National Aeronautics and Space Administration

NASA UAS Integration Into the NAS Project
Human Systems Integration

AUVSI

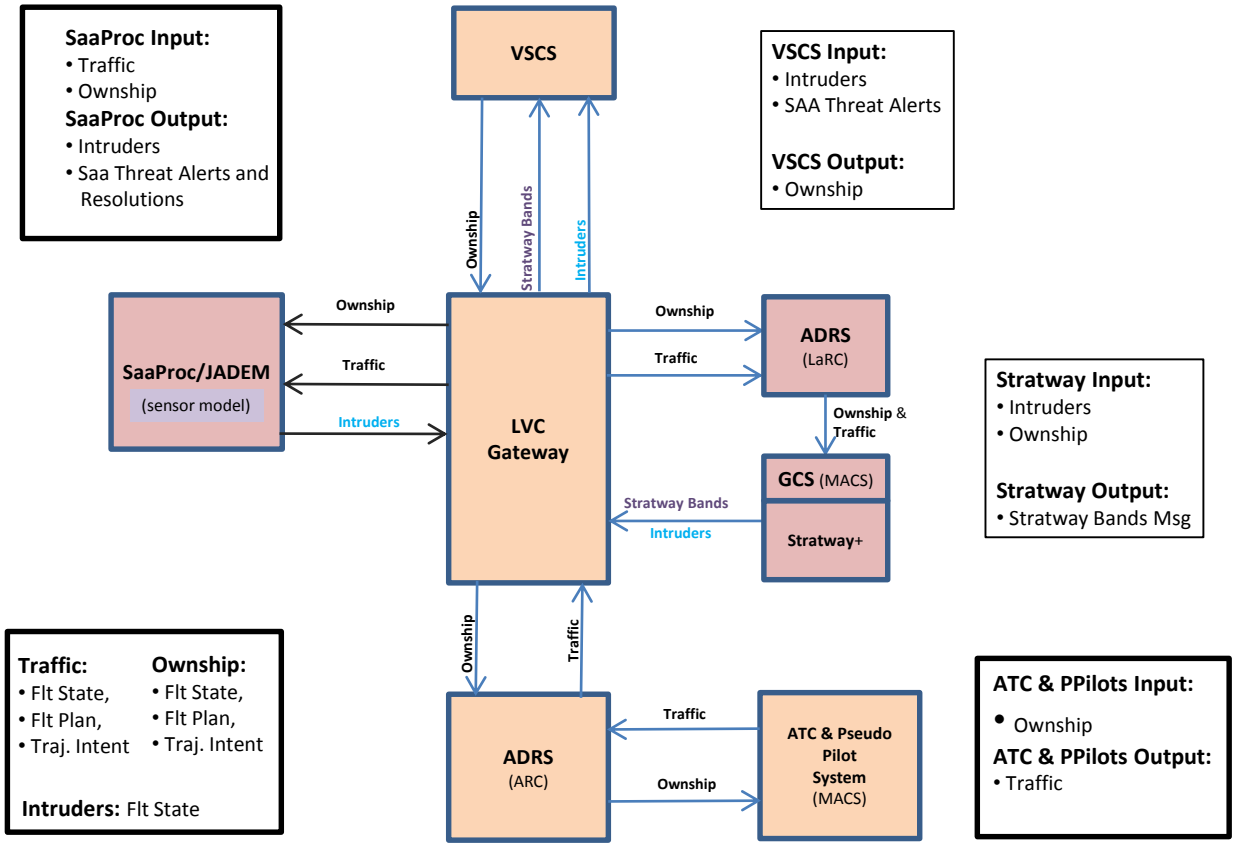
May 5, 2016

Jay Shively (Robert.J.Shively@NASA.GOV)
NASA Ames Research Center

Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

Simulation Environment: LVC Architecture



Project Background

- Approach: Conduct a series of iterative human in the loop experiments, in a representative simulation environment, with different display configurations to objectively measure pilot performance when maintaining well clear from scripted conflicts
  - Key metrics: pilot response time, losses of well clear, severity of losses of well clear
  - Three simulations have been conducted: PT4, iHITL, PT5
    - Displays are modified/improved/changed based on data/observations
    - Displays are carried through to new HITLs to create anchors or linkages to previous data for comparison
    - New displays are developed for test
    - Test/simulation environment/protocols also updated and improved between HITLs
  - Two "mini-HITLs" (i.e., engineering evaluations)
    - TCAS interoperability
    - Missing Information

