



# **GDTI**

**A *GROUND STATION DISPLAY OF TRAFFIC INFORMATION* FOR USE IN SENSE AND AVOID OPERATIONS**

Steven Bell • DASC • October 17, 2012

# Nominal GBSAA Operation



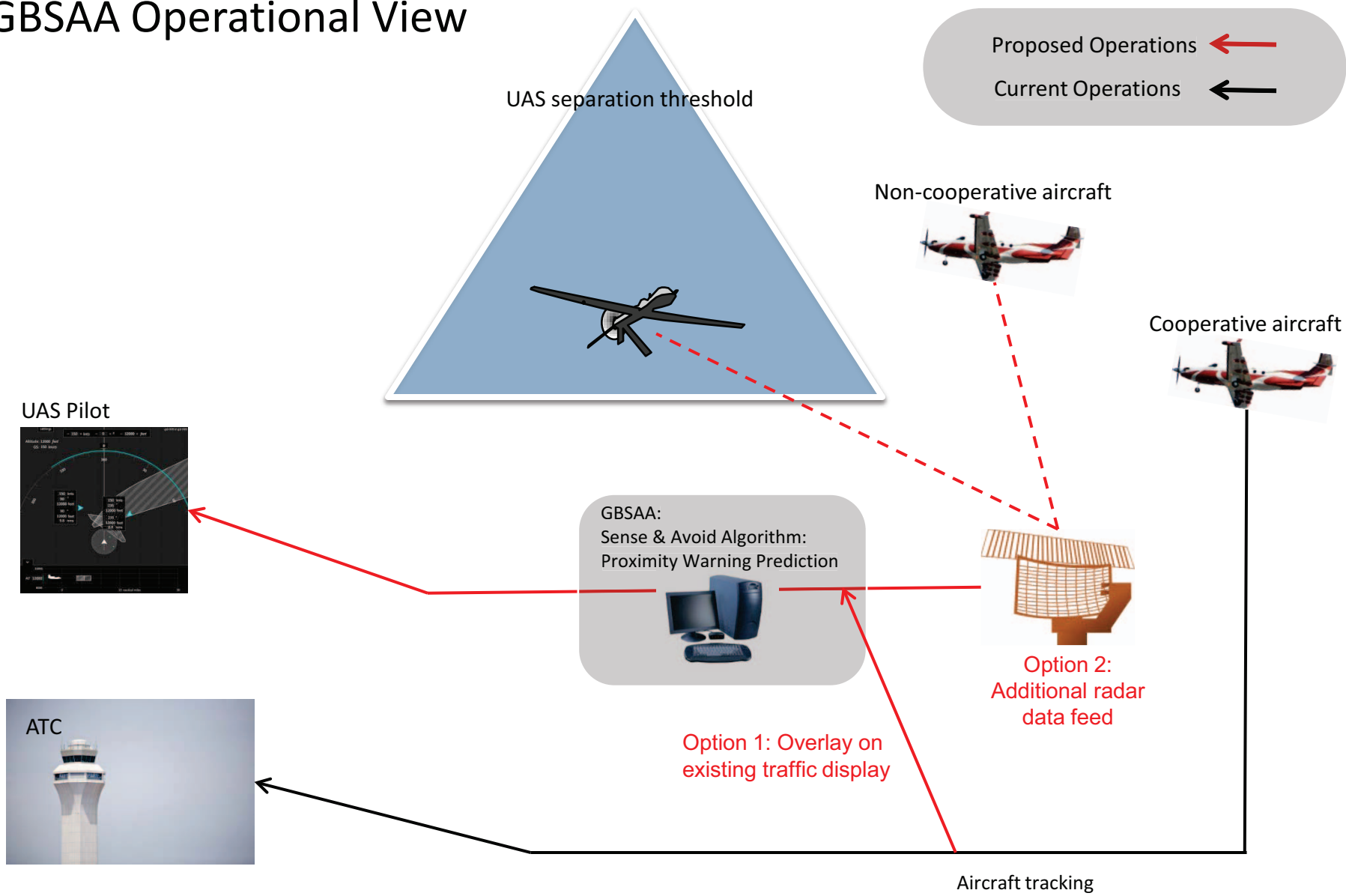
IFR/VFR Cooperative



Non-Cooperative



# GBSAA Operational View

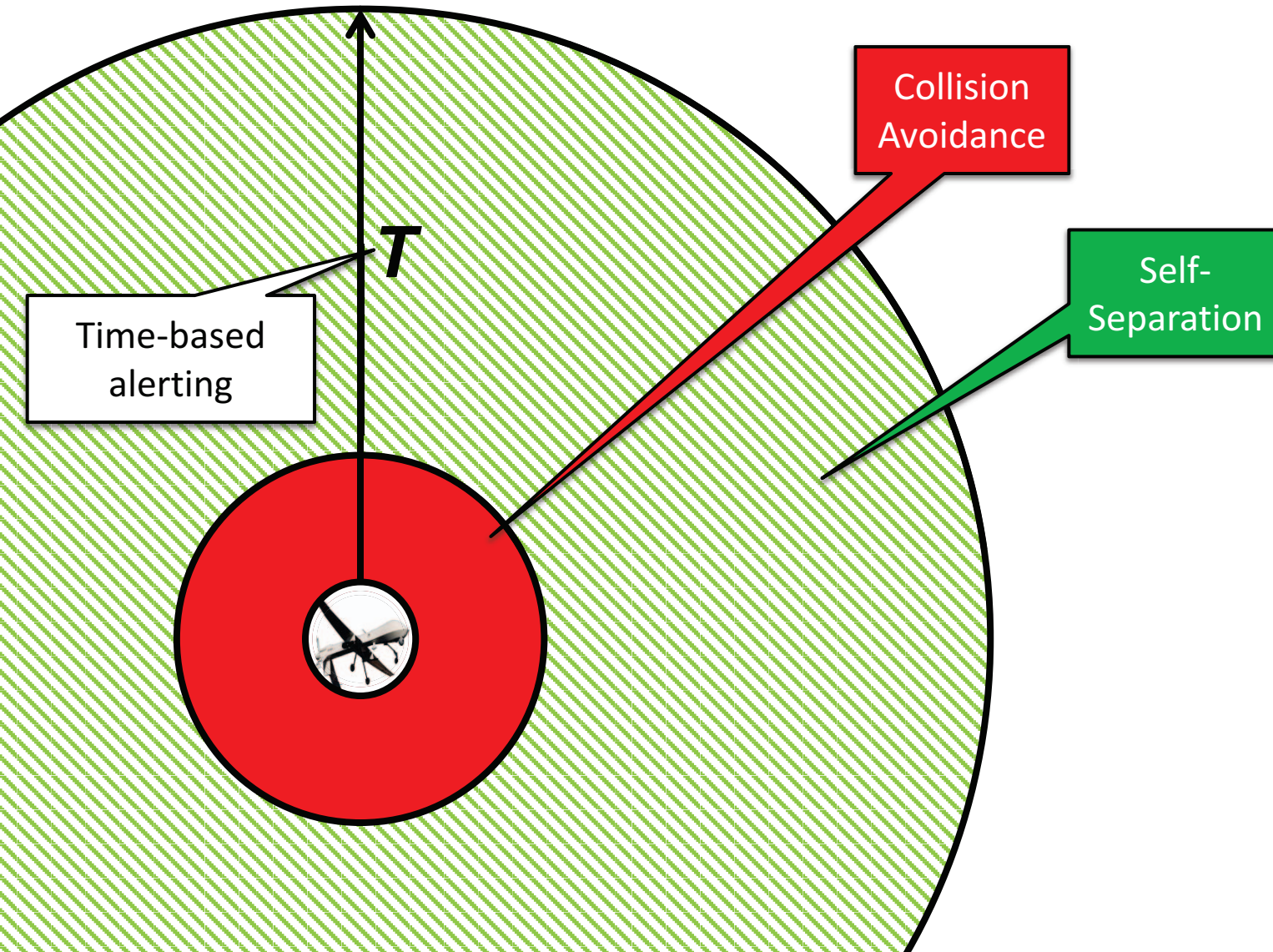


# Research Goals

- Explore situation awareness alone as a baseline for Sense and Avoid operations
- Explore display overlays as they affect the ability to execute an appropriate avoidance maneuver
- Explore the concept of self-separation as it relates to UAS

