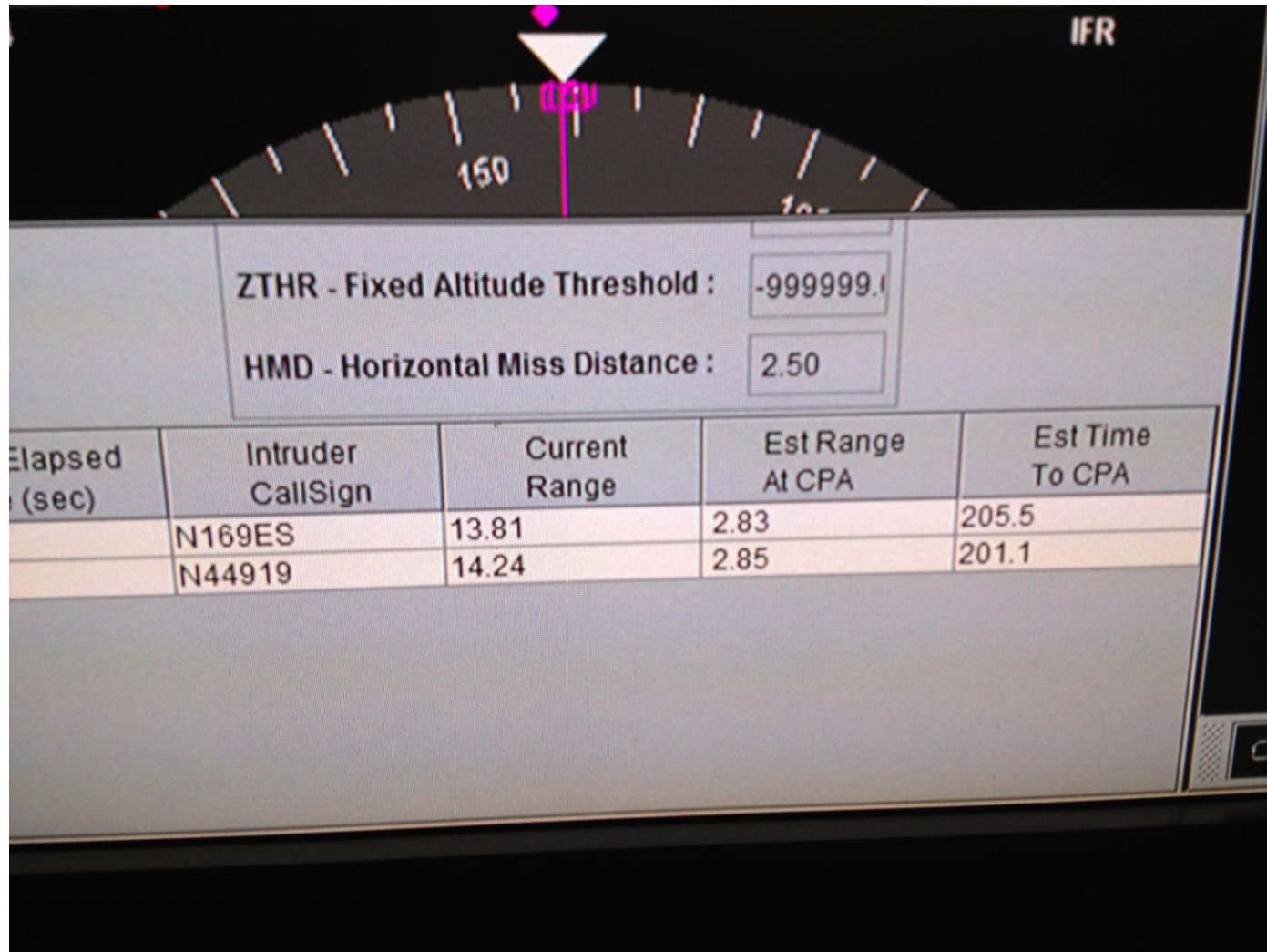


SS Bands Example: Crossing, No Conflict (yet)





Self Separation Simulation Monitor





SS Bands Example: Overtake, Well Clear





SS Bands Example: Overtake, Well Clear





SS Bands Example: Overtake, Not Well Clear





CAS1 Initial Data

Based on 14 ATC Test Subjects
1176 HMD Acceptability Ratings

NASA LaRC - April 22, 2014



Rating scale used for encounter assessment



After each “well clear encounter” test subjects were asked to rate the horizontal miss distance on a five-point scale:

