Optimum CG position

What is the best CG position for an aircraft?
Impact of Centre of Gravity

- Centre of gravity
- Optimize CG:
  - For best takeoff performance
  - Usually aft CG minimizes fuel consumption
  - To be able to reach optimum CG in flight (aircraft with trim tank)
Introduction

“What is the best CG position for an aircraft?”

“25% MAC so that the aircraft is balanced”

“AFT”

“as AFT as possible”

AFT of what?
Introduction

What is the best CG position for an aircraft?

Well, any CG inside the limits is OK. But there is a range of recommended CG positions and this range differs from one aircraft to the other.
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?
- Why would I select an optimum CG position?
- What is the best Center of Gravity position for an aircraft?
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?
- Why would I select an optimum CG position?
- What is the best Center of Gravity position for an aircraft?
How to place aircraft CG at the optimum?

**Aircraft Basic configuration**

- Low flexibility

**Operator’s items and DOW**

- Low flexibility

**Fuel**

- NO flexibility
How to place aircraft CG at the optimum?

**Passengers**

![Diagram of an airplane cabin with a partial flexibility label]

**Cargo**

Several constraints:
- Priority
- Temperature and ventilation
- Incompatibilities
- Pyramidal loading
- Aircraft stability on ground
- ....
How to place aircraft CG at the optimum?

• Conclusion:
  ‣ Main actor is the Load Planner
  ‣ He can control ZFCG and TOCG positions
  ‣ He has many constraints to consider
  ‣ It is not so easy to place the CG at the optimum

« Any CG inside the operational limits is OK »
How to place aircraft CG at the optimum?

• Conclusion:

“What is the best CG position for an aircraft?”

Give Load Planners an “Optimum ZFCG range” or an “Optimum TOCG range” instead of an optimum CG position.
How to place aircraft CG position at the optimum? Is it a flexible process?

Why would I select an optimum CG position?

What is the best Center of Gravity position for an aircraft?
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?
- Why would I select an optimum range of CG positions?
- What is the best Center of Gravity position for an aircraft?
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?
- Why would I select an optimum range of CG positions?
  - To reduce my fuel consumption
  - To benefit from better Takeoff and Landing performance
- What is the best Center of Gravity position for an aircraft?
Why would I select an optimum range of CG positions?

- To reduce my fuel consumption

To maintain the aircraft stable, tail down force is mandatory.
Why would I select an optimum range of CG positions?

- To reduce my fuel consumption

To maintain the aircraft stable, tail down force is mandatory.

The more forward the CG, the higher the tail down force.

The higher the tail down force,
- the higher the lift necessary to maintain the flight
- the higher the drag
- the higher the fuel consumption.
Why would I select an optimum range of CG positions?

- **To reduce my fuel consumption**

  The more forward the CG, the higher the fuel consumption, **IN GENERAL**

  **But for Single Aisle aircraft**
  - Complex aerodynamic interaction Wing-Tail
  - Optimum CG is not the most aft but somewhere inside the CG limits
  - Optimum CG position highly depends on aircraft Flight Level (FL)
  - Difference in fuel consumption between two CG positions inside the CG limits is low

  The more forward the CG, the higher the fuel consumption, **IN GENERAL**

  For Single Aisle aircraft, **NO effect** of CG position on fuel consumption.
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?

- Why would I select an optimum range of CG positions?
  - To reduce my fuel consumption
  - To benefit from better Takeoff and Landing performance

- What is the best Center of Gravity position for an aircraft?
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance

To fly the aircraft, Lift must be higher than (Weight + Tail down force).

The more forward the CG, the higher the tail down force.

The higher the tail down force,
- the higher the lift necessary to maintain the flight
- the higher the minimum speed (Vs1g) necessary to maintain the flight.
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance

The more forward the CG, the higher the minimum speed ($V_{s1g}$) necessary to maintain the flight.

Take-off performance

$$V_2 \geq 1.13 \ V_{s1g}$$

$V_{s1g}$ ➔ $V_2$ ➔ $V_{LOF}$ ➔ $V_R$ ➔ $V_1$ ➔ TOD ➔ TOW ➔ $V_2$

The more forward the CG, the lower the takeoff performance.
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance

\[ V_{app} \geq 1.23 \ V_{S1g} \]

Landing performance

The more forward the CG, the higher the minimum speed \( V_{S1g} \) necessary to maintain the flight.

The more forward the CG, the lower the takeoff and landing performance.
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance

  The more forward the CG, the lower the takeoff and landing performance.