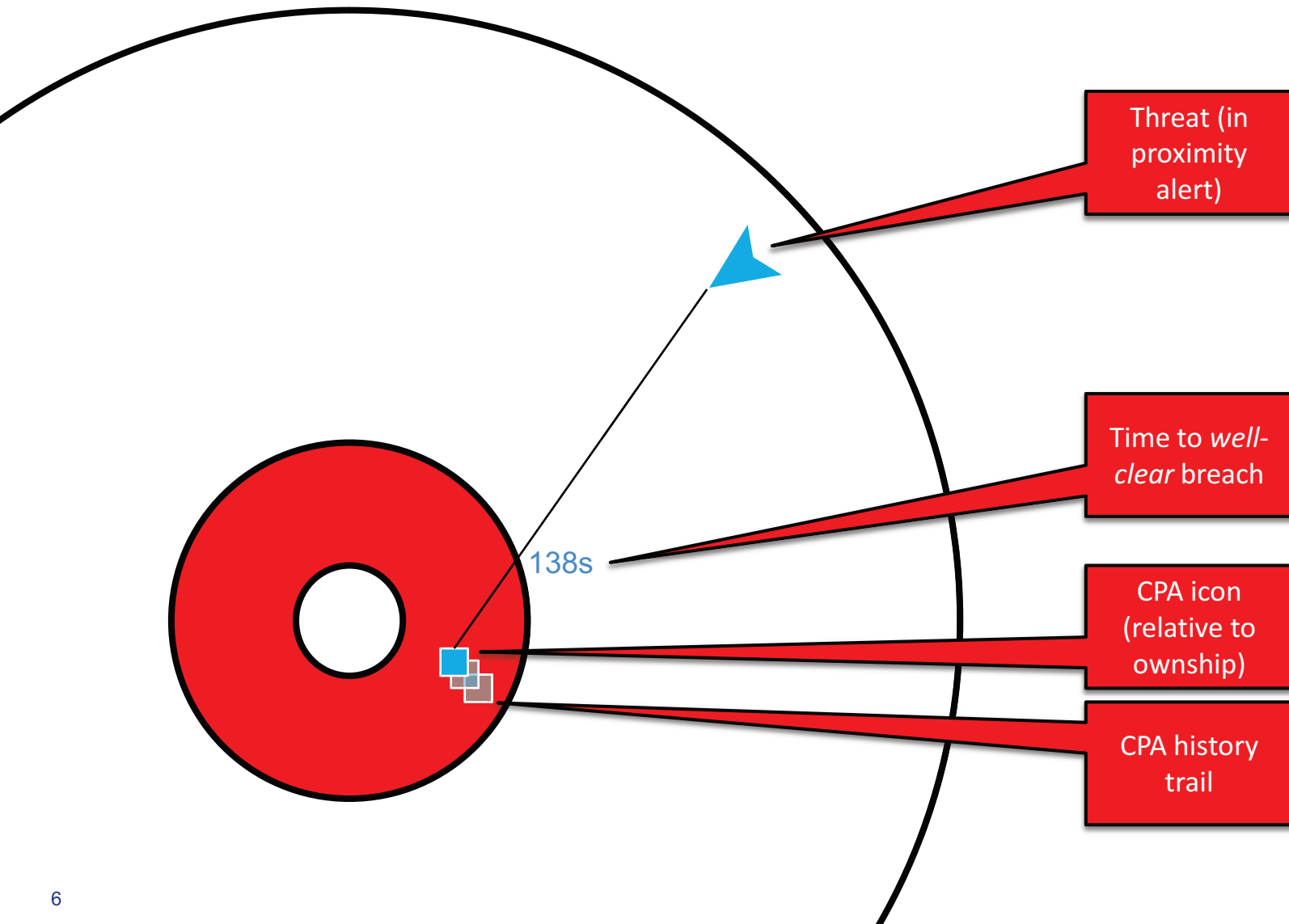


# Separation Vs. Collision Avoidance



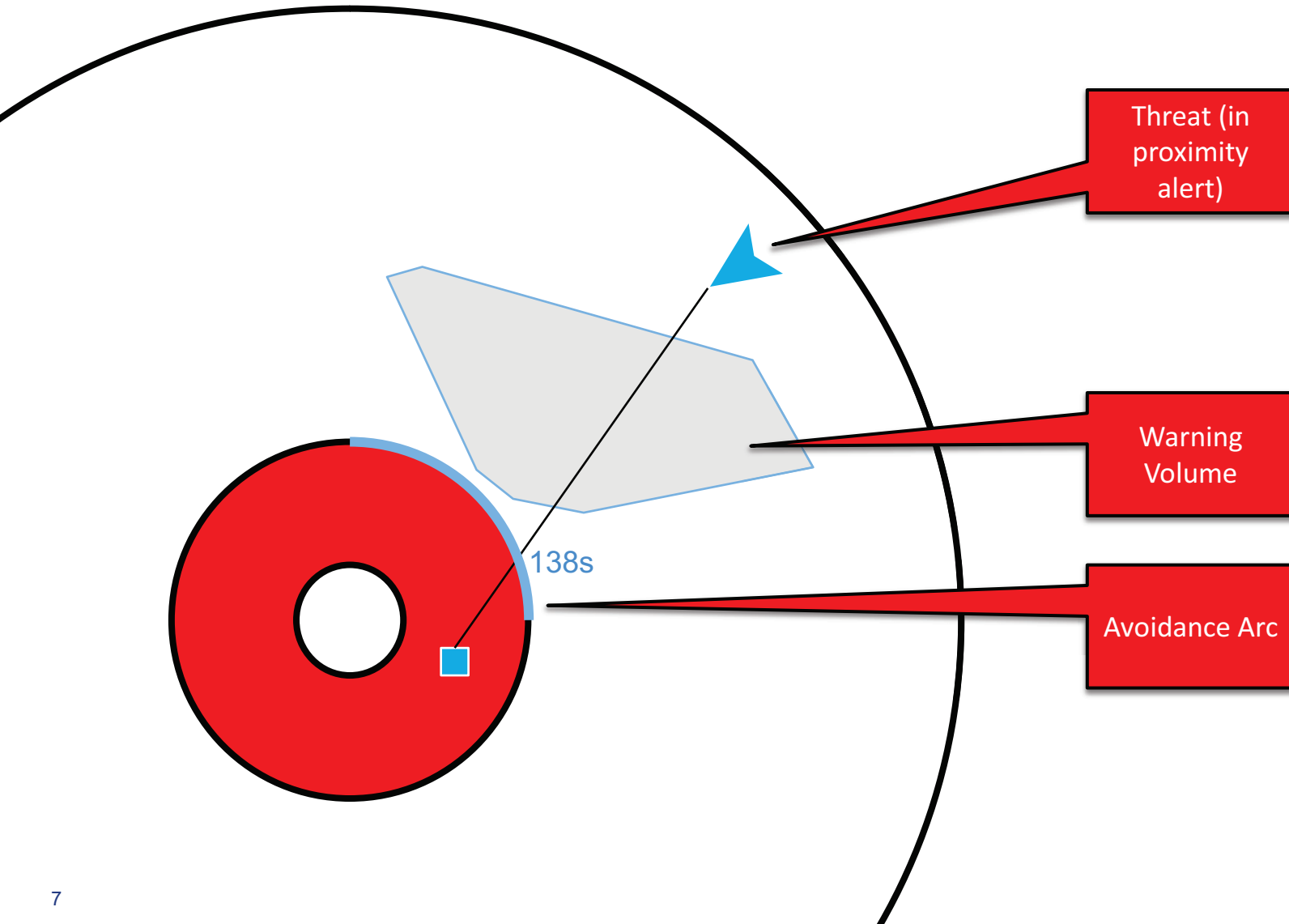
# R-CPA.

Relative Closest Point of Approach

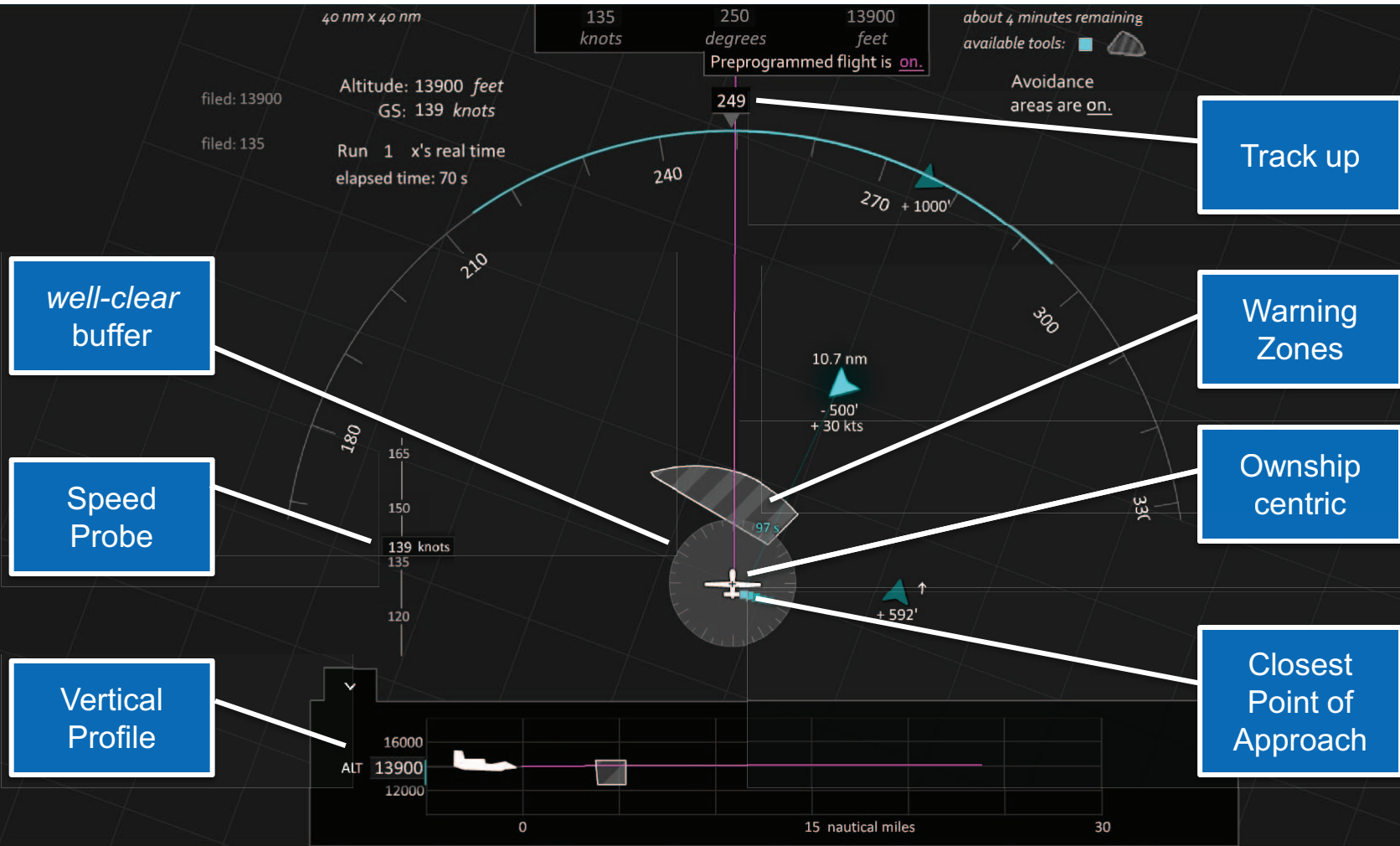


# Avoidance Areas

Depicting Uncertainty



# Interface Overlays



# Distributed Concept Evaluations

## Participation

- Two-phases of evaluation
- Over 40 UAS pilot participants (DoD)
- Industry
- Research/Academia

## Technology

- Internet-based
- Rapid prototype capabilities
- Data collection





CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

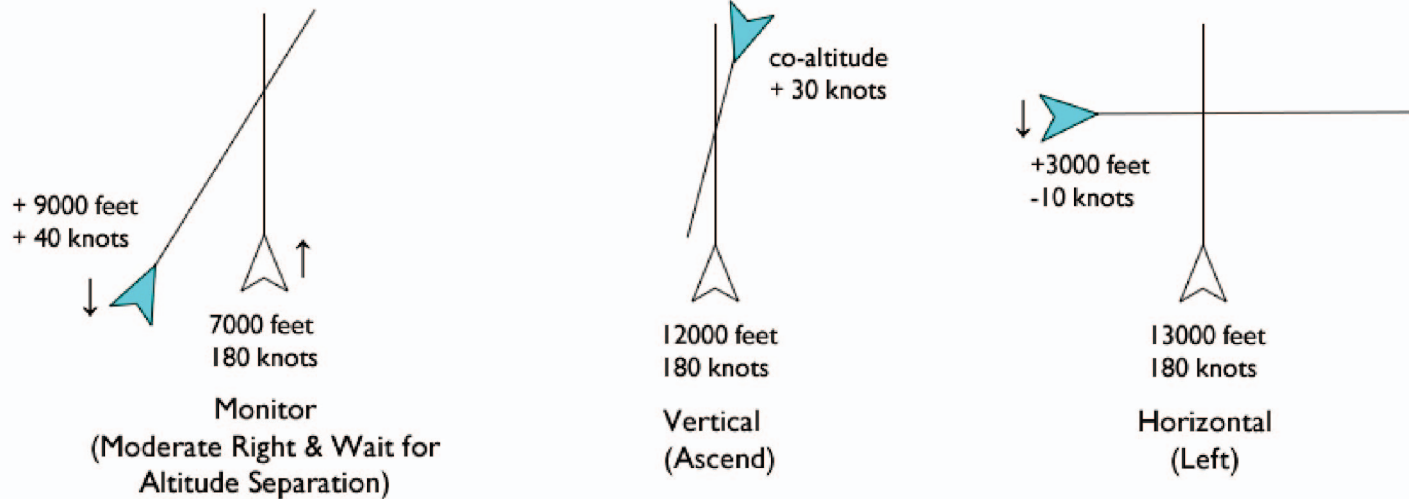


# Methodology

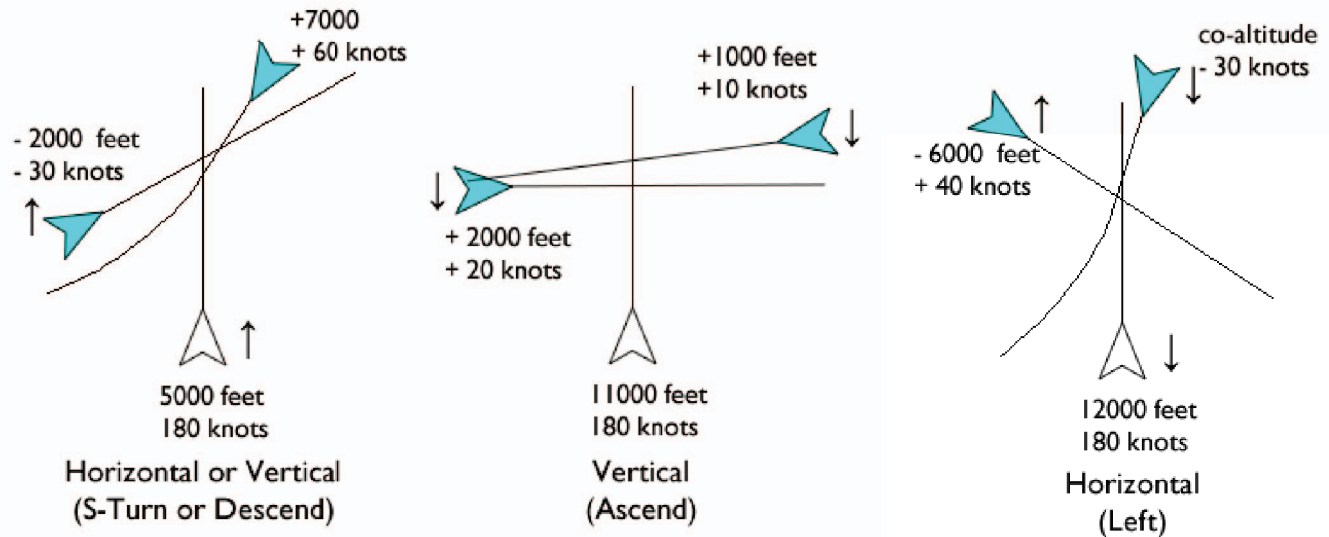


# Manipulations & Encounter Geometries (Phase 1)

## One Intruder



## Two Intruders



# Evaluation Metrics

## *Objective*

1. Loss of Separation
2. Maneuver Choice
3. Lateral Distance Travelled off Track
4. Vertical Distance Travelled off Track

## *Subjective*

5. Usability
6. Concept Operational Acceptability
7. Toolset Operational Acceptability

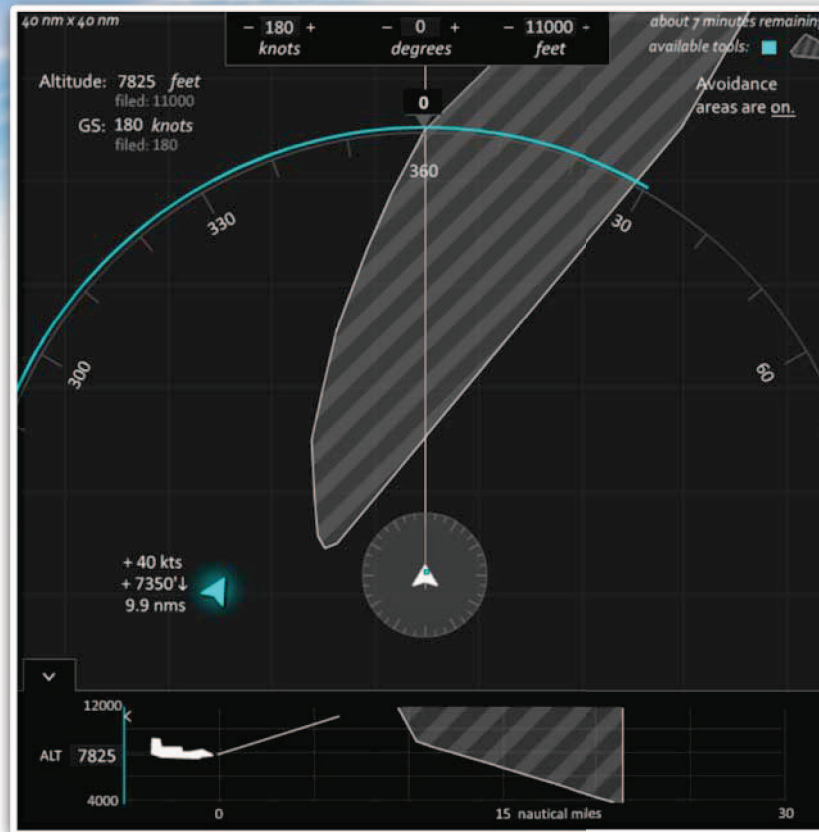




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# Results



## Monitor Scenario Results

*Hypothesis: The increased uncertainty resulting from slow overtake will obviate the benefits of the vertical avoidance areas. The display features will encourage earlier and larger maneuvers in the avoidance area and cpa conditions*