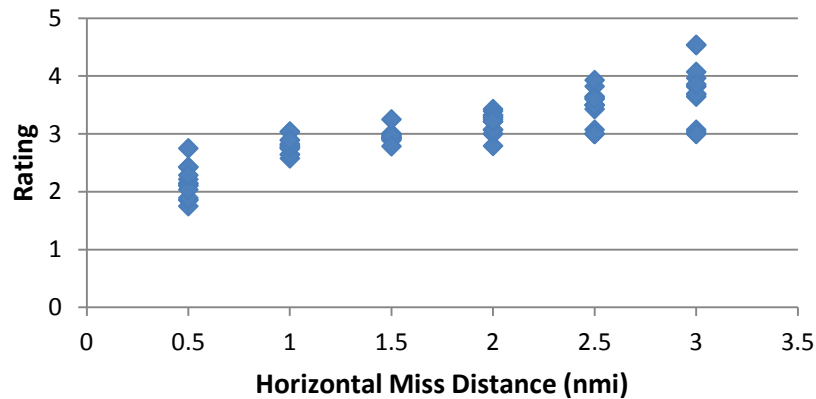
1. Much too close; unsafe or potentially so; cause or potential cause for issuance of a traffic alert
 2. Somewhat close, some cause for concern
 3. Neither unsafely close nor disruptively large, did not perceive the encounter to be an issue
 4. Somewhat wide, a bit unexpected; might be disruptive or potentially disruptive in congested airspace and/or with high workload
 5. Excessively wide, unexpected; disruptive or potentially disruptive in congested airspace and/or with high workload
- Note that some encounters did not result in a maneuver by the UAS (e.g., all crossing encounters with a faster intruder)
 - Fractional responses, e.g., 1.5 ... 4.5 were acceptable.



Ratings by Horizontal Miss Distance (HMD) Mean of 14 ATC subjects for each encounter

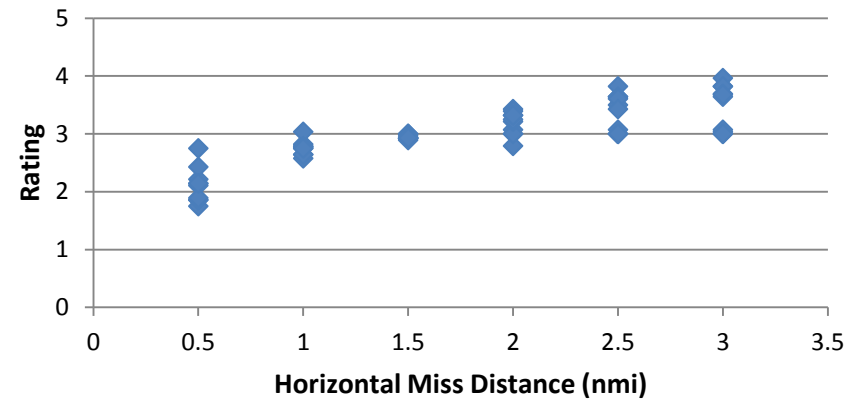


Ratings by HMD (all geometries)



The plot above includes mean Ratings for **all Encounter Geometries** (Crossing, Overtake, Opposite Direction) and at **all speed differences** between encounter aircraft.

Ratings by HMD (all crossings)



The plot above includes only **Crossing encounters**, but at **all speed differences** between encounter aircraft.

