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# COVER SHEET
## Access 5 Project Deliverable

**Deliverable Number**: *SIM007*

**Title**: AVCS Simulator Test Plan and Design Guide

**Filename:** SIM007_ AVCS Simulator Test Plan and Design Guide_v1_FINAL.doc

**Abstract:**
*Internal document for communication of AVCS direction and documentation of simulator functionality. Discusses methods for AVCS simulation evaluation of pilot functions, implementation strategy of varying functional representation of pilot tasks (by instantiations of a base AVCS to reasonably approximate the interface of various vehicles—e.g. Altair, GlobalHawk, etc.).*

**Status**:
*This documents main purpose was to align the members of the Simulation IPT in regards to direction of the AVCS effort. It its current form, its utility is limited, but does provide an accurate representation of Air Vehicle Control Station (AVCS) simulation capabilities at NASA Ames Research Center.*

# AVCS Simulator
# Test Plan

## and Design Guide

## WBS: 1.4.3.1.8.0

## May 04, 2005

Stephen Shelden

- Simulation IPT -



*The following document was prepared by a collaborative team through the noted work package. This was a funded effort under the Access 5 Project.*

**Table of Contents**





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## Goals / Objectives

Design, code, and implement an Unmanned Aerial Vehicle (UAV) Ground Control Station (GCS) simulator to evaluate Access 5 (A5) policies, procedures, technology, collision avoidance, etc. The A5 - Air Vehicle Control Station (A5-AVCS) will, in its ***final*** instantiation, be a functionally reconfigurable GCS capable of representing a variety of air vehicles, proposed to include Global Hawk, Altair, and Perseus among others.

In its initial instantiation, the A5-AVCS will represent the functionality of the Altair air vehicle. At its core will be:

- An Altair aero-model.
- Connectivity to the AOS, using VAST-RT technology.
- Fundamental flight control, modeled on the Altair UI.
- Operator and aircraft data collection capability.

**Figure 1** Altair.

## A5-AVCS Simulator Description / Capabilities

The initial A5-AVCS is to be modeled on the General Atomics – Aerospace Systems Incorporated (GA-ASI), Altair UAV ground station. The goal is to accurately represent the Altair GCS functionality in the A5-AVCS. Important to note is that it is not our goal to replicate – one-for-one – the Altair GCS, in its entirety.


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At this time 6 major components are slated for incorporation into the A5-AVCS simulator – Tracker Display (what is referred to henceforth as the Navigation Display), Flight Display, Aircraft Status Display, Command Display, Communications Panel, and Flight Control Hardware. The reader is referred to the figure and component descriptions that follow.

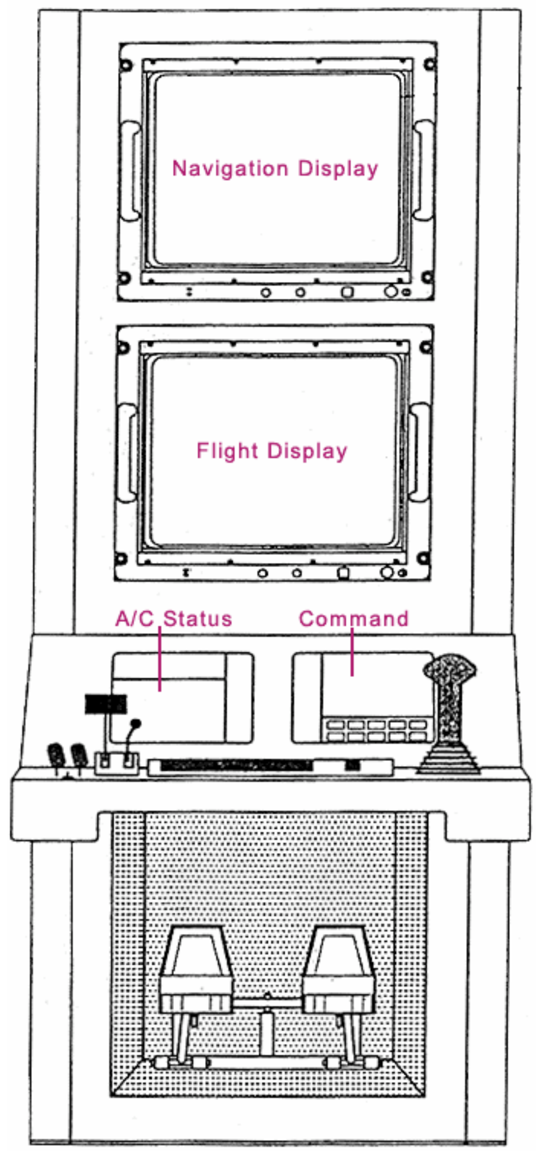


**Figure 2** Altair GCS schematic.

<u>Navigation Display</u>

The navigation display provides a (Jeppesen) map background, overlaid with an aircraft icon and navigational data, for example waypoints, predicted direction of travel, and a course history. For A5-AVCS purposes we refer to the Altair GCS Tracker Display as the Navigation Display.

<u>Flight Display</u>

The flight display presents an out-the-window 'background' view, courtesy of a forward-looking camera. The field-of-view is 30 degrees. Overlaid on the camera view is a head up display (HUD) resembling that used in the F-16.

<u>Aircraft Status Display</u>

The aircraft status display provides the operator with information on aircraft system parameters. Three dedicated areas on the display respectively provide data on operational warnings, aircraft function status, and "Variable Information Tables" (VIT) that contain 'mine-able' data.


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Command Display

The command display provides an interface between the pilot and various controls. Again, three dedicated areas on the display respectively provide for datalink status, a menu button interface (for data and control navigation), and another VIT.

Communications Panel

In the Altair GCS, communications between the aircraft pilot and Air traffic Control (ATC) are effected using hardware in the station's center console. For A5-AVCS purposes, a simple software-based communications panel will be incorporated into the interface.

Flight Control Hardware

To facilitate hands-on operator control of the aircraft, a fly-box will be substituted for the Altair's 'hard' controls. As it may not be possible to have every physical Altair control present in a fly-box, it may be necessary to substitute on-screen controls, for example, for flap management, landing gear control, etc. However, it will be our goal to mirror Altair's functionality to the highest possible degree, irrespective of the precise presentation/interaction format.

Rudder operation (effected in the Altair GCS using pedals, with toe brakes) is a to-be-determined item, in terms of how to instantiate this in the A5-AVCS. Hardware may be made available for the simulator, or, aircraft turns will all be coordinated, with any necessary rudder input transparent to the aircraft operator. Braking upon landing, when it becomes necessary in the later "Steps" of Access 5 simulations, may also need to be a transparent, automated operation.


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## Proposed Operator / Aircraft Metrics

Integral to Access 5 simulation research activities will be the need to collect operator and aircraft (performance) data for analysis and reporting. At the highest level, metrics of interest will encompass:

- Time-stamped, operator user interface inputs and activities.
- Concurrent with that above, aircraft operational / performance data.
- Traffic data.

<u>Operator Metrics</u>

Measures related to operator performance may include:

- Number and types of interface inputs.
- Time to initiate aircraft course changes (at the request of ATC).
- Workload / Situation Awareness (SA) measures.

<u>Aircraft Operational / Performance Metrics</u>

Measures related to aircraft operation and performance may include:

- Deviations from flight plan.
- Operating threshold 'exceed-ances,' in terms of mins/maxs.

<u>Traffic Metrics</u>

To the degree that the AOS-side of A5 simulations does not do so, the A5-AVCS will record such elements as:

- Proximal traffic, and Closest Point of Approach (CPA).
- Intersection geometry requiring UAV course changes.


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- If collision detection/alerting is incorporated, alert levels.
- Secondary course changes precipitated by an AVCS' flight path.

A further goal for the A5-AVCS is to incorporate the ability to run simulations, with traffic, in a "stand-alone" mode, i.e. independent of the AOS. This will permit a focus to be placed on the operator, without the need for extensive support staff and associated costs.

### Simulation Coding

The A5-AVCS Simulator will be coded in C++ for the Linux Operating System. This will help ensure broad acceptance by research and/or academic entities interested in employing the software in the future, for Access 5 participation, or other research.

### Schedule

The A5-AVCS development schedule is comprised of multiple, sometimes overlapping tracks. The core components include:

- Aero-model generation, based on supplied data.
- AOS connectivity, using VAST-RT technology.
- Data collection definition.
- User Interface design guidance.
- Software coding.
- Testing and review.

Aero-model Generation

Building an aero-model for the A5-AVCS is (almost completely) dependent on our obtaining the necessary aircraft operating data and "coefficients" necessary to code this into being. At writing, a request has been sent to General Atomics for the needed information.

AOS Connectivity

A5-AVCS connectivity to the Airspace Operations Simulation (AOS) lab is to be facilitated by the Virtual Airspace Simulation Technology (VAST) group at NASA Ames. VAST uses the HLA software protocol to move data via Ethernet hardware. Participants in a simulation exercise receive a software toolkit that facilitates their connecting to the network.

Data Collection

Data collection, in the form of specific measures to be recorded, is to be defined for incorporation into the A5-AVCS simulator software. The list of metrics will be developed in consultation with the Sim IPT partners, and other A5 groups.

User Interface Design Guidance

UI design guidance is to be based on the best available data and presentation information available, with the goal of mirroring, as best is possible and practical, the Altair's functionality. Direction with respect to the UI is to be included in a separate 'living' document, however, the reader is referred to the appendices for more information on the manner in which the Altair UI is be to be modeled and presented as part of the A5-AVCS simulator.

Software Coding

Coding will take place in parallel with other A5-AVCS activities. The reader is referred to the "Timeline" below.