# Monitor Scenario: BWCB\* and Maneuver Choice

**Number and Duration of  
BWCB Events by Interface**

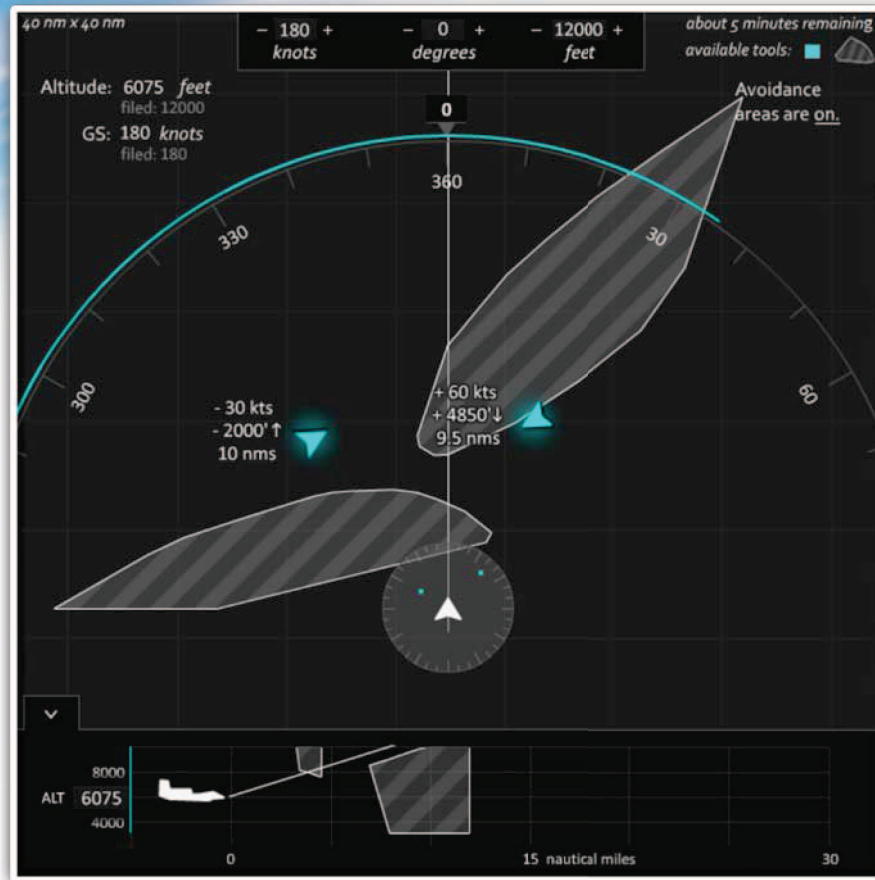
	Count	Time in <i>Well-clear</i> (s)
basic	1	24
cpa	1	20
avoidance areas	1	2

**Average Lateral and Vertical  
Deviation by Interface**

	Average Lateral Deviation (nm)	CI	Magnitude of Vertical Deviation (feet)	CI	Relative Maneuver Preference
basic	0.6	0.5	722	642	-0.8
cpa	1.1	0.7	424	247	-0.1
avoidance areas	3.3	1.4	682	560	0.9

*favor vertical*    *favor lateral*





## S-Turn Scenario

*Hypothesis: The need for multiple lateral maneuvers and pilot aversion to descending will favor the CPA and Avoidance Areas conditions resulting in better maneuver selection and fewer loss of separation events*



# S-Turn: BWCB and Maneuver Choice

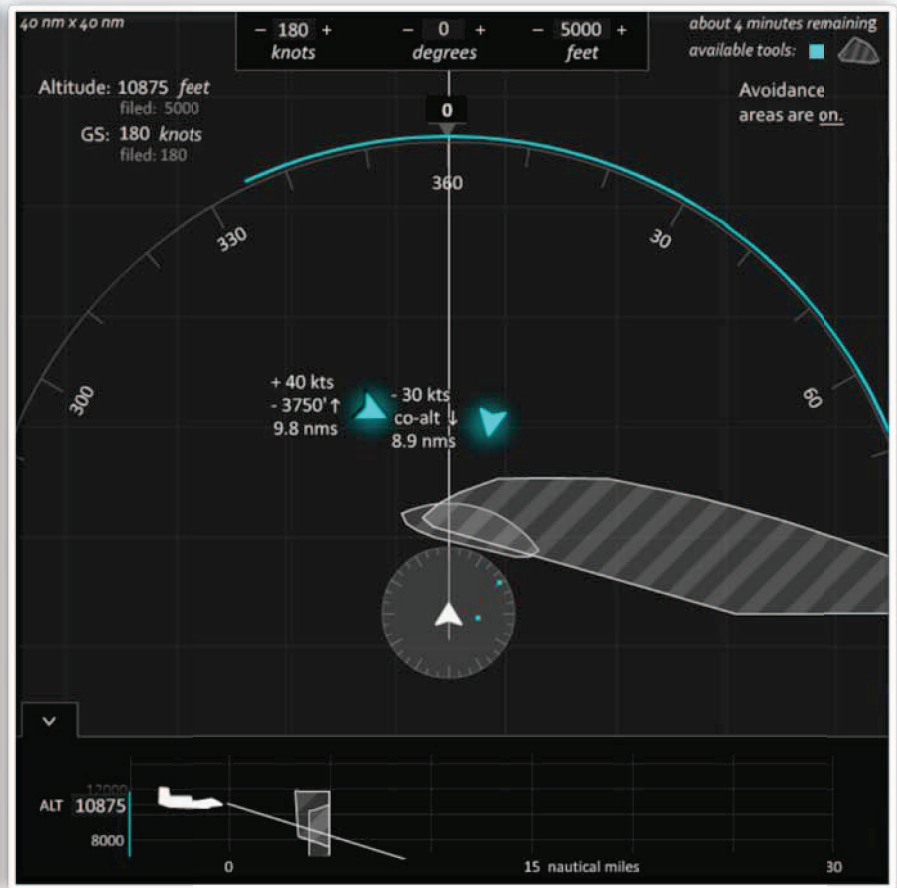
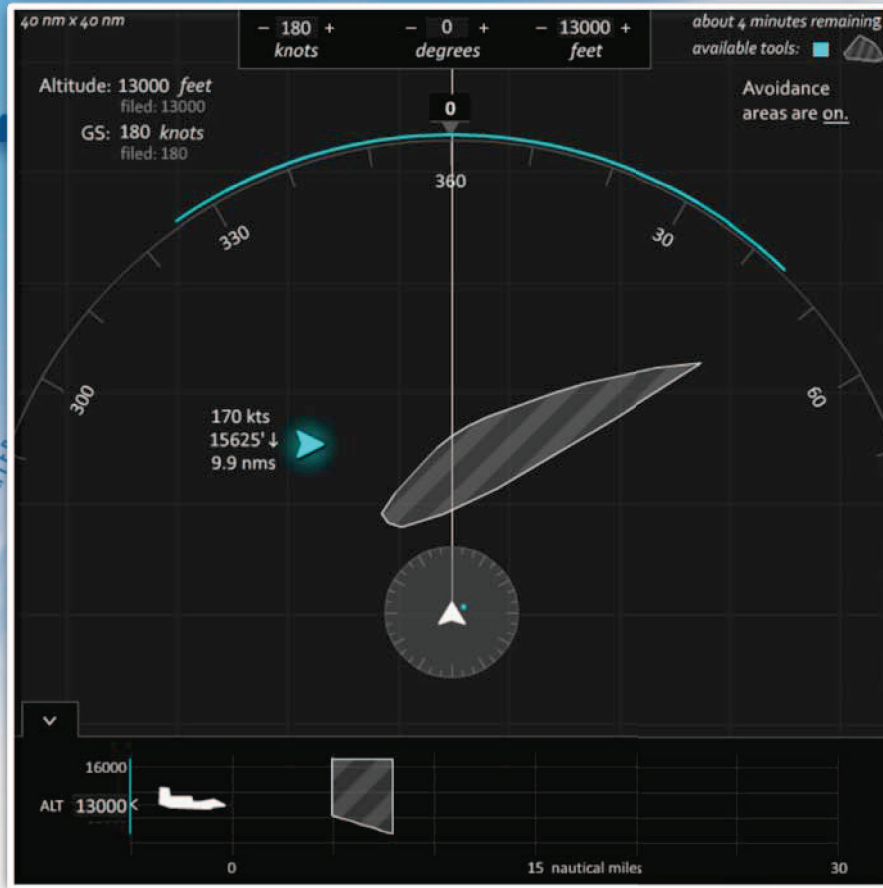
**Number and Duration of  
BWCB Events by Interface**

	<b>Count</b>	<b>Time in Well-clear (s)</b>
basic <i>(1 near collision)</i>	4	22
cpa	1	7
avoidance areas	0	-

**Average Lateral and Vertical  
Deviation by Interface**

	Average Lateral Deviation (nm)		Magnitude of Vertical Deviation (feet)		Relative Maneuver Preference
		CI		CI	
basic	1.6	0.7	546	602	-0.4
cpa	2.4	1.8	603	696	-0.1
avoidance areas	3.4	2.0	475	632	0.5

*favor vertical* | *favor lateral*



## Horizontal Scenarios



*Hypothesis: The simplicity of the resolution in both the single and multiple intruder case will result in no benefit for the GBSAA toolset conditions*

# Horizontal: BWCB and Maneuver Choice

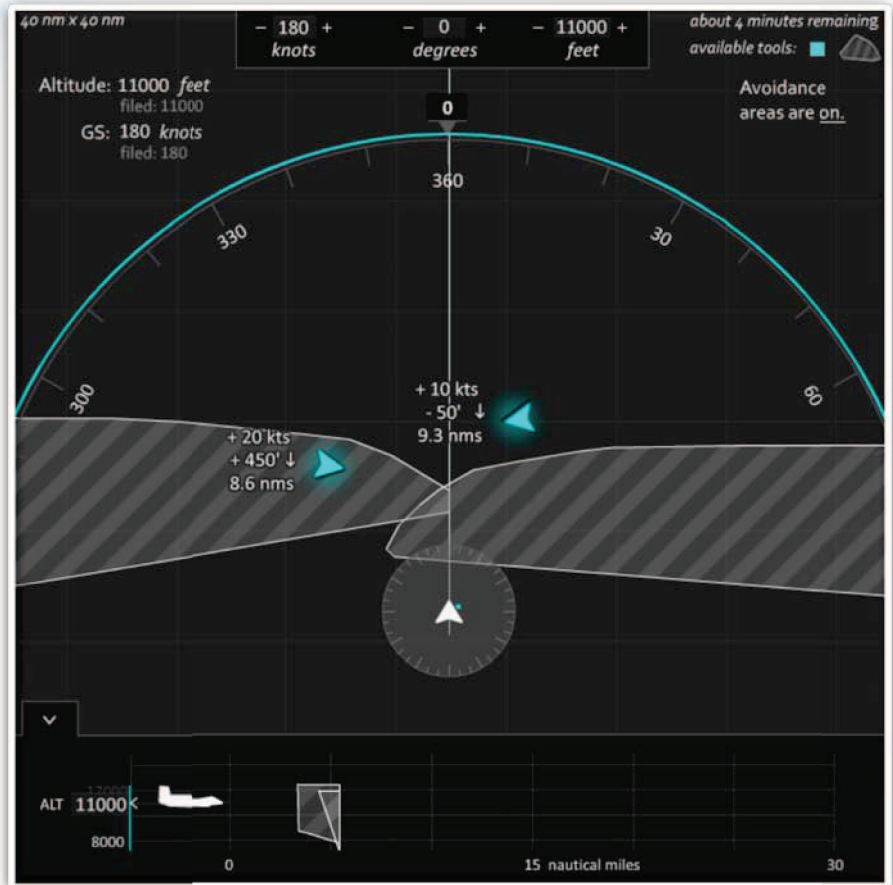
**Number and Duration of  
BCWB Events by Interface**

		<b>Count</b>	<b>Time in Well-clear (s)</b>
Horizontal One	basic	1	34
	cpa	0	-
	avoidance areas	0	-
Horizontal Two	basic	1	22
	cpa	0	-
	avoidance areas	0	-

**Average Lateral and Vertical  
Deviation by Interface**

		Average Lateral Deviation (nm)		Magnitude of Vertical Deviation (feet)		Relative Maneuver Preference
			CI		CI	
One	basic	2.8	1.5	352	450	0.2
	cpa	2.4	0.3	387	400	0.0
	avoidance areas	2.4	1.0	415	526	-0.1
Two	basic	1.3	0.5	482	474	0.6
	cpa	0.7	0.3	1,013	1,060	-0.6
	avoidance areas	1.2	0.6	907	680	0.0

