Attachment 2 (Control Station and RC) to Application for Certificate of Authorization (COA) Reference COA Draft #2608 for the U.S. Army Aeroflightdynamics Directorate RMAX Unmanned Aircraft System at Moffett Field, CA

1. Introduction

The AFDD Autonomous Rotorcraft Project operates two Yamaha RMAX helicopters (Fig. 1-1). This document describes the mobile ground control station, RC transmitter, and autonomous control system engagement.

Fig 1-1. AFDD Autonomous Rotorcraft Project RMAX helicopter in operation at Fort Hunter Liggett in California.

2. Mobile Ground Station

A dedicated mobile ground station enables the ARP team to be self-supported for conducting research both at Moffett Field and at remote locations (Figs. 2-1 to 2-3). The mobile ground station has four operator workstations, a vibration-isolated equipment rack, sound system, UHF trunking radio system for communication with the external crew and the ATC tower ground frequency, external mast antennas, roof-mounted tracking camera, weather station, 7000W generator with an approximately 20 hr endurance, storage cabinets, tool set kept in a shadowed toolbox for inspection, a tie-down area for the helicopters and other equipment, and a hoist system for lifting the aircraft on and off a rolling work stand. Two roof-mounted 13,500 BTU air conditioning/heat pump units maintain the environmental conditions inside the ground station.

Fig 2-1.Mobile ground station.

Fig 2-2. Ground station interior (front).

Fig 2-3. Ground station interior (rear).

The ground station equipment rack contains the majority of the equipment necessary for operations. At the bottom of the rack are two uninterruptible power supplies, which guarantee at least 20 minutes of operation following a generator failure. There is an Ashtech Z-sensor GPS base station. There is a single computer configured as a multi-seat workstation that drives three of the workstations. There is a Mac mini which drives the fourth workstation. A DVI recorder records the Situational Awareness (SA) display and is triggered by the data recording. A GPS-based NTP time server supplies a time code to synchronize all of the system component clocks including the aircraft. A 2-to-8 DVI splitter is used to distribute the SA display to the five monitors and the DVI recorder. A rack-mounted circuit breaker panel controls power to individual system components.

Not included in the equipment rack are the radio modem, amplified 802.11g, and trunking radio systems – these are mounted elsewhere to be as close to the transmit/receive antennas as possible.

The ground station is equipped with two operator stations and two mission specialist stations. Each workstation is equipped with two displays (Fig. 2-4). The upper display in each case is the SA display so that each team member can easily status and progress of the flight test. A fifth SA is mounted in the visitor gallery near the doorway.

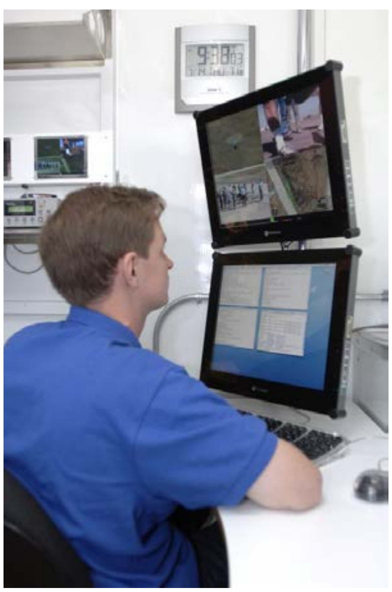

Fig 2-4. Operator workstation.

2.1 Situational Awareness (SA) Display

The SA display enables each team member to easily monitor status and progress of the flight test.

The SA display includes five major components. The first component is the GPS-based moving map display. The base of the map is typically geo-rectified satellite imagery but can also be flight charts, topographic maps, or combinations of the above. The map graphically displays both the commanded and actual flight path and heading. The aircraft position data are updated at 10 Hz with a typical delay of less than 250 milliseconds. Also included in this display are the current GPS location and speed in digital format. Real-time wind speed and direction, as measured at the ground station, are shown in the lower left corner. Lastly, an inset displays text messages that can be generated elsewhere in the system; e.g., messages from a mission planner giving status and intent.

Fig 2-2. Screen capture of SA display in ARP ground station during autonomous landing; clockwise from lower right: ground station tracking camera, moving map display including planner messages, computer-generated view of helicopter driven by telemetry stream, live digital image stream from on-board camera, status and warning lights (bottom).

The second component is a tracking camera display generated by a roof-mounted pan/tilt/zoom camera. This camera is driven based on the aircraft GPS location.

