

# Load Planning

A discussion of fuel cost containment relevant to load planning

When you pack your car for a family vacation, you carefully plan where the luggage will be loaded and where the passengers will sit. Too much weight in the car can cause it to “bottom out” if you hit bumps in the road, causing damage to the car. Too much weight on top will tip the

car when going around curves. Just as planning the location of people and bags is a key safety feature to prevent you from damaging the car and hurting its occupants, the same care must be taken when loading an aircraft. However, a different set of gravitational rules — called aerodynamics — applies to an aircraft during flight.

Just like a car, every aircraft has certain structural weight restrictions, which are determined by the manufacturer. There are fixed limits to the payload (the total weight of passengers, baggage and cargo) an individual aircraft may safely carry. This payload must be distributed so that the aircraft's balance — the position of the aircraft's center of gravity — is maintained within stated limits. The airline is legally bound by these limitations and must not exceed the stipulated restrictions when loading the aircraft, in the interest of not only safety, but also efficiency. Obviously then, proper and accurate load planning is crucial to airlines today.

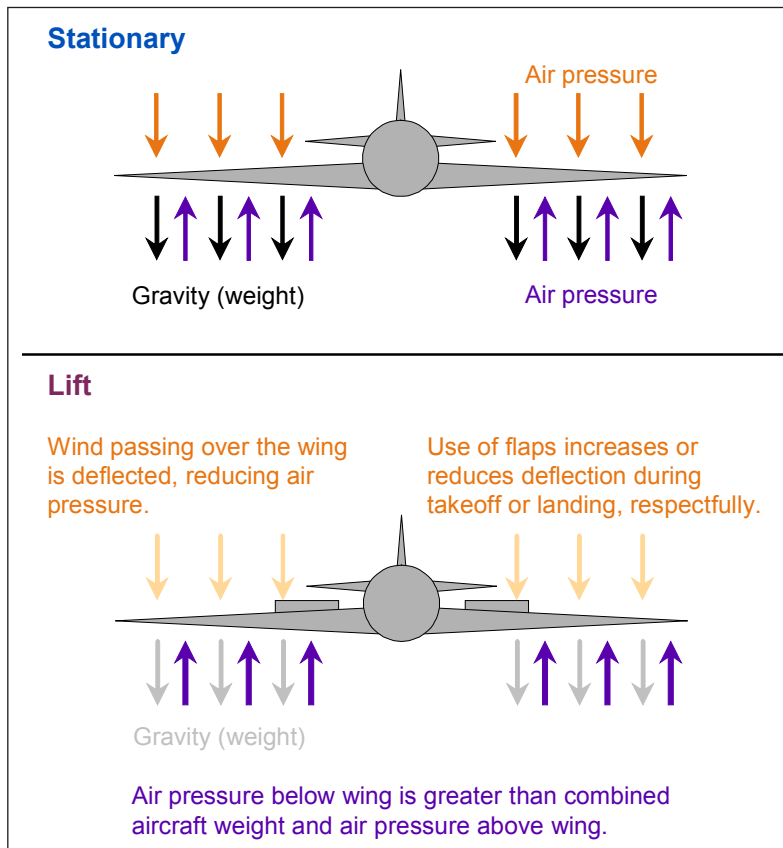
Two industry terms for the safe loading of an aircraft are "weight and balance" and "load

planning." Both refer to the same aspects of aircraft loading issues. Before discussing these terms, let's look at the laws of physics that apply to flight and why proper planning is essential.

## Aerodynamics

What makes an aircraft go up? An aircraft flies through the air by continually pushing and pulling the surrounding air downward. In response to the force of moving the air down, the air pushes the aircraft upward. Newton's third law of motion states that for every action there is an equal and opposite reaction. An aircraft wing is shaped so that the top and bottom surface deflect the air. The wind passing on top of the wing is deflected higher causing reduced pressure. Hence, lift is created when the pressure or force below the wing is greater (Figure 1).

