



"No two flights are ever the same..."

The Spitfire MKI/II Accu-Sim Expansion Pack

About This Manual

While much of the information in this manual is basic to many of our readers, we assume that the reader has no knowledge of combustion engine theory. This manual is for *everyone*, and uses colorful illustrations to teach the basics. The Accu-Sim system, however, is not basic, but is programmed with advanced physics which the professional pilot will appreciate. If you are an advanced pilot, you can likely just briefly skim over the contents of this manual; however, if you are eager to learn a bit about how a great big radial engine works, welcome and read on.



Table of Contents

Chapter 1: Welcome.....	1
Installation.....	1
Refer to Your A2A Simulations Spitfire Pilot's Manual.....	1
Designer's Notes.....	2
The A2A Simulations Spitfire Accu-Sim Expansion Pack Features	3
Chapter 2: Accu-Sim and the Combustion Engine.....	5
The Combustion Engine.....	5
Overview of How the Engine Works and Creates Power.....	5
Air Temperature.....	8
Mixture.....	9
The Mixture Lever.....	10
Induction.....	11
Manifold Pressure = Air Pressure.....	12
Supercharging.....	13
Supercharging Heats The Air.....	15
Ignition.....	16
Engine Temperature.....	17
CHT (Cylinder Head Temperature)	18
Lubrication System (Oil).....	19
More Cylinders, More Power.....	20
The Pratt & Whitney R4360.....	21
Torque vs Horsepower.....	22
Chapter 3: Accu-Sim and the Supermarine Spitfire.....	23
Accu-Sim Expansion Pack.....	24
What is the philosophy behind Accu-Sim?.....	24
Actions Lead to Consequences.....	24
Your Aircraft Talks.....	25
Be Prepared – Stay Out of Trouble.....	25
Key Things to Keep Engine Temperatures in Check.....	26
Engine Priming.....	26
Engine Starters	27
Manifold Pressure.....	28
Oil Pressure.....	29

Pneumatic System.....	29
Landing Gear.....	31
Flaps.....	31
Oxygen and Hypoxia.....	32
Auto Mixture.....	33
Coolant and Oil Temperature.....	34
Persistent Aircraft.....	35
Electrical System and Battery.....	35
Sounds Generated by Physics.....	37
Gauge Physics	37
Propellers.....	38
The Airfoil: How a wing creates lift.....	39
Lift vs Angle of Attack.....	42
Propeller Efficiency.....	43
The Fixed Pitch Propeller	44
The Variable Speed Propeller	45
From Stall to Full Power	47
Prop Overspeed.....	48
Types You Can Fly.....	49
Takeoff and Acceleration.....	49
Air, Humidity, Visibility.....	51
Landings.....	52
Your Turn To Fly.....	53
Enjoy.....	54
Presenting the A2A “Accu-Sim” Supermarine Spitfire MK Ia and IIa and b For FSX.....	55
An Imperfect Work of Inspired Aeronautical Art and Science.....	57
Negative “G” Means No Power.....	60
Stay Cool, Man.....	62
Draggy Radiators.....	63
You Can't Get There From Here.....	65
“The Faceless Few”.....	66
“One Hit in The Wrong Place and You're a Goner!”.....	68
A Delight in the Air, a Dog on the Ground.....	69
Wing Too Long – Roll Too Slow.....	70

Chapter 1: Welcome

Installation

Once your A2A Simulations Spitfire is installed, run the Spitfire Accu-Sim expansion pack installer and follow the on screen prompts. The installer should find both Flight Simulator X and the A2A Simulations Spitfire automatically. If not, it will ask you to BROWSE for the correct location. Keep in mind, if Microsoft Flight Simulator X is properly installed, the Accu-Sim installation should be simple and straight forward.

Refer to Your A2A Simulations Spitfire Pilot's Manual

Included with your A2A Simulations Spitfire is a detailed pilot's manual that covers most of what you need to know to operate the Spitfire MkI and MkII with the Merlin III and XII engines.

The Accu-Sim upgrade is built into this product from the ground up, so refer to your pilot's manual for specific systems operation and limitations.



Designer's Notes

I'd like to introduce you to our latest creation, the Supermarine Spitfire, with the Rolls Royce Merlin, liquid-cooled 1,300 horsepower V-12 engine. This entire aircraft was born as a racer, yet it's participation in World War II was the first critical step towards the ultimate allied victory. Whether your passion is Warbirds, general aviation, or airliners, the Spitfire's beauty is timeless. This airframe could have been conceived and created today along with every other modern aircraft, and it would still be the most beautiful airframe seen at any modern-day airport. This is the mark of a true thoroughbred.

The Spitfire is lightweight and powerful, yet graceful. It's a very forgiving airplane. Perhaps it's best virtue is that it has no vices (except perhaps for a narrow landing gear). At A2A, we take the first truth of any aviator, it's all about celebrating the passion we all feel for these beautiful flying machines. It's truly a wonder, how a metal machine can defy it's traditional physics, and take to the air.

From the moment you sit in this Accu-Sim Spitfire, we try to make this aircraft speak to you and say "I am actually here." From the click of a switch to the kick of the starter to the shudder of the airframe, hopefully you can both see and hear that this plane is made of metal, bolts, rubber, and oil.

Have you ever driven a car, and pushed down hard on the accelerator? Do you notice the feel of that engine when it is working (as opposed to it when it is running under a light load)? It growls, vibrates, and most importantly, lets you know how it is feeling. You know when it is happy, when it is under a heavy strain, or even when something inside may not be working right. The combustion engine is truly part of our every day lives. We use these engines every day in our automobiles, motorcycles, and lawn mowers and through this daily contact, we have developed an intuitiveness about them. You use this intuition in an airplane, and your learned knowledge of the systems to determine how things are. However, if something isn't right, you, the pilot, must know how things mechanically are working under the hood. It is this knowledge that allows the pilot in command to make the best decision under every possible situation that is thrown your way.

Experience what it is like to own and operate not just an exciting aircraft, but a highly desired Merlin-powered, Supermarine Spitfire. We put you in the cockpit of some of the worlds most exciting aircraft.

Welcome to the world of Accu-Sim.

Scott Gentile
Accu-Sim Project Manager



The A2A Simulations Spitfire Accu-Sim Expansion Pack Features



- Introducing a **true propeller simulation**
- **Feel the exhilaration** of flying an Accu-Sim-powered Supermarine Spitfire.
- **Rolls Royce Merlin V-12** liquid cooled Mk III and higher output Mk XII engine built to manufacturer's specifications.
- Install a Weybridge two-bladed fixed-pitch wooden, De Havilland three-bladed two-speed variable, or Rotol constant speed propeller in the maintenance hangar.
- Both electric and **explosive cartridge starters** modeled.
- Immersive in-cockpit, physics-driven sound environment from A2A engineered Spitfire recordings.
- **Complete maintenance hangar** including landing gear, internal systems and detailed engine tests including compression checks.
- Understand how a high-performance aircraft behaves and see how well you can cope with all of the unexpected things that can happen. **No two flights are ever the same.**
- **Piston combustion engine modeling.** Air comes in, it mixes with fuel and ignites, parts move, heat up, and all work in harmony to produce the wonderful sound of a V-12, liquid-cooled racing engine. Now the gauges look beneath the skin of your aircraft and show you what Accu-Sim is all about.
- Airflow, density and it's temperature not only affect the way your aircraft flies, but how the internal systems operate.
- Real-world conditions affect system conditions, including engine temperatures. **Manage temperatures with a radiator flap and proper flying techniques.**
- Spark plugs can clog and eventually foul if the engine is allowed to idle too low for too long. Throttling up an engine with oil-soaked spark plugs can help clear them out and smoke.

- Overheating can cause scoring of cylinder head walls which could ultimately lead to failure if warnings are ignored and overly abused.
- The Spitfire has a small radiator and must get airborne in under ten minutes or it will overheat. Once airborne, it owns the sky.
- **Engine, airframe, cockpit panel and individual gauges tremble** from the power of a high-performance combustion engine.
- Authentic component drag. Dropping your gear will pull your aircraft realistically as the landing gear is deployed along with cooling flaps, or even opening the canopy. Drop your gear, deploy your flaps, or just try a dive, and **listen to your airframe**.
- System failures, including flaps that can independently break based on the actual forces put upon them. If you deploy your flaps at too high a speed, you could find yourself in a very dangerous situation.
- **Total audible cockpit** made with recordings from the actual aircraft. Before you fly, enjoy clicking everything.
- Primer system modeled. Accu-Sim monitors the amount of fuel injected and it's effectiveness to start the engine. **Cold mornings require as many as 12 strokes** and warm starts may only need a single shot.
- **Authentic battery**. The battery capacity is based on temperature. The major draw comes from engine starting.
- Oil pressure system is affected by oil viscosity (oil thickness). Oil viscosity is affected by oil temp and oil dilution level. Now when you start the engine, you need to be careful and not raise RPM too much until oil temp is high enough to give proper oil pressure. If you raise RPM too high on a cold engine, especially very cold, oil pressure can raise to over 150 psi. Oil pump failure can result. Extended inverted flight (negative g) can uncover the oil sump and reduce oil pressure. Do not fly in a negative g situation for more than 5 seconds.
- **Oxygen starvation (hypoxia) is modeled**. Just take off and climb without oxygen to see.