Maximum Allowed Takeoff and Landing Weight

Takeoff and Landing performance is computed not knowing what is the real aircraft CG position.

The method applied must be conservative -> computation at the most forward allowed CG position.

For aircraft that are naturally aft loaded ->

  the aircraft could takeoff or land higher weight than the dispatch ones.

  so there are two certified forward CG limits

  - CG in the forward part of CG range -> conservative performance
  - CG in the aft part of CG range -> better performance
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff and Landing performance

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Takeoff CG Position</th>
<th>Landing CG Position</th>
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<tbody>
<tr>
<td>A318</td>
<td>Forward CG 22%MAC</td>
<td></td>
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Content

- How to place aircraft CG position at the optimum? Is it a flexible process?
- Why would I select an optimum range of CG positions?
- What is the best Center of Gravity position for an aircraft?
  - To reduce my fuel consumption
  - To benefit from better Takeoff and Landing performance
What is the best CG position for an aircraft?

Best CG is \( X \).

Optimum TOCG range is \( Y \).

Optimum ZFCG range is \( Z \).
What is the optimum CG range for an aircraft?

- To reduce my fuel consumption

Wide Body, Long Range Families: « The optimum CG is … »

Large Aircraft Family: « The optimum CG is … »

Single Aisle Family: « The optimum CG is … »
What is the optimum CG range for an aircraft?

- To reduce my fuel consumption

These aircraft are equipped with a Trim tank and with in-flight CG target system.

The system optimises the aircraft CG in-flight by transferring fuel from the wing area to the trim tank.

Wide Body, Long Range Families:
« The optimum CG is … »

ZFCG aft enough to reach AFT CG Target during the flight
ZFCG too forward to reach AFT CG Target during the flight
What is the optimum CG range for an aircraft?

- To reduce my fuel consumption

3 ZFCG zones can be defined:

1. CG range with AFT CG target not reachable
2. CG range with AFT CG target reachable after transfer to the trim tank
3. CG range with AFT CG target reachable after transfer to the trim tank and fuel burn

Wide Body, Long Range Families:
« The optimum ZFCG is aft enough to enable reaching AFT CG target during flight »
What is the optimum CG range for an aircraft?

- To reduce my fuel consumption

Large Aircraft Family:
« The optimum ZFCG or TOCG range is any CG inside the operational CG limits »
What is the optimum CG range for an aircraft?

• To reduce my fuel consumption

Single Aisle Family:
« The optimum ZFCG or TOCG range is any CG inside the operational CG limits »

The more forward the CG, the higher the fuel consumption, **IN GENERAL**
For Single Aisle aircraft, NO effect of CG position on fuel consumption.
Content

- How to place aircraft CG position at the optimum? Is it a flexible process?

- Why would I select an optimum range of CG positions?

- What is the best Center of Gravity position for an aircraft?
  - To reduce my fuel consumption
  - To benefit from better Takeoff and Landing performance
Why would I select an optimum range of CG positions?

- To benefit from better Takeoff performance
What is the optimum CG range for an aircraft?

- To benefit from better Takeoff performance

Any aircraft concerned:

« The optimum TOCG range is any CG aft of the most aft certified takeoff limit taking into account operational CG margin »
What is the optimum CG range for an aircraft?

- To benefit from better Takeoff performance

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2% is an average operational CG margin
What is the optimum CG range for an aircraft?

• To benefit from better Landing performance

Any aircraft concerned:
« The optimum LDCG range is any CG aft of the most aft certified landing limit taking into account operational CG margin »
What is the optimum CG range for an aircraft?

• To benefit from better Landing performance
What is the optimum CG range for an aircraft?

- To benefit from better Landing performance

Any aircraft concerned:

« The optimum LDCG range is any CG aft of the most aft certified landing limit taking into account operational CG margin »

« The optimum ZFCG range is any CG in the aft ZFCG limit »
Conclusion

“What is the best CG position for an aircraft?”

« Any CG inside the operational limits is OK »
Conclusion

“What is the best CG position for an aircraft?”

« Optimum ZFCG range » or « Optimum TOCG range » is better than « Optimum CG position »

Fuel Consumption

- **Single Aisle and Large Aircraft:**
  - NO OPTIMUM

- **Wide Body, Long Range Aircraft:**
  - ZFCG aft enough to reach AFT CG target

Takeoff performance

- **A320, A340:**
  - TOCG aft of most aft certified Takeoff CG limit + operational margin

- **A318, A319, A320, A340:**
  - ZFCG in the aft ZFCG limit (Landing CG is aft of most aft certified Landing CG)
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