Testing and Review

Testing and expert reviews of the A5-AVCS simulator will be undertaken periodically, with the goals of ensuring accuracy and reliability of the aero-model, and to help ensure that functional 'equivalence' is present. In addition, a functional analysis of the operator's tasks is in the process of being completed, and will be used to support development, and assess the adequacy of the A5-AVCS simulator.

Timeline

| **Altair** & **Global Hawk** | March | April | May | June | July | Aug. | Sept. |
|---|---|---|---|---|---|---|---|
| **Aero-Model** | ◇ | x | | | | | |
| **AOS Connectivity** | ◇ | x | | | | | |
| **Data Definition** | ◇ | x | | | | | |
| **UI Design Guidance** | ◇ | x | x | | | | |
| **Software Coding** | | x | x | x | | | |
| **Testing & Reviews** | | | x | x | x | | |
| **Aero-Model** | | | | x | x | | |
| **UI Design Guidance** | | | | | x | x | |
| **Software Coding** | | | | | x | x | x |

◇ = Task started, progress made. x = Item scheduled for activity. ● = Completed.

## Risks

Designing, coding, and implementing the A5-AVCS carries certain risks related to the stated goals and schedule outlined above. Low to moderate probability risks include:

- Obtaining data on the Altair, sufficient to build an accurate aero-model.
- Being able to replicate Altair functionality, with sufficient fidelity.

## A5-AVCS Simulation 1

The first simulation incorporating the A5-AVCS will be used as a final test of the major components, including the simulator fidelity, data collection functions, and connectivity. The aircraft will fly within AOS' airspace and respond to operator inputs occasioned by direction from ATC, but for the most part be only a passive 'player' in the airspace initially.

## Appendices

At this time, the majority of the following appendices refer directly to Altair, its operating characteristics, and how the Sim IPT plans to transition the GCS from the real-world to simulation. This is solely a consequence of the fact that Altair is to be the first air vehicle incorporated into the A5-AVCS.

A – Key Altair Performance Data.
B – A5-AVCS / Altair Aero-model Data Requirements.
C – Altair/Predator GCS.
D – Altair GCS – A5-AVCS Transition.
E – Functionality Required for ROA Operation in the NAS.
F – Glossary of Terms


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## Appendix A
## Key Altair Performance Data

| Performance Parameter | Capability** |
|---:|---|
| Gross Takeoff Weight | 7,700 LB |
| Internal Payload Capacity Maximum | 750 LB |
| Maximum Density Altitude | 52,000 Feet |
| Maneuver Air Speed | 142 KIAS |
| Cruise Air Speed (at 12K Density Alt.) | 151 KIAS |
| Dive Speed | 224 KIAS |
| Maximum Rate of Climb (at sea level) | 2000 FPM |
| Endurance at Altitude (w/ 700 lb payload) | 32 Hours |
| Maximum Range (Round Trip) | 2585 NMI |
| Landing Sink Rate (No Damage) | 9 Feet/Sec |
| Takeoff Ground Roll Required (Altitude dependent) | 1,200 – 1,650 Feet (3,000 ft runway) |
| Landing Ground Roll Required (Altitude dependent) | 1,000 – 1,350 Feet (3,000 ft runway) |
| Avionics | HUD, TCAS, ATC Voice Relay |
| Communications | C-Band (LOS) Ku-Band (OTH) |
| Vision System | Forward-looking Camera |
| C-Band LOS Range Limit | 100 NM |

* Assumes a 7,700 lb GTOW (includes 3,500 lb fuel, 660 lb sensor payload)

** See Altair Experimenter's Handbook (GA-ASI) for additional details.

## Appendix B

## A5-AVCS / Altair Aero-model Data Requirements

The ***Altair Experimenter's Handbook*** (HSI copy is dated October 15, 2001), Appendix B contains a series of Altair Performance Charts. These have provided limited direction with respect to developing the A5-AVCS aero-model. The reader is referred to the handbook for specific details.

Additional data required for building the aero-model was identified (March 10, 2005), and a request sent to General Atomics (March 11, 2005), consisting of the following:

**1.** wing area
**2.** wing span
**3.** mean chord (m.a.c.)
**4.** mass

**5.** Ixx = rolling moment of inertia (x-axis)
**6.** Iyy = pitching moment of inertia (y-axis)
**7.** Izz = yawing moment of inertia (z-axis)
**8.** Ixz = first product of inertia (x-z axes)

**9.** thrust (min. and max. values)

**10.** aileron deflection (min and max values)
**11.** elevator deflection (min and max values)
**12.** rudder deflection (min and max values)


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**13.** CLzero = lift coefficient at 0 angle of attack (alpha=0)

**14.** CLalpha = lift curve slope (linear portion)

**15.** CLalphadot = rate of change of the lift curve slope w.r.t. alpha

**16.** CLq = change in lift coefficient (CL) due to pitch rate (q)

**17.** CLde = change in lift coefficient (CL) due to elevator deflection (de)

**18.** CDzero = drag coefficient (CD) at 0 alpha, a.k.a. profile drag coefficient

**19.** CDalpha = lift-drag (CL/CD) curve slope (drag due to lift)

**20.** CDbeta = change in drag due to sideslip angle (beta)

**21.** CDde = change in drag due to elevator deflection (de)

**22.** CYbeta = change in side force due to sideslip angle (beta)

**23.** CYp = change in side force due to roll rate (p)

**24.** CYr = change in side force due to yaw rate (r)

**25.** CYda = change in side force due to aileron deflection angle (da)

**26.** CYdr = change in side force due to rudder deflection angle (dr)

**27.** Clbeta = change in rolling moment due to sideslip angle (beta)

**28.** Clp = change in rolling moment due to roll rate (p), a.k.a. roll damping

**29.** Clr = change in rolling moment due to yaw rate (r)

**30.** Clda = change in rolling moment due to aileron deflection angle (da)

**31.** Cldr = change in rolling moment due to rudder deflection angle (dr)

**32.** Cmzero = pitching moment coefficient (Cm) at 0 alpha

**33.** Cmalpha = change in pitching moment due to change in alpha

**34.** Cmalphadot = change in pitching moment coefficient due to rate of change in alpha

**35.** Cmq = change in pitching moment due to pitch rate (q), a.k.a. pitch damping

**36.** Cmde = change in pitching moment due to elevator deflection (de)


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**37.** Cnbeta = change in yawing moment due to sideslip angle (beta)

**38.** Cnp = change in yawing moment due to roll rate (p)

**39.** Cnr = change in yawing moment due to yaw rate (r), a.k.a. yaw damping

**40.** Cnda = change in yawing moment due to aileron deflection angle (da)

**41.** Cndr = change in yawing moment due to rudder deflection angle (dr)

The exact nomenclature and stability derivative definitions is in: "Flight Stability and Automatic Control", Robert C. Nelson. 2nd ed. nomenclature: Appendix B, pg. 398.

Axis definition is: left-hand axis system with index finger = x, thumb = y, and middle finger = z (pointing down).

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AOS supplied data:

- V-True = 190kts at FL410 is 80kts calibrated airspeed (CA).
- Dash Speed = 90kts CA at FL410.


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## Appendix C
## Altair/Predator GCS

