HeliSAS® Technical Overview

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The Genesys HeliSAS is a stability augmentation system (SAS) and two-axis autopilot that provides attitude stabilization and force feedback to the cyclic control for helicopters with hydraulic controls. The system architecture is a parallel design that maintains the integrity of the basic helicopter flight control rods while using electro-mechanical servo actuators that are connected to the helicopter's flight controls rods with parallel linkage.

The HeliSAS is designed as an attitude-based system that accepts attitude source data using a combination of the installed attitude gyro or digital attitude heading reference system (AHRS) inputs, and motion sensors located in the Flight Control Computer (FCC). The FCC commands the servo actuators to apply small corrections to the cyclic as required to maintain attitude.

The HeliSAS system is designed to be engaged at all times: **“SAS” on** before takeoff, and **“SAS” off** after landing. The “force feel” (force trim) feature enhances handling characteristics and mitigates inadvertent cyclic control inputs that could result in dangerous attitudes. The pilot may override the HeliSAS at any time with manual cyclic inputs. Only 3.5 lbs of pilot force in the pitch axis, and 3.0 lbs in the roll axis, at the cyclic control is required to override the system for pilot desired maneuvering when either the SAS or autopilot modes are engaged.

In cases where a pilot may lose visual reference due to limited visibility conditions, releasing the cyclic allows the helicopter to automatically return to a near-level attitude when the “SAS” is on.

The servo actuators are connected to the dual cyclic controls by push/pull rods coupled by electromagnetic clutches within the servos. When the system is disengaged, the electromagnetic clutches provide positive disconnect of the servo actuators from the cyclic controls, and flying qualities revert to the basic helicopter control characteristics. Additionally, safety monitors in the FCC automatically disengage both servo actuators if a system malfunction is detected.

HeliSAS® Components and Description

The SAS and Autopilot system consist of the following components:

HeliSAS Control Panel (HCP) – Illustrated in Figure 1 - HeliSAS Control Panel. The HCP interfaces with the FCC. This push button panel located in the cockpit within the pilot's reach provides for engagement of the SAS and the desired autopilot mode selections of altitude hold, heading hold, navigation signal tracking, and vertical (approach) navigation features, which are controlled via the six push buttons on the panel.

Flight Control Computer (FCC) – The Flight Control Computer receives inputs from the HCP as well as from the on-board NAV, GPS and Attitude systems and commands the pitch and roll servos to perform the selected autopilot function.

HeliSAS® Components and Description

Internal to the FCC are three body axis rate sensors, a triaxial accelerometer, two differential pressure sensors, and one absolute pressure sensor. The rate sensors and accelerometer are used to sense the rotational velocities and acceleration of the HeliSAS in three orthogonal axes. The pressure sensors are used to detect and calculate the indicated airspeed and altitude of the airframe.

The FCC uses RS-232, RS-422, and ARINC 429 digital communications ports as the primary means of transferring data. The HCP communicates with the FCC via RS-422. The attitude data is received by the FCC via ARINC 429 or analog signals depending on the attitude source. GPS data is transmitted to the FCC via ARINC 429. The FCC also receives discrete inputs from the Momentary Trim (TRIM) switch and AP / SAS Disengage (AP DISC) switch mounted on the Left and Right Cyclic controls. Additional FCC outputs include the current commands to drive the pitch and roll servo brushless motors and clutches as well as an aural warning tone to the audio panel that alerts the crew whenever a HeliSAS mode has disengaged. The FCC also receives and processes air data directly from the pitot/static system.

HeliSAS® Components and Description

HeliSAS employs a dual fail passive architecture wherein identical safety monitors are implemented in both of the internal processors and either processor can disengage the system if a monitor is tripped. When a safety monitor is tripped, the FCC will disengage the servo clutches, set the servo servo-motor commands to zero, and activate an aural warning tone that the SAS/AP has disengaged.

