ELECTRONIC SYSTEM

The Shadow 200 TUAV System is equipped with an electronic system consisting of the Airborne Computer Equipment version 2 (ACE II Box), Flight Control System (FCS) Sensor, and FCS Servos.

AIRBORNE COMPUTING EQUIPMENT

The ACE II Box provides signals to Data Links, FCS Servos, Payload, and Flight Control Sensors. It s comprised of the Flight Processor Card (FPC), Mission Processor Card (MPC), Integrated Measurement Unit (IMU) (Accelerometers, Rate Gyros), Magnetometer and the Global Positioning System (GPS).

FLIGHT PROCESSOR CARD: The Flight Processor positions the AV control surfaces (actuated by the servos). The flight processor contains an autopilot program that generates pulse-width-modulated (PWM) signals. These signals control the pitch, roll, yaw, and throttle of the AV. This autopilot can also support hold or preprogrammed/emergency modes. The autopilot accepts heading (or roll), altitude, and/or airspeed input and maintain desired flight parameters by supplying commands to control pitch and roll. The Flight Processor also reads the external FCS sensor and internal sensors and reports the current AV attitude and location.

MISSION PROCESSOR CARD: The mission processor card contains two processors; the Mission Processor and the Payload Processor.

MISSION PROCESSOR: The Mission Processor controls the AV flight mode. AV flight modes fall into two categories: GCS Flight Control and Emergency Navigation Flight.

- **GCS FLIGHT CONTROL MODES**

  The GCS uses one of five GCS Flight Control Modes to control the AV in real time. Only one mode may be selected. One good uplink channel to the AV must exist to select a mode. If both uplinks are lost for two seconds, the AV will enter either Return Home (Return to Base) or Glide mode. Entry into Return Home (Return to Base) mode can be delayed by operator choice for a total of 32 seconds (if chosen before loss of both links). The five possible flight control modes are: knobs mode, points navigation mode, flight plan mode, TALS Loiter mode, and auto-launch mode.

  - **KNOBS MODE** is the most common mode for controlling the AV on a mission. In this mode, the AVO controls the AV by selecting the desired altitude, airspeed, and either heading or bank angle. Historically, the AVO used knobs on the AVO panel to make this selection; hence, it has come to be known as “knobs” mode. The altitude, airspeed, and heading commands are sent to the autopilot flight processor, where the outer loop applies gains and limits to keep the AV in stable flight at the indicated parameter values, similar to orbiting a point, where the altitude, airspeed, and bank angle commands are sent to the autopilot processor.
  - **POINTS NAVIGATION MODE** upon initial selection the point is placed 3 km in front of the AV and holds AV in a 1.2 km radius for a fixed interval. The Flight Controller receives and executes this mode. If no uplink is present when selecting “Points Nav”, the AV will enter the current emergency mode selected. Any of the following will inhibit Points
  - **FLIGHT PLAN MODE** (also called Preprogrammed Way Point Mode) causes the AV to execute a preprogrammed flight plan consisting of a series of waypoints and legs between them. Table 3 describes the data associated with each waypoint. TALS Loiter MODE commands the AV to proceed to a pre-loaded acquisition point and loiter.
  - **AUTOLAUNCH MODE** commands the AV to execute its internal launch routine, which is to increase RPM, holds launcher pitch angle, and aim for a point in the sky directly

ahead of the LAU. This mode may only be selected once preflight is complete and the AV is ready to launch. It does not command the LAU to launch. The Crew Chief manually performs the launch command.

The Mission Processor accepts the flight plans and stores them in nonvolatile memory. It also implements the capability to read memory flight plan waypoints and legs back to the GCS. Upon selection of this mode, the Mission Processor determines the most appropriate source of AV location information and actively navigates the AV through the flight plan. AV position is computed 50 times per second. When executing a flight plan, the GCS compares AV position with desired flight plan and accordingly adjusts heading, air speed, and altitude. The AV heads to the first waypoint along a direct vector from the current position using the present or last valid commanded airspeed and altitude. After over flying a waypoint, the AV will then enter orbit at the selected airspeed and altitude for the amount of time selected by the AVO. If no loiter has been ordered, (zero orbit time selected), the AV will proceed to the next waypoint, changing airspeed, altitude, data link, recorder, and payload status as commanded by the program. The AV navigates to stay as close as possible to the desired course. The effects of wind at altitude are included in the airspeed and altitude calculations. GCS uplink is not necessary during Flight Plan Mode; the AV will execute the flight plan and attempt to return to the last commanded manual flight mode after completion. If no uplink is present at that point, the AV will enter either Return Home (Return to Base) or Glide mode. Any of the following will inhibit Flight Plan Mode: Generator Fail, Battery Fail, Ignition Fail, Autopilot Fail, or Flight Controller Self-Test fail. If the GPS is not available for any reason, the Flight Processor will automatically default to Dead Reckoning until the GPS source can be utilized.