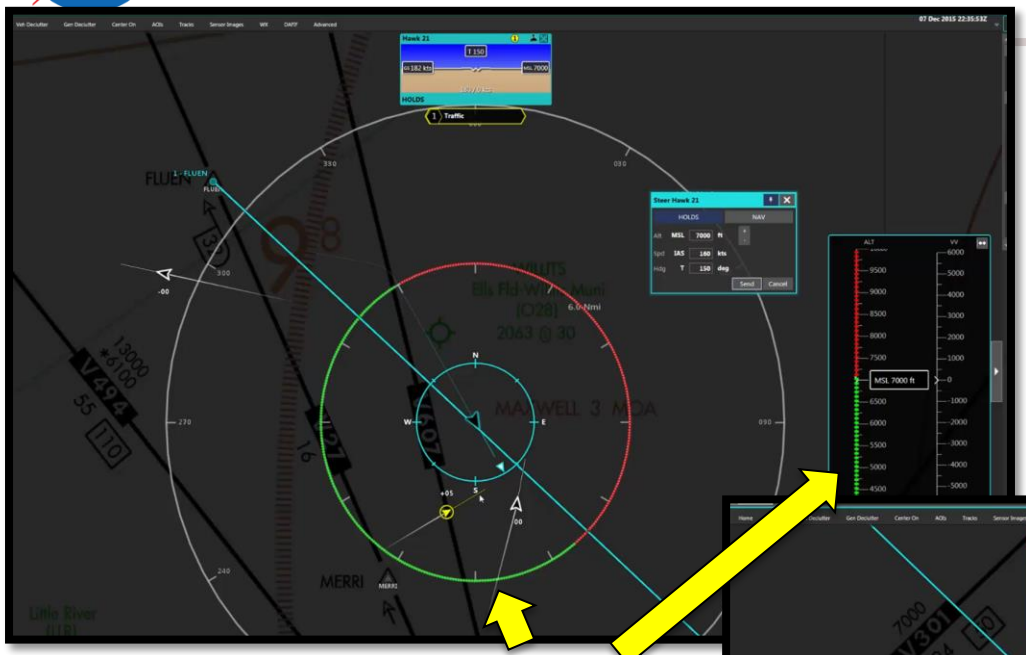
Project Background

- Display Types:
  - Informative: Provides essential information of a hazard that the remote pilot may use to develop and execute an avoidance maneuver. ***No maneuver guidance or decision aiding is provided to the pilot***.
  - Suggestive: ***Provides a range of potential resolution maneuvers to avoid a hazard with manual execution***. An algorithm provides the pilot with maneuver decision aiding regarding advantageous or disadvantageous maneuvers.
  - Directive: ***Provides specific recommended resolution guidance to avoid a hazard with manual or automated execution***. An algorithm provides the pilot with specific maneuver guidance on when and how to perform the maneuver.

Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

DAA Guidance Display



Green Bands

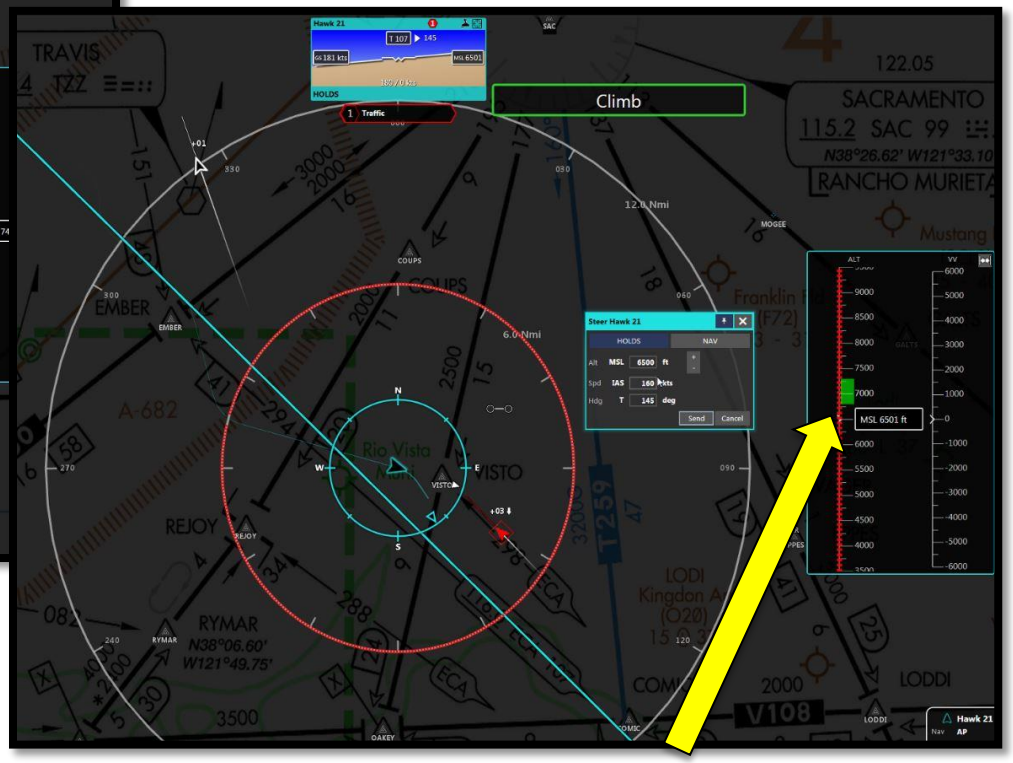
No Green Bands

Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

Loss of Well Clear Guidance

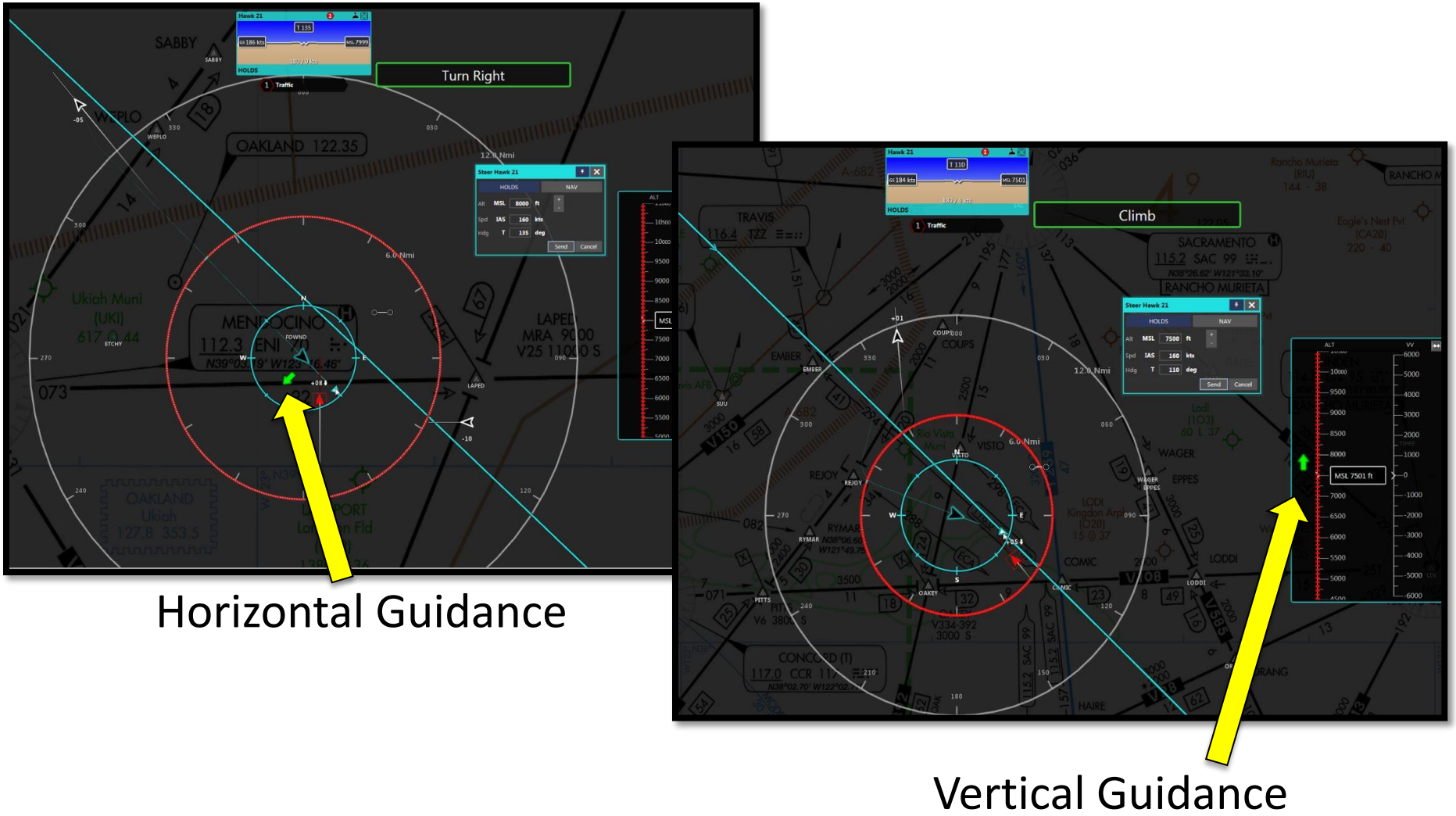
Horizontal Guidance



Vertical Guidance

Limited Suggestive

Loss of Well Clear: Directional



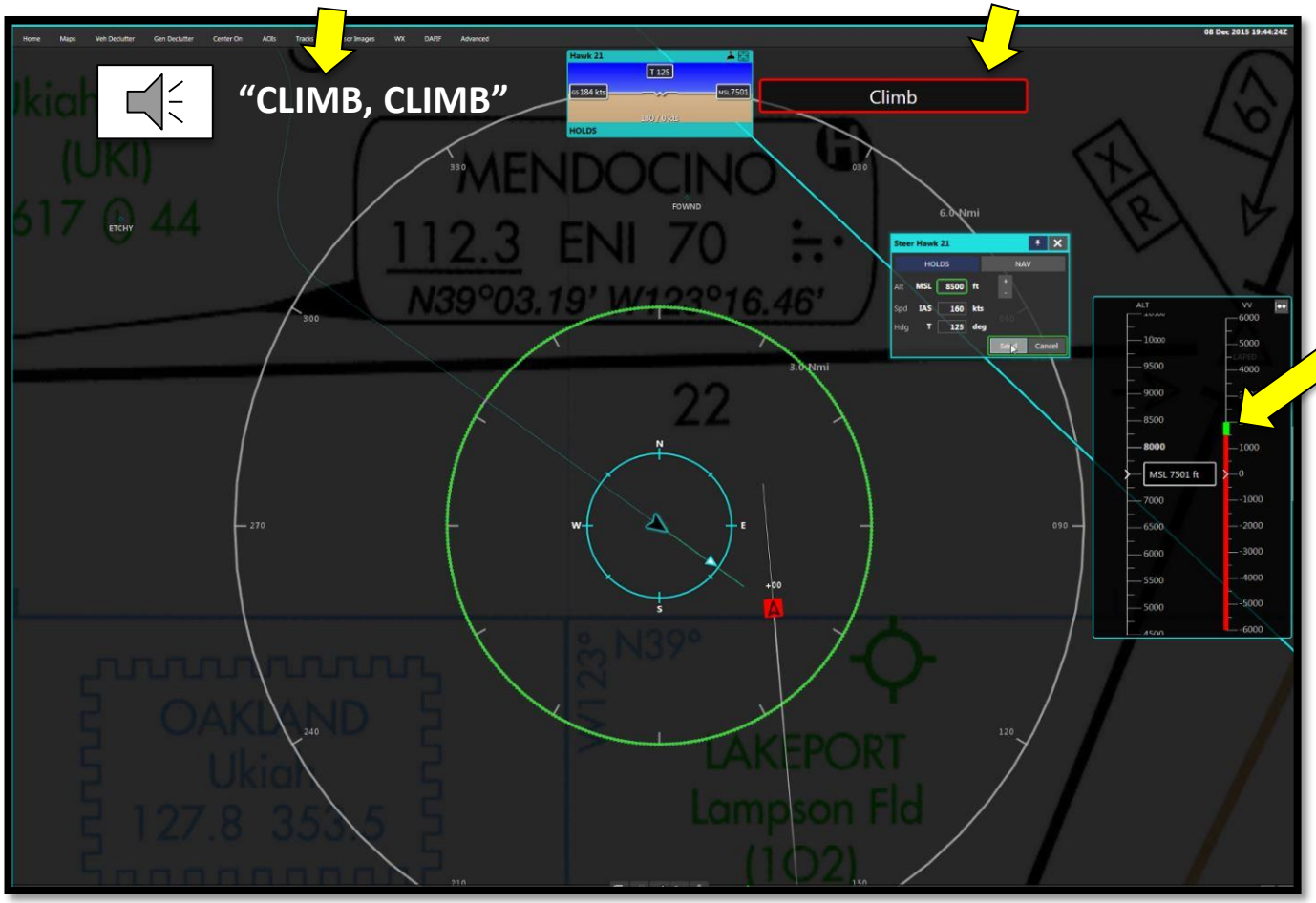
Directional

Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

Latest Display

- Auditory Alert
  - RA sense presented aurally (source: TCAS II v7.1)
- Text Based
  - RA sense shown in text box next to Baseball Card



- Vertical Rate Guidance
  - Presented within VVI
  - Green = desired vertical speed
  - Red = vertical speed to avoid

TCAS Interoperability

