



Dror Artzi

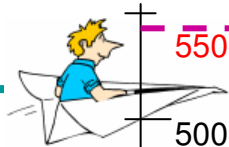


דרור ארצי *Dror Artzi Aeronautical Engineer*

מהנדס אוירונאוטי - יעוץ, תכנון, אנליזות וניהול פרויקטים

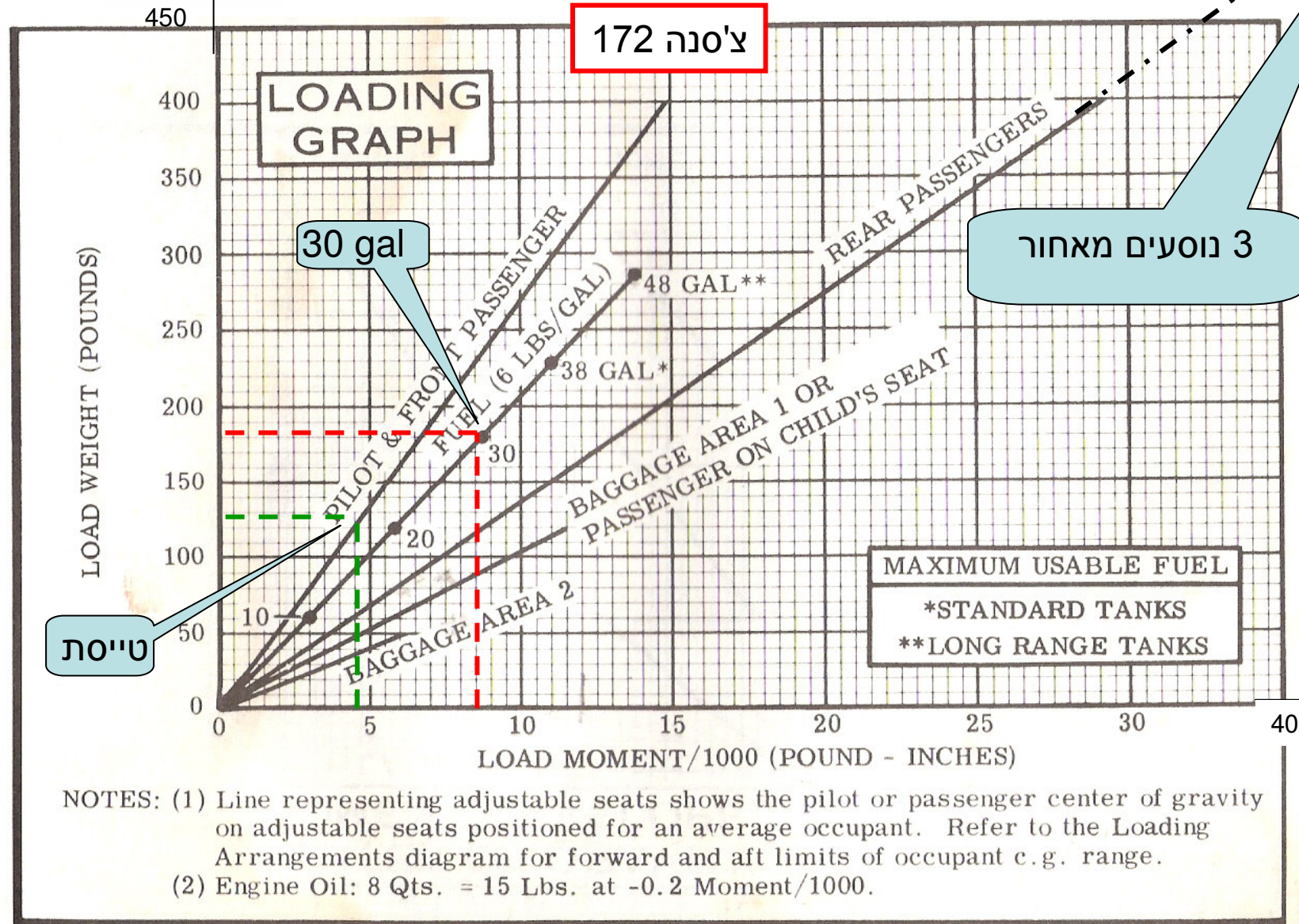
פקס' 04 8243095 טל' 04 8266114 Tel: drorar1@netvision.net.il

לא דוקטורט ולא בחינות מיון פשוט בדוק משקל ואיזון



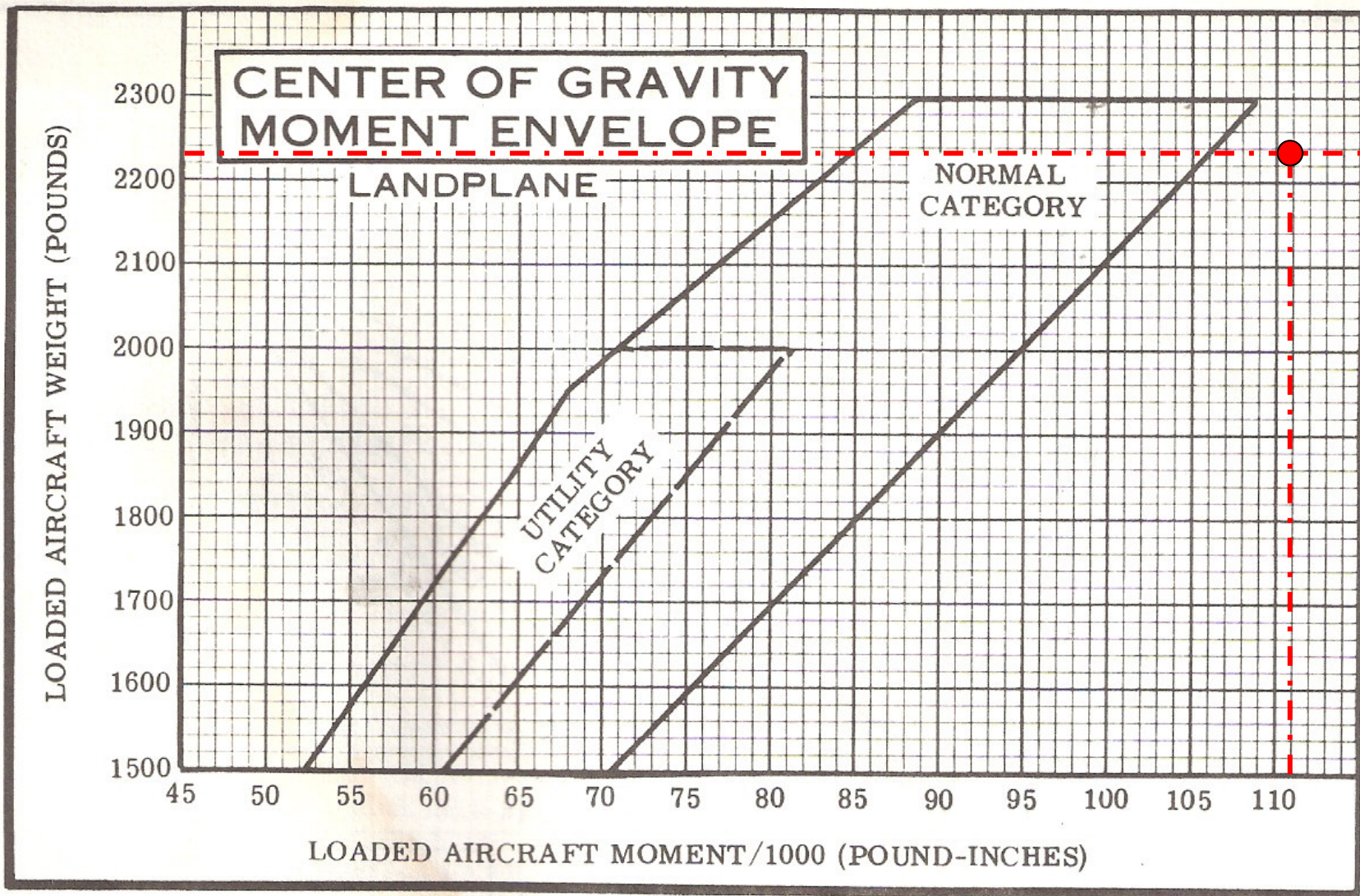
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תרגיל היפוטטי





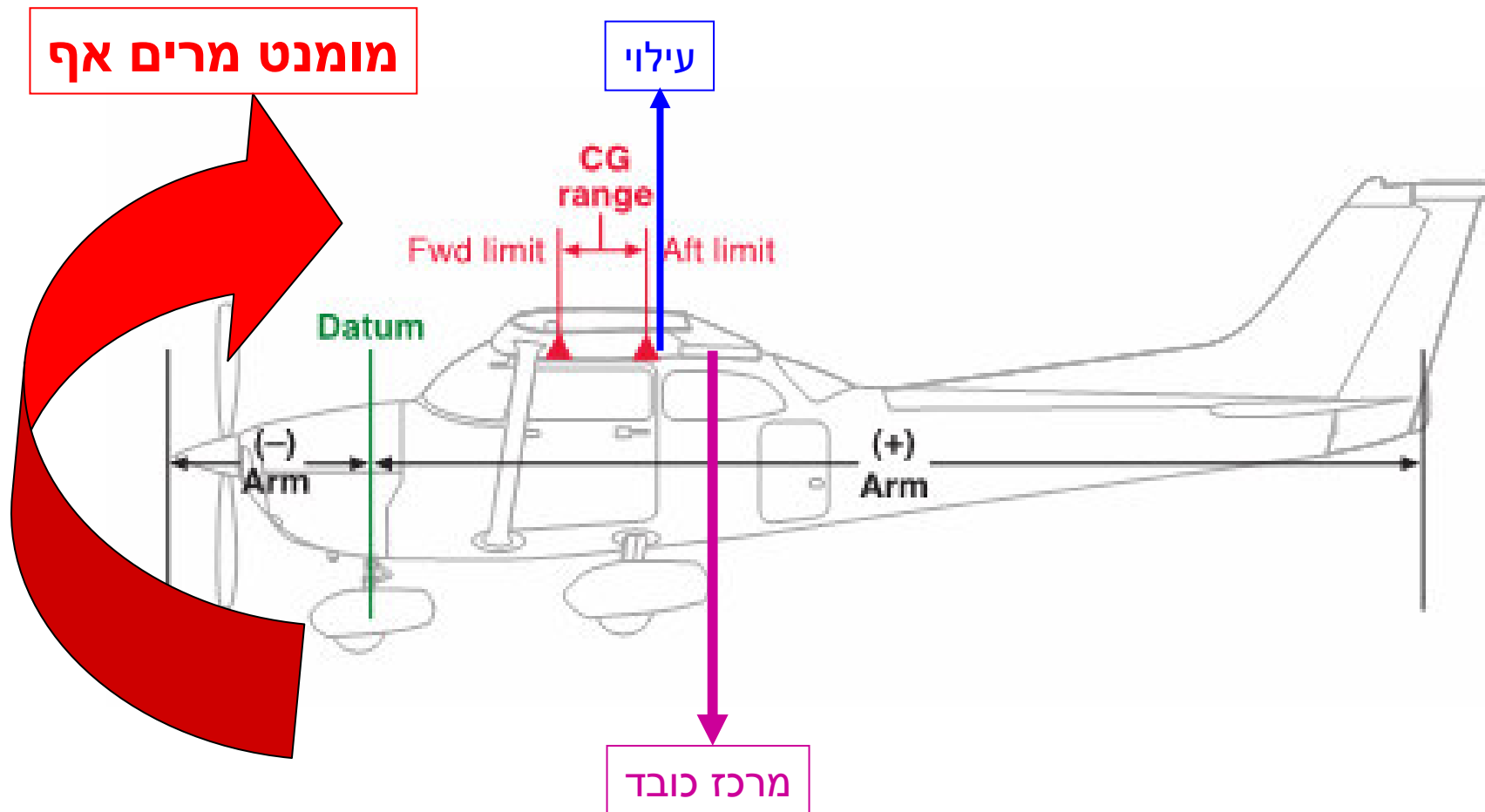
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אז מה קרה בתרגיל ההיפוטטי





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Namibia – Olympia Air Cessna 210 Crash

11.1.2008



December 2008

Weight & Balance



- **A COMBINATION** of pilot errors have been identified as the probable cause of the aircraft crash that claimed the lives of a **young South African pilot** and **five Israeli passengers** in Windhoek's Olympia area in January this year.
- The report indicates that a critical combination of factors resulted in the stall:
 - the aircraft was overloaded;
 - the aircraft load was positioned too far to the back of the plane, shifting its centre of gravity to the back and leading to the plane's nose lifting prematurely during take-off;
 - the pilot chose a short runway for the take-off;
 - the high temperature that day, combined with the high altitude of the airport, appear not to have been properly taken into account by the pilot;
 - and the pilot was relatively inexperienced and was not properly briefed about conditions at Eros Airport.



- The pilot calculation of the passengers combined weight however was between 47 and 78 kilograms lower than what the actual weight was calculated at during the investigation.
- The end result was that the weight of the plane exceeded its maximum specified take-off weight by between 105 and 134 kg,
- and that the aircraft's centre of gravity had shifted too far towards its tail.



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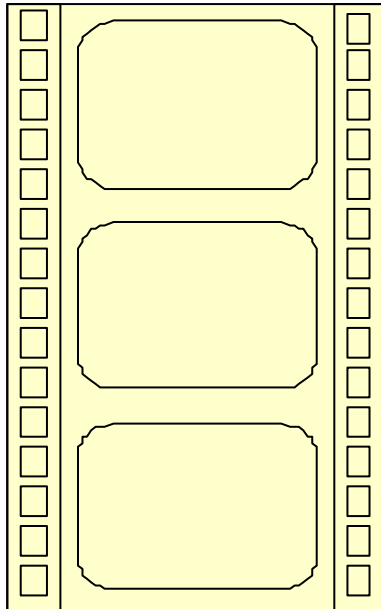
Loss of Pitch Control During Takeoff

Air Midwest Flight 5481

Raytheon (Beechcraft) 1900D, N233YV

Charlotte, North Carolina

January 8, 2003





- On January 8, 2003, Air Midwest flight 5481, a Raytheon (Beechcraft) 1900D, N233YV, crashed shortly after takeoff from runway 18R at Charlotte-Douglas International Airport, Charlotte, North Carolina.
- The **2 flight crewmembers and 19 passengers** aboard the airplane **were killed**,
- 1 person on the ground received minor injuries,
- and the airplane was destroyed by impact forces and a postcrash fire.



- The National Transportation Safety Board determines that the probable cause of this accident was the airplane's **loss of pitch control during takeoff.**
- The loss of pitch control resulted from the incorrect rigging of the elevator control system
- compounded by the airplane's **aft center of gravity, which was substantially aft of the certified aft limit.**



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AIRCRAFT ACCIDENT REPORT

UNCONTROLLED IMPACT WITH TERRAIN

FINE AIRLINES FLIGHT 101
DOUGLAS DC-8-61, N27UA
MIAMI, FLORIDA
AUGUST 7, 1997



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aviation-safety.net

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McDonnell Douglas DC-8-61F N27UA



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Abstract: This report explains the accident involving Fine Airlines flight 101, a Douglas DC-8-61, which crashed after takeoff from runway 27R at Miami International Airport, Miami, Florida, on August 7, 1997. Safety issues in the report include the effects of improper cargo loading on airplane performance and handling, operator oversight of cargo loading and training of cargo loading personnel, the loss of critical flight data recorder information, and FAA surveillance of cargo carrier operations.

Injuries to Persons

<u>Injuries</u>	<u>Flightcrew</u>	<u>Cabin Crew</u>	<u>Passengers</u>	<u>Other</u>	<u>Total</u>
Fatal	3	0	1	1	5
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
Total	3	0	1	1	5



CONCLUSIONS

Findings

7. The airplane pitched up quickly into a stall, recovered briefly from the stall, and stalled again; recovery before ground impact was unlikely once the stall series began.
8. The center of gravity (CG) of the accident airplane was near or even aft of the airplane's aft CG limit.