Chapter 2: Accu-Sim and the Combustion Engine

The Combustion Engine

The combustion engine is basically an air pump. It creates power by pulling in an air / fuel mixture, igniting it, and turning the explosion into usable power. The explosion pushes a piston down that turns a crankshaft. As the pistons run up and down with controlled explosions, the crankshaft spins. For an automobile, the spinning crankshaft is connected to a transmission (with gears) that is connected to a driveshaft, which is then connected to the wheels. This is literally “putting power to the pavement.” For an aircraft, the crankshaft is connected to a propeller shaft and the power comes when that spinning propeller takes a bite of the air and pulls the aircraft forward.

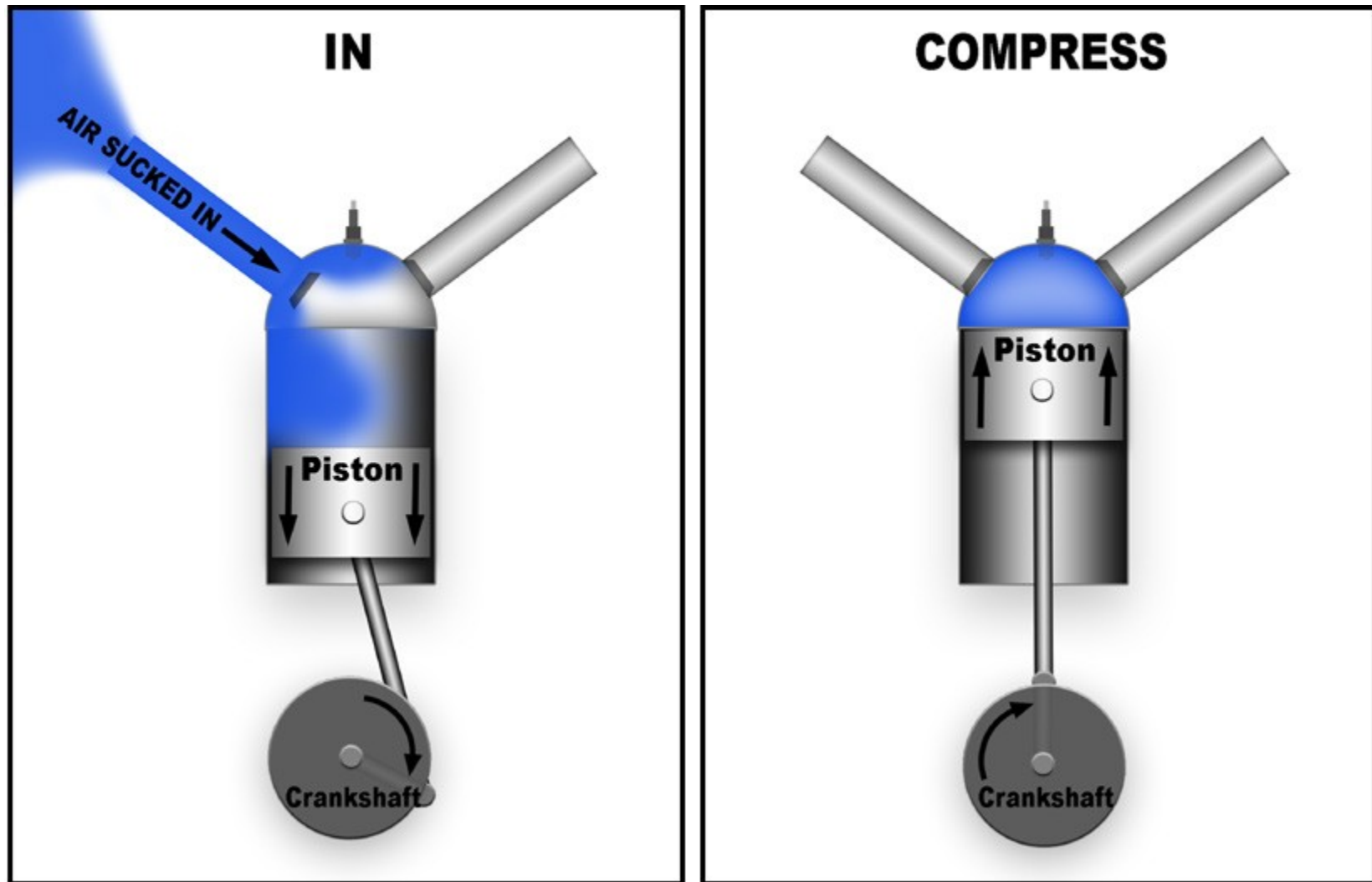
The main difference between an engine designed for an automobile and one designed for an aircraft is the aircraft engine will have to produce power up high where the air is thin. To function better in that high, thin air, a supercharger can be installed to push more air into the engine.

Overview of How the Engine Works and Creates Power

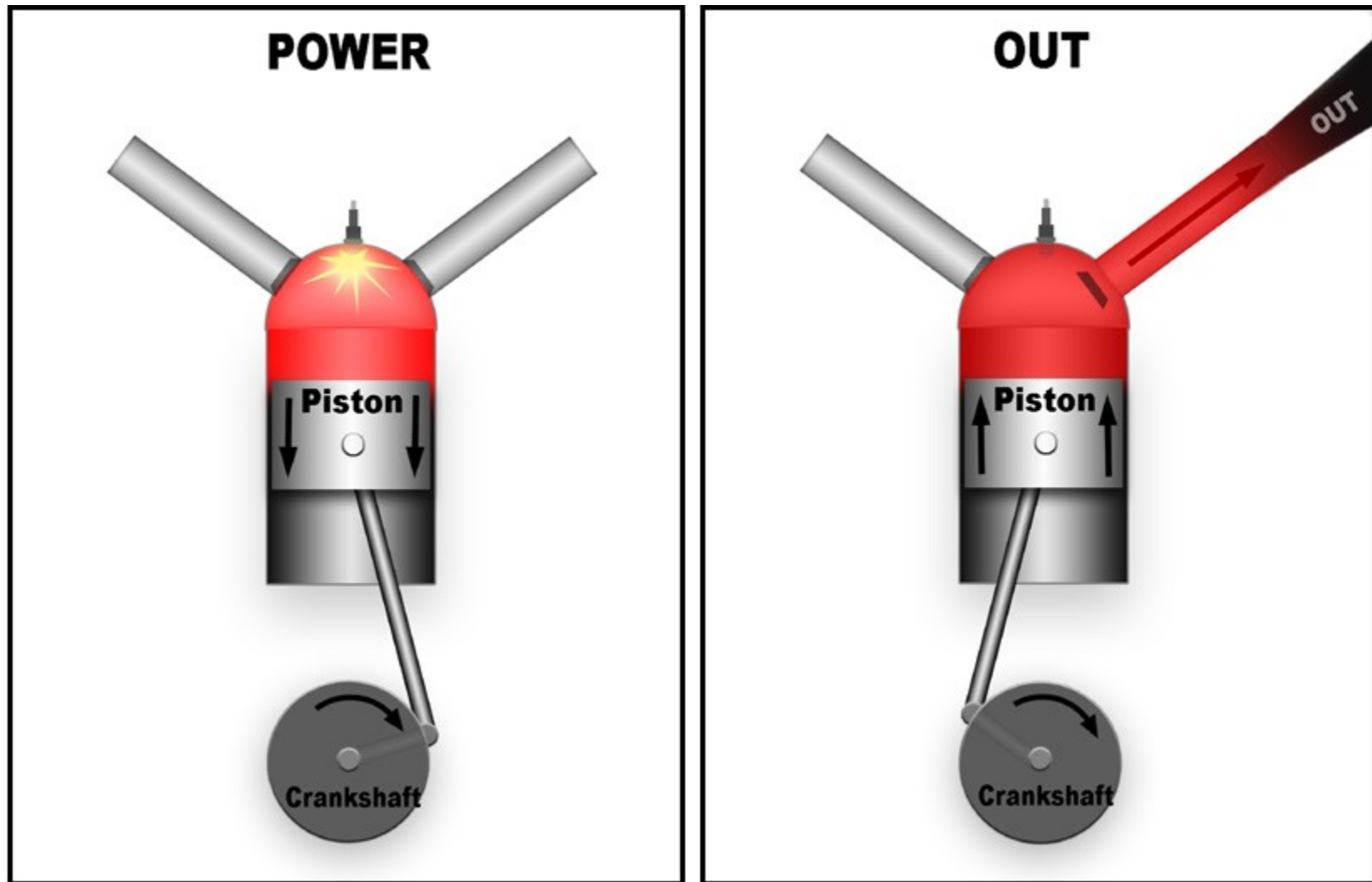
Fire needs air. We need air. Engines need air. Engines are just like us as – they need oxygen to work. Why? Because fire needs oxygen to burn. If you cover a fire, it goes out because you starved it of oxygen. If you have ever used a wood stove or fireplace, you know when you open the vent to allow more air to come in, the fire will burn more. The same principle applies to an engine. Think of an engine like a fire that will burn as hot and fast as *you* let it.