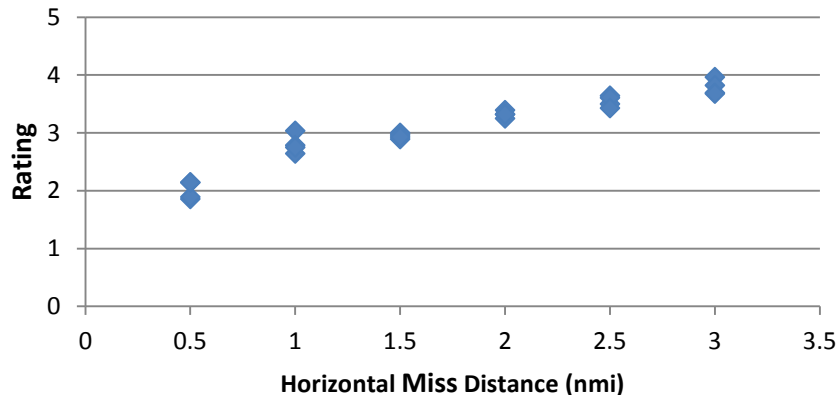


Ratings for UA faster than encounter aircraft

Mean of 14 ATC subjects for each encounter

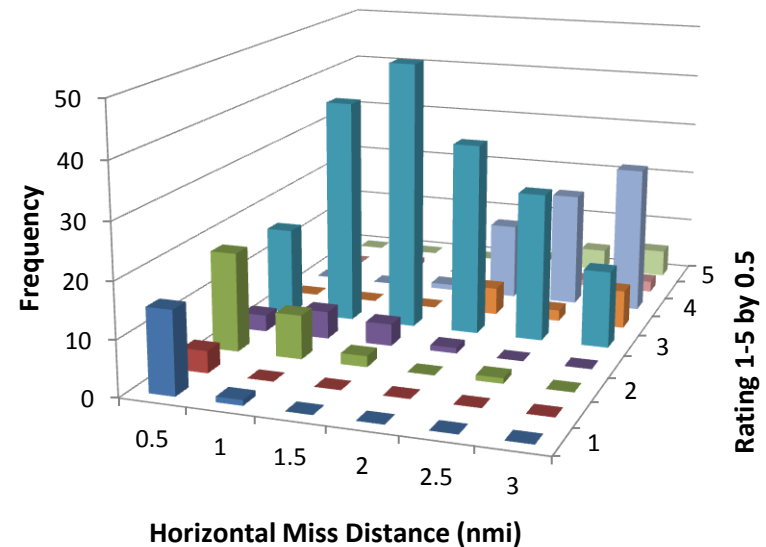


Ratings by HMD (UA faster)



The plot above includes only **Crossing** encounters where the UA was **faster** than the encounter aircraft.

Ratings for Crossings (UA Faster)



Plot of frequency of Rating responses when UA was **faster** than the encounter aircraft.

Note: Horizontal Miss Distances > 1.5 nmi required a UAS lateral maneuver

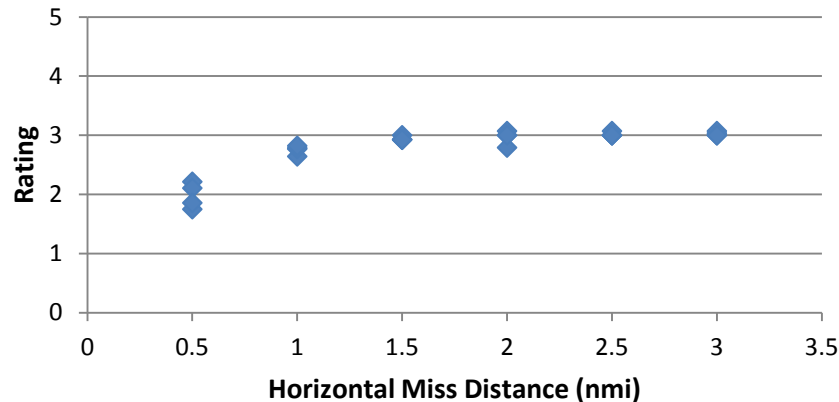


Ratings for UA slower than encounter aircraft

Mean of 14 ATC subjects for each encounter

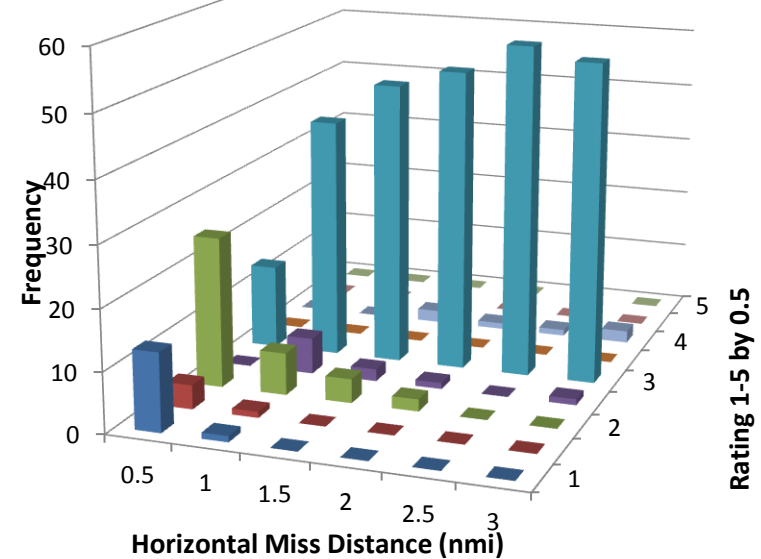


Ratings by HMD (UA Slower)



The plot above includes only **Crossing** encounters where the UA was **slower** than the encounter aircraft.