- A TCAS Interoperability Workshop was held to determine potential display/alerting/guidance issues that could be explored in a NASA “mini” HITL
  - Development of a DAA-TCAS Interoperability concept
  - Prioritized list of independent variables for experimental design
  - Set of use cases to stress TCAS Interoperability
- Main Issues for DAA-TCAS Interoperability
  - TCAS is not aware of all aircraft and so can give guidance that causes conflicts with non-cooperative aircraft
  - DAA system is aware of all aircraft and must conform to TCAS functioning
    - Key interoperability issues with DAA during “well clear recovery”
      - When a loss of well clear can no longer be avoided
    - Urgency of well clear penetration and need to interoperate with TCAS drives a **directive** or **limited suggestive** guidance solution

TCAS Interoperability

- DAA-TCAS Interoperability Concept:
  - Any target with an active corrective RA should be removed from all DAA guidance calculations
    - Horizontal DAA guidance will be shown for non-RA aircraft
    - All DAA vertical guidance should be *suppressed* during a corrective RA to prevent showing conflicting guidance to the pilot
  - During a preventive RA, TCAS guidance should be an input to the DAA vertical guidance so that it is consistent
  - Well clear recovery is limited to horizontal only for cooperative intruders
    - Prevents pilots from making maneuvers near the collision avoidance boundary which may degrade TCAS II performance
- Purpose of HITL:
  1. Examine performance difference for different methods of showing well clear recovery and DAA guidance
  2. Test overall suitability of interoperability concept