**Figure 1** For every action there is an equal and opposite reaction. As the pressure over the wing decreases, the pressure below it increases — resulting in lift.



the nose of an aircraft is rounded so it can push through the air more easily. The front edge of each wing is rounded also. An aircraft built like a railroad boxcar wouldn't fly well.

Inclining the wing to the wind also produces more deflection and more lift. The wings of an aircraft have adjustable flaps that can be extended or retracted. When extended, the flaps increase the deflection of the air and provide greater lift for takeoff and landing.

During flight, an aircraft is in the center of four forces. As depicted in Figure 2, lift and thrust elevate the aircraft. Gravity and drag try to pull the aircraft down and slow its speed. An aircraft must be built so that lift and thrust are stronger than the pull of gravity and drag by just the right amount. Lift from the wings is used to overcome the force of gravity. Shape is important in overcoming drag. For example,

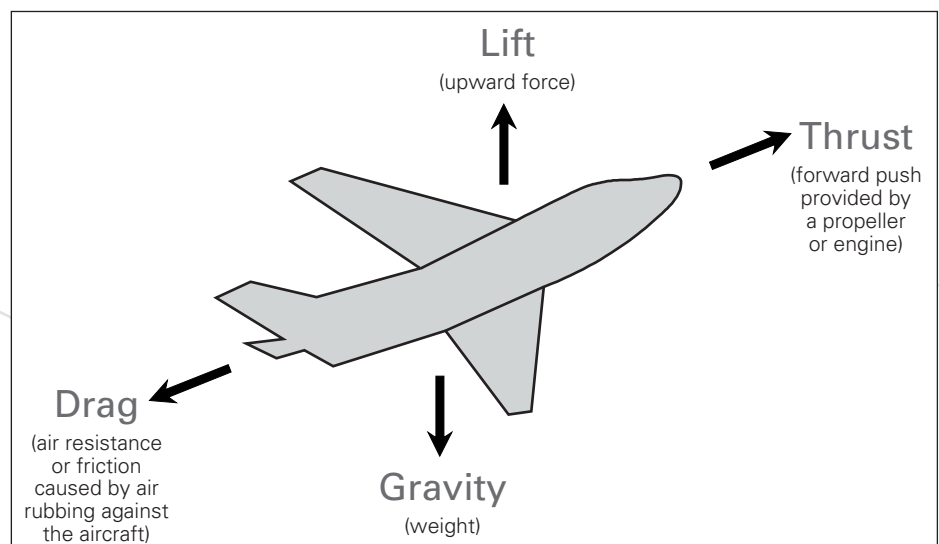
## Aircraft Characteristics

The major components of flight include aircraft balance and aircraft weight. Load planning is required to keep an aircraft within the acceptable limits of the laws of aerodynamics.

### Balance

Balance refers to the location of the center of gravity along the longitudinal axis. An aircraft is a flexible structure, and the fuselage contorts or twists during flight according to the loads it contains. To keep the fuselage from twisting beyond the maximum allowed