- **EMERGENCY NAVIGATION FLIGHT MODES:** Emergency Navigation Flight has four modes: Return Home (Return to Base), Return Home Delay, Glide, and Take Off.

  - **RETURN HOME (RETURN TO BASE) MODE**. The AVO has the capability to plan and upload a return home plan that consists of multiple waypoints. The VCS Mission Planner supports the creation, editing, upload, and download of a Return Home Plan (RHP); similar to how mission plans are created and uploaded. The GCS uploads Return Home (Return to Base) information and sends it to the AV at the command of the AVO. The Flight Controller is responsible for reception and validation of the uplinked program and for program execution if the link is lost. The Flight Controller will command Return Home (Return to Base) Mode upon loss of both command uplinks from the ground station after a GCS-determined 2 or 32-second delay. RETURN HOME emergency flight mode will cause the return to base to be executed after a 2 second loss of link.
  - **RETURN HOME DELAY** emergency flight mode will cause the return to base to be executed after a 32 second loss of link.
    Return Home (Return to Base) consists of the following steps:
    1. AV executes the Return Home Plan that was loaded from the GCS.
    2. AV flies at the specified altitude and airspeed along the Return Home flight path to the Return Home point contained in RHP.
    3. AV spirals up/down to final holding altitude as commanded by the RHP loaded.
    4. AV circles at final holding altitude until GCS communication is reestablished or fuel is exhausted.
  - **GLIDE MODE.** The AV enters Glide Mode upon link loss if any conditions inhibiting Return to Base mode are present. AV control surfaces deflect in the appropriate directions to maintain wings level; flaps remain where they are set; throttle is set to idle

and airspeed Knobs Mode is selected with the commanded airspeed set to AV optimum glide speed. The AV will exit this mode if communication is restored.

- **TAKE OFF/CLIMB MODE**. The AV enters Take Off/Climb Mode upon link loss when the last valid frame received commanded the AV to be in Take Off/Climb Mode and air speed is 60 knots or greater. If AV speed is less than 60 knots, the AV will enter the Glide Mode. In Take Off/Climb mode, the AV is given the following commands:
  1. Maintain current heading.
  2. Full throttle.
  3. Pitch command to nose up.
  4. Maintain climb for 1,000 feet (command altitude to current altitude + 1000 feet).
  5. Transition to Return Home (Return to Base) Mode following attainment of above altitude.

GPS

The SAASM capable GPS receiver is a P(Y) code, twelve channel continuous tracking unit. It is a circuit card, physically located within the ACE II housing that passively receives GPS satellite constellation signals and determines AV position and velocity in earth-centered, earth-fixed coordinates. It is capable of 5 meters (16.4 feet) positional accuracy, 0.1 meters per second velocity accuracy, and one microsecond time accuracy. It is 3.14” x 3.82” x 0.5” and weighs 0.204 pounds. Unit information is sent to the ACE II once each second.

FLIGHT CONTROL SYSTEM SENSOR

The ACE II Box uses one external sensor, the magnetometer (MMU), to measure parameters used in controlling AV flight. The signals from this sensor are used by the FCS control loops and any measurement changes cause the servo/actuators to move the flight surfaces or throttle according to commands. If the sensor malfunctions, a failure signal is sent to the GCS.

The MMU is located on the left-hand side rail and indicates AV directional heading relative to magnetic north. It functions as a magnetic compass and compensates for movement and changes along the AV horizontal and longitudinal axes during flight. The MMU consists of three coils, perpendicular to one another, representing the three vector components of the magnetometer in the plane of operation. These three coils, or magnetometers, measure the three projections hx, hy, and hz of the horizontal component h of the earth’s magnetic field. To maintain the magnetometer axes in the horizontal plane, the components are compensated using the hz component of the system. An electronic circuit enables measurement of the resulting hysteresis cycle and dissymmetry. A negative feedback circuit zeros the field inside the winding. The negative feedback field current, and hence the magnetic field value, is measured.

The ACE II Box contains a number of internal sensors used to determine the altitude and airspeed of the Shadow 200 AV. These sensors can be placed in two groups, Inertial Measurement Unit (IMU) and Air Data Sensor (ADS).

The IMU consists of three solid-state rate gyros and three solid-state accelerometers. The rate gyros are used to measure angular rotation (roll, pitch and yaw) caused by both AV motion and earth rate induced motion. The accelerometers measure the apparent g force on the AV. This force is a combination of earth gravity and AV accelerations due to motion. These rate gyros and accelerometers require no external calibration. The ACE II Box uses the data from these sensors and the GPS position and magnetometer to determine both the AV attitude and calibration constants needed for the rate gyros and accelerometers.