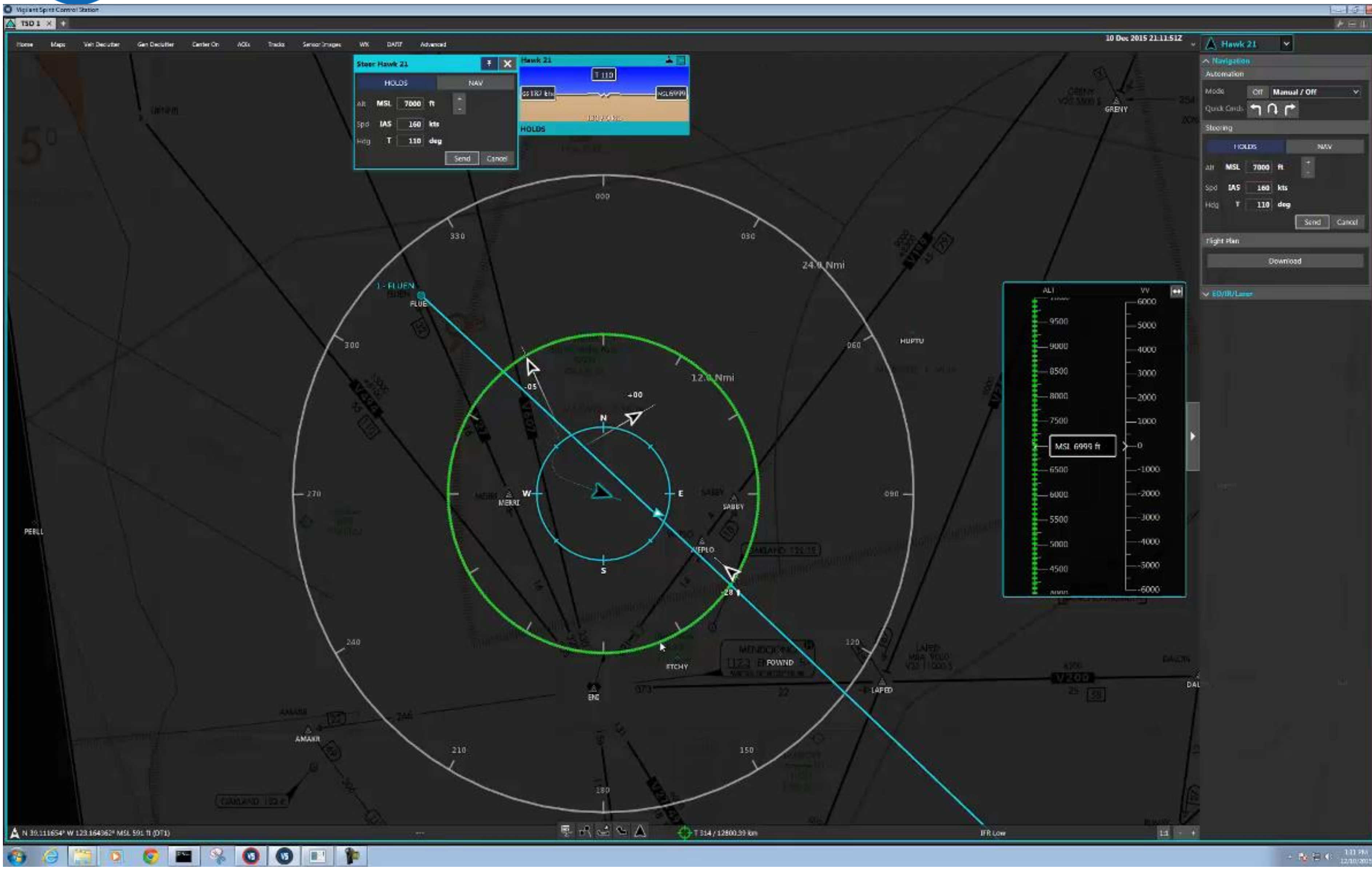
Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

DAA-TCAS Alerting Structure

Symbol	Name	Pilot Action	Buffered Well Clear Criteria	Alerting Time Threshold	Aural Alert Verbiage
	TCAS RA	• **Immediate action required** • Comply with RA sense and vertical rate • Notify ATC as soon as practicable after taking action	(Driven by TCAS-II)	x	"Climb/Descend"
	DAA Warning Alert	• ***Immediate action required*** • Notify ATC as soon as practicable after taking action	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	25 sec (TCPA approximate: 60 sec)	"Traffic, Maneuver Now"
	DAA Corrective Alert	• On current course, ***corrective action required*** • Coordinate with ATC to determine an appropriate maneuver	DMOD = 0.75 nmi HMD = 0.75 nmi ZTHR = 450 ft modTau = 35 sec	55 sec (TCPA approximate: 90 sec)	"Traffic, Avoid"
	DAA Preventive Alert	• On current course, corrective action ***should not be required*** • Monitor for intruder course changes • Talk with ATC if desired	DMOD = 1.0 nmi HMD = 1.0 nmi ZTHR = 700 ft modTau = 35 sec	55 sec (TCPA approximate: 90 sec)	"Traffic, Monitor"
	Remaining Traffic	• No action expected	Within surveillance field of regard	X	N/A