*favor vertical* | *favor lateral*



## Vertical Scenarios

*Hypothesis: The avoidance areas will rightly encourage a vertical maneuver via the avoidance areas in the vertical profile*



# Vertical: BWCB and Maneuver Choice

**Number and Duration of BWCB Events by Interface**

		Count	Time in Well-clear (s)
Vertical One	basic	2	16
	cpa	1	17
	avoidance areas	1	3
Vertical Two	basic	2	32
	cpa	2	23
	avoidance areas	2	5

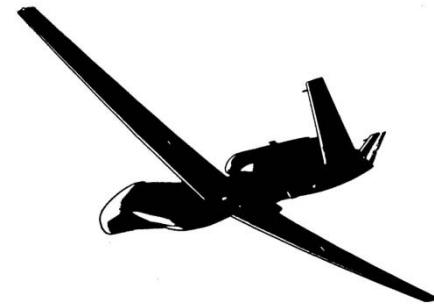
**Average Lateral and Vertical Deviation by Interface**

		Average Lateral Deviation (nm)	CI	Magnitude of Vertical Deviation (feet)	CI	Relative Maneuver Preference
One	basic	2.1	1.2	526	265	0.5
	cpa	2.3	1.4	713	401	0.3
	avoidance areas	0.8	0.8	930	275	-0.8
Two	basic	3.5	2.6	546	287	1.2
	cpa	1.9	1.7	842	253	0.0
	avoidance areas	0.1	0.3	1,079	235	-1.2

*favor vertical* | *favor lateral*



CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

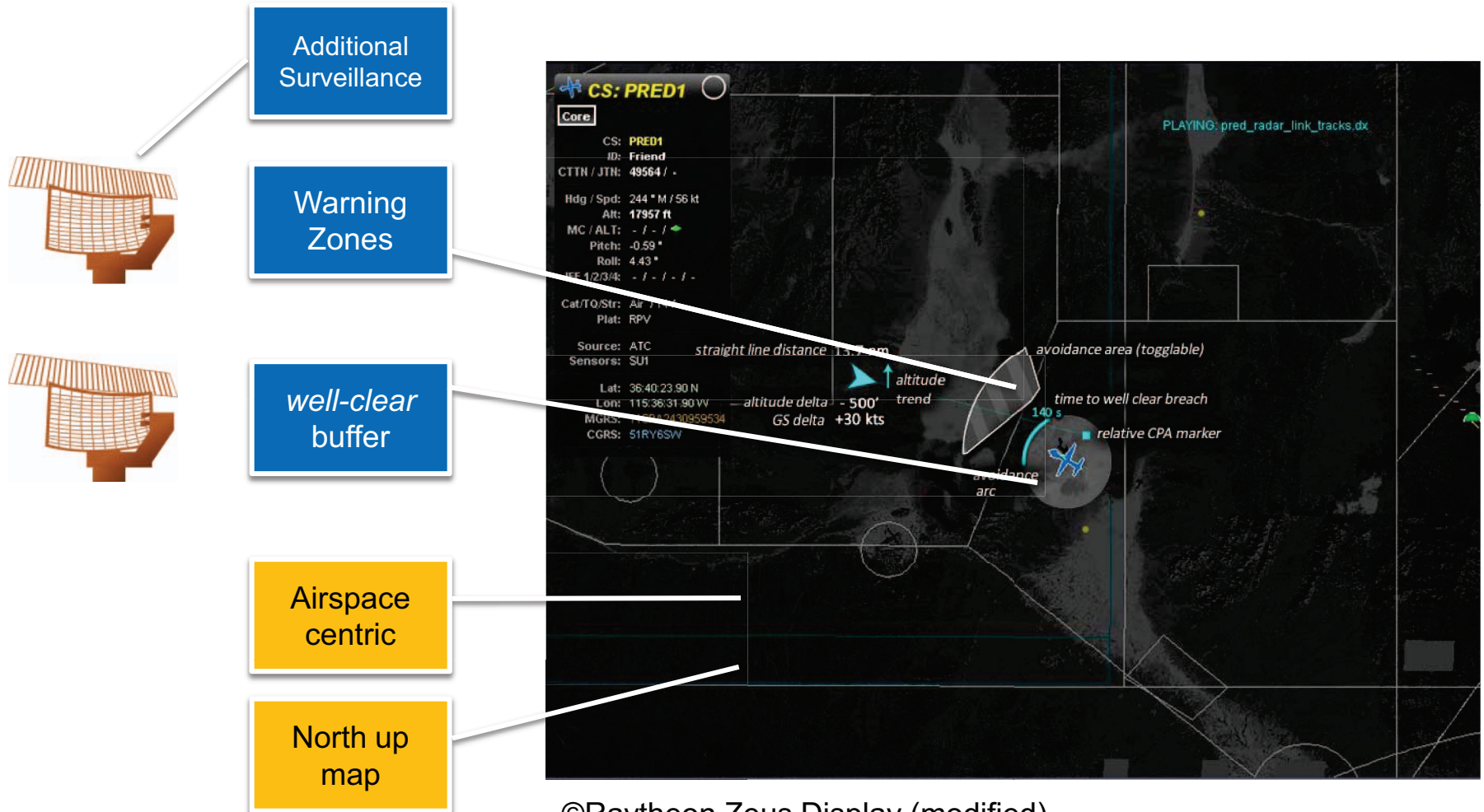


# Implications Beyond the Sensor



# Beyond the Surveillance Source

Universal Potential of Concepts



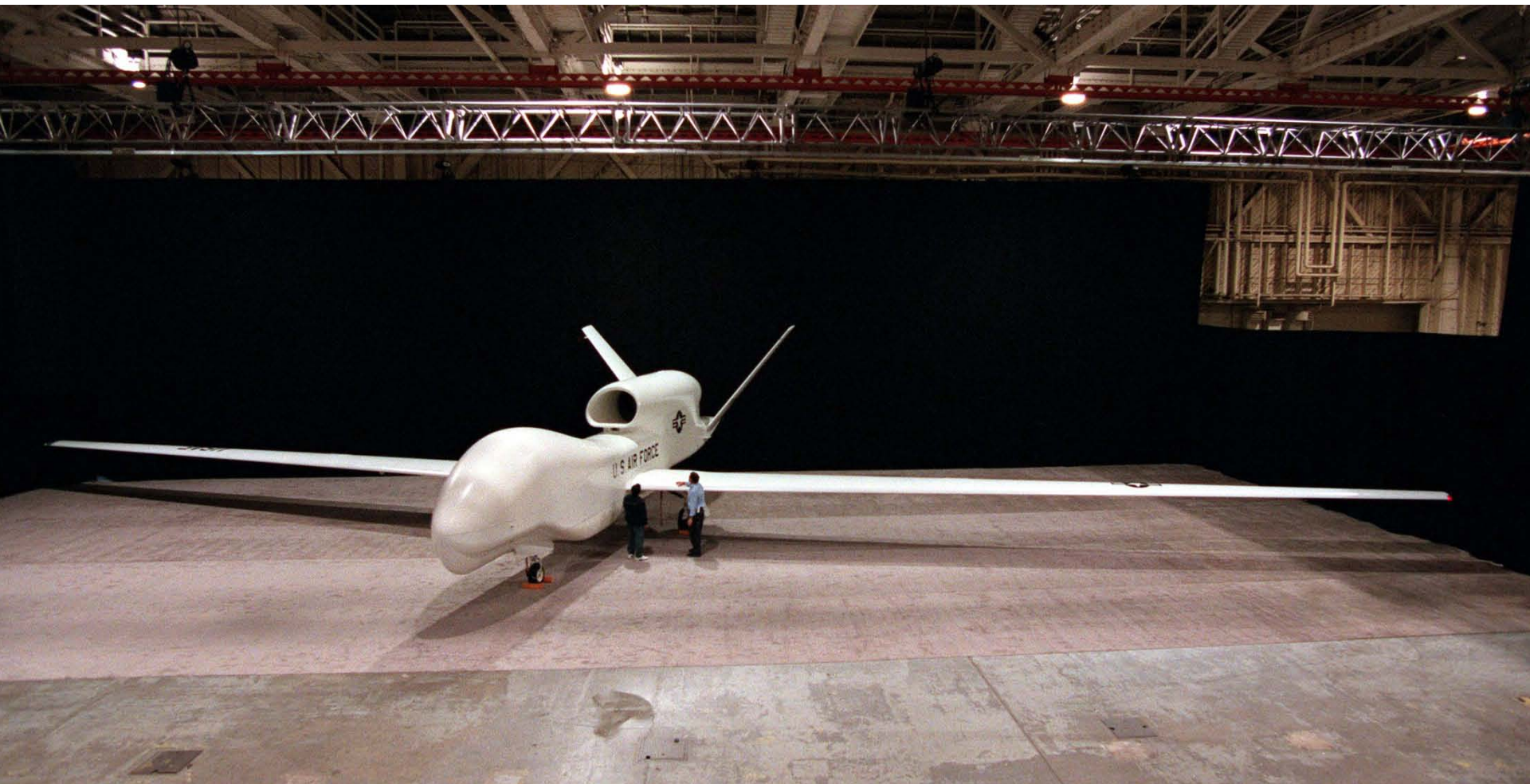
©Raytheon Zeus Display (modified)

# Summary

- **Maneuver Selection**
  - **Pilots better selected safe and appropriate maneuvers with the GBSAA toolsets**
- **Loss of Separation**
  - **The GBSAA toolsets conditions consistently had fewer LOS events than the basic condition and duration of LOS was much shorter in the avoidance areas condition**
- **Pilot Opinion**
  - **Pilot opinion was very favorable**

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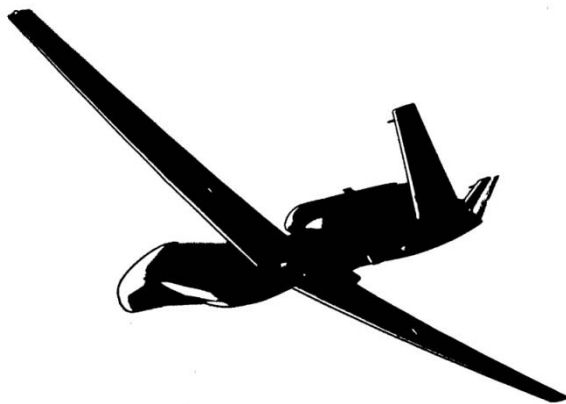
Approved for Public Release: 12-4245. Distribution Unlimited.





CENTER FOR ADVANCED AVIATION SYSTEM DEVELOPMENT (CAASD)

**Thanks!**  
**Steven Bell: [sbell@mitre.org](mailto:sbell@mitre.org)**  
**703-983-7562**

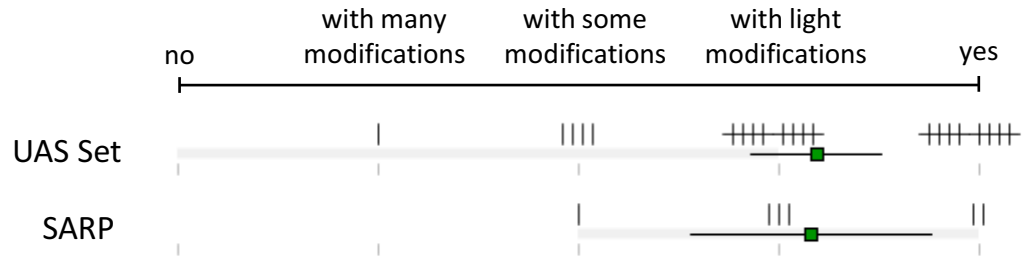




# Extra Slides (results already PRS in paper)

# Operationally Acceptable

**Would you consider the use of this traffic display for the purpose of maintaining separation from VFR traffic to be operationally acceptable?**



## Comments

Could be a very useful tool, I am hesitant to fully endorse because anything would look great next to what we have now (nothing). It certainly has potential. I would add a suggested heading or altitude change. It would be nice to integrate this system with terrain avoidance.

Understand this is a "two handed" tool for today's configurations.



# 10 Miles

**Ten miles allows adequate time to assess AND respond to an intruder.**

	UAS	
	Pilots	SARP
Agree	21	6
Disagree	6	1

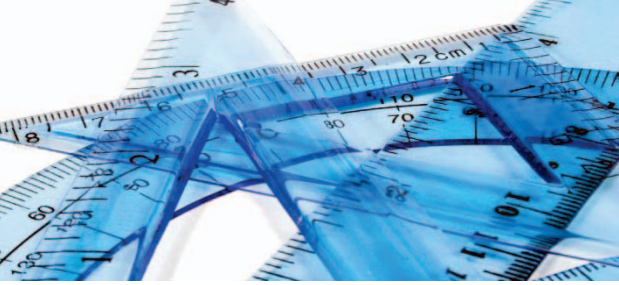
## *Comments*

“The cpa tool would be useful beyond ten miles. It would be better to make small corrections farther out if a conflict is suspected. “

“If the other target is slow, then 10 miles is adequate. If it moving faster, than 10 miles is not enough.

