

National Aeronautics and Space Administration



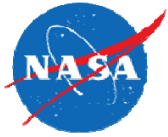
MACS Enhancements for UAS Integration HITL Experiments

Separation Assurance/Sense and Avoid Interoperability Subproject

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SGT Inc.
NASA Langley Research Center

NASA UAS Integration in the NAS
Annual Meeting
July 31-August 1, 2012
Mountain View, CA

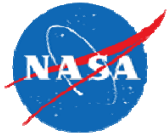




Presentation Outline



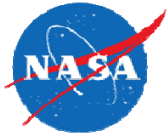
- Overview of MACS and UAS Integration HITL Experiments
- Surveillance support (ADS-B, ADS-R, TIS-B)
- UAS Ground Control Station (GCS)
- Vehicle/GCS communication links
- Vehicle operational limitations configurability



Basic MACS Capabilities



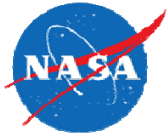
- Aircraft flight simulation
 - Simple equations of motion – point mass or 4DoF
 - Single or multi-aircraft pilot interfaces
- ATC controller displays
 - DSR
 - STARS
 - Etc.
- UAS simulation (new)
 - GCS
 - UAS appropriate vehicle simulation



Preliminary Requirements for Controller-in-the-loop Experiment Design



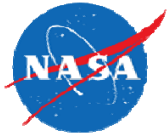
- ATC Controller experiment subject(s)
- Federate UAS GCS pilot(s)
- Federate conventional aircraft pilot(s)
- Likely scenarios (definition in progress)
 - Various conflict geometries
 - En route and terminal airspace
 - Mixed avionics equipage capabilities.



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ADS-B: Automatic Dependent Surveillance – Broadcast Services



- ADS-B provides air-to-air and air-to-ground surveillance
- ADS-B implemented using either 1090 ES (ModeS) or UAT communication link

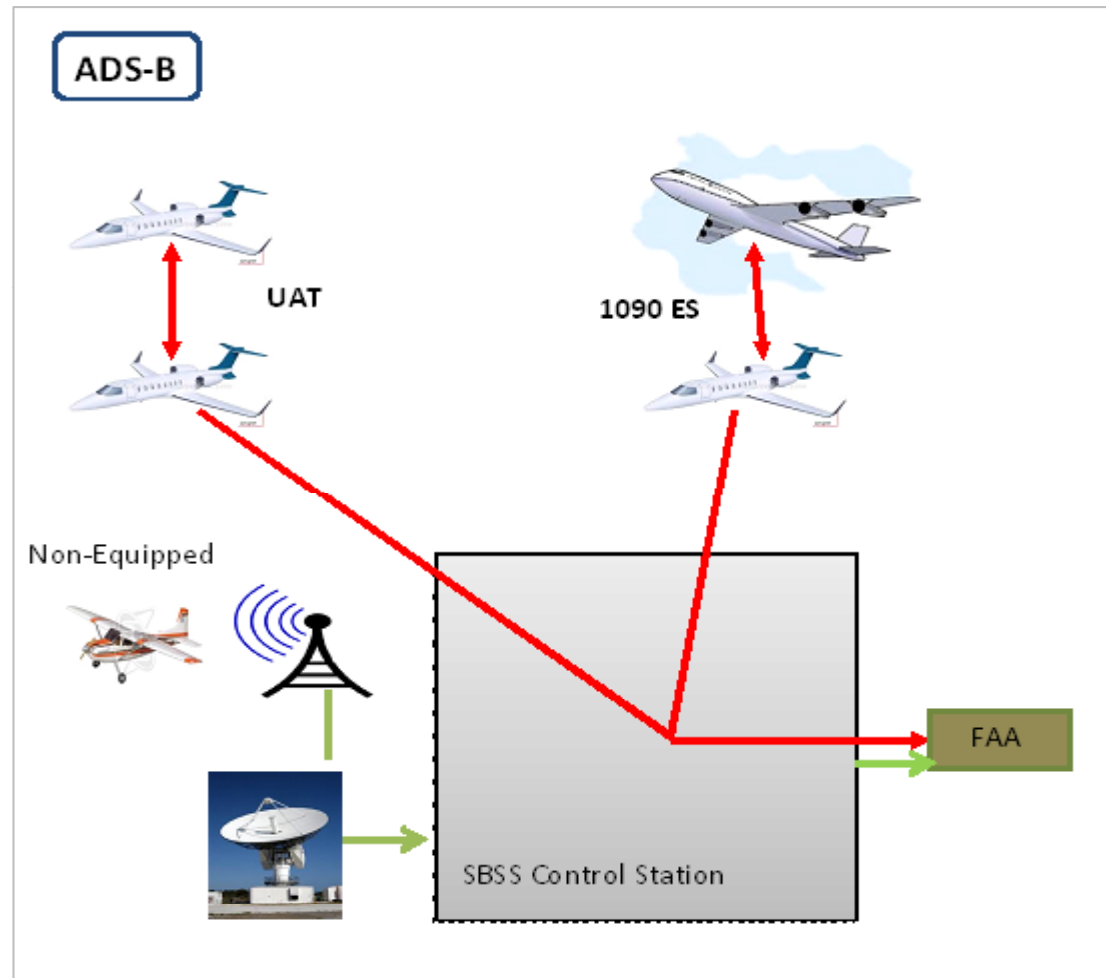
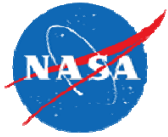