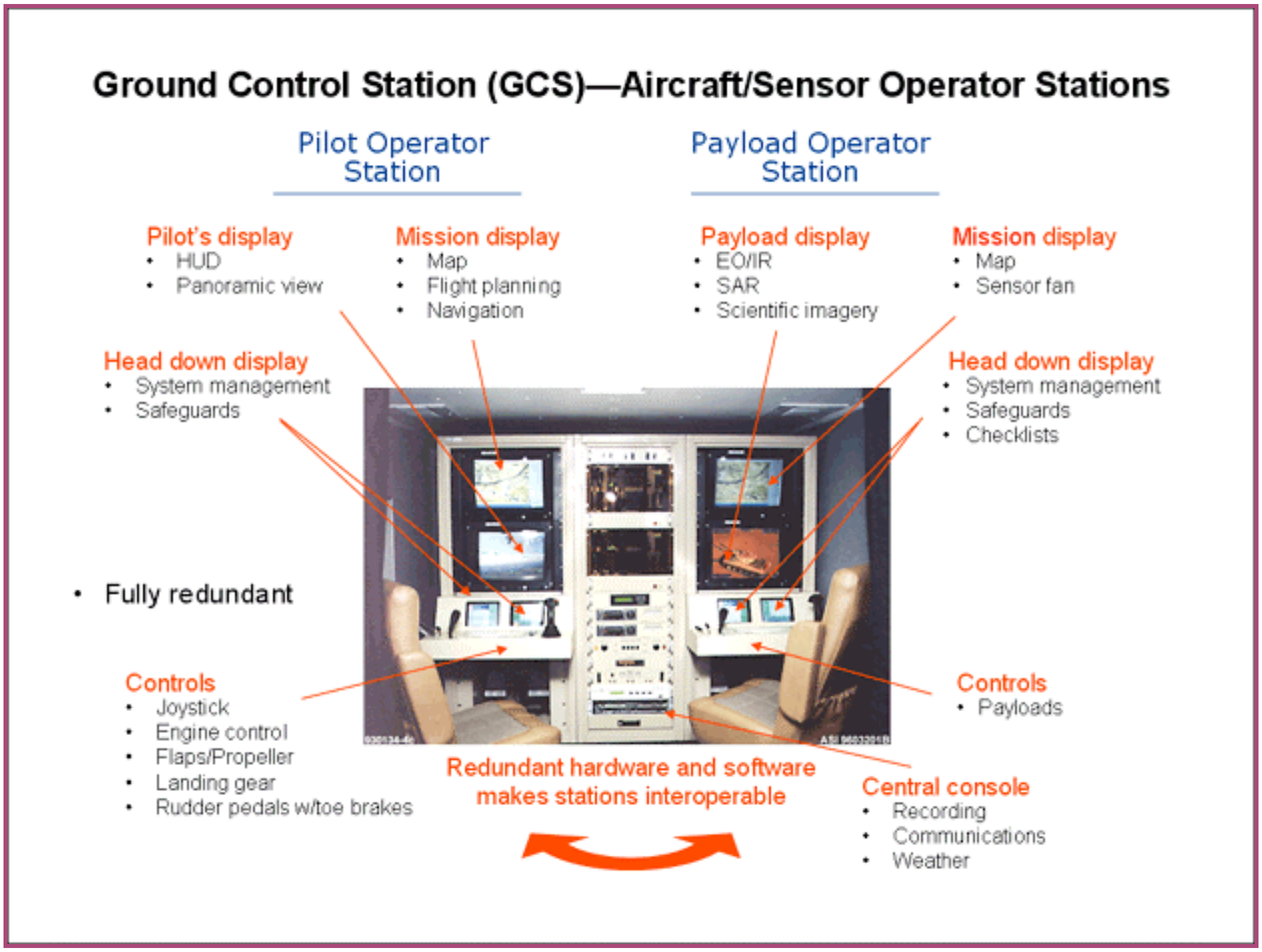


**Figure 3** Altair GCS overview. (Courtesy of Bill Miles, Boeing)

Altair is 34 feet long, with a wingspan of 86 feet. A 700 horsepower, rear-mounted turboprop engine powers the three-blade, controllable-pitch propeller. Altair is configured with a fault-tolerant, dual-architecture flight control system. The aircraft is equipped with an automated collision-avoidance system, and air traffic control voice relay.

## Appendix D
## Altair GCS – A5-AVCS Transition

The 'transition' of the Altair GCS to the A5-AVCS is illustrated below. In short, the Altair's collection of screens will be compressed and presented on a single, large-screen, high-resolution monitor. The specifics for accomplishing this are being defined (for coding personnel) in a separate document.

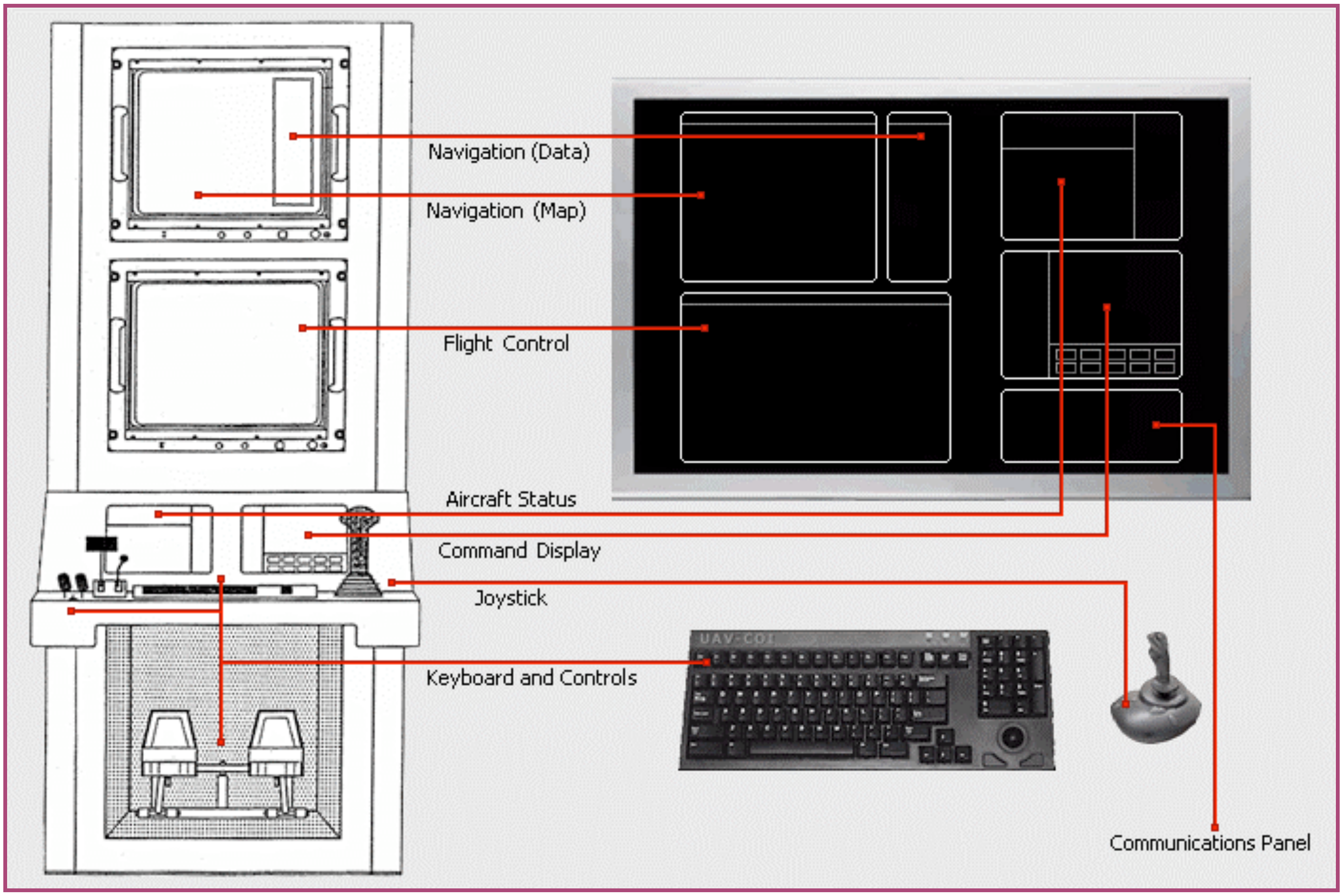


**Figure 4** Altair GCS to A5-AVCS.

The proposed A5-AVCS monitor is a 30" Cinema Display, 2500 x 1600 maximum resolution, capable of 16M plus colors.

## Appendix E

## Functionality Required for ROA Operation in the NAS*

| ID | Functionality Description | Altair (1) |
|---|---|---|
| | **FLIGHT (2)** | |
| 1 | Pitch, Roll, Yaw | YES |
| 2 | True Airspeed | YES |
| 3 | Ground Speed | YES |
| 4 | Indicated/Calibrated/Equivalent Airspeed | YES |
| 5 | Mach Number | YES |
| 6 | Altitude | YES |
| 7 | Barometric Altimeter Setting | YES |
| 8 | Height Above Ground (3) | YES |
| 9 | Vertical Speed | YES |
| 10 | Flight Path Angle | YES |
| 11 | Bank Angle Limit | YES |
| 12 | Pilot-ATC Communication | YES |
| 13 | Pilot-ROA Communication | YES |
| 14 | DELETED | - - |
| 15 | ROA-ATC Communication | YES |
| 16 | Heading | YES |
| 17 | Heading Intent (4) | YES |
| 18 | Track (Magnetic/True) | YES |
| 19 | Track Intent (8) | YES |
| 20 | Vertical Profile Guidance | YES |
| 21 | Vertical Profile Deviation | YES |
| 22 | Lateral Profile Guidance | YES |
| 23 | Lateral Profile Deviation | YES |
| 24 | True Airspeed Intent (8) | NO |
| 25 | Ground Speed Intent (8) | NO |
| 26 | Indicated/Calibrated/Equivalent Airspeed Intent (8) | NO |
| 27 | Mach Number Intent (8) | NO |
| 28 | Altitude Intent (8) | NO |
| 29 | Vertical Speed Intent (8) | NO |
| 30 | Interactive Flight Plan Revising | YES |

| | | |
|---|---|---|
| 31 | Flight Path Angle Intent (8) | NO |
| 32 | RNAV Capability (via GPS, INS, or equivalent) | YES |
| 33 | Radio (VHF/UHF) | YES |
| 34 | DME (5) | NO |
| 35 | Precision Approach | YES |
| 36 | Non-Precision Approach | YES |
| 37 | Automatic Direction Finding (VHF/UHF) | NO |
| 38 | Marker Beacon Identification | NO |
| 39 | Global Navigation Satellite System (Enroute) | NO |
| 40 | Future Air Navigation System (FANS) | NO |
| 41 | Distance to Go | YES |
| 42 | Time to Go | YES |
| 43 | Wind Speed and Direction | YES |
| 44 | Estimated Time of Arrival at Waypoint | YES |
| 45 | Required Navigation Performance/ Actual Navigation Performance (RNP/ANP) | NO |
| 46 | Aircraft Position | YES |
| 47 | Predicted Navigation Performance (6) | YES |
| 48 | Ground Mapping Radar | YES |
| 49 | Identify Ground Traffic (Direct View) (7) | YES |
| 50 | Identify Ground Traffic (Electronically) (8) | YES |
| 51 | Follow Ground Traffic (Direct View) (11) | YES |
| 52 | Follow Ground Traffic (Electronically) (12) | YES |
| 53 | Identify Hold Lines | YES |
| 54 | Identify Flight Traffic (Direct View) (11) | YES |
| 55 | Identify Flight Traffic (Electronically) (12) | YES |
| 56 | Follow Flight Traffic (Direct View) (11) | YES |
| 57 | Follow Flight Traffic (Electronically) (12) | YES |
| 58 | Formation Flight Capability | YES |
| **SURVEILLANCE** | | |
| 59 | Permit ATC Secondary Surv. Radar Identification via Transponder or Datalink | YES |
| **HAZARD AVOIDANCE - SURVEILLANCE** | | |
| 60 | Weather (Direct View) (11) | YES |
| 61 | Weather (Radar) | YES |
| 62 | Precipitation (Direct View) (11) | YES |
| 63 | Precipitation (Electronic) (9) | YES |
| 64 | Turbulence (Direct View) (11) | YES |


