How do pilots deal with an engine failure on takeoff?

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News

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Aug 8, 2020

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An engine failure on takeoff is one of the most challenging situations a pilot can face. The sudden asymmetry of thrust can cause the nose to lurch to one side, requiring immediate and instinctive reactions. If the engine has caught fire, alarm bells will be ringing (physically and metaphorically) and lights will be flashing. It's the pilot's job to block all these out and focus on the task at hand.

However alarming this may seem, this situation will not be alien to the pilot. The likelihood is that they have never experienced this for real before, but they will have seen it scores of times in the simulator. Every six months, pilots are put through their paces to ensure that they are up to speed with emergency procedures. The time in the simulator also to gives them the chance to practice these scenarios should they ever happen for real.

De-rated takeoff

Contrary to popular belief, aircraft very rarely use full power during takeoff. Runways at most international airports such as London Heathrow and Los Angeles are nearly 2.5 miles long, which is more than enough for even the heaviest of aircraft to get airborne.

So why increase the strain on the engines when you can utilise the runway length by accelerating more slowly and still getting safely airborne by the end?

Manufacturers design the aircraft and engines to be able to get airborne using as little engine power as possible. This is known as a de-rated takeoff. Not only does save on engine wear, but it also reduces the noise experienced by those who live and work near the airport.

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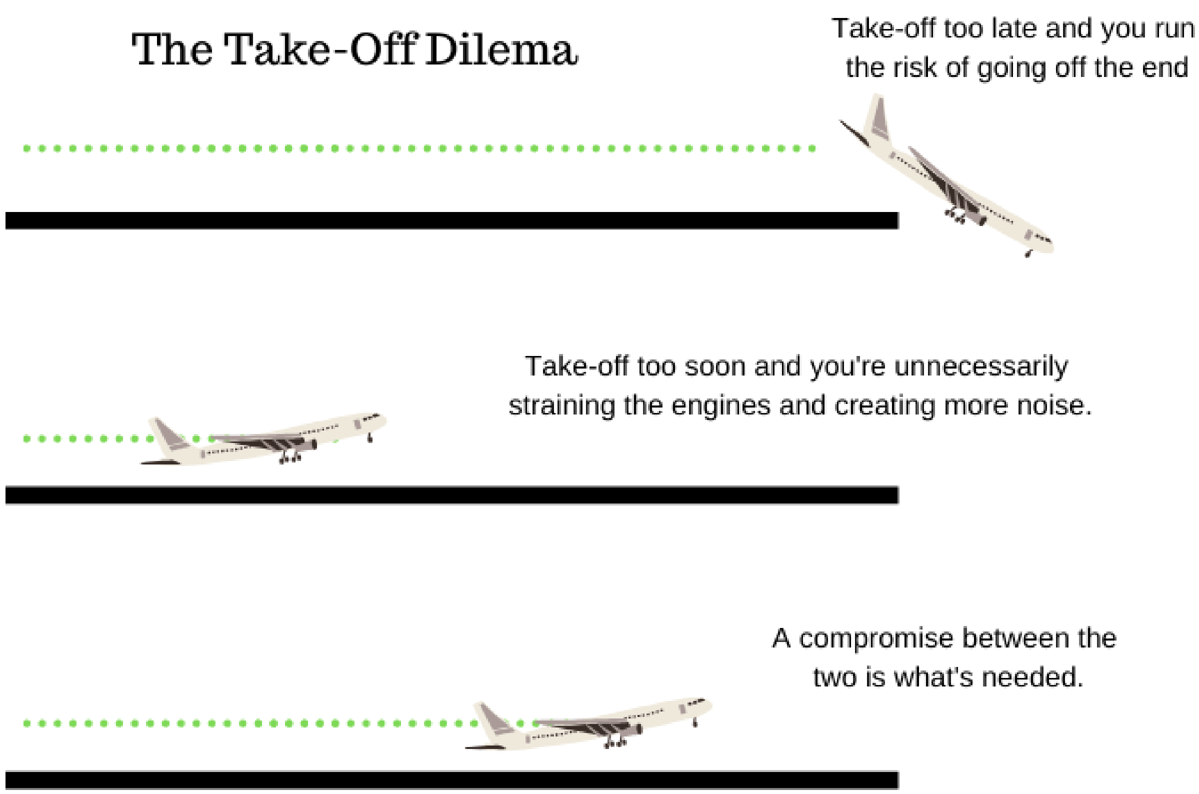

(Image by Charlie Page/The Points Guy)

However, this creates a trade-off. Take off too far down the runway and you run the risk of going off the end should something unexpected happen. Take off too soon and you're using more engine power than you need to, increasing engine wear and fuel burn.