Look at the four pictures below and you will understand basically how an engine operates.

The piston pulls in the fuel / air mixture, then compresses the mixture on its way back up.

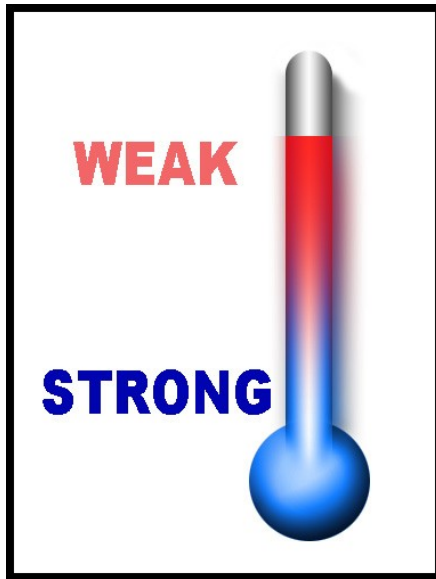


The spark plug ignites the compressed air / fuel mixture, driving the piston down (power), then on it's way back up, the burned mixture is forced out the exhaust.



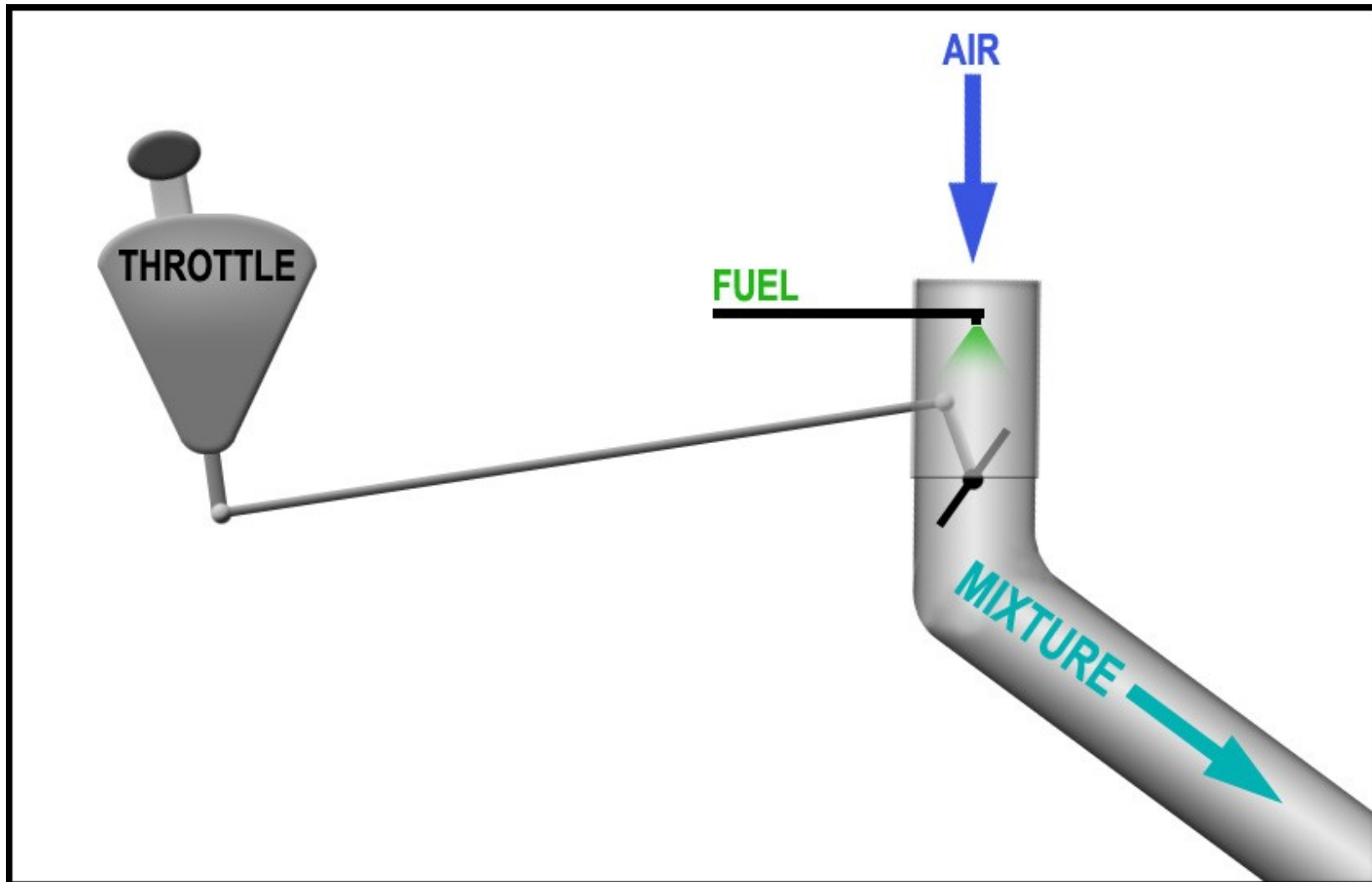
Air Temperature

Have you ever noticed that your car engine runs smoother and stronger in the cold weather? This is because cold air is denser than hot air and has more oxygen. Hotter air means less power.



Mixture

Just before the air enters the combustion chamber it is mixed with fuel. Think of it as an air / fuel mist.



A general rule is a 0.08% fuel to air ratio will produce the most *power*. 0.08% is less than 1%, meaning for every 100 parts of air, there is just less than 1 part fuel. The best economical mixture is 0.0625%.

Why not just use the most economical mixture all the time?

Because a leaner mixture means a hotter running engine. Fuel actually acts as an engine coolant, so the richer the mixture, the cooler the engine will run.

However, since the engine at high power will be nearing its maximum acceptable temperature, you would use your best power mixture (0.08%) when you need power (takeoff, climbing), and your best economy mixture (.0625%) when throttled back in a cruise when engine temperatures are low.

So, think of it this way:

For HIGH POWER, use a RICH mixture.

For LOW POWER, use a WEAK mixture.

The Mixture Lever

Most piston aircraft have a mixture lever in the cockpit that the pilot can operate. The higher you fly, the thinner the air, and the less fuel you need to achieve the same mixture. So, in general, as you climb you will be gradually pulling that mixture lever backwards, leaning it out as you go to the higher, thinner air.

How do you know when you have the right mixture?

The standard technique to achieve the proper mixture in flight is to lean the mixture until you just notice the engine getting a bit weaker, then richen the mixture until the engine sounds smooth. It is this threshold that you are dialing into your 0.08%, best power mixture. Be aware, if you pull the mixture all the way back to the leanest position, this is mixture cutoff, which will stop the engine.

