



Presented by:



Catherine BONNET
Flight Operations,
Weight and Balance Engineer



Optimum CG position

What is the best CG position for an aircraft ?

Introduction

Impact of Centre of Gravity

DISPATCH
TRANSIT
COCKPIT PREPARATION
DEPARTURE
TAXI - OUT
TAKEOFF
CLIMB
CRUISE
DESCENT
HOLDING
APPROACH
LANDING
TAXI - IN

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)



Optimum CG position
What is the best CG position for an aircraft?

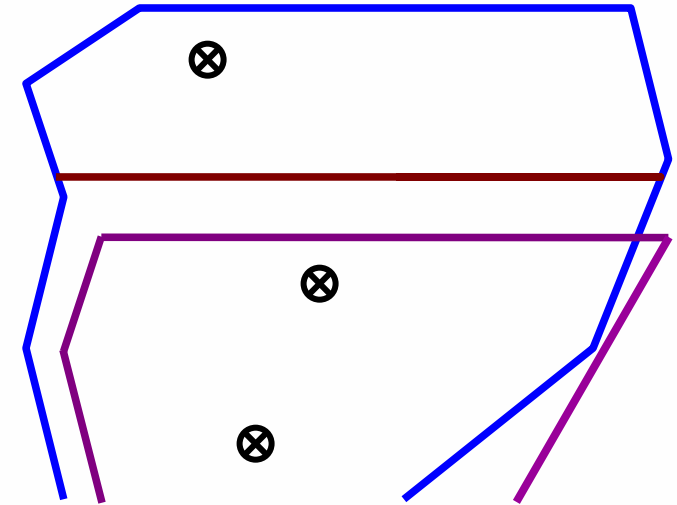
16th Performance and Operations conference May 2009 Page 10

S7 Airline economics

The influence of some parameters on fuel consumption

By Monique Fueri and Yves Lemelle

Slide 10



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 ?





“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

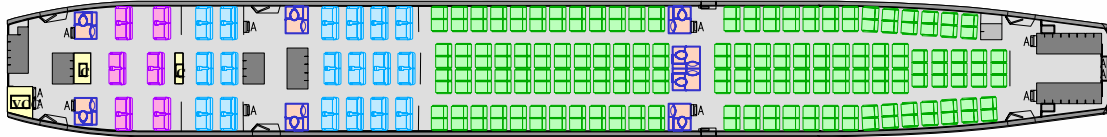
- How to place aircraft CG position at the optimum ?
Is it a flexible process ?
- Why would I select an optimum CG position ?
- What is the best Center of Gravity position for an aircraft?

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?

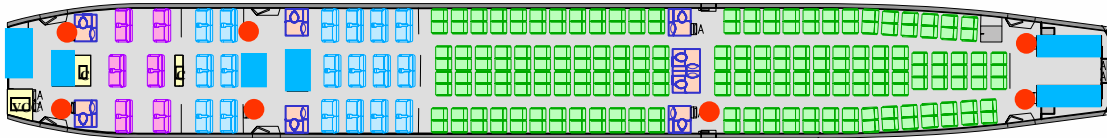
How to place aircraft CG at the optimum ?

Aircraft Basic configuration



Low flexibility

Operator's items and DOW



Low flexibility

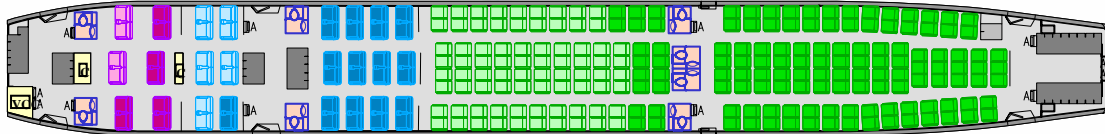
Fuel



NO flexibility

How to place aircraft CG at the optimum ?

Passengers



Partial flexibility

Cargo

Several constraints:

- Priority
- Temperature and ventilation
- Incompatibilities
- Pyramidal loading
- Aircraft stability on ground
-

High flexibility



How to place aircraft CG at the optimum ?