A happy medium needs to be found between the two — a takeoff point which optimises engine power whilst leaving enough runway to stop if the need arises.

On a twin-engine aircraft such as the 787 Dreamliner, the loss of power from one engine during the takeoff run is one of the more serious events that could happen. Although this is highly unlikely, we always plan for the worst possible scenario.

Should an engine fail just as the aircraft lifts off, the performance must still ensure that it reaches a height of 35 feet by the end of the runway on the power of the remaining engine. This is the key part of the takeoff performance.

Even though an aircraft can safely climb away from the runway on just one engine, should the failure happen whilst still on the ground, it would be preferable for the pilots to reject the takeoff and stop on the runway. However, there comes a point where there will not be enough runway remaining in which to stop safely. So how do we know where this point is?

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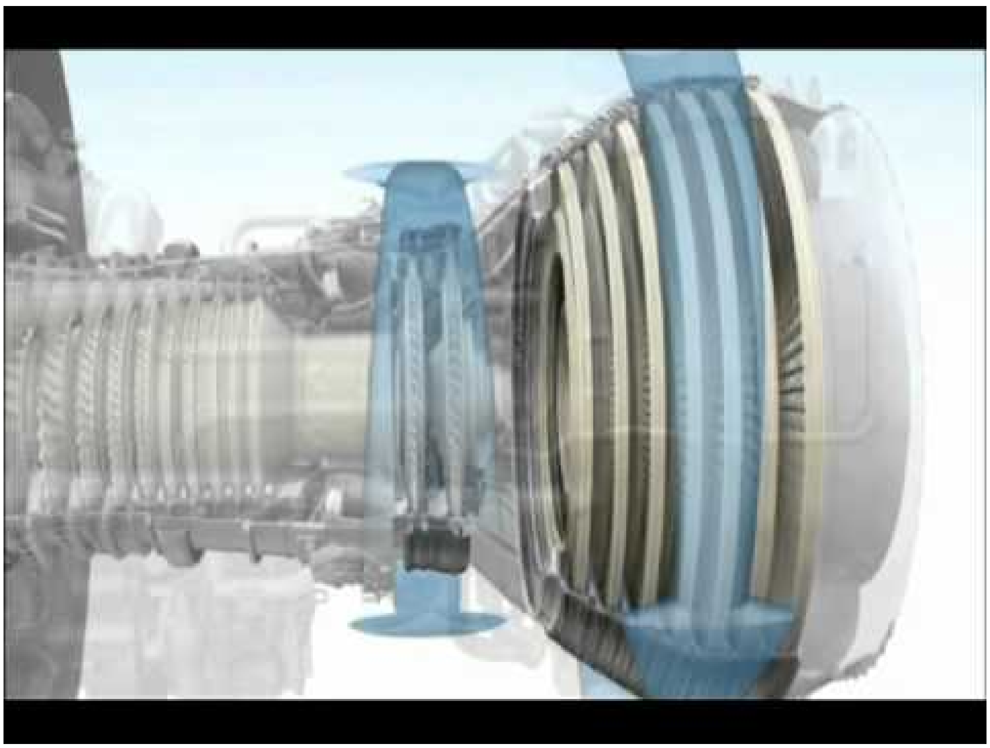

Watch Video At: https://youtu.be/S1ahHWXGx5Y

Before every takeoff, the pilots must calculate the speeds, flap setting and engine power required to take off safely. This includes the engine failure scenario.

One of the speeds that are calculated is called V1 — "the maximum speed in the takeoff at which the pilot must take the first action to stop the aeroplane within the accelerate-stop distance".