Report on the accident to Fokker F27-600 Friendship, G-CHNL Near Guernsey Airport, Channel Islands on 12 January 1999



The accident occurred when control of the cargo aircraft, carrying three tonnes of newspapers, was lost during the final stages of an approach to Guernsey Airport. Moments after the wing flaps were lowered to their fully down position, the nose of the aircraft rose and the crew were unable to prevent it rising further. The nose continued to rise until the aircraft's pitch attitude was near vertical. Although the crew applied nose down pitch trim and high engine power, the aircraft lost flying speed, stalled and entered an incipient spin. It descended in a shallow nose down pitch attitude with little forward speed and crashed at the rear of a private house, striking the house with its port wing. Both the house and the aircraft caught fire. The two pilots were killed but the sole occupant of the house escaped without physical injury.



Conclusions

- (iii) The weight of the cargo submitted for carriage was considered to be within measurement tolerances.
- (iv) Upon completion of the loading the aircraft's centre of gravity was significantly aft of the approved limit.
- (vii) The pilots were unlikely to have experienced any strikingly unusual handling qualities until the approach phase.
- (viii) Deployment of full flap initiated the undemanded pitch-up on final approach.
- (x) After the aircraft pitched up uncontrollably, it is unlikely that either pilot could have done anything to recover control from the combination of low airspeed, aft centre of gravity and low height.



Causal factors

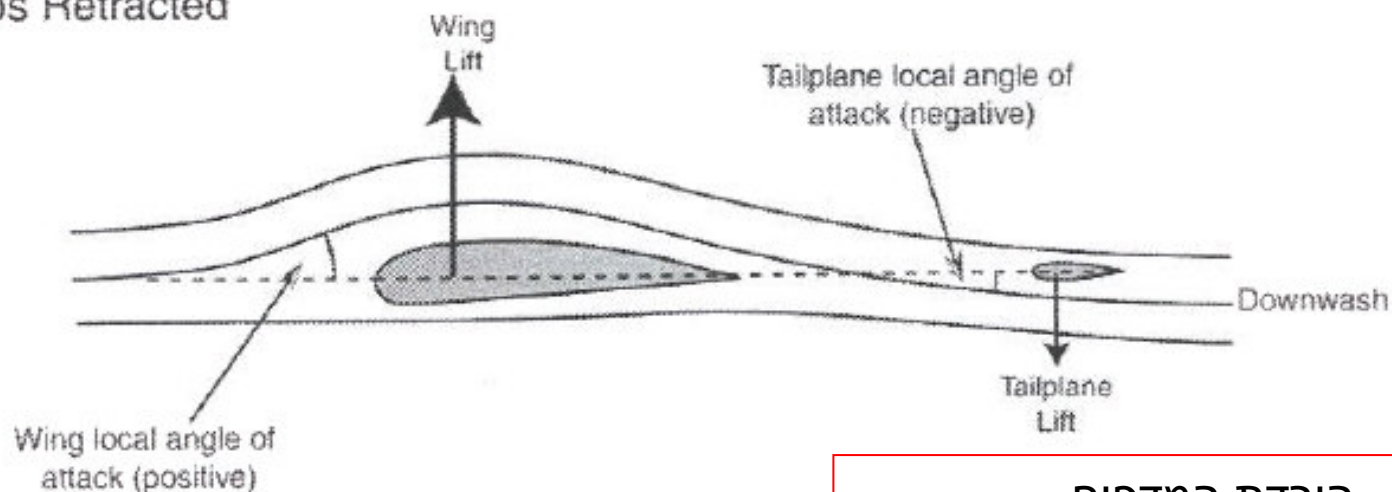
The investigation identified the following causal factors:

- (i) The aircraft was operated outside the load and balance limitations.
- (ii) Loading distribution errors went undetected because the load sheet signatories did not reconcile the cargo distribution in the aircraft with the load and balance sheet.
- (iii) The crew received insufficient formal training in load management.



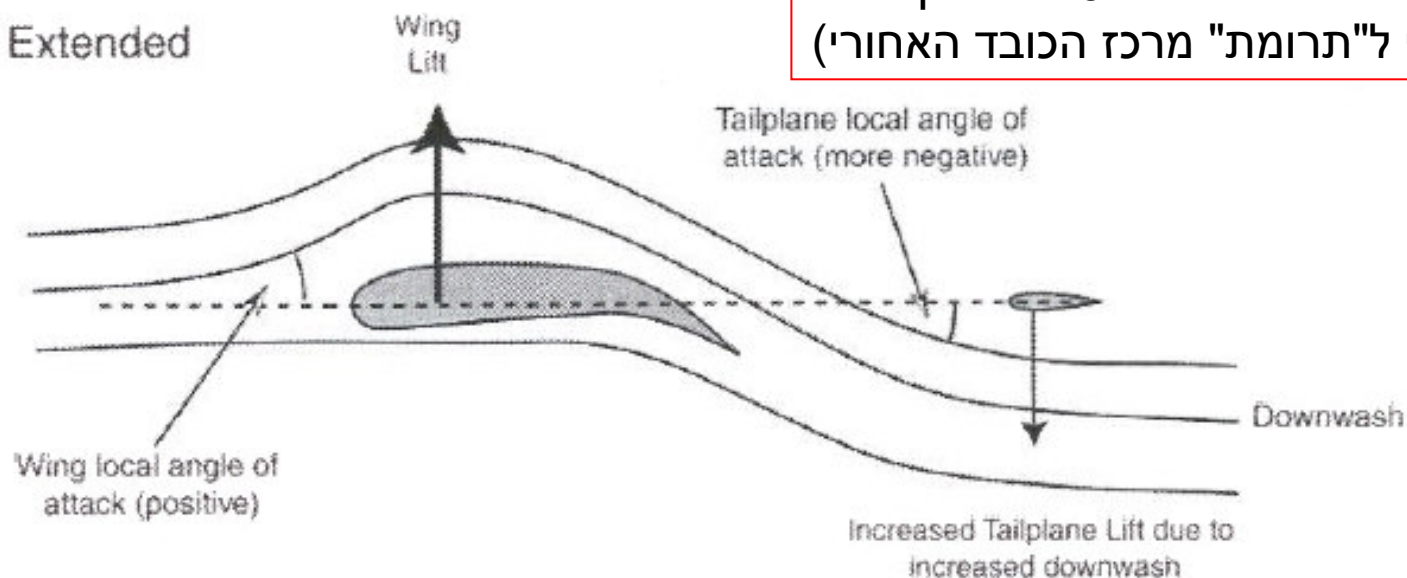
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Flaps Retracted



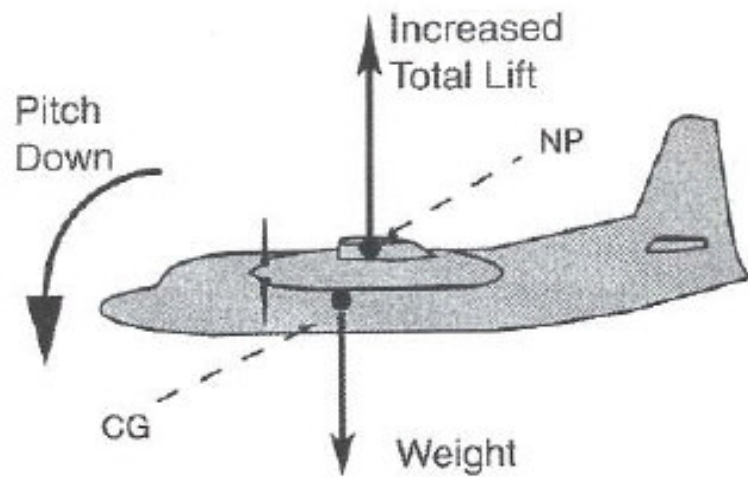
הורדת המדפים
הגדילה את המומנט מרים אף
(בנוסף ל"תרומת" מרכז הכובד האחורי)

Flaps Extended

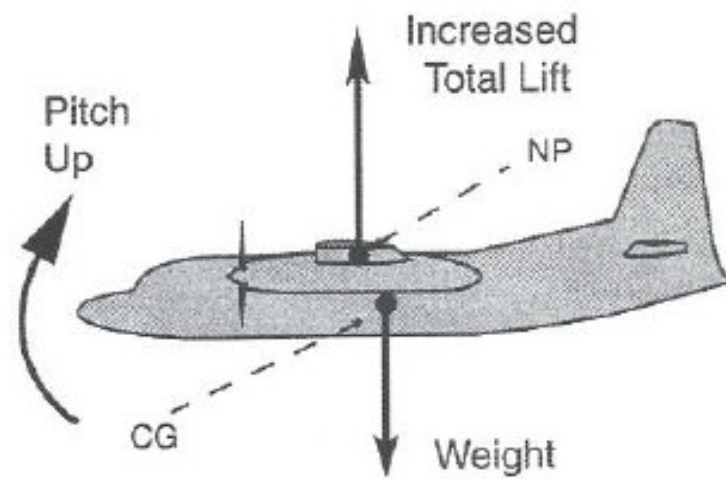




STABLE SITUATION



UNSTABLE SITUATION





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NTSB: Improper Loading Caused Challenger Jet Crash



On February 2, 2005, a Bombardier Challenger CL-600-1A11, during takeoff, ran off the departure end of runway 6 at Teterboro Airport, Teterboro, New Jersey; through an airport perimeter fence; across a six-lane highway (where it struck a vehicle); and into a parking lot before impacting a building. The **two pilots were seriously injured**,

In a final report adopted October 31, 2006, the National Transportation Safety Board determined the probable cause of a corporate jet accident, was the flight crew's **failure to ensure the airplane was loaded within weight and balance limits** and their attempt to take off with the **center of gravity well forward of the forward takeoff limit**, which prevented the airplane from rotating at the intended rotation speed



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Tail strike during take-off

Boeing 737-800, registration PH-HZB,
Rotterdam Airport, January 12th 2003



SYNOPSIS

During take-off from runway 24 at Rotterdam Airport a Transavia airlines Boeing 737-800 pitched nose-up just after take-off thrust had been selected. The pitch up movement stopped when the aft fuselage and the tailskid assembly contacted the runway. The crew rejected the take-off, after which the aircraft's nose came down again to the ground.



- passengers were not seated according to the passenger distribution table;
- there was no adequate response from the cockpit crew to the report of the purser about the incorrect passenger distribution;
- the skidding of the nose gear during line up was not recognized (by the F/O) as an indication of a possible tail heavy condition;
- after the incident the cockpit crew initially did not understand that the occurrence was caused by the fact that almost all passengers were seated in the rear of the aircraft.

FINDINGS

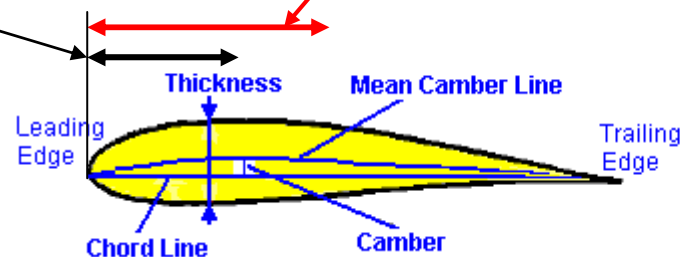
When the crew started the take-off roll by selecting take-off thrust the nose pitched up.

The pitch up movement of the nose was caused by application of thrust together with the CG behind the aft limit for take-off.

Seat assignment was not according to the passenger distribution table.

The passenger distribution was not according the load and trim sheet and the passenger distribution table.

The actual centre of gravity at take-off was 40.8% MAC and exceeded the aft limit for take-off of 29.2% MAC, as indicated on the load and trim sheet.

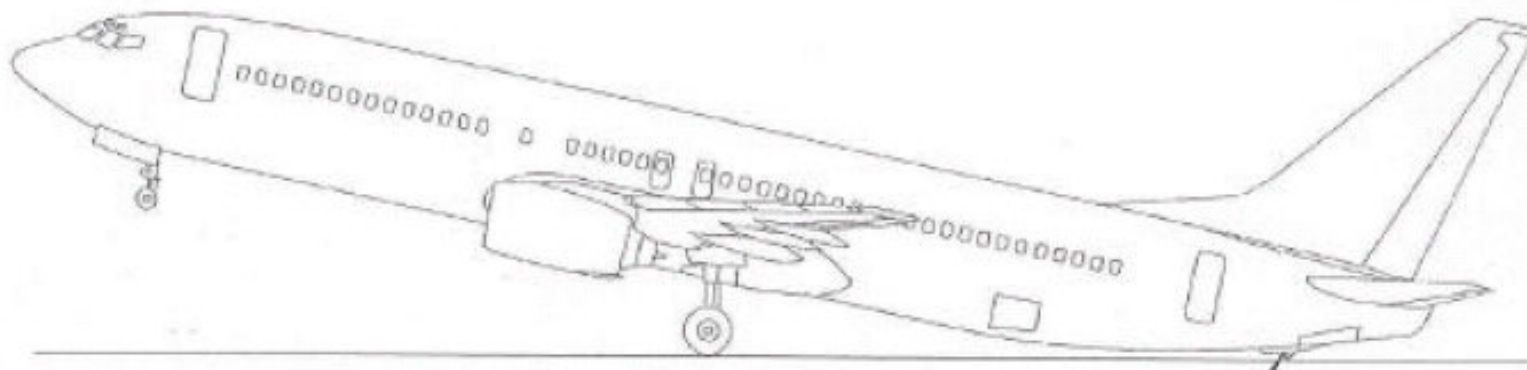




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BOEING

737-600/700/800/900 AIRCRAFT MAINTENANCE MANUAL



December 2008

Weight & Balance



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AIRPLANE STABILITY

Static Stability

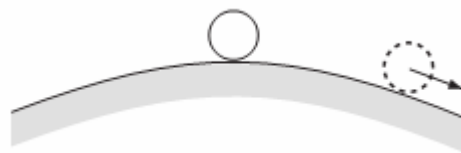
Statically stable. If the forces and moments on the body caused by a disturbance tend initially to return the body toward its equilibrium position, the body is *statically stable*.

כאשר הכוחות והמומנטים הפועלים על הגוף כתוצאה מהפרעה נוטים להביא את הגוף למצב שיווי משקל הגוף יוגדר כיציב סטאטי



כאשר הכוחות והמומנטים הפועלים על הגוף כתוצאה מהפרעה יגרמו לגוף להתרחק ממצב שיווי משקל הגוף יוגדר כלא יציב סטאטי

Statically unstable. If the forces and moments are such that the body continues to move away from its equilibrium position after being disturbed, the body is *statically unstable*.



Neutrally stable. If the body is disturbed but the moments remain zero, the body stays in equilibrium and is *neutrally stable*.

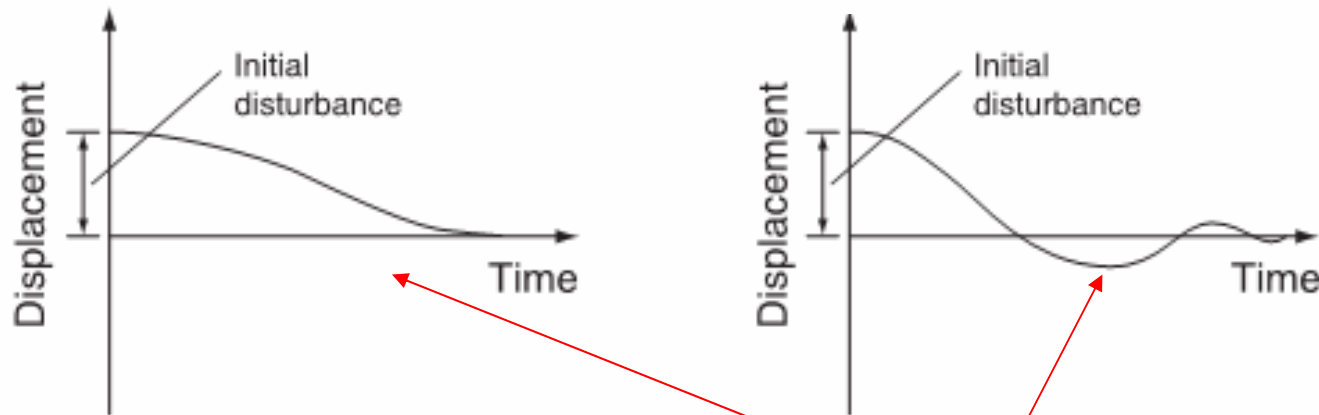
אם פועלת הפרעה על הגוף אך המומנטים עליו סכומם אפס יישאר הגוף במצב שיווי משקל והגוף יוגדר כנייטרלי-יציב





Dynamic Stability

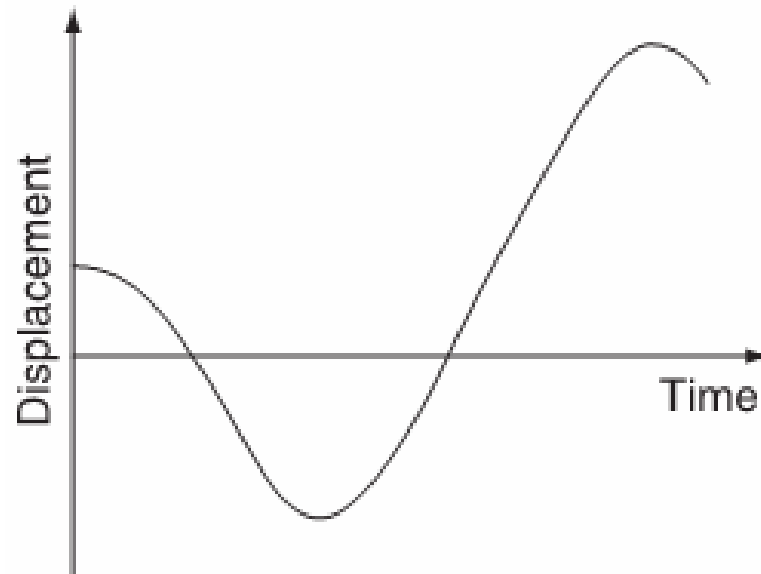
Dynamically stable behavior.