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| | | |
|---|---|---|
| 65 | Turbulence (Electronic) (12) | YES |
| 66 | Lightning (Direct View) (11) | YES |
| 67 | Lightning (Electronic) (12) | YES |
| 68 | Volcanic Ash (Direct View) (11) | YES |
| 69 | Wind shear (electronic) (10) | YES |
| 70 | Terrain (Direct View) (11) | YES |
| 71 | Terrain (Electronically) (11) | YES |
| 72 | Ground Traffic (Direct View) (11) | YES |
| 73 | Ground Traffic (Electronically) (12) | NO |
| 74 | Flight Traffic (Direct View) (11) | YES |
| 75 | Flight Traffic (Electronically) (12) | NO |
| 76 | Cockpit Display of Traffic Information | NO |
| 77 | Inspect/Clear Taxiway or Runway (Direct View) (11) | YES |
| 78 | Inspect/Clear Area Prior to Departure (Direct View) (11) | YES |
| 79 | Inspect/Clear Area Prior to Arrival (Direct View or electronic) (11, 12) | YES |
| **HAZARD AVOIDANCE – VEHICLE SUB-SYSTEMS** | | |
| 80 | Icing – Structural | YES |
| 81 | Icing – Engine | YES |
| 82 | Icing/Fogging – Imaging System | YES |
| 83 | Extended Electrical Power Duration | YES |
| **MISCELLANEOUS** | | |
| 84 | Identify Visual Flight Rules Conditions (13) | YES |

* HSI Concept Requirements and Definition – Access 5 Technology IPT 09/2004, Sally Moore.

**Notes**

1. "YES" indicates the vehicle has the capability to satisfy the functionality requirement. "NO" indicates the vehicle does not contain the functionality at all or it has limited functionality which, in the opinion of the authors, is insufficient to satisfy the Functionality Description. Also, "NO" is shown if (1) the vehicle is using a payload to accomplish the function and the payload is not a basic feature of the aircraft or (2) the function is not available full-time.
2. Control or display capability.
3. From radar altimeter or GPS.
4. Intent information is an element of certain future FAA and international Communications / Navigation / Surveillance – Air Traffic Management concepts. It is a prediction of the future state of a vehicle parameter used by ATC for traffic planning purposes.
5. Use only of VORTACs or TACANs to derive distances. Does not refer to distance determination by GPS or other self-contained navigation method.

6. This is an aspect of RNP/ANP operations.
7. Direct View – Visual observation or video picture of object of interest. A "YES" indicates that the direct view provided is functionally equivalent to that of an inhabited aircraft. The pilot should be able to perform the function as well and in the same amount of time as when in an inhabited aircraft. "NO" is shown if the imaging device is not part of the basic aircraft, is a payload, or it not available full-time.
8. Electronic – Data displayed to pilot that shows a parameter of interest. A "YES" indicates that this information has the required detail and is timely.
9. Derived from weather radar.
10. Wind shear can be determined by the pilot, to a degree, without reactive or predictive wind shear systems. Information is available on or prior to approach when wind shear may be or will be encountered.
11. Depicted on terrain database, ground mapping radar, forward looking radar, or other system.
12. Radar altimeter only.
13. Ability to determine VFR as defined in FAR Part 91 [based on distance to clouds (above, below, and horizontally) and flight visibility] by using the imaging system. This is not a reference to visual meteorological conditions (VMC).

## Appendix F

## Glossary of Terms

| | |
|---|---|
| C-band | “Compromise” band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 4 to 6 GHz. C-band is primarily used for satellite communications. |
| | |
| $K_u$-band | “Kay-yoo” (kurz-under band) is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 11 to 18 GHz. $K_u$ band is primarily used for satellite communications. |


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## A5-AVCS Design Guide

The concept of "transitioning" the Altair to the A5-AVCS is detailed above, in Appendix D.

Guidance for implementation of the A5-AVCS "components" is detailed below, parsed by the major component sub-systems:

- Navigation Display
- Flight Display
- Aircraft Status Display
- Command Display
- Communications Panel
- Flight Control Hardware

The monitor to be used for presentation of the AVCS components is proposed to be an Apple Cinema Display, 25.24" x 15.80" – 1920 x 1440 pixels (76px/in. x 91px/in.). Details provided below with respect to window dimensions and the size of specific graphical elements is based on this.

**Navigation Display**

The Navigation Display ("Tracker Display") is used to monitor the aircraft's geographic location. The display presents a digitized (Jeppesen) map background, overlaid with an aircraft icon and navigational data, for example waypoints, predicted direction of travel, and a course history.

Map (Background)

A ***single*** map will cover the entire operational area of the A5-AVCS, as currently proposed for the simulation missions. The map will approximate to the A5-AVCS operational area covered by the three high-altitude sectors set for operations in Cleveland ARTCC – Gueage (45), combined sectors Wayne/Lake (29/26), and Gamble (19).

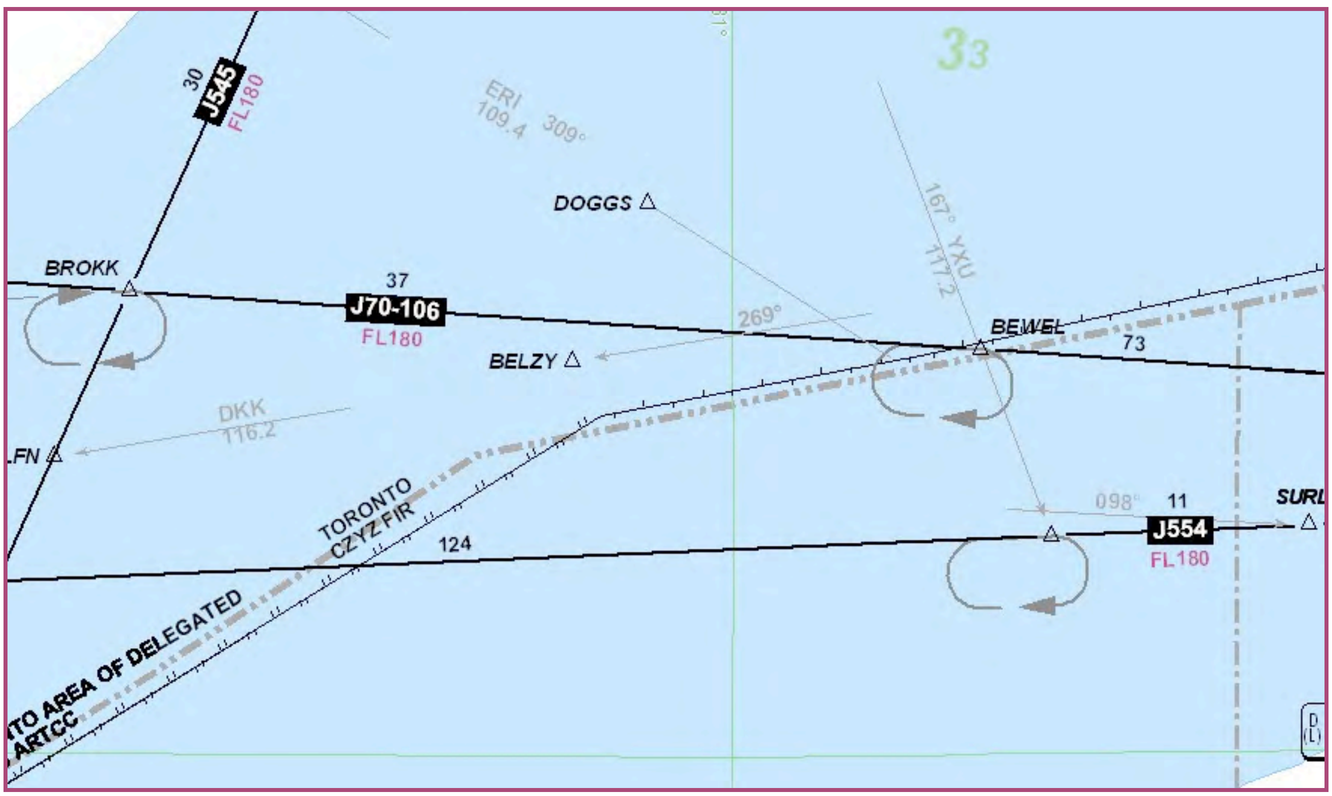


**Figure 5** Section of airspace from ZOB map.

The initial map file "**mapZOB_01.jpg**" was delivered April 11, 2005, a small section of which appears above.

The map will be ***north-up***, requiring the operator re-center the map around the aircraft's location, as needed or desired. Movement of the map will be facilitated by presentation of vertical and horizontal scroll bars. This mirrors the current Altair/Predator GCS. A vehicle *track-up* map will be 'built' at a later time.

Navigation Elements (Foreground)

The core vehicle navigation elements that will need to be presented on this display, see illustration(s) below, include:

- File Menu: Across the top of the map window will be a File Menu allowing the operator to access various, relevant functionality. At this time, the underlying File Menu functionality has been limited to the absolute minimum believed to be necessary for A5 simulation activities.
- Navigation Elements: In addition to an Altair aircraft symbol, flight plan waypoints, and associated path data will need to be displayed. A data tag should be appended to the aircraft symbol, and provision made for displaying an aircraft path history, time duration TBD.
- UAV Status: To the right of the map window will be a data window presenting myriad data relevant to the location of the vehicle, fuel status, and waypoint information.
- Compass Rose: Below the UAV Status window is a – fixed, north-up – compass rose that depicts the heading of the aircraft, and if the auto-pilot is engaged, the heading to which the aircraft should be flying (or be turning to, to fly).
- Pilot Station: Below the compass rose, a non-interactive label should appear that identifies this GCS as being applicable to the UAV pilot. (The absence of a payload or sensor-side to our GCS negates the need for this element to be interactive.)


