TECHNICAL MANUAL
OPERATOR'S MANUAL

FOR

TEST BED AIRCRAFT, UNMANNED AERIAL VEHICLE
WITH STABILITY AUGMENTATION SYSTEM
(USAS)

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DEPARTMENT OF AEROSPACE ENGINEERING SCIENCES
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DISCLAIMER
The general format and outline for this manual was borrowed from TM 1-1520-238-10, Operator's Manual for AH-64A Apache Helicopter, Headquarters, Department of the Army, September 1996. No specific information contained within that manual was used herein. This document contains no classified information.
CHAPTER 1
INTRODUCTION

1.1 GENERAL
This manual covers operation, implementation, and maintenance of the UAV Stability Augmentation System, Test Bed Aircraft, and SAS electronics.

1.2 WARNINGS, CAUTIONS, AND NOTES
Throughout this document, important items are highlighted using the following:

WARNING
An operating procedure or condition which, if not followed may result in personal injury or catastrophic damage to the aircraft.

CAUTION
An operating procedure or condition which, if not followed may result in damage to the aircraft or systems.

NOTE
An operating procedure or other item which is important to highlight.

1.3 APPLICABILITY AND USE
This manual is intended to ensure the proper operation of the USAS Aircraft and associated systems. This manual must be readily available when operating the aircraft or applying electrical power to any of the systems. In addition, all items contained in Chapter 9 (Emergency Procedures) as well as all warnings, cautions, and notes, should be committed to memory. Normal operating procedures must be followed when operating the aircraft and systems, unless specific emergency or unusual conditions exist.
CHAPTER 2
AIRCRAFT AND SYSTEMS DESCRIPTION

SECTION I - SYSTEMS OVERVIEW

2.1 GENERAL
The USAS Test Bed Aircraft (TBA) is a single engine, radio-controlled, electric powered experimental unmanned aerial vehicle. It is specifically designed for tests of pitch rate stability augmentation systems for UAVs.

2.2 GENERAL ARRANGEMENT
Figure [xx] depicts the general design of the aircraft.

2.3 FUSELAGE
The fuselage consists of a composite aerodynamic shell, a channel structure, and the integrated backbone assembly. The backbone assembly is a CNC machined aluminum channel which runs longitudinally along the centerline of the fuselage. All primary loads (wing lift, landing gear, motor mount, tailboom mount, and CG apparatus) are transmitted directly to the backbone. Attached directly to the backbone are the motor mount, the nosewheel steering bearing mount, the NWS servo, the wing mounts, tailboom adapter, CG control apparatus, and fuselage channel. The fuselage channel is a carbon/kevlar composite channel bonded to the aerodynamic shell, which provides the purpose of CG control housing, main battery mount, and fuselage-to-backbone interface. The aerodynamic shell is a lightweight glass-fiber composite shell which houses the aircraft systems and reduces drag. In addition, it provides a cooling air channel for the motor, speed control and main batteries.

2.4 WINGS
The wings are of tapered unswept design with 3 degrees dihedral and 4.5 ft² total area. The airfoil section transitions from a S4233 section (2% camber) at the root to an SD7062 (4% camber) at the tip. The wing has 3 degrees of geometric washout, and 1 degree of aerodynamic washout (twist). The overall aerodynamic design was chosen for good L/D and a nearly elliptic lift distribution. The structure is primarily sandwich core construction using glass-fiber composite over white foam. The center section and spar sections are reinforced with carbon fiber composite. The bending moment is transmitted to the center section through a carbon fiber laminated plywood spar of 50% span. Roll control is provided by 40% span ailerons powered by high speed metal gear R/C servos. The servos are mounted directly to access panels attached to the underside of each wing panel. The wing mounting system consists of a single plywood pin at the leading edge and two mounting holes for 1/4" bolts at the rear. Airspeed measurement is facilitated by a wing mounted pitot-static probe mounted in the port wing.

2.5 TAIL SECTION
The tail section is mounted to the backbone using a tailboom adapter. The design facilitates adjustment of the aircraft tail volume using multiple mounting positions on the adapter. Five positions allow the tail to be moved between 26 and 30 inches from the
wing aerodynamic center. The tail surfaces are balsa over foam sandwich core construction, with glass-fiber composite for surface finish. The tailboom consists of an aluminum channel, to which the elevator and rudder servos are mounted, as well as the stabilizer and vertical fin. A tailskid is mounted to the rudder servo mounts to protect the servos during takeoff and landing.

2.6 LANDING GEAR
The main landing gear consists of a carbon-kevlar composite strut with lightweight 3" diameter wheels. The nosegear is steerable for directional control on the ground and consists of a 5/32" wire spring strut, a lightweight 2 1/2" wheel, and steering servo.

2.7 POWERPLANT
The main propulsion system consists of a 1.4 HP electric motor, an electronic speed control, and a 30-cell, 36V Ni-Cd battery. The propulsion system drives a 14" x 8" propeller.

WARNING
Improper operation of the propulsion system may result in damage to the aircraft or propulsion system, or personal injury. Never stand in front of the aircraft when the fuse is installed. Never install the fuse without first applying power to the flight control system and verifying that the throttle is set to IDLE. Never service the propulsion system with the fuse installed. Only qualified personnel must operate or service the propulsion system.

