Area of Operation **II** - Task **F**

Airplane Weight & Balance

Content

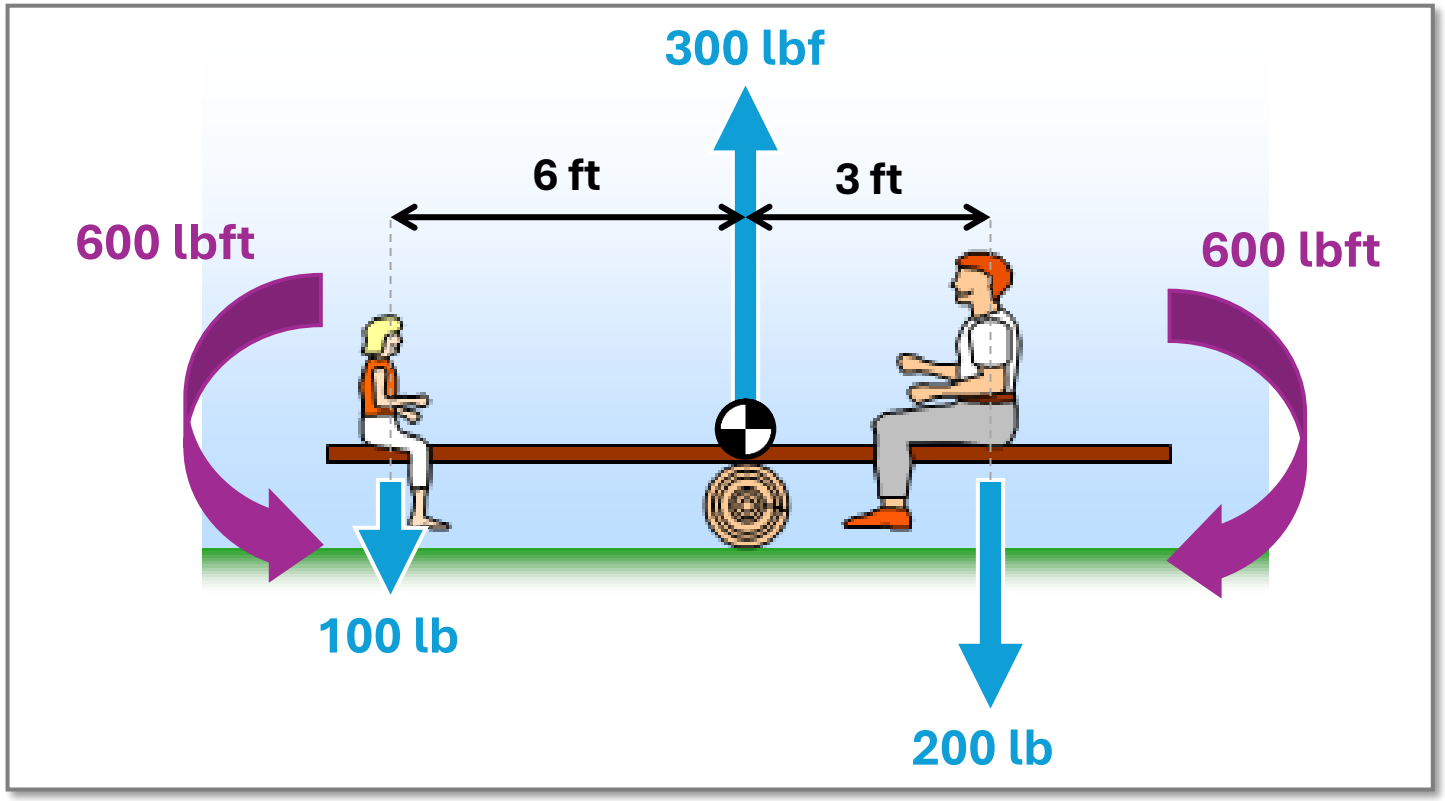
Key References:

- Airplane Flying Handbook
- Pilot's Handbook of Aeronautical Knowledge
- Weight and Balance Handbook, AC120-27 (Aircraft Weight and Balance Control), POH

1. Introduction

- **What**: Introduce the concept of balancing the airplane and calculating total weight, as well as ensuring it is within the limits (envelop) of the airplane
- **Why**: The airplane flying characteristics changes depending on weight and location of the center of gravity. Operating outside of the W&B limits is hazardous and compromises the airplane's structural integrity

- **Fundamentals**
  - Equilibrium
    - No acceleration
    - Sum of all **Forces = 0**
    - Sum of all **Moments = 0**
  - Center of Gravity
    - Point at which all the weight is mathematically concentrated



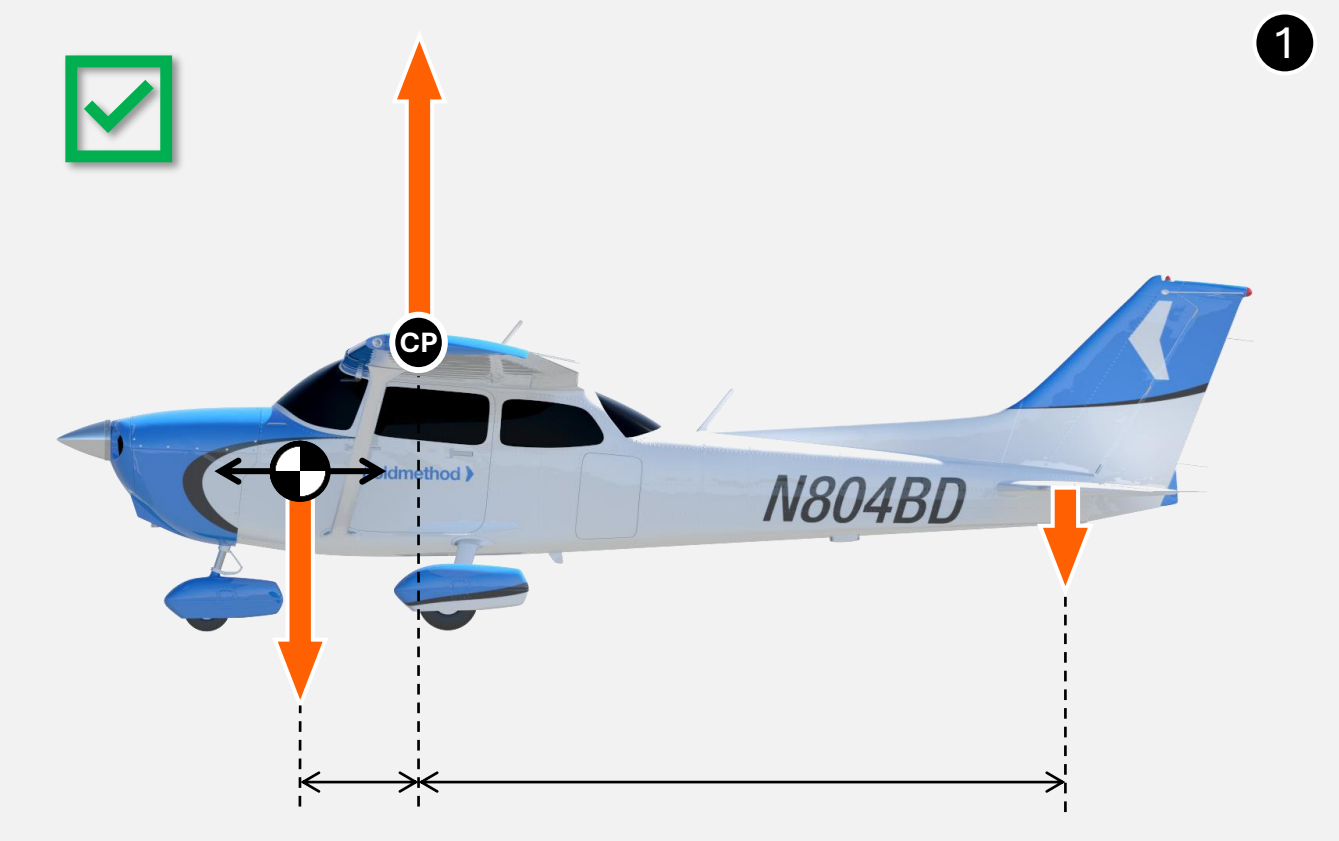
2. Weight & Balance Definitions

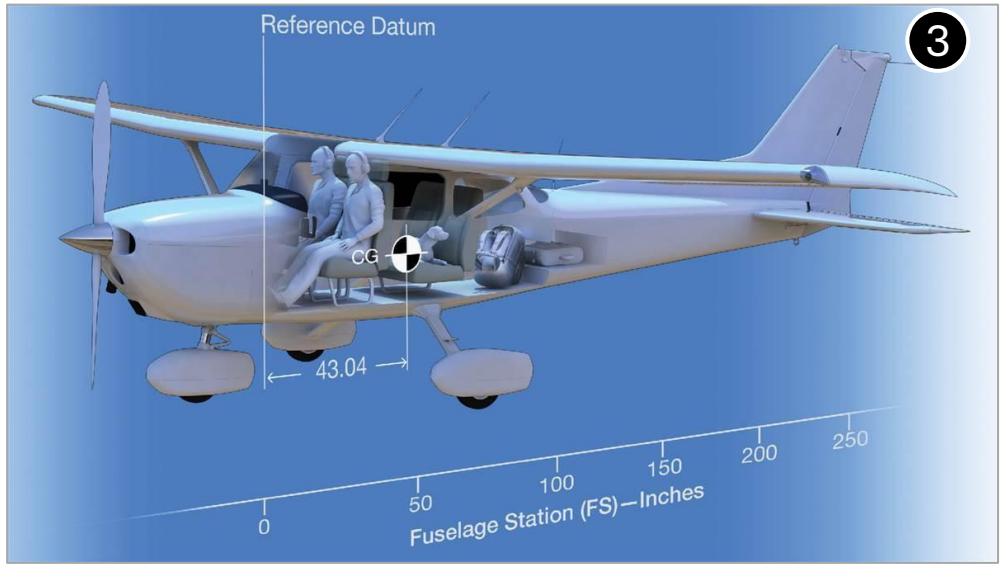
- **Terms** (most defined in AC 120-27 Appendix A)
  - Datum: an imaginary vertical plane from which all horizontal distances are measured for balance purpose
  - Arm: horizontal distance from the reference datum or the CG
  - Station – Location in the aircraft identified by a designatedg distance from the datum
  - Moment – Weight multiplied by the arm of an item (expressed in pound-inches)
  - Center of Gravity – Point at which an airplane would balance, if suspended at that point
  - Basic Empty Weight – Weight of the airplane, optional equipment, unusable fuel, full fluids
  - Max Ramp Weight – Total permitted weight of a loaded aircraft, including all fuel
  - Max Takeoff Weight (MTOW) – Greatest weight allowed for takeoff
    - *Useful Load – Basic empty weight subtracted from the maximum allowable gross weight*
    - *Payload – Weight of the occupants, cargo and baggage*
  - Max Landing Weight – Greatest weight allowed for landing
  - Maximum Zero Fuel Weight – Max allowable weight, exclusive of usable fuel (wing structural reasons)