Figure 2: Surveillance of ADS-B equipped aircraft*

*Based on the U.S. Department of Transportation FAA Surveillance Broadcast Services Program, SBS Air Interface Document V 0.90, Figure 1-2



ADS-R: Automatic Dependent Surveillance – Rebroadcast



- ADS-R is the bridge between the 1090 ES and UAT links provided by the control stations infrastructure
- ADS-R rebroadcasts the surveillance data received in one link onto the other link

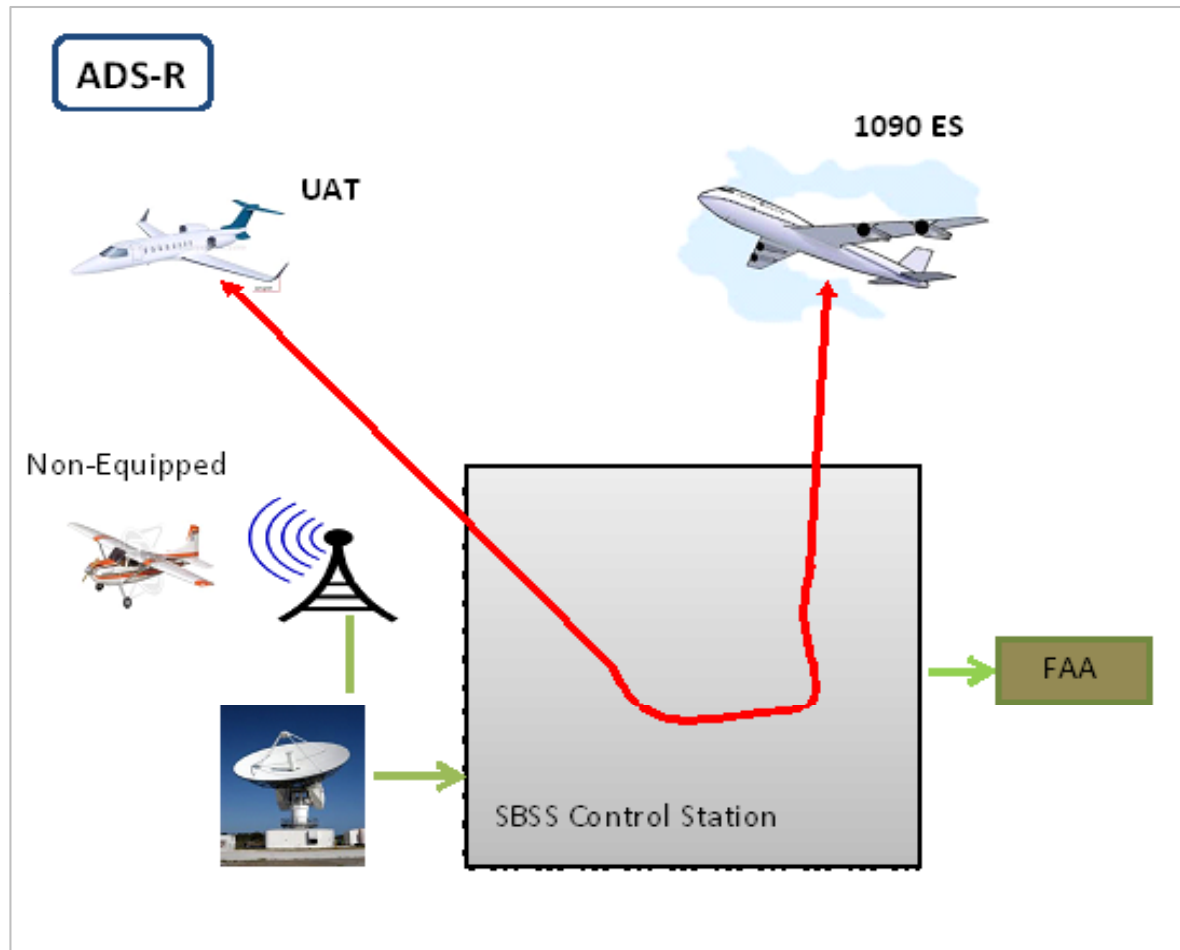
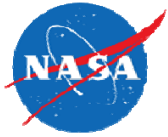