2.8 FLIGHT CONTROL SYSTEM
Flight control is provided by means of a 72 MHz radio control receiver and transmitter, and miniature electric flight control servos. The transmitter has two control sticks, which control directional control via the flight controls, and the throttle setting. The right hand stick operates the elevator (pitch control) and ailerons (roll control), and the left hand stick operates the throttle, rudder (yaw control) and nosewheel steering. The rudder and nosewheel steering are linked to the same function and move in unison. The sticks are self-centering, except for the throttle, which has approximately 30 detents. Each stick has an associated trim control lever, which may be used to adjust trim during operation. Additionally, the pilot transmitter function 5 is controlled by a knob, allowing adjustment of proportional pitch rate gain, and function 6 is controlled by a switch on the left hand side, which activates/deactivates the SAS. When the switch is moved towards the pilot, the SAS is deactivated, and the command override function is activated. The command override function automatically moves the CG shuttle to the full forward position and disables the SAS. Command override is automatically enabled if the SAS system power drops below 4.5 V.

WARNING
Aircraft taxi, runup, or flight must be performed only by qualified personnel. A flight control operational check and radio range check must be performed before takeoff.
CAUTION
The pilot transmitter power must be activated prior to activating the aircraft flight control system, to prevent uncommanded actuation of the servos, and possible damage to the flight controls.

2.9 STABILITY AUGMENTATION SYSTEM
The stability augmentation system (SAS) is designed to provide inflight pitch rate damping, and flight data acquisition. The system consists of a microcontroller unit (MCU), sensor assembly, memory module, and radio control receiver. The MCU is a Microchip PIC18F452 controller, operating at 40 MHz. The system software is contained onboard the MCU in program FLASH memory. Data acquisition is facilitated by the 512 kB memory module. The sensor assembly provides pitch rate, vertical acceleration and airspeed data, which are input to the analog-to-digital conversion module onboard the MCU. The radio control receiver transmits the CG control command, derivative gain, and data on/off command to the MCU via a pulse-position-modulation (PPM) signal and interconnect cable.

WARNING
Should the SAS system fail inflight, loss of control may result. Pilot and systems operator action must be immediate to prevent aircraft destruction, damage to property or personal injury. The SAS may be operated during takeoff and landing, however, sensor noise due to vibrations transmitted through the landing gear may cause erratic behavior. This is particularly hazardous during takeoff, due to high speed and high power settings. A SAS malfunction near the ground may be catastrophic as the pilot may not have sufficient reaction time to take corrective action. If system voltage is lost or drops below 4.5 V, the command override function is automatically activated. The SAS battery must be recharged after no more than 30 minutes operation to prevent inadvertent activation of command override during flight.

CAUTION
The wiring connections to the SAS must be thoroughly checked for proper installation prior to applying power to the system. Failure to do so may result in damage to the electronics or flight control systems.

NOTE
Upon activation of the SAS, the elevator may exhibit momentary instability. The system should be reset prior to flight operations, to ensure that the memory module is cleared and set to zero.

2.10 CG CONTROL SYSTEM
The CG control system is designed to facilitate inflight testing of reduced static stability. The system consists of a CG balance weight shuttle, control servo, and integrated rack gear and roller track. The rack gear and roller track are an integral component of the backbone, and provide the longitudinal track for the shuttle, and the rack gear to which the servo engages. The shuttle and servo move through 11.5" longitudinally as the pinion gear on the servo rotates against the rack. The system effectively moves the center of
gravity of the aircraft fore and aft by approximately 0.7" at specification weight. This constitutes a 10% change in static margin.

**WARNING**
Prior to takeoff, the system operator must verify that the CG control is placed in the full forward position. Failure to do so may result in loss of control after takeoff. CG control actuation in flight must be performed with care, as the longitudinal trim of the aircraft, and inherent aircraft stability are affected. CG control actuation in flight must be coordinated between the pilot and systems operator. If the pilot activates command override inflight while the CG position is aft, a momentary or total loss of control may result. The command override should only be activated after the systems operator has commanded the CG to the full forward position, except during an emergency.

**CAUTION**
Excessive operation of the CG control system may result in damage to the CG control servo or wiring harness. CG operation should be limited to preflight testing and controlled operation during flight to minimize loads on the system.

**NOTE**
The command override function moves the CG to the full forward position, however, the shuttle may not move all the way forward. If the CG system is not to be used in flight, the systems operator should manually move the CG shuttle to the full forward position, then deactivate the system.

### 2.11 SYSTEMS CONTROLS
The systems operator actuates the CG control system and data acquisition via the systems operator's transmitter. The CG control is operated using the left hand stick, function 3. The full forward stick position moves the CG to the full forward position (when enabled by pilot function SAS-ON), and full aft moves the CG shuttle to the corresponding full aft position. The transmitter function 5 knob controls the pitch rate derivative gain setting. The data acquisition system is operated by the function 6 switch. When the switch is moved towards the operator, the data acquisition system is activated. Each time the switch is toggled from OFF to ON, a mark is placed in the data.