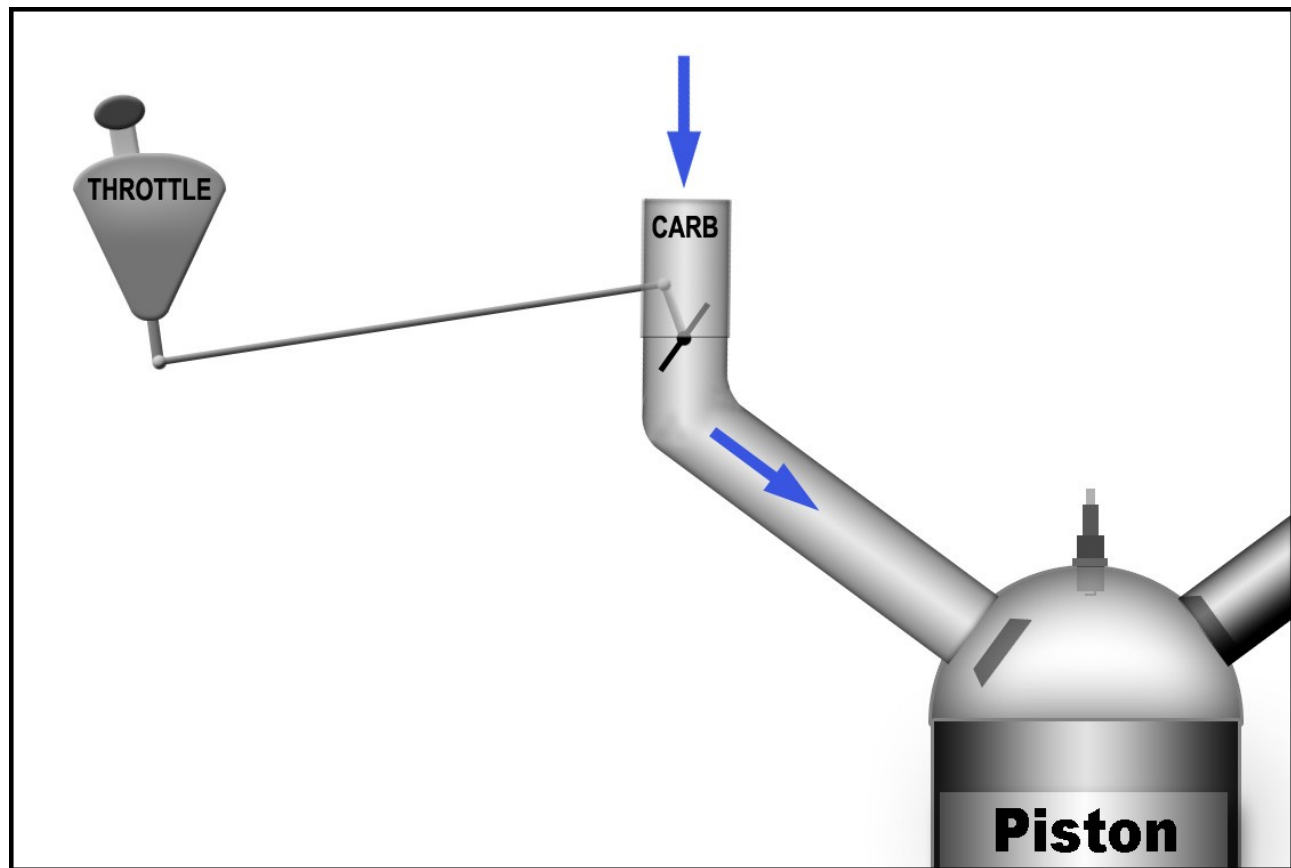
Auto-Rich and Auto-Lean

More advanced aircraft may have an AUTO-MIXTURE system, with AUTO-RICH and AUTO-LEAN settings. You simply select which one you want and the auto-mixture system automatically adjusts the mixture for you based on altitude and power setting. In the Spitfire, the term WEAK is used for LEAN.

Induction

As you now know, an engine is an air pump that runs based on timed explosions. Just like a forest fire, it would run out of control unless it is limited. When you push the throttle forward, you are opening a valve allowing your engine to suck in more fuel / air mixture. When at full throttle, your engine is pulling in as much air as your intake system will allow. It is not unlike a watering hose – you crimp the hose and restrict the water. Think of full power as you just opening that water valve and letting the water run free. This is 100% full power.

In general, we don't run an airplane engine at full power for extended periods of time. Full power is only used when it is absolutely necessary, sometimes on takeoff, and otherwise in an emergency situation that requires it. For the most part, you will be 'throttling' your motor, meaning you will be setting the limit.



Manifold Pressure = Air Pressure

You have probably watched the weather on television and seen a large letter L showing where big storms are located. L stands for LOW BAROMETRIC PRESSURE (low air pressure). You've seen the H as well, which stands for HIGH BAROMETRIC PRESSURE (high air pressure). While air pressure changes all over the world based on weather conditions, these air pressure changes are minor compared to the difference in air pressure with altitude. The higher the altitude, the *much* lower the air pressure.

On a standard day (59 F), the air pressure at sea level is 29.92Hg BAROMETRIC PRESSURE. To keep things simple, let's say 30Hg is standard air pressure. You have just taken off and begin to climb. As you reach higher altitudes, you notice your rate of climb slowly getting lower. This is because the higher you fly, the thinner the air is, and the less power your engine can produce. You should also notice your MANIFOLD PRESSURE decreases as you climb as well.

Why does your manifold pressure decrease as you climb?

Because manifold pressure *is* air pressure, only it's measured inside your engine's intake manifold. Since your engine needs air to breath, manifold pressure is a good indicator of how much power your engine can produce.

Now, if you start the engine and idle, why does the manifold pressure go way down?

When your engine idles, it is being choked of air. It is given just enough air to sustain itself without stalling. If you could look down your carburetor throat when an engine is idling, those throttle plates would look like they were closed. However if you looked at it really closely, you would notice a little space on the edge of the throttle valve. Through that little crack, air is streaming in. If you turned your ear toward it, you could probably even hear a loud sucking sound. That is how much that engine is trying to breath. Those throttle valves are located at the base of your carburetor, and your carburetor is bolted on top of your intake manifold. Just below those throttle valves and inside your intake manifold, the air is in a vacuum. This is where your manifold pressure gauge's sensor is, and when you are idling, that sensor is reading that very low air pressure in that vacuum.

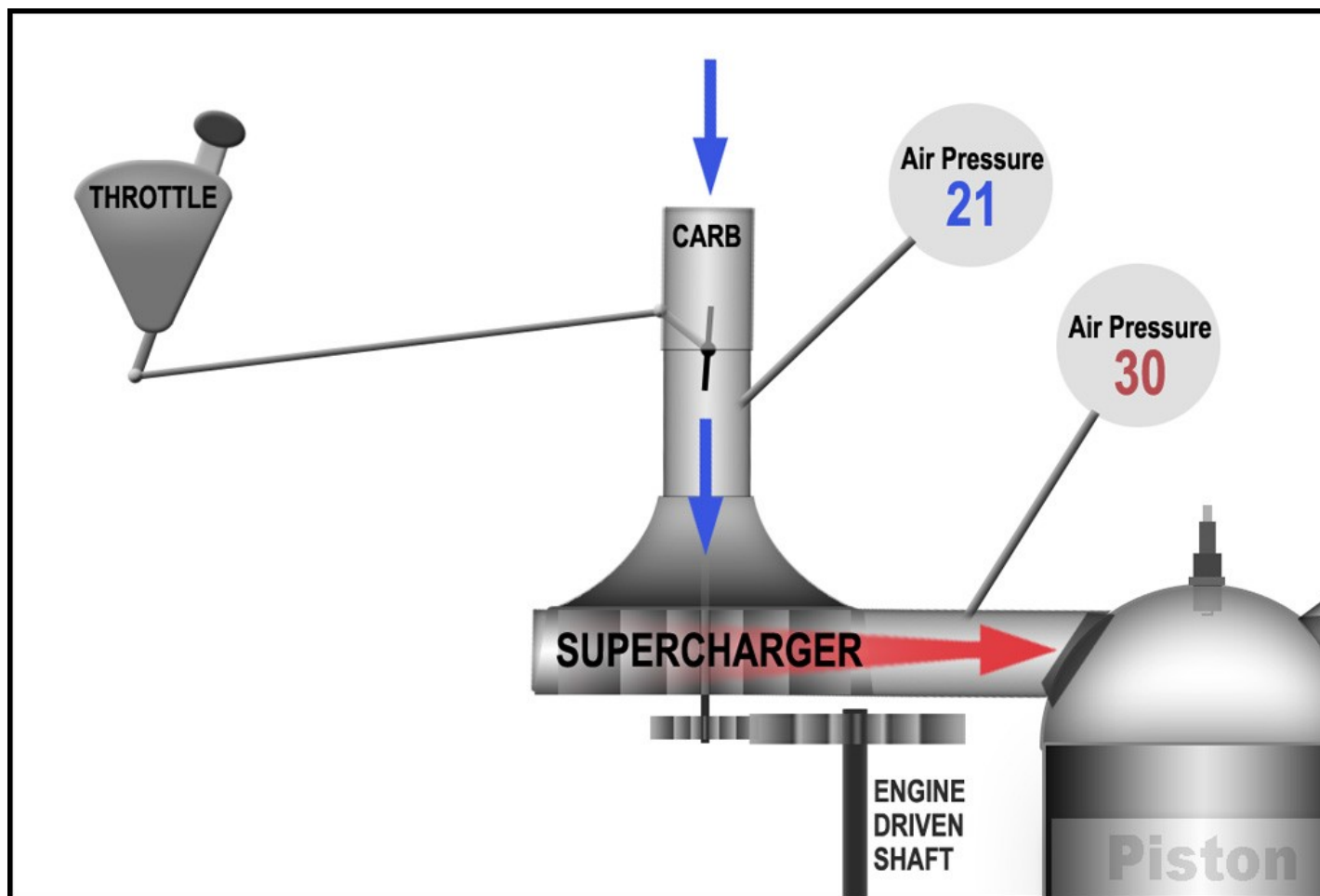
As you increase power, you will notice your manifold pressure comes up. This is simply because you have used your throttle to open those throttle plates more, and the engine is able to get the air it wants. If you apply full power on a normal engine, that pressure will ultimately reach about the same pressure as the outside, which really just means the air is now equalized as your engine's intake system is running wide open. So if you turned your engine off, your manifold pressure would rise to the outside pressure. So on a standard day at sea level, your manifold pressure with the engine off will be 30".