Video Demo

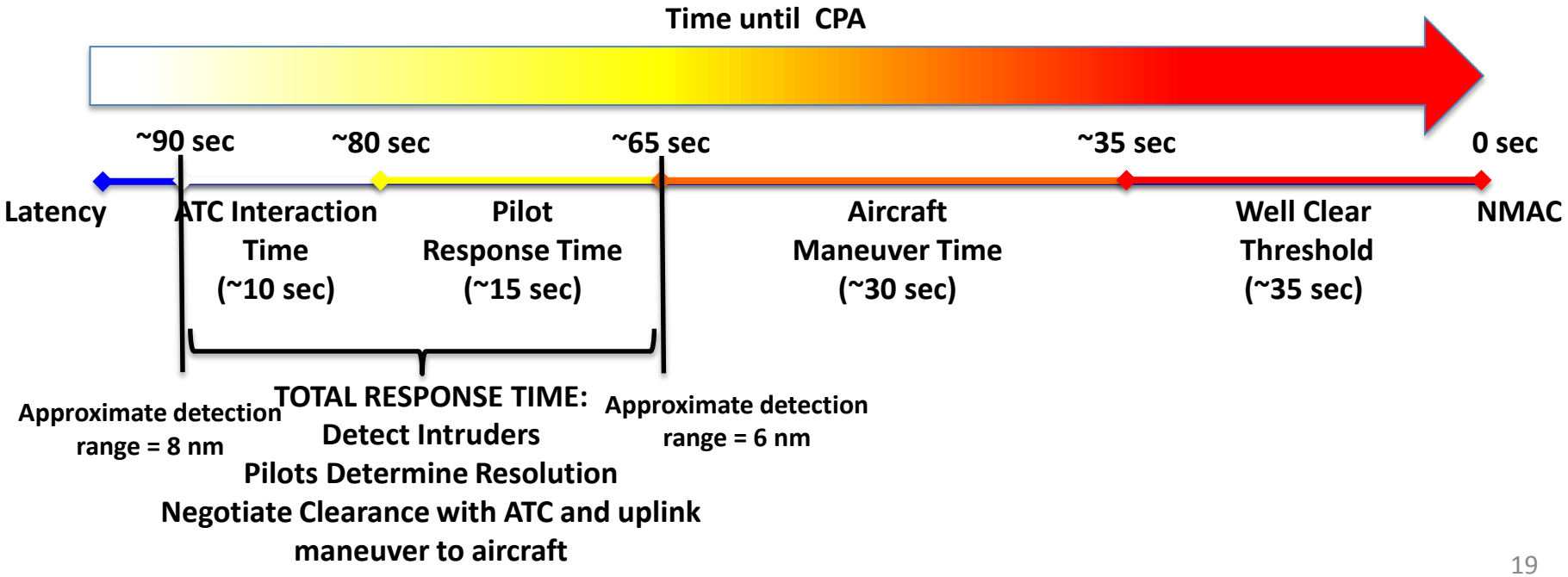


Vigilant Spirit Control Station
TSD 1
Home
Maps
Veh Declutter
Gen Declutter
Center On
AOIs
Tracks
Sensor Images
WX
DART
Advanced
10 Dec 2015 21:11:51Z
Hawk 21
Steer Hawk 21
HOLDS
NAV
Alt MSL 7000 ft
Spd IAS 160 kts
Hdg T 110 deg
Send
Cancel
Navigation
Automation
Mode
Manual / Off
Quick Cmds
Steering
Flight Plan
Download
EO/IR/Laser
ALT
VV
MSL 6999 ft
24.0 Nmi
12.0 Nmi
IFR Low