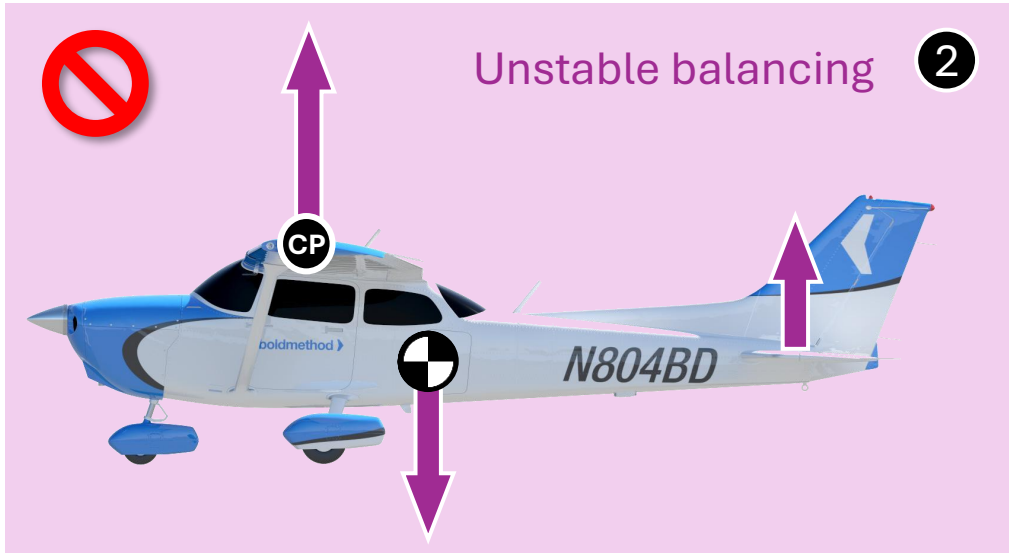
- **Standard Weights (per Gallon):**
  - Gas (6 lbs), Jet Fuel (6.8 lbs), Oil (7.5 lbs), Water (8.35 lbs)

3. Weight & Balance Basics

1. Airplanes are balanced like “seesaws” (compromise)
2. CG aft the Center of Pressure makes it unstable
3. W&B before each flight to ensure CG and Weight within limits







