Information regarding the Lockheed F-104 Starfighter

F-104 Flight Controls

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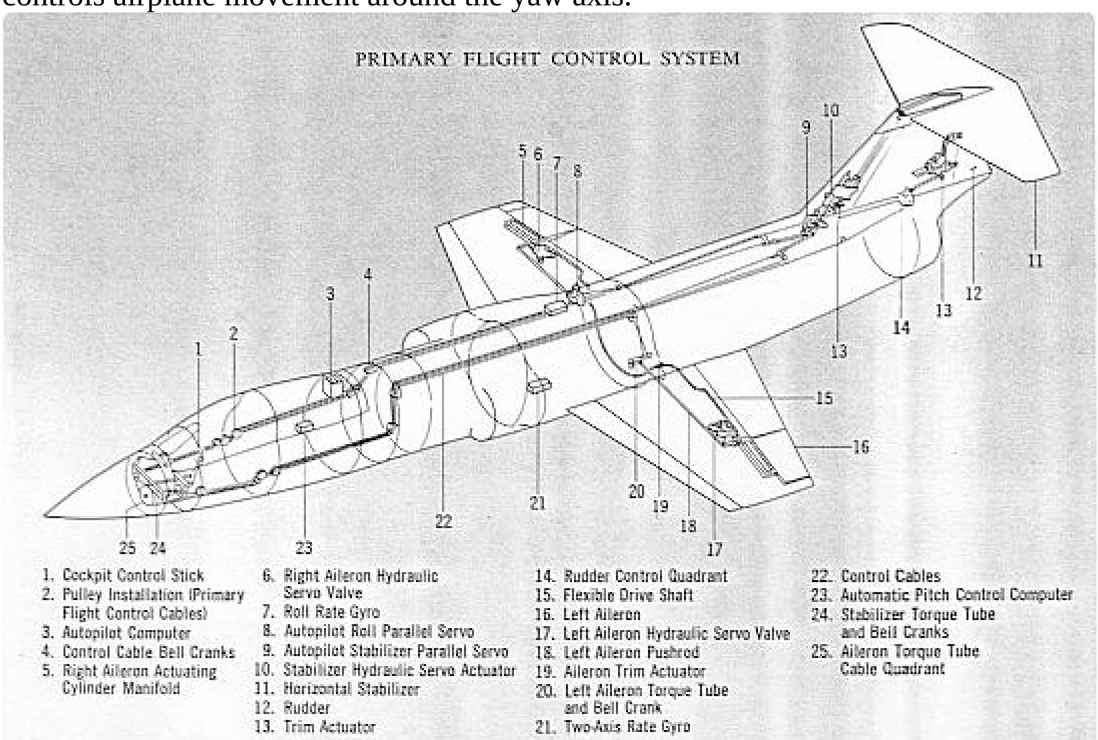
1. FLIGHT CONTROLS

1.1 Primary flight controls

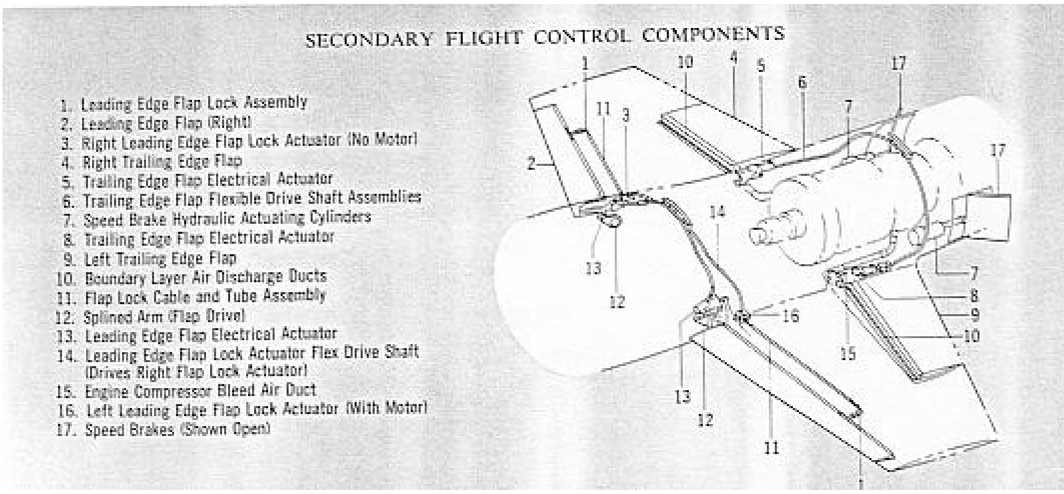
Flight control of F-104G airplanes is achieved by the use of primary and secondary control surfaces.
The primary flight control surfaces enable control of the airplane about the yaw, pitch, and roll axis.
The F-104 primary flight control system consists of a hydraulically powered rudder, ailerons, and a one-piece horizontal stabilizer. The ailerons are hinged to the trailing edge of each wing panel, between the outboard end of the trailing edge flaps and the wing tip trailing edge.
The ailerons are used to control airplane movement about the roll axis.
The horizontal stabilizer is a movable surface mounted at the top of the vertical stabilizer, (vertical fin) used to control airplane movement about the pitch axis. The rudder is installed at the trailing edge of the vertical fin below the horizontal stabilizer, and controls airplane movement around the yaw axis.



The secondary flight control system incorporates leading and trailing edge wing flaps for increasing lift, and speed brakes for increasing drag.
A further increase in lift for landing is achieved with the boundary layer control system which blows bleed air, from the 17th engine compressor stage, back over the trailing edge flaps, when they are extended to the landing position. (See Zipper 45 Bleed Air Systems)
Supplementing the systems which control the primary and secondary surfaces are an automatic flight control system (AFCS), which includes autopilot, stability augmentation, and automatic pitch control (APC) equipment; aileron, stabilizer, and rudder trim system.

