G650 Flight Control System
Electrically-controlled

Brains

Three (3) Axis Fly-by-wire Flight Control System (FCS)

Hydraulically-actuated

Muscles

Backup
Electrically-controlled

**Software:**

- Flight Control Law Modes

**Hardware:**

- Flight Control Computers
  - FCC1 A B
  - FCC2 A B

- Backup Flight Control Unit
  - BFCU

- Flight Control Batteries
  - EBHA Batt
  - UPS Batt

- Remote Electronic Units
  - REU
Flight Control Law Modes

Normal

Alternate

Direct

Backup

Minimum Requirements:

1. One (1) IRU
2. One (1) FCC Channel
3. Two (2) ADS
4. HSCU Not Reporting Backup Control
**CAS Message:** FCC Alternate Mode

1. Two ADS
2. IRU Conflict
   - AHRS conflict
3. HSCU 1/2 is reporting backup control

Probability of occurrence: < 1 per 10 million flight hours

- FLT CTRL RESET switch may allow return to NORMAL if the reason for degrade is resolved
- CAS MESSAGE: FCC Direct Mode

- All channels are invalid (software problem)

- Command C and Monitor M lanes do not agree

- Return to Normal or Alternate not possible

- Flying qualities are identical to FCC Alternate Mode
- **CAS Message:** BFCU Active

- Channels cannot compute control law (hardware problem)

- BFCU and its own control laws provides **Get Home** capability

- BFCU communicates directly with EBHA actuators

- Probability of occurrence: <1 in a billion flight hours
Any Flight Control Law other than NORMAL:

1. Takeoff is prohibited
2. Maximum landing crosswind: 10 knots
3. Maximum speed: 285 KCAS/M0.90
4. Flight into known icing conditions prohibited. If in icing conditions exit icing conditions
5. $V_{ref} + 10$ minimum
Air Data Probes AND Flight Controls

After selecting Anti-ice heaters to **ON** wait five (5) seconds before moving the flight control surfaces to prevent FCC1 FCC2 from reverting to **DIRECT** mode.

![FCC Alternate Mode](image)

**NORMAL**

**ANTI ICE HTR**

<table>
<thead>
<tr>
<th>Probe1</th>
<th>Probe2</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>OFF</td>
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</table>

<table>
<thead>
<tr>
<th>Probe3</th>
<th>Probe4</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFF</td>
<td>OFF</td>
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</tbody>
</table>

+ 5 seconds =

![Planes](image)
Flight Control Computers (FCCs)

- Brains of the FCS
- Located in the LEER and REER

- **Convert** input from the crew/autopilot to an electrical output

- **Provide** a command to the hydraulic actuators which move the flight control surfaces to the requested position

- Each FCC has two (2) channels for a total of four (4) channels

- A single FCC channel can operate the flight controls
- Each FCC channel has two (2) lanes:
  1. A Command C lane, and
  2. A Monitor M lane

- Their purpose is to provide system integrity by computing input using different software and having to come up with the same output result.

- Any significant difference between a C and a M lane causes that channel to fail.
- **Power Sources:**

- Three (3) separate power sources required.
- Dispatch with one (1) FCC channel inoperative is possible under the MMEL provided the remaining three (3) channels are powered by three (3) separate power sources.

Inop (1A)

Inop (2B)
- Flight Control Reset Switch

• Located on center pedestal

• When pressed:
  - Resets A and B channels in both FCCs
  - Resets all sixteen (16) flight control surface actuators

• Used when directed by a checklist

• Does not work in:

  - FCC Direct Mode
  - BFCU Active
Flight Control Laws (CLAWS)

Protective Features:

- FCC1
- FCC2

contain software called Control Laws or CLAWS. Its purpose is:

- Make the aircraft fly like a Gulfstream
- Dampen undesirable aircraft motions such as Dutch Roll
- Implement several protective features:

1. **Maneuver Load Alleviation:**

Ailerons symmetrically deflect upwards to reduce loads when the pilot commands $> 1.5$ Gs

Reaches maximum $3^\circ$ deflection $> 2.5$ Gs
2 Speedbrake - Auto Retract:

Stuck or jammed Speed Brake handle

95% Throttle Resolver Angle (TRA)

Speed brakes retract but speed brake handle does not
③ **Dynamic Rudder Limiting:**

Helps prevent a pilot from overstressing the rudder

Low speed: High deflection

High speed: Low deflection

④ **Elevator Split Load Limiting:**

Protects against large torque associated with a split elevator (i.e., jammed elevator)
5 AOA Limiting:

- 0.75 AOA - Pitch Limit Indicator (PLI) Appears

- 0.87 - 0.93 AOA Limiting (Based on Closure Rate)