Figure 2 Four forces



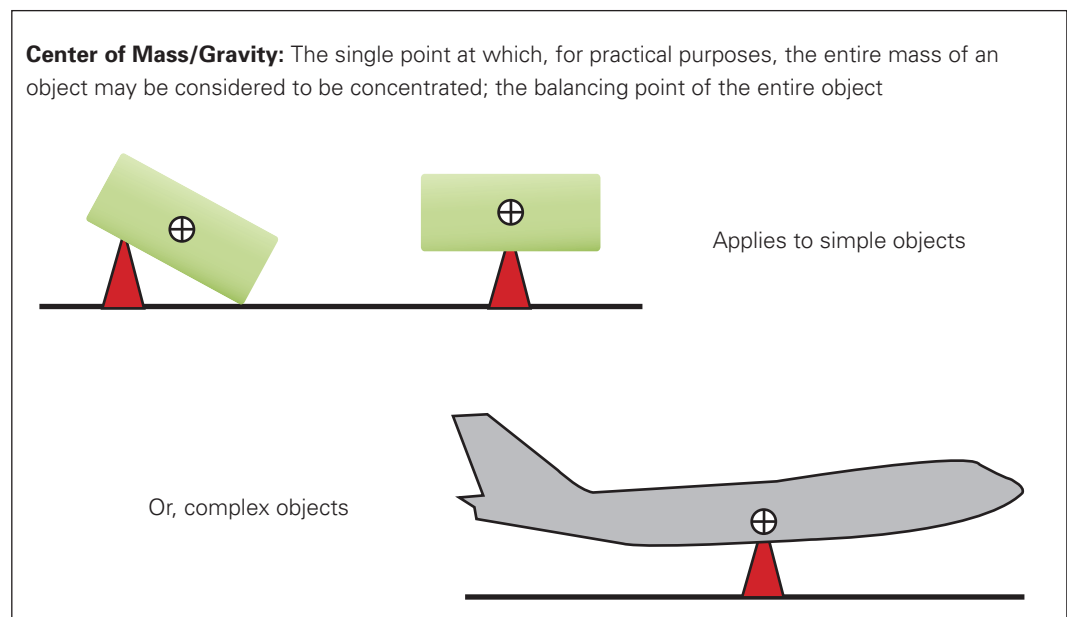
limit (resulting in permanent damage), the manufacturer specifies the maximum acceptable load allowed in each bulk hold section. This limitation prevents the weight of the load from exceeding the capability of the aircraft structure. When loading an aircraft, the center of gravity must be within the permissible range and remain so during the flight to ensure stability and maneuverability during flight.

The aircraft's center of gravity is the precise point on the aircraft where all weight is concentrated or balanced (Figure 3). You can locate the center of gravity of a toy airplane by balancing it on your finger. The center of gravity may be determined after all the weight — including fuel, passengers and cargo — is loaded into the aircraft. The exact location of each item is critical to the performance characteristics and aircraft stability.

The position of the center of gravity within the aircraft will vary according to the seating of passengers and loading of cargo and luggage. The knowledge of the total mass of the loaded aircraft and the center of gravity position — the weight and balance — is crucial.

The position of the center of gravity along its longitudinal axis affects the stability of the aircraft. Aircraft design engineers set acceptable forward and aft center-of-gravity limits. These limits are established to ensure that sufficient elevator deflection — the ability to control the pitch of the aircraft — is available for all phases of flight. If the center of gravity is too far forward, the aircraft will be nose heavy; if too far aft, tail heavy. An aircraft whose center of gravity is too far aft may be dangerously unstable and will possess abnormal stall and spin characteristics. Recovery may be difficult if not impossible because the pilot is running out of elevator control. It is, therefore, the load planning agent's responsibility when planning the loading of an aircraft to see that the center of gravity lies within the recommended limits.

Figure 3



As the flight of the aircraft progresses and fuel is consumed, the weight of the aircraft decreases. Consequently, the distribution of weight also changes, and as a result, so does the center of gravity. The load planning agent must take into account this situation and calculate the weight and balance not only for the beginning of the flight but also for the time in flight and during the landing.

### Weight

For an aircraft to fly, land and takeoff safely, strict control must be applied to the weight of the aircraft, its load and the distribution of the