**SECTION II - PROPULSION SYSTEM**

![Figure 1 - Propulsion System](image-url)
2.12 MOTOR
The main propulsion motor is an AstroFlight 661 direct-drive cobalt permanent magnet DC motor. The motor is rated at 1200 W (1.4 HP) continuous power at 35 amps and 36 volts. The motor is 3” in length and 2.1” in diameter, and weighs 22 oz.

CAUTION
The motor is rated at 35 amps continuous power; however the power system is capable of supplying greater than 35 amps to the motor. Operation at above 35 amps for extended periods of time may shorten motor life or cause premature failure of the motor, damage to the magnets or accelerated brush wear. Full power operation should be limited to takeoff and short duration use during flight.

2.13 PROPELLER
The recommended propeller is a 14x8 APC pattern propeller. Other propellers may be used, however, reduced performance may result.

2.14 SPEED CONTROL
The motor speed is controlled using a digital PWM speed control, AstroFlight 204D. The controller regulates power to the motor using 2800 Hz PWM switching. The controller is connected to the throttle channel of the pilot receiver via a control cable. It is rated for 60 amps continuous current at 72 volts, and 75 amps for two minutes.

WARNING
Radio interference may cause the speed control to supply power to the motor without advancing the throttle at any time. Personnel should remain clear of the front of the aircraft when the fuse is installed.

2.15 FUSE
A 40A fuse is used to prevent system current from exceeding 40 amps for an extended period of time. During normal operation with the recommended propeller and batteries, this current will not be exceeded; however, current may exceed 40 amps if the propeller's rotation is blocked. The fuse is used as a safety device to prevent accidental operation of the motor during ground operations. The fuse should be installed only for taxi and takeoff, and removed immediately after landing.

2.16 MAIN BATTERY
The main battery consists of two 15-cell nickel-cadmium (Ni-Cd) packs, mounted to each side of the fuselage channel. The battery provides a nominal voltage of 36 volts, and provides power for 5-7 minutes of flight. Flight time varies, depending upon power settings. The Ni-Cd packs should be discharged when not in use, and charged at 4 amps for quick charging prior to use. Batteries should be allowed to cool to less than 100 degrees F (warm to touch) prior to charging/discharging.
NOTE
Flight at elevated power settings for extended periods of time may cause batteries to overheat, reducing performance and endurance.

SECTION III - FLIGHT CONTROLS

2.17 AILERONS
The ailerons provide roll control of the aircraft. They are mechanically independent, each with its own metal gear, high-speed servo and associated linkage. Both servos operate from the same transmitter channel (Channel 1). The servo output arm is attached to the servo output shaft with a single machine screw. The linkage is connected to the servo with a pin clevis and to the aileron control horn with a ball joint. The servo is mounted directly to its access panel, which is secured to the wing with four flat head screws. The wiring for the servos is routed through channels in the wing core to a common exit at the wing center section. The port aileron servo shares a common compartment with the wing mounted pitot-static probe. The ailerons are rigged to provide differential throw. Full up deflection is set to approximately 1/2" whereas full down is about 3/8". The differential throw reduces adverse yaw effect during aileron deflection.

CAUTION
The aileron servo arm screw should be secured using threadlocker (LocTite). The condition and security of the output arm should be periodically checked, particularly after any incident which may have applied excessive stress to the arm, such as an off-runway landing. The aileron access panel is a structural component of the wing. The panel screws must be of the proper allen head flat head design, and must be torqued to the proper specification (30-50 oz-in) to ensure the structural integrity of the wing.

Figure 2 - Aileron and Servo
2.18 ELEVATOR
The elevator is used for pitch control. It is also the primary SAS actuator. The elevator is controlled with a high speed digital servo, specifically designed for use with gyro stabilization systems. The servo is mounted on brackets attached to the tailboom. The elevator linkage is connected to the servo via a pin clevis and to the elevator control horn with a ball joint.

CAUTION
The SAS system outputs a 200 Hz PWM signal compatible with the digital servo, but not compatible with standard servos. Connecting a standard servo to the SAS output without reducing the PRF in the software may damage the servo, or result in erratic servo operation.

Figure 3- Tail Assembly

2.19 RUDDER AND NWS
The rudder is used for yaw control inflight and directional control in high speed ground operation, such as during takeoff and landing. The NWS is mechanically independent of the rudder, but shares the rudder channel on the receiver (Channel 4). Both the rudder and NWS use high speed metal gear servos. The NWS servo is protected from vibrations transmitted through the nosegear with a spring loaded shock absorber in the control linkage. The servo is mounted on brackets attached to the tailboom. A tailskid is attached to the same mounts, and protects the servos from damage should the tail contact the ground during takeoff, taxi, and landing.
NOTE
The rudder and NWS do not have independent trim adjustments. If NWS trim is adjusted for ground handling, the rudder trim will be affected. Proper trim adjustment may require mechanical trim adjustments.

Figure 4 - NWS
CHAPTER 3
AVIONICS

3.1 GENERAL
The avionics package of the USAS TBA consists of the SAS electronics. The SAS electronics is a microprocessor based system specifically designed to provide artificial pitch rate damping for small UAVs. Artificial pitch rate damping compensates for changes in static margin due to weight, balance, and configuration changes, as well as environmental conditions. Additional functions, such as stall prevention, load factor limiting, and inflight gain control are also provided by the system.