In both situations the airplane eventually returns to its equilibrium position after some time interval. In the first case the vehicle approaches monotonically the equilibrium position (*aperiodic behavior*), while in the second case, it overshoots the equilibrium position (*damped oscillation*). A body is *dynamically stable* if, out of its own accord, it eventually returns to and remains at its equilibrium position over a period of time.



Dynamically unstable behavior.





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מטוס חשוף להפרעות שונות כגון משבים, רוח צד או זרימה טורבולנטית

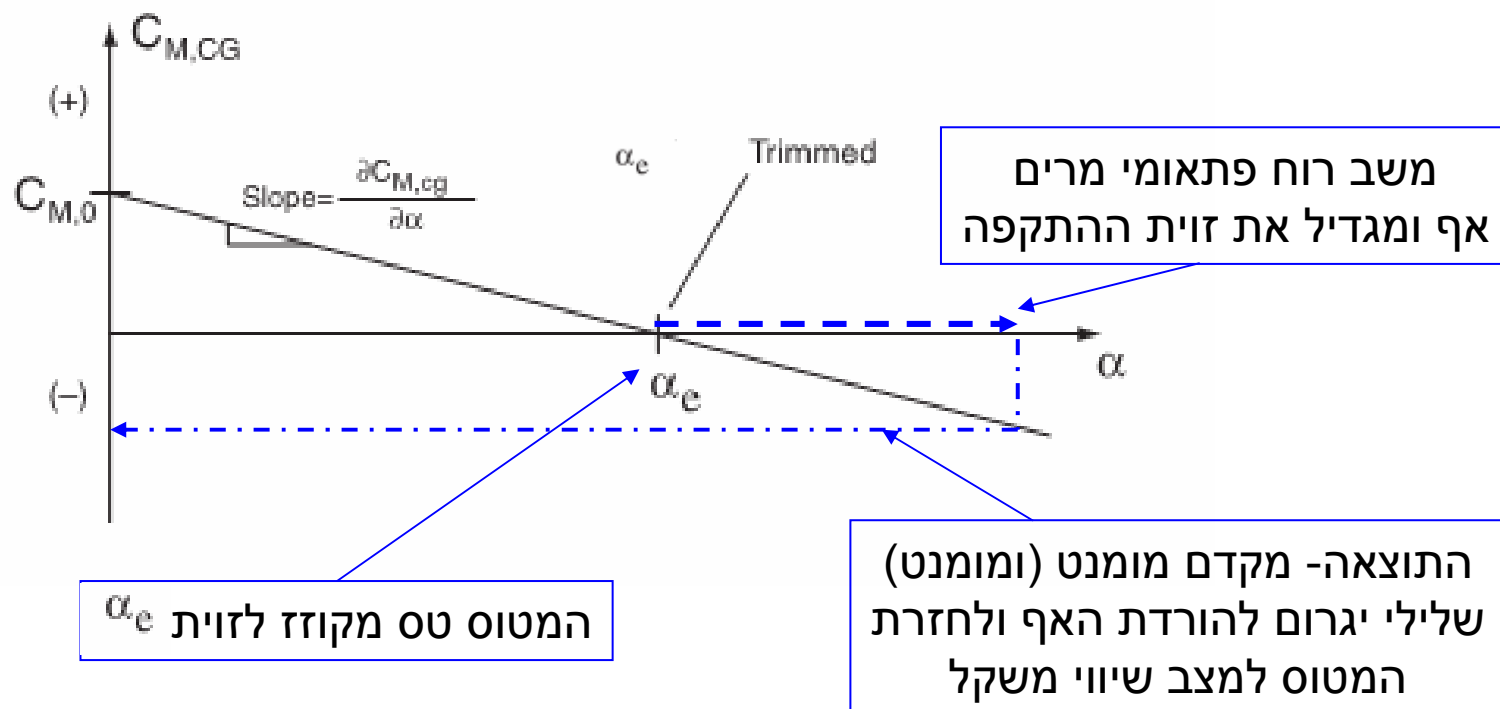


במידה והמטוס "יתאושש" מהשפעת ההפרעות
באופן אוטומטי וללא התערבות הטייס
נוכל לומר שהמטוס יציב מבחינה אורכית



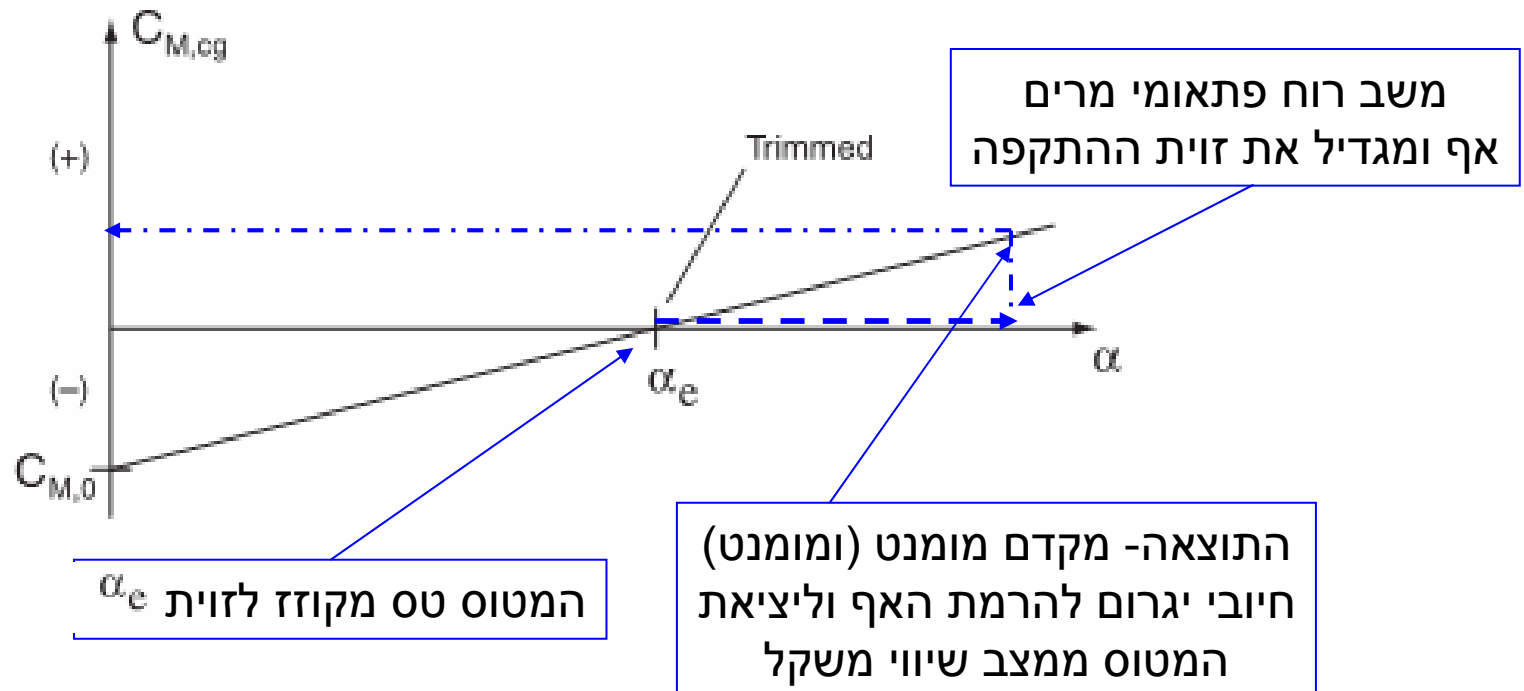
הסבר פיסיקלי (בלי נוסחאות!!!)

מקדם המומנט סביב מרכז הכובד כפונקציה של זווית ההתקפה במטוס יציב אורכית





מקדם המומנט סביב מרכז הכובד כפונקציה של זווית ההתקפה במטוס לא יציב אורכית





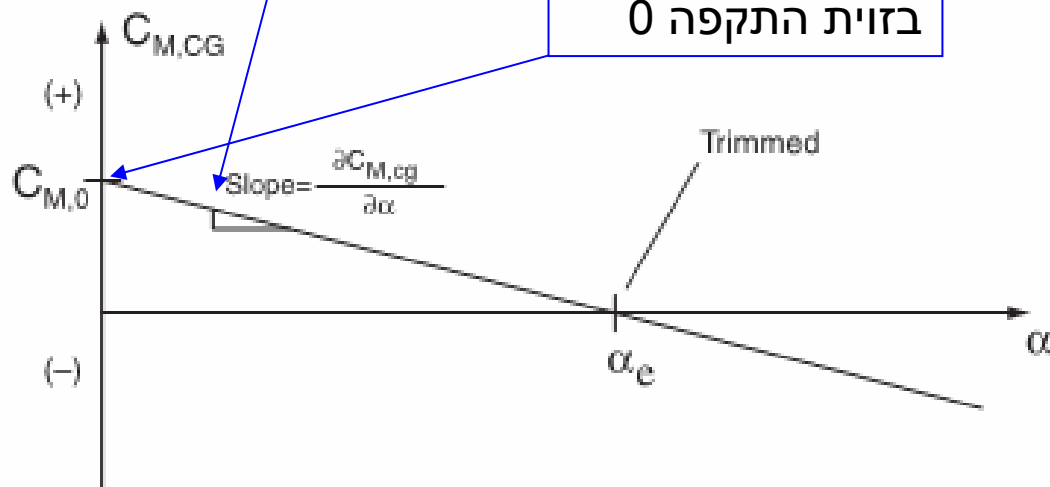
והתנאי לכן למטוס יציב אורכית הינו

נוסחא קטנטנה....

$$\frac{\partial C_{M,CG}}{\partial \alpha} < 0 \quad \text{and} \quad C_{M,0} > 0$$

כלומר – שיפוע שלילי

ומקדם מומנט חיובי
בזווית התקפה 0



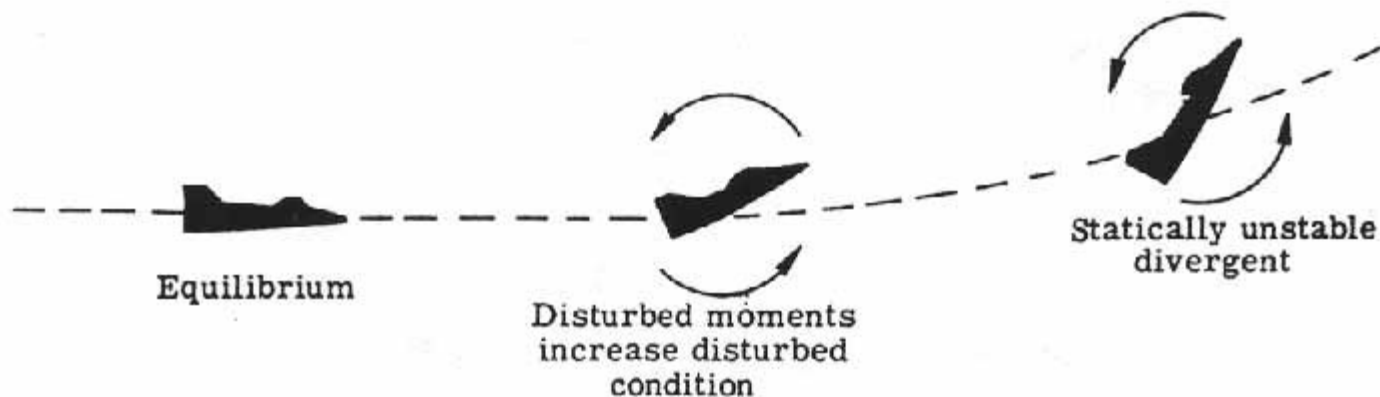


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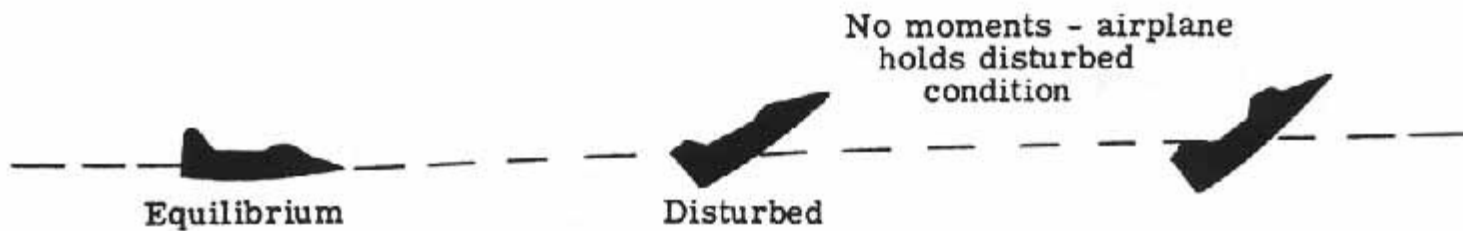
Lift = weight
Thrust = drag
No net moments



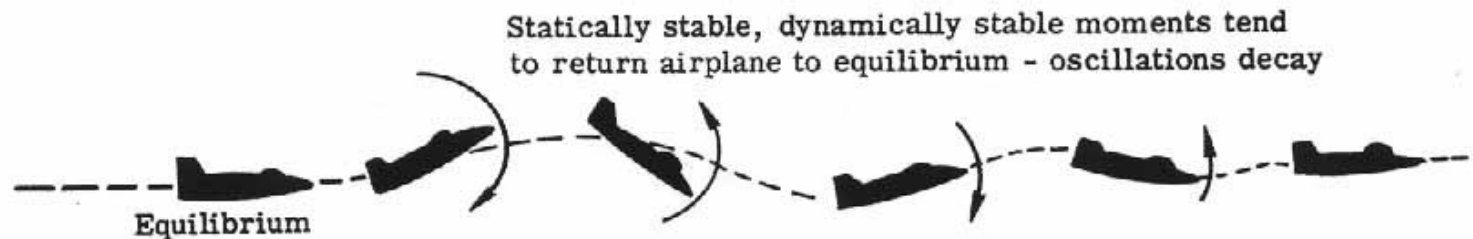
(a) Equilibrium flight.



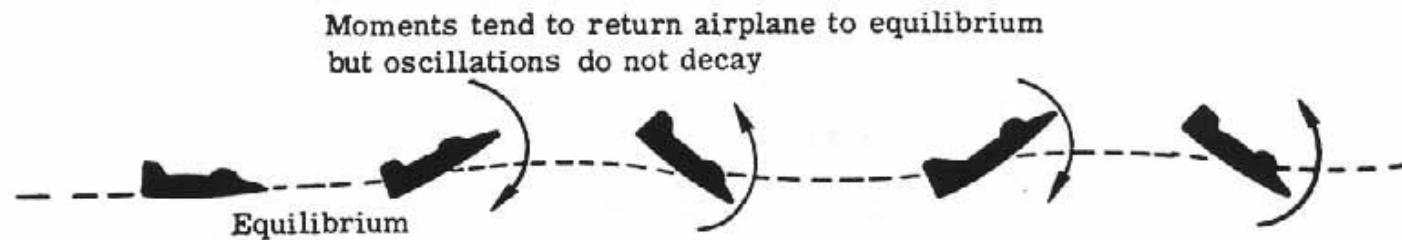
(b) Statically unstable airplane.