Ratings for Crossings (UA Slower)



Plot of frequency of Rating responses when UA was **slower** than the encounter aircraft.

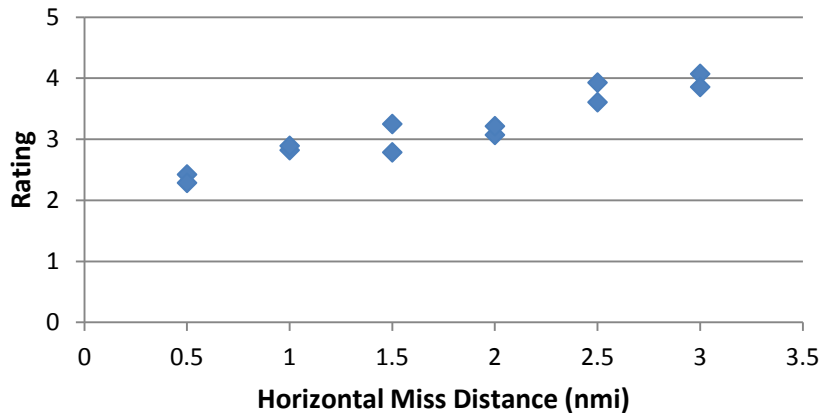
Note: All Horizontal Miss Distances achieved without a UAS lateral maneuver



Ratings for Overtake encounters

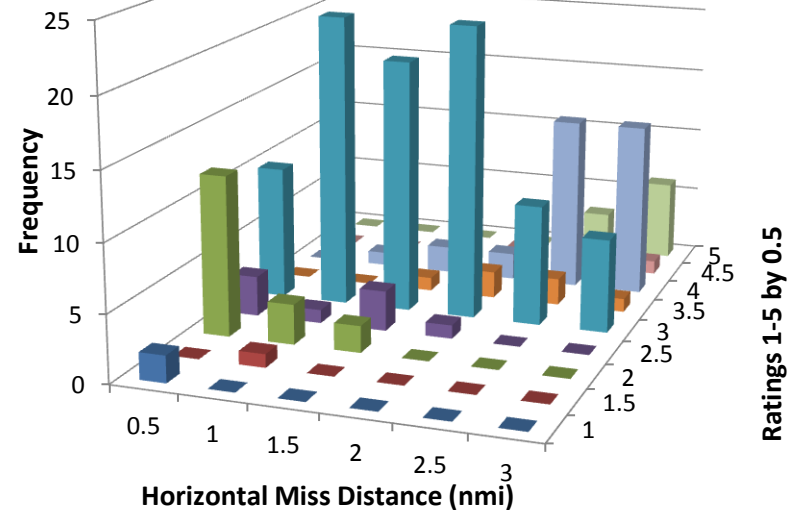
Mean of 14 ATC subjects for each encounter

Ratings by HMD (Overtake)



The plot above shows Mean Ratings for **overtake** encounters.

Ratings by HMD (Overtake)



Plot of frequency of Rating responses for **overtake** encounters.

Note: All Horizontal Miss Distances required a UAS lateral maneuver (initially a collision course)