Figure 3: Surveillance of ADS-B equipped aircraft in non-comparable links - Cross linking of ADS-B data*

* Based on the U.S. Department of Transportation FAA Surveillance Broadcast Services Program, SBS Air Interface Document V 0.90 , Figure 1-3



TIS-B Traffic Information Services – Broadcast



TIS-B Service provides ADS-B equipped aircraft with surveillance information for aircraft that are not ADS-B equipped within a limited volume; non-ADS-B surveillance systems include radar sources, ASDE-X and multi-lateration systems

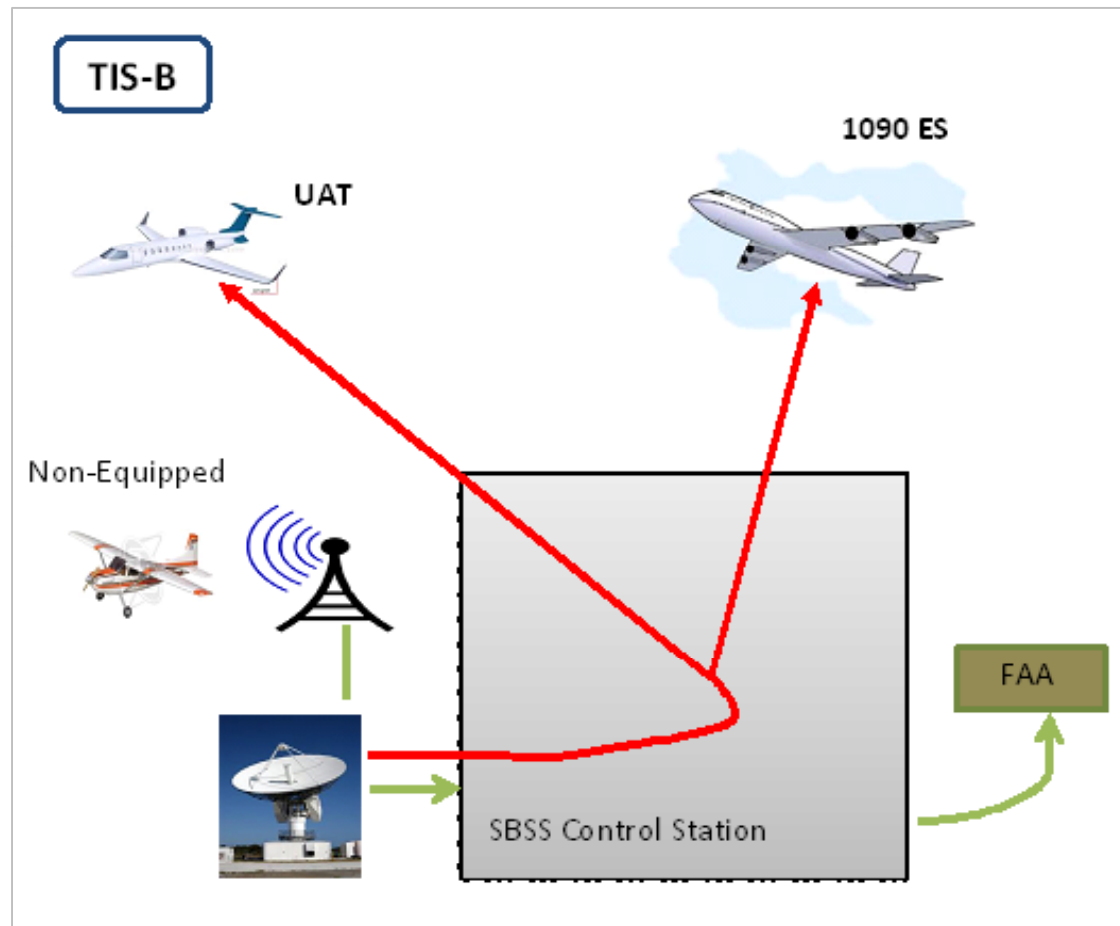
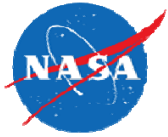


Figure 4: Uplink of Surveillance Data of non-ADS-B equipped aircraft using the TIS-B link*