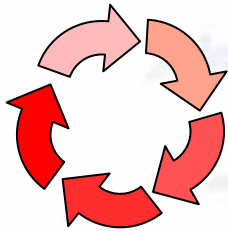
- Conclusion:

- ▶ 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

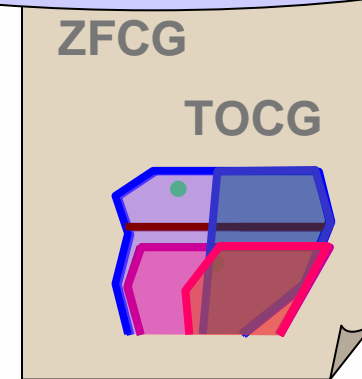
« Any CG inside the operational limits
is OK »

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

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

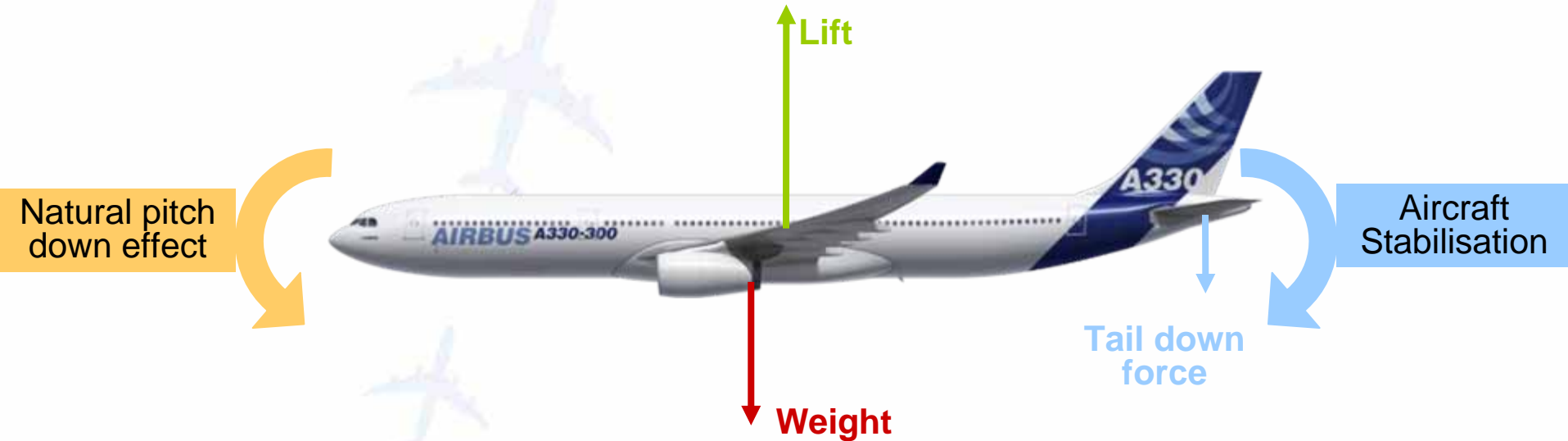
- How to place aircraft CG position at the optimum ?
Is it a flexible process ?
- Why would I select an optimum range of CG positions ?
- What is the best Center of Gravity position for an aircraft?

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 ?

