Effect of ZFW / ZFWCG on Aircraft Operations
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Single-Aisle (SA)

- FM Architecture
- FAC Architecture
- Incorrect ZFW entered on the MCDU
- Incorrect ZFWCG entered on the MCDU
The Flight Management computes the Gross Weight and the Center of Gravity based on:
- ZFW/ZFWCG entered by the pilot
- The fuel quantity indication (from the FQI)
- The fuel flow information (from the FADEC)
• The **GW** is displayed on the **ECAM**.

• Both the **GW** and **CG** are displayed on the **MCDU’s FUEL PRED page**.

![Diagram showing the fuel management system and its components](image-url)
• Both the **GW** and **CG** are used by the **FM** for predictions that include optimum managed speeds and operating speeds (Vls, Vapp, F, S and green dot)
SA: FAC Architecture …

• On the A320, the FAC computes its own CG and GW from aerodynamic data.

• These values have a minor impact on ELAC control laws and FG control laws, as they are used to adjust the gains of the flight control laws.

• Also, the FAC computes the operating speeds (Vls, F, S, O) that are displayed on the PFD.
SA: FAC Architecture ...

Pilot Input

MCDU

FQI

ZFW

ZFWCG

FM

Fuel qty

Fuel flow

ECAM

MCDU

Predictions/Speeds

ADIRS

A/C Config

Thrust

THS Position

FAC

GW, CG

Speeds

ELAC

FG

PFD

Control laws

Control laws

EXCEPT A318

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15000 feet, or Speed above 250 knots

GW from FM

GW = f(AOA)

GW = f(FF)

GW = f(AOA)

GW = f(FF)

GW from FM

SA: FAC Architecture...

EXCEPT A318
SA: If Incorrect ZFW Entered

- The GW, computed by the FM and displayed on the ECAM, is incorrect.
SA: If Incorrect ZFW Entered...

The GW and CG, displayed on MCDU, are incorrect.
SA: If Incorrect ZFW Entered…

- The **FM** predictions are **affected**.
A discrepancy can be observed between the operating speeds, displayed on the MCDU and those displayed on the PFD (PFD speeds are not affected (Except on the A318)).
In flight if the ZFW error is significant, the « CHECK GW » message automatically triggers if the FM and FAC GW differ by more than 7 tons.
SA: If Incorrect ZFWCG Entered

- An incorrect ZFWCG has a minor impact on the predictions computed by the FM.

- There is an impact on the Vls and VApp that is displayed on the MCDU.

- On SA (except A318), there is no effect on the Vls displayed on PFD, due to the fact that, in flight, the FAC computes its own CG.
SA: If Incorrect ZFWCG Entered …

• In flight, the correct CG is not accessible:
  – The pilot has no access to the FAC value (It is never displayed on the ECAM).
  – In flight, the THS position is not representative of the current CG (depends on Mach, weight, altitude):

  *In flight, the THS position does not enable the current CG to be determined.*
A318: FM and FAC Architecture

• Goal of the A318 FAC Standard:
  ▶ To cancel speed discrepancies between the MCDU and the PFD.

• A318 FAC Design:
  ▶ The FAC uses the GW/CG, computed by the FM, only for the computation of the operating speeds that are displayed on the PFD.

• The rest of the FAC architecture remains unchanged. In particular, the comparison between the GW computed by the FM and FAC (CHECK GW message).
A318: FM and FAC Architecture ...

- Pilot Input
  - MCDU
    - FQI
    - FADEC
      - Fuel qty
      - Fuel flow
      - GW
      - CG
      - FM
        - Predictions/Speeds
        - GW
        - CG
        - FAC
          - GW, CG
          - FG
            - ELAC
              - Control laws
              - Control laws
            - PFD
              - Speeds
- ADIRS
  - A/C config
  - Thrust
  - THS position
- ZFW: FM and FAC Architecture...
- ZFWCG: Predictions/Speeds
- ZFW: Control laws
- ZFWCG: Control laws
The rest of the FAC architecture remains unchanged.

The comparison between the GW computed by the FM and FAC still exists.