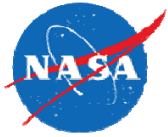
* Based on the U.S. Department of Transportation FAA Surveillance Broadcast Services Program, SBS Air Interface Document V 0.90 , Figure 1-4



MACS Airborne Surveillance Implementation



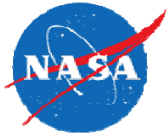
- Components of the surveillance implementation in MACS
 - Vehicles
 - Ground Station
 - Aircraft Traffic List (maintained by vehicles)
 - Reception Model



Implementation of Surveillance Messages in MACS Vehicle



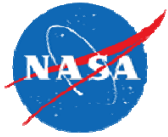
- In MACS, Airborne Surveillance Services to ADS-B equipped aircraft, including UAS vehicles, are being addressed
- MACS models the following: ADS-B, ADS-R, TIS-B services in
 - UAT
 - ModeS (1090 ES) modes
- MACS is able to communicate with the Airspace and Traffic Operations Simulation (ATOS) system and other MACS instances, and within it's own instance using ADS-B, ADS-R, and TIS-B airborne surveillance using both UAT and 1090 ES communication links
- MACS models ADS-B Ground Stations provide ADS-R and TIS-B services
- MACS ADS-B/ADS-R and TIS-B messages route through the Aeronautical Data Link Radar Simulator (ADRS)
- MACS ADS-B/ADS-R and TIS-B support remain integrated with ATOS
- Vehicles surveillance equipage and delay are configurable
- Each ADS-B IN equipped vehicle includes configurable surveillance message reception modeling



Implementation of Surveillance Messages in MACS ADS-B Ground Station



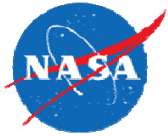
- MACS is capable of modeling multiple ADS-B Ground Stations
- Each ADS-B Ground Station is capable of selectively relaying (ADS-R) the following ADS-B messages:
 - 1090 ES: AirbornePosition, IdentificationAndCategory, AirborneVelocityGrndRef, AirborneVelocityAirRef, AircraftStatusType1 (Emerg/Prior & Mode A), TargetStateAndStatus, OperationalStatusAir, GenericTrajectoryChange, GenericTraconMessage
Excludes: OperationalStatusSurface, SurfacePosition, AircraftStatusType2 (TCAS RA), CoarsePosition.
 - UAT: Type0 (SV), Type1 (SV, MS, Aux SV), Type3 (SV, MS, TS), GenericTrajectoryChange, GenericTraconMessage
- For ground surveilled targets for which no ADS-B has been received by the ADS-B Ground Station, the following TIS-B messages are selectively generated:
 - 1090 ES: (Fine)AirbornePosition, IdentificationAndCategory, AirborneVelocityGrndRef, AirborneVelocityAirRef. Excludes: (Fine)SurfacePosition
 - UAT: Type1 (SV, MS, Aux SV), Type3 (SV, MS, TS)
- Message selectivity is based on a configurable service volume and proximity of the target to an ADS-B IN equipped vehicle on the given link (UAT/1090 ES)
- Each ADS-B Ground Station includes configurable ADS-B reception modeling



ADS-B/ADS-R/TIS-B Reception Model



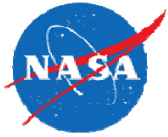
- Reception model used to simulate surveillance limitations
- Three levels of fidelity supported
 - Perfect model
 - All transmissions in band (ModeS or UAT) are received
 - Simple range-limit
 - All transmissions in band within range are received
 - Stochastic physics-based
 - Reception probability based on signal strength, sensitivity, interference (FRUIT)



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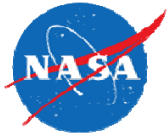
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- Vehicle/GCS communication links
- Vehicle operational limitations configurability