- 0.94 AOA - Stick Shaker Activates

- 0.96 Max AOA Limit *

* Even with control column full aft the aircraft will not stall
6 High Speed Protection:

- Available when:
  - Autopilot is OFF
  - Vmo/Mmo + 5 (depending on acceleration rate)

- Pitch control restricted by the FCS

- Helps prevent an overspeed condition by decreasing pitch nose down authority 75%

- Protection inhibited with autopilot on or at a high bank angle (protection fades out > 60° bank)

- **Does not prevent exceeding Vmo/Mmo**
NORMAL sub-modes:

Cruise
(Gear/flaps up or AP on)

- Surface deflection based on altitude and airspeed
- Pitch trim moves elevator then stabilizer off-loads elevator

Takeoff and Landing
(Gear/flaps down and AP off)

- 10' AGL
- Surface deflection based on altitude and airspeed
- Pitch trim moves stab

On Ground

- Pilot input direct
- Pitch trim moves stab
- >60 kts YD functions
Backup Flight Control Unit (BFCU)

- Designed to provide a **Get Home** capability if both FCCs should fail.

- The **BFCU** is located under the floor and can be deferred as per the MEL.

- Once active it cannot be reset in flight.

- Inop <47 knots

- Powered by **FCC UPS Bus**
BFCU Active

Pilot input

BFCU

Output

Electrically-controlled

REU

Hydraulically-actuated

EBHA

Spoilers (outboard only)

Flight control actuation

Roll

Pitch

Yaw

Get home capability
Remote Electronic Units (REU)

- There are sixteen (16) REUs
- The REUs control the hydraulic actuators and horizontal stabilizer control unit based on FCC commands
There are two Flight Control System (FCS) batteries:

1. Electrical Backup Hydraulic Actuator (EBHA) Battery

2. Uninterruptible Power Supply (UPS) Battery

The FCS batteries can power the flight controls for thirty (30) minutes.

- Illuminated ON ON if no AC power is being produced and they power their own buses (discharging)
- System Power ON Self Test (SPOST)

- Selected ON first, then selected ON

- Forty five (45) second test

- No electrical interruptions during SPOST or a complete power down is required

- FCS Batteries - Charger/Transformer Rectifier

*Dual function: Charger and TR
- Electrical Backup Hydraulic Actuator
  - Nicad
  - Located in the tail compartment

- Powers seven (7)

- Can be charged by the \( \text{RAT} \) via the \( \text{GEN} \) via the \( \text{RAT} \)

- Must be removed from aircraft in cold soaked conditions \( \leq -20^\circ \text{C} \) and stored in a location warmer \( > -20^\circ \text{C} \) and cooler than \( +40^\circ \text{C} \)
- **Uninterruptible Power Supply (UPS)**
  - Lead acid
  - Located in the REER

- Powers Flight Control Computers channels 1A and 2B

- Can be charged by via the Emergency AC Bus
Flight Control Law Mode

L GEN

ON

L IDG

L MAIN AC

Emergency AC Bus

EBHA Battery Charger

R GEN

ON

R IDG

R MAIN AC

EBHA Batt

EBHA Bus

Fcc UPS Bus

BFCU

HSCU

1 2

FCC 1B

MCE x7

FCC 2A

FCC 2B

R ESS TRU

R ESS DC

L ESS TRU

L ESS DC
Flight Control Law Mode

RAT Generator ON

RAT GEN

(>180 KTs)

Emergency AC Bus

EBHA Battery Charger

UPS Battery Charger

L ESS TRU

L ESS DC

EBHA Batt

EBHA Bus

FCC UPS Bus

MCE x7

HSCU 1

R ESS TRU

R ESS DC

FCC 1B

FCC 1A

FCC 2B

FCC 2A

BFCU

H650_flight_control_system
Flight Control Law Mode

**MAIN BATTERIES**
- Left: ON
- Right: ON

**EBHA**
- ON

**UPS**
- ON
Flight Control Law Mode

EBHA

ON

UPS

ON

EBHA BATT

FCC UPS BUS

BFCU

FCC 1A

FCC 2B

MCE x 7

EBHA BUS

FCC UPS BUS
Hydraulically actuated

- Hydraulic fluid and pressure provided by:

  - There are sixteen (16) hydraulic actuators
  - Two (2) actuators for each primary flight control surface:
    - Ailerons (4)
    - Elevators (4) > Ten (10)
    - Rudder (2)
  - There is one (1) actuator for each spoiler panel:
    - Inboard (2)
    - Midboard (2) > Six (6)
    - Outboard (2)
There are two types of actuators:

- **Hydraulic Actuator (HA)**
  - One for each primary flight surface
  - One for each inboard and midboard spoiler