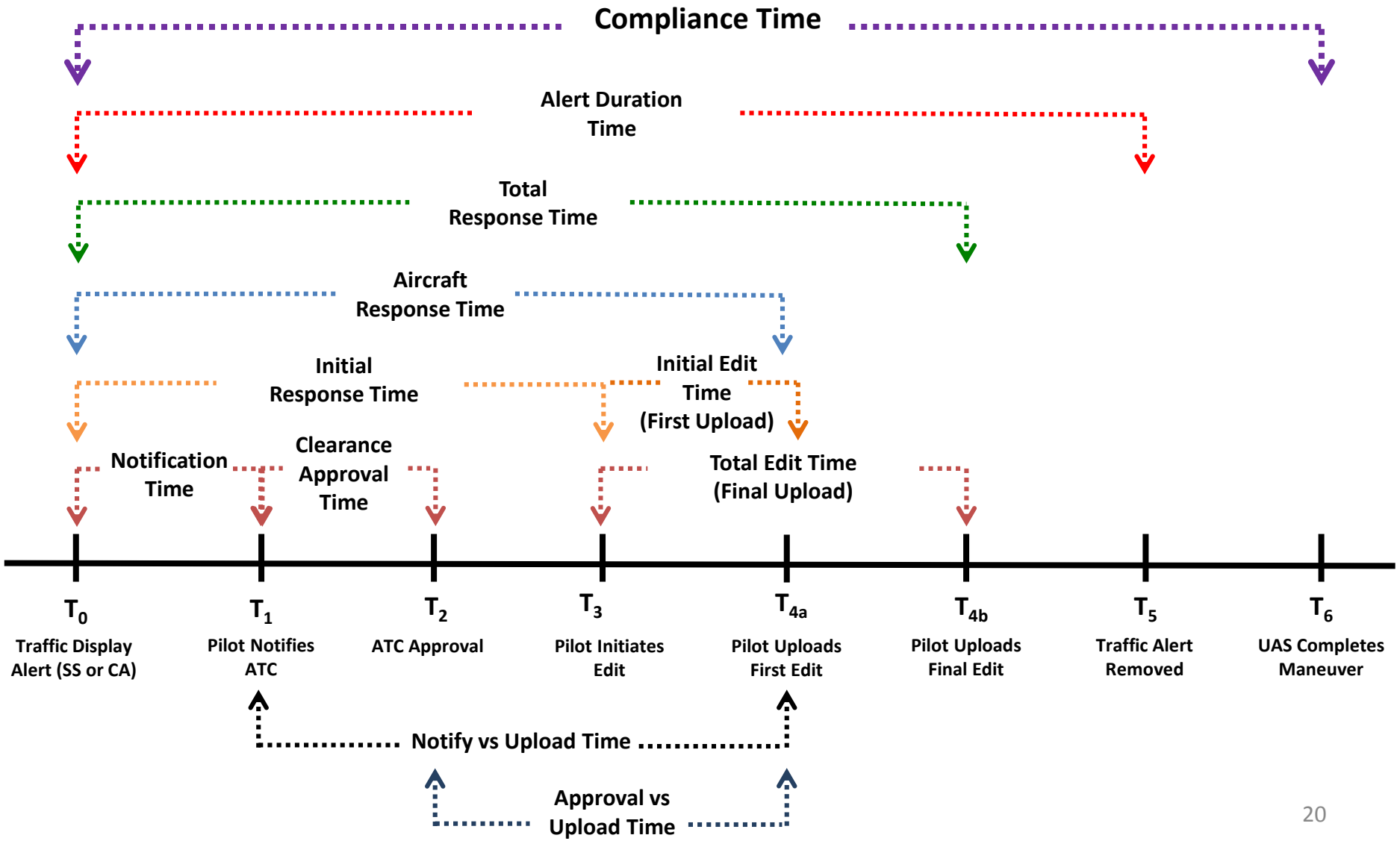
Summary of Contributions

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

Self-Separation Timeline



Pilot-DAA Timeline



Summary

- Suggestive Displays
  - Guidance Bands
- Integrated or stand alone*
- Alerting Logic
- Minimum Information tags
- TCAS/DAA interop logic
- Well Clear Recovery logic/display
- Pilot response timeline
  - Derived RADAR Requirements

RTCA SC 228

- Phase 1 MOPS – Final Aug 2016
  - Alerting
  - Guidance
  - Displays

Next Steps

- Support SC 228 Phase 2 MOPS
  - Terminal Areas
  - ACAS-Xu
  - Alternative Sensors
  - GBSAA
  - Mid-size A/C
- Support ICAO – RPAS - Human In The System (HITS) working group
- “Common” GCS
- GCS Guidelines

Questions?