

<b>Objectives</b>	<ul style="list-style-type: none"> <li>▪ The student will understand the theory behind weight and balance and will obtain the skills needed to calculate an aircraft's weight and balance</li> </ul>
<b>Motivation</b>	<ul style="list-style-type: none"> <li>▪ <u><i>F-27 Guernsey</i></u></li> <li>▪ <u><i>Atlas Air 747</i></u></li> </ul>
<b>Elements</b>	<ul style="list-style-type: none"> <li>▪ Terms</li> <li>▪ Weight &amp; Flight Characteristics</li> <li>▪ Center of Gravity &amp; Flight Characteristics</li> <li>▪ W&amp;B Control</li> <li>▪ Ways to Calculate W&amp;B</li> <li>▪ Weight Shift</li> </ul>
<b>Schedule</b>	<ul style="list-style-type: none"> <li>▪ Overview</li> <li>▪ Terms</li> <li>▪ Content</li> <li>▪ Conclusion &amp; Review</li> </ul>
<b>Equipment</b>	<ul style="list-style-type: none"> <li>▪ White Board &amp; Marker</li> <li>▪ Miniature Aircraft</li> <li>▪ Ruler</li> <li>▪ Pen</li> <li>▪ Quarters or Small Weights</li> </ul>
<b>CFI Actions</b>	<ul style="list-style-type: none"> <li>▪ Present lesson</li> <li>▪ Use teaching aids</li> <li>▪ Provide sample problems</li> <li>▪ Ask/ answer questions</li> </ul>
<b>Student Actions</b>	<ul style="list-style-type: none"> <li>▪ Participate in discussion</li> <li>▪ Take notes</li> <li>▪ Ask / answer questions</li> <li>▪ Review printout and sample problems as homework</li> </ul>
<b>Completion Standards</b>	<ul style="list-style-type: none"> <li>▪ The Student Understands the Factors Relating to Weight and Balance and How It Effects Airplane Control, Stability and Performance. The Student Also Can Calculate the Weight and Balance for A Given Situation and Adjust as Necessary.</li> </ul>

## Introduction

### Overview

Review Objectives / Elements

### What

Airplane weight and balance is basically, balancing the airplane within approved limits

### Why

Pilots need to keep the aircraft within safe limits and balance the loads carried to maintain control of the airplane

### How

## Terms

- **Reference Datum (RD)** - An imaginary vertical plane from which all horizontal distances are measured for balance purposes
  - The datum may be located anywhere the manufacturer chooses
  - Common locations are the nose, the engine firewall, the wing's leading edge, or ahead of the nose
- **Station** - A location on the airplane fuselage usually given in terms of distance from the reference datum
- **Arm** – The horizontal distance, usually in inches, from the RD to the Center of Gravity of an item
  - Arms ahead of the reference datum are negative and those behind the reference datum are positive
    - If the reference datum is ahead of the nose, all the arms are positive
- **Moment** – A force that causes or tries to cause an object to rotate
  - It is the product of the weight of an item multiplied by its arm and expressed in pound-inches
- **Moment Index** – The moment divided by a reduction number (100/1000) to get it smaller/reduce errors
- **Center of Gravity (CG)** – the point at which an airplane would balance if it were suspended at that point
  - The distance of the CG from the RD is found by dividing the total moment by total weight
- **CG Limits** – The extreme (forward/aft) CG locations within which the plane must be operated at a weight
- **Usable Fuel** – the fuel available for flight planning
- **Unusable Fuel** – the fuel in the tanks that cannot be safely used in flight or drained on the ground
- **Basic Empty Weight** – the weight of the standard airplane, optional equipment, unusable fuel, and full operating fluids (including oil)

- **Payload** – the weight of the occupants, cargo and baggage
- **Useful Load** – difference between takeoff weight (or ramp weight if applicable) and basic empty weight
- **Max Ramp Weight** – the max weight approved for ground maneuvers (includes start, taxi, run-up fuel)
- **Max Takeoff Weight** – the max weight approved for the start of the takeoff run
- **Max LDG Weight** – The max weight approved for landing touchdown
- **Max Zero Fuel Weight** – the max weight exclusive of usable fuel
- **Standard Weights** – Established for numerous items in weight and balance computations
  - **100LL:** 6lbs , **Jet Fuel:** 7lbs, **Oil:** 7.5lbs, **Water:** 8.35lbs (all per gallon)

## Weight & Flight Performance

### Weight & Flight Performance

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- Operating above the max gross weight will result in:
  - Higher takeoff speeds, longer takeoff roll, reduce rate of climb, lower maximum altitude, reduced cruise speed, shorter range, reduced maneuverability, higher stall speed, longer landing roll, excessive weight on nose wheel
  - The decreased climb and cruise performance can lead to excessive wear on the engine and increased fuel burn

### Weight and structure

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- Structural failures from overloading may be catastrophic, but often they affect the aircraft structure progressively making it difficult to detect or repair
- An airplane is designed to withstand the loads presented in section 2 of the POH/AFM

### Weight and stability

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- Weight distribution has a great effect on how the aircraft acts

### Airplane with forward loading

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- Slower compared to a forward cg
  - More downforce is required to keep nose up which results in higher AOA in cruise flight thus, more drag and higher stall speeds
  - “Already closer to critical angle of attack”
  - The airplane is more controllable due to the leverage on control surfaces
  - **Demonstrate with plane**
  - Stalls are easier to recover from due to the “heavy nose”

### Airplane with Aft Loading

- Requires less downforce to maintain level flight resulting in lower AOA and higher cruise speeds
- Stall speeds are lower due to the lower AOA
  - Although stall speed is lower stall recovery is harder due to the tail-heavy nature
  - If CG goes aft out of the limits, stall and spin recovery may become impossible
- Controls are less effective due to the shorter arm between CG and empennage

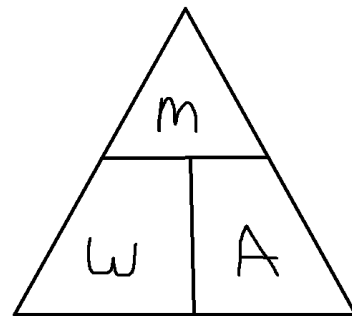
### Weight Balance Control

- Use the AFM/POH for aircraft weight and balance
  - Do not exceed the manufacturer's weight and CG limits
- There are various methods to determine weight and balance:
  - Computational
  - Graphical
  - Table

### Determining Weight & Balance

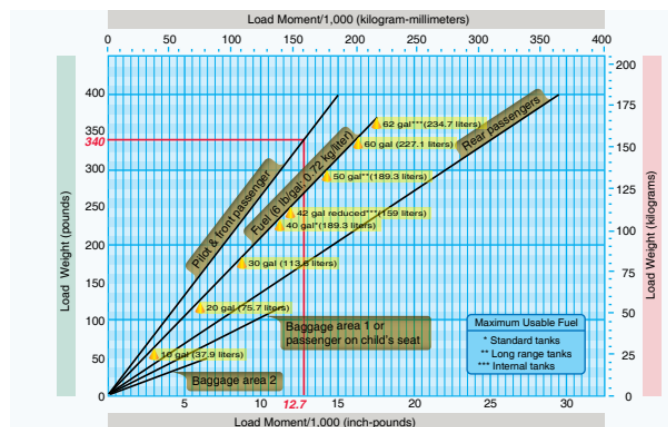
#### Computational Method

- The computational method uses basic math functions to compute W&B
  - Teach how to use the W&B pyramid
- Add up all the weights
- Find the arms from the POH then use the computational method to determine the CG and total weight
  - If weight is too high remove items, fuel or passengers
  - If CG is out of limits, move items to attempt to bring it back into limits



#### Graphical method

- The computational method uses a variety of charts to determine the moment and CG of an aircraft
- To use it, simply plot the weight on the Y axis and move over until you intercept a line for the given station. Your moment will be directly below this on the X axis



References: FAA-H-8083-1, FAA-H-8083-3, FAA-H-8083-25

## Table Method

- The table method uses a table for each station. The table has a variety of weights that will give you the moment.
- Values may need to be interpolated

**Usable Fuel**

Main Wing Tanks Arm 75		
Gallons	Weight	Moment/100
5	30	22
10	60	45
15	90	68
20	120	90
25	150	112
30	180	135
35	210	158
40	240	180
44	264	198

**\*Oil**

Quarts	Weight	Moment
10	19	5

\*Included in basic empty weight  
Empty Weight - 2,015  
MOM 100 - 1,554

**Moment Limits vs Weight**

Weight Condition	CG Limit	
	Forward	AFT
2,950 lb (takeoff or landing)	82.1	84.7
2,525 lb	77.5	85.7
2,475 lb or less	77.0	85.7

**Sample Loading Problem**

	Weight	Moment
Basic empty weight	2,015	1,554
Fuel main tanks (44 gal)	264	198
*Front seat passengers	300	254
*Rear seat passengers	190	230
Baggage	30	42
<b>Total</b>	<b>2,799</b>	<b>2,278/100</b>

\* Interpolate or, as in this case, add appropriate numbers.

**Occupants**

Front Seat Arm 85				Rear Seats Arm 121			
Weight	Moment	Weight	Moment	Weight	Moment	Weight	Moment
120	102	120	145	2,400	1,848	2,057	
130	110	130	157	2,410	1,856	2,065	
140	119	140	169	2,420	1,863	2,074	
150	128	150	182	2,430	1,871	2,083	
160	136	160	194	2,440	1,879	2,091	
170	144	170	206	2,450	1,887	2,100	
180	153	180	218	2,460	1,894	2,108	
190	162	190	230	2,470	1,892	2,117	
200	170	200	242	2,480	1,911	2,125	
				2,490	1,921	2,134	
				2,500	1,932	2,143	
				2,510	1,942	2,151	
				2,520	1,953	2,160	
				2,530	1,963	2,168	
				2,540	1,974	2,176	
				2,550	1,984	2,184	
				2,560	1,995	2,192	
				2,570	2,005	2,200	
				2,580	2,016	2,208	
				2,590	2,026	2,216	
				2,600	2,037	2,224	
				2,610	2,048	2,232	
				2,620	2,058	2,239	
				2,630	2,069	2,247	
				2,640	2,080	2,255	
				2,650	2,090	2,263	
				2,660	2,101	2,271	
				2,670	2,112	2,279	
				2,680	2,123	2,287	
				2,690	2,133	2,295	
				2,700	2,144	2,303	
				2,710	2,155	2,311	
				2,720	2,166	2,319	
				2,730	2,177	2,326	
				2,740	2,188	2,334	
				2,750	2,199	2,342	
				2,760	2,210	2,350	
				2,770	2,221	2,358	
				2,780	2,232	2,366	
				2,790	2,243	2,374	
				2,800	2,254	2,381	
				2,810	2,265	2,389	
				2,820	2,276	2,397	
				2,830	2,287	2,405	
				2,840	2,298	2,413	
				2,850	2,309	2,421	
				2,860	2,320	2,428	
				2,870	2,332	2,436	
				2,880	2,343	2,444	
				2,890	2,354	2,452	
				2,900	2,365	2,460	
				2,910	2,377	2,468	
				2,920	2,388	2,475	
				2,930	2,399	2,483	
				2,940	2,411	2,491	
				2,950	2,422	2,499	

## Weight Shift

- When items are shifted around the aircraft, the weight shift formula can be used to quickly find the new CG
- This gives a Delta CG or Change in CG
- The value will either be positive or negative (added or subtracted from previous CG)

$$\frac{\text{Weight shifted}}{\text{Total weight}} = \frac{\Delta \text{CG (change of CG)}}{\text{Distance weight is shifted}}$$

## Conclusion & Review

### Review the Main Lesson Points

- Weight and balance greatly affect flight and therefore, its very important to the safety of flight

### Review

- Weight and balance terms
- Effects on weight balance on performance
- Methods of weight and balance control
- Sample problems on printout