3.2 MAINBOARD
The heart of the SAS electronics consists of a mainboard, to which is mounted a microcontroller unit (MCU), a diagnostic LCD display, and associated power and support electronics. The MCU is an 8-bit microprocessor with multiple input and output functions, operating at 40 MHz. The MCU stores the SAS software onboard its internal nonvolatile program memory. The nonvolatile memory allows the software to remain in memory with power off.

CAUTION
Improper handling of the SAS electronics, particularly the mainboard, may result in damage due to electrostatic discharge (ESD) proper grounding and care in handling is required to prevent damage to the sensitive electronics or to the software. Observe standard ESD prevention practices when handling the equipment.

3.3 POWER
The SAS electronics requires a regulated 5V supply. The mainboard has an onboard voltage regulator, which may be powered by 7 - 35 V DC through a coaxial power jack. 7 VDC minimum is required for SAS operation, and 18 VDC minimum is required for programming. Inflight power is provided by a 9V rechargeable Ni-Cd battery. The battery is connected to a separate modular connector mounted on the component side of the mainboard. The connector is designed so that it may be installed in either direction. The SAS electronics, including the sensor assembly draws approximately 100 mA. If direct battery power is used, the SAS electronics draws about 65 mA.

CAUTION
A separate modular connector is provided for direct power by a 4.8V battery (unregulated). The 9V battery must not be connected to this input, or damage to the electronics may result

NOTE
The 9V battery provides power for about 1 hour operation. The battery should be recharged after 30 minutes operation or two flights to ensure reliable operation of the SAS.
3.4 SENSOR ASSEMBLY
The sensor assembly (SA) is a modular component mounted to a connector on the mainboard. The SA consists of a differential pressure transducer for measuring airspeed, a rate gyro for pitch rate, and a linear accelerometer for z-axis acceleration. Additionally, the SA has onboard dynamic filtering to reduce noise. The SA receives 5V power from the mainboard, and outputs voltages proportional to measured values. The voltages are converted to numeric values using an integrated analog-to-digital conversion unit on the MCU.

CAUTION
The components on the SA are shock-sensitive. If the SA is handled carelessly or dropped, the sensitive components may be damaged. The SA may be installed in the reverse direction on the mainboard. If the SAS power is activated while the SA is installed incorrectly, damage to the SA and possibly the mainboard will result. The SA should be installed with the component side facing towards the center of the mainboard.

3.5 MEMORY MODULE
An external memory module provides data storage capability. The module uses nonvolatile EEPROM memory (512 kB) which retains data with power off. The memory module should be cleared prior to performing experimental tests, in order to ensure that only new data is recovered after flight, and to reset the memory address to zero. This is accomplished by pressing and holding button 2 on the SAS electronics. At this time a prompt will appear on the diagnostic display. Pressing button 1 confirms the operation, and pressing button 2 again will cancel. If performing the erase function with the electronics enclosure sealed, press button 2 on the enclosure until the status LED stops flashing, then press button 1. Memory erase takes about 60 seconds to complete. At the completion of the operation, the status LED will begin flashing again.

3.6 PROGRAMMING
The SAS mainboard has an onboard programmer module, which alleviates the need for external programming hardware (such as the Microchip ICD). Programming is accomplished using a serial interface and special software. The software may be downloaded from [http://www.fored.co.uk/PicProg32.zip](http://www.fored.co.uk/PicProg32.zip).

In order for the software to properly program the MCU, the configuration file must be updated. After installing the software, navigate to the software’s resident folder and open the file, Proctype.ini using Notepad. Find the [18Fxx8] configuration block and edit the ConfigAndMasks line to ConfigAndMasks=ffff,ffff,ffff,ffff,ffff,ffff, then save the file. This enables the configuration words on the MCU to be programmed correctly.

A special purpose serial cable is required to program the MCU. The following diagram shows the required connections. Connector X1A is a female R/C servo connector, or a 3x1 0.100” Molex connector. Connector X1B is a standard DB9 female connector.
Before programming the serial port configuration must be properly set. Set baud rate to 19200, and select the appropriate COM port.

Programming is accomplished by compiling the software to a .hex file format, using the Microchip IDE, then transferring the file to the MCU using the serial cable and the FED Pic software. See applicable documentation for use of the development tools.

NOTE
Programming requires at least 18 VDC. A standard 12V AC-DC wall transformer will typically output the required voltage.

3.7 SERIAL DATA TRANSFER
Experimental data is retrieved from the memory module using serial data transfer. The same cable described in section 3.6 is used for downloading data. Any terminal emulation software, such as HyperTerminal, may be used to connect to the MCU. The terminal software should be configured as follows: 19200 baud, 8 data bits, 1 stop bit, no parity. Data transfer is initiated by first configuring the terminal software to capture data, then pressing and holding button 1 on the electronics. Release the button when data transfer starts. About 15 minutes are required to download 512 kB.

NOTE
If button 2 is inadvertently pressed, a memory erase may be initiated, resulting in loss of data.