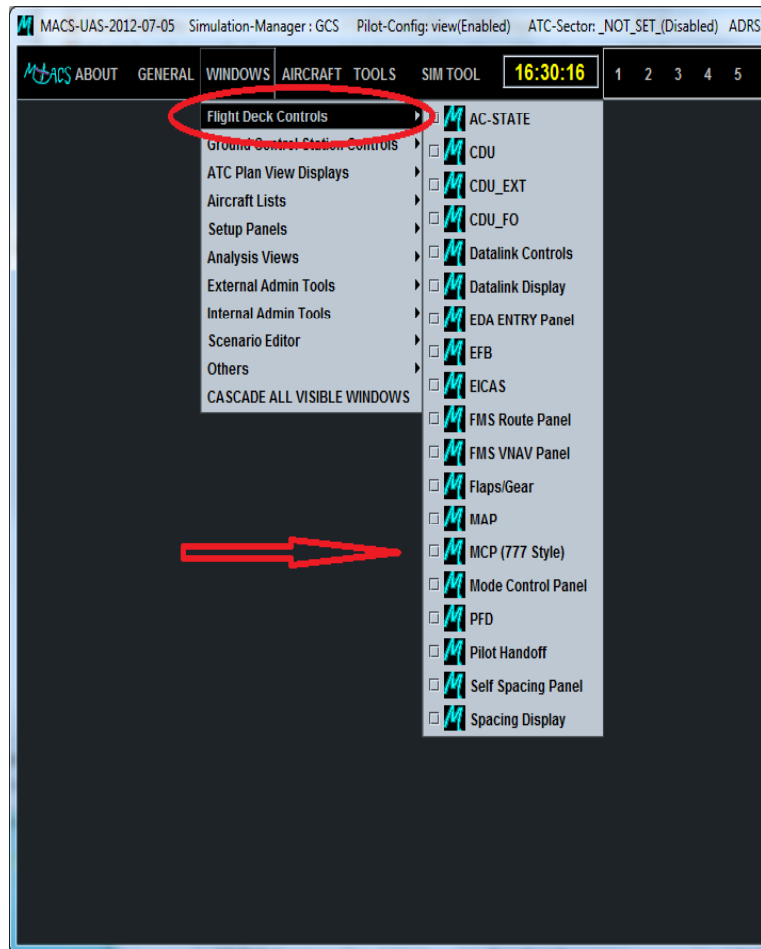
Experimental UAS Ground Control Station Elements



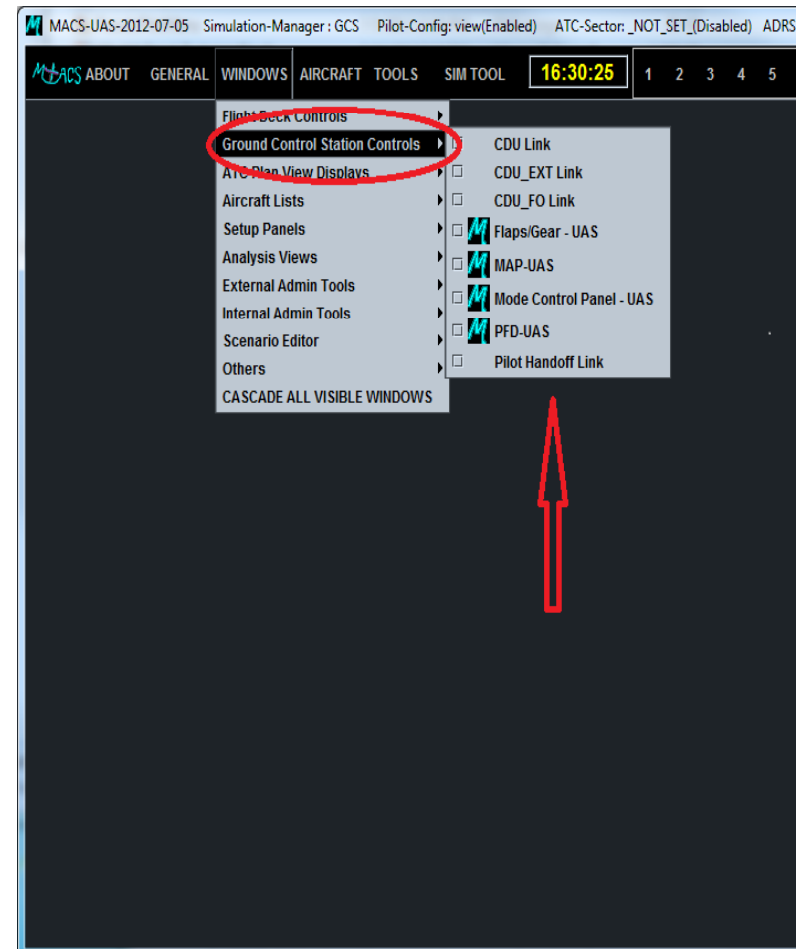
- New GCS window menu
- Copies of:
 - MCDU
 - Handoff panel
 - Aircraft lists
- Modified version of key displays from existing flight deck:
 - Map display
 - PFD
 - MCP
 - Flap/gear control panel
- Modifications include
 - Addition of communication link delay modeling
 - New SA/SAA support functionality
 - Other adaptations for ground-pilot use.