So how can an engine produce more power at high altitudes where the air is so thin?

Since the power an engine can produce is directly associated with the pressure of the air it can take, at some point during your climb (above 10,000 feet or so), that engine will be producing so little power that the aircraft can no longer climb. This is the point where the engine can barely sustain level flight, and is considered the aircraft's service ceiling. A supercharger can raise this ceiling.

Supercharging

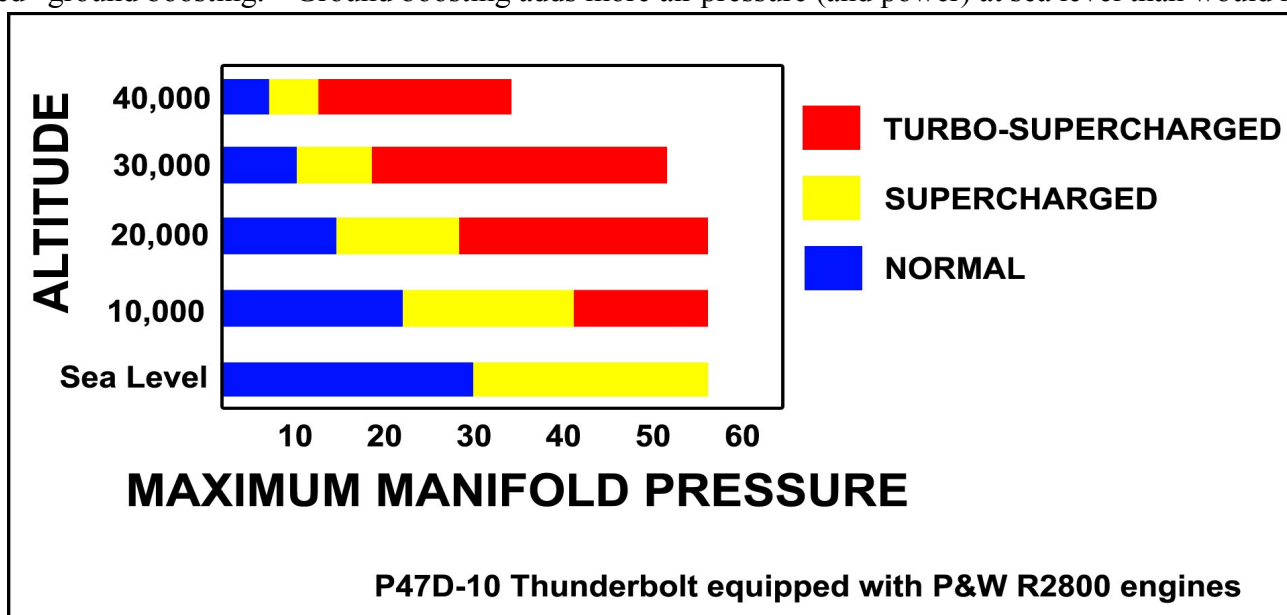
The supercharger has a powerful fan installed in your intake system that forces *more* air into the engine. As you fly higher and the air pressure decreases, your supercharger will help to compensate and keep air pressure higher than it would be otherwise.



Let's say while air pressure at sea level is 30", it is 21" at 10,000. At 10,000 feet, your supercharger fan pushes in more air to increase your manifold pressure to 30". Now your engine will produce the same power at 10,000 feet as it would at sea level. It would feel every bit as strong as it did when you took off.

However, even a supercharger has its limitations. At some point, it will hit its own limit of how much air it can force and manifold pressure will again start to drop off. Some aircraft, like the Merlin-powered, P-51 Mustang include a second stage supercharger, this is basically a HIGH / LOW gear. Some planes may automatically kick into HIGH at a certain altitude. When you hit this altitude, you will notice a nice punch of power. Other planes, like the P-47 Thunderbolt, use both a turbocharger and a supercharger. A turbocharger does the exact same thing as a supercharger, except while a supercharger is driven directly off the engine by mechanical gears, a turbocharger is driven by the power of the exhaust pressure. This is where the term ‘turbo lag’ comes from. Turbo lag is the time delay after you apply power and before the exhaust has enough pressure to spin the turbo charger hard enough to push more air into your engine. The turbo, being driven off exhaust, is only applying power when the engine is *producing* power. So the turbo process is a cycle – engine power produces more turbo power that produces more engine power and so on. It’s like rolling a snowball down a hill, this is your turbo ‘spooling’ up. Since the supercharger is gear driven, it moves perfectly in step with engine RPM – it’s there and ready when you apply throttle.

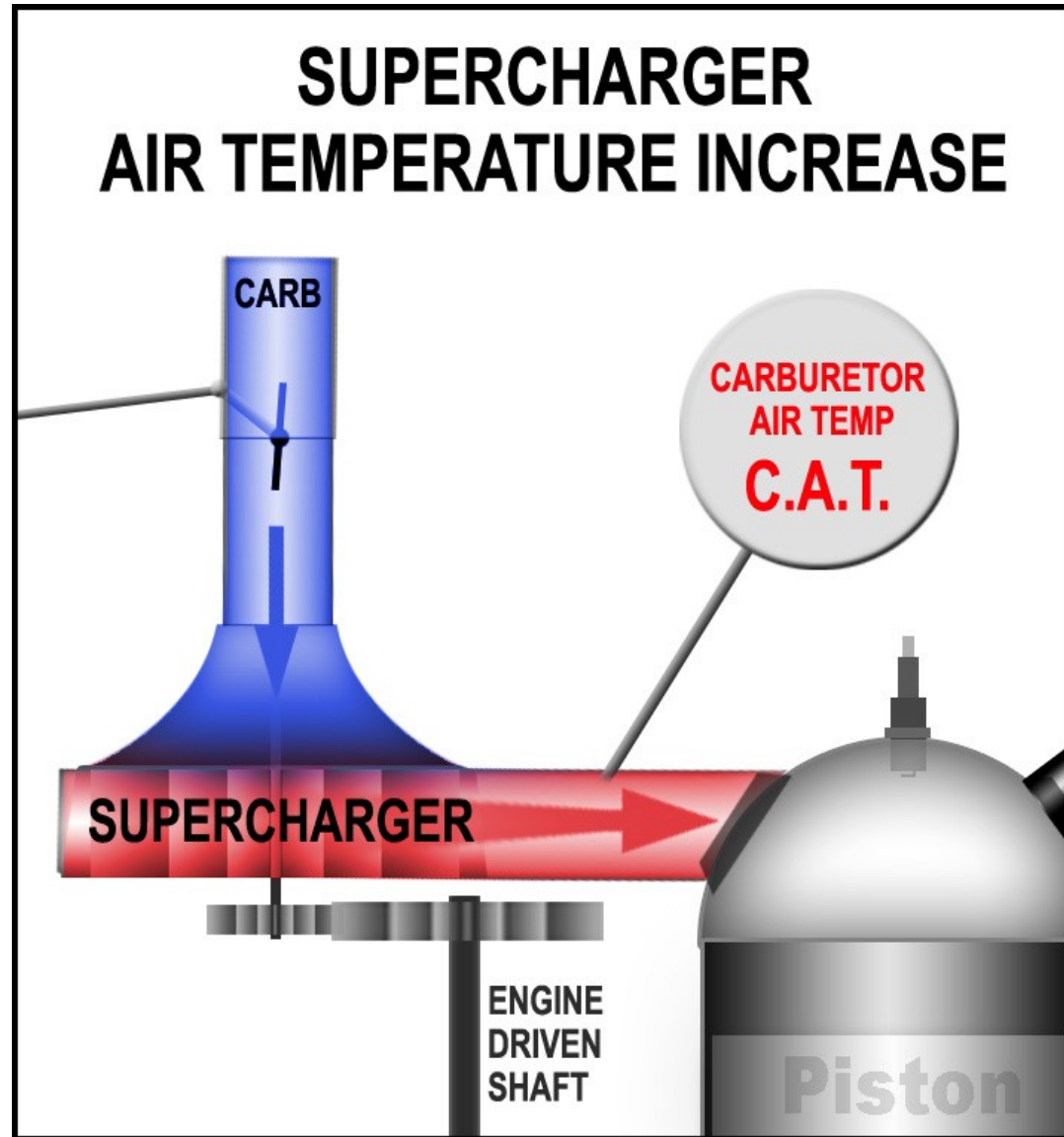
While turbo and superchargers can be used to compensate for lost air pressure up high, they can also be used to *over-boost* the power at sea level. This is called “ground boosting.” Ground boosting adds more air pressure (and power) at sea level than would normally be available.



If you add power and see your manifold pressure rise above 30”, then you have some form of supercharging or turbocharging adding more air into the engine than would normally be available. A normal engine that is producing 1,000 horsepower at 30” will produce 2,000 horsepower at 60”, since it is twice the pressure. 45” produces 1,500 horsepower and so on.