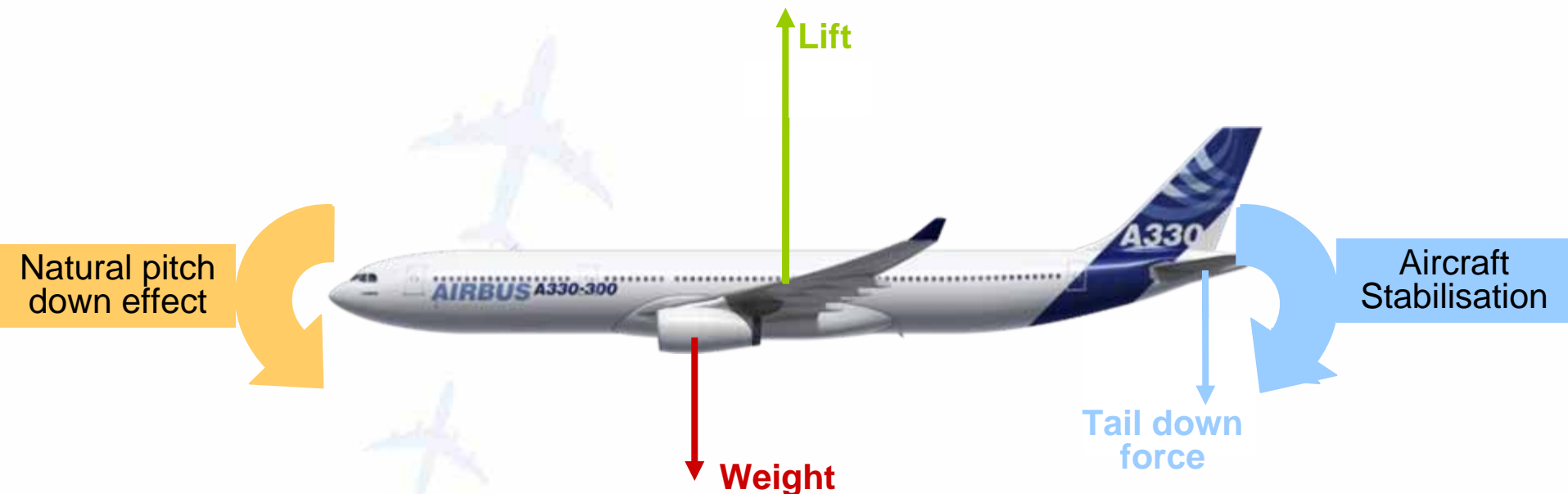
- To reduce my fuel consumption



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

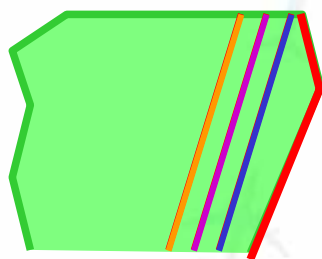
the higher the fuel consumption.

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



FL₁

FL₂

FL₃

- 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***

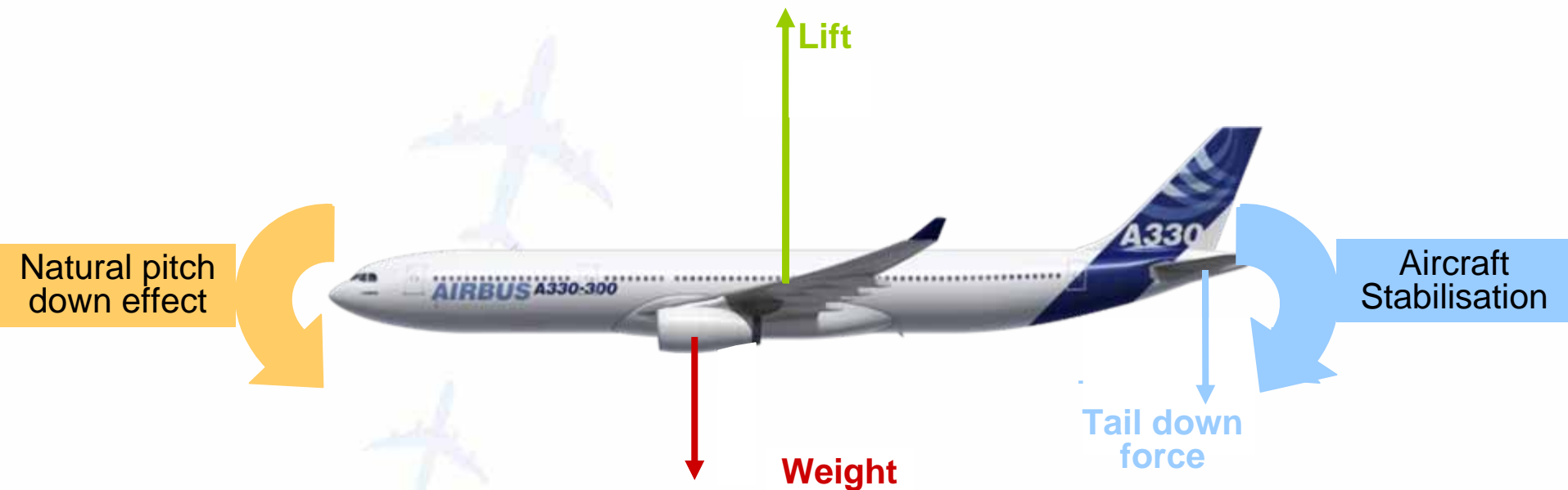
For Single Aisle aircraft, **NO effect** of CG position on fuel consumption.

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 (V_{s1g}) 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

$$V_2 \geq 1.13 V_{S1g} \Rightarrow V_{S1g} \nearrow \Rightarrow V_2 \nearrow \begin{cases} \nearrow \text{TOD} \nearrow \\ \searrow \text{TOW} \searrow \end{cases}$$



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

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

Landing performance

$$V_{app} \geq 1.23 V_{S1g} \Rightarrow V_{S1g} \Rightarrow V_{app} \Rightarrow \begin{matrix} LD \nearrow \\ LW \searrow \end{matrix}$$