3.8 PILOT RECEIVER
The pilot receiver processes flight control commands, the command override function, and the pitch rate proportional gain. The receiver operates on the 72 MHz Aircraft radio control band. The receiver has direct outputs for servo control, but has been modified to output a PPM signal for use by the SAS electronics. The PPM signal contains timing information relating to pulsewidth commands for each servo channel. The PPM signal is routed to the SAS electronics and the internally generated PWN signals are routed to the...
appropriate servos. The PPM signal consists of a synchronization pulse, which signals the start of a series of timing pulses. The SAS electronics detects the synch pulse, and then decodes the timing pulses into flight control positions and commands. The pilot receiver is connected to the SAS electronics via jumper wires. The PPM signal and the elevator PWM signals are utilized. The remaining PWM channels are routed directly to the corresponding flight controls.

![Figure 6 - Receiver Signal Processing](image)

### 3.9 SAS RECEIVER

The SAS is configured similar to the pilot receiver. It processes the CG position command, pitch rate derivative gain, and data acquisition command. The receiver is mounted within the SAS electronics enclosure, and connected to the SAS electronics with jumper wires. The PPM signal and the CG position PWM signal are utilized.
CHAPTER 4  
SPECIAL EQUIPMENT

4.1 CG CONTROL SYSTEM  
The CG control system (CGC) is designed to facilitate takeoff with a normal static margin and flight testing at reduced stability. The system consists of the integrated backbone track and rack gear, and a sail winch servo and pinion gear, mounted to a rolling shuttle assembly. The shuttle assembly’s bearing rollers engage in the track grooves in the backbone. Forward and aft limit stops prevent the shuttle assembly from moving past the ends of the rack gear. The servo has its own battery for power, which is mounted directly to the servo, for additional weight. Additional weight is also provided by self-adhesive lead weights attached to the shuttle. The wiring harness for the servo is routed outside the channel. The wiring harness is kept taut to prevent fouling in the mechanism, using a coil spring system.

In flight, the CGC is disabled when command override is on. When the SAS is enabled, the systems operator controls the position of the CGC with the left hand transmitter stick. Each detent of the transmitter stick moves the shuttle approximately ½”. The following table shows the range of CG shift for various shuttle weights.

<table>
<thead>
<tr>
<th>Shuttle Weight, lb</th>
<th>0.6</th>
<th>0.8</th>
<th>1.0</th>
<th>1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max CG Shift, in</td>
<td>0.46</td>
<td>0.61</td>
<td>0.76</td>
<td>0.92</td>
</tr>
<tr>
<td>SM Change, %</td>
<td>5.0</td>
<td>6.6</td>
<td>8.3</td>
<td>10</td>
</tr>
</tbody>
</table>

4.2 ADJUSTABLE TAIL VOLUME  
The position and size of the tail directly affect the pitch damping effect of the wing-tail combination. In order to facilitate tests with different tail configurations, an adjustable tailboom is implemented. The tailboom adapter has five sets of mounting holes at 1” intervals. The tail assembly is attached to the adapter using two 6-32 bolts with compression spacers inside the adapter channel.

4.3 RABBIT’S FOOT  
A rabbit’s foot is affixed to the transmitter carrying handle. Flight without rabbit’s foot installed is prohibited.
5.1 GENERAL
Operating limits are based on known performance data, and are intended to prevent damage to the aircraft and subsystems. Intentional operation beyond normal operating limits is restricted to approved experimental tests performed by qualified personnel.

5.2 MOTOR AND POWER LIMITS
Full power operation is limited to a maximum of 30 seconds, before allowing the propulsion system to cool for 20 seconds at reduced power (75% throttle or less).

5.3 LOAD FACTOR LIMITS
The maximum allowable load factor is dependent upon aircraft gross weight. The maximum load factor is based upon aircraft structural limits. The maximum load factor cannot be exceeded, provided the aircraft airspeed limits are not exceeded.

5.4 AIRSPEED LIMITS
The maximum allowable flight speed is 187 ft/s (6000 ft pressure altitude).

5.5 MANEUVERING LIMITS
There are no specific maneuvering limits. Normal flight, aerobatic flight, and experimental tests are restricted to qualified personnel only.

5.6 ENVIRONMENTAL RESTRICTIONS
Rain and snow may damage the motor and electronic components, and may cause the airspeed measurement system to malfunction. The externally mounted servos on the tailboom are especially susceptible to moisture. Flight in rain, snow, or other visible precipitation is prohibited.

The motor and airspeed measurement system are susceptible to damage from ingestion of dust or other particles. Takeoff and landing from other than improved runway surfaces (paved or concrete) is prohibited. Off-runway landings are prohibited except when it is not possible to land on the runway, e.g. due to engine failure, etc.

Flight under instrument meteorological conditions (IMC) is prohibited. IMC is defined as ceiling less than 1000 feet AGL and/or visibility less than 3 nautical miles.

Takeoff is prohibited if surface winds exceed 25 KTAS.