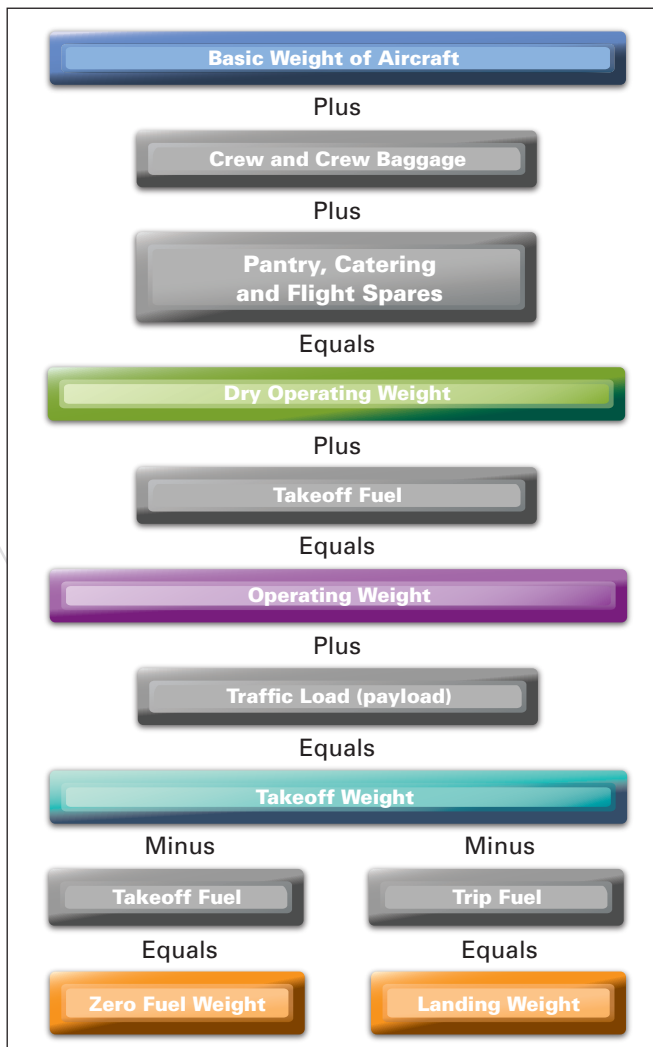
load in the aircraft. The aircraft manuals list separate weight limitations for the baggage and cargo compartments in addition to the gross weight limitation of the whole aircraft. The load planning agent must pay close attention to these limits, for overloading the cargo compartment (even if the aircraft itself is not overloaded) may move the center of gravity too far aft and affect longitudinal control.

Just as your car has a maximum amount of weight it can carry, so does an aircraft. Each aircraft has a maximum structural weight that cannot be exceeded, whether the aircraft is parked, taxiing, landing or taking off. This maximum applies whether the aircraft is under its own engine power or is being pushed or towed by a tractor. Each aircraft is designed with a maximum structural weight for takeoff, enroute flight and landing. All of this serves to ensure the aircraft operates within the limits set by the manufacture to prevent damage.

Bear in mind that these limits relate to the structural strength of a new aircraft — and structures lose strength as they age. An important reason to comply with the load plan and the aircraft weight limits. Additionally, as aircraft age, they also suffer from service weight pickup (Figure 4); they tend to put on weight through modifications, additional instruments, a larger fuel tank and accumulation of paint and dirt — all of which reduce payload capability.

Now that we have a fundamental understanding of the basic laws of physics that apply to flight, let's focus on the principles and benefits resulting from effective load planning.

Figure 4 Illustration of the build-up of weight associated with the operations of an aircraft.



## Load Planning

It is the job of the load planner to ensure that the aircraft is within load limits. A load planner's responsibility includes coordination with the flight crew, dispatchers, fuelers, cargo agents, check-in agents and ramp personnel to arrive at the most effective and safest aircraft load plan. Load planning is the detailed process of gathering data on items to be loaded on the aircraft and calculating the load plan based on the aircraft's basic operating empty weight or

dry operating weight, meaning without fuel. Included in the items to be loaded are the booked passengers, estimated bags, mail and cargo for a particular flight leg, resulting in an estimated zero fuel weight.