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 ->

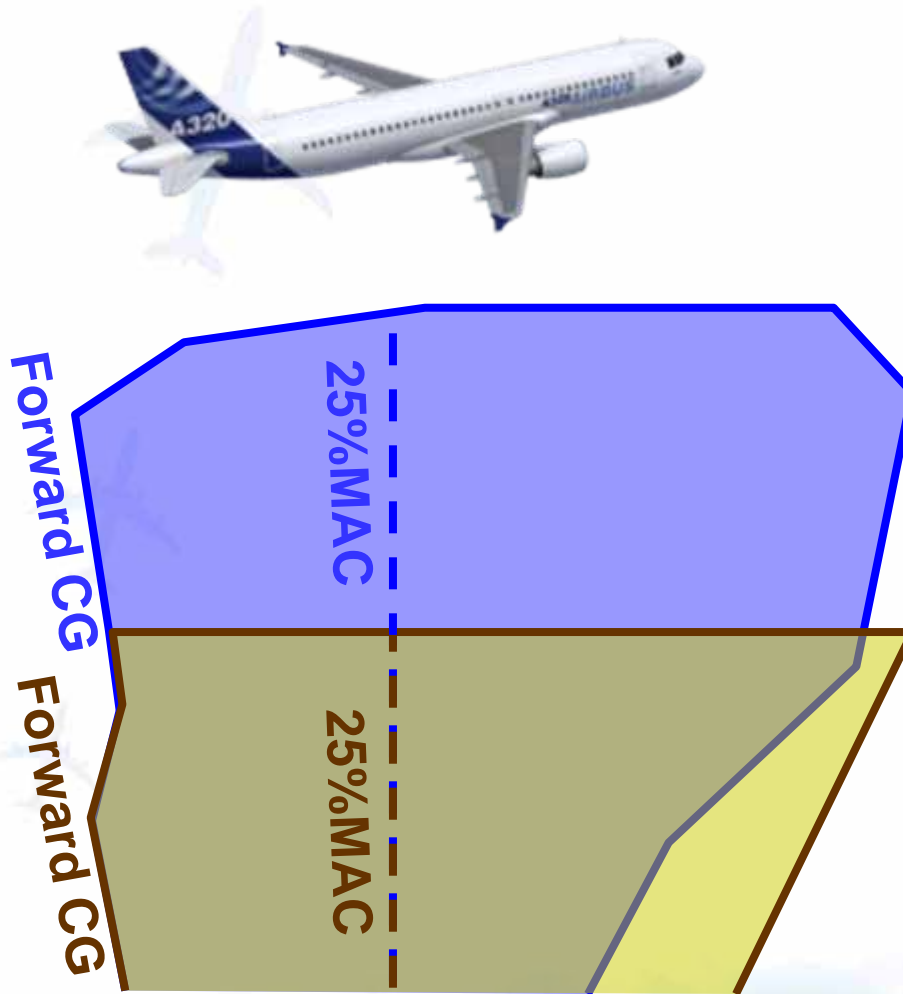
the aircraft could takeoff or land higher weight than the dispatch ones.