There are no temperature restrictions; however, extremely cold conditions may result in reduced battery performance.
CHAPTER 6
WEIGHT AND BALANCE

6.1 LOADING
The maximum allowable takeoff gross weight is 15 pounds.

6.2 CENTER OF GRAVITY
The center of gravity must be located at or forward of 5.5” from the leading edge apex of the wing, when the tail assembly is mounted in the aft-most position. The apex is the point of contact with the forward wing mount, not where the leading edge exits the fuselage. The center of gravity is sensitive to the location of the main propulsion batteries. Care must be exercised when mounting the main batteries, to ensure proper location and security.

CAUTION
Failure to securely fasten the main batteries could result in loss of control of the aircraft, should one or both batteries dislodge inflight.
7.1 USE OF PERFORMANCE DATA
Performance data is given for stall speed and minimum takeoff distance. Stall speed is given with no margin of safety. Stall speed may be affected by mechanical condition of aircraft, especially the wings, soil, damage, or insects on the wings or relative humidity. Compute the stall speed by interpolating along the pressure altitude or temperature to the takeoff gross weight, then reading the stall speed at the left.

Takeoff distance is based on stall speed times 1.16, which gives a reasonable factor of safety above stall speed for takeoff. Takeoff distance is based on a 14x8 propeller. Compute the takeoff distance by interpolating the takeoff gross weight along the temperature line then reading the takeoff distance at the left.

7.2 STALL SPEED - PRESSURE ALTITUDE, STD TEMP

![Stall Speed Graph](image-url)
7.3 STALL SPEED - TEMPERATURE, 6000 FT

![Stall Speed Graph](image1)

7.4 TAKEOFF DISTANCE, 6000 FT

![Takeoff Distance Graph](image2)
CHAPTER 8
NORMAL PROCEDURES

SECTION I - CREW DUTIES

8.1 PILOT
The pilot is ultimately responsible for the safety of the aircraft and all crewmembers. The pilot must ensure that proper safety procedures and operational procedures are adhered to, including all aspects of flight planning, crew briefing, preflight, and operation of the aircraft. The primary duty of the pilot is that of aircraft control. All other duties are subordinate to this task.

8.2 CREW CHIEF
The crew chief is responsible for operational maintenance of the aircraft and associated ground support equipment. The crew chief ensures that all operational equipment is on hand during the mission, and that proper preventative maintenance is accomplished. The crew chief coordinates all ground operations.

8.3 SYSTEMS OPERATOR / COPILOT
The systems operator/copilot is responsible for operation of the systems control transmitter, including CG control and data acquisition. The systems operator must be well acquainted with flight operations in order to facilitate efficient communication with the pilot and should have some flight experience. The systems operator will be familiar with the pilot duties, and assist the pilot as necessary.

8.4 CREW BRIEFING
A crew briefing will be conducted prior to each flight. As a minimum, the pilot and systems operator will discuss the nature of operations and any special operational procedures that apply to the mission. The briefing should also include a discussion of operational terms as it applies to the particular mission, such that communication between the pilot and systems operator are clearly understood during the mission.

SAMPLE BRIEFING CONTENT

1. Equipment
   a) Battery Chargers
   b) Radio Equipment
   c) Assembly Procedures

2. Mission
   a) Preflight
   b) Flight Plan
   c) Maneuvers

3. Safety Procedures
   a) Hazard Areas
   b) Frequency Assignments
   c) Electrical Systems
   d) Radio Range Check Procedure
e) Fuse Installation
f) Flight Control and Systems Check

4. Normal Procedures
   a) Pilot / Systems Operator Communication
   b) Systems Operational Procedures
   c) Takeoff / Landing
   d) Battery Endurance

5. Emergency Procedures
   a) Systems Malfunctions
   b) Emergency Landing

8.5 MISSION PLANNING
Mission planning ensures efficient and safe operation of the equipment. Prior to
deployment to the flying site, essential elements of the mission should be identified in
order to ensure that the necessary preparations are made in order to ensure success.
Upon arrival at the site, the essential mission elements are reviewed to ensure that the
required goals are achieved during the flight. The planned maneuvers should be written
down and discussed prior to each flight. Each flight should be evaluated after landing in
order to update the mission plan accordingly. After completion of flight operations, the
mission should be evaluated to highlight items of particular difficulty and to highlight
effective procedures.

SECTION II - OPERATIONAL PROCEDURES

8.6 PRE-DEPLOYMENT
TRANSMITTER BATTERIES - FULLY CHARGED
RECEIVER BATTERIES - FULLY CHARGED
SAS BATTERY - FULLY CHARGED
CGC BATTERY - FULLY CHARGED
EQUIPMENT - CHECK
   1. TRANSMITTERS
   2. TOOLS
   3. BATTERIES
   4. AIRCRAFT (ALL COMPONENTS INSTALLED)
   5. SUPPORT EQUIPMENT