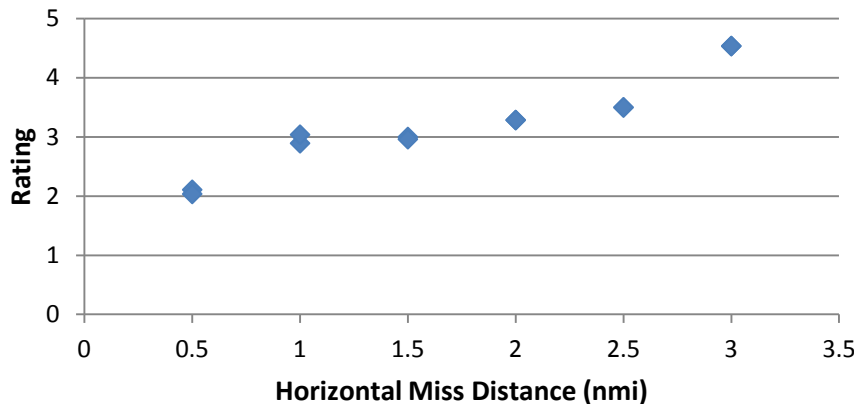


Ratings for Opposite Direction encounters

Mean of 14 ATC subjects for each encounter

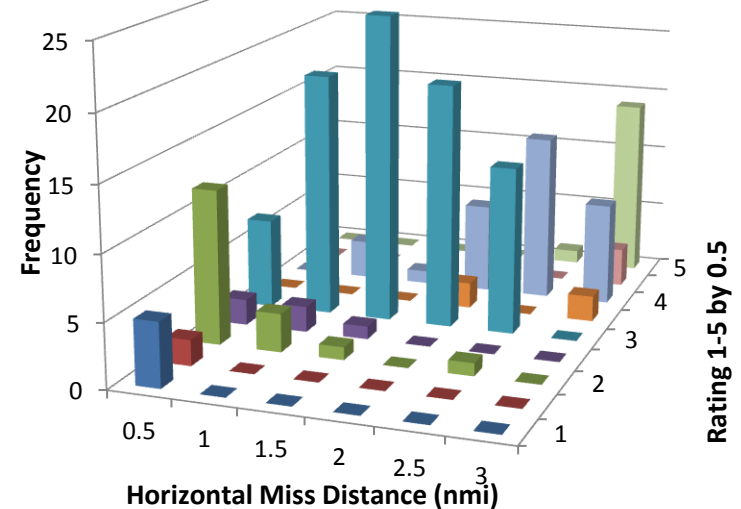


Ratings by HMD (Opposite Direction)



The plot above shows Mean Ratings for **opposite direction** encounters.

Ratings by HMD (Opposite Direction)



Plot of frequency of Rating responses for **opposite direction** encounters.

Note: All Horizontal Miss Distances required a UAS lateral maneuver (initially a collision course)

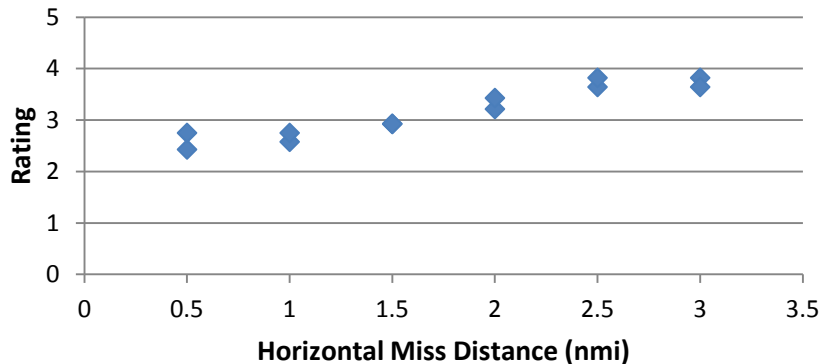


Ratings for Same-speed Crossing encounters

Mean of 14 ATC subjects for each encounter

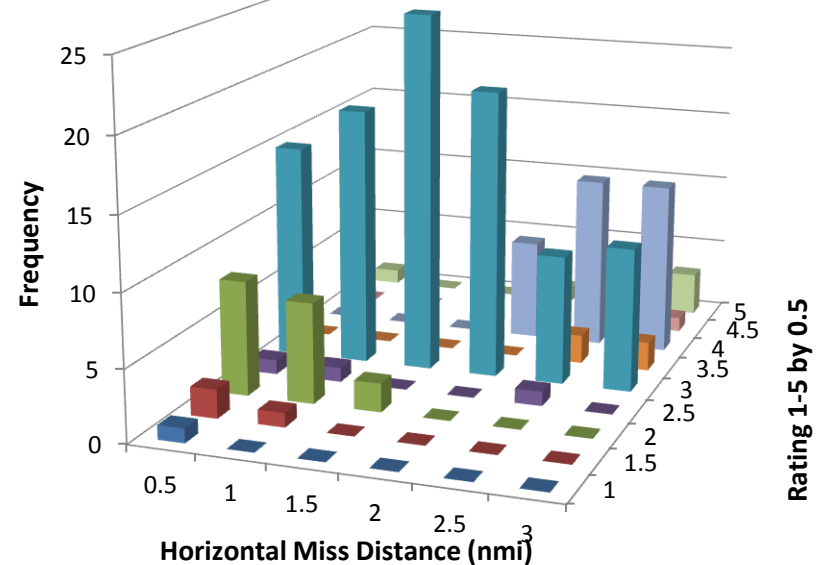


Ratings by HMD (Same Speed)