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

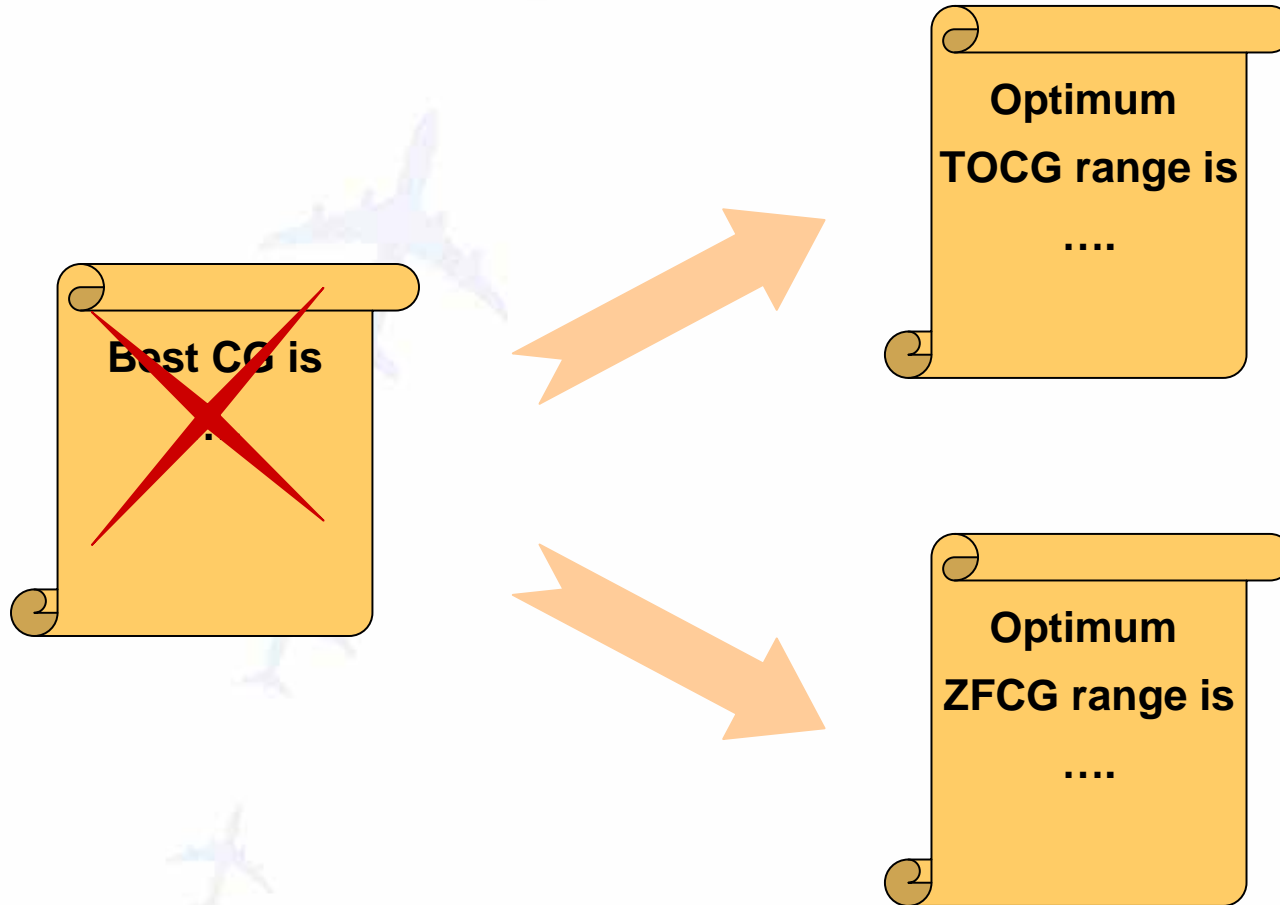


	TAKEOFF	LANDING
A318		Forward CG 22%MAC
A319		Forward CG 25%MAC
A320	Forward CG 25%MAC	Forward CG 25%MAC
A340-200/300	Forward CG 26%MAC	Forward CG 26%MAC
A340-500	Forward CG 28%MAC	Forward CG 28%MAC
A340-600	Forward CG 23%MAC	Forward CG 23%MAC

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 ?



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.

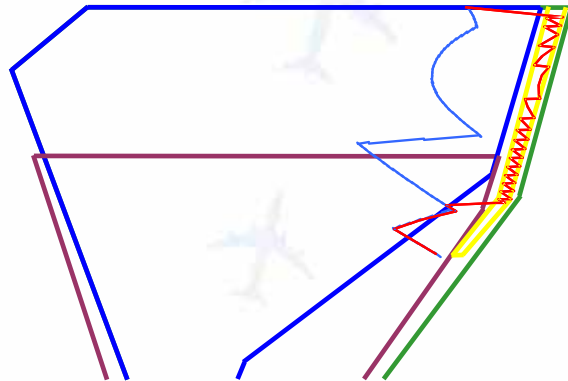
The system optimises the aircraft CG in-flight by transferring fuel from the wing area to the trim tank.

Wide Body, Long Range

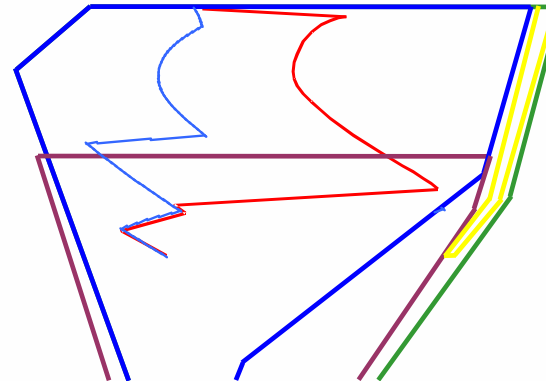
Families:

« **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 ?

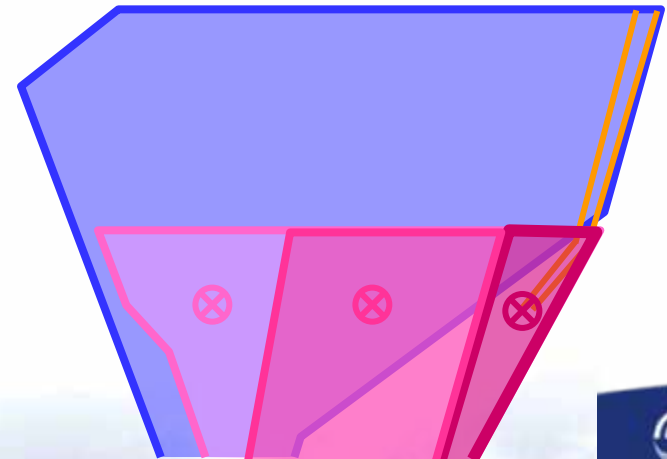
- To reduce my fuel consumption

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 »