“15 miles may be more appropriate for first time users. I think that after sufficient training 10 miles may be adequate for multiple threat A/C”

“I think 20+ miles would be better. Especially if other aircraft are flying 400+knots.”



# Distance versus Time



**A distance value is more preferable than a time based value.**

	UAS	
	Pilots	SARP
Agree	13	2
Disagree	14	5

## *Comments*

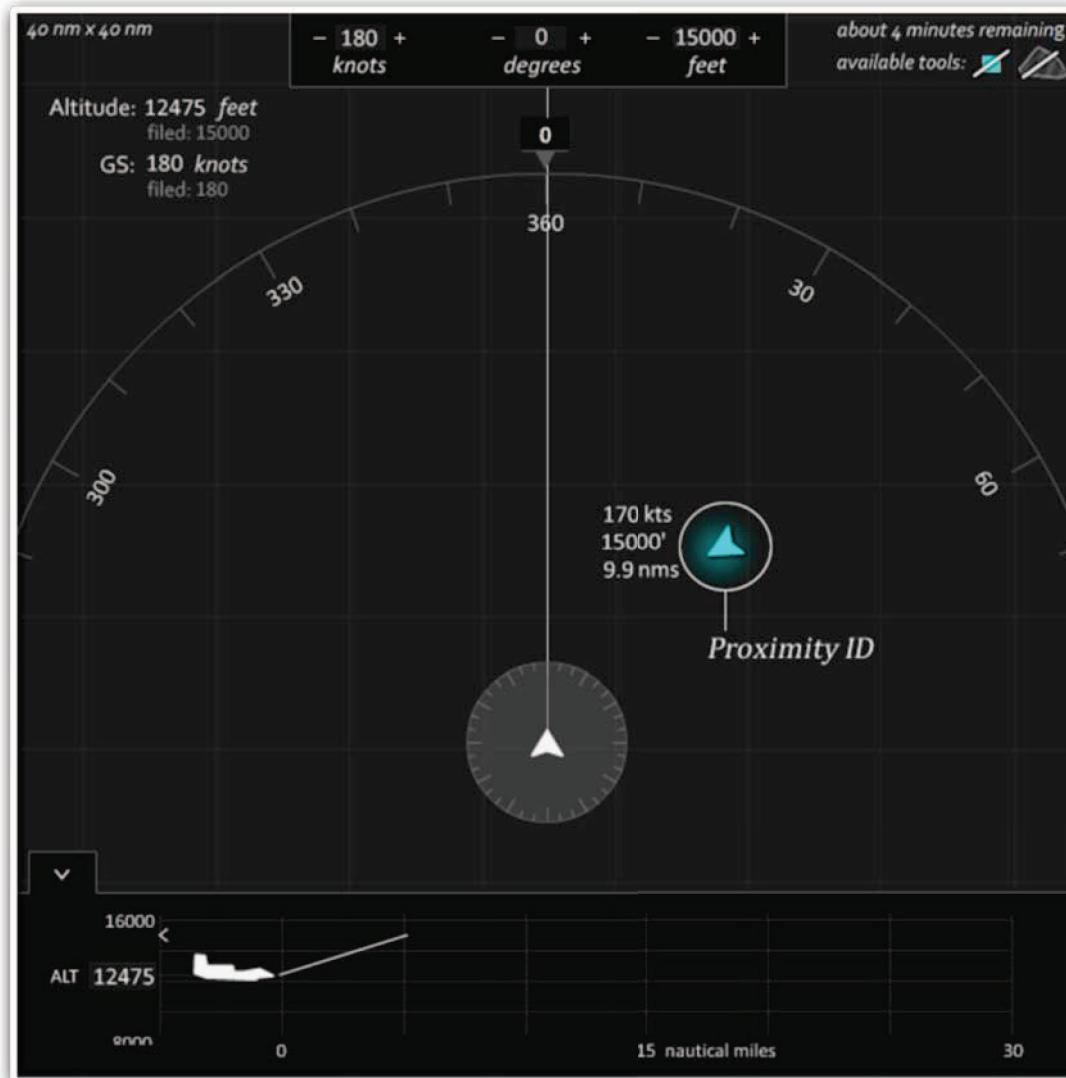
“A time based value would allow for maneuvers but not lead to maneuvering too early or late.”

“Closure rates dictate how quickly you have to adjust flight path to deconflict with traffic distance is not as important as time. “

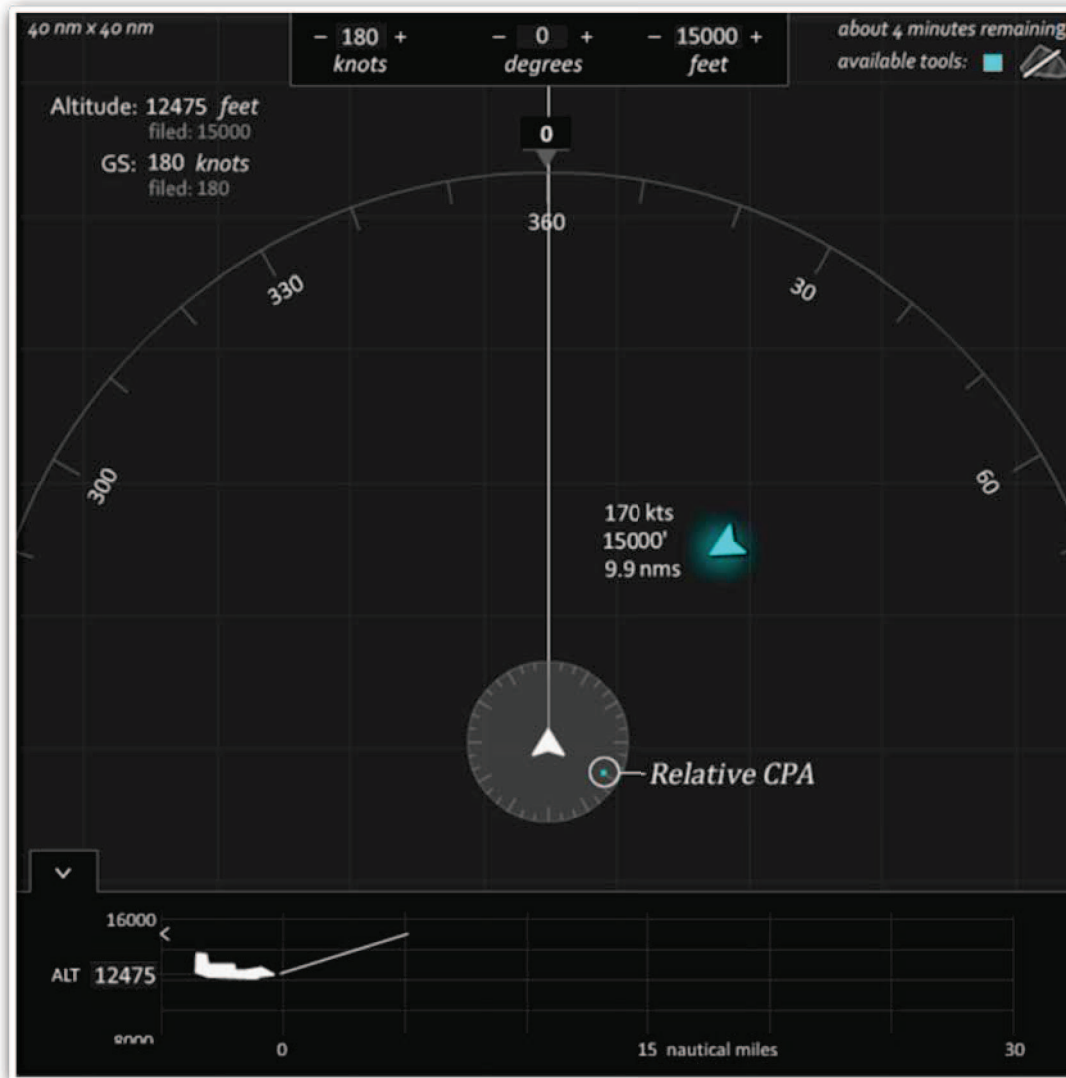
“The ability to react really has nothing to do with distance.”

“Distance is easier to compute and track than time calculations.”