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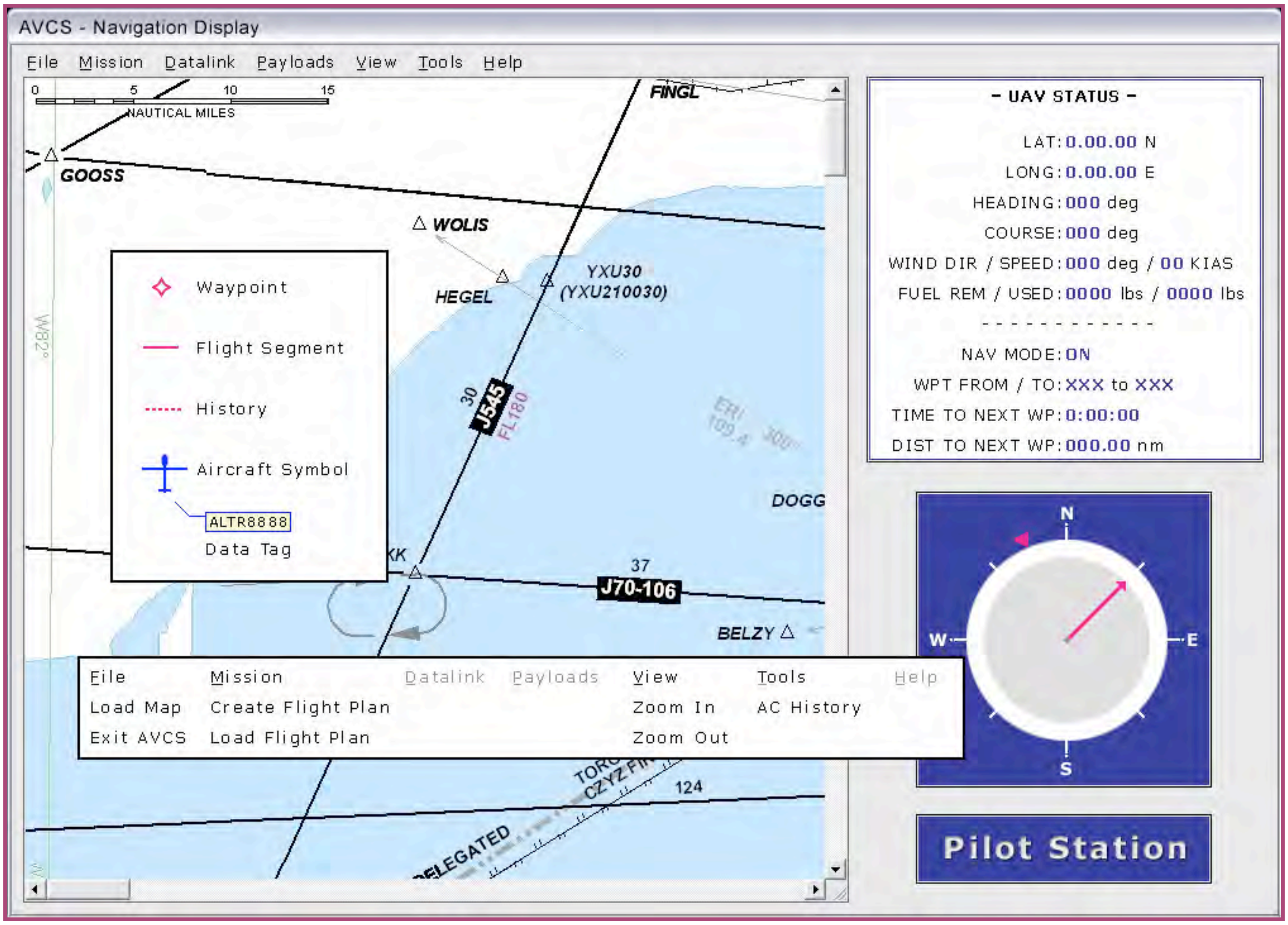


**Figure 6** Navigation display. Insets illustrate required navigational graphics, and File Menu items.

Based on use of a 30" Cinema Display, the Navigation Display should be 1008 (W) x 720 (H) pixels in size (at 96 pixels per inch), equal to 10.5 in. x 7.5 in.

*Note: The ability to create a flight plan in advance of a mission will be needed... need to get guidance from Tom M. on the best way to accomplish this, within the framework of U-SIM.*

**Flight Display**

The Flight Display is the pilot's visual interface, from the aircraft to the external environment. Video from the aircraft's forward-looking camera is displayed in the 'background' of the flight display. Flight data and symbology presented in the 'foreground' overlays the external view.

Out-The-Window-View (Background)

The (background) of the flight display presents the external view provided by the aircraft's forward-looking camera – specifically a 30 degree FOV. For initial A5 simulations (where the AVCS aircraft is at FL430 and higher), it may be acceptable to overlook providing any external surface features, instead focusing on presentation of traffic and a realistic, high-altitude environment – some light clouds, maybe?

Head Up Display (Foreground)

The aircraft data and associated symbology detailed here for the AVCS HUD comes from the limited Altair documentation at hand. Consistent with the overall effort to keep coding requirements to a minimum (at least early in the development process) some HUD data that may not be absolutely necessary – given how the AVCS aero-model operates – has been set aside, to be addressed later. If the contrary is true in any instance detailed below, or if a U-SIM 'hook' to the data already exists, let me know and I'll add the element/graphic into the display, revising this document accordingly.

A further caveat is that precisely how the Altair's HUD graphics operate is not clearly communicated in the (GA) documentation. As a consequence, some intelligent(?) assumptions have had to be made. Below is a HUD feature comparison table, followed by an AVCS HUD image and supporting descriptions of how the various elements would/should/could operate.


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Altair HUD / AVCS HUD – Feature Comparison

| Altair HUD Component | Included in proposed AVCS HUD |
|---|---|
| Magnetic Heading Indicator | YES [1] |
| Magnetic Heading Readout | YES [2] |
| Yaw Rate Indicator | NO |
| Warning/Feedback Indicator Area | YES (below Magnetic Hdg. Indicator) [3] |
| Engine RPM Indicator (dial) | NO |
| Engine SRL/EGT Indicator (dial) | NO |
| Engine Torque Indicator (dial) | NO |
| Vertical Velocity Moving Bar | YES [4] |
| Altitude Indicator (digital readout) | YES [5] |
| Fuel Pressure Indicator (dial) | NO |
| Engine Oil Pressure Indicator (dial) | NO |
| Vertical Velocity (digital readout) | YES [6] |
| G-Meter | NO |
| Altimeter Setting | YES (added label) [7] |
| Climb/Dive Ladder | YES [8] |
| Turn/Slip Indicator w/ Bank Angle | NO |
| Gyro Horizon Line | Horizon Line, YES [9] |
| Ground Speed (digital readout) | YES [10] |
| True Airspeed (digital readout) | YES [11] |
| Distance from GCS | NO |
| Landing Gear Indicator | YES [12] |
| Zero Airspeed Reference | NO (Not clear what this is) |
| Airspeed Moving Bar | YES [13] |
| Stall Speed Moving Bar | YES (but fixed on alt. scale) [14] |
| Airspeed Indicator | YES [15] |
| Angle of Attack | NO |


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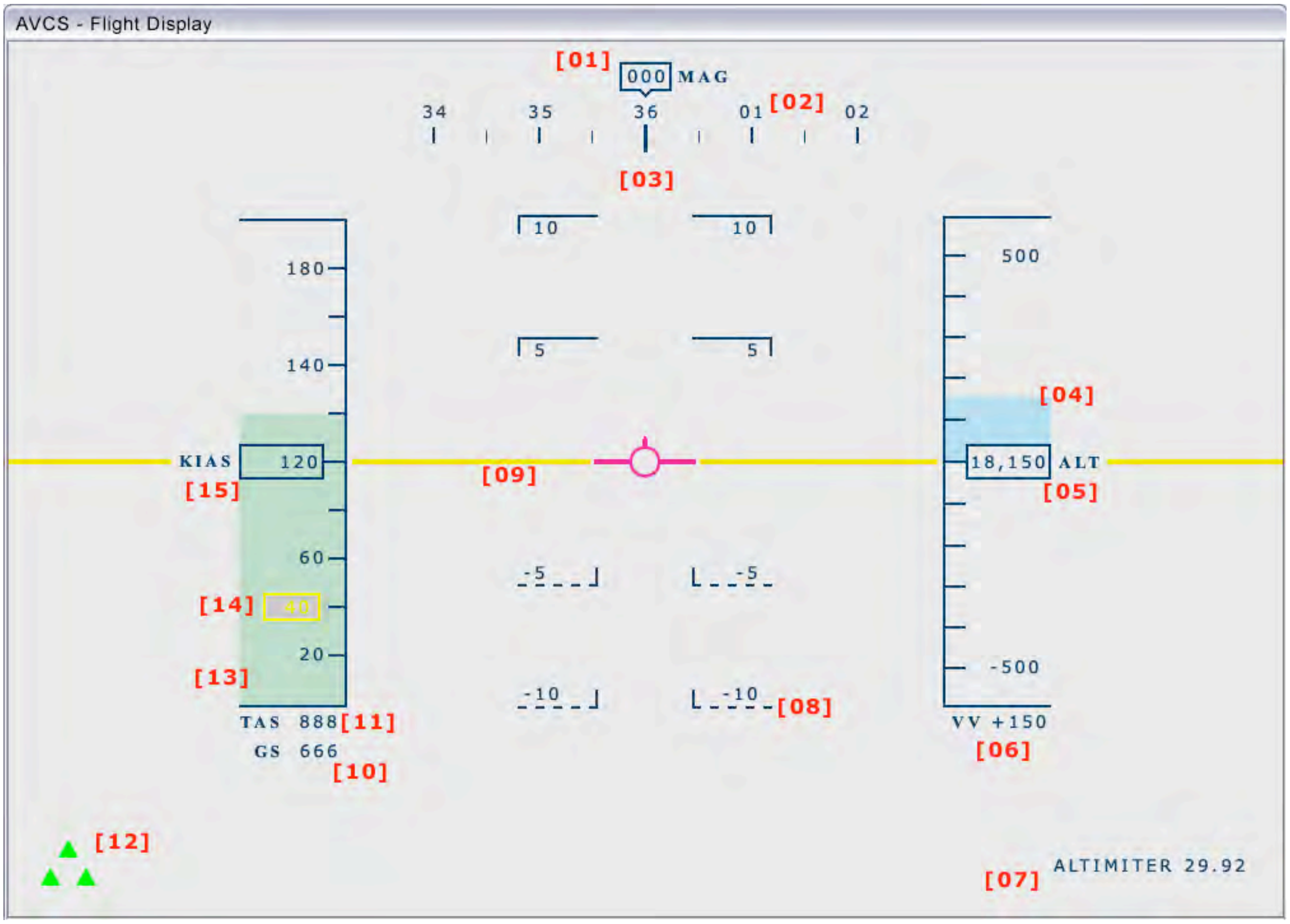