Supercharging Heats The Air

The downside to supercharging is heat. The more you compress air, the more the temperature increases, therefore more supercharging = higher CAT temperatures. The increase in temperature can be extreme. -40 degree air coming into the intake system can be 100 degrees hotter after it exits the supercharger. This is where your INTERCOOLER comes into play. The INTERCOOLER is a heat exchange, and is basically a radiator taking heat out of the incoming air. Use your INTERCOOLER FLAPS to transfer heat out of your intake manifold and out the flap doors. The more you open your intercooler flaps, the more heat you remove. Use your intercooler flaps to keep CAT temps nice and low for a strong and healthy running engine.



Ignition

The ignition system provides timed sparks to trigger timed explosions. For safety, aircraft are usually equipped with two completely independent ignition systems. In the event one fails, the other will continue to provide sparks and the engine will continue to run. This means each cylinder will have two spark plugs installed.

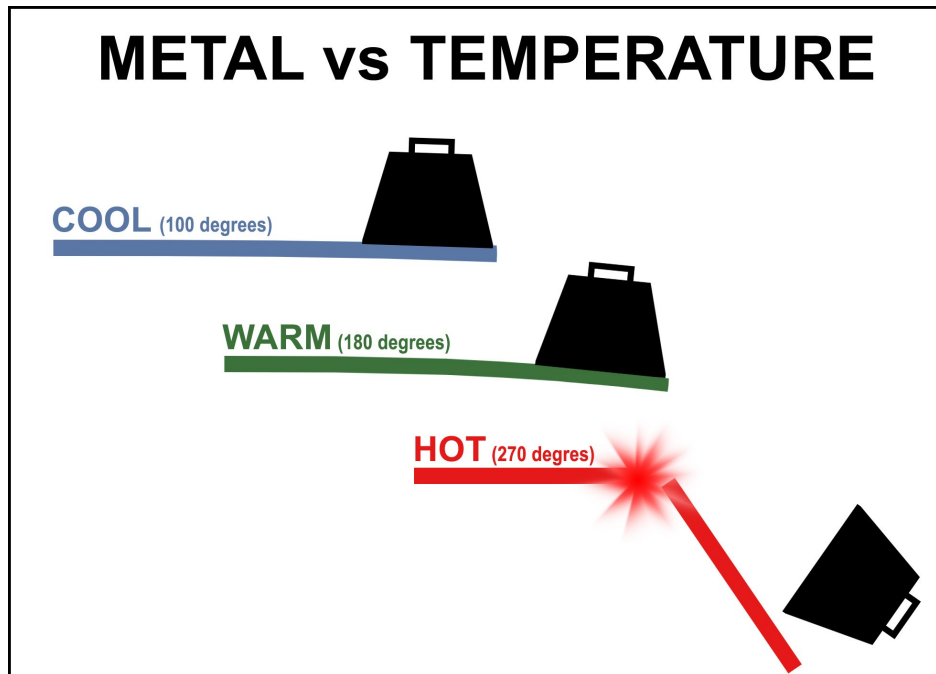
An added advantage to having two sparks instead of one is more sparks means a little more power. The pilot can select Ignition 1, Ignition 2, or BOTH by using the MAG switch. You can test that each ignition is working on the ground by selecting each one and watching your engine RPM. There will be a slight drop when you go from BOTH to just one ignition system. This is normal, provided the drop is within your pilot's manual limitation.



Engine Temperature

All sorts of things create heat in an engine, like friction, air temp, etc., but nothing produces heat like COMBUSTION.

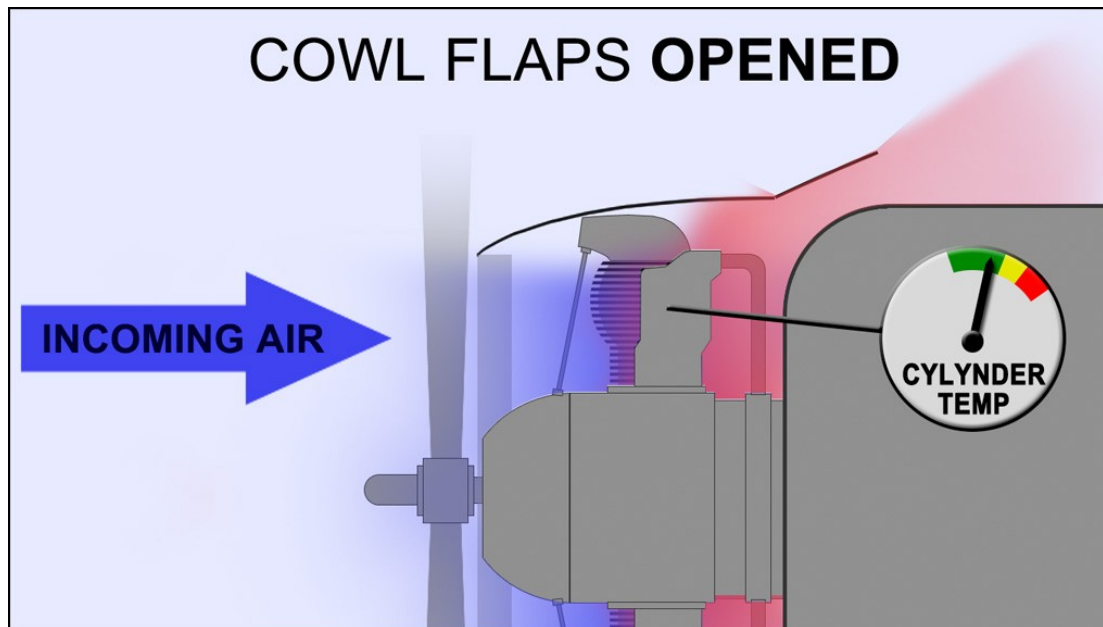
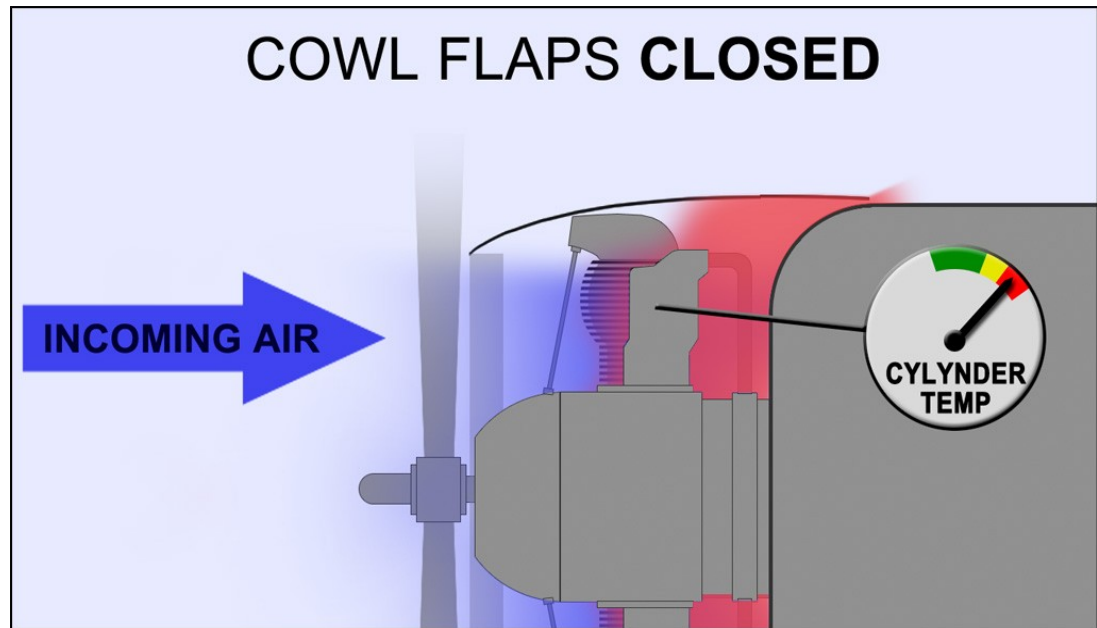
The hotter the metal, the weaker its strength.



Aircraft engines are made of aluminum alloy, due to its strong but lightweight properties. Aluminum maintains most of its strength up to about 150 degrees Celsius. As the temperature approaches 200 deg C, the strength starts to drop. An aluminum rod at 0 degrees Celsius is about 5X stronger than the same rod at 250 degrees Celsius, so an engine is most prone to fail when it is running hot. Keep your engine temperatures down to keep a healthy running engine.

CHT (Cylinder Head Temperature)

CHT is a measurement of the temperature in the back of the cylinder head. The combustion is happening right inside the cylinder head, so high power will increase temperature rapidly. The key is to watch and manage your cylinder head temperature by being aware of the outside air temp, keeping your speed up, and using your cowl flaps to control how much cooling is applied. The largest CHT rise will come from sitting on a hot ramp, just after takeoff, or in a slow and steep climb.