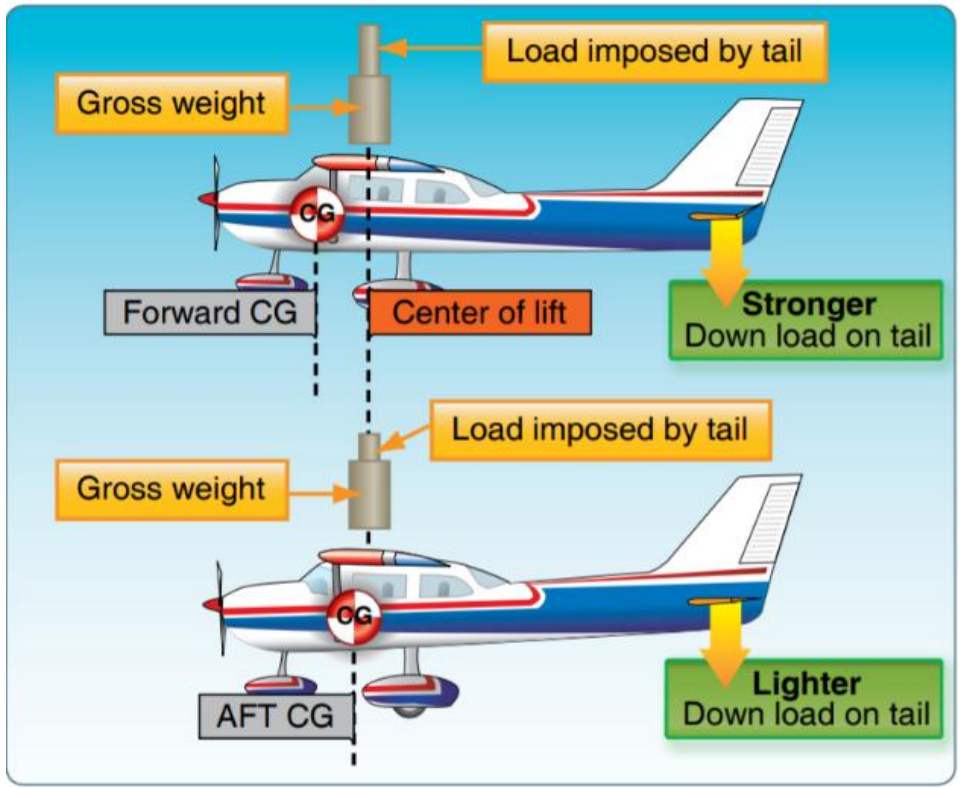
4. Effect of W&B on Performance

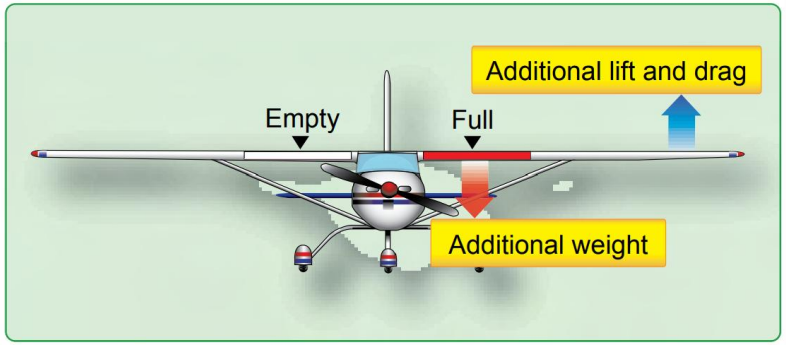
- **Weight (Heavier Aircraft)**
  - More stable (higher inertia)
  - Higher takeoff speed and longer takeoff run
  - Reduce rate and angle of climb
  - Slower cruise speed, lower range, higher fuel consumption
  - Longer landing roll
  - Higher stall speed
  - Excessive load on nose wheel
  - Performance degrades overall

- **Hazards on Overloading**
  - May not climb or lift off
  - May not achieve max altitude
  - Engine wear and Airframe overstress (failure happens over time)

4. Effect of W&B on Performance

- **Forward CG**
  - Needs higher elevator down forces (higher load in the wings)
  - Higher load required higher AoA ➔ more induced drag, slower cruise speed, and a higher stall speed
  - Stall and Spin recovery becomes easier as the CG moves fwd (longer arm from the CG to the elevator and rudder)
  - More stable (nose drop faster), less maneuverable
- **Aft CG**
  - Needs less elevator down forces (lower load in the wings)
  - Lower load required lower AoA ➔ less induced drag, faster cruise speed, and a lower stall speed
  - Stall recovery becomes more difficult as the CG moves aft (shorter arm from the CG to the elevator and rudder)
  - Less stable, more maneuverable
- **Lateral Loading:** increase drag and decrease efficiency