**Figure 7** Proposed AVCS HUD, shown absent any external (background) view. Current KIAS is 120 knots, VSI is +150 ft/min. and altitude is 18,150. **[NN]** = refer to descriptions below.

1. Magnetic Heading – Consistent with U-SIM.

2. Magnetic Heading Readout (MAG) – Consistent with U-SIM.

3. Warning/Feedback Area – Caution (yellow) and alert (red) warnings appear in this general area. Specifics can come later when contingencies become a research issue.

4. Vertical Velocity Moving Bar – A bar moves up and down from the midpoint horizon line, indicating feet/min vertical movement. (See the Vertical Velocity - VV Indicator, below.) I'm assuming this 'gauge' is the functional equivalent of a Vertical Speed Indicator (VSI).

5. Altitude Indicator (ALT) – A digital readout, fixed location on the VV bar.


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6. Vertical Velocity (VV) Indicator – This digital readout should mirror the value displayed graphically by the VV Moving Bar, see above. I'm assuming this is the functional equivalent of a Vertical Speed Indicator (VSI).
7. Altimeter Setting – This is set to "29.92" above FL180 MSL, so for the time being it can be a fixed/static element, given that the near-term simulations are all to be above FL430.
8. Climb/Dive Ladder – Incremented by 5 degrees per hash mark.
9. Horizon Line –Consistent with U-SIM.
10. Ground Speed Indicator (GS) – Consistent with U-SIM.
11. True Airspeed Indicator (TAS) – Consistent with U-SIM.
12. Landing Gear Indication – This can be a fixed/static element, given that near-term simulations are all to be above FL430. Takeoffs and landings will not be a simulation element for some time.
13. Airspeed Moving Bar – The bar moves up and down, adjacent to the scale, set at 20 knot increments.
14. Stall Speed Indicator – Lies on the airspeed scale at the appropriate point. Changes as the aircraft's altitude and speed change(?).
15. Airspeed Indicator (KIAS) – Consistent with U-SIM.

As the Altair documentation I have is black and white, and no color images are available, we will need to review the precise colors used for the AVCS HUD, to ensure there is sufficient contrast with whatever out-the-window view is incorporated. This will likely be an iterative process. However, for example, the Altair documentation states the horizon line is yellow, but this would perhaps seem a poor choice given the need for contrast with the external view. In short, please consider this issue in coding the HUD, that is, the need to adjust the HUD colors later.

Related to the above, a monochrome green HUD image is presented below. While this is ***not*** an Altair option, to the best of my knowledge, it may be prudent to provide the AVCS pilot with this, as an alternative. It may provide better utility if night operations are ever undertaken, or if it contrasts better with the external view.

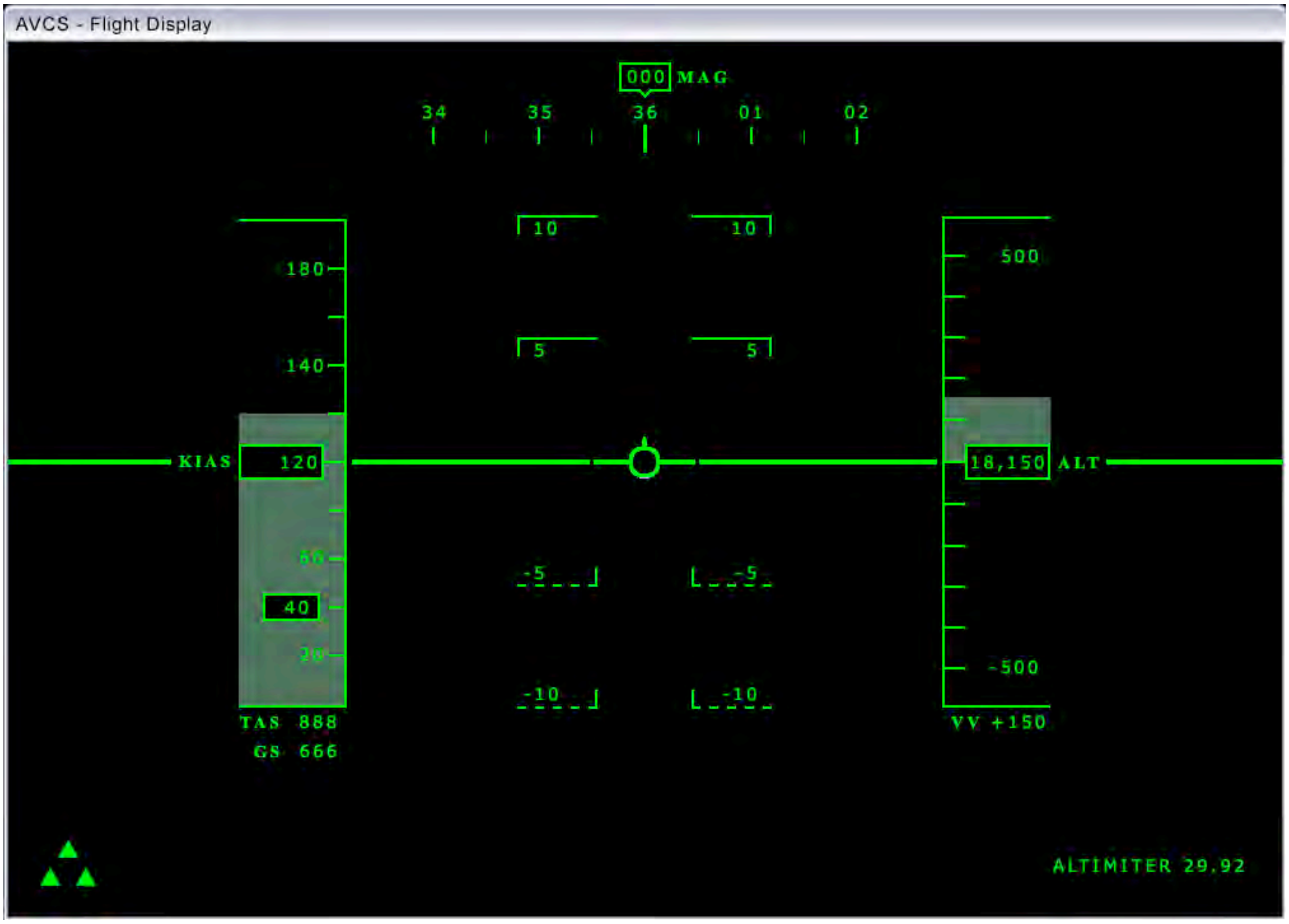


**Figure 8** AVCS HUD – monochrome on black background.

Based on use of a 30" Cinema Display, the Flight Display should be 1008 (W) x 720 (H) pixels in size (at 96 pixels per inch), equal to 10.5 in. x 7.5 in.


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## Aircraft Status Display

The aircraft status display provides information on system parameters, and is divided into three sections. Top left is the *Warning Area* where alerts regarding the aircraft are communicated. Below this is space for a *Variable Information Table* (VIT). To the right is an aircraft *Status Display* area.

