G650 Flight Control System
G650 Flight Control System (FCS)

Electrically-controlled

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

Hydraulically-actuated

Backup
**Software:**

- **Flight Control Law Modes**

**Diagram:**

- **NORMAL**
- **ALTERNATE**
- **DIRECT**
- **BACKUP**

**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**
  - Two Way
  - One Way
- **ALTERNATE**
  - One Way
- **DIRECT**
  - One Way
- **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 ADS
2. IRU Conflict
   \[ \text{Invalid data} \rightarrow \text{AHRS conflict} \]
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

• All 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**

- FCC 1
- FCC 2

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 \textbf{NORMAL}:

1. \[ V_{ref} + 10 \text{ minimum} \]
2. Maximum crosswind: 10 knots
3. Maximum speed: 285 KCAS/\text{MO.90}
4. Flight into known icing conditions prohibited. If in icing conditions exit icing conditions.
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 of FCC Alternate and Normal modes]

![Diagram of anti-ice heaters settings]

+ 5 seconds =

![OK symbol for both flight control surfaces]
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**:

![Diagram of power sources](image)

- **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:

![Flight Control Reset Switch](image)
Flight Control Laws (CLAWS)

Protective Features:

FCC1
A B

FCC2
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

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**95% Throttle Resolver Angle (TRA)**

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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.
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 *

  * Stall Protection Active

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

- **Available when:**
  - Autopilot is OFF
  - V\textsuperscript{mo}/M\textsuperscript{mo} + 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 V\textsuperscript{mo}/M\textsuperscript{mo}**
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**
Pilot input → BFCU → Output

Electrically-controlled → REU → 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 \[ \text{ON} \] \[ \text{ON} \] if no \[ \text{AC} \] 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**
- Electrical Backup Hydraulic Actuator
  - Nicad
  - Located in the tail compartment

- Powers seven (7) EBHA actuators

- Can be charged by RAT via the RAT

- Must be removed from aircraft in cold soaked conditions (≤ -20°C) and stored in a location warmer > -20°C and cooler than +40°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
  - L ESS TRU
  - L ESS DC
  - EBHA BATT
  - EBHA Bus
  - FCC 1B
  - MCE x 7

R GEN
- ON
- R IDG
- R MAIN AC
  - R ESS TRU
  - R ESS DC
  - UPS BATT
  - FCC UPS Bus
  - BFCU
  - FCC 1A
  - FCC 2A

Emergency AC Bus

HSCU
- 1
- 2

Diagram of aircraft control systems, with various components connected and labeled.
Flight Control Law Mode

APU GEN

ON

APU GEN

L MAIN AC

EMERGENCY AC BUS

EBHA BATT

UPS BATT

EBHA Bus

FCC UPS BUS

FCC 1B

MCE x 7

FCC 1A

FCC 2B

HSCU 1 2

R MAIN AC

ESS TRU

ESS DC

ESS DC

ESS TRU

R BATT

UPS BATT
Flight Control Law Mode

**MAIN BATTERIES**
- LEFT: ON
- RIGHT: ON

**EBHA**
- ON

**UPS**
- ON
**Hydraulically-actuated**

- hydraulic fluid and pressure is provided by:

![Hydraulic Fluid Diagram]

- 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)  \( \Rightarrow \) six (6)
  - outboard (2)
There are two types of actuators:

- Hydraulic Actuator
- One for each primary flight surface
- One for each inboard and midboard spoiler
- Uses left and right hydraulic systems
- Commanded by an
- 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 → EHS A
• 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

Active Mode

Electric Backup \(E\) Mode
- 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 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

```
GND SPLR
FLAP ORIDE
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= inhibits “Too low flaps”

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1. Touch and go landings, or
2. INOP:
   - Day and wet (≤ 3 mm) runway
   - Flaps $20^\circ$
**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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<th>VFE</th>
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<tbody>
<tr>
<td>250 KCAS</td>
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<tr>
<td>220 KCAS</td>
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<tr>
<td>190 KCAS</td>
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Maximum G-loads

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

<table>
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<th>Altitude</th>
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<tr>
<td>≤ 25,000'</td>
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<td>≤ 25,000'</td>
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<tr>
<td>≤ 20,000'</td>
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HORIZONTAL STABILIZER

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

  ![HSTA Switches](image)

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

  ![HSCU Switches](image)
1. Failure of HSCU 12 or, 3. Failure of HSTA A B or, 3. Jammed Stabilizer

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

2. FCC alternate:

3. FCC direct:

Backup Pitch 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!