- Uses left and right hydraulic systems
- Commanded by an **REU → HA**
- Two modes:
  1. **Active Mode:** Normal state of operation
  2. **Damped Bypass Mode:** passively follows the working actuator
• Electrical Backup Hydraulic Actuator (EBHA)
  • One for each primary flight surface
  • One for each outboard spoiler panel

• Normally uses left and right hydraulic systems
• Normally commanded by an REU → HA
• If normal hydraulic pressure is not available, it reverts to Electric Backup (EB) mode

• Three (3) modes:
  1. Active Mode: Normal state of operation
  2. Damped Bypass Mode: passively follows the working actuator
  3. EB Mode
**EB Mode:**

- Electric power to drive a pump at the actuator
- Pressurizes trapped hydraulic fluid
- Acts as a third Hydraulic System

- A Motor Control Electronics (MCE) is used to control the EBHA motor-pump when the actuator is in the Electric Backup [E] state due to hydraulic or REU failures.

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**Active Mode**

![Active Mode Diagram]

**Electric Backup [E] Mode**

![Electric Backup Mode Diagram]
• **Loss of midboard spoilers only**
• **All actuators powered by the left hydraulic system operate in damped bypass mode**
• **Maximum speed:** 285 KCAS/M0.90
• Loss of inboard spoilers only
• Outboard spoiler actuators operating in EB E mode
• All other actuators powered by the Right Hydraulic System operate in damped bypass mode
• Maximum speed: 285 KCAS/M0.90
- Loss of midboard and inboard spoilers
- All EBHA actuators operate in EB E mode
- All other actuators operate in damped bypass mode
- All flight control surfaces powered by a single actuator
- Maximum speed: 285 KCAS/M0.90
Spoilers

- Electrically-controlled via speed brake handle:

- Hydraulically-powered by:

Six (6) spoiler panels - One (1) actuator each
1. Roll Augmentation: mid and outboard panels

   Up To **55°**

2. Speed Brakes (In flight)

   Up To **30°**

3. Ground spoilers (on ground)

   Flaps UP: **30°**

   Flaps ≥ **10° = 55°**
Ground spoilers automatically extend:

1. Thrust levers - idle on landing
2. Under the following conditions:
   - Main wheel spin up if flaps > 22°, or
   - Main wheel spin up if flaps < 22°, and

   = inhibits "Too low flaps"

1. Touch and go landings, or
2. INOP:
   - Day and wet (≤3mm) runway
   - Flaps 20°
Do not extend spoilers inflight with gear down or flaps 39°

Prohibited

Do not arm ground spoilers for touch and go landings
FLAPS

- **Electrically** controlled by flap handle:

- **Hydraulically** powered by:

- **Mechanically** actuated by:
  - Flap Electronic Control Unit (FECU)
    - It commands flap movement by electrically controlling:
      - Hydraulic Control Module (HCM)
        - The HCM controls hydraulic power to:
          - Power Drive Unit (PDU)
            - The PDU drives the mechanical actuator
**Electrically-controlled**

**Hydraulically-powered**

**Mechanically-actuated**

**Fowler-type single flap surface**
**Maximum Extension/Extended Speed**

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<thead>
<tr>
<th>VFE</th>
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<tbody>
<tr>
<td>250 KCAS</td>
<td>220 KCAS</td>
<td>190 KCAS</td>
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**Maximum G-loads**

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<tr>
<th>-1 To +2.5g</th>
<th>0 To +2g</th>
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<tr>
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<td>O To +2g</td>
<td>O To +2g</td>
<td>O To +1.5g</td>
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<td></td>
<td></td>
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<td>(&gt; MLW)</td>
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**Maximum Operating Altitude**

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<tr>
<td>≤ 25,000'</td>
<td>≤ 25,000'</td>
<td>≤ 20,000'</td>
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HORIZONTAL STABILIZER TRIM SYSTEM (HSTS)

- Fully trimmable horizontal stabilizer control surface
- Pitch trim is controlled by the split-trim switch on either control wheel or the backup pitch trim switch

- Input from these switches is transmitted to:

  ![FCC 1 and FCC 2 diagrams]

- Stabilizer surface is moved by the dual electric motor horizontal stabilizer trim actuator (HSTA)

- The HSTA is electrically controlled from the dual channel horizontal stabilizer control unit (HSCU)
1. Failure of HSCU 1 2 or,
2. Failure of HSTA A B or,
3. Jammed stabilizer

- Pitch trim switches control/trim elevators
- No elevator off-load feature
If no communication between FCC1 and FCC2 and HSCU or channels invalid.

FCC Alternate Mode

FCC Direct Mode

Backup Pitch

HSCU 1 2

HSTA A B

Controls horizontal stabilizer at a reduced rate of 0.15°/second (normal = 0.4°/s)
Questions, comments or errors...please send me an email: ivan@code7700.com

Thank you!