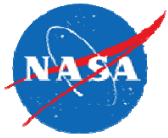
MACS Menu Modifications



ORIGINAL



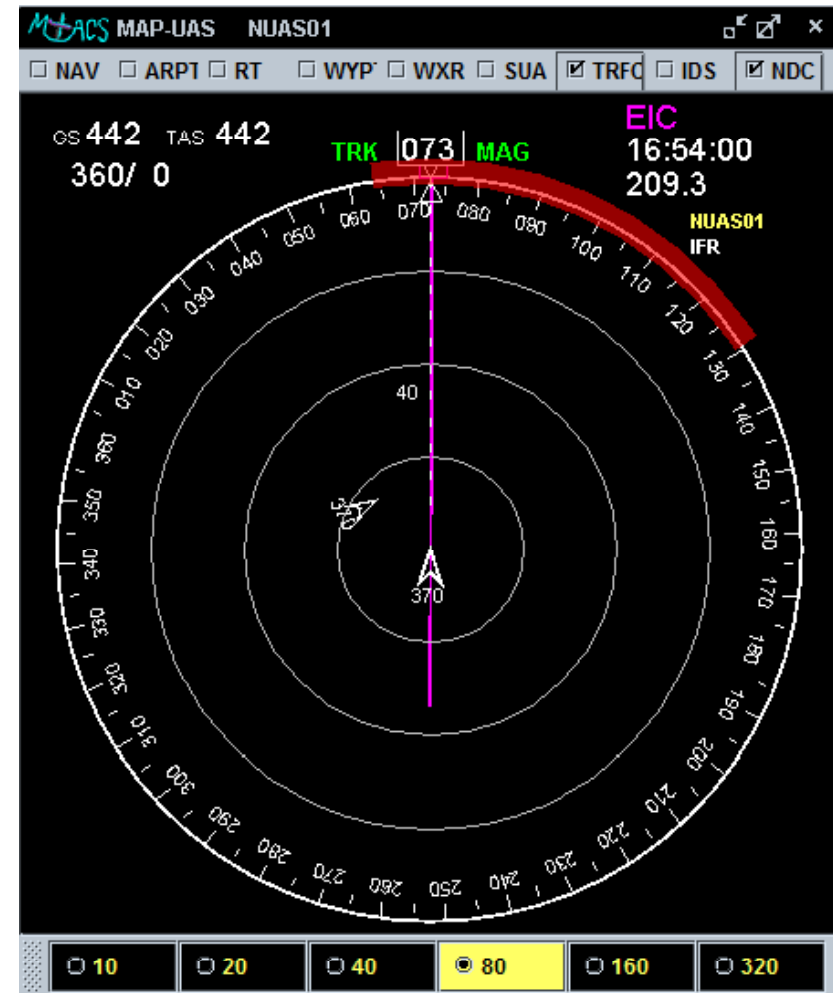
GCS



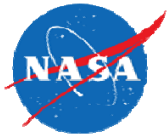