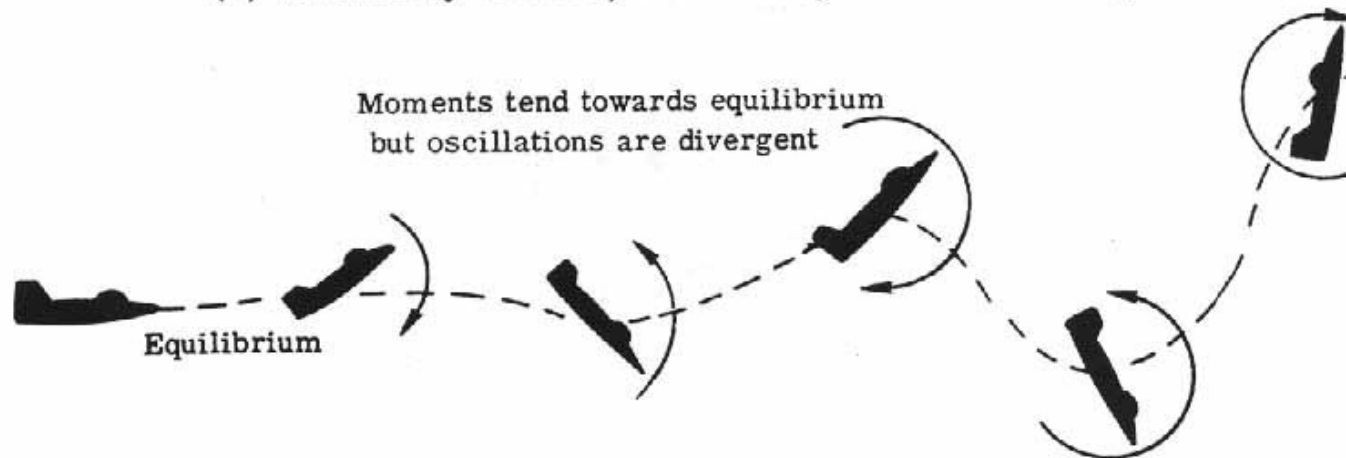
(c) Neutral static stability.



(a) Statically and dynamically stable.



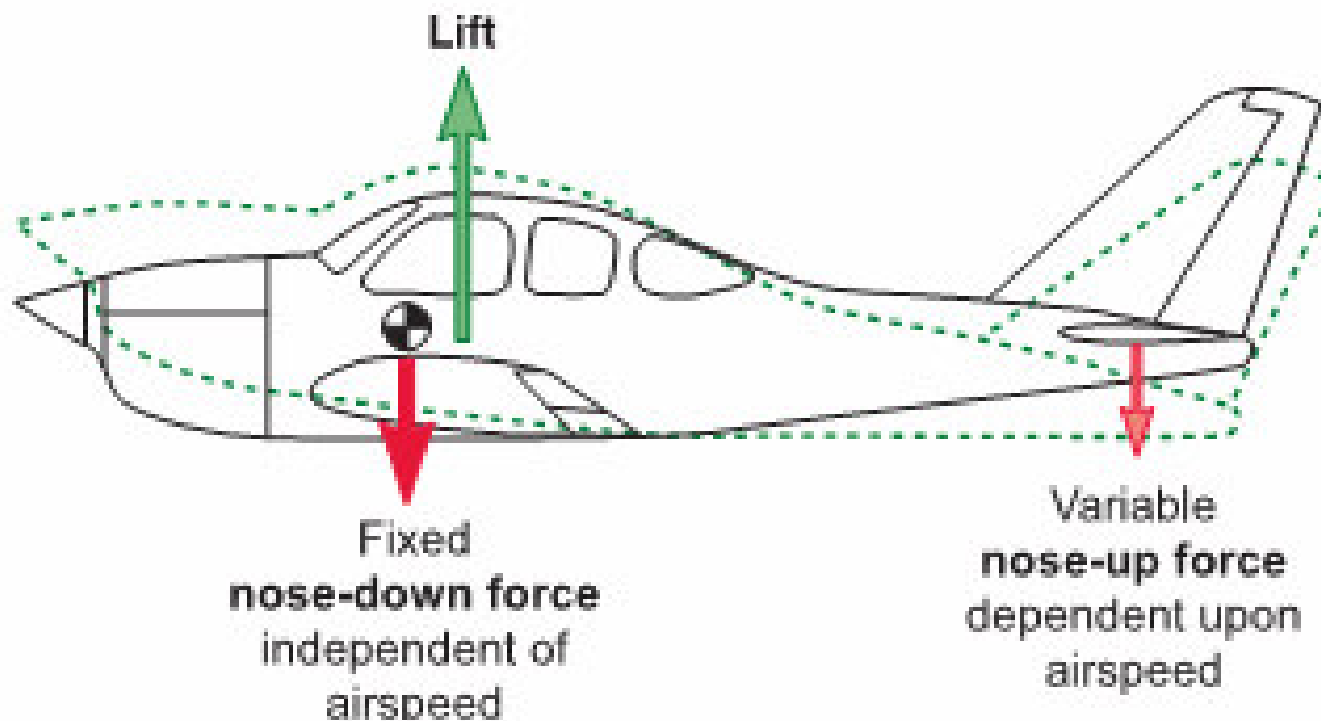
(b) Statically stable; neutral dynamic stability.



(c) Statically stable; dynamically unstable.

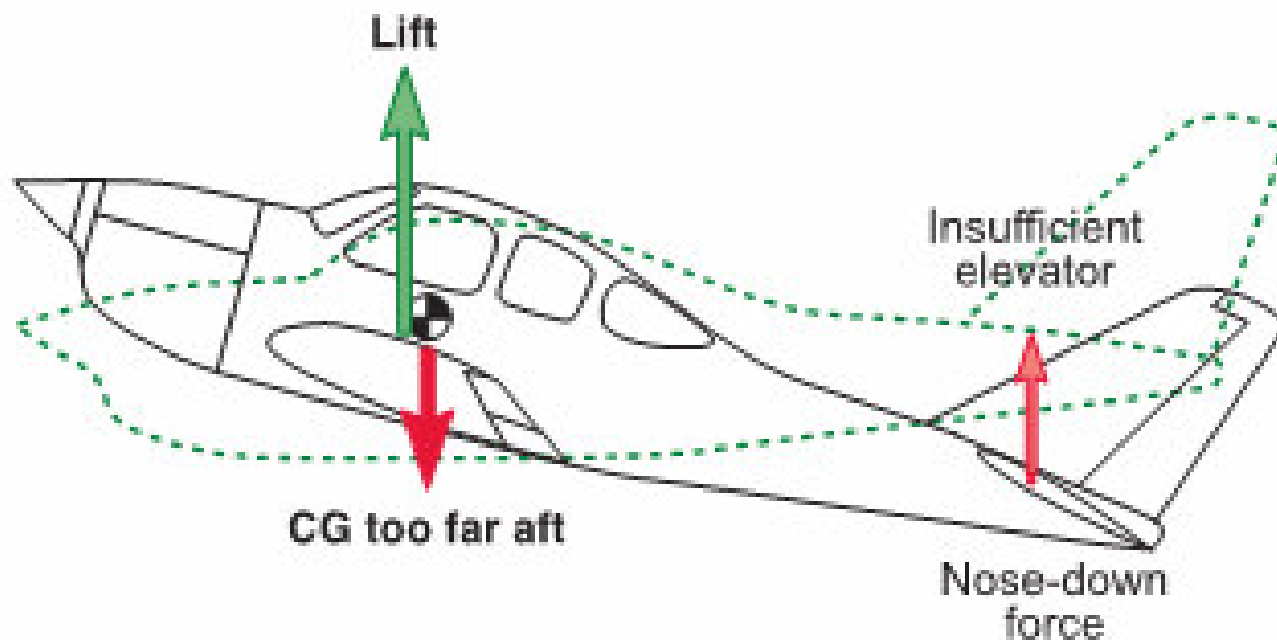


Longitudinal forces acting on an airplane in flight.



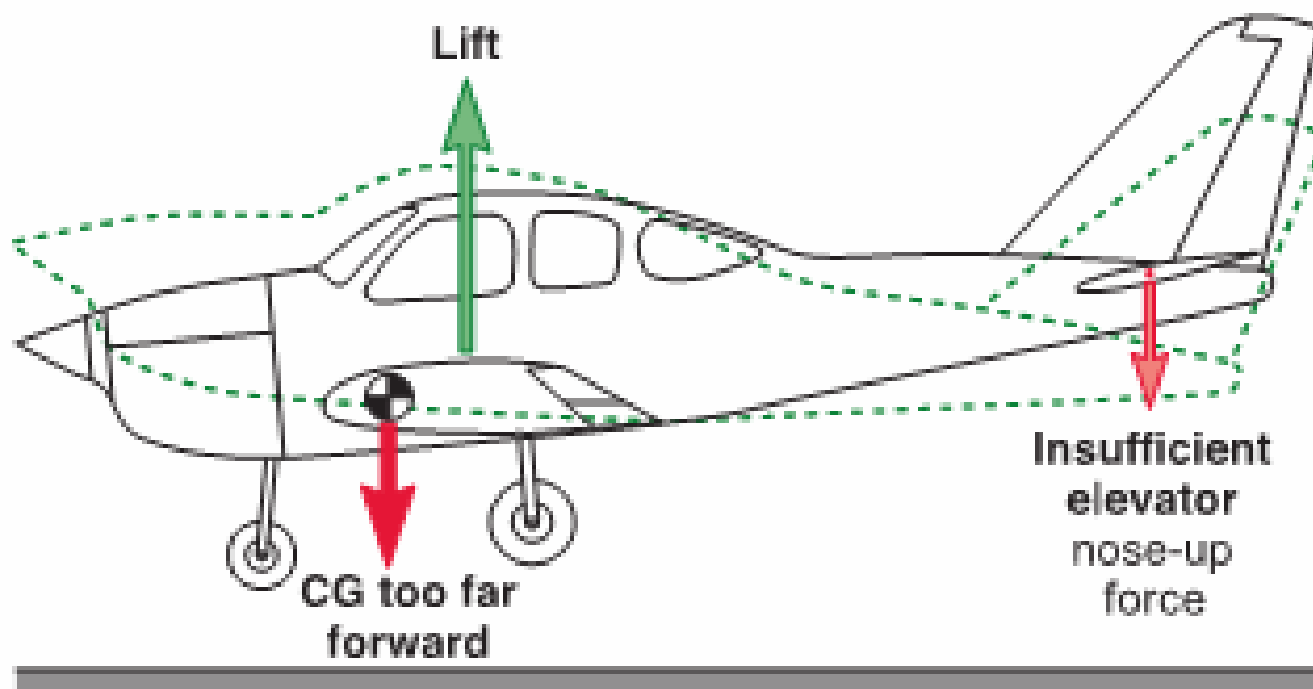


במידה ומיקום מרכז הכובד אחורי מידי, עלול להיווצר מצב בו במהירות נמוכה (קרוב להזדקרות) לא יהיה מספיק כח מוריד אף בהגה כדי להחלץ מהמצב





במידה ומיקום מרכז הכובד קידמי מידי,
לא יהיה מספיק כח מרים אף בהגה
כדי לבצע את ה FLARE בשלב הנחיתה



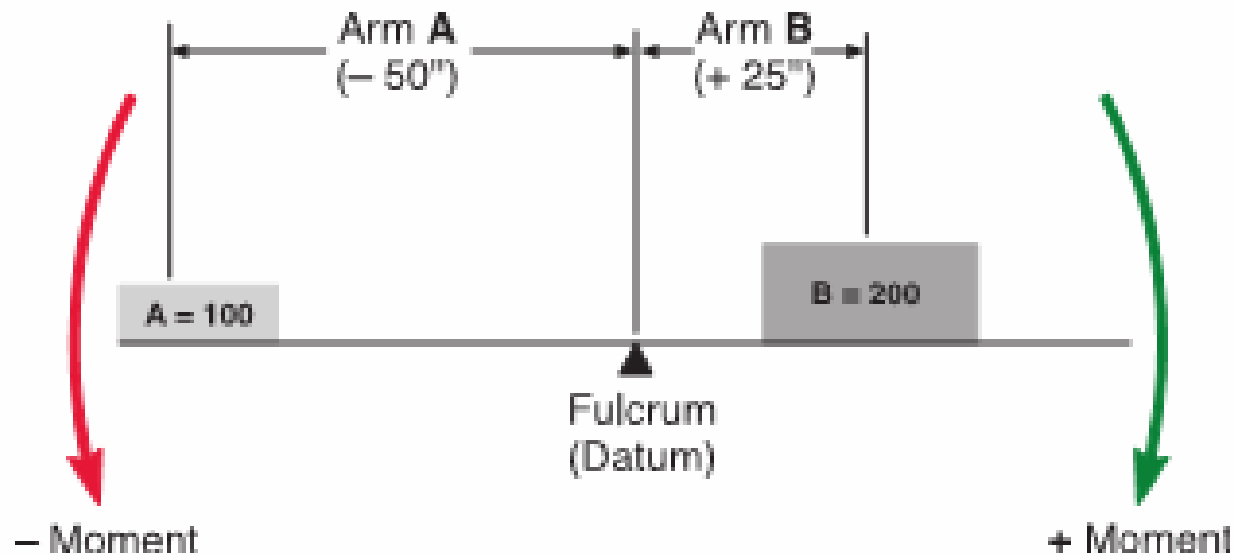


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וקצת על חישוב מומנטים



ה"נדנדה" תהיה מאוזנת (בשיווי משקל)
כאשר סכום המומנטים סביב נקודת / קו ייחוס יהיה אפס (0)



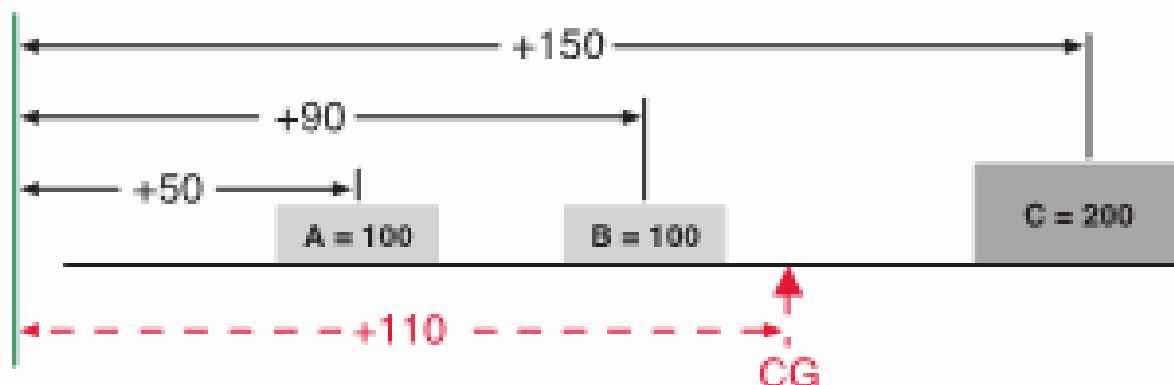
Item	Weight (lb)	Arm (In)	Moment (lb-in)
Weight A	100	-50	-5,000
Weight B	200	+25	+5,000
	300		0



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מציאת מרכז כובד יחסית לקו ייחוס