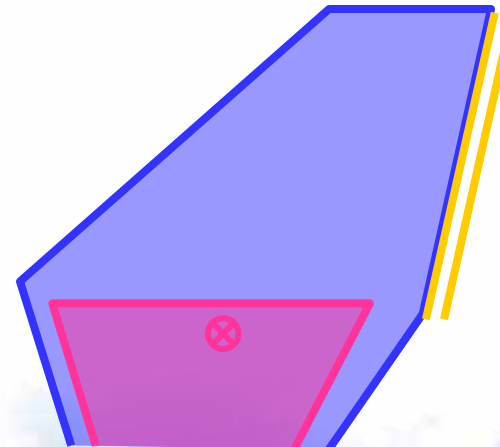


What is the optimum CG range for an aircraft ?

- 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 »**

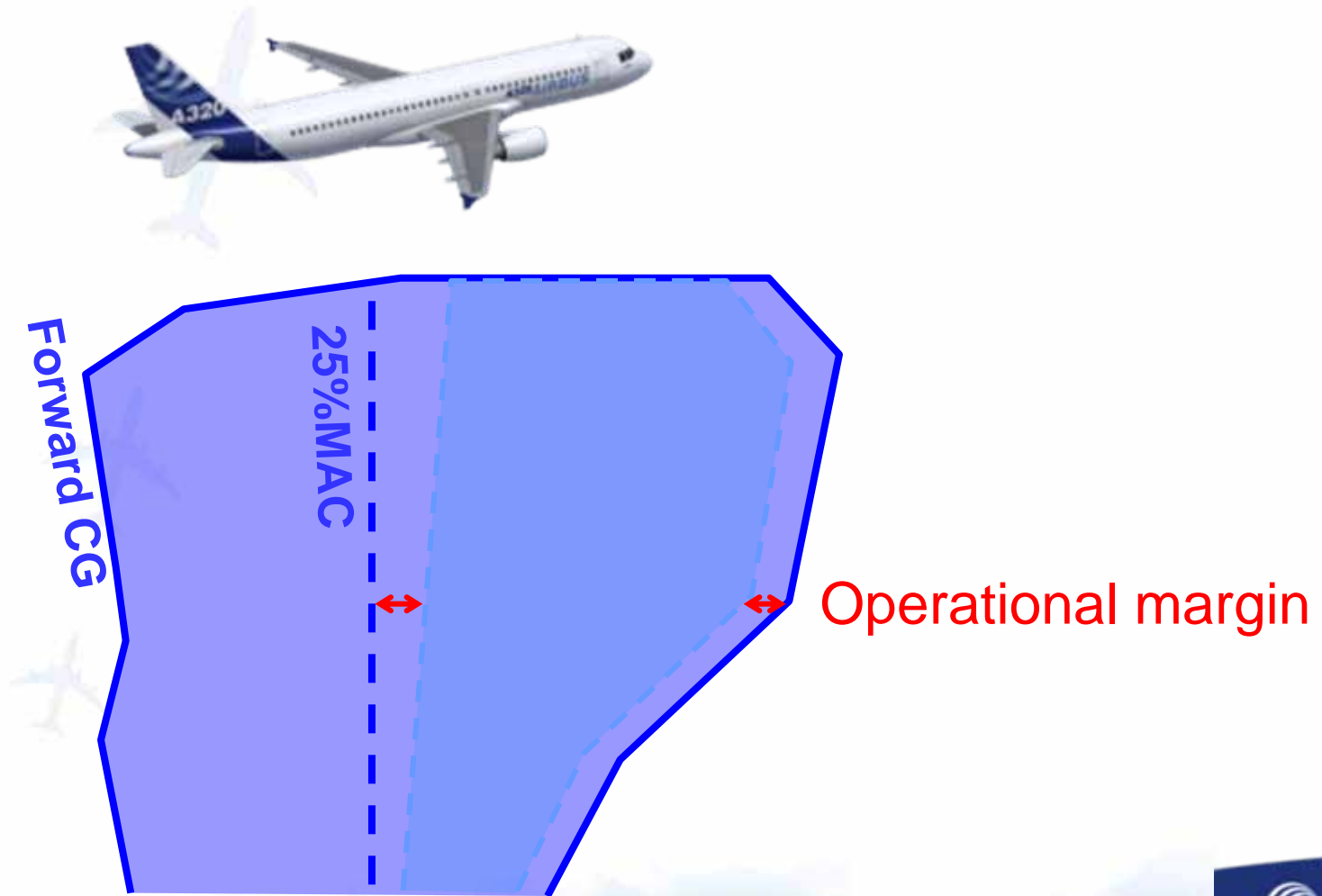
The more forward the CG, the higher the fuel consumption, ***IN GENERAL***
For Single Aisle aircraft, NO effect of CG position on fuel consumption.