Map Display Modifications



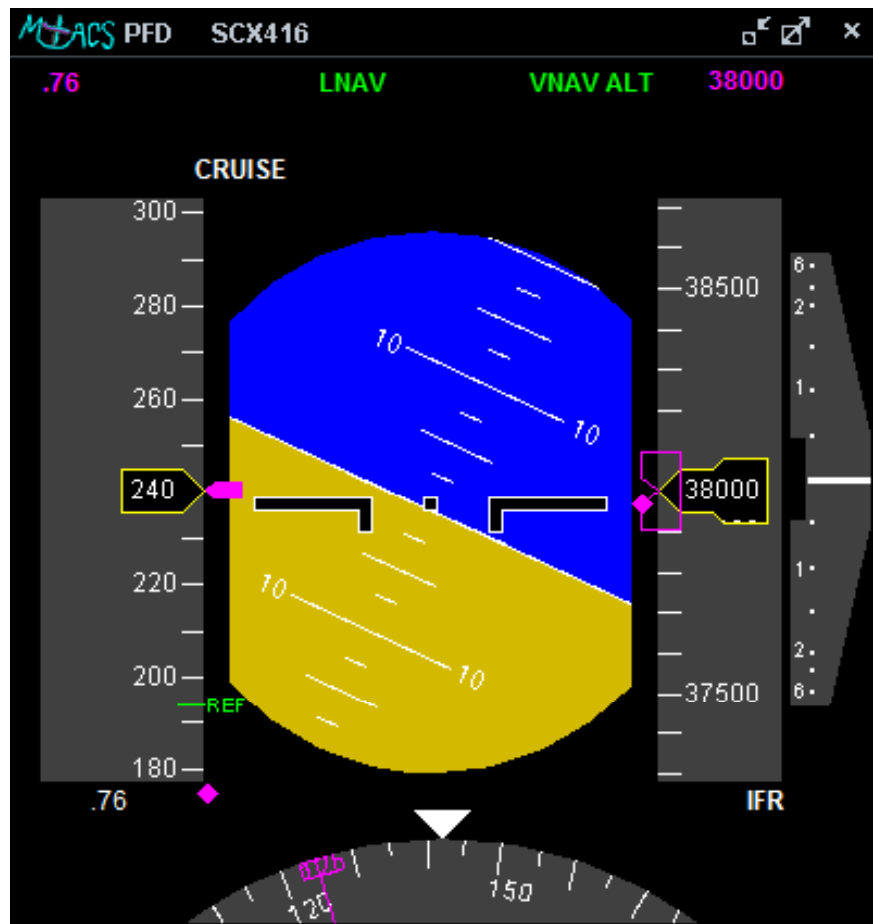
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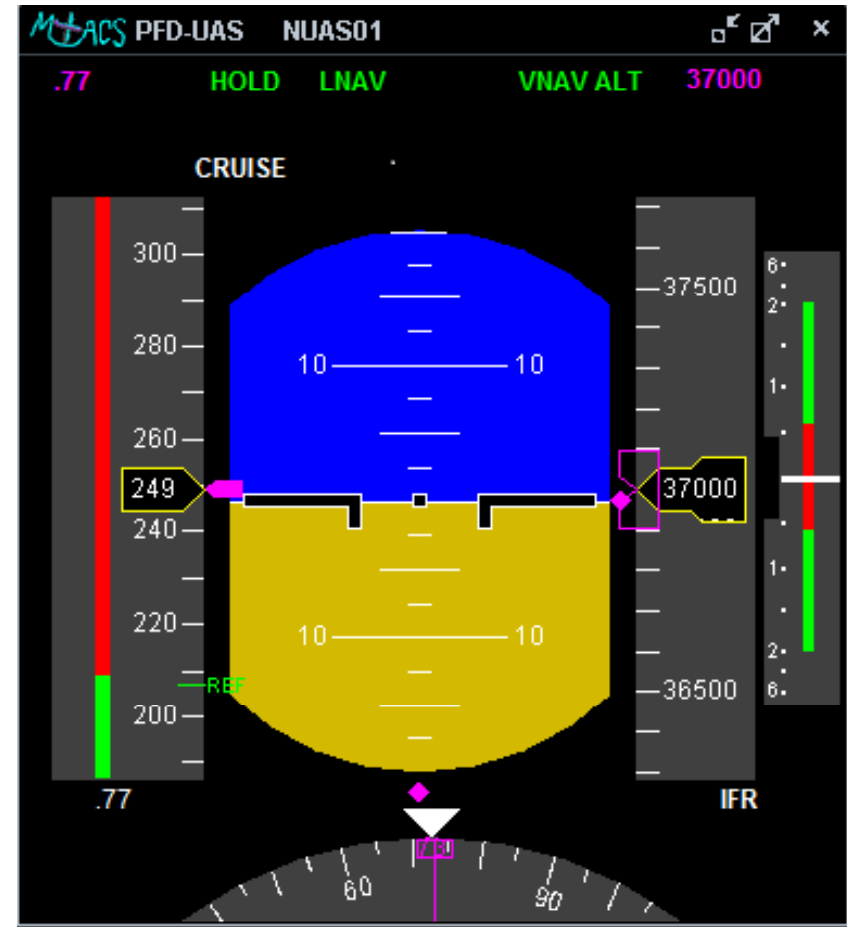
GCS