The FCC is shown in Figure 3 - SAS and Autopilot System Block Diagram. This component consists of four connectors. One connector interfaces with the attitude gyro and the cyclic AP DISC and trim button, one interfaces with the roll servo, one interfaces with the pitch Servo, and one interfaces with the HCP. The FCC sends error signals to the roll servo and pitch servo. There are no switches or controls on the FCC. The FCC receives inputs from:

Roll Servo – Illustrated in Figure 3 - SAS and Autopilot System Block Diagram, receives roll error signals from the FCC and provides roll correction to the cyclic controls through electromagnetic clutches located within the servo.

Pitch Servo – Illustrated in Figure 3 - SAS and Autopilot System Block Diagram, receives pitch error signals from the FCC and provides pitch correction to the cyclic controls through electromagnetic clutches located within the servo.

HeliSAS® Components and Description

Attitude Gyro - Illustrated in Figure 3 - SAS and Autopilot System Block Diagram, sends attitude signals to the FCC. The attitude reference for the FCC can also be provided by a digital AHRS or ADAHRS (not shown in this illustration).

TRIM Switch - Illustrated in Figure 2 – Force Trim Release (FTR) Switch and AP DISC Switch. The cyclic mounted trim switch is discussed below under Cyclic Controls and under General Theory of Operation.

AP DISC Switch - Illustrated in Figure 2 - FTR Switch and AP DISC Switch. The cyclic-mounted AP DISC switch disengages the SAS mode when pressed.

Cyclic Controls - The HeliSAS installation includes a modification to the cyclic controls to add a Momentary Trim button and an AP / SAS DISC button. The Momentary Trim button provides a force-trim-release function to allow the pilot to retrim to a new pitch or roll attitude in SAS mode. Holding down the momentary trim button for at least 1.25 seconds engages SAS. The Momentary Trim button can also be used to reset the reference altitude in the altitude-hold mode. It can also be used to reset the reference track angle in HDG mode if no heading source is available.

If the autopilot is engaged, pushing the AP DISC button causes the autopilot modes to disengage, while the SAS remains engaged. Pushing the button twice causes the autopilot and SAS to disengage. If only the SAS is engaged, pushing the button once disengages the SAS.

Servos - The servos are electromechanical servo-actuators consisting of a DC brushless commutating motor, low ratio gearbox, clutch, and servo position feedback resolvers that control the pitch and roll axes of the helicopter. The servo-actuators are connected to the flight control system in parallel with the basic helicopter control rods and have manual servo motor back-drive capability. The clutches consist of an electromagnetic pressure plate design that disconnects the servo-actuators from the flight control system when the HeliSAS is selected off. Loss of power to the clutches causes them to fail to the open, clutch face separated position. The gear ratio between the cyclic stick and the servo-motor is sufficiently low so that the helicopter can be safely flown with the SAS disengaged and the clutch stuck closed (i.e., the pilot can back drive the gearbox and servo-motor with negligible resistance).

General Theory of Control

The HeliSAS is a two-axis attitude hold, attitude command, flight control system. The system has two basic functions: SAS to aid with aircraft stability and autopilot outer loop control modes for altitude hold, and heading select and navigation sensor coupling. The SAS and Autopilot System provide a significant reduction in pilot workload, from takeoff to landing. The SAS mode should be engaged prior to liftoff, and disengaged following touchdown. The various autopilot modes can only be engaged when the SAS mode is already engaged and the airspeed is greater than designated minimum engagement airspeed for the autopilot (44 KIAS).

A pair of servos is coupled to the cyclic through electromagnetic clutches as a means to control the helicopter for a given mode of operation. One servo controls the cyclic about the roll axis, and the other servo controls the cyclic about the pitch axis. These servos are driven by error signals received from the Flight Control Computer (FCC), which in turn receives inputs from:

- Attitude Gyro or Attitude Heading and Reference System (AHRS)
- Heading System (HSI or Electronic Flight Instrument System [EFIS])
- VHF Navigation Receiver
- GPS Navigation Receiver

General Theory of Control

The SAS and autopilot system makes it possible to fly for indefinite periods, with hand off the cyclic. Due to the unstable nature of helicopters, the pilot must always be prepared to assume immediate manual control of the cyclic in the event of an automatic HeliSAS disengagement resulting from a system failure. In addition, despite an engaged SAS mode and the main rotor speed governor in the helicopter, the pilot is not relieved of their responsibility to closely monitor helicopter attitude and main rotor RPM at all times.