Datum



Item	Weight	Arm	Moment	CG
Weight A	100	50	5,000	
Weight B	100	90	9,000	
Weight C	200	150	30,000	
	400		44,000	110

$$CG = \frac{\text{Total moment}}{\text{Total weight}}$$

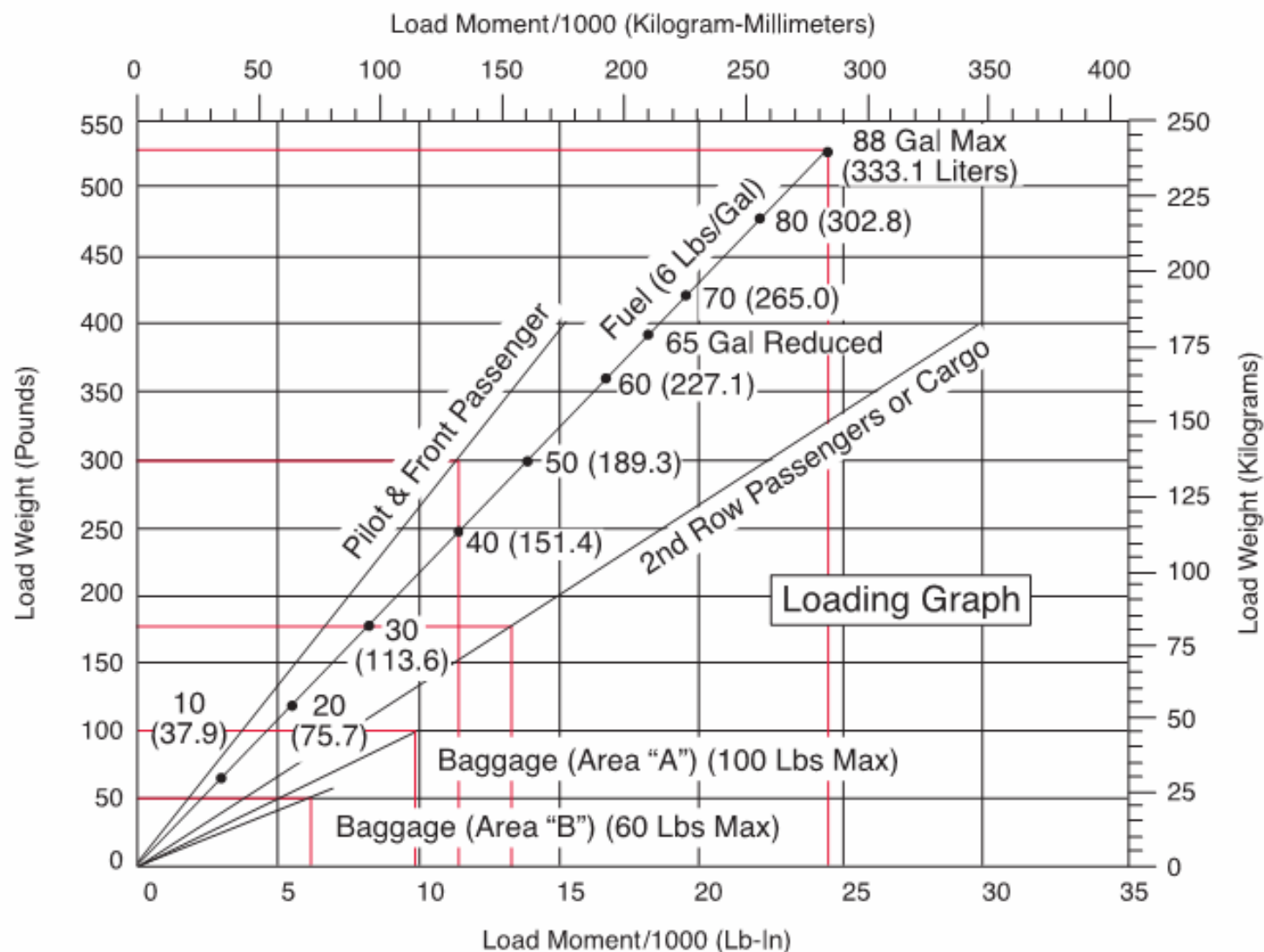
$$= \frac{44,000}{400}$$

= 110 inches from the datum



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Typical loading graph.





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תרגול

• טיסת 4X-CGL לטורקיה

– 3 טייסים

– תיקי יד

– מפות וציוד טיסה

– ג'ריקן דלק נוסף

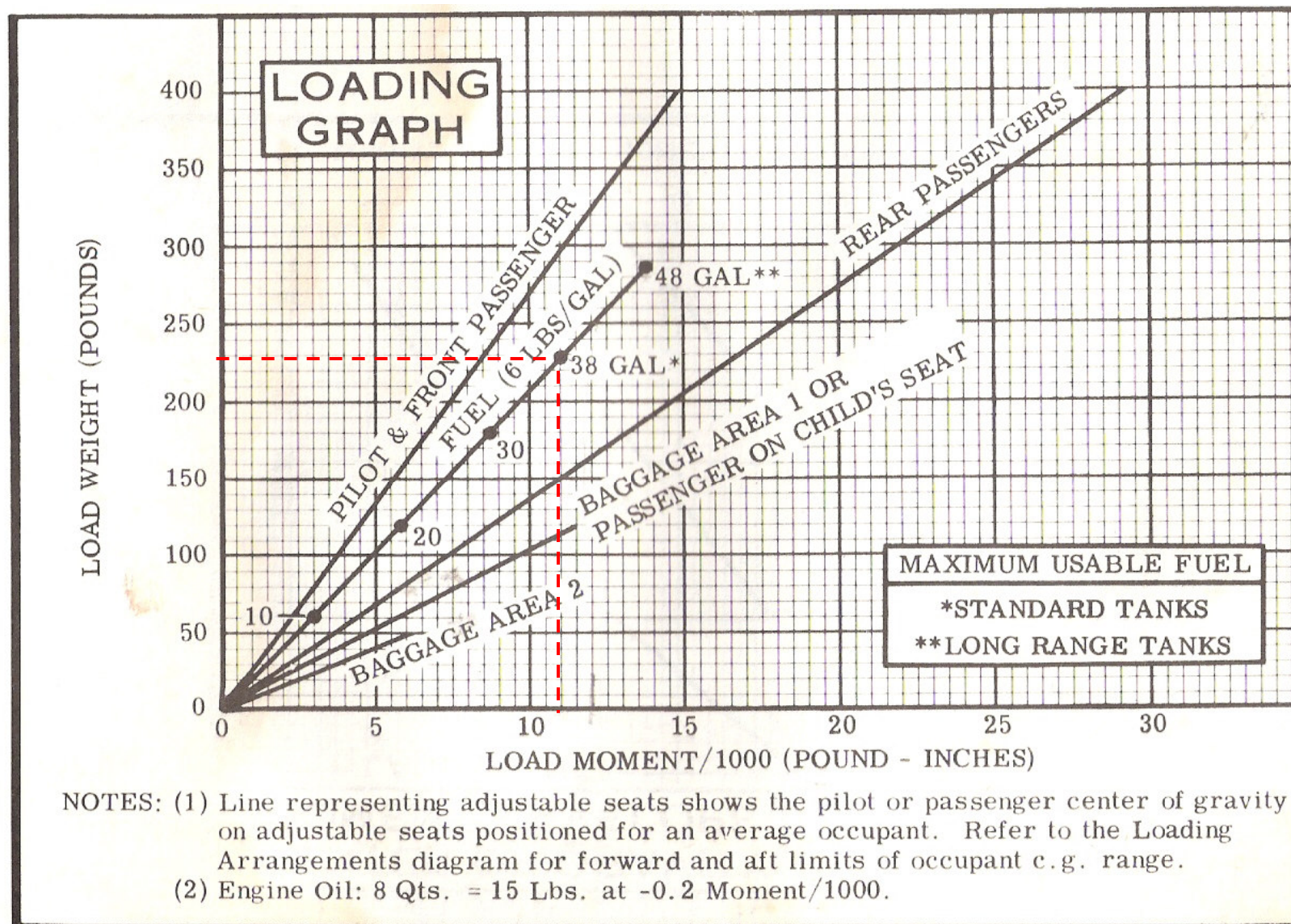




CESSNA 172 Skyhawk Loading Sheet		YOUR AIRPLANE	
		Weight (lbs.)	Moment (lb. -ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)		1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 lbs. at -0.2 Moment/1000).		15	-0.2
3. Usable Fuel (At 6 lbs./Gal.)			
Standard Tanks (38 Gal. Maximum)			
Long Range Tanks (43 Gal. Maximum)			
4. Pilot and Front Passenger (Station 34 to 46)			
5. Rear Passengers			
6.* Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 Lbs. Max.			
7.* Baggage Area 2 (Station 108 to 142) 50 Lbs. Max.			
8. TOTAL WEIGHT AND MOMENT			



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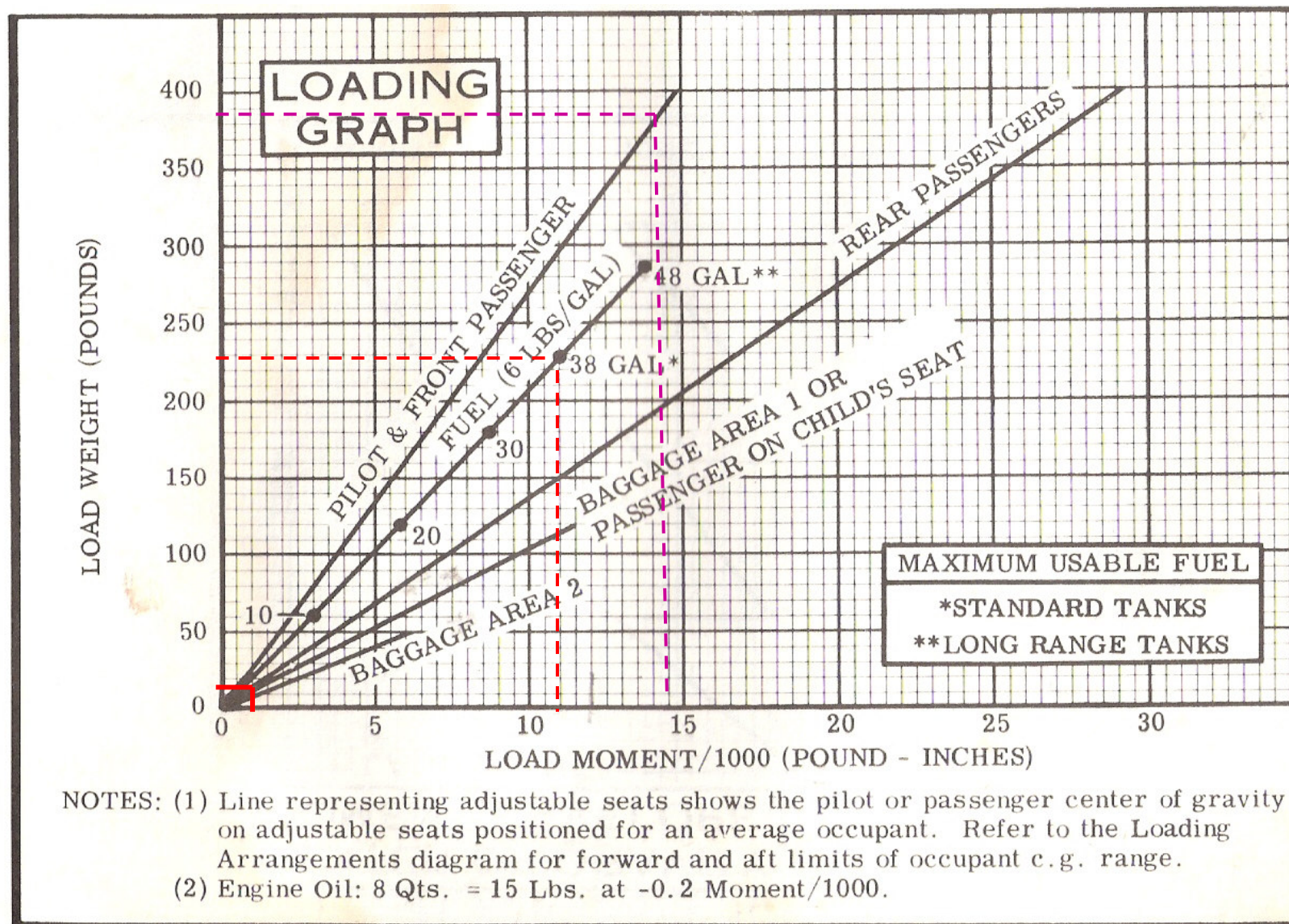




CESSNA 172 Skyhawk Loading Sheet		YOUR AIRPLANE	
		Weight (lbs.)	Moment (lb.-ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)		1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 Lbs. at -0.2 Moment/1000).		15	-0.2
3. Usable Fuel (At 6 Lbs. Gal.)			
Standard Tanks (39 Gal. Maximum)		228	10.9
Long Range Tanks (43 Gal. Maximum)			
4. Pilot and Front Passenger (Station 34 to 46)			
5. Rear Passengers			
6.* Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 Lbs. Max.			
7.* Baggage Area 2 (Station 108 to 142) 50 Lbs. Max.			
8. TOTAL WEIGHT AND MOMENT			



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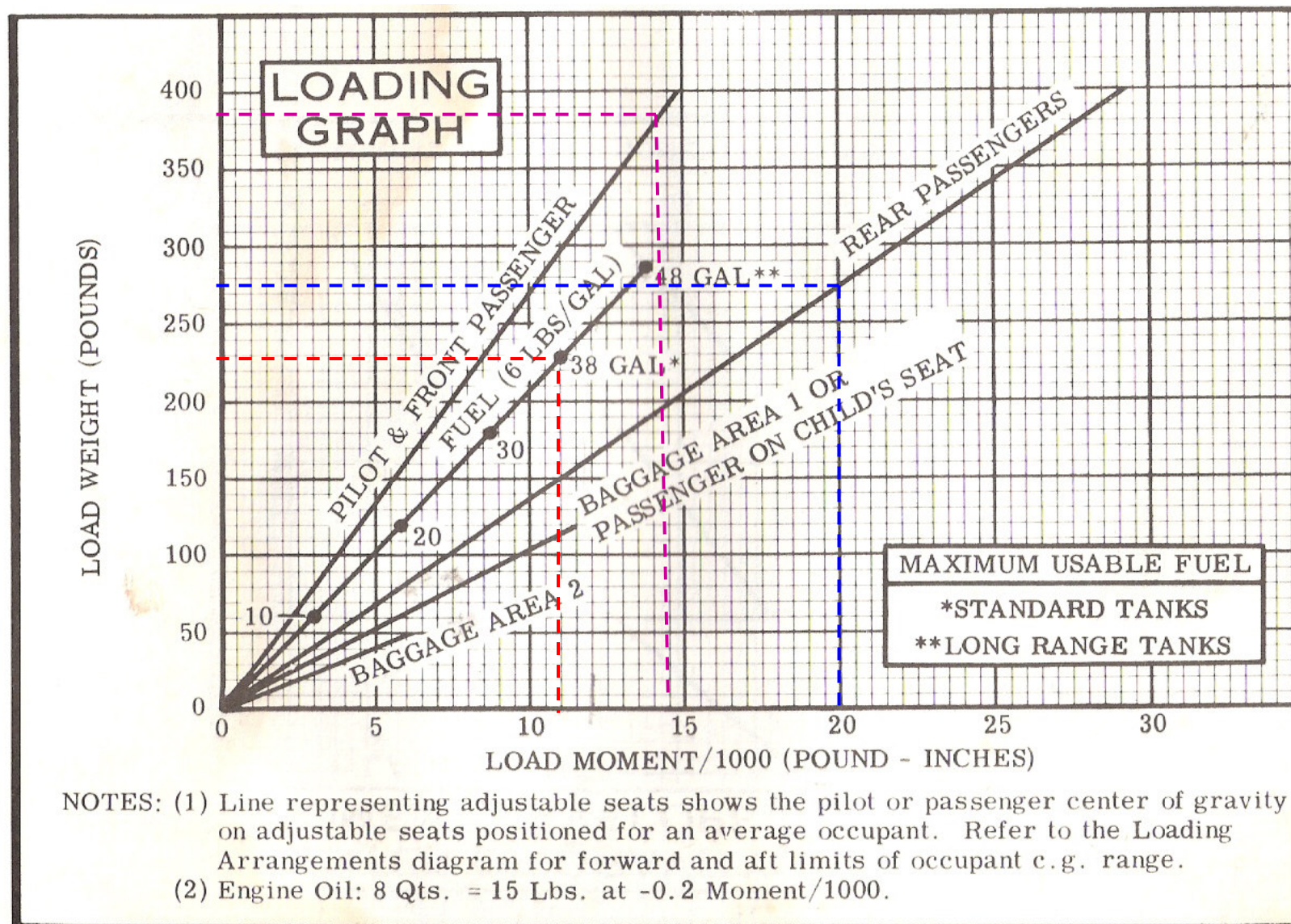




CESSNA 172 Skyhawk Loading Sheet	YOUR AIRPLANE	
	Weight (lbs.)	Moment (lb.-ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)	1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 lbs. at -0.2 Moment/1000).	15	-0.2
3. Usable Fuel (At 6 Lbs. /Gal.) Standard Tanks (38 Gal. Maximum)	228	10.9
Long Range Tanks (43 Gal. Maximum).		
4. Pilot and Front Passenger (Station 34 to 46)	385	14.5
5. Rear Passengers		
6.*Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 Lbs. Max.		
7.*Baggage Area 2 (Station 108 to 142) 50 Lbs. Max. . .		
8. TOTAL WEIGHT AND MOMENT		