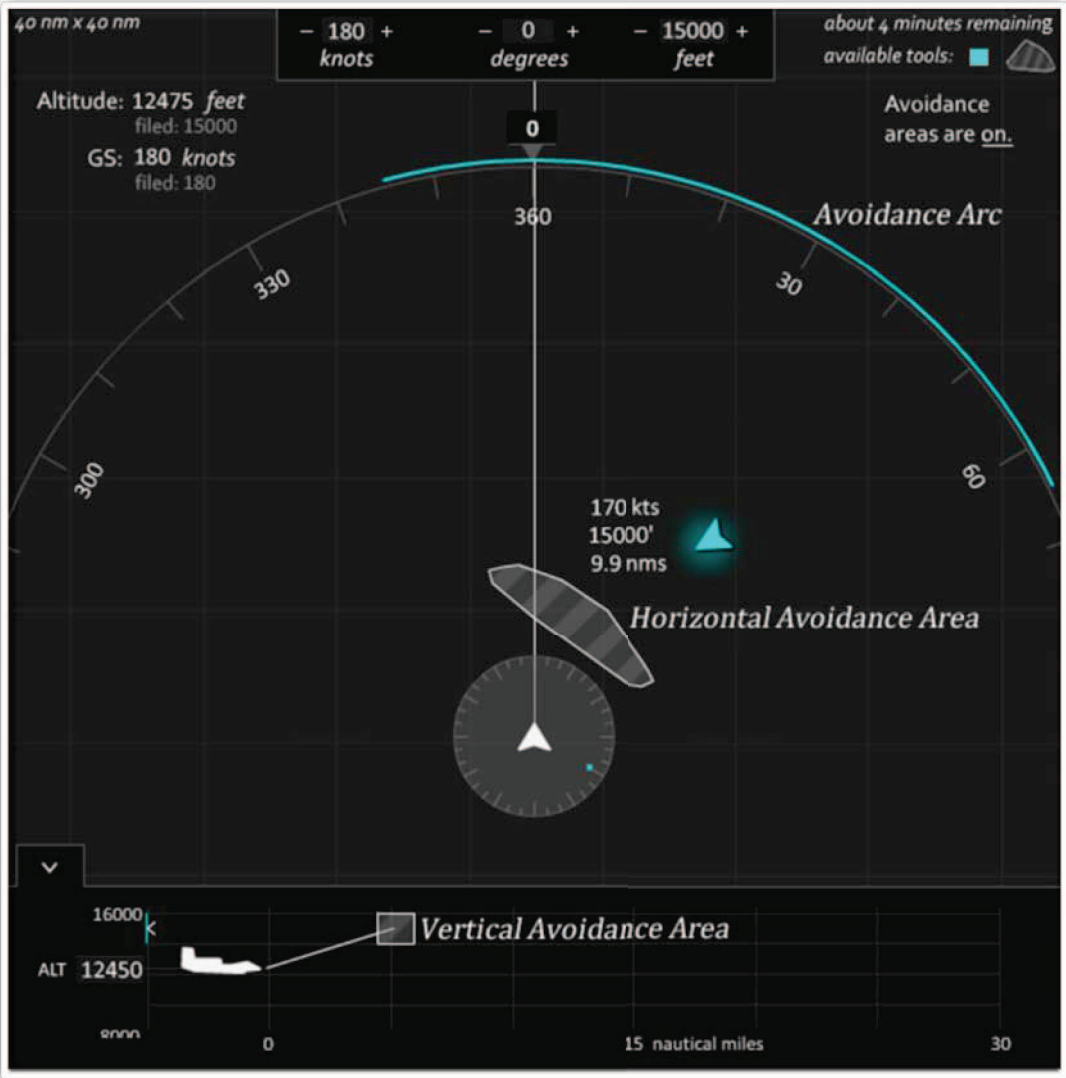
# Basic Interface



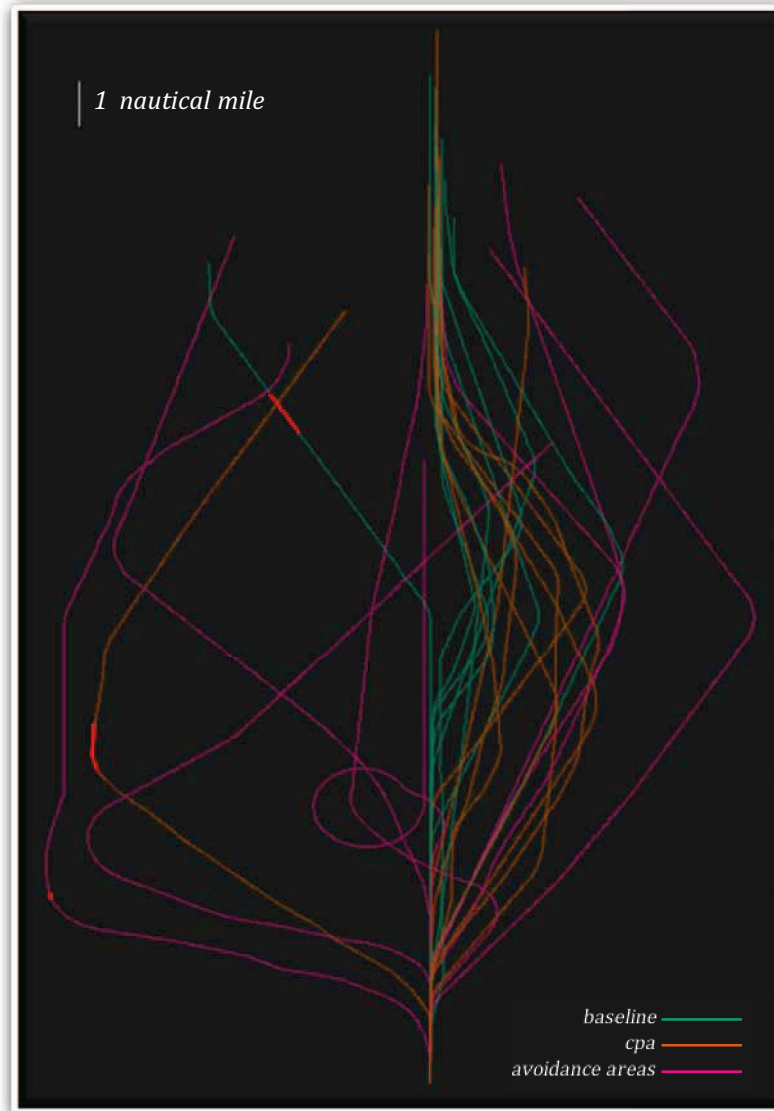
# CPA Interface



# Avoidance Areas Interface

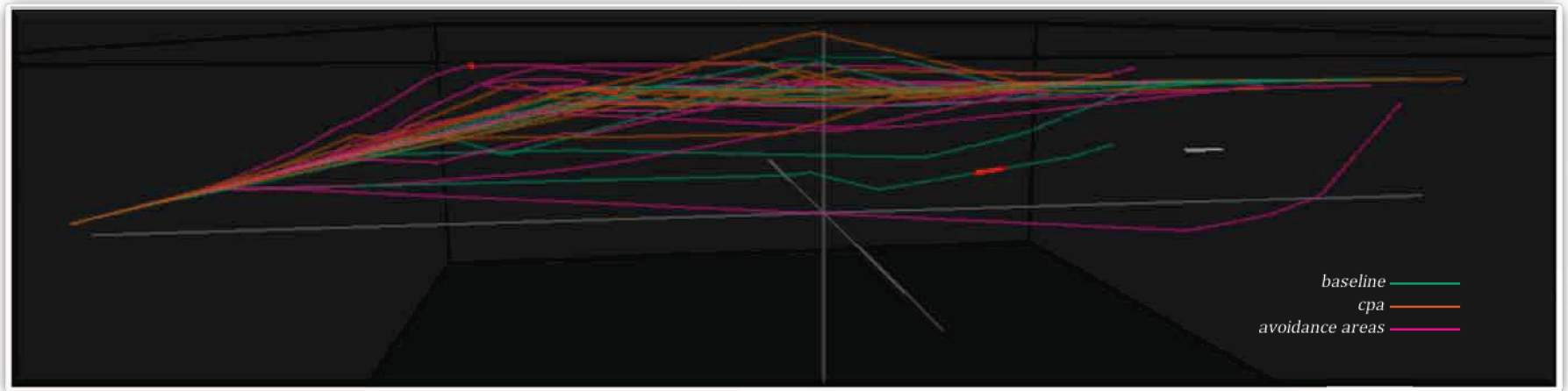


# Monitor Scenario: Horizontal Tracks





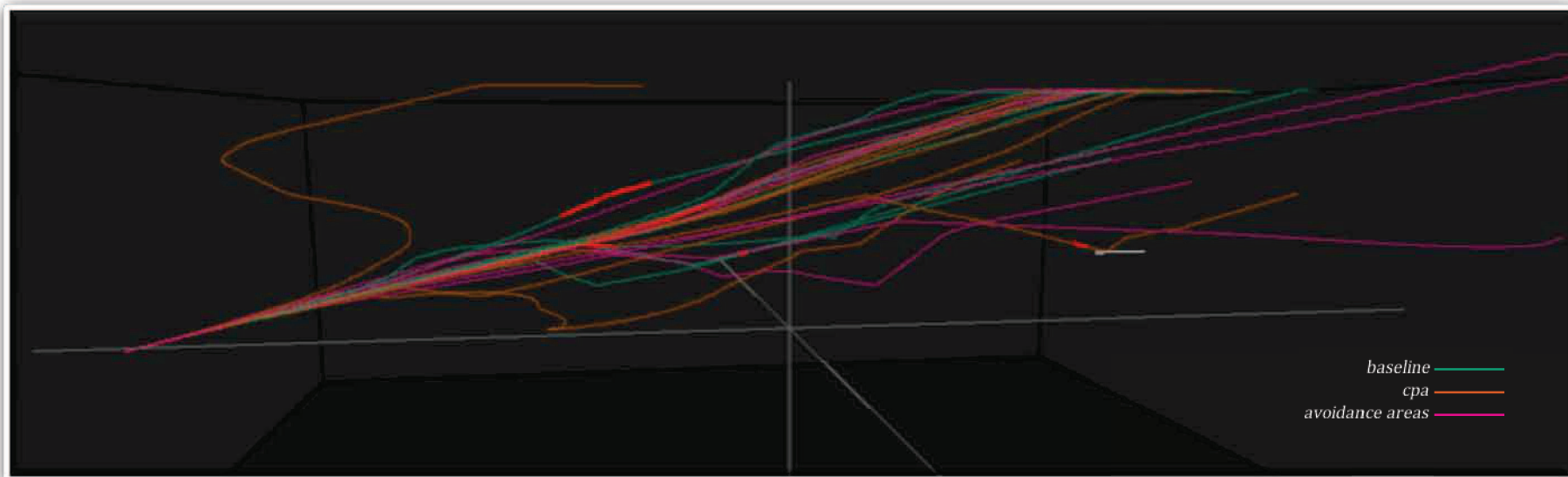
# Monitor Scenario: Vertical Tracks



# S-Turn: Horizontal Tracks



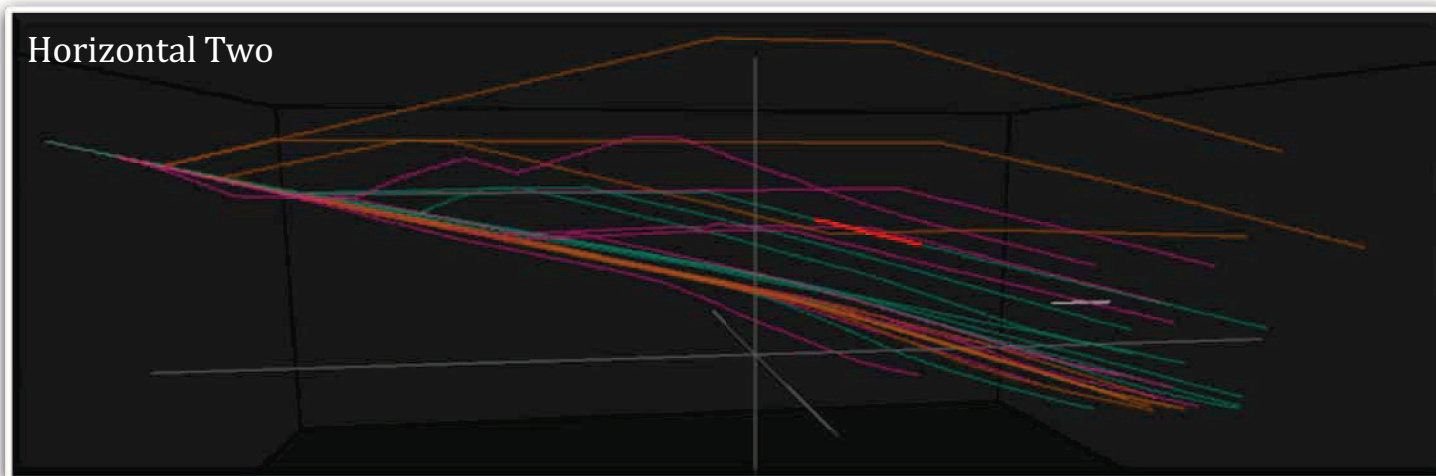
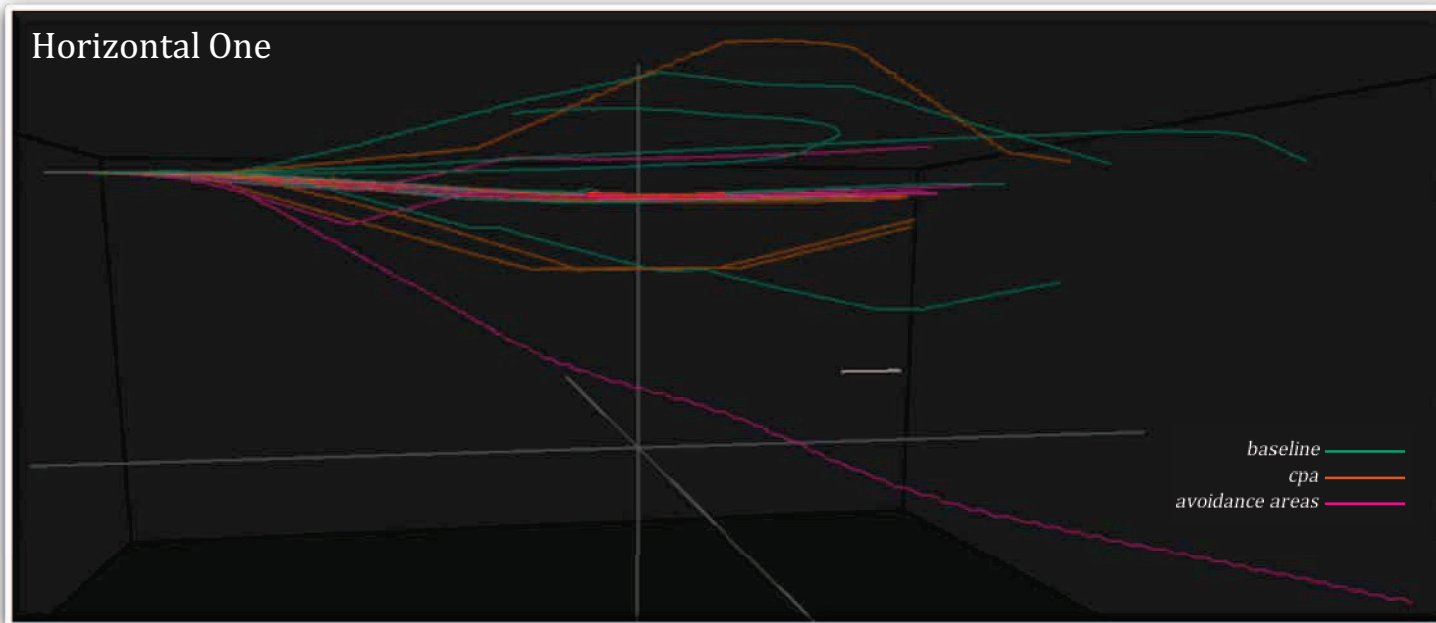
# S-Turn: Vertical Tracks