(CHECK GW message)
A318: If Incorrect ZFW Entered

• As with the A320:
  ‣ Same effect on FM predictions/speeds

• The Speeds (Vls, F, S, O) that are displayed on the PFD are impacted in the same way as on the MCDU (no longer speed discrepancies).

But $V_{a\text{ PROT}}$, $V_{a\text{ MAX}}$ and $V_{SW}$ are not affected since based on aerodynamic data.
A318: If Incorrect ZFW Entered…

• As with the A320:

If the ZFW error is significant:

- The « CHECK GW » message automatically triggers once, in flight, if the FM and the FAC GW differs by more than 7 tons.
A318: If Incorrect ZFWCG Entered

- As with the A320:
  - Same effect on FM predictions / speeds.

- The VLS that is displayed on the PFD is impacted in the same way as on the MCDU.
  - No PFD/MCDU discrepancy

But $V_{a\text{PROT}}$, $V_{a\text{MAX}}$, and $V_{SW}$ are not affected since based on aerodynamic data.
Long-Range (LR)

- FCMC/FE Architecture
- CG Control
- If Incorrect ZFW entered on the MCDU
- If Incorrect ZFWCG entered on the MCDU
LR: FCMC/FE Architecture

- The **Fuel Control and Monitoring Computer (FCMC)** computes the **GW** and **CG**, based on the:
  - Mandatory **ZFW** and **ZFCG** entered by the pilot, and
  - The fuel quantities gauged in each individual tank.

![Diagram showing the FCMC/FE Architecture](image-url)
• The current GW and CG are displayed on the ECAM.
• They are also displayed on the MCDU’s FUEL PRED page.
• And transmitted to the Flight Envelope (FE).

![Diagram showing the FCMC/FE architecture]

- Pilot input
- MCDU
- Gauged fuel quantities
- FCMC
- ZFW
- ZFWCG
- ECAM
- MCDU
- GW
- CG
- FE
- GW/CG display
The FE transmits the GW and CG, computed by the FCMC, to the FM, PRIM and FG, for a use similar to that of Single-Aisle aircraft.
The **GW** and **CG** from **FCMC** are also used by the **FE** for computing the **operating speeds** displayed on the **PFD**.

![Diagram showing the integration of GW and CG for operating speed calculations](image)
The FCMC also ensures CG control according to the current GW and CG,

It moves the CG backwards, and maintain the AFT CG target to reduce fuel consumption in cruise.
LR: AFT CG Target

WEIGHT

FCMC

AFT CG target - 0.5%

AFT certified limit

FUEL BURN
AUTOMATIC TRIM
TANK TRANSFER

LR: AFT CG Target
LR: FE’s Backup GW and CG

• A backup CG, along with the backup GW, are computed by the FE from aerodynamic data.

• It is used by the FM, FG and PRIMs, in case of a dual FCMC GW/CG failure.
LR: EXCESS AFT CG Warning

- An **EXCESS AFT CG** warning is also generated **independently** from the CG computed by FCMC, in order to limit the AFT CG.

![Diagram showing the Backup GW/CG computation process involving Speed or Mach, Thrust, Altitude, THS Position, ELEVATOR Position, PRIM, CG, GW, and FE.](image)
LR: If Incorrect ZFW Entered

- The **GW** that is computed by the FCMC is incorrect.
- The **CG** that is computed by the FCMC is also incorrect.

Incorrect ZFW

MCDU

ZFW

ZFWCG

FCMC

Gauged fuel quantities

GW/CG display

ECAM

MCDU

GW

CG

CG Regulation (slightly affected)

FE

FM

FG

PRIM

PFD

PREDICTION SPEEDS

CONTROL LAWS

SPEEDS
LR: If Incorrect ZFW Entered…

The GW and CG displayed on ECAM/MCDU are incorrect.

- Incorrect ZFW
- Gauged fuel quantities
- CG Regulation (slightly affected)
- ECAM
- MCDU
- GW/CG display
- FM
- FG
- FE
- PRIM
- PFD
- PREDICTION SPEEDS
- CONTROL LAWS
- SPEEDS
LR: If Incorrect ZFW Entered …

The CG regulation is slightly affected, since the AFT CG target depends on the weight.