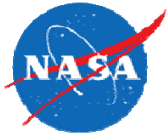
Primary Flight Display Modifications



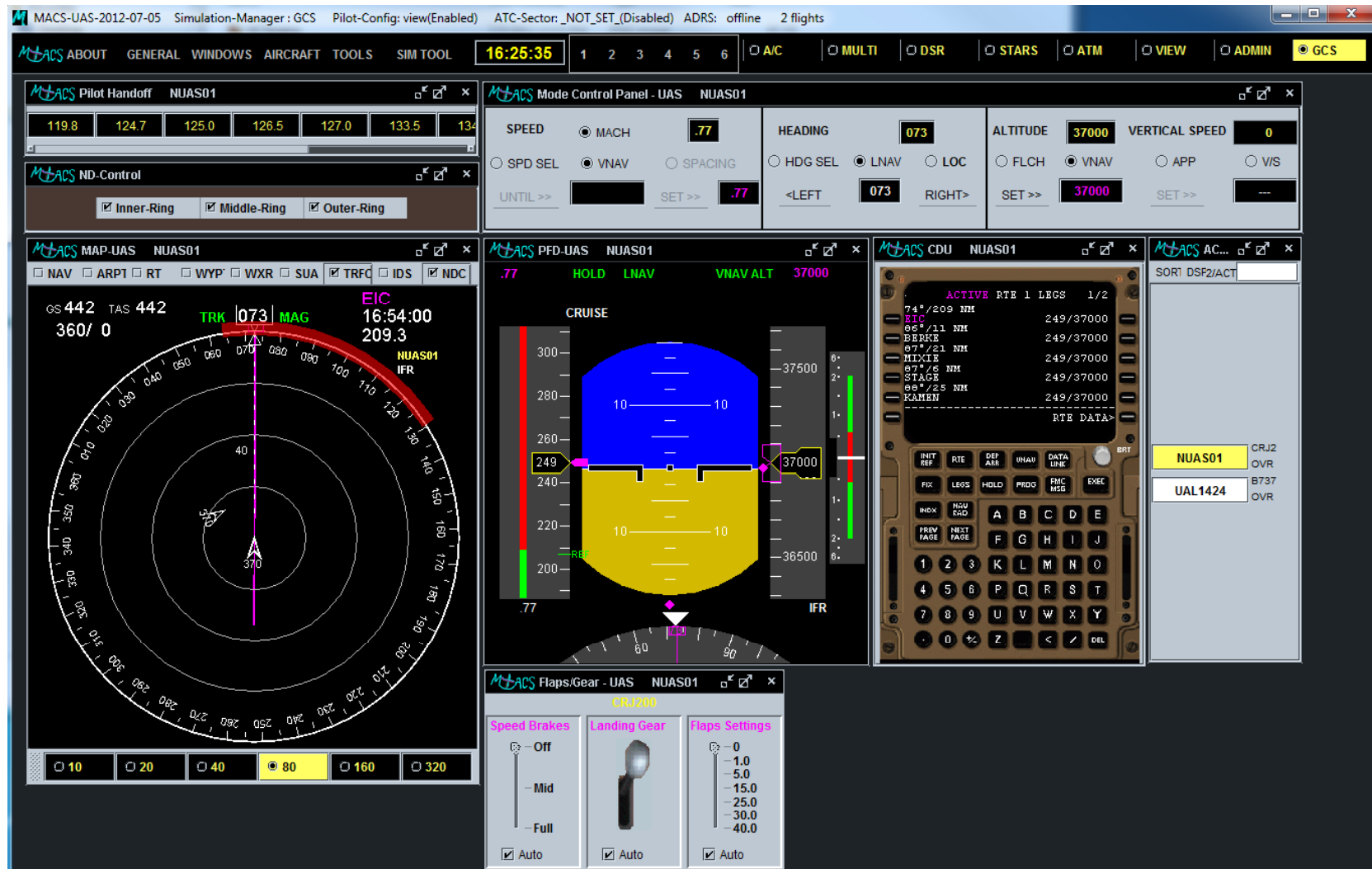
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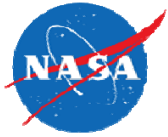


GCS



UAS Ground Control Station Display

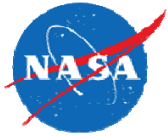




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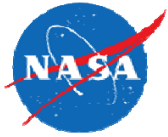
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Vehicle/GCS Communication Delays



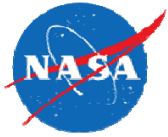
- Delay of vehicle state information
 - Flight State
 - Guidance Data
 - Traffic Data
 - Traffic Conflict Data
- Delay of pilot inputs to vehicle
 - Flight mode changes
 - Track/heading changes
 - Altitude changes
 - Speed changes



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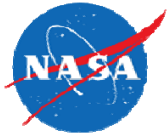
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UAS Vehicle Performance



- MACS baseline has some support for aircraft operational limits (commonObjects.PerfDescr) but still has some hard-coded constants incompatible with some UAS types.
- Adding support for additional operational limits for each vehicle type:
 - Bank angle
 - Roll rate
 - Heading rate
 - Normal acceleration
 - Longitudinal acceleration
 - Stall buffer
 - V_{NE} /Mach-limit buffer



Summary



- The LaRC UAS development team is enhancing MACS to support:
 - Airborne surveillance (ADS-B, ADS-R, TIS-B)
 - UAS Ground Control Station (GCS)
 - Vehicle/GCS communication links
 - Vehicle operational limitations configurability
- These enhancements to the MACS software will be used to conduct the upcoming controller-in-the-loop experiments
- Once completed and verified, these changes will be integrated back into the MACS development baseline.