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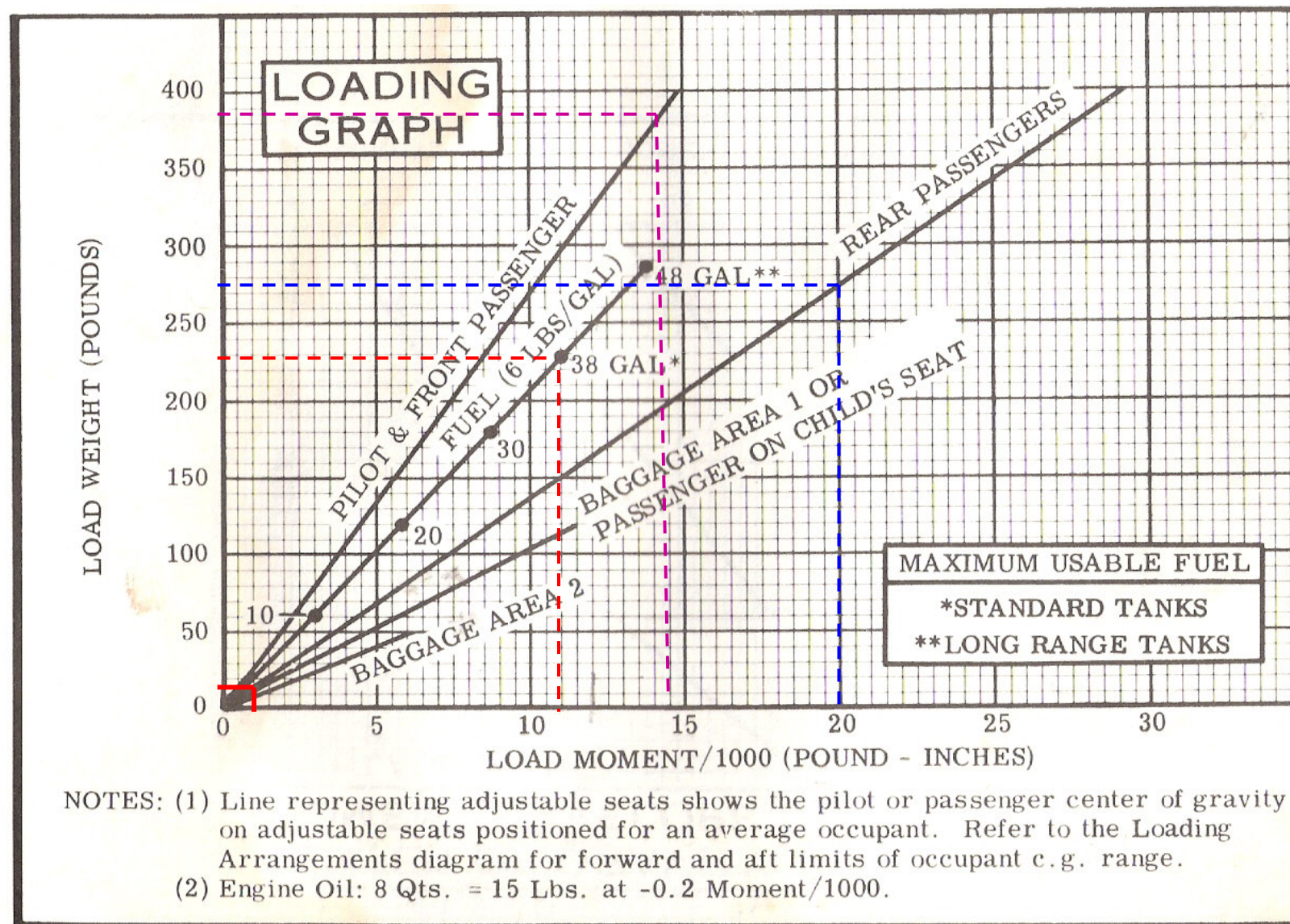




CESSNA 172 Skyhawk Loading Sheet	YOUR AIRPLANE	
	Weight (lbs.)	Moment (lb.-ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)	1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 lbs. at -0.2 Moment/1000).	15	-0.2
3. Usable Fuel (At 6 Gals. / Gal.)		
Standard Tanks (39 Gal. Maximum)	228	10.9
Long Range Tanks (43 Gal. Maximum)		
4. Pilot and Front Passenger (Station 34 to 46)	385	14.5
5. Rear Passengers	275	20.0
6.* Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 Lbs. Max.		
7.* Baggage Area 2 (Station 108 to 142) 50 Lbs. Max.		
8. TOTAL WEIGHT AND MOMENT		



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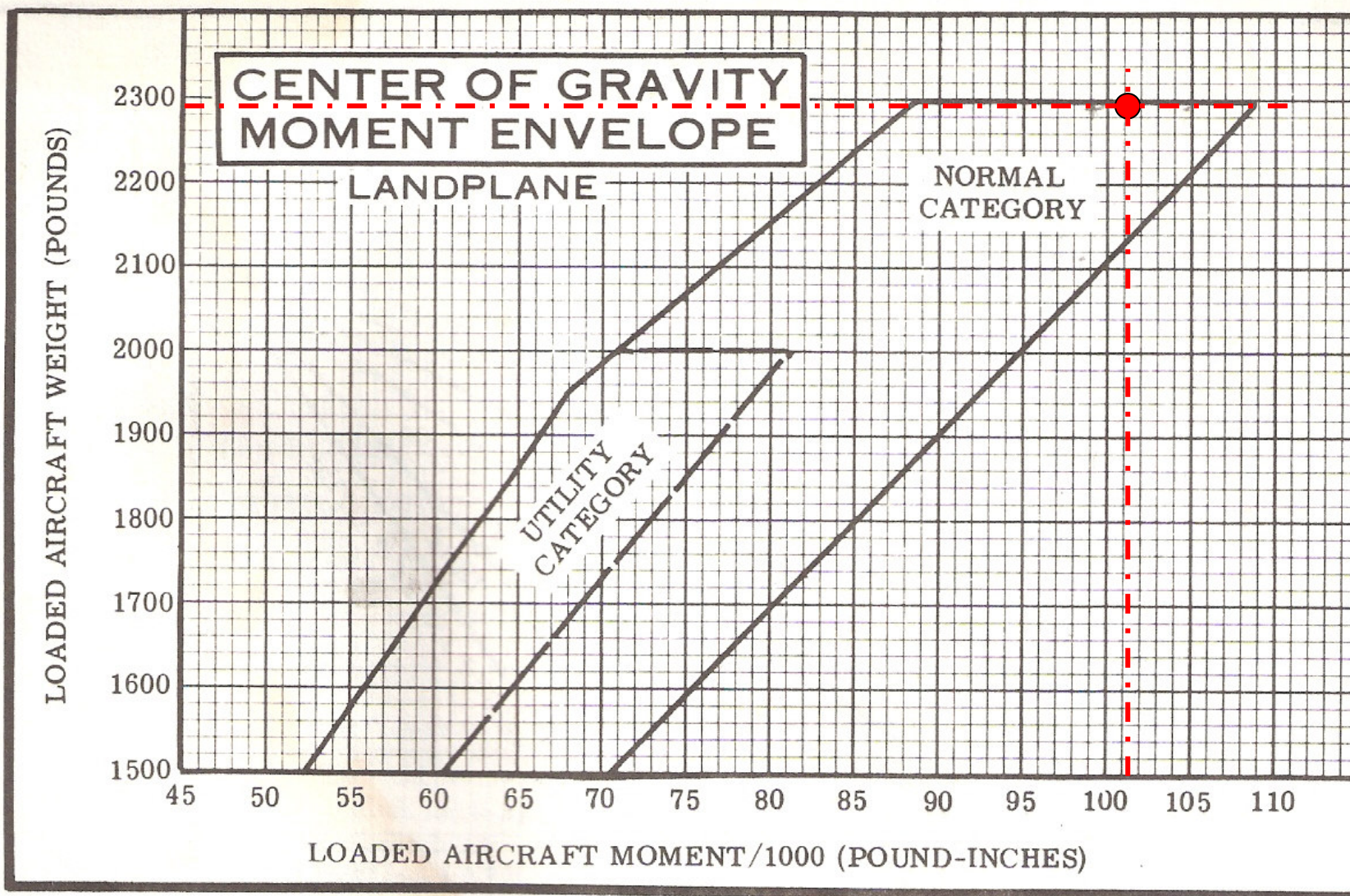
CESSNA 172 Skyhawk Loading Sheet		YOUR AIRPLANE	
		Weight (lbs.)	Moment (lb.-ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)		1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 lbs. at -0.2 Moment/1000).		15	-0.2
3. Usable Fuel (At 6 lbs./Gal.)			
Standard Tanks (30 Gal. Maximum)		228	10.9
Long Range Tanks (43 Gal. Maximum).			
4. Pilot and Front Passenger (Station 34 to 46)		385	14.5
5. Rear Passengers		275	20.0
6.* Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 lbs. Max.		12	2.0
7.* Baggage Area 2 (Station 108 to 142) 50 Lbs. Max. . .			
8. TOTAL WEIGHT AND MOMENT			



CESSNA 172 Skyhawk Loading Sheet	YOUR AIRPLANE	
	Weight (lbs.)	Moment (lb. -ins. /1000)
1. Licensed Empty Weight (Use the data pertaining to your airplane as it is presently equipped. Includes unusable fuel.)	1380	53.8
2. Oil (8 Qts. - The weight of full oil may be used for all calculations. 8 Qts. 15 lbs. at -0.2 Moment/1000).	15	-0.2
3. Usable Fuel (At 6 Lbs./Gal.) Standard Tanks (38 Gal. Maximum)	228	10.9
Long Range Tanks (43 Gal. Maximum).		
4. Pilot and Front Passenger (Station 34 to 46)	385	14.5
5. Rear Passengers	275	20.0
6.*Baggage Area 1 or Passenger on Child's Seat (Station 82 to 108) 120 Lbs. Max.	12	2.0
7.*Baggage Area 2 (Station 108 to 142) 50 Lbs. Max. . .		
8. TOTAL WEIGHT AND MOMENT	2295	101.0



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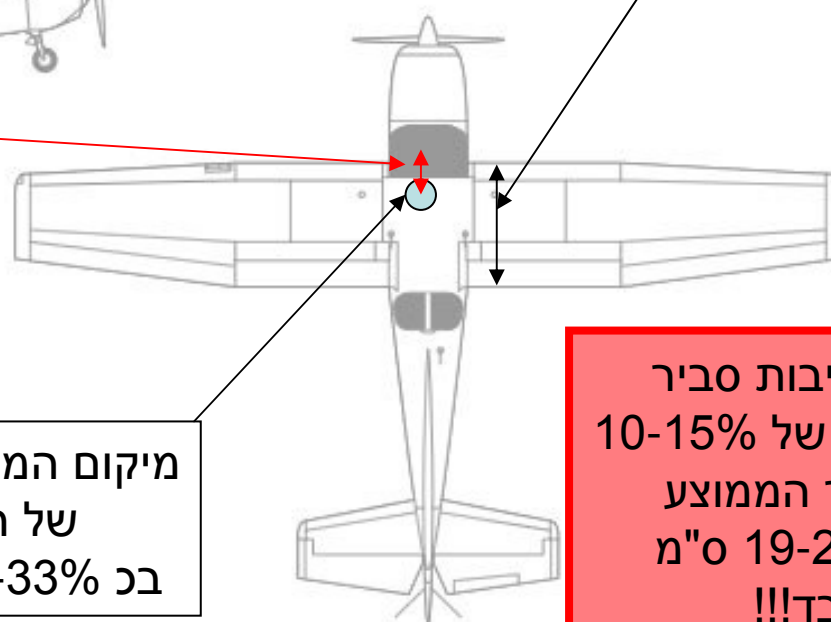
המחשה של גודל מירווח היציבות

חישוב "אצבע" בלבד



ואנו נדרשים לשמור
את מרכז הכובד לפני
המרכז האווירודינמי

מיקום המרכז האווירודינמי
של המטוס הוא
בכ 25-33% מיתר הכנף



מיתר = כ- 1.9 מ'

מרווח יציבות סביר
הינו בתחום של 10-15%
מהמיתר הממוצע
כלומר 19-28 ס"מ
בלבד!!!



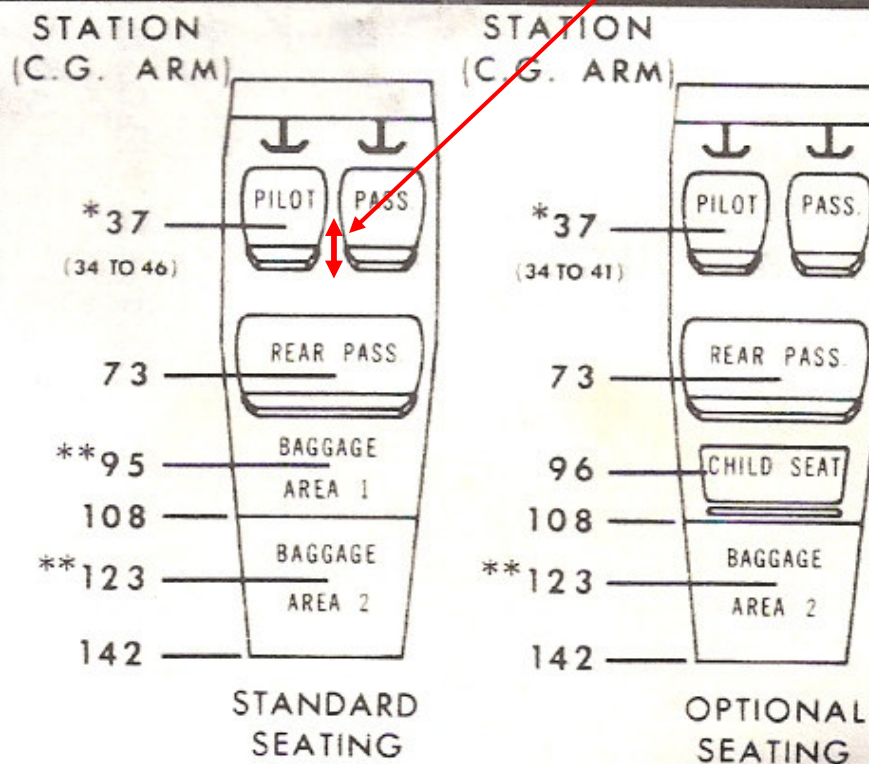
זה כל מרווח היציבות שלנו

LOADING ARRANGEMENTS

* Pilot or passenger center of gravity on adjustable seats positioned for average occupant. Numbers in parentheses indicate forward and aft limits of occupant center of gravity range.

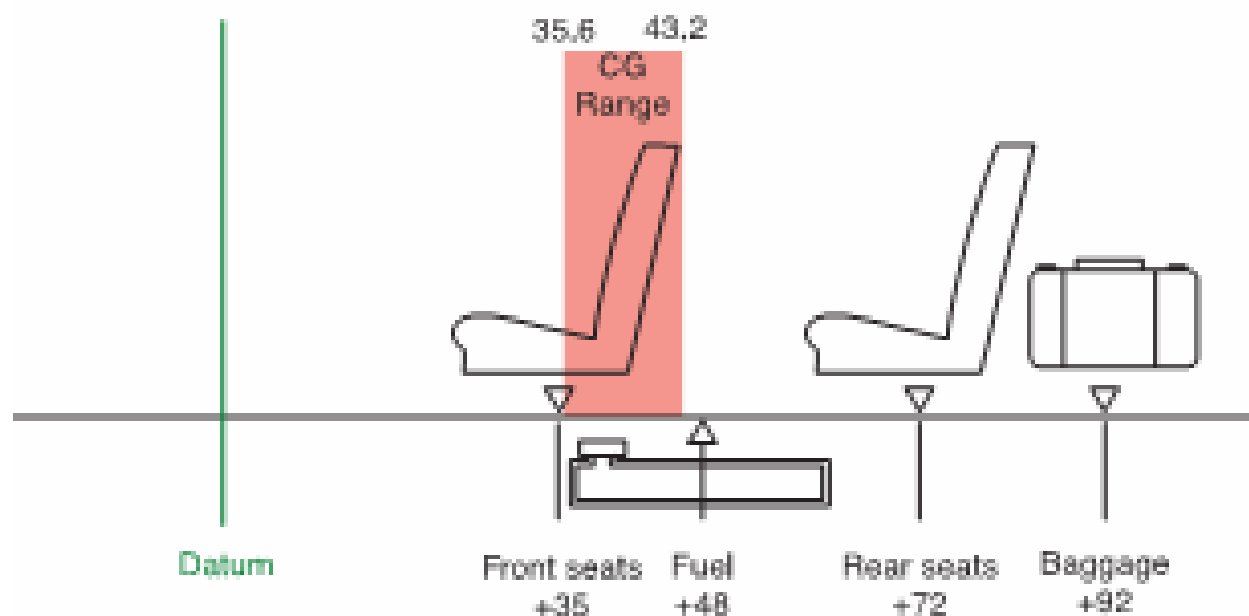
** Arm measured to the center of the areas shown.