If an event occurs before the aircraft reaches the V1 speed, the pilots know that they are able to stop safely. Any events occurring after V1, the pilots must continue to get airborne. The decision to stop or go isn't made in the heat of the moment — it's a binary decision calculated at a time of low workload.

The critical speeds: V1, Vr and V2

In order to understand how we control an engine failure on takeoff, it's important to understand some key speeds. The values of V1, Vr and V2 are all calculated before each departure and determine how we fly the takeoff, either with both engines running normally or with an engine failure.

V1

V1 is the speed at which the aircraft can both reject the takeoff, stoping safely on the runway and also at which it can continue to take off safely. To put this into more practical terms, the European Aviation Safety Agency (EASA) and the Federal Aviation Administration (FAA) defines V1 as "the maximum speed during takeoff at which the pilot must take the first action to stop the aircraft".

It is often referred to as the "takeoff decision speed" but this isn't totally accurate. The actual decision to reject the takeoff must be made before V1 has been reached. This gives the pilot enough time to react and make the first action to reject the takeoff before the aircraft reaches the V1 speed.

If the decision to stop is made *at* V1, by the time the first action is taken to stop, the aircraft will be travelling in excess of the V1 speed, putting it at risk of going off the end of the runway. Seeing as some runways finish in the sea or with steep embankments, this is undesirable, to say the least.

Flying above V2 is paramount when taking off. (Photo by YOSHIKAZU TSUNO/AFP/Getty Images)

The V1 for any departure will depend on a range of variables such as aircraft weight, runway length, air pressure, air temperature and wind speed and direction. It also varies with the runway condition. If a runway is dry, the stopping efficiency is much better than if the runway is wet or slippery. As a result, the V1 will be slower on a wet runway. This means there will be more runway remaining on which to stop when the V1 speed is reached.

If a problem occurs after V1, we must continue to get airborne. Even in the event of an engine failure, we can still climb away safely. The performance which we calculate before departure is based on this very event.

Vr

Vr is the speed at which we gently ease back on the control column and rotate the nose into the air. However, it is still not quite fast enough to fly. In the few seconds it takes to rotate the nose up towards the initial climb angle, the continued acceleration will take the speed to V2.

V2

V2 is known as the takeoff safety speed, the speed at which the aircraft will climb safely in the event of an engine failure. As we'll see later, flying at, or above, V2 is critical when flying the engine failure manoeuvre.

Following the definitions above, it is clear that V1 and Vr must always be less than V2. However, V1 can be less than or the same as Vr.

Engine failure on lift-off

The most challenging time for an engine to fail is between V1 and V2. In this window, we are going too fast to abort the takeoff but too slow to fly safely. In some situations, like with a wet or slippery runway, the gap between V1 and Vr may be quite considerable. At high weights on a 787 Dreamliner, it could be around 30 mph.

This means that even if we know that an engine has failed or caught fire, we must ignore all the alarms going off and continue to Vr before taking the aircraft into the air.

There are a variety of reasons why an engine might fail so instead of immediately trying to identify the cause, we simply identify the fact that is has happened. Depending on the severity of the failure, this could be blindingly obvious or so subtle we barely notice.

The video below is a textbook example of how pilots deal with engine failure. After hitting a bird as they rotated, the engine began to surge. This would have been quite alarming for all those on board, with each bang no doubt accompanied by severe airframe vibration.

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Watch Video At: https://youtu.be/9KhZwsYtNDE

Keep it straight

In the case of a severe and sudden failure, there could be a loud bang with the aircraft's nose swinging in one direction or another. When there is a near-instantaneous loss of power on one side of the aircraft, the power from the remaining side causes the aircraft to swing in the opposite direction.

Our first action in this situation is to keep the nose straight by applying the correct rudder input with our feet. We are aiming to keep the aircraft straight and fly it through imaginary goalposts at the end of the runway.

If the nose swings left, we instinctively push our right foot forward, applying right-rudder, to regain the runway centre line. Conversely, if the nose swings right, we apply left rudder. Depending on the severity of the failure, we may have to apply full rudder or only a small amount — whatever it takes to keep the nose tracking straight. We then keep this rudder input until we are airborne.

