G650 Flight Control System
G650 Flight Control System (FCS)

Electrically-controlled

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

Hydraulically-actuated

Brains

FCC1
A B

BFCU

FCC2
A B

Backup

Muscles

L Hyd Sys

R Hyd Sys

Backup
**Software:**
- Flight Control Laws Modes

**Hardware:**
- Flight Control Computers
  - FCC 1
  - FCC 2
- Flight Control Batteries
  - EBHA BATT
  - UPS BATT
- Backup Flight Control Unit
  - BFCU
- Remote Electronic Units
  - REU
Flight Control Law Modes

Normal

Alternate

Direct

Backup

Minimum Requirements:

1. One IRU
2. One FCC Channel
3. Two ADS
4. HSCU Not Reporting Backup Control
• CAS MESSAGE: FCC ALTERNATE

  1. Two (2) ADS
  2. Invalid data
     /\ Conflict
    " AHRS conflict"

  3. HSCU 12 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**

• All **FCC 1** and **FCC 2** channels are invalid

• Command **C** and Monitor **M** lanes do not agree

• Return to **NORMAL** or **ALTERNATE** not possible

• Flying qualities are identical to **FCC ALTERNATE**
- **CAS Message:** BFCU Active

- **All Channels Cannot Compute**

- **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. **Vref + 10 minimum**
2. **Maximum crosswind**: 10 knots
3. **Maximum speed**: 285 KCAS/M0.90
4. Flight into known icing conditions prohibited. If in icing conditions, exit icing conditions.

- **FCC Alternate**
- **FCC Direct**
- **BFCU Active**
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.

![Diagram showing FCC Alternate and Normal modes with anti-ice heaters in OFF and ON positions.](image)

+ 5 seconds =

![OK symbol indicating correct configuration.](image)
Pilot/autopilot input

FCC 1
A B
FCC 2
A B

CONTROL LAWS

Electrally-controlled output

REU (16) (Remote Electronic Units)

Hydraulically-actuated

HA EBHA

Spoilers

Flight Control Actuation

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

- **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
    - BFCU Active
Flight Control Laws (CLAWS)

Protective Features:

FCC 1
A B
FCC 2
A B

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° 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

   ![Diagram showing low speed equals high deflection and high speed equals low deflection](image)

4. **Elevator Split Load Limiting:**
   Protects against large torque associated with a split elevator

   ![Diagram showing elevator split load limiting](image)
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 *

- Stall Protection Active

* Even with control column full aft the aircraft will not stall
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 35%

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

**On Ground**
- Pilot input direct
- Pitch trim moves stab
- > 60 KT's YD functions

5.3
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
Pilot input

BFCU

Electrically-controlled

REU (16)

Hydraulically-actuated

EBHA (7)

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 (2) 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
  - **Forty five (45) second test**
  - **No electrical interruptions during SPOST or a complete power down is required**

- **FCS Batteries - Charger/Transformer Rectifier**

  ![Diagram of Emergency AC Bus and Dual Function Charger and TR](image-url)
- Electrical Backup Hydraulic Actuator
  - Nicad
  - Located in the tail compartment

- Powers seven (7) EBHA actuators

- Can be charged by RAT GEN via the RAT

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

- Powers Flight Control Computers channels 1A and 2B

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

NORMAL

L GEN
ON

L IDG

L MAIN AC

EMERGENCY AC BUS

EBHA BATT

UPS BATT

EBHA BUS

Fcc UPS Bus

FCC 1B

MCE

FCC 1A

FCC 2B

HSCU
1 2

R GEN
ON

R IDG

R MAIN AC

EBHA BATT

UPS BATT

R ESS TRU

R ESS DC

BFCU

FCC 2A

ESS

EBHA

ESS

ESS

ESS

ESS

ESS

ESS

ESS

EBHA

EBHA

EBHA

EBHA

EBHA

EBHA
Flight Control Law Mode

MAIN BATTERIES
ON ON
LEFT RIGHT

EBHA
ON ON

UPS
ON ON

L MAIN BATT

L ESS TRU

L ESS DC

EBHA BATT

EBHA BUS

FCC 1B

MCE x 7

R MAIN BATT

R ESS TRU

R ESS DC

FCC UPS BUS

BFCU

FCC 1A

FCC 2A

FCC 2B
Flight Control Law Mode

EBHA

ON

UPS

ON

EBHA BATT

EBHA Bus

MCE

Fcc UPS Bus

BFCU

FCC 1A

FCC 2B

ENSA ENHA ENHA ENHA

ENSA ENHA ENHA ENHA

ENSA ENHA ENHA ENHA

ENSA ENHA ENHA ENHA
- **Hydraulically-actuated**

- Hydraulic fluid and pressure is provided by:

  ![Diagram of left and right hydraulic systems]

- **There are sixteen (16) hydraulic actuators**

- **Two (2) actuators for each primary flight control surface**:
  - Ailerons (4)
  - Elevators (4)  \(\Rightarrow\)  Ten (10)
  - Rudder (2)

- **There is one (1) actuator for each spoiler panel**:
  - Inboard (2)  \(\Rightarrow\)  Six (6)
  - Midboard (2)  \(\Rightarrow\)  Two (2)
  - Outboard (2)
- There are two (2) types of actuators:
  - Hydraulic Actuator [HA] (9)
    - One (1) for each primary flight surface
    - One (1) for each inboard and midboard spoiler
  - Uses left and right hydraulic systems
  - Commanded by an [REU] → [HA]
  - Two (2) 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**
• 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
• 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 $> 22^\circ$, or
   - Main wheel spin up if flaps $< 22^\circ$, and

   = inhibits "Too low flaps"

1. Touch and go landings, or
2. INOP:
   - Day and wet (≤3 mm) 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 via flap handle:
  
  UP

  10° FLAP

  TO/20° DOWN

- Hydraulically-powered by either:
  
  L Hyd Sys  AUX  PTU

- Mechanically-actuated:

  • 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

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

| 25,000' | 25,000' | 20,000' |
- **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:

  ![Backup Pitch Switch Diagram]

  ![FCC 1 and FCC 2 Diagram]

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

  ![HSTA Diagram]

- The HSTA A B is electrically controlled from the dual channel horizontal stabilizer control unit (HSCU)

  ![HSCU Diagram]
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
① If no communication between FCC1 FCC2 and HSCU OR
② FCC1 FCC2 channels invalid

FCC ALTERNATE

FCC DIRECT

Backup Pitch

Nose Down

HSCU 1 2

HSTA A B

Nose Up

Backup Pitch

Nose Down

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 e-mail: ivan.luciani@gmail.com

Thank you!