The panel-mounted HeliSAS Control Panel (HCP), shown in Figure 1 - HeliSAS Control Panel, contains a mode selector switch for each of the six modes of operation. There is a mode LED located above each respective mode selector switch. During the system power-up self-test all of these LEDs are flashing, alternately between white and green. Upon completion of the self-test, all HCP LEDs remain illuminated white, indicating that the system is in Standby mode.

Figure 1 - HeliSAS Control Panel

SAS Trim

Pressing the SAS mode selector switch will engage the SAS mode (i.e., enable SAS). The system acknowledges this by changing the SAS mode LED color from white to green, and extinguishing all other mode LEDs. With the SAS mode engaged, the system holds the current (captured) roll attitude and pitch attitude. Pressing the SAS mode selector switch again will disengage the SAS mode, returning the system to Standby mode.

A cyclic-mounted TRIM Switch and AP DISC Switch are shown in Figure 2 - FTR Switch and AP DISC Switch. When the system is in Standby mode, pressing and holding the TRIM Switch for more than 1.25 seconds will engage the SAS mode. With the SAS mode engaged it may be desired to capture and hold a new attitude about the roll and pitch axes. This is accomplished by using the cyclic to manually "fly through the system" to capture the new attitude and then momentarily pressing and releasing the TRIM Switch to hold the new attitude.

When pressing and holding the trim switch, all force is removed from the cyclic. Upon subsequently releasing the trim switch, all force is then reapplied to the cyclic. For this reason, the sequence of pressing and releasing the trim switch is also referred to as activating Force Trim Release (FTR).

Figure 2 - FTR Switch and AP DISC Switch

The FTR Switch should not be pressed and held while maneuvering the helicopter to the new attitude, as this negates the stability offered by the SAS mode. Rather, it is much better to fly through the system until the new attitude has been captured and then press and release the FTR Switch to hold the new altitude.

The FTR should also be activated whenever there is residual force on the cyclic in order to reduce this force and hence pilot workload.

Pressing the AP DISC Switch will disengage the SAS mode, returning the system to the Standby mode.

Pilot Technique with SAS Trim

The SAS mode responds to very small movements of the cyclic in the performance of its stabilizing action. If the pilot should hold the cyclic with too tight a grip, the stabilizing action is reduced and could even become inhibited. Consequently, proper technique requires that the pilot just loosely grips the cyclic, ensuring that it can continue to make the required small movements within the pilot's grip, in order for the SAS mode to function properly. This is especially true in a hover.

CAUTION

Never use cyclic friction when the SAS mode is engaged, as it will inhibit the ability of the system to stabilize the helicopter. The cyclic friction must be all the way OFF when the SAS mode is engaged.

When the SAS mode is not engaged, electrical power is removed from the pitch and roll Servos. This releases each servo electromagnetic clutch, allowing the cyclic to move freely; with “SAS” off there is no force feedback to the pilot. On the contrary, when the SAS mode is engaged there exists a force gradient on the cyclic that acts like a centering spring. This is referred to as a "force feel system.“ As a consequence, when maneuvering the helicopter by flying through the system the pilot will feel some resistance in the cyclic.

Because of the force feel system inclusive in the SAS mode, it is possible to fly through the system to accomplish normal low speed, hover, and up-and-away maneuvers.

The FTR should also be activated whenever airspeed changes are desired in order to reduce the corresponding residual force on the cyclic and hence pilot workload.

Monitoring of Controls with SAS Trim

By reducing pilot workload, the SAS mode serves to enhance safety. Even so, the SAS mode is not a substitute for pilot skill, and does not relieve the pilot of the responsibility to maintain adequate outside visual reference.

