G650 Flight Control System
G650 Flight Control System (FCS)

Electrically-controlled

Brains

FCC 1
A B

FCC 2
A B

Backup

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

Hydraulically-actuated

Muscles

L Hyd Sys

R Hyd Sys

Backup

Primary FCS

Secondary FCS
Electrically-controlled × Hydraulically-actuated

Normal AC and DC power sources
Minimum requirements:

1. One IRU
2. One FCC channel
3. Two ADS
4. HSCU not reporting backup control
**ALTERNATE**

1. Two (2) ADS
2. IRU = Conflict
   \AHRS conflict
3. HSCU is reporting Backup control

**DIRECT**

All FCC 1              FCC 2
A  B              A  B
\times \times

**BACKUP**

All FCC 1              FCC 2
A  B              A  B

\times \times

*Get Home* capability

**BFCU ACTIVE**

All channels are invalid

All channels cannot compute
Any flight control law other than **NORMAL**:

1. \( V_{REF} + 10 \) 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.
Flight Control Laws (CLAWS)

Protective Features:

1. Maneuver Load Alleviation:

2. Speed Brake Auto-Retract:

Speed brakes retract but speed brake handle does not
Flight Control Laws (CLAWS)

3. Dynamic Rudder Limiter:

Low speed = High deflection  
High speed = Low deflection

4. Elevator split limiting:

Protects against large torque associated with a split elevator
NORMAL sub-modes:

1. **AOA Limiting**:
   - 0.75 *Pitch Limit Indicator (PLI) appears \( \downarrow \) \( \downarrow \) \( \downarrow \) \( \downarrow \) \( \downarrow \)
   - 0.87 - 0.93 AOA Limiting (Based on Closure Rate)
   - 0.94 **Stick Shaker activates**
   - 0.96 **Max AOA Limit** *

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

2. **High Speed Protection**:
   - > Vmo Pitch Nose Down Authority decreases by 75%
   - Looks at CAS only
   - Protection inhibited with autopilot on
   - Does not prevent exceeding Vmo
**On Ground**

- Pilot input direct
- Pitch trim moves stab
- > 60 KTS YD functions

**Takeoff and Landing**

(gear/flaps down and AP off)

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

**Cruise**

(gear/flaps up or AP on)

- Surface deflection based on altitude and airspeed
- Pitch trim moves elevator then stabilizer off-loads elevator
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 FCC Direct mode.
- **Brains of the FCS**
- Located in LEER and REER
- Convert **input** from crew/autopilot to an electrical **output**
- Provide a command to the hydraulic actuators, which move the flight control surfaces to the requested position

```
FCC 1  FCC 2
A   B   A   B
```

**Backed up by:**

Backup Flight Control Unit **BFCU**

```
C   BFCU Active   C
```

```
FCC 1
A B
```

```
FCC 2
A B
```

**BFCU**

**Primary FCS** → **Secondary FCS**

*Get home* capability
- Each FCC has two (2) channels - [A B]
- A single FCC channel can operate the flight controls.
- Each FCC channel has two (2) lanes: a Command [C] and a Monitor [M] lane, which provide system integrity.
- Any significant difference between a [C] and a [M] lane causes the channel to shutdown.

![Diagram of a flight control system]

- FCC 1
  - A
  - B
  - CMCM
- FCC 2
  - A
  - B
  - CMCM
- FCC UPS Bus
- L ESS
- R ESS
- BFCU

- Under the floor
  - Can be MEL'ed

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Flight Control Computers (FCC)

Pilot input
Autopilot input

FCC 1
A  B
FCC 2
A  B

Control Laws

FCC Software (flight envelope)

Spoilers
Flight Control Actuation

Roll
Pitch
Yaw
Backup Flight Control Unit (BFCU)

Pilot input

BFCU

Control Laws

BFCU Software

EBHA

Roll Pitch Yaw

Flight Control Actuation

Spoilers
(outboard only)

Get Home capability
FC5 Batteries

- Two (2) flight control batteries:
  - Power the flight controls for 30 minutes
  - Illuminated ON if no AC power is being produced and batteries power their own buses (discharging)

- FTL CTRL BATTERIES
  - EBHA ON, UPS OFF
  - EBHA OFF, UPS ON

System Power ON Self Test (SPOST)
  - EBHA BATT selected ON first then UPS BATT
  - Forty five (45) second test
  - No electrical interruptions during SPOST or a complete power down required
- 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 via the Emergency AC Bus
- FCS Batteries - Charger/Transformer Rectifier

![Diagram](image)

*Dual function: Charger and TR*
Electrical Systems - Failures and Backup: (RAT only)

- LEER
  - FCC 1
    - A
    - B
- BFCU
- LESS DC
- LESS TRU
- REER
  - FCC 2
    - A
    - B
- LESS DC
- LESS TRU

* FCCs go to FCC ALTERNATE but can be reset back to NORMAL

- EMERGENCY AC BUS
  - EBHA Bus
    - EBHA Batt
  - FCC UPS Bus
    - UPS Batt
- FLT CTRL RESET ON
- L IAG
- APU GEN
- RAT
- R IAG
Electrical Systems - Failures and Backup:
(Main Batts/UPS Batt only)