A pilot must know the maximum structural and actual gross weight of the aircraft and how it affects the scheduled flight. The center of gravity must be within specified limits. Figure 5 shows an example of a loadsheets produced from the load calculations that can be provided to the pilot. The sheet includes relative information identifying the fuel loads, passengers, cargo and center of gravity calculations.

## Fuel Savings

The primary importance of exact load planning for an airline is legality and safety. However, efficiency of loading and unloading the aircraft are also very important to an airline's ground operations. With today's price of aviation fuel, the savings that can be provided through proper load planning and adherence to this load plan is extremely important to an airline's operational costs.

Successful airlines carefully calculate passenger, cargo and fuel weights to provide the most effective load plans which can reduce fuel burn enroute. These airlines try to create the optimal aircraft center-of-gravity balance to meet these goals as well as save fuel. The automated load planning system improves weight calculations by automatically allocating weight according to passenger type: adult (male or female), child and infant. The user can define special weight parameters for winter and summer as well as special weights

Figure 5 Sample loadsheet

<b>SABRE AIRLINE SOLUTIONS</b>			
LOADSHEET	CHECKED	APPROVED	EDNO
ALL WEIGHTS IN KILOGRAMS	D JIMENEZ		1
FROM/TO FLIGHT A/C REG VERSION CREW DATE TIME			
DFW MIA	U0300/22	5BDAQ 28C213Y	2/10 22FEB07 1031
WEIGHT DISTRIBUTION			
LOAD IN COMPARTMENTS	3300	1/0 2/0 4/3025	5/275
PASSENGER/CABIN BAG	9169	78/37/13/1	TTL 129 CAB 0
	CY 6/122	SOC 0/0	
TOTAL TRAFFIC LOAD 12469			
DRY OPERATING WEIGHT 78815			
ZERO FUEL WEIGHT ACTUAL 91284 MAX 111500 L			
TAKE OFF FUEL 9750			
TAKE OFF WEIGHT ACTUAL 101034 MAX 138600			
TRIP FUEL 7750			
LANDING WEIGHT ACTUAL 93284 MAX 121500			
TAXI OUT FUEL 250			
LAST MINUTE CHANGES			
BALANCE AND SEATING CONDITIONS DESTS PEC CL/CPT +- WEIGHT			
BI	-0.1	DOI	-1.5
DLI	1.8	MACDLW	134.5
LIZFW	1.4	MACZFW	28.1
LITOW	2.5	MACTOW	30.1
LILAW	2.0	MACLAW	29.3
AND	0.2		
CABIN CLASS TRIM			
C	6	-0.5	Y 1221.5
UNDERLOAD BEFORE LMC 20216 LMC TOTAL +-			
CAPTAIN:			
CAPTAINS INFORMATION/NOTES			
BW	76972	BI	-0.1
MATW 139500 RAMP TAXI WEIGHT ACTUAL 101284			
CG LIMITS LIZFW FWD -3.1 AFT 3.7			
	LITOW	FWD	-3.4 AFT 4.1
	LILAW	FWD	-4.1 AFT 4.5
B/	800	C/	2000 M/
			200
PANTRY CODE A /962			