An automatic HeliSAS disengagement resulting from a system failure may cause a rapid roll or pitch excursion, requiring the pilot to assume immediate manual control of the cyclic in order to avoid dangerous attitudes. Other events requiring the pilot to assume immediate manual control of the cyclic are engine, drive train, and hydraulic system failures. Consequently, it is imperative that the pilot closely monitor the cyclic at all times.

The pilot is required to have a hand on the cyclic at airspeeds below 44 KIAS, when operating in close proximity to the terrain, and at all times at airspeeds above (VNE – 5) KIAS. At low airspeeds, in close proximity to the terrain, this requirement is simply a matter of good practice in the event a system failure should occur. At high airspeeds this requirement is imposed because a system failure is much more critical near redline. With the pilot's hand on the cyclic at the instant of a system failure, the maximum force applied to the cyclic at any airspeed is 3 lbs.

Autopilot Modes

The autopilot modes of operation, and their respective mode selector switches, are as follows:

Autopilot Mode:	Heading	Navigation	Back Course	Altitude Hold	Vertical Navigation
Mode Selector Switch:	HDG	NAV	BC	ALT	VRT

An autopilot mode can only be engaged when the SAS mode has previously been engaged and the airspeed is greater than 44 KIAS. Pressing a particular autopilot mode selector switch engages the respective mode. The system acknowledges this by illuminating the corresponding mode LED green. Under some specific flight conditions a mode is armed prior to its engagement. The system acknowledges this by illuminating the corresponding mode LED white.

The autopilot modes serve to enhance safety by reducing pilot workload. The autopilot modes are not a substitute for pilot skill, and do not relieve the pilot of the responsibility to maintain adequate outside visual reference.

Safety Monitors

The HeliSAS system is equipped with safety monitors, that serve to effect those actions described hereafter.

Power-Up

During the system power-up self-test, an aural alert comprised of four 600 Hz beeps is heard in the headset.

SAS Mode Engaged

If the safety monitors detect a system failure affecting the integrity of the engaged SAS mode, they will automatically disengage the SAS mode along with any other autopilot modes that may happen to be engaged, and return the system to Standby Mode. This is accompanied by the four-beep aural alert sequence heard in the headset.

If the pilot intentionally disengages the SAS mode the system will be returned to Standby mode. This is accompanied by the four beep aural alert sequence heard in the headset.

Safety Monitors

SAS Mode and Autopilot Mode(s) Engaged

If the safety monitors detect a system failure affecting the integrity of an engaged autopilot mode they will then automatically disengage that particular autopilot mode, leaving the SAS mode engaged. This will be accompanied by a single beep aural alert heard in the headset.

If the safety monitors detect the loss of a navigation signal they will then automatically disengage the particular autopilot mode dependent upon that signal, but leave the SAS mode engaged. This will be accompanied by a single beep aural alert heard in the headset.

If the pilot intentionally disengages a particular autopilot mode the SAS mode will remain engaged and there will be no accompanying aural alert heard in the headset.

Pressing the cyclic-mounted TRIM Switch once disengages all autopilot modes. A second press disengages the SAS mode. Pressing and holding the cyclic mounted AP DISC Switch for more than 1.25 seconds disengages the SAS mode and all autopilot modes.

Modes of Operation

Standby Control

- Standby Mode

  Ready for SAS Mode to be engaged

Roll Axis Control Modes

- Stability Augmentation System (SAS) Mode

  Used to Hold Roll Attitude
- Heading (HDG) Mode

  Used to Turn to a Selected Heading and Hold it
- Navigation (NAV) Mode

  Used to Intercept and Track a VOR, LOC FRONT Course, GPS Course
- BC (Back Course) Mode

  Used to Intercept and Track a Reciprocal VOR, LOC BACK Course, GPS Course

Pitch Axis Control Modes

- Stability Augmentation System (SAS) Mode

  Used to Hold Pitch Attitude
- Altitude (ALT) Mode

  Used to Hold Altitude
- Vertical Navigation (VRT) Mode

  Used to Intercept and Track an ILS Glideslope, and GPS VNAV, LNAV +V, or LPV Glidepath