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 ?

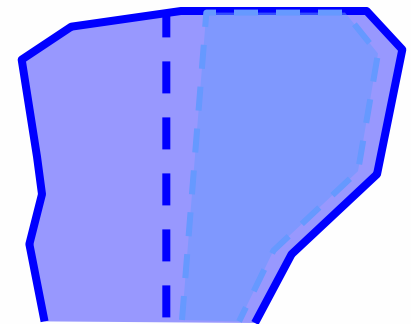
- To benefit from better Takeoff performance



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



	TAKEOFF
A320	Aft of (25+2)%MAC
A340-200/300	Aft of (26+2)%MAC
A340-500	Aft of (28+2)%MAC
A340-600	Aft of (23+2)%MAC

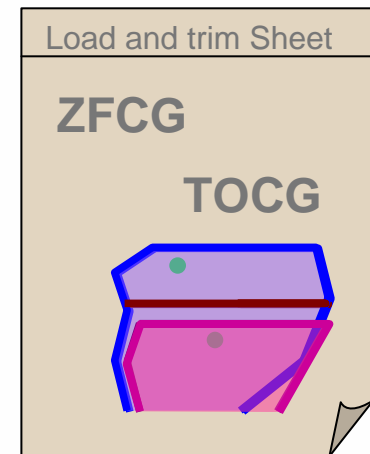
2% is an average operational CG margin

What is the optimum CG range for an aircraft ?