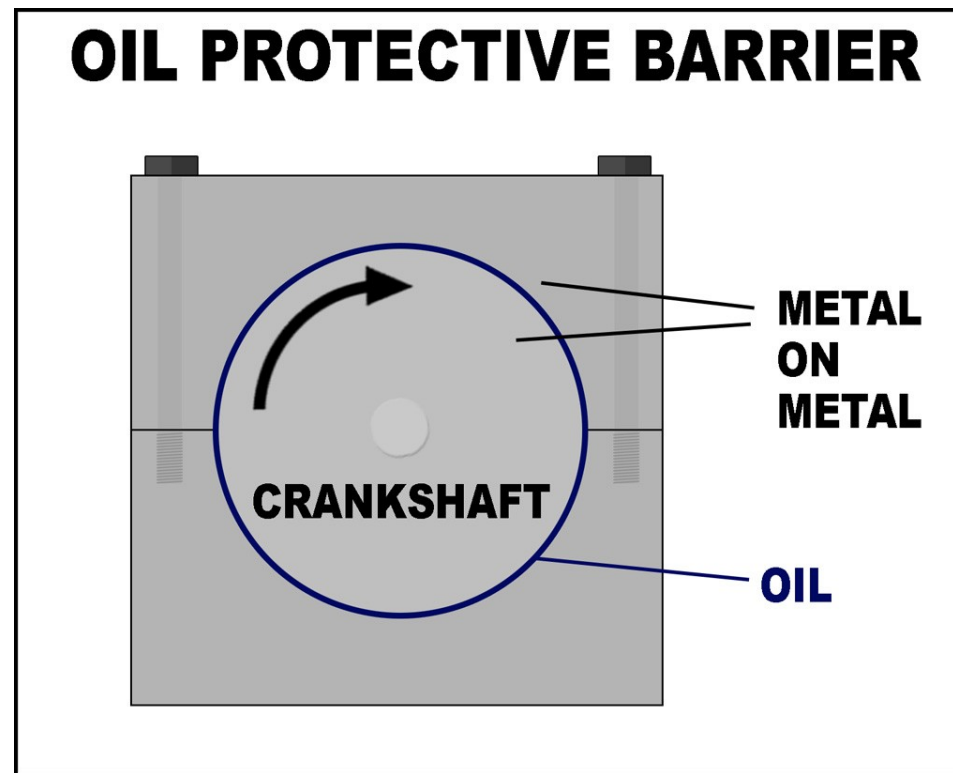


Lubrication System (Oil)

An internal combustion engine has precision machined metal parts that are designed to run against other metal surfaces. There needs to be a layer of oil between those surfaces at all times. If you were to run an engine and pull the oil plug and let all the oil drain out, after just minutes, the engine would run hot, slow down, and ultimately seize up completely from the metal on metal friction.

There is a minimum amount of oil pressure required for every engine to run safely. If the oil pressure falls below this minimum, then the engine parts are in danger of making contact with each other and incurring damage. A trained pilot quickly learns to look at his oil pressure gauge as soon as the engine starts, because if the oil pressure does not rise within seconds, then the engine must be shut down immediately.

Below is a simple illustration of a crankshaft that is located between two metal caps, bolted together. This is the very crankshaft where all of the engine's power ends up. Vital oil is pressure-injected in between these surfaces when the engine is running. The only time the crankshaft ever physically touches these metal caps is at startup and shutdown. The moment oil pressure drops below its minimum, these surfaces make contact. The crankshaft is where all the power comes from, so if you starve this vital component of oil, the engine can seize. However, this is just one of hundreds of moving parts in an engine that need a constant supply of oil to run properly.

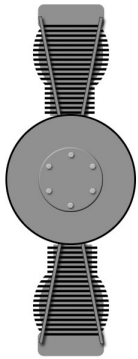


More Cylinders, More Power

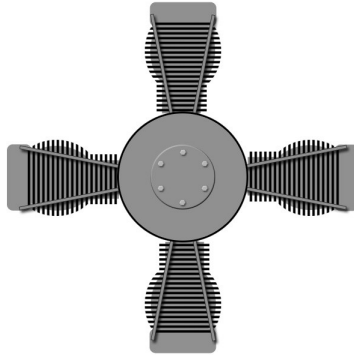
The very first combustion engines were just one or two cylinders. Then, as technology advanced, and the demand for more power increased, cylinders were made larger. Ultimately, they were not only made larger, but more were added to an engine.

Here are some illustrations to show how an engine may be configured as more cylinders are added.

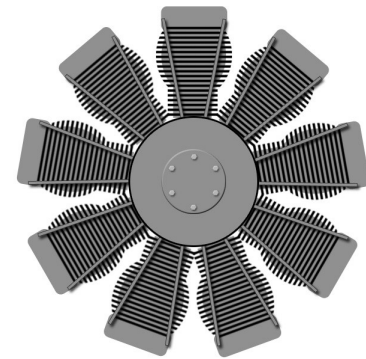
2 Cylinders



4 Cylinders



9 Cylinders



The more cylinders you add to an engine, the more heat it produces. Eventually, engine manufacturers started to add additional “rows” of cylinders. Sometimes two engines would literally be mated together, with the 2nd row being rotated slightly so the cylinders could get a direct flow of air.

The Pratt & Whitney R4360

Pratt & Whitney took this even further, creating the R4360, with 28 Cylinders. The cylinders were so run so deep, it became known as the “Corn Cob.” This is the most powerful piston aircraft engine to reach production. There are a LOT of moving parts on this engine.



Torque vs Horsepower

Torque is a measure of twisting force. If you put a foot long wrench on a bolt, and applied 1 pound of force at the handle, you would be applying 1 foot-pound of torque to that bolt. The moment a spark triggers an explosion, and that piston is driven down, that is the moment that piston is creating torque, and using that torque to twist the crankshaft. With a more powerful explosion, comes more torque. The more fuel and air that can be exploded, the more torque. You can increase an engine's power by either making bigger cylinders, adding more cylinders, or both.

Horsepower, on the other hand, is the TOTAL power that engine is creating. Horsepower is calculated by combining torque with speed (RPM). If an engine can produce 500 foot pounds of torque at 1,000 RPM and produce the same amount of torque at 2,000 RPM, then that engine is producing twice the HORSEPOWER at 2,000 RPM than it is at 1,000 RPM. Torque is the twisting force. Horsepower is how fast that twisting force is being applied.

If your airplane has a torque meter, keep that engine torque within the limits or you can break internal components. Typically, an engine produces the most torque in the low to mid RPM range, and highest horsepower in the upper RPM range.

Chapter 3: Accu-Sim and the Supermarine Spitfire



Developed for:



Accu-Sim Expansion Pack

Accu-Sim is A2A Simulations' growing flight simulation engine, which is now connectable to other host simulations. In this case, we have attached our Accu-Sim Spitfire MkI and MkII to Microsoft Flight Simulator X to provide the maximum amount of realism and immersion possible.

What is the philosophy behind Accu-Sim?

Pilots will tell you that no two aircraft are the same. Even taking the same aircraft up from the same airport to the same location will result in a different experience. For example, you may notice one day your engine is running a bit hotter than usual and you might just open your cowl flaps a bit more and be on your way, or maybe this is a sign of something more serious developing under the hood. Regardless, you expect these things to occur in a simulation just as they do in life. This is Accu-Sim, where no two flights are ever the same.

Realism does not mean having a difficult time with your flying. While Accu-Sim is created by pilots, it is built for *everyone*. This means everything from having a professional crew there to help you manage the systems, to an intuitive layout, or just the ability to turn the system on or off with a single switch. However, if Accu-Sim is enabled and the needles are in the red, there will be consequences. It is no longer just an aircraft, it's a simulation.

Actions Lead to Consequences

Your A2A Simulations Spitfire is a complete aircraft with full system modeling. However, flying an aircraft as large and complex as the A2A Spitfire requires constant attention to the systems. The infinite changing conditions around you and your aircraft have impact on these systems. As systems operate both inside and outside their limitations, they behave differently. For example, the temperature of the air that enters your carburetor has a direct impact on the power your engine can produce. Pushing an engine too hard may produce just slight damage that you, as a pilot, may see as it just not running quite as good as it was on a previous flight. You may run an engine so hot, that it catches fire. However, it may not catch fire; it may just quit, or may not run smoothly. This is Accu-Sim – it's both the realism of all of these systems working in harmony, and all the subtle, and sometimes not so subtle, unpredictability of it all. The end result is when flying in an Accu-Sim powered aircraft, it just feels real enough that you can almost smell the avgas.

Your Aircraft Talks

We have gone to great lengths to bring the internal physics of the airframe, engine, and systems to life. Now, when the engine coughs, you can hear it and see a puff of smoke. If you push the engine too hard, you can also hear signs that this is happening. Just like an actual pilot, you will get to know the sounds of your aircraft, from the tires scrubbing on landing to the stresses of the airframe to the canopy that is cracked opened.