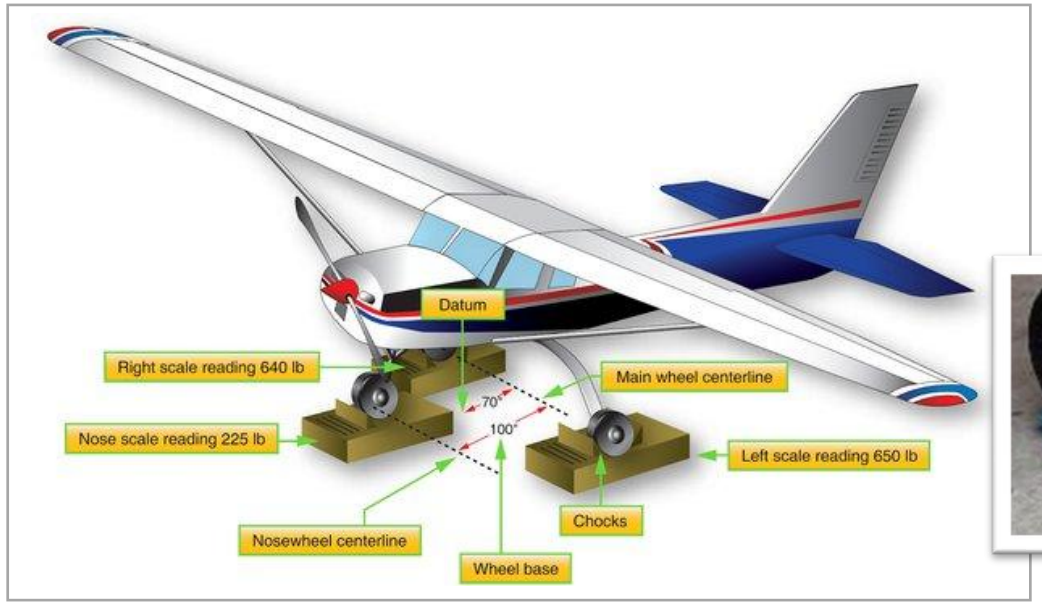


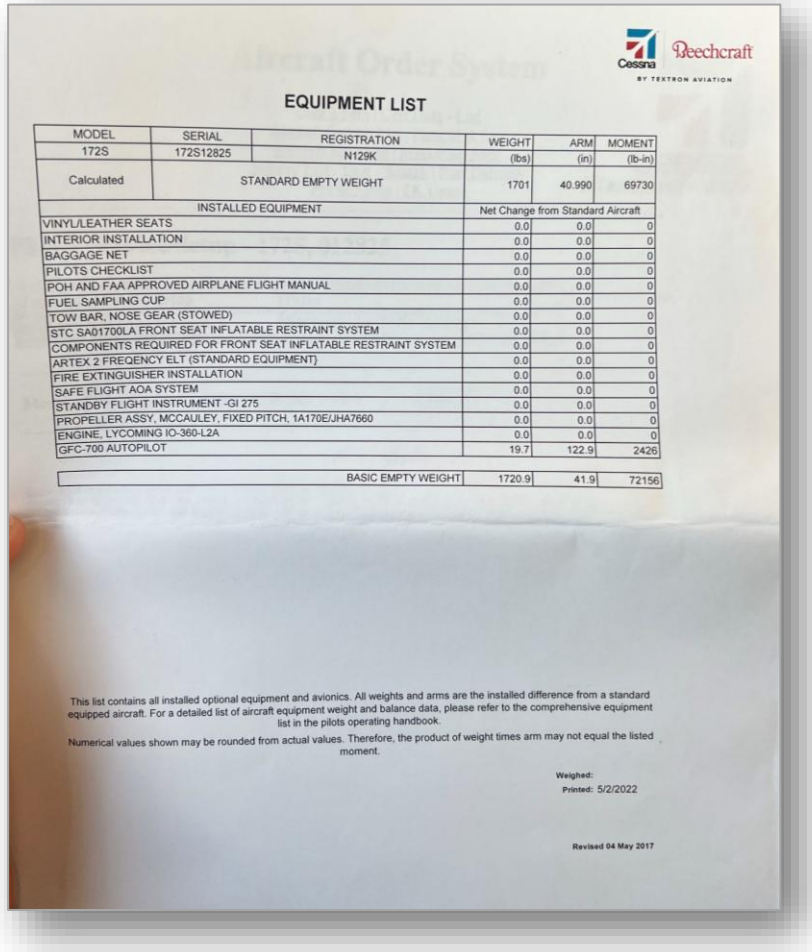


5. Methods of W&B Control

- **W&B Limits**
  - Manufacturer must identify CG Limits by the Airworthiness Certification Standards (14 CFR Part 23.2100)
    - *PIC Required to comply with Operating Limitations (§91.9)*
    - *Prior to every flight, determine and adjust for W&B*
      - *W&B Control ➔ Reduce fuel, move/reduce passengers/cargo*
  - Operator: ensure W&B document is updated after modifications