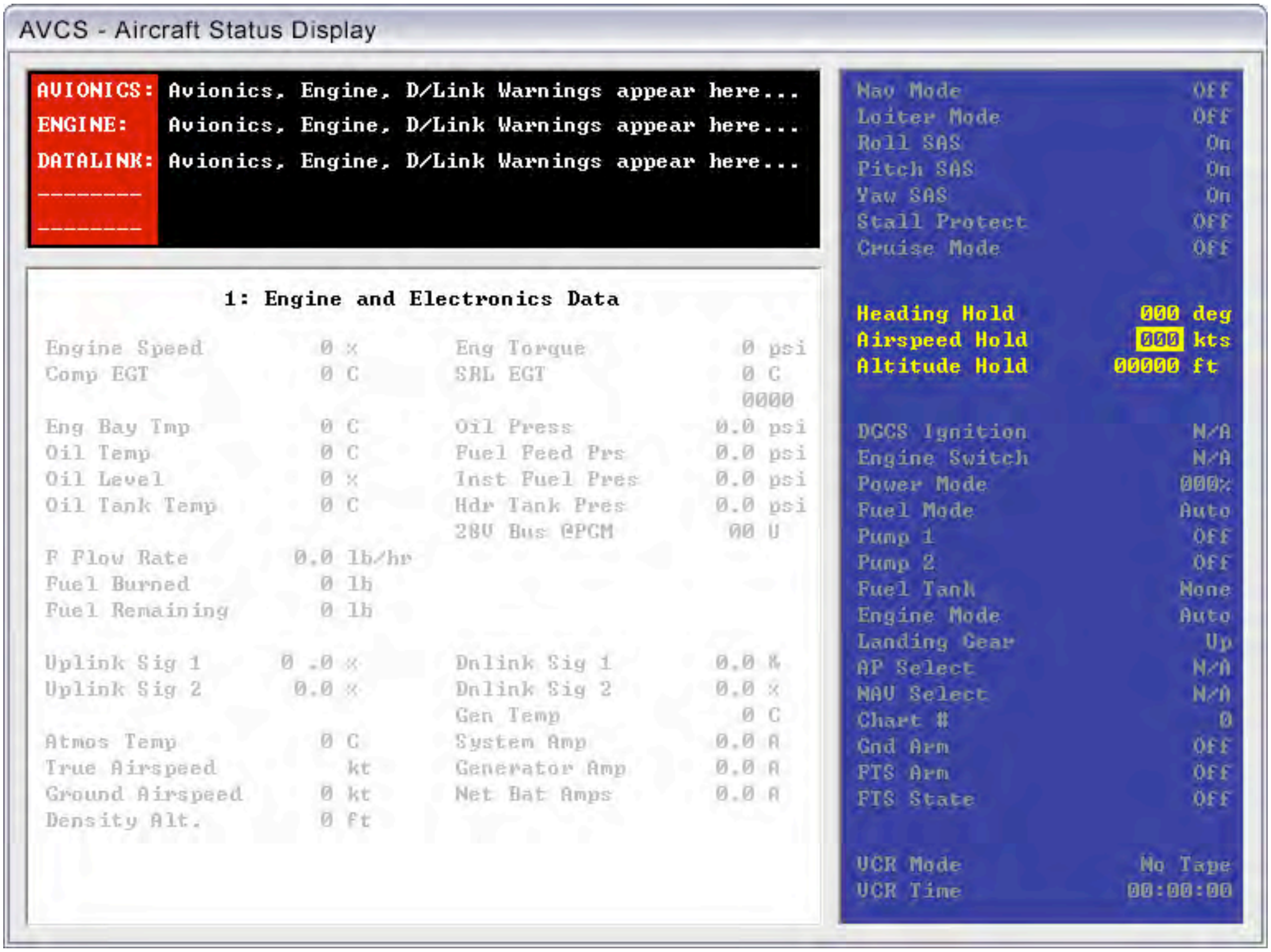


**Figure 9** Aircraft Status Display.

Items depicted on the above display in gray are placeholders only, for the time being, and not active or updated. They should, nonetheless, still be shown as illustrated.


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If basic AVCS (U-SIM) warnings are available, they can be displayed in the *Warning Area*, shown above. Otherwise, this panel should be replicated as illustrated.

For the time being, the Engine and Electronics Data *VIT* should be presented as illustrated. When 'hooks' to data that can represent these elements are determined, they can progressively be incorporated and made 'real.'

In the *Status Display* area above, when the operator inputs or modifies heading, airspeed, or altitude (via the menu on the Command Display, see below), the change is reflected here.

Based on use of a 30" Cinema Display, the Aircraft Status Display should be 768 (W) x 576 (H) pixels in size (at 96 pixels per inch), equal to 8.0 in. x 6.0 in.

**Figure 10** Altair GCS, showing HUD and Head Down displays.

## Command Display

The command status display provides information on system parameters in two areas, and a menu in the third. At left is the *DataLink Status* area. To its right is space for another *Variable Information Table* (VIT). Below these is a *Menu* area through which the operator can interact with the aircraft.


**Figure 11** Aircraft Command Display.

With respect to the *DataLink Status* and *VIT* areas illustrated above, items depicted in gray are placeholders only, for the time being, and not active or updated. They should, nonetheless, still be shown as illustrated. The Air and Control Data elements in the *VIT* (shown in black, with the data value in reverse video) are, however, 'real' and need to be made available to the operator.


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The *Menu* area is where the operator initiates changes in, for example, heading, airspeed, altitude, and what VITs are displayed. The method by which this is accomplished is that the operator presses a corresponding F-key until the desired parameter is reached, at which point the parameter is entered or otherwise modified using the keyboard. In some instances, a toggle state exists, for example with respect to the landing gear. In this instance, the operator would click F5 > F3 > F1 to cycle the gear.

The specifics for the menu area, the navigation and functionality permitted the operator in the AVCS, are detailed below. Tables outline the navigation in text form, and examples follow to further illustrate the method of navigation / interaction.

Based on use of a 30” Cinema Display, the Aircraft Status Display should be 768 (W) x 576 (H) pixels in size (at 96 pixels per inch), equal to 8.0 in. x 6.0 in.

**Command Display – Button Color Scheme**

The Altair documentation refers to a color scheme for the button backgrounds, which I have outlined below:

| | |
|---|---|
| Green (medium) | • default state / executable |
| Green (dark) | • not available / not executable |
| Orange (medium) | • alternate state / for example *Altitude Hold Off* |
| Blue (medium) | • in transition / processing |
| Red (medium) | • fault (not applicable to the AVCS at this time) |

To provide for sufficient contrast, the text should be white on the two green backgrounds, and black against the orange, blue, and red backgrounds. Gray text indicates not available / executable.

**Command Display Menu Navigation and Functionality**

The Command Display menu navigation, and functionality upon which it acts, is outlined below:

**Default Display at Start Up (F1 – F2 – F5)**

| | | | | |
|---|---|---|---|---|
| **F1** | | | | **Status Screen Table** |
| | F2 | | | Engine/Electronics Data VIT |
| | F3 | | | Air/Control Data VIT |
| | F5 | | | Done |
| | | | | |
| **F2** | | | | **Command Screen Table** |
| | F2 | | | Engine/Electronics Data |
| | F3 | | | Air/Control Data |
| | F5 | | | Done |
| | | | | |
| **F5** | | | | **Mission Display (Main Menu)** |
| | F1 | | | Autopilot |
| | F2 | | | Overrides |
| | F3 | | | Critical Switches |
| | F4 | | | Display Control |
| | F5 | | | Other Switches |
| | F6 | | | Payload and Frequency Control |
| | F7 | | | Configuration |
| | F8 | | | Presets |
| | F9 | | | Warnings Acknowledged |
| | F10 | | | Done |

**Notes**

F1 > F2 / F3 Inserts one of the VITs into the Status Screen

F2 > F2 / F3 Inserts one of the VITs into the Command Screen

F5 > F2 / F5, F6, F7 Buttons will be present, but grayed out, i.e. non-executable.

F5 > All other options, see tables that follow...


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Mission Display Sub-Menus

| | | | | | |
|---|---|---|---|---|---|
| F5 | | | | | Mission Display |
| | F1 | | | | **Autopilot** |
| | | F1 | | | Hold Modes |
| | | F10 | | | Done |
| | | | F1 | | Heading Hold |
| | | | | F1 | Enter New Heading (keyboard entry, 0 to 360) |
| | | | | F2 | Heading Hold (On/Off toggle) |
| | | | | F10 | Done |
| | | | F2 | | Airspeed Hold |
| | | | | F1 | Enter New Airspeed (keyboard entry, 0 to 300) |
| | | | | F2 | Airspeed Hold (On/Off toggle) |
| | | | | F10 | Done |
| | | | F3 | | Altitude Hold |
| | | | | F1 | Enter New Altitude (keyboard entry, 0 to 80,000) |
| | | | | F2 | Altitude Hold (On/Off toggle) |
| | | | | F10 | Done |
| | | | F10 | | Done |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F2 | | | | Overrides |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F3 | | | | **Critical Switches** |
| | | F1 | | | Landing Gear (Up/Down toggle) |
| | | F10 | | | Done |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F4 | | | | **Display Control** |
| | | F1 | | | Heads Up Displays |
| | | | F1 | | Altitude Display (MSL/AGL toggle) |
| | | | F2 | | Heading (Mag/True toggle) |
| | | | F10 | | Done |
| | | F2 | | | Heads Down Displays |
| | | F10 | | | Done |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F5 | | | | Other Switches |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F6 | | | | Payload/Frequency Control |


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| | | | | | |
|---|---|---|---|---|---|
| F5 | F7 | | | | Configuration |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F8 | | | | **Presets** |
| | | F1 | | | Barometric Pressure (keyboard entry, 25.00 to 32.00) |
| | | F10 | | | Done |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F9 | | | | **Acknowledge Warning** |

| | | | | | |
|---|---|---|---|---|---|
| F5 | F10 | | | | **Done** |

**Notes**

F5 > F2 Not executable – present but grayed out.

F5 > F3 > F1 Not executable – present but grayed out.

F5 > F4 > F2 Not executable – present but grayed out.

F5 > F5 Not executable – present but grayed out.

F5 > F6 Not executable – present but grayed out.

F5 > F7 Not executable – present but grayed out.

At the 2nd through 5th menu levels, F10 will always be present as a "Done" button. The "Done" button takes the user up one tier in the navigation structure.