8.7 PREFLIGHT
FUSE - REMOVE
FUSELAGE - CHECK FOR FOD / LOOSE OBJECTS
FUSELAGE - CHECK SECURITY OF INTERNAL BOLTS
MPS BATTERIES - FULLY CHARGED
MPS BATTERIES - INSTALL / SECURE
MPS CONNECTORS - SECURE
WING - ATTACH / BOLTS SECURE
SAS CONNECTORS - SECURE / CHECK CONNECTIONS
SAS FUNCTIONS - CHECK
1) PILOT TRANSMITTER - ON
2) SYS TRANSMITTER - ON
3) RECEIVERS - ON
4) SAS POWER - ON
5) COMMAND OVERRIDE - ON
6) CGC POWER - ON (VERIFY CG SHUTTLE FULL FORWARD)
7) COMMAND OVERRIDE - OFF
8) MANUAL CG CONTROL - CHECK OPERATION
9) FLIGHT CONTROLS - CHECK
10) PGAIN - 100%
11) SAS OPERATION - CHECK (ELEVATOR DEFLECTS WHEN AIRCRAFT MOVED IN PITCH)
12) CGC POWER - OFF
13) SAS MEMORY - RESET
14) SAS POWER - OFF (AFTER RESET COMPLETE)
15) RECEIVERS - OFF
16) TRANSMITTERS - OFF

COWLING - INSTALL
LANDING GEAR - CHECK SECURITY OF COLLARS
PROPELLER / SPINNER - CHECK
FLIGHT CONTROLS - CHECK MECHANICAL CONDITION
TAILBOOM ATTACHMENT BOLTS - CHECK

8.8 BEFORE TAKEOFF
SYSTEM CONTROLS - SET
   1) COMMAND OVERRIDE - ON
   2) GAINS - SET
   3) CGC - FULL FORWARD
   4) DATA SWITCH - OFF
TRANSMITTERS - ON
RECEIVERS - ON
SAS POWER - ON
CGC POWER - ON (AS REQUIRED)
THROTTLE - IDLE
PROPELLER AREA - CLEAR
FUSE - INSTALL
POWER - CHECK
WIND - CHECK
TRAFFIC - CHECK
DATA SWITCH - ON

8.9 AFTER TAKEOFF
COMMAND OVERRIDE - OFF (AS REQUIRED)
8.10 BEFORE LANDING
CGC - FULL FORWARD
COMMAND OVERRIDE - ON (AS REQUIRED)

8.11 AFTER LANDING
DATA SWITCH - OFF
THROTTLE - IDLE
FUSE - REMOVE
CGC POWER - OFF
SAS POWER - OFF
RECEIVERS - OFF
TRANSMITTERS - OFF
CHAPTER 9
EMERGENCY PROCEDURES

NOTE
Some emergency situations require immediate and instinctive action by the pilot and/or systems operator. The most important consideration at any time is aircraft control. All other actions are subordinate to this requirement.

9.1 DEFINITIONS
Emergency steps must be executed promptly and in the proper sequence. Underlined steps must be performed without delay, and non-underlined steps should be performed as soon as the situation dictates.

a) The term LAND AS SOON AS POSSIBLE is defined as landing at the runway immediately. A situation requiring such action gives the pilot immediate priority to land, regardless of other traffic in the area. If the situation dictates, an off-runway landing may be necessary.

b) The term LAND AS SOON AS PRACTICABLE is defined as landing at the runway as soon as traffic and conditions permit.

c) The term TERMINATE FLIGHT IMMEDIATELY is defined as performing an immediate control input procedure to bring the aircraft to the ground as quickly as possible. This maneuver may result in destruction of the aircraft, and is intended to prevent property damage or personal injury in the event of a catastrophic emergency. The following procedure applies:

Elevator - FULL UP
Ailerons - FULL LEFT
Throttle - CUT
Rudder - FULL RIGHT

This action is initiated by moving both sticks all the way down and towards the center of the transmitter. This maneuver will initiate an immediate spin and vertical descent.
9.2 ENGINE FAILURE - GENERAL
Failures of the propulsion system may result in total or partial loss of power. Immediate action is required to minimize the potential of damage to the aircraft. Pitch attitude control is critical to ensure that the aircraft maintains sufficient speed for power off glide. Immediate corrective action must be taken if the aircraft has a nose-high attitude at the time of failure. If the situation dictates, a rolling maneuver may place the aircraft in a nose-down attitude more expeditiously and with less energy loss than a pitch-down maneuver. Pilot situational awareness is critical as wind direction and speed and aircraft attitude at the time of failure will dictate proper corrective action. The CGC must be commanded to the full forward position prior to landing.

9.3 ENGINE FAILURE – INFLIGHT
The pilot should attempt to turn the aircraft into the wind. If the situation dictates, attain a shallow descent that will maintain airspeed and attempt to perform a power off approach to the runway.

CGC – FULL FORWARD (Coordinate actions with pilot)
LAND AS SOON AS POSSIBLE

9.4 ENGINE FAILURE – LOW ALTITUDE
Failure of the propulsion system at low altitude requires immediate action by the pilot. It may not be possible to land into the wind. If the aircraft has sufficient speed, it may be possible to execute a zoom climb to allow the aircraft to be pointed into the wind.

CGC – FULL FORWARD (Time permitting - coordinate actions with pilot)
LAND AS SOON AS POSSIBLE

9.5 ENGINE FAILURE – TAKEOFF
Should power failure occur during takeoff, pilot action will be dictated by the aircraft speed and distance available on the runway. Unless the aircraft has reached suitable altitude and speed to execute a turn, a landing must be made in the takeoff direction. If an attempt is made to turn the aircraft towards the runway, the aircraft will be pointed downwind. If the failure occurs during initial climbout, speed will bleed off quickly, depending upon the pitch attitude.