The plot above shows Mean Ratings for **crossing** encounters where both aircraft were at the **same speed**.

Ratings for Crossings (Same Speed)



Plot of frequency of Rating responses when both aircraft were at the **same speed**.

Note: Horizontal Miss Distances > 1.5 nmi required a UAS lateral maneuver



Initial Conclusions

- A horizontal miss distance (HMD) of ~1.5 nmi appears to be optimal for ATC acceptability (away from the airport vicinity)
- HMD of 1.5 nmi is >150% larger than the TCAS RA HMD for all airspace below Class A, and 136% larger in Class A
- 500' IFR-VFR vertical separation (with no vertical closure rate) was universally acceptable during debrief sessions (some controllers were ok with less)
- Controllers think the SAA integration concept as presented is viable
 - “definitely viable”
 - “absolutely viable”
 - “really impressed, way beyond expectations” [from before seeing it]
 - [worked] “surprisingly well”
 - “impressed with it”
 - “don’t see any controller having an issue with” [concept as seen]



Other Considerations

- 1.5 nmi HMD matches controller separation standards between VFR and large/turbojet IFR aircraft in Class B airspace
- Just opinion at this point but... 1.5 nmi HMD would likely be acceptable to the pilot community as “safely well clear”
- Various options for the time element of well clear:
 - Set to the same value(s) as TCAS CAT, to minimize RA issuance if intruder (or the UAS) is TCAS II equipped
 - Set to less than TCAS RA CAT values, possibly for non-cooperative intruders, to minimize range demands on SAA sensors



Questions?





Backup Charts (from subject training materials)