NOTE: The rear cabin wall (approximate station 108) or aft baggage wall (approximate station 142) can be used as convenient interior reference points for determining the location of baggage area fuselage stations.





Loading diagram for a typical single-engine airplane.

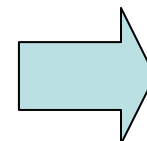


CG Range

Normal Category

(+82.0) to (+93.0) at 2,050 pounds.

(+87.4) to (+93.0) at 2,450 pounds.



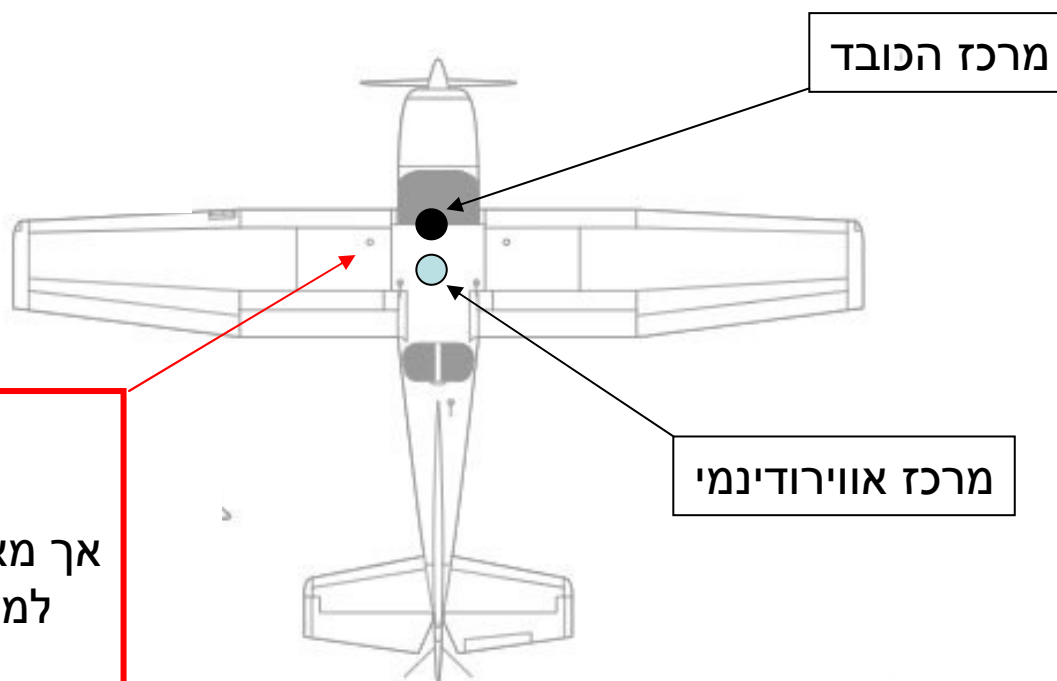
n"n 275



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השפעת צריכת דלק על מרכז הכובד

מטוס עם כנפיים ישרות



הדלק במטוס
נמצא קרוב למרכז הכובד
אך מאחוריו ולכן צריכת הדלק תגרום
למטוס להיות "קל יותר מאחור"
ולכן:
להזזת מרכז הכובד קדימה

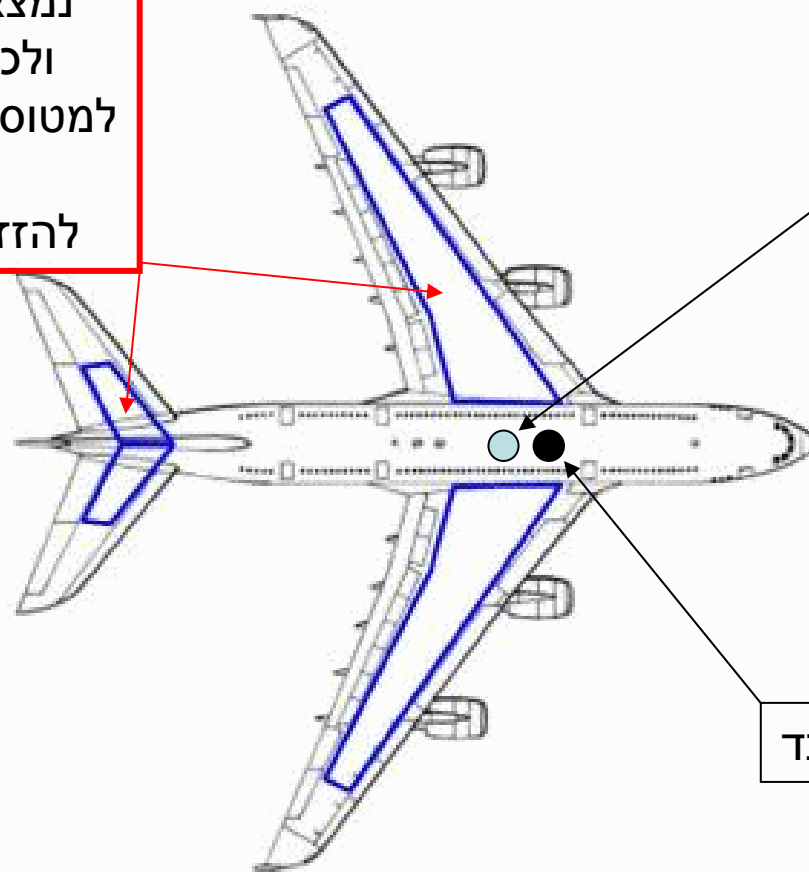


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השפעת צריכת דלק על מרכז הכובד

מטוס נוסעים עם כנפיים משוכות לאחור

רוב נפח הדלק במטוס
נמצא מאחורי מרכז הכובד
ולכן צריכת הדלק תגרום
למטוס להיות "קל יותר מאחור"
ולכן:
להזזת מרכז הכובד קדימה



מרכז אווירודינמי

מרכז הכובד

Airbus A380 Fuel Tank Locations



747-400

ממיכל מ.כ קדימה

לק ממיכלי הכנף תזיז מ.כ קדימה

2644 GAL - 10000 L

1164 GAL - 4402 L

25000 GAL - 94633 L

17164 GAL - 64873 L

21000 GAL - 79833 L

1164 GAL - 4402 L

2644 GAL - 10000 L

צריכת דלק ממיכל
אחורי תזיז מ.כ קדימה

צריכת דלק ממיכלי הכנף החיצוניים תזיז מ.כ קדימה



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השפעת קיפול כנע נסע על מרכז הכובד

PA 23-250 AZTEC



כן נסע קידמי מתקפל לאחור
ולכן מרכז הכובד יזוז לאחור
בעת קיפול כן הנסע

כן נסע ראשי מתקפל אל מרכז הגוף
ללא הזזת משקלו קדימה או אחורה
ולכן אינו משפיע על מרכז הכובד



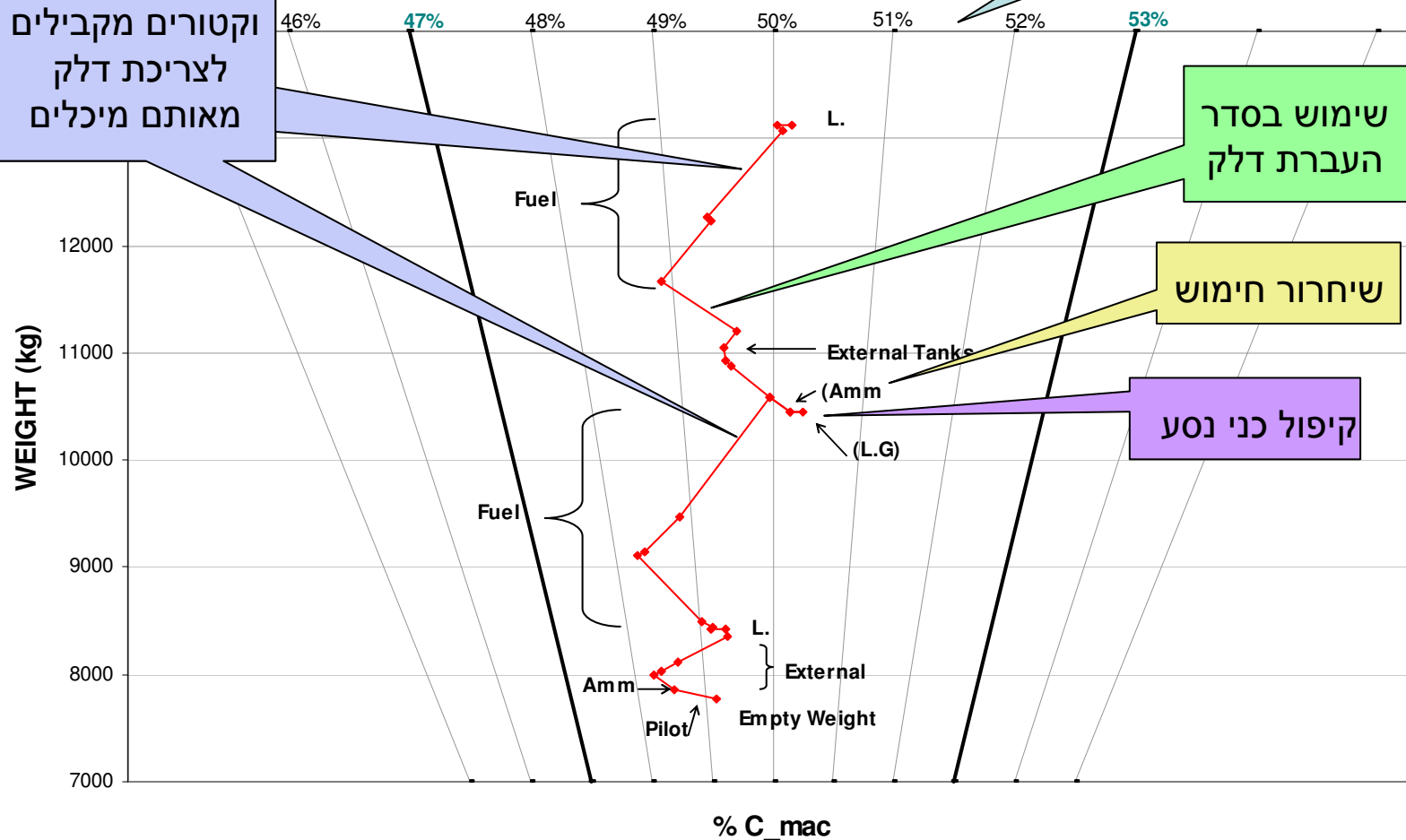
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צנטרוגרמה

Typical Fighter Centrogram

6% מרווח יציבות
= 120 מ"מ למיתר
ממוצע של 2 מ'

וקטורים מקבילים
לצריכת דלק
מאותם מיכלים



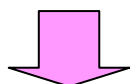
שימוש בסדר
העברת דלק

שיחרור חימוש

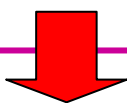
קיפול כני נסע



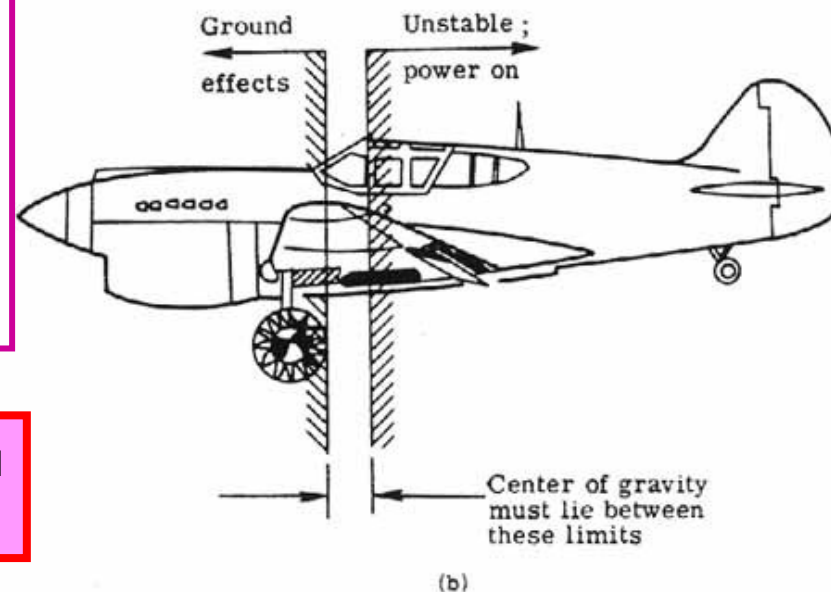
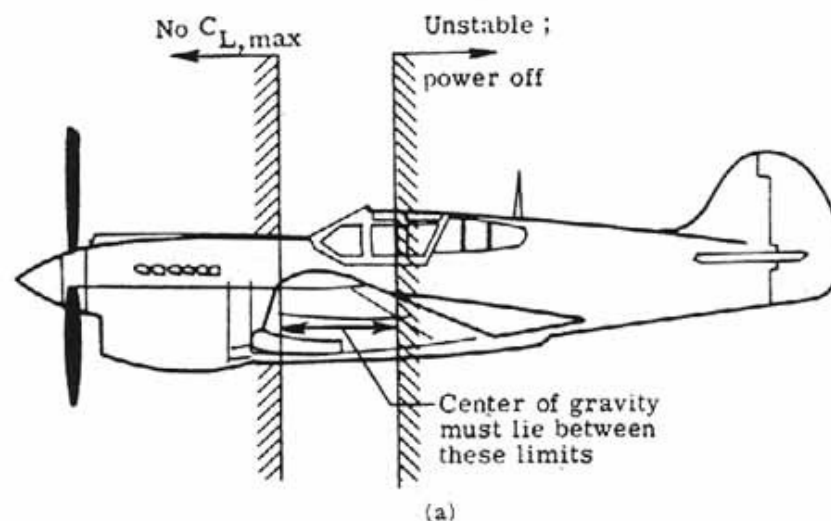
קיימים גורמים נוספים אשר מקטינים את טווח התזוזה ה"שימושי" של מרכז הכובד (ומשפיעים בכך על הקטנת מרווח היציבות) כגון אפקט דחף מנוע (engine-on thrust) ואפקט הקרקע (כולל כן נסע ומדפים)



כלומר בפועל בהתקרב המטוס לקרקע לנחיתה ה"טווח" בו מותר למרכז הכובד להימצא נעשה קטן יותר ויציבות המטוס הרבה יותר רגישה לכל שינוי כגון: קיפול כן נסע, הפעלת מדפים, שינוי דרסטי בדחף מנוע.