# Horizontal: Lateral Tracks



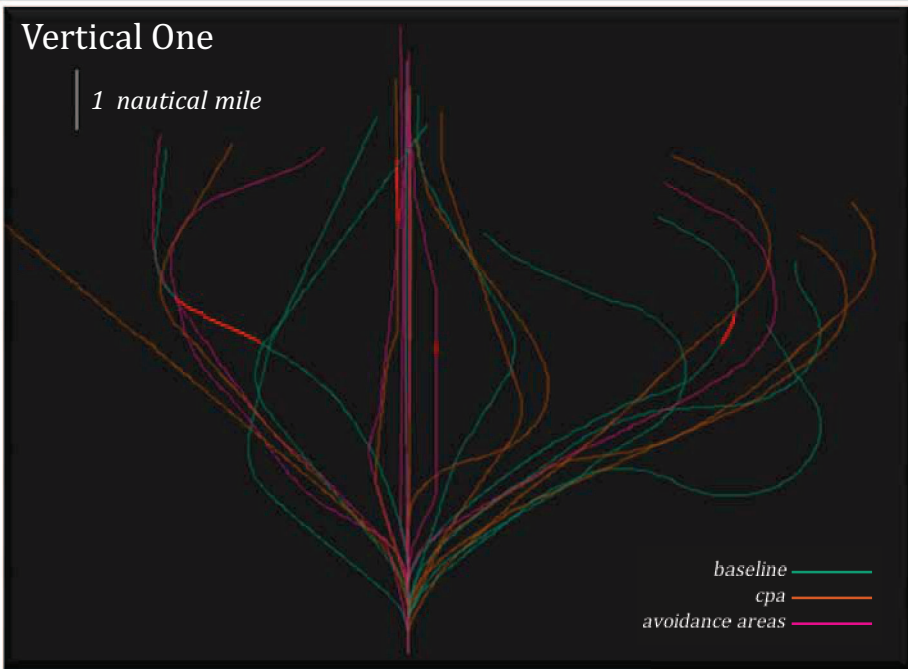
# Horizontal: Vertical Tracks



# Vertical: Lateral Tracks

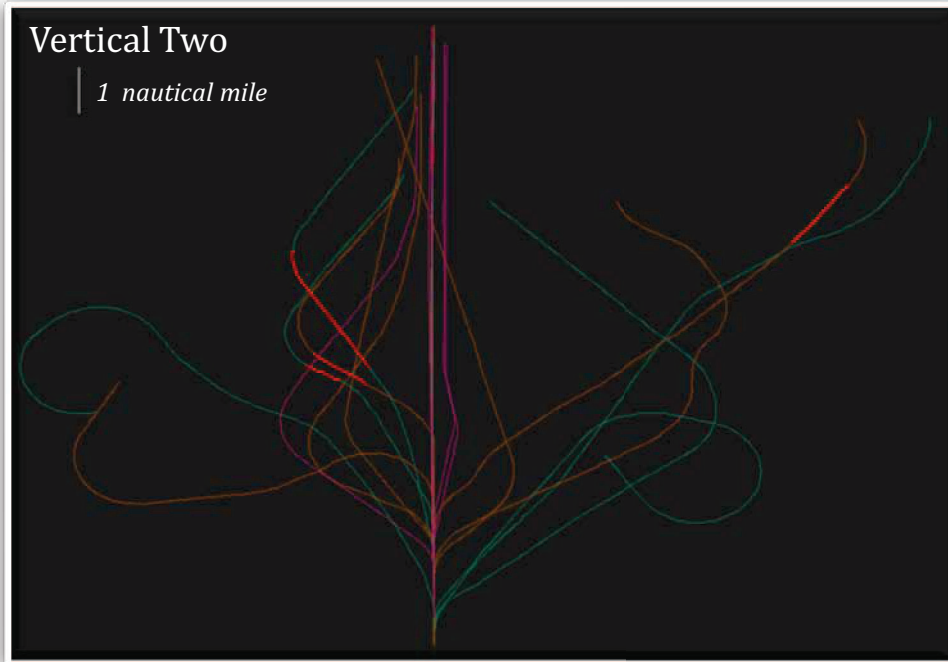
Vertical One

1 nautical mile



Vertical Two

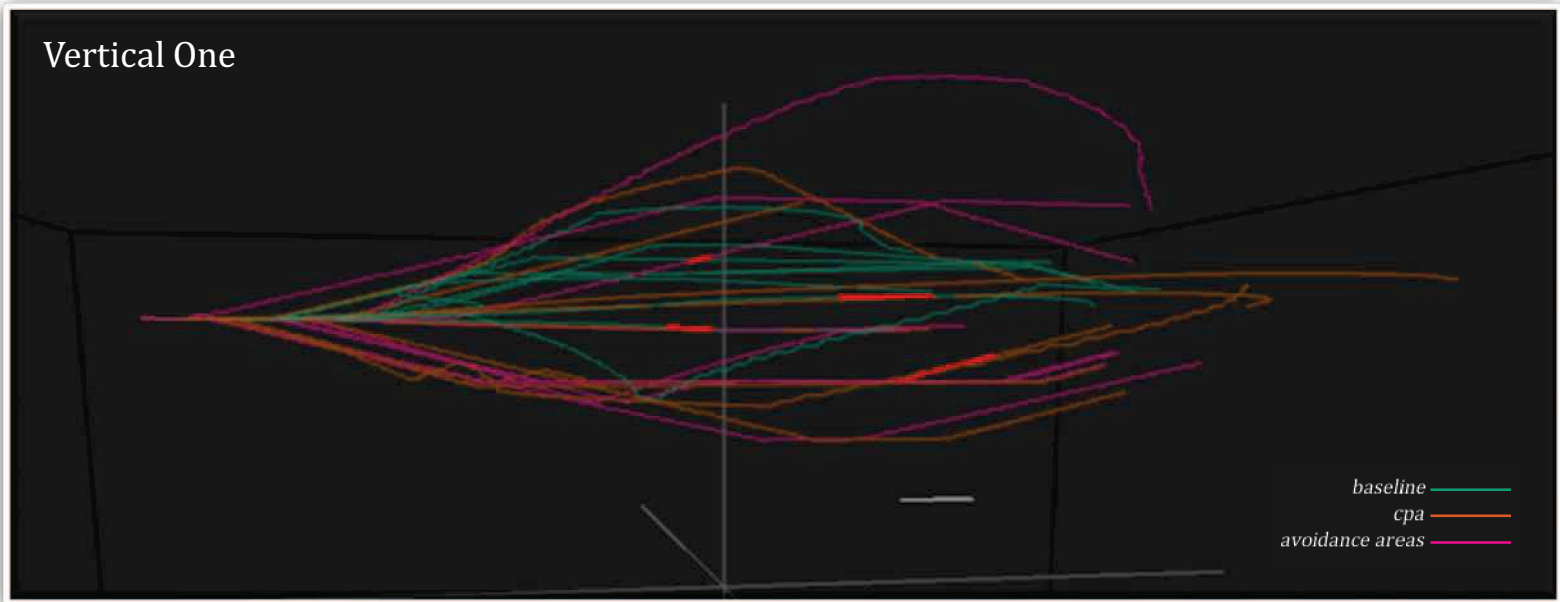
1 nautical mile



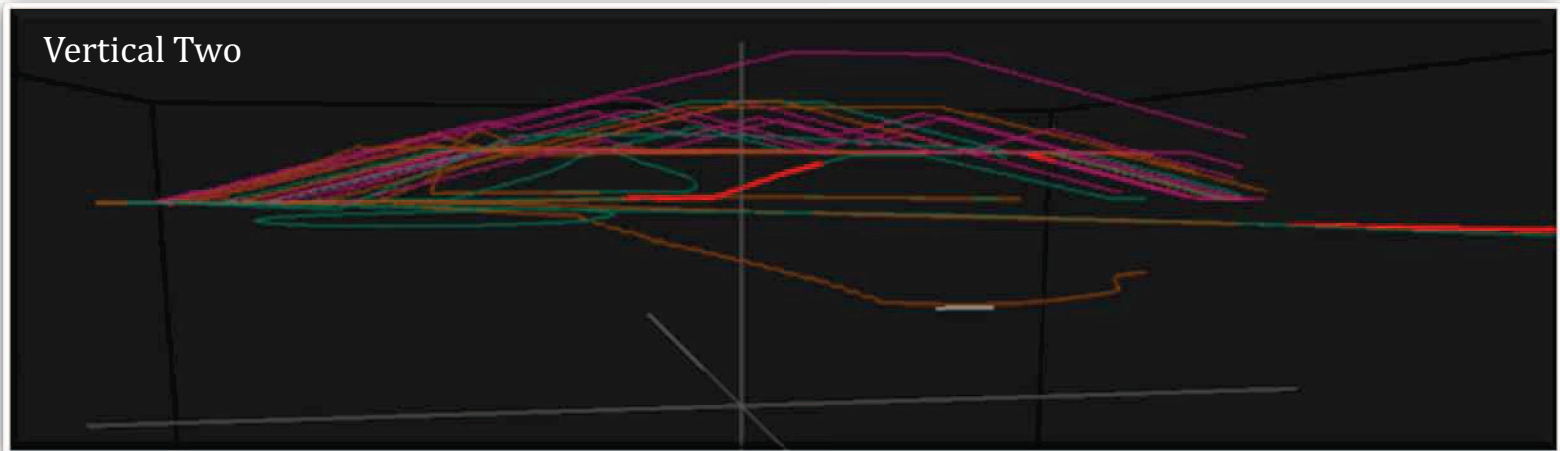


# Vertical: Vertical Tracks

Vertical One

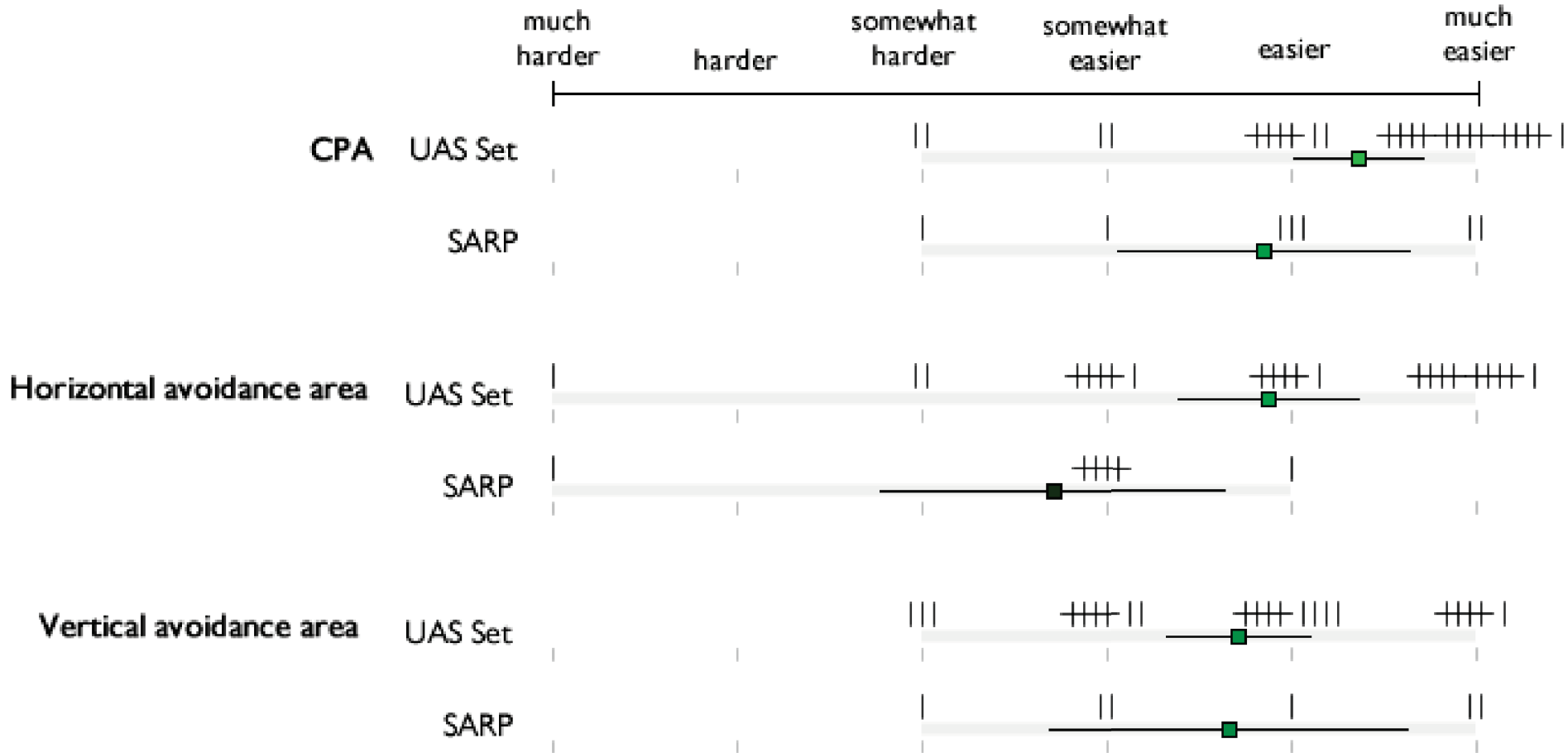


Vertical Two



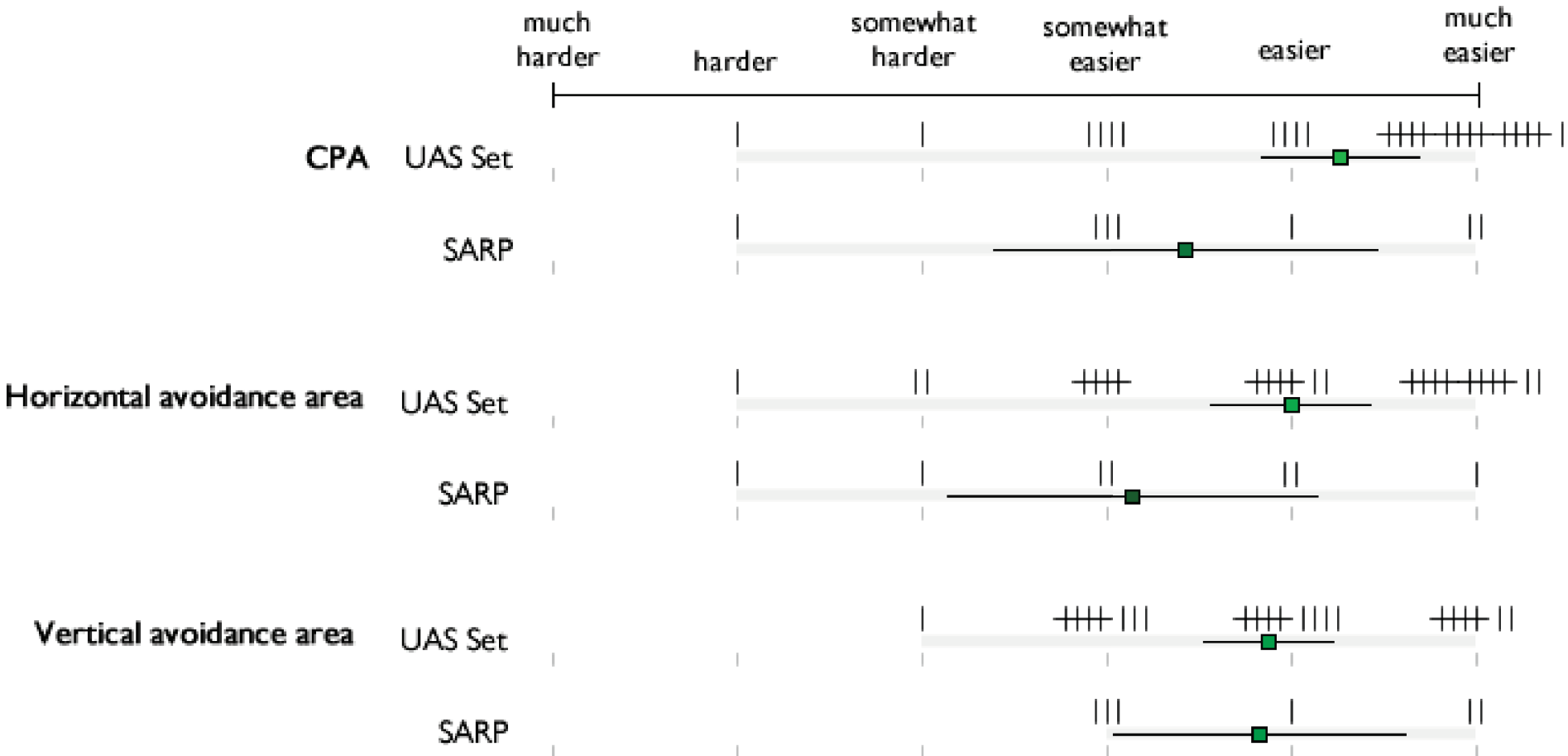
# Conflict: Identify

Over the course of the evaluation it was \_\_\_\_\_ to identify conflicts with the tool than without it.