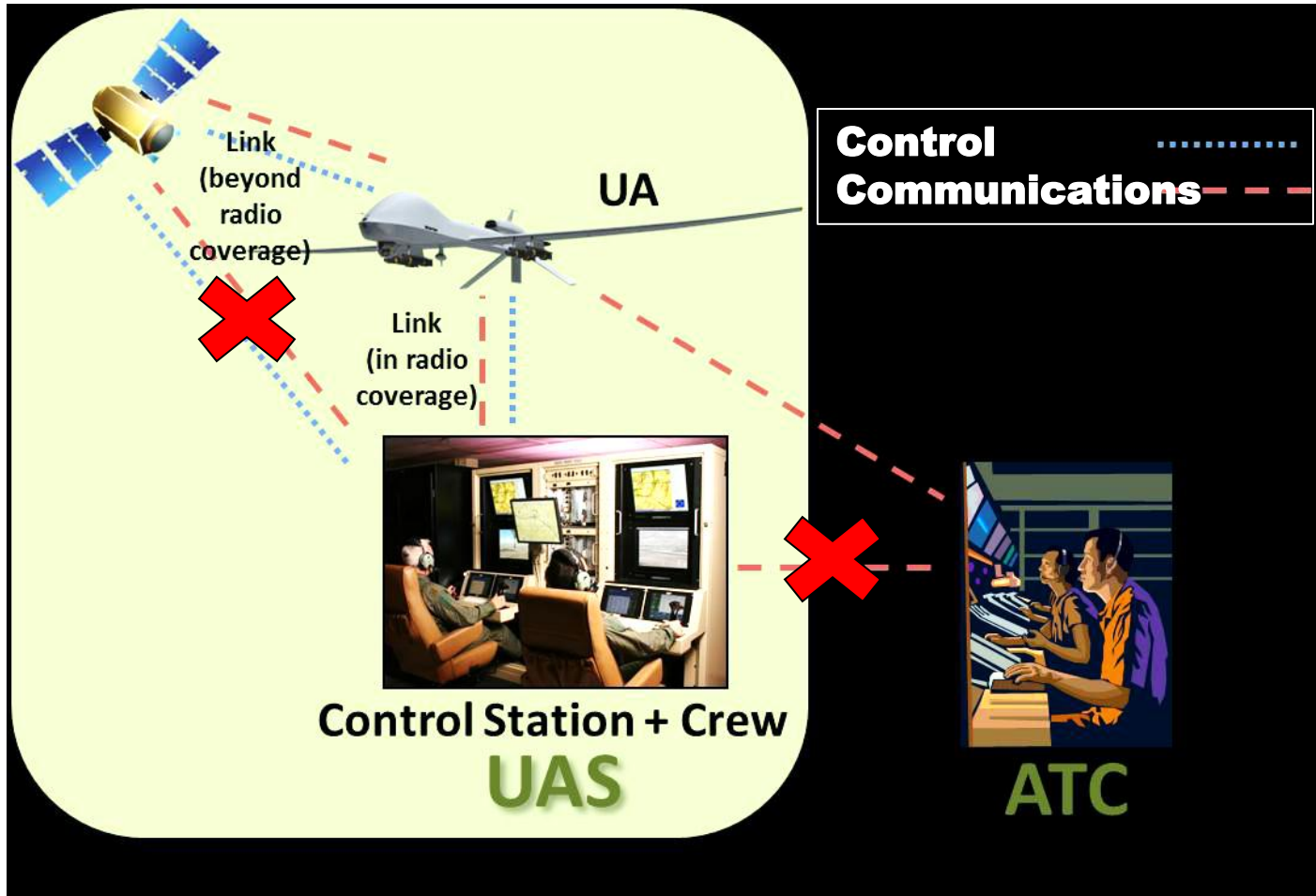


SAA Procedures and Phraseology



- Assume the UAS pilot can “sense” and avoid proximate traffic with his/her SAA equipment in a similar manner and with comparable reliability to a manned aircraft’s ability to see and avoid
- Issue traffic advisories and (if necessary) traffic alerts to UAS in the same manner as to manned aircraft
- If the UAS pilot detects the called traffic they will respond with “traffic detected” (rather than “in sight”) and may or may not request a maneuver
- The UAS pilot may ask for a deviation (or deviate and then advise) without a prior traffic advisory (same as a manned aircraft)
- Arriving UAS will be on an RNAV approach and cannot accept visual approaches

Notional Diagram of Unmanned Aircraft System (UAS)





The Sense and Avoid (SAA) Challenge for UAS



- Pilots are required to see and avoid other aircraft
 - 14CFR 91.111 (a) No person may operate an aircraft **so close to another aircraft as to create a collision hazard.**
 - 14CFR 91.113 (b) *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.**
- Sense and Avoid (SAA) was defined by the FAA-sponsored SAA for UAS Workshop Final Report published in October 9, 2009 as “the combination of UAS Self-Separation (SS) plus Collision Avoidance (CA) as a means of compliance with 14CFR Part 91, § 91.111 and § 91.113”
- SAA-equipped UAS should seamlessly interoperate with other aircraft, air traffic services and existing collision avoidance technologies



Self Separation and Collision Avoidance



From the SAA Workshop Final Report:*

- Self Separation (SS) Function
 - SS is “essential” and “could be the only function” of SAA
 - Intended as a means to remain “well clear”
 - “Normal/operational, non obtrusive maneuvers”
 - Maneuvers made early enough to avoid CA activation
- Collision Avoidance (CA) Function
 - CA engages “when all other modes of separation fail”
 - Intended as a means to avoid Near Mid-Air Collisions (NMACs)
 - CA maneuvers made “within a relatively short time horizon before closest point of approach [CPA]”

* Sense and Avoid (SAA) for Unmanned Aircraft Systems (UAS). Prepared by: FAA Sponsored Sense and Avoid Workshop, October 9, 2009.



Direct Query After Each Encounter



After each “well clear encounter” you will be asked to rate the horizontal miss distance on a five-point scale:

1. Much too close; unsafe or potentially so; cause or potential cause for issuance of a traffic alert
2. Somewhat close, some cause for concern
3. Neither unsafely close nor disruptively large, did not perceive the encounter to be an issue
4. Somewhat wide, a bit unexpected; might be disruptive or potentially disruptive in congested airspace and/or with high workload
5. Excessively wide, unexpected; disruptive or potentially disruptive in congested airspace and/or with high workload

Note that some encounters will not result in a maneuver by the UAS