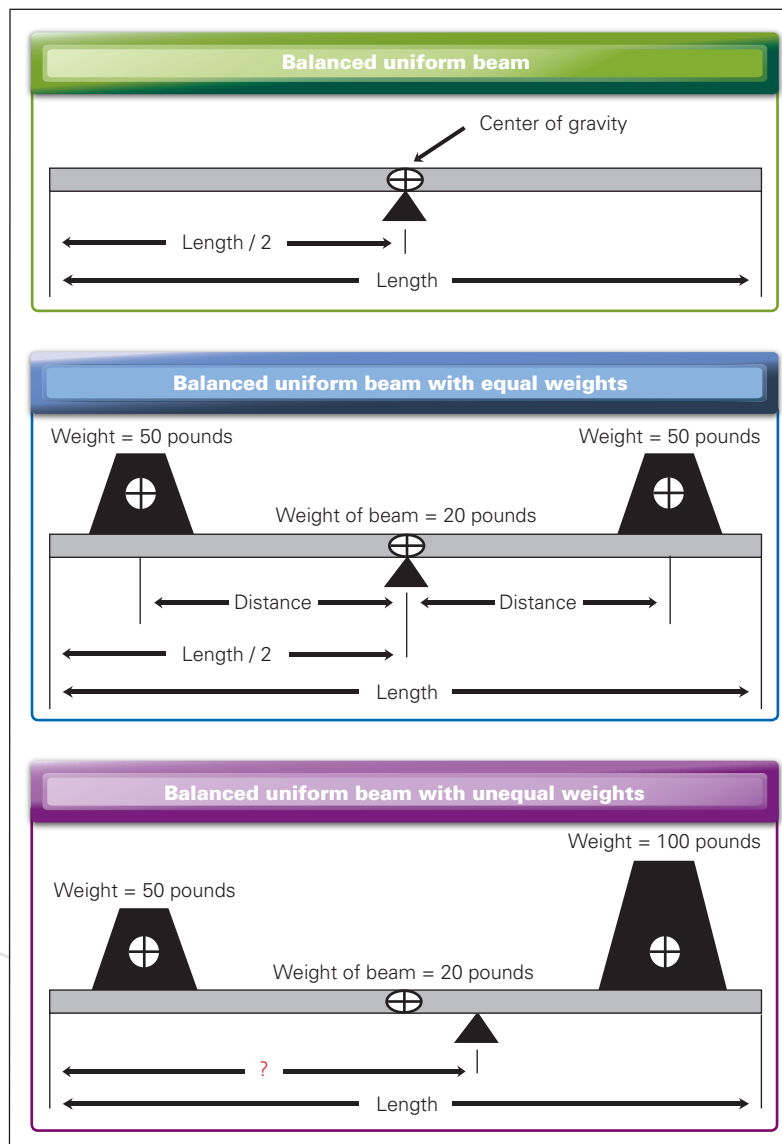
for heavier passengers (football teams). Any unused weight allowance can be reallocated for additional cargo or revenue passengers.

An automated load planning system calculates the ideal trim — the optimum balance of lift and drag produced by the wings and control surfaces over a wide range of load and airspeed. This process reduces the effort required to adjust and maintain a desired flight attitude. The system then issues loading instructions to achieve the optimum center of gravity. The optimized center of gravity produces the ideal trim during the final stages

of load planning and accounts for any in-flight center-of-gravity changes caused by the reduction or burning of fuel. By using the ideal-trim tools and loading aircraft to the optimized center of gravity, airlines can potentially reduce their fuel costs by .03 percent to .05 percent.

From a fuel burn perspective the further aft the center of gravity is positioned, the lower the fuel burn will be. From a fuel savings point of view, the further-aft center of gravity is the optimum. This is offset with the efficiency of loading and unloading the aircraft to expedite ground time for departures and the baggage delivery time for passengers on arrivals. Baggage may have to be dispersed front and rear to make these ground goals. Otherwise, the aft center of gravity is the best load plan (Figure 6).

Figure 6 Text



## Conclusion

Similar to planning where luggage will be loaded when you pack your car for a family vacation, extreme care must be taken when loading an aircraft. The laws of physics and aerodynamics still apply to an aircraft during flight just as they did in the days of the Wright brothers.

However, the impact of other components of flying — size, weight, distance flown and speed — have increased by tremendous proportions, and the price of fuel has grown in even greater proportions. As a result, airlines are searching for all ways possible to reduce these costs.

Adherence to proper load planning techniques and actual loading of the aircraft according to these plans has proven to reduce fuel burn by enabling the aircraft to operate at the optimum flight attitude — reducing drag and improving lift. Today, generating the most efficient load plans is made possible through automated load planning applications.

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