ולכן יש להקפיד פי כמה שמיקום מרכז הכובד ההתחלתי יהיה נכון





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אפקט קרקע



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מתוך דו"ח החקירה בוננזה A36 4X DZL חיפה 7.8.2008

שני הטייסים לא היו מודעים, בשלב זה

ומרגיע, עמד

מטוס, שהיה בהשפעת אנ

של ה"הליכ

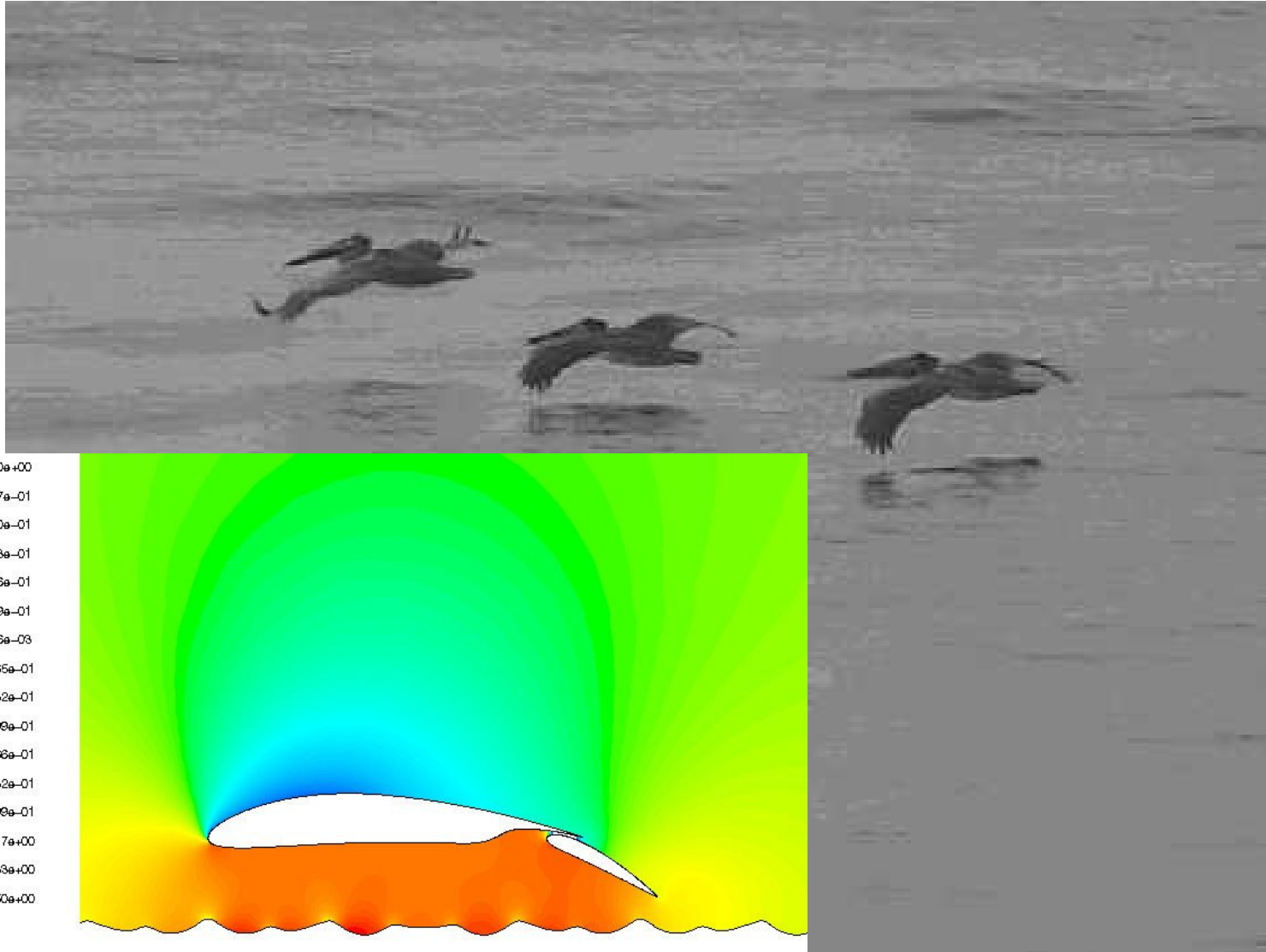
כל שנייה לו

הטייס-מפקד הגיב מיידית, ללא חשיבה מקדימה, פתח מנוע והמטוס, שהיה
תחת אפקט הקרקע עם מרכז כובד אחורי ביותר, "הרים אף" ובכך נתן את
התחושה כי המטוס "חיי" ובעל פוטנציאל.



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Ground Effect:



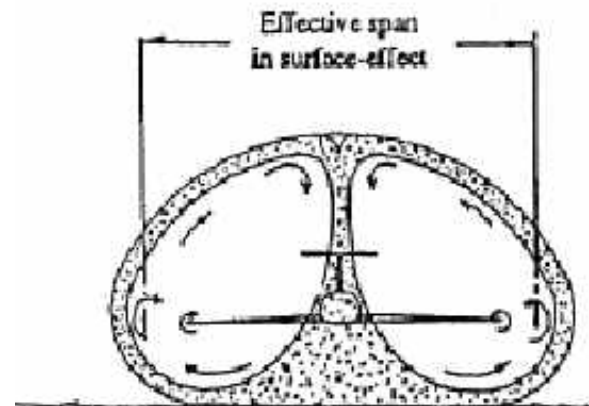
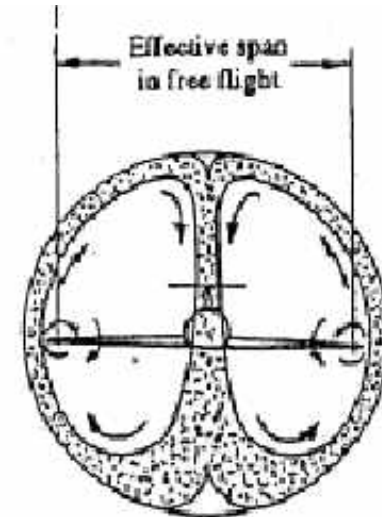
December 2008

Weight & Balance



Ground Effect:

- **Tip vortex decrease**
- **The pressure under the wing increases**
- **Lift increases**
- **Drag decreases**





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Orlenok, 1974



השפעת משקל מוגדל על ביצועי המטוס

- המטוס יצטרך מהירות המראה גדולה יותר וכתוצאה מכך גם ריצת המראה ארוכה יותר
- קצב הנסיקה וזווית הנסיקה ייקטנו
- תקרת הטייס תקטן
- מהירות השיוט תקטן
- הטווח יקטן
- יכולת התמרון תיקטן
- תהליך ומסלול הנחיתה יהיו ארוכים יותר כתוצאה מהגדלת מהירות הנחיתה הנדרשת
- מבנה המטוס ייחשף לעומסים גבוהים יותר במהלך הטיסה ובמיוחד כני הנסע בזמן הנחיתה



מה התשלום עבור מרווח יציבות גדול

- המטוס יהיה יותר "עייף" (sluggish)
- הזנב האופקי "יתנגד" לנסיונות הטייס לשנות את זווית ההתקפה
- אם נרצה לתקן זאת ע"י זנב גדול יותר – נוסיף משקל ומחיר למטוס
- זנב מוגדל יוסיף גם גרר למטוס
- לחילופין נצטרך להאריך את הגוף כדי להגדיל את זרוע המומנט ולאפשר הורדה או הרמת אף



ועבור מרווח יציבות קטן

- המטוס יהיה יותר "זריז" ובעל יכולת תימרון טובה יותר
- במטוסי קרב מקובל "להקריב" את היציבות הסטאטית תמורת שיפור יכולת התמרון
- בכמה מטוסים הדרישה לשיפור כושר התמרון הביאה אף למרווח יציבות שלילי (כלומר מ.כ אחרי מרכז הלחץ)
- אך מכיוון שטייס אנושי אינו זריז מספיק כדי להגיב ולשלוט במטוס משולבים חיישנים ומותקן בו גם מחשב טיסה
- וכמובן שבמקרה זה המחשב מגובה במחשב (ים) נוסף



TERMS ALL PILOTS SHOULD KNOW

arm (moment arm)—the horizontal distance in inches from the reference datum to the item. The algebraic sign is plus (+) if measured aft of the datum and minus (-) if measured forward of the datum;

center of gravity (c.g.)—the point about which an aircraft would balance if it were possible to suspend it at that point. It is the mass center of the aircraft or the theoretical point at which the entire weight of the aircraft is assumed to be concentrated;

center of gravity limits—the specified forward and aft points beyond which the c.g. must not be located during flight. The c.g. moment envelope is contained in the aircraft flight manual and FAA Aircraft Specifications or Data Sheets;

center of gravity range—the distance between the forward and aft c.g. limits;

datum line—an imaginary vertical plane or line from which all measurements of arm are taken. The datum is established by the manufacturer. After the datum is selected all moment arms and the c.g. range must be computed with reference to that point;



moment—the product of the weight of an item multiplied by its arm. Moments are expressed in inch pound (in.-lb.);

total moment—the weight of the aircraft multiplied by the distance between the datum and the c.g.;

mean aerodynamic chord (MAC)—the average distance from the leading edge to the trailing edge of the wing. The MAC is specified for the aircraft by determining the average chord of an imaginary wing which has the same aerodynamic characteristics of the actual wing. Center of gravity is usually located at or near the forward 25 percent of the chord;

station—a location in the aircraft which is identified by a number designating its distance in inches from the datum. The datum is therefore identified as zero and the station and arm are usually identical;

useful load—the weight of the pilot, copilot, passengers, baggage, usable fuel, and drainable oil;

empty weight—the airframe, engines, and all items of operating equipment that have fixed locations and are permanently installed in the aircraft. It includes optional and special equipment, fixed ballast, hydraulic fluid, unusable (residual) fuel, and undrainable (residual) oil.

Weight & Balance Calculators - JavaScript - Microsoft Internet Explorer

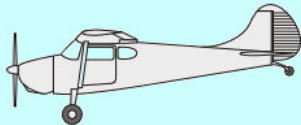
File Edit View Favorites Tools Help

Address <http://home.roadrunner.com/~trumpetb/alph/index.html>

Google Weight & balance

Weight & balance

Weight Balance Cal...



Cessna 170B

Weight and Balance Calculator

Or try one of these other aircraft examples:

[Cessna 170B](#) | [Cessna 152](#) | [Cessna 172N](#) | [Cessna 177B](#) | [Cessna 180](#) | [Cessna 182R](#) | [Cessna 185D](#) | [Cessna 210M](#) | [Cessna 421](#) |
[Socata TB9 Tampico](#) | [Socata T200 Tobago](#) | [Piper PA-28-140](#) | [Piper PA-28-180](#) | [Piper PA-28R-200](#) | [Piper PA-46-310P](#) |
[Mooney M20J](#) | [Bonanza V35B](#) | [Cirrus SR22](#) |

Form default data is for N3224A. Use your own AC data !		Weight (lbs)	Arm (inches)	Moment (in-lb)
Empty Weight		1349	39.4	53151
Oil (8 qt max, 7 lb/gal)	qt : 8	14	-20	-280
Front Seat L & R	150 125	35.9	9873	
Fuel (37 gal useable)	gal: 37	222	47.7	10589
Rear Seat L & R	170 125	70	20650	
Baggage (120 lb max)	45	95	4275	
Calculate Reset				
Gross Weight (2200 lb max):		2200		98258
Loaded Center of Gravity:			44.66	
Maneuvering speed, V _{man} (mph):		115	<=(decr. with decr. wt.)	

start | Internet | 23:35

Weight & Balance Calculators - JavaScript - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://home.roadrunner.com/~trumpetb/alph/index.html

Google Weight & balance

Weight & balance

Weight Balance Cal...

Calculated **Gross Weight** and **C.G.** point must lie within the utility or normal category envelope limits per the *Airplane Flight Manual*, landplane example below...

Loading Examples Chart - [or, here's a [CSS Active Plot Version](#)]

Cessna 170B Load Limits

Gross Weight, lbs.

Utility Category

Normal Category

From Datum (Firewall):

Oil	-20.0 in.
Front Seats	35.9
Fuel	47.7
Rear Seats	70.0
Baggage	95.0
L.E.M.A.C.	25.9
(M.A.C: 58.4)	

C.G., inches

(18% MAC) 36.4 40.8 46.4 (35.1% MAC)

(24.8% MAC)

(calculator example values)

Warning: This calculator is presented for educational purposes only. You, as pilot in command, are solely responsible for assuring correct data and proper loading of your aircraft prior to flight.

- Empty weight and C.G. data comes from your **AC current weight & balance records**.
- Station arms, load limits, and airspeed limits come from the *Airplane Flight Manual* (before 03-01-79) or *Pilot's Operating Handbook [POH]* (after 03-01-79) [[pop-up more detail](#)], or the [FAA Type Certificate Data Sheet \(TCDS\)](#). Downloading the TCDS is recommended to learn more about your AC.

start

Inbox - Outlook Ex... Gmail - שלח... Weight & Balance... Microsoft PowerP...

Internet

EN 23:36



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מטוס הלבאי



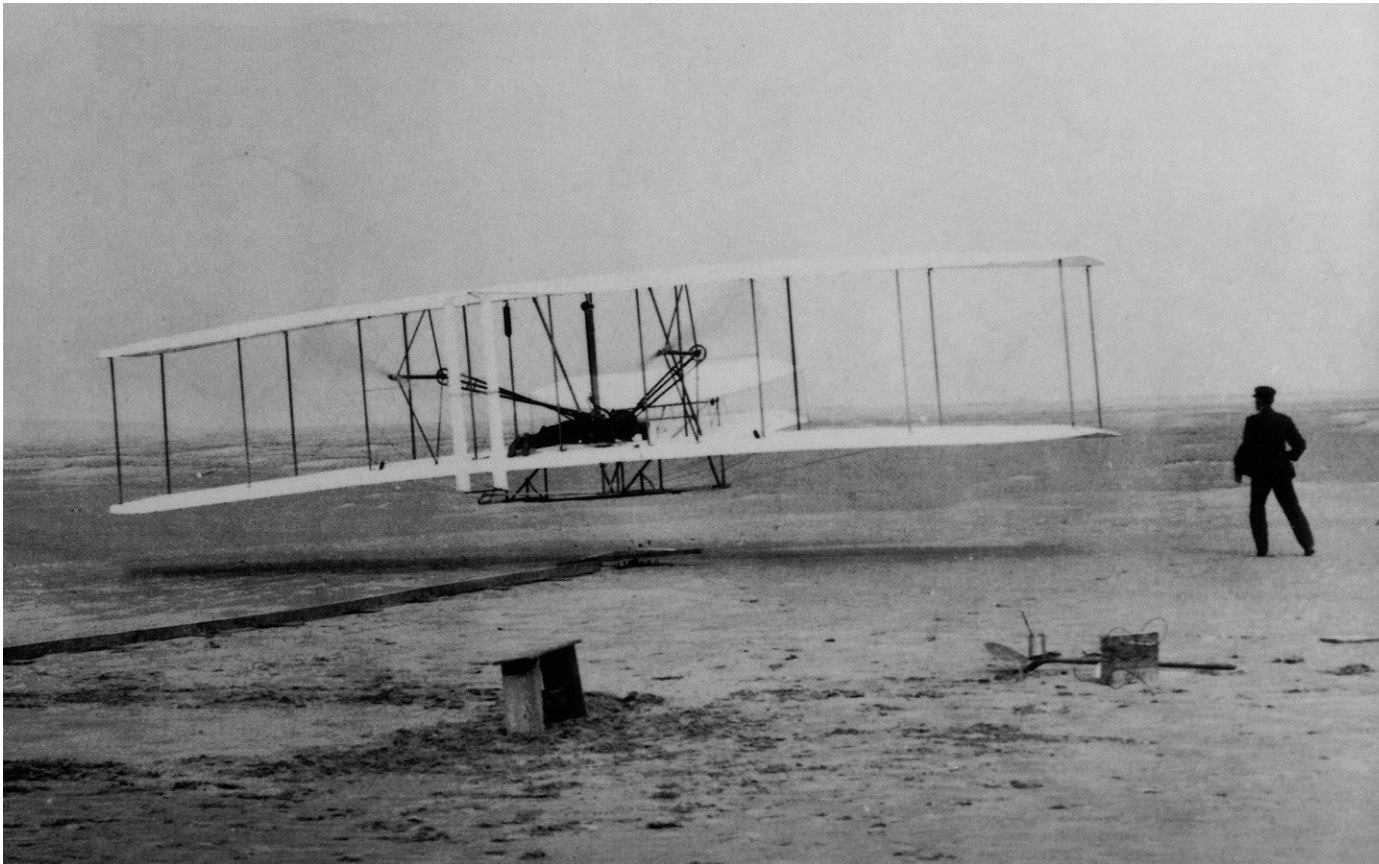
December 2008

Weight & Balance



Dror Artzi

December 17 1903 At 10:35



December 2008

Weight & Balance



Dror Artzi

כי הרי כל העניין הוא לגעת בשמיים, ולהנות



December 2008

Weight & Balance



התחביב שלנו אינו תחביב הוא מקצוע

וכך צריך לנהוג בו





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לקריאה נוספת



December 2008

Weight & Balance



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www.caa.govt.nz, for details of more CAA safety publications.



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שאלות?