Be Prepared – Stay Out of Trouble

The key to successfully operating your Spitfire, or any high performance aircraft for that matter, is to stay ahead of the curve and on top of things. Aircraft are not like automobiles, in the sense that weight plays a key role in the creation of every component. So, almost every system on your aircraft is created to be just strong enough to give you, the pilot, enough margin of error to operate safely, but these margins are smaller than those you find in an automobile. So, piloting an aircraft requires both precision and respect of the machine you are managing.

It is important that you always keep an eye on your oil pressure and engine temperature gauges. On cold engine starts, the oil is thick and until it reaches a proper operating temperature, this thick oil results in much higher than normal oil temperatures. In extreme cold, once the engine is started, watch that oil pressure gauge and idle the engine as low as possible, keeping the oil pressure under 120psi.

The oil and coolant temperature gauges are critical throughout your flight. Idling too long on the pavement will overheat this Spitfire because its cooling radiator is inadequate. Plan to be off the ground in under ten minutes. Don't let your engine exceed 100 degrees Celsius before your takeoff roll.

Once airborne, you will want to avoid steep climbs, especially in hot weather, to keep good airflow to your radiator. You will also want to keep your radiator opened at all times during flight, adjusting it to maintain temperatures around 100 degrees if possible, never more than 120 degrees. High engine power increases both water and oil temperatures, but oil is also heated up quite a bit by engine friction (RPM). So if you are running hot oil temperatures, you may wish to also decrease your engine RPM.

Key Things to Keep Engine Temperatures in Check

1. Open radiator cooling flap
2. Get off the ground as soon as possible. Prolonged idling and taxiing will overheat your engine.
3. Reduce power immediately after takeoff to climb power
4. Do not climb too steeply to ensure adequate airflow – keep speeds at or above 160mph if possible
5. Lower RPM to further reduce oil temperature

Engine Priming

Accu-Sim models the priming system which basically pumps fuel into the intake so the engine can start. If you do not prime the motor prior to starting, it is unlikely it will start. Over priming can also make for hard starts. If you do over prime, wait a few minutes then try to start again.

Recommended Primer Strokes

Air Temperature °C	Primer Strokes
+30	3
+20	3 ½
+10	7
0	12 ½



Engine Starters

Electric Starter

Your Spitfire MkI is equipped with a direct-drive electric starter. This engages a starter motor gear directly to the engine, cranking it with electric power supplied by either your battery or an APU. Be aware that the starter motor rapidly heats up with continued cranking. As per the manual, it is advised to not crank the starter for more than 30 seconds at a time, allowing several minutes to cool before cranking again.



Cartridge (Explosive) Starter

For those who have flown our Accu-Sim P-47, you know how an inertia starter operates. Now it's time to show what an explosive cartridge starter can do. The design is simple, yet brilliant. Take an explosive shell, much like a shotgun shell, stick it in a breach, explode it, and use the expansion of hot air to turn the motor over. It's cheap, effective, and lightweight. Think of a cartridge starter as an air starter. Air compresses, so while the starter goes BANG! The motor gets a firm, yet somewhat gentle push.

Your spitfire holds up to three cartridges, so make each one count. Do all of our checks, make sure everything is on and ready, and prime it according to your checklist based on the temperature of the engine. One shot should do it.

Manifold Pressure

The manifold pressure is your best way to judge the power your engine is producing. However, be aware that manifold pressure is simply the pressure of the air before it enters your engine and, more accurately, is an indication of “potential” power.

Assuming manifold pressure is the same, the following things can affect the actual power your engine is producing:

1. RPM. Remember, your engine is an air pump, so a higher RPM will produce more power than a lower RPM at the same manifold pressures. **NOTE:** Never use low RPM and high manifold pressure. This condition can create critically high torque and stress a motor.
2. Mixture. If your mixture is too lean or too rich it will produce less power than if it is at the optimum power-rich setting. Your mixture is constantly changing based on the power your aircraft is producing. In certain circumstances, a WEAK mixture setting can produce more power than RICH mixture setting, since at high power settings more fuel is added to keep the engine cool. If the power is high enough, a WEAK mixture setting may actually provide the best power mixture. However, you do not want to apply high power with a WEAK mixture setting as this will create high engine temperatures, This is just something you should be aware of.
3. Engine health. An old worn engine will not have the tight compression a new engine will have and this older engine will produce less power than the newer one at the same manifold pressure.
4. Air Temperature. For the most part, cooler air is denser and will produce higher manifold pressure, but manifold pressure and power output can be inconsistent at different air temps.



Oil Pressure

Accu-Sim models oil thickness (viscosity). The colder the oil temp, the thicker it is, and the more oil pressure there is in the engine. If you start your engine on a cold morning, you may see oil pressures as high as 150 psi or more. This is far above the limit and it is critical that you do not push the engine with cold, thick oil. Pushing an engine with thick, cold oil can premature cause oil system leaks or worse.

If you have just started a very cold engine, idle at the lowest possible RPM and wait until the oil temperature warms and pressure drops.



Pneumatic System

The pneumatic system uses an engine-driven air pump which powers the brakes and flaps. The system can be pressurized on the ground when the engine is off through your Fuel and Load Manager (Shift-4), or by the engine driven pump.

You can see the main air supply in your BRAKES triple gauge, along with pressure to your brakes. The brakes in the Spitfire are controlled by a finger-operated lever on the yoke. This lever sends pressure from the main supply to the brakes, which gives you brake power. We use the trigger on the stick to operate this lever. If you have rudder pedals, using either the left or right toe brakes will also operate this lever.

Differential braking is done by using the rudder pedals, not the toe brakes on your rudder pedals. The turning of the rudder vectors more pressure to the inside turning brake, and releases pressure from the outside turning brake. See below for examples of different system states:

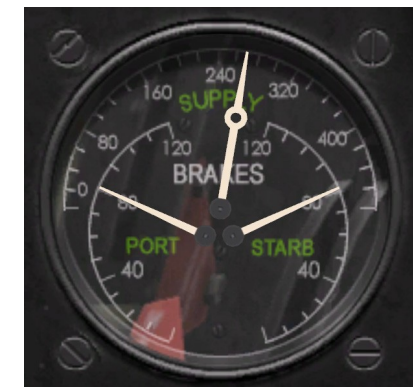
Brakes OFF

This is the system with the supply charged, either from the fuel and load manger, or by the engine driven pump.



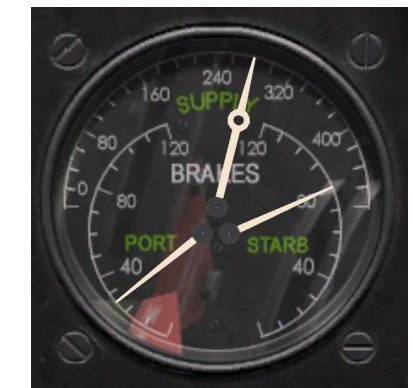
Brakes ON

Notice the brake pressure goes up, and the supply dips a bit. If the engine driven pump is running, it will replenish this supply in a few seconds.



Right rudder

You can see, when turning right, the inside brake holds pressure while the outside releases it, for a tighter, more controlled turn. You will hear air escaping occasionally with brakes going on and off. This is normal, as the sound is air escaping into the atmosphere via a relief valve.



Landing Gear

Do not lower your landing gear if you are above 140mph IAS (indicated airspeed). Once down, the landing gear not only creates enormous drag, but does so out on each wing. To make matters worse, the left and right landing gear do not operate in sync. So, as you drop your gear, one wheel may pop out while the other is still in the wheel well. At this point, you will experience a possible extreme yaw to that side. This is normal and is experienced in the actual Spitfire. Also, take care on your landings as the landing gear on the Spitfire is adequate, yet not that rugged.



Flaps

Do not lower your flaps above 160mph IAS. Doing so can damage, jam, or possibly even break your flaps. Accu-Sim measures the forces on the flap based on the actual air pressure on the flap itself. As the flap moves to higher angles, the pressure (and drag) quickly builds up. If you were to, for example, jam your left flap down and then raise your flaps, you could be in a dangerous situation. If this happens, lower your flaps until they are equal and land at the nearest airfield. If you were to break a flap at high speeds when deployed, your aircraft could immediately go into an uncontrollable flying attitude. Watch your speeds and LISTEN to your aircraft.



Oxygen and Hypoxia

The higher the altitude, the thinner the air, and the less oxygen available for each breath you take. Without an oxygen mask, above 12,500 feet you can start to feel the effects of hypoxia (oxygen starvation). Hypoxia is very dangerous as it can sneak up on a pilot without him realizing, and render him unconscious. As you gain experience as a pilot, you learn to notice these signs. Turn the altitude to the altitude you are flying at, as this meters the amount of oxygen needed at that chosen altitude.