LEER
FCC 1
A B

LESS DC

BFCU

REER
FCC 2
A B

RESS DC

L MAIN BATT

EBHA BUS

FCC UPS BUS

R MAIN BATT

EBHA BATT

UPS BATT

Emergency AC Bus

L IDG

APU GEN

RAT

RIDG
Electrical Systems - failures and backup:
(UPS BATT only)

LEER
FCC1
A B

LE SS DC

BFCU

REER
FCC2
A B

RE SS DC

L MAIN BATT

EBHA BUS

FCC UPS BUS

R MAIN BATT

EBHA BATT

UPS BATT

EMERGENCY AC BUS

L IAG

APU GEN

RAT

R IAG
**Electrically-controlled ** × **Hydraulically-actuated**

**Hydraulic Actuators**

**L Hyd Sys**
- Hydraulic Supply
- Electrical Supply
- FCC input
- FCC input

**Actuator**

**Hydraulic Manifold**

**REU**

**L Aileron**

**R Hyd Sys**
- Hydraulic Supply
- Electrical Supply
- FCC input
- FCC input
- BFCU input
- FCC input

**Actuator**

**Hydraulic Manifold**

**REU**

**MCE**

**REMOTE ELECTRONICS UNIT - REU:**

- Mounted on associated hydraulic manifold
- Averages FCC\_A\_B and FCC\_A\_B commands
- Electrically controls a valve in the hydraulic manifold to control HA and EBHA position to match FCC\_A\_B and FCC\_A\_B commands

**MOTOR CONTROL ELECTRONICS - MCE:**

- Controls operation of electric E backup motor
Electrically-controlled × Hydraulically-actuated

Hydraulic Actuators

Hydraulic Actuators — Powered by

HA EBHA

Nine (9) Hydraulic Actuators (HA)

Seven (7) Electric Backup Hydraulic Actuators (EBHA)
Electrically-controlled × Hydraulically-actuated

Hydraulic Actuators

Ailerons and Elevators

**Outboard** = HA

**Inboard** = EBHA

Rudder

**Upper** = HA

**Lower** = EBHA

Spoilers

**Outboard** = EBHA

**Mid/Inboard** = HA

Active State

HA → Damped Bypass State

EBHA

Active State

Damped Bypass State

Electric Backup

After engine shutdown HA Trap hydraulic fluid and act as gust dampers
Hydraulic Systems - failures and backup:

Ailerons
Elevators
Rudder
Spoilers

* GET home capability
** Outboard panels only

Speed brakes
Ground spoilers
Stick shaker

EBHA

FCC1
FCC2

NORMAL

L Sys
R Sys

L Sys
R Sys
The failure of the **LEFT** engine will result in a number of hydraulic actuators powered by the **L** Hydraulic system going into a damped state. The remaining actuators, powered by the **R** Hydraulic system, will power all primary flight controls.
Hydraulic Systems - failures and backup:

The failure of the **Right** engine will result in a number of hydraulic actuators powered by the **R** Hydraulic system going into a damped state. The remaining actuators, powered by the **L** Hydraulic system, will power all primary flight controls.

---

(outboard spoiler panel OK)
**FLIGHT CONTROL**

- Pilot input
- Autopilot input

- **ROLL** (Ailerons)

- Electrically-controlled (output)

- Remote Electronic Units (REU)
  - REU
  - REU
  - HA
  - EBHA

- **L** Hyd System
- **R** Hyd System

- Hydraulically-actuated

- Ailerons
Pitch (ELEVATORS)

Pilot input
Autopilot input

FCC 1
A
B

BFCU

FCC 2
A
B

Electrically-controlled (output)

REU

REU

REMOTE ELECTRONIC UNITS (REU)

HA
EBHA

Hydraulically-actuated

L Hyd System
R Hyd System

ELEVATORS

G650

g650_flight_control_system
Spoilers

Electrically-controlled via speed brake handle.

Hydraulically-powered by:

L Hyd Sys  R Hyd Sys

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°
Do not extend spoilers in flight with gear down or flaps 39°.

Prohibited

Do not arm ground spoilers for touch and go landings.
FLAPS

- Electrically-controlled via flap handle:

- Hydraulically-powered by either:

- 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

<table>
<thead>
<tr>
<th>Flap</th>
<th>VFE</th>
<th>VFE</th>
<th>VFE</th>
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<tbody>
<tr>
<td>0</td>
<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></th>
<th>-1 To +2.5 g</th>
<th>0 To +2 g</th>
<th>0 To +2 g</th>
<th>0 To +2 g</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0 To +1.5 g</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(&lt; MLW)</td>
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</tbody>
</table>

Maximum Operating Altitude

<table>
<thead>
<tr>
<th></th>
<th>25,000'</th>
<th>25,000'</th>
<th>20,000'</th>
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</thead>
</table>

Flap 0

Flap 10

Flap 20

Flap 30
- 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:

- 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 \text{12} or, 3. Failure of HSTA \text{AB} or, 3. Jammed Stabilizer

- Pitch Trim switches control/trim elevators
- No elevator off-load feature
1. If no communication between FCC and HSCU, or channels invalid.

2. FCC alternate, FCC direct.

Backup Pitch controls horizontal stabilizer at a reduced rate of 0.15°/second (normal = 0.4°/s).

Nose down.

Nose up.
Questions, comments or errors?
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Thank you!