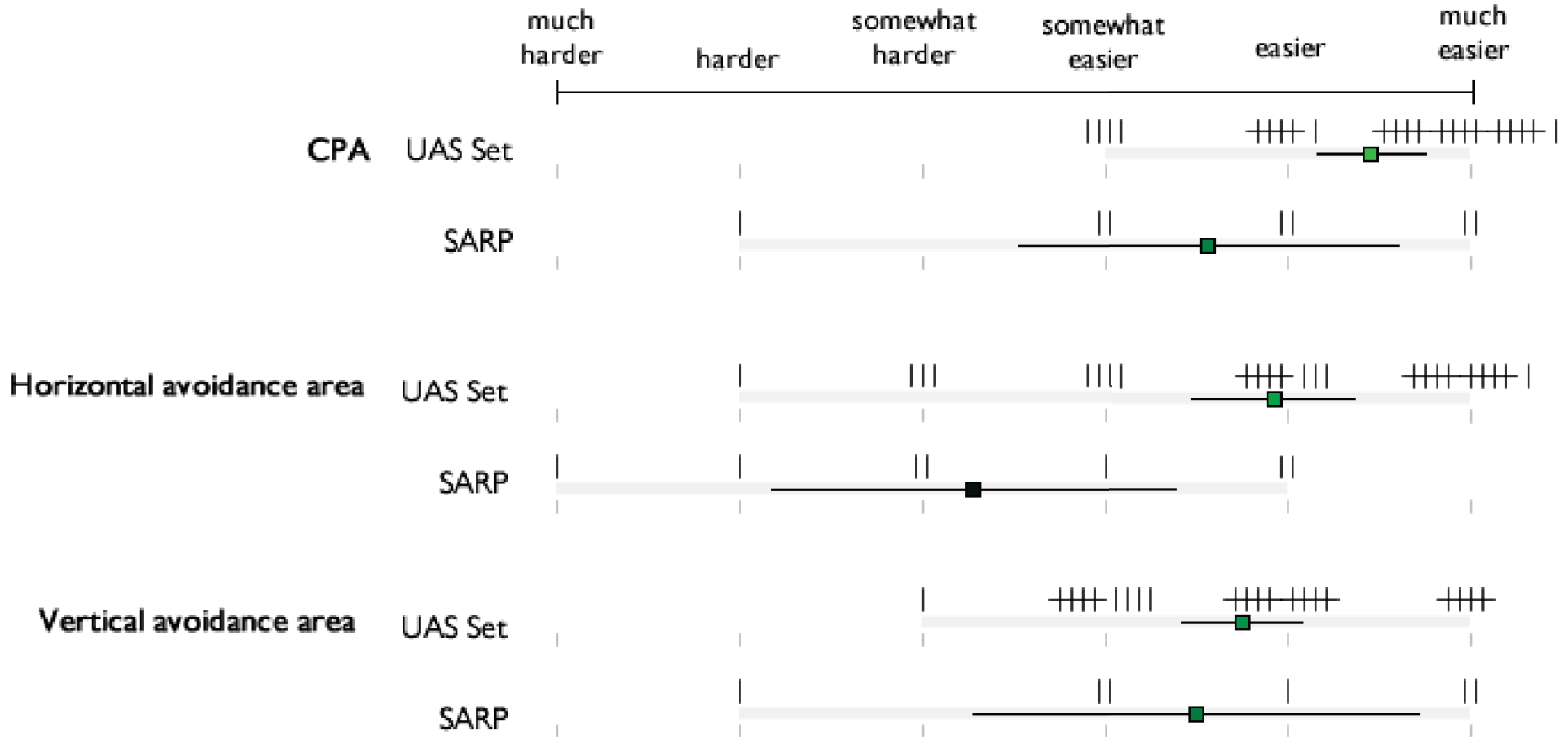
# Conflict: Determine Maneuver

Over the course of the evaluation it was \_\_\_\_\_ to determine avoidance maneuvers with the tool than without it



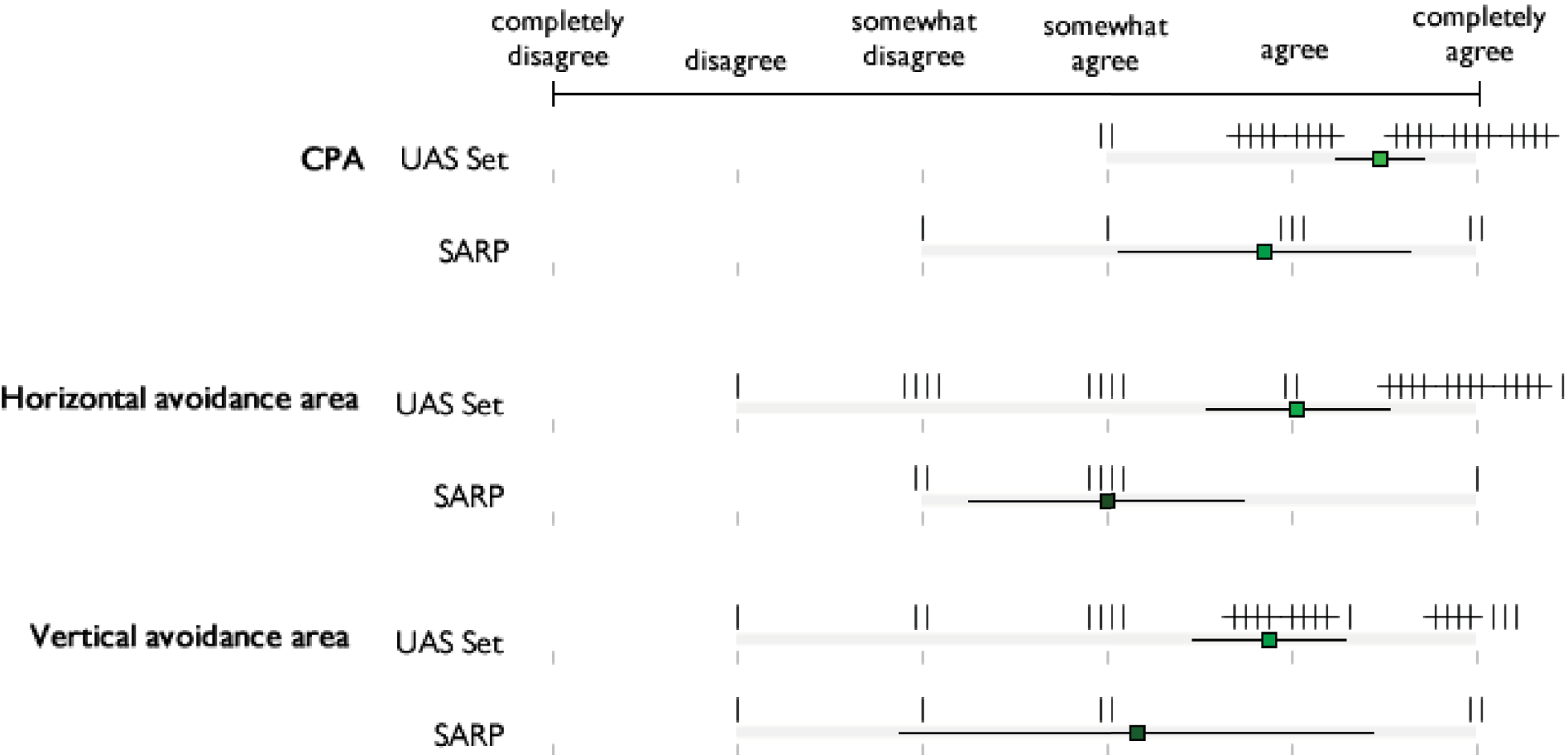
# Conflict: Monitor Maneuver

Over the course of the evaluation it was \_\_\_\_\_ to evaluate the progress of the avoidance maneuvers with the tool than without it.



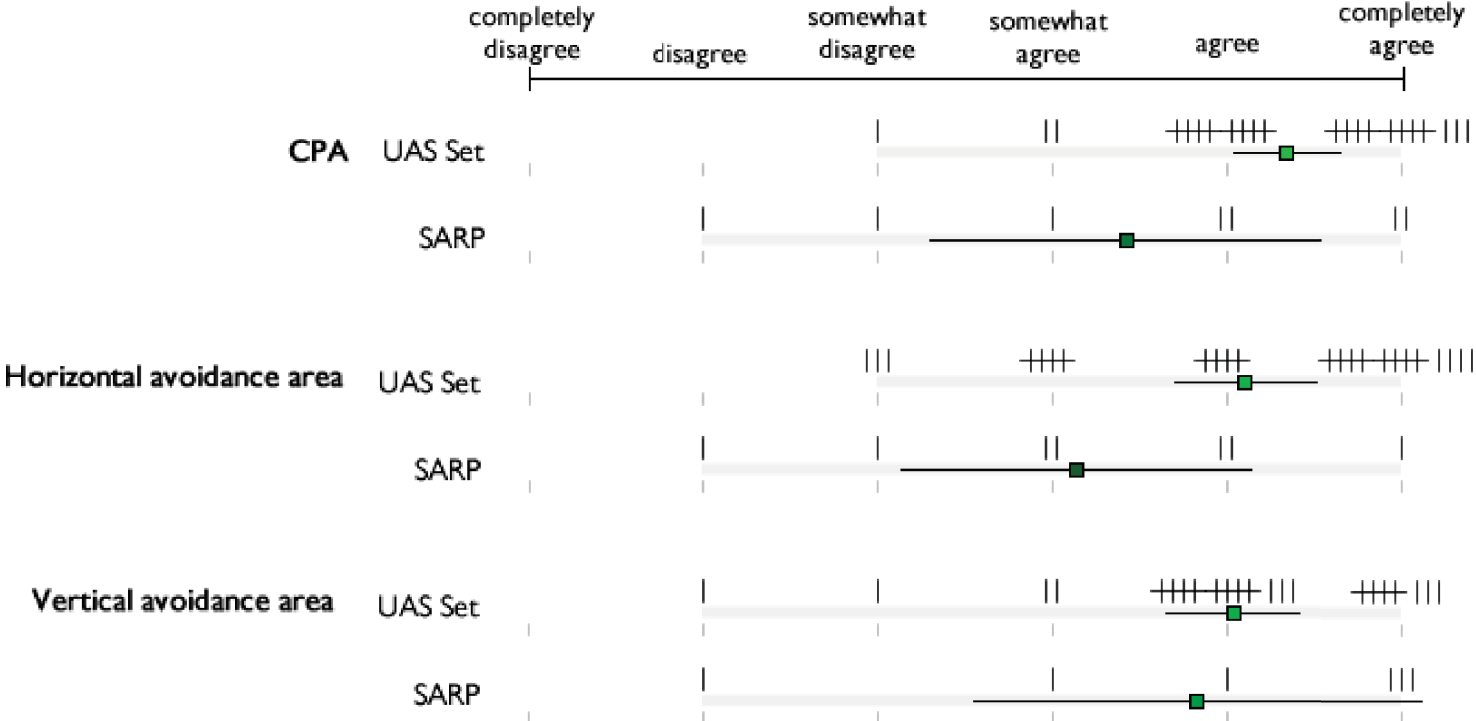
# Easy to Learn

The information provided by the tool was easy to learn



# Easy to Use

The information provided by the tool was easy to use





# Design Improvements

Is there anything that you would change on the display?

	UAS	
	Pilots	SARP
Yes	10	4
No	16	3

## Comments

“A suggested heading or altitude to avoid conflict would be great.”

“Time to intrusion”

“3-D display with God's eye (horizontal) display is the preferred method for understanding vertical-horizontal encounters. However, this has to be the best attempt at multi-encounter with PITL (pilot-in-the-loop) maneuvering to date in my 12+ years within the UAV/UAS business.”

“Possibly climb rate (vertical speed indication) for ownship. It was difficult to determine if and when to initiate a climb or descent without knowing how fast one was climbing or descending potentially including rate of decent of other aircraft”