But, the “EXCESS AFT CG” warning is not affected.
The incorrect GW and CG are transmitted by the FE to the FM, FG and PRIM.

**LR: If Incorrect ZFW Entered ...**

Incorrect ZFW

MCDU

---

Gauged fuel quantities

FCMC

---

ZFW

ZFWCG

---

CG Regulation (slightly affected)

---

ECAM

MCDU

---

GW/CG display

---

FM

---

PREDICTION SPEEDS

---

FG

---

CONTROL LAWS

---

PRIM

---

CONTROL LAWS

---

FE

---

PFD

---

SPEEDS
LR: If Incorrect ZFW Entered …

The FM predictions/speeds will be affected …

- Incorrect ZFW
- Gauged fuel quantities
- ZFW
- ZFWCG
- FCMC
- GW/CG display
- ECAM
- MCDU
- FM
- FG
- PRIM
- PFD
- GW
- CG
- CG Regulation (slightly affected)
LR: If Incorrect ZFW Entered …

The FG and PRIM control laws are slightly affected.

![Diagram showing the impact of incorrect ZFW on various aircraft systems.](image-url)
LR: If Incorrect **ZFW** Entered …

Vls, F, S, and green dot displayed on the PFD are affected.

- **MCDU**
- **ZFW** → **FCMC**
- **Gauged fuel quantities** → **GW**
- **CG Regulation** (slightly affected)
- **PFD**
- **ECAM**
- **MCDU**
- **GW/CG display**
  - **FM**
  - **FG**
  - **FE**
  - **PRIM**
  - **PFD**

**PREDICTION SPEEDS**

**CONTROL LAWS** (slightly affected)

**CONTROL LAWS** (slightly affected)

**SPEEDS**
LR: If Incorrect ZFW Entered …

Vls, F, S, and green dot displayed on the PFD are affected.

But $V_{aPROT}$, $V_{aMAX}$ and $V_{SW}$ are not affected since based on aerodynamic data.
LR: If Incorrect ZFWCG Entered

The CG computed by the FCMC is incorrect.
LR: If Incorrect ZFWCG Entered …

Incorrect CG is displayed on the ECAM / MCDU.
LR: If Incorrect ZFWCG Entered …

CG regulation may be affected.

But the “EXCESS AFT CG” warning is not affected.
LR: If Incorrect ZFWCG Entered …

The incorrect CG is transmitted by the FE to the FM, FG, PRIM and PFD.

Incorrect ZFWCG

MCDU

Gauged fuel quantities

ZFW

FCMC

GW

CG Regulation

FE

ECAM

MCDU

GW/CG display

ECAM

MCDU

PREDICTION SPEEDS

FM

CONTROL LAWS

FG

PRIM

PFD

CONTROL LAWS

SPEEDS
LR: If Incorrect ZFWCG Entered …

FM Predictions and speeds will be impacted.

Diagram:
- Incorrect ZFWCG
- ZFW
- Gauged fuel quantities
- GW/CG display
- EW/CG Regulation
- FE
- PREDICTION SPEEDS
- CONTROL LAWS
- PFD
- PRIM
- FG
- MCDU
- ECAM
- FM
- GW/CG display
- ZFWCG
- CG Regulation
- MCDU
- GW
- CG
- FCMC
- Gauged fuel quantities
- MCDU
- ECAM
- GW/CG display
- ZFWCG
- CG Regulation
- MCDU
- ECAM
- GW/CG display
- ZFWCG
- CG Regulation
- MCDU
- ECAM
- GW/CG display
- ZFWCG
- CG Regulation
- MCDU
- ECAM
- GW/CG display
LR: If Incorrect ZFWCG Entered …

- FG and PRIM control laws are slightly affected.
- VLS displayed on PFD is impacted.

But $V_{a\text{PROT}}$, $V_{a\text{MAX}}$ and $V_{\text{SW}}$ are not affected since based on aerodynamic data.
LR: If Incorrect ZFWCG Entered …

• As with SA aircraft, the correct CG is not accessible:

  – The pilot has no access to the FE value (It is never displayed on the ECAM).