HeliSAS Block Diagram as installed in a Bell 206B Jet Ranger

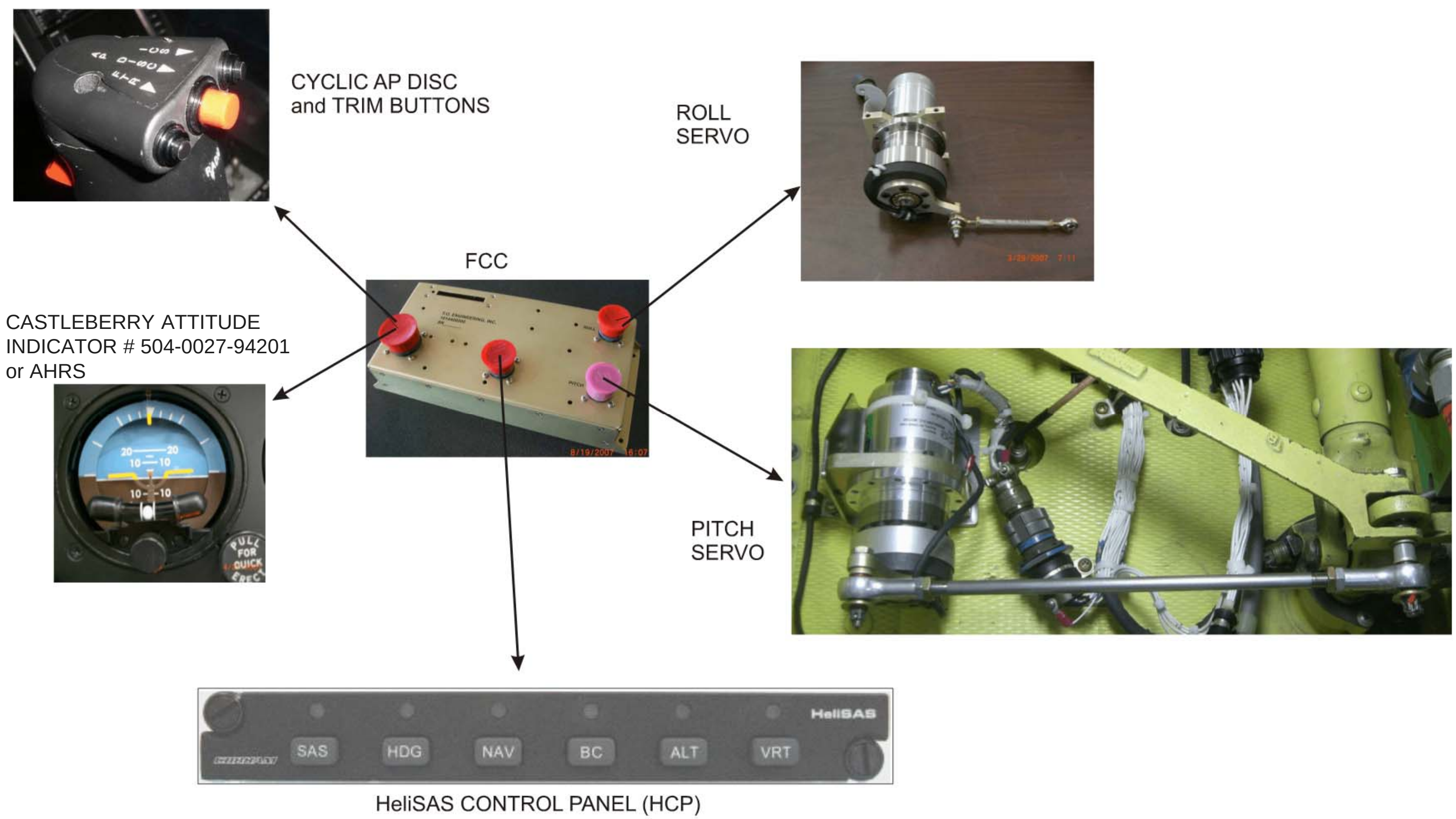

Figure 3 - HeliSAS Block Diagram

Contact Information

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