ELEVATOR – REDUCE AFT PRESSURE
CGC – FULL FORWARD (Coordinate actions with pilot)
AIRCRAFT – LEVEL
LAND AS SOON AS POSSIBLE

9.6 ENGINE FAILURE – LANDING/FINAL APPROACH
An engine failure during final approach or landing dictates that the aircraft must land with no chance of a missed approach. Should the landing approach be short of the runway threshold, sufficient energy may not be available to reach the runway. If the landing approach dictates a touchdown past the first half of the runway, the pilot should attempt to bleed off as much speed as possible prior to rolling past the end of the runway.

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PITCH – REDUCE TO POWER OFF GLIDE ATTITUDE
CGC – FULL FORWARD (Coordinate actions with pilot)
CONTINUE APPROACH (Power off descent glide)
LAND AS SOON AS PRACTICABLE

9.7 SINGLE CHANNEL FAILURE – THROTTLE
Should the throttle become inoperative, it may become impossible to slow the aircraft for
descent and landing until battery power diminishes. When this occurs, the pilot must be
prepared for landing, as battery power may fall off quickly if the throttle was initially at a
high setting. If there is insufficient power to climb, the pilot may desire to orbit the
above the field in the vicinity of the approach path until a landing becomes possible.

ALTITUDE – CLimb TO SAFE ALTITUDE (As situation dictates)
POSITION – MAINTAIN NEAR APPROACH PATH
LAND AS SOON AS PRACTICABLE

9.8 FLIGHT CONTROLS
Failure of the flight controls may result in loss of aircraft control. Often, failure of a
single control surface may be compensated for by using the other flight controls, with
reduced performance. Pilot action is ultimately dictated by the situation.

9.9 SINGLE CHANNEL/MECHANICAL FAILURE – AILERONS
Aircraft roll control may be maintained using rudder control, should the ailerons fail.
Due to increased differential lift on the wing during rudder-only turns, airspeed must be
kept above that which could result in a spin. A shallow approach to landing should be
executed to allow sufficient time to attain runway alignment.

AIRSPEED – Vs + 10KTAS, MINIMUM
CGC – FULL FORWARD (Coordinate actions with pilot)
RUDDER – UTILIZE FOR ROLL/DIRECTIONAL CONTROL
LAND AS SOON AS PRACTICABLE

9.10 SINGLE CHANNEL/MECHANICAL FAILURE – RUDDER
Loss of rudder control will not significantly affect performance or maneuverability,
however, limited or no directional control may occur after the aircraft has touched down.
If the controls are failed in a fixed position other than centered and uncommanded yaw
may occur after landing.

CGC – FULL FORWARD (Coordinate actions with pilot)
LAND AS SOON AS PRACTICABLE

9.11 SINGLE CHANNEL/MECHANICAL FAILURE – ELEVATOR
Loss of elevator control constitutes a critical emergency. Some pitch control may be
available using the throttle, however limited. The aircraft has marginal pitch-velocity
stability with the CG full forward, and may be unstable (aircraft may tuck under,
regardless of power setting) with the CG in an aft position. If the position of the elevator is fixed in a nose-high attitude, pitch control may be attainable by performing sideslip maneuvers or turns to lower the nose. Power should be used to minimize pitch oscillations. Loss of pitch control may be due to SAS malfunction. The SAS should be disengaged immediately (command override – ON) upon loss of control due to elevator malfunction. If control is not possible, it may become necessary to terminate flight, to prevent property damage or personal injury.

**CGC – FULL FORWARD (Time permitting)**
**COMMAND OVERRIDE – ON**
**LAND AS SOON AS POSSIBLE**
**TERMINATE FLIGHT IMMEDIATELY** (As situation dictates)

### 9.12 CONTROL SURFACE FLUTTER
Control surface flutter may occur if control linkages become loose or damaged, or if control surface hinges become fatigued. Flutter is detected by a buzzing sound. Flutter may be reduced or entirely stopped by reducing airspeed. This condition requires prompt attention, as flight control failure may be imminent.

**Airspeed – Reduce**
**Land as soon as practicable**

### 9.13 SYSTEMS FAILURES – GENERAL
Failures of the SAS or associated systems may result in reduced performance or loss of control. If a SAS malfunction is suspected, the system must be disabled. Depending upon the situation, the pilot may elect to manually move the CGC full forward prior to using command override.

### 9.14 SAS MALFUNCTION
Depending upon the severity of the malfunction, partial or total loss of elevator and/or CGC control may occur. A full up or down elevator deflection or sudden CGC translation will require immediate action by the pilot and systems operator.

**Command Override – ON**
**CGC – FULL FORWARD**
**Land as soon as practicable**

### 9.15 CGC MALFUNCTION
Should the CGC system malfunction inflight, immediate action may be required to prevent loss of control. CGC malfunction may be detected by an uncommanded pitch trim change. The pilot should activate command override in the event of such a failure.

**Command Override – ON**
**CGC – FULL FORWARD**
**Land as soon as practicable**