The primary flight control surfaces are operated by three basically similar control systems consisting of stick or rudder pedal cockpit controls and electro-mechanically activated hydraulic servo assemblies.

Four servo assemblies are provide-one for each control surface. Each servo assembly controls the application of hydraulic power to actuating cylinders connected to a control surface.



Conventional control cables, torque tubes, quadrants, and pushrods transmit stick and rudder pedal movements to servo input linkages. Movement of each servo input linkage results in its servo assembly applying hydraulic power from the airplane hydraulic system to its associated actuating cylinders, which in return deflects the control surface.

Mechanical follow-up linkages automatically terminate the flow of hydraulic fluid to the cylinders when control surface deflection proportional to control movement is attained.

The control surface is then hydraulically locked by fluid trapped within the actuating cylinders and servo assembly.

Operation of the autopilot operates the aileron and stabilizer servo assembly input linkages.

Similarly, actuation of the APC actuator moves the stabilizer servo input linkage.

Aerodynamic loads on the control surfaces are not transmitted back to the control stick and rudder pedals. To provide the pilot a sense of control feel and response, artificial feel systems employing cams and springs are provided.

To minimize the possibility of application of excessive airloads on the rudder and aileron surfaces when the airplane is in other than take off or land configuration, control surface travel limiters are installed. The limiters, when engaged, restrict rudder and aileron travel to approximately half normal travel.

The primary flight control surfaces are actuated by servos, which are powered by the Nos. 1 and 2 hydraulic systems. Input signals are sent to the servos from the pilot’s control stick and rudder, from the stability augmentation system, and from the trim and autopilot systems.

The hydraulic systems are independent and normally are in simultaneous operation, supplying fluid at a pressure of 3000 PSI. Flight control surface actuating cylinders are arranged so that half of the cylinders function under pressure received from one hydraulic system and the other half of the cylinders function under pressure from the other hydraulic system. This arrangement enables the control systems to continue functioning in event either of the hydraulic systems fail. In event hydraulic systems fail and sufficient fluid is available, an emergency ram-air turbine driven pump will furnish fluid pressure through the no 1 or emergency hydraulic system for flight control.

1.2 Automatic flight control system

The automatic flight control system (AFCS) consists of the stability augmentation, autopilot, and automatic pitch control equipment. Through this equipment, the AFCS provides the airplane with automatic stability augmentation about all three-flight axis, autopilot control through aileron and stabilizer to various references, and automatic pitch-up control of the pitch axis.

The stability augmentation system provides maximum stability of the F-104 in any flight attitude or manoeuvre. Rate-sensing gyros detect any sudden change of attitude about the aircraft's three axis and produce electrical signals proportional to the deviation they have detected. These signals, after being amplified, are send to the proper control surface servo valve which produces the proportional surface adjustment to correct the attitude.

A synchronous transmitter on the servo valve supplies a feedback signal, which cancels the original signal causing any oscillation to be damped.

The trim system is powered and controlled electrically, and the trim actuator output is connected mechanically to its respective servo valve input arm. Energizing the actuator causes the input arm to change position, thereby changing the position of the control surface. In each case, the amount of trim selected limits surface movement in that direction by the same amount. Movement of the servo input linkages by the trim actuators causes deflection of the control surfaces to the trimmed position, but does not affect cockpit control stick and rudder neutral positions. A toggle switch located on the control stick grip, and an auxiliary switch located on the left console are used to control the aileron and stabilizer trim actuators. A three-position toggle switch on the left console is used to adjust rudder trim. Lights are provided to indicate take-off trim positions of the control surfaces. In flight, only the aileron take-off trim light provides an indication of control surface trim. Electro-mechanical actuators position the wing leading and trailing edge flaps. A flexible shaft interconnects the drive motors for each wing to synchronize the flaps and enable one motor to drive both flaps should the other malfunction. The flaps have three pre-set positions: Up, which is zero degrees deflection, or the faired position for the trailing edge flaps, and 3°downward deflection for the leading edge flaps; intermediate position, which is 15° downward deflection for both leading and trailing edge flaps, and is used for take-off or manoeuvring flight; and Land which is 45° downward deflection for the trailing edge flaps, and 30° downward deflection for the leading edge flaps.

Speed brakes, installed on each side of the fuselage aft of the wings, provide a means of reducing airplane speed in flight.

The two speed brakes are hydraulically powered and electrically controlled. They operate in synchronisation, and the pilot may select any position between ”full open” and ”full closed ”.

In event of loss of electrical power should occur, the brakes would close automatically. No position indication is provided.

The autopilot system controls attitude in roll and pitch through its aileron and horizontal stabilizer actuators. Various input signals are sensed or initiated in components of the autopilot and other electronic equipment. These input signals are combined, by computing functions within the autopilot portion of the AFCS computer, to produce pitch and roll command output signals. The system provides heading hold in conjunction with either altitude hold or Mach number hold. The pilot can use the control stick steering provisions to manoeuvre the airplane in autopilot without disengaging the system. At any time the pilot can over-ride the automatic control.

The automatic pitch control system (APC) functions as a stall-prevention device. Inputs from a angle-of-attack vane and pitch rate gyro are fed into a computer which, when the aircraft first approaches a stall, causes the pilot's control stick to shake as a warning. Should the nose-up attitude be continued until a stall becomes imminent, the computer commands a pitch signal to a hydraulic servo, which quickly and firmly moves the control stick forward, while also positioning the horizontal stabilizer for a nose-down attitude. Visual indication of the pitch attitude is presented to the pilot on the instrument panel. Like all automatic functions of the flight control system, the pilot can override the automatic pitch control.