- To benefit from better Landing performance

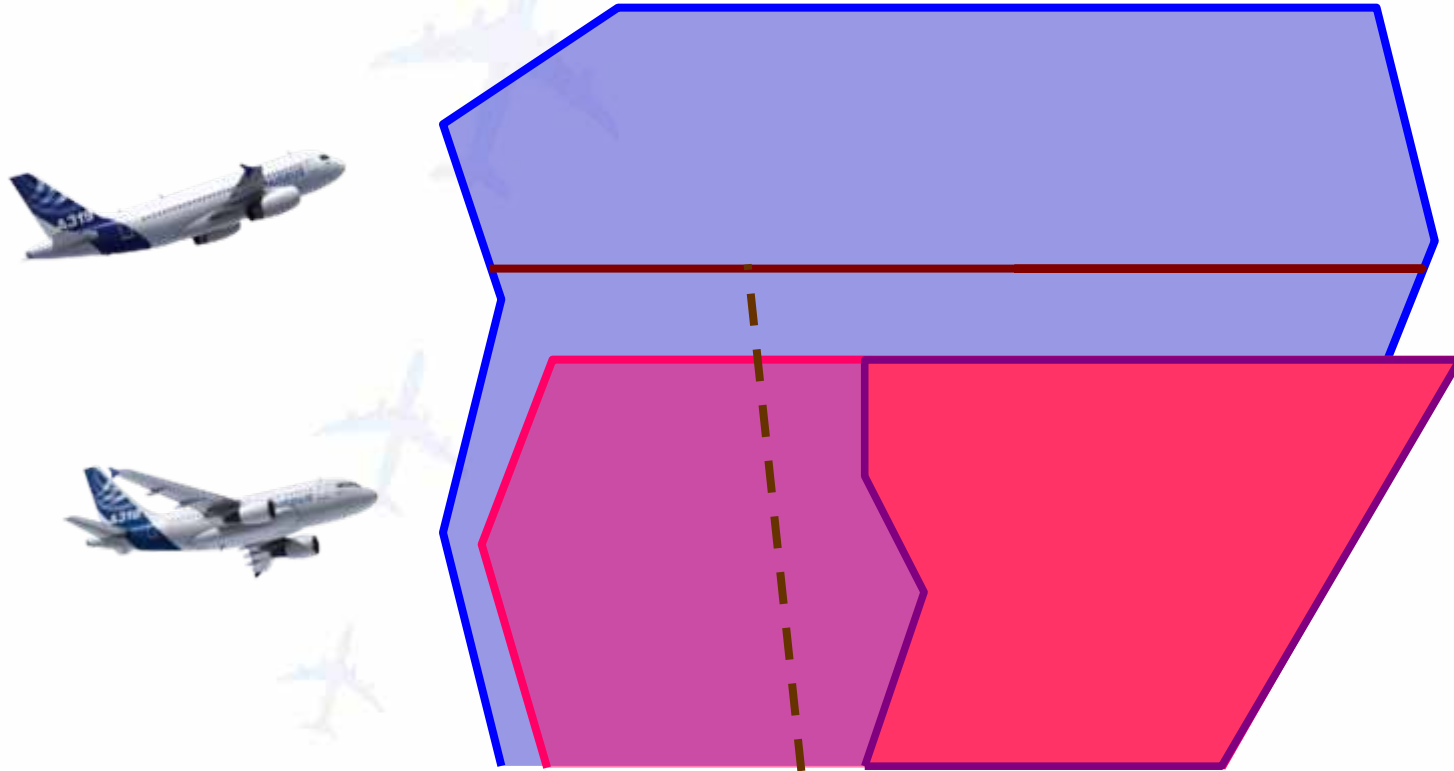


**Any aircraft concerned:
« The optimum
LDCG range is
any CG aft of the most aft
certified landing limit
taking into account
operational CG margin »**



What is the optimum CG range for an aircraft ?

- To benefit from better Landing performance

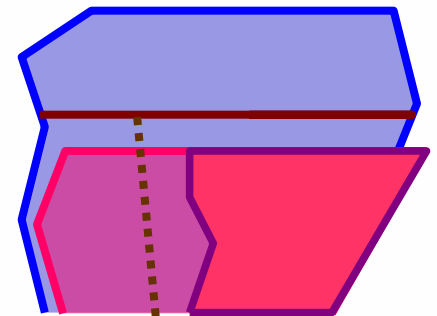


What is the optimum CG range for an aircraft ?

- To benefit from better Landing performance

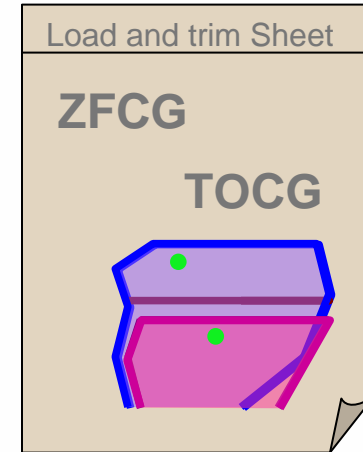
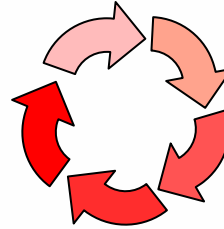
Any aircraft concerned:
« The optimum
LDCG range is
any CG aft of the most aft
certified landing limit
taking into account
operational CG margin »

« 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

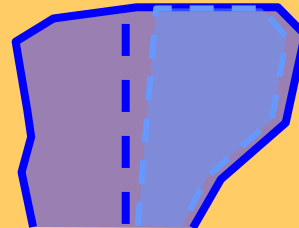
Range Aircraft:

ZFCG aft enough to reach AFT CG target

Takeoff performance

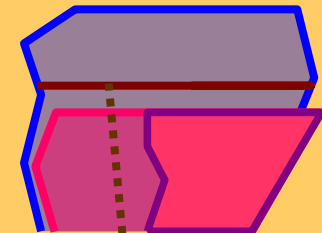
A320, A340:

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)



Proprietary document.

By taking delivery of this Presentation (hereafter "Presentation"), you accept on behalf of your company to comply with the following. No other property rights are granted by the delivery of this Presentation than the right to read it, for the sole purpose of information. This Presentation, its content, illustrations and photos shall not be modified nor reproduced without prior written consent of Airbus S.A.S. This Presentation and the materials it contains shall not, in whole or in part, be sold, rented, or licensed to any third party subject to payment or not. This Presentation may contain market-sensitive or other information that is correct at the time of going to press. This information involves a number of factors which could change over time, affecting the true public representation. Airbus assumes no obligation to update any information contained in this document or with respect to the information described herein. The statements made herein do not constitute an offer or form part of any contract. They are based on Airbus information and are expressed in good faith but no warranty or representation is given as to their accuracy. When additional information is required, Airbus S.A.S can be contacted to provide further details. Airbus S.A.S shall assume no liability for any damage in connection with the use of this Presentation and the materials it contains, even if Airbus S.A.S has been advised of the likelihood of such damages. This licence is governed by French law and exclusive jurisdiction is given to the courts and tribunals of Toulouse (France) without prejudice to the right of Airbus to bring proceedings for infringement of copyright or any other intellectual property right in any other court of competent jurisdiction.



AIRBUS

AIRBUS S.A.S.
31707 BLAGNAC CEDEX, FRANCE

© AIRBUS S.A.S. 2006
ALL RIGHTS RESERVED
AIRBUS, ITS LOGO, A300, A310, A318,
A319, A320, A321, A330, A340, A350
A380, A400M ARE REGISTERED
TRADEMARKS

AN EADS COMPANY