  – In flight, the THS position is not representative of the current CG (depends on Mach, weight, altitude):

  In flight, the THS position does not enable the CG to be determined.
Airbus Recommendations

FLIGHT PREPARATION

• LTS ZFW and ZFCG must be computed CAREFULLY.

• Incorrect ZFW and ZFWCG computation:
  ‣ May significantly affect predictions and speeds…
  ‣ May significantly affect V1, V2, and VR computation.

The only way for the crew to check
ZFW, ZFCG, V1, V2, VR is EXPERIENCE…
Cockpit Preparation (All FBW)

• **ZFW** and **ZFCG** must be entered/checked CAREFULLY...

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**Airbus Recommendations**

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**FMGS DATA INSERTION**

GROSS WEIGHT INSERTION (INIT B page):

*— ZFCG/ZFW .................................................. INSERT

*— BLOCK FUEL .................................................. INSERT

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**CAUTION**

Part of characteristic speeds displayed on PFD (green dot, F, S, VLS) are computed from the ZFW and ZFCG entered by the crew on the MCDU. Therefore these data must be carefully checked (captain responsibility).
Airbus Recommendations …

Before Pushback, or Start, when the final LTS is available (All FBW):

• Check the final ZFW / ZFCG with the previously-entered data (FCOM 3.03.07)

• Always check that TOCG is within the LTS operational limits, not the certified limits:
  
  ‣ The Operational limits include tolerance on cargo loading and passenger distribution
  
  ‣ The certified limits take no margin.
Airbus Recommendations …

• For the A330/A340

  › A discrepancy between the LTS CG and the ECAM CG may occur since:

    – The LTS Fuel distribution is based on **standard refuel distribution**.

    – Manual refueling with non standard distribution may inadvertently be performed.
Airbus Recommendations …

• For the A330/A340 …

In case of a greater than 2% discrepancy between the final LTS CG and the ECAM CG:

› Check that the ZFW / ZFCG have been entered correctly.

› If the discrepancy remains, rely on the ECAM CG. BUT, check that it is within the LTS operational limits (not the certified limits).

› The ECAM CG can also be crosschecked by using the LPC weight and balance module or the FCOM 2.01.40.
Airbus Recommendations ...

**Airbus Recommendations**

**AIRCRAFT**
- A/C Type: A330-243
- Tail Number: F-330A
- AIP: LFBO

**CONFIGURATION**
- Conf. Code: Summer
- Crew: 2/12
- Catering: Type B
- Miscellaneous: NONE
- DOW: 124420 kg
- DOCG: 26.2% MAC
- MTOW (kg): 230000
- MLW (kg): 180000

**LOADING**
- PAX: 150/50
- Cargo (kg): 8000
- FOB (kg): 82000
- Fuel Density (kg/l): 0.786
- Taxi Fuel (kg): 1000
- Trip Fuel (kg): 75000
- Underload: 1130 kg limited by Takeoff
- Total PAX: 150/50
- Total Cargo: 8000 kg

**RESULTS**
- Dry Oper: 134420 kg 28.2%
- Payload: 23450 kg
- Zero Fuel: 147870 kg 33.0%
- T/O Fuel: 81000kg
- Take Off: 228870 kg 30.7%
- Trip Fuel: 75000 kg
- Landing: 153870 kg 31.1%
- THS: 2.1 Up

**PAYLOAD DISTRIBUTION**

**FUEL DISTRIBUTION**

**AIRBUS LPC**
Airbus Recommendations …

• For the A330/A340 …

  ‣ In case of a less than 2% discrepancy between the final LTS CG and the ECAM CG:

    – No further action is required.
    
    – BUT, nevertheless, always check that the ECAM CG is within the LTS operational limits.
Conclusion

• Predictions and speed computations are impacted by ZFW/ZFWCG.

⇒ **On ground:**
  - LTS ZFW/ZFWCG should be **carefully computed**.
  - The crew should **carefully check** these values and that TOCG is **within the operational limits**.

⇒ **However, in flight:**
  - GW/C CG is also **computed independently** from these values:
    - a GW crosscheck is available in flight (SA family)
    - a CG crosscheck is available in flight (LR family)
  - Protection speeds are **not impacted** by ZFW and ZFCG entered by the crew.