The third component is an animated view of the helicopter driven by the telemetered aircraft state data. This display also shows the intended flight path, ground plane, and scanning laser returns.

The fourth element is the onboard camera display. This image is driven using a JPEG stream from the onboard camera. The image update rate varies with telemetry quality but is typically 2-7 Hz.

The last element is the status and warning display along the bottom edge of the SA display. This display shows the current system engage status; GPS health; aircraft system health; fuel status; weight-on-wheels switch state; telemetry health; RC transmitter status; aircraft generator supply voltage status; aircraft engine temperature; and density altitude, temperature and dew point as measured at the ground station.

3. RC Control

The Yamaha RMAX transmitter is shown in figure 3-1. This transmitter is purpose-built by Yamaha for use with the RMAX. The transmitter is ruggedized, with a metal housing and is weather-sealed.

The transmitter is configured as a typical helicopter RC transmitter with collective and yaw control on the left and cyclic on the right. Trim adjustment can be made for the four axes. RPM trim adjustments can be made via a covered pot at the top of the transmitter. On the upper right edge is a switch that is used for engaging and disengaging the autonomous flight control system. A red momentary switch in the upper left is used to kill the engine. Directly adjacent to the engine kill is a rotor air brake switch which commands the collective to its full down position to help slow the rotor once the vehicle has landed.

The transmitter frequency is in the 72 Mhz band. RMAX tail no. 444 uses 72.11 Mhz (Ch 16) and tail no. 445 uses 72.13 Mhz (Ch 17). The setting can be changed between these two frequencies using a screwdriver in a rotary switch on the back of the transmitter.

Fig 3-1. RMAX RC transmitter.

4. Autonomous Control System Engagement

Reliable, efficient crew coordination during engagement of the flight control system is critically important. The flight control system has been designed to provide a transient-free engagement and to do so only when the system has been properly armed by the GSO and manually engaged by the EP. The steps for engagement are as follows:

1. The project manager (PM) obtains verbal confirmation from the team members that they are READY to engage. This requires that the ground station operator (GSO) clear any faults from the flight control system and that the other team members have any desired observation or recording software ready for use. It also requires that the engage switch on the RC transmitter be out.

2. Upon receiving confirmation from all team members, the PM instructs the GSO to ARM the flight control system. Software monitors prevent the system from arming if any system faults still exist or if the engage switch on the RC transmitter has been left depressed.

3. The GSO arms the system at which time an audible tone and voice advisory are automatically sounded to alert the EP and the ground station crew. The system engage status is also indicated on the SA display. The audible tone and voice are sounded to the ground station crew through a speaker system and to the EP via the trunking radio system and with an outdoor speaker as backup.

4. The EP maneuvers the RMAX into a hover that is stable enough that he feels he can safely remove his hands from the control inputs for the few seconds necessary to engage the system. (Note that for autonomous takeoff the EP positions the collective to the bottom stop instead) The engage button has no effect unless the GSO has properly armed the system.

5. Once a stable hover is achieved, the EP presses the engage switch on the RC transmitter. An audible tone and voice advisory are automatically sounded when the system is engaged.

The EP can disengage the system at any time by depressing the engage switch on the RC transmitter. Doing so causes the RMAX to immediately revert to normal RC control. An audible tone and voice warning are automatically sounded when the system is disengaged.

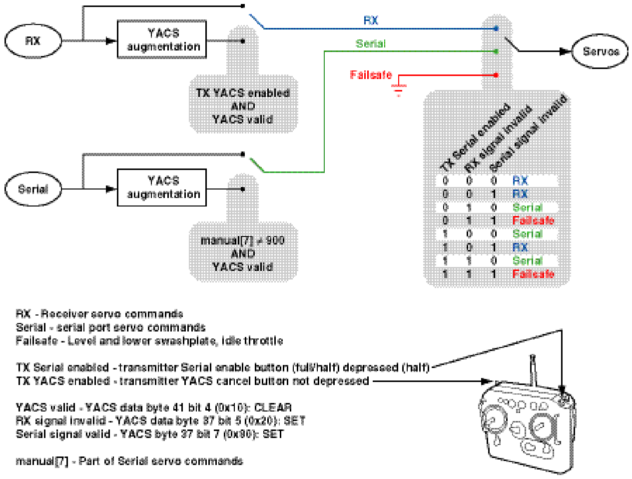

Figure 4-1. RC transmitter engagement button and RMAX engagement logic.