The video below shows how the asymmetric thrust will cause the nose to swing to one side and how the rudder input by the pilot flying keeps the aircraft straight.

Watch Video At: https://youtu.be/PS1YAX70edc

This is a basic flying skill, taught to cadet pilots during flight school on twin-engine propellor aircraft. Not only does it control the aircraft, but it also gives us a clue as to which engine has failed.

For those of you who have flown twin-engine prop aircraft, the phrase "right leg dead, right engine dead" will be well known. This means that the leg which is not doing anything (dead) is the same as the engine that has failed.

Rotate

With the nose tracking down the runway, we must wait until the aircraft speed reaches Vr. This could be immediate or it could be several seconds later. When the aircraft reaches Vr, the pilot flying the aircraft (PF) pulls back on the control column. The aim is to attain V2 by the time we are 35 feet above the ground.

However, with an engine failure, there is a difference to a normal takeoff.

The rotation of an airliner is normally around 2 to 3 degrees a second, reaching the 15 degrees nose-up altitudes in around five seconds. In the engine failure case, because of the reduced power, the aircraft will accelerate at a slower rate. If we rotate at the normal rate, there's a good chance that we will get airborne before reaching V2 — a dangerous situation to be in.

If this were to happen, the only way to gain those extra few knots of airspeed is by pushing the nose down and reducing the rate of climb. Not something you want to be doing when you're practically skimming treetops. As a result, it's imperative that we rotate at a slower rate, around 1.5 to 2.5 degrees a second, giving the aircraft time to accelerate to V2. This results in a nose-up angle of around 12 to 13 degrees.

TO/GA reference line

On the 787, the HUD (head-up display) plays a major part in enabling us to fly this critical manoeuvre accurately. As part of the display, a line called the TOGA reference line helps us fly the correct pitch (nose-up angle) on takeoff.

With TO/GA (takeoff/go-around) mode selected, the TO/GA reference line gives us a target to aim for which will achieve the optimum climb away from the runway.

In the case of an engine failure, flying this line accurately is key. As we rotate the aircraft at a slower rate, we aim to pitch the nose towards, but not above, the TO/GA reference line. If we pitch too high and point the nose above the line, the speed will reduce, possibly below V2.

If the speed starts to decay, the TO/GA reference line will drop, telling us to reduce the pitch of the nose.

The climb out

With the rudder keeping us straight and the pitch angle flown accurately keeping the speed above V2, the aircraft will fly away from the ground, albeit at a very slow rate. With this climb established, the landing gear is raised, reducing drag and improving climb performance. It may take around 30 seconds or so to reach 200 feet, at which point the autopilot can be engaged.

By making maximum use of the automatics, it enables us to sit back and assess what has happened. Both pilots are then able to take a good look at the engine indications to start diagnosing which engine has failed. It may not be immediately obvious so careful analysis of the available data is critical in ensuring that we don't shut down the wrong engine.

As the aircraft reaches 400 feet, if there has been severe damage or there is an engine fire, we can start to carry out the first of the checklists. As the PF continues to monitor the flight path of the aircraft like a hawk, the pilot monitoring (PM) shuts the engine down.

On the 787 this involves moving four switches or levers, all of which must be confirmed by the PF to ensure that we shut down the correct engine.

With the engine secured, we can then focus on continuing the climb and retracting the flaps before deciding our next course of action.

Bottom line

Whilst one of the more serious failures that could happen to an aircraft, an engine failure on takeoff is the one event which is practised most by pilots. As a result, should this once in a lifetime event occur, the pilots will be well versed in what to do.

The key to a successful takeoff with engine failure is a slow rotation. After this, with the speed above V2, the aircraft will climb away from the ground. With the flight path of the aircraft secure, only then will the crew start to look at the engine problem and begin the process of shutting it down.

Featured photo by aviation-images.com/Universal Images Group via Getty Images.

Charlie Page Charlie Page is an airline pilot flying the Boeing 787 Dreamliner. Each Saturday he gives you a 'behind the cockpit door' insight to life in the flight deck.