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## Command Display Menu Navigation and Functionality

The Command Display menu navigation, and functionality upon which it acts, is illustrated below, for select examples:


**Figure 12** To toggle heading type.



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**Figure 13** To enter a new altitude.

**Communications Panel**

The A5-AVCS operator will need to communicate with Air Traffic Control (that is, with the participant controllers in the AOS). If this is to be facilitated using VoIP (or some other 'soft' method) a communications panel interface will be required, see illustrations below.

The operator sets the "Standby" frequency by clicking on the dial below the digital readout. Clicking the outer part of the dial, above the mid-line, increases the whole number digits. Clicking the outer part of the dial, below the mid-line, decreases the whole number digits. Clicking the inner dial, above the mid-line, increases the fractional numbers. Clicking the inner dial, below the mid-line, decreases the fractional numbers.

Clicking the button between the two digits has the effect of moving the Standby frequency to Active, and the Active frequency to Standby. If multiple VHF channels need to be incorporated later, access to these can be added in the space below the Active frequency readout.

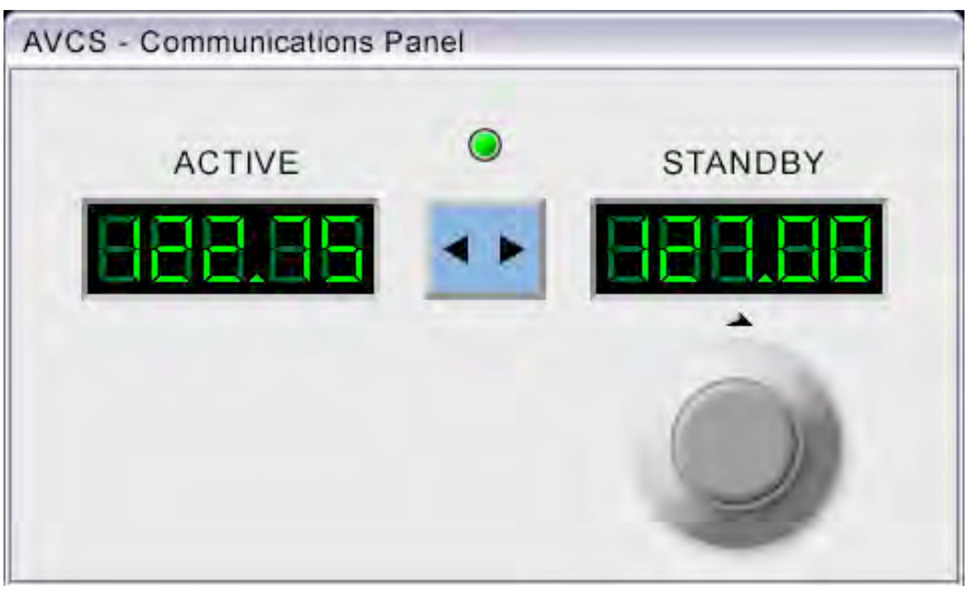


**Figure 14** Communications Panel, normal operational mode illustrated.

The additional user interface elements required to instantiate the communications panel are illustrated below, respectively, what the panel should look like when ***not*** active/available to the operator; the movement – clockwise and counter-clockwise – of the tuning dial, resulting from a click in one of the 4 ‘quadrants;’ the action of the frequency switching button (shown depressed); and the range of digits possible for the frequencies.

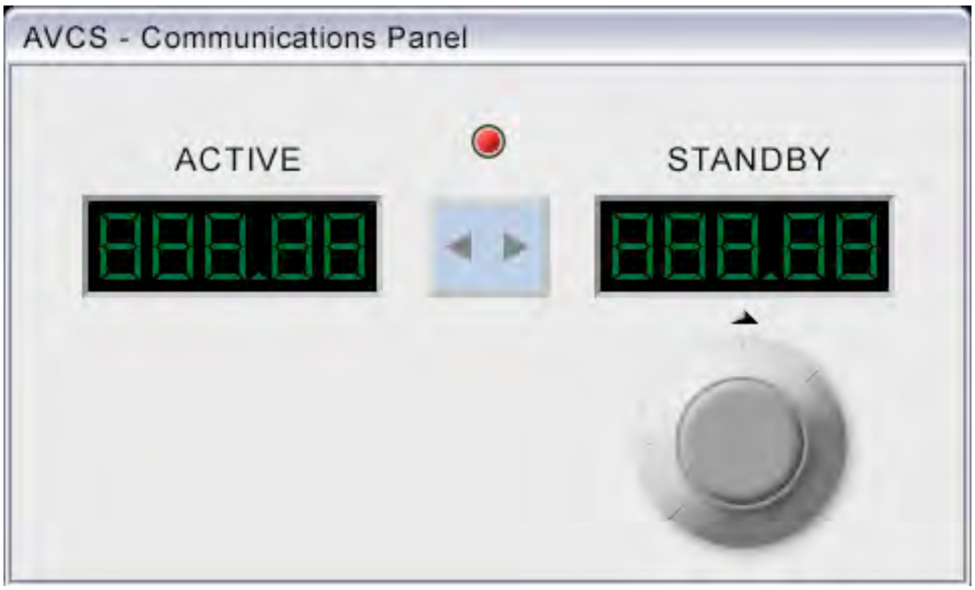


**Figure 15** Communications panel, not available.


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**Figure 16** Frequency tuning dial actions illustrated, L to R - CCW, CW, neutral.

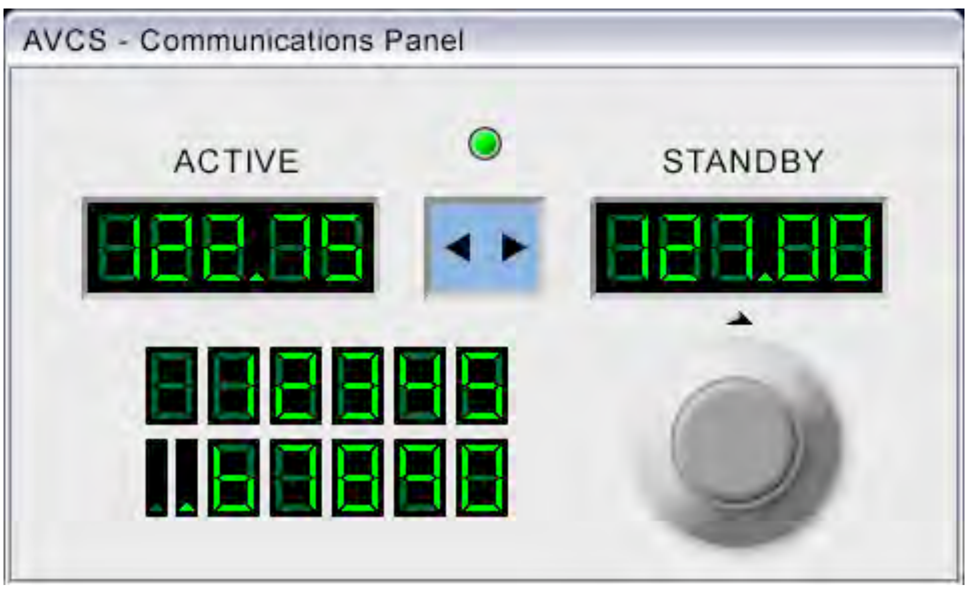


**Figure 17** Frequency switching button shown depressed, along with number set.

Based on use of a 30” Cinema Display, the Communications Panel should be 480 (W) x 288 (H) pixels in size (at 96 pixels per inch), equal to 5 in. x 3 in.


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**Flight Control Hardware**

At its most basic level, the Altair flight control hardware consists of a series of levers, a control stick (joystick), and rudder pedals. One lever controls flap movement, the others a variety of power and engine functions, some not essential for A5 simulation near-term. The same is true for a variety of functions initiated through a series of buttons atop the control stick. Accordingly, what I have attempted to do below is first, briefly cover ***what hardware is desirable*** to have, keeping in mind that later we will want to enhance functionality, and second, describe the immediate, minimum hardware control ***functionality*** needed for A5.

In terms of flight control ***hardware*** that will accommodate our near ***and*** far term needs, we need:

- One or more control boxes that have 4 levers available. The Altair uses one each to control flaps, feather/shut-down, engine power, and speed.
- A 4-way control stick (joystick) with 3 buttons across the top, a single side button on the right, and a trigger. The Altair uses the control stick to make pitch and heading changes, the three buttons to set landing configurations, trim, and SAS on/off, the single button on the right for radio transmission, and the trigger for a variety of mode specific functions.
- Rudder pedals, that as best I can tell work in the traditional manner, including toe braking.

In terms of flight control ***functionality*** needed near-term for A5, several requirements are driven by the degree to which flight elements are automatically computed and input to the aircraft, transparent to the operator and his or her control stick inputs. Tom has advised that incorporating rudder pedals is to be avoided, as what would be the result of these inputs is automatically computed (by a control stick movement or data change), and transparent to the operator.


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Accordingly, as best I can determine we need the following at a minimum:

- A Power/Speed lever that adjusts the engine to increase/decrease speed.
- A Control Stick that permits pitch and heading inputs.

With the hardware ***and*** functionality needs in mind, I have shown components below that I believe will satisfy our needs in both areas – near and long term – and provide us with a 'generic' hardware interface for other UAV models.

**Figure 18** USB Control Stick.
Fighterstick USB Joystick,
(#3768) AVshop.com

**Figure 19** USB Throttle Box.
GoFlight GF-TQ6 Throttle System,
(#5588) AVshop.com

Click the link in the caption for complete details.

The above two items, plus a keyboard, could be mounted on a 1" high panel (wood or maybe Plexiglas) to secure each in place, and provide a 'slot' underneath to accommodate the cabling.


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