The ADS contains both a barometric altitude sensor and air speed sensor. These sensors are used by the autopilot to determine the current altitude of the AV and its indicated airspeed. These sensors require no calibration. The altitude as measured by the ADS is corrected for non-standard sea level pressure using the GCS.

AIR VEHICLE FLIGHT CONTROL SYSTEM

The FCS provides AV stabilization by computing AV sensor data and guidance commands from the GCS/PGCS and the surface servo-actuators. Stabilization and loop closure on commands of pitch angle, roll angle, yaw rate, altitude, airspeed and heading are performed by the Flight Processor Card (FPC) in the ACE II box. The FCS is comprised of an FPC, Mission Processor Card (MPC), servo-actuators and FCS sensors. The FCC board is responsible for Point NAV, Waypoint NAV and Return Home functions and commands. There are eight servo actuators and five FCS sensors. The FTS is comprised of a recovery parachute, deployment initiation mechanism (DIM), and ground release mechanism (GRM). The eight servo actuators are the Servo Ele-rudder Units (SERU) 2 each, Servo Aileron Left (SAL) 1 each, Servo Aileron Right (SAR) 1 each, Servo Flap Units (SFU) 2 each, Servo Throttle Unit (STU) 1 each and Servo (Nose) Wheel Unit (SWU) 1 each. Below is a list of internal and external FCS sensors.

- Three-axis accelerometer
- Three-axis rate gyro
- Airspeed Transducer
- Barometric Pressure
- Magnetometer
- The Inertial Measurement Unit (IMU) uses inputs from the FCS sensors to compute attitude.
- The FPC is also responsible for reading the flight related internal sensors and internal Selective Availability Anti-Spoof Module (SAASM) capable GPS
- Additionally, a temperature/humidity sensor is located on the underside of the fuselage within the aft fairing
- The WP titled Electronic System Theory of Operation of this DTM covers the FCS in more detail

FLIGHT TERMINATION SYSTEM

The FTS function is to recover the AV with minimum damage during an emergency flight termination. The recovery parachute is located on the fuselage underside. During flight, it is stowed folded under a cover attached to the fuselage with an open-faced hinge mechanism. The open-faced hinge mechanism is held closed by a collette which is attached to a deployment latch inside the A/V. The intermediate riser from the recovery parachute fastens to a connector link that connects exterior bridles to interior bridles that then attach to the fuselage.

Recovery parachute's function is to recover the AV with minimum damage during an emergency flight termination. The recovery parachute is located on the fuselage underside. During flight, it is stowed folded under a cover attached to the fuselage with an open-faced hinge mechanism. The open-faced hinge mechanism is held closed by a solenoid release pin. The intermediate riser from the recovery parachute fastens to a carabineer that connects to the parachute bridle, which attaches to the fuselage.

The ACE II box, located in the fuselage, receives AVO command signals from the GCS or PGCS to release the recovery parachute. The ACE II box commands engine kill prior to chute deployment. The ACE II box then sends the command to the Power Distribution Unit (PDU), which forwards the energize command to the Deployment Initiation Mechanism (DIM), initiating parachute release. As the parachute deploys, aerodynamic forces carry it clear of the empennage and inflate the canopy. When fully deployed, the recovery parachute flips the AV upside down to prevent payload damage. When ground contact is made the GRM will release the parachute free of the AV, preventing any further damage to the A/V and payload.

Under certain AV failure conditions, the AV can autonomously command parachute deployment through the ACE II box – PDU – DIM process. These autonomous flight terminations are intended to preclude a catastrophic flight process failure from leading to the AV exiting an area without possibility of AVO intervention, or an autonomous termination on loss of both uplinks and loss of engine and impending ground contact. There are 3 separate events that will trigger an automatic chute deployment under these specific conditions. All the conditions to arm the auto chute deploy are preprogrammed as follows:

1. Total uplink loss (primary and secondary).
2. Ignition switch ON.
3. Airspeed > 30 Kts.
4. Ignition Fail (RPM 0 and Bus voltage ≤ 24).

When all of the conditions above exist, ANY of the following conditions will trigger the chute deployment:

1. UAV Altitude < 500 Ft above launched altitude, or
2. UAV Bus Voltage ≤ 19V, or
3. Dual uplink loss for 10 minutes or longer.
4. IMU sensor failure.

TALS landing is not an option due to the requirement of the airspeed downlink report required by the TALS. Attempt to deploy the FTS while the AV is at the Return Home point if all possible actions have been taken to re-establish downlink. The Chute command button must be enabled prior to being able to send the command to deploy the parachute. The parachute should be deployed above 500 feet AGL. The AV will orbit if uplink has not been established because the command to deploy the FTS will not be received by the AV. Eventually the AV will meet the conditions to deploy the FTS automatically.