- **Finding the aircraft <u>Empty Weight</u> and <u>CG</u>**





Cessna Beechcraft BY TEXTRON AVIATION

EQUIPMENT LIST

MODEL	SERIAL	REGISTRATION	WEIGHT	ARM	MOMENT
172S	172S12825	N129K	(lbs)	(in)	(lb-in)
Calculated	STANDARD EMPTY WEIGHT		1701	40.990	69730
INSTALLED EQUIPMENT			Net Change from Standard Aircraft		
VINYL/LEATHER SEATS			0.0	0.0	0
INTERIOR INSTALLATION			0.0	0.0	0
BAGGAGE NET			0.0	0.0	0
PILOTS CHECKLIST			0.0	0.0	0
POH AND FAA APPROVED AIRPLANE FLIGHT MANUAL			0.0	0.0	0
FUEL SAMPLING CUP			0.0	0.0	0
TOW BAR, NOSE GEAR (STOWED)			0.0	0.0	0
STC SA01700LA FRONT SEAT INFLATABLE RESTRAINT SYSTEM			0.0	0.0	0
COMPONENTS REQUIRED FOR FRONT SEAT INFLATABLE RESTRAINT SYSTEM			0.0	0.0	0
ARTEX 2 FREQENCY ELT (STANDARD EQUIPMENT)			0.0	0.0	0
FIRE EXTINGUISHER INSTALLATION			0.0	0.0	0
SAFE FLIGHT AOA SYSTEM			0.0	0.0	0
STANDBY FLIGHT INSTRUMENT -GI 275			0.0	0.0	0
PROPELLER ASSY, MCCAULEY, FIXED PITCH, 1A170E/JHA7660			0.0	0.0	0
ENGINE, LYCOMING IO-360-L2A			0.0	0.0	0
GFC-700 AUTOPILOT			19.7	122.9	2426
BASIC EMPTY WEIGHT			1720.9	41.9	72156

This list contains all installed optional equipment and avionics. All weights and arms are the installed difference from a standard equipped aircraft. For a detailed list of aircraft equipment weight and balance data, please refer to the comprehensive equipment list in the pilots operating handbook.

Numerical values shown may be rounded from actual values. Therefore, the product of weight times arm may not equal the listed moment.

Weighed:
Printed: 5/2/2022

Revised 04 May 2017

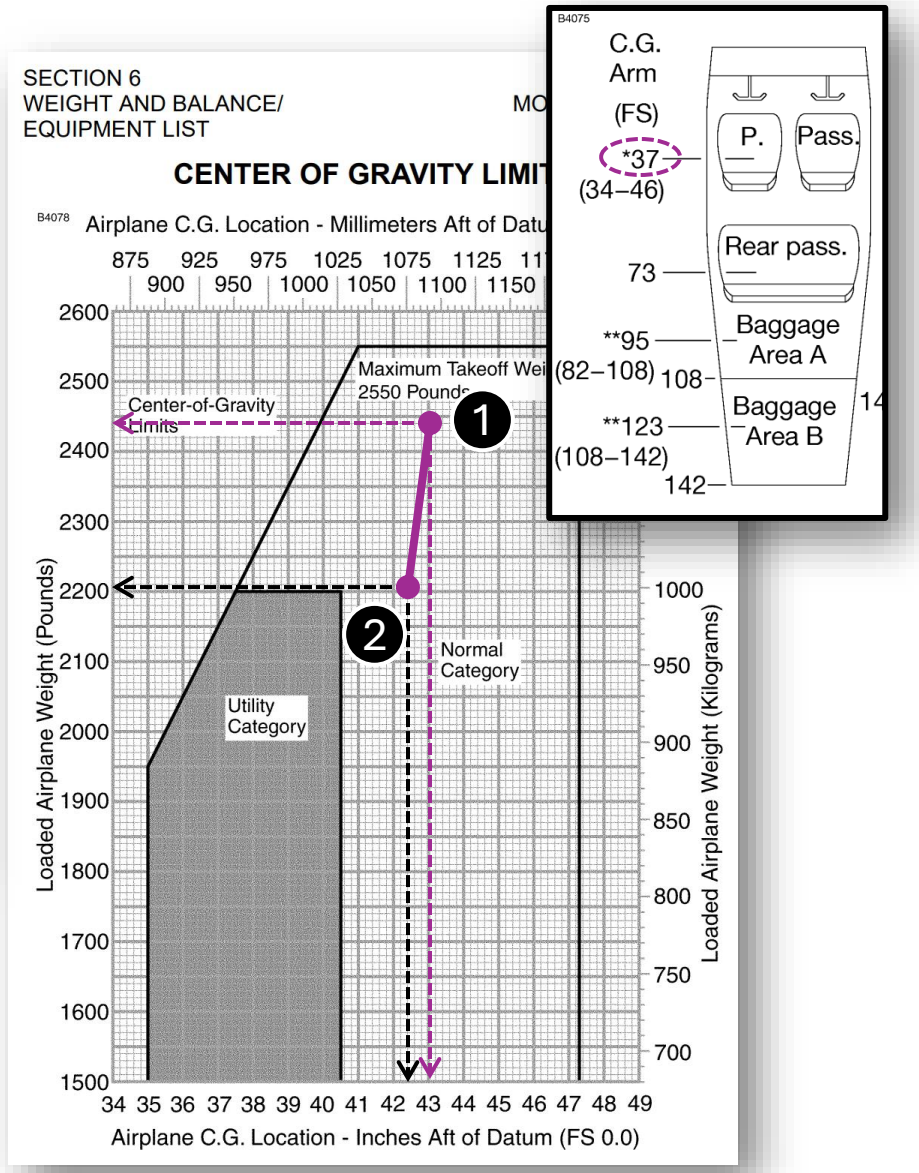
6. Determining Weight & Balance

RAINIER FLIGHT SERVICE

N129K

	Weight	Arm/CG	Moment
Basic Empty Weight	1720.9	41.9	72156
Pilot	160 lb	34 – 46 37	5920
Pax 1	200 lb	34 – 46 37	7400
Pax 2		73	
Pax 3		73	
Fuel (318 lbs max)	53G x 6 = 318 lb	48	15264
Baggage Area 1 (120 lbs max)*	50 lb	95	4750
Baggage Area 2 (50 lbs max)*		123	
Ramp Weight (2558 lbs max)	2448.9 lb	43.1	105439.7
Taxi Burn	-1G x 6 = -6 lb	48	-288
Takeoff Weight (2550 lbs max) ①	2442.9 lb	43.0	105151.7
Enroute Burn	-40G x 6 = -240 lb	48	-11520
Landing Weight (2550 lbs max) ②	2202.9 lb	42.5	93631.7

*120 lbs max combined weight both baggage areas



- **CG = Moment / Weight**
- Pilot must verity MTOW envelope
- Pilot must verify CG envelope

6. Determining Weight & Balance

Changes to W&B:

1. Reduce the Weight and Moment
2. Add new Weight and Moment
3. Recalculate Total Weight and CG

Example:

- Move all baggage from Area 1 to Area 2?

Remove: *-50lb x 95 (Area 1) = -4750*
Add: *+50lb x 123 (Area 2) = +6150*

- *Change in Weight ➔ 0 lbs*
- *Change in Moment ➔ +1400*

$$\Delta \text{ CG} = \frac{\text{Weight shifted} \times \text{Distance weight is shifted}}{\text{Total weight}}$$

RAINIER FLIGHT SERVICE

N129K

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Landing Weight (2550 lbs max)	***2202.9 lb***	***42.5***	***93631.7***

*120 lbs max combined weight both baggage areas

Current Take Off Weight	*2442.9 lb*	*43.0*	*105,151.7*
Adjustments	*+0 lbs*		*+1,400*
New Take Off Weight	***2442.9 lb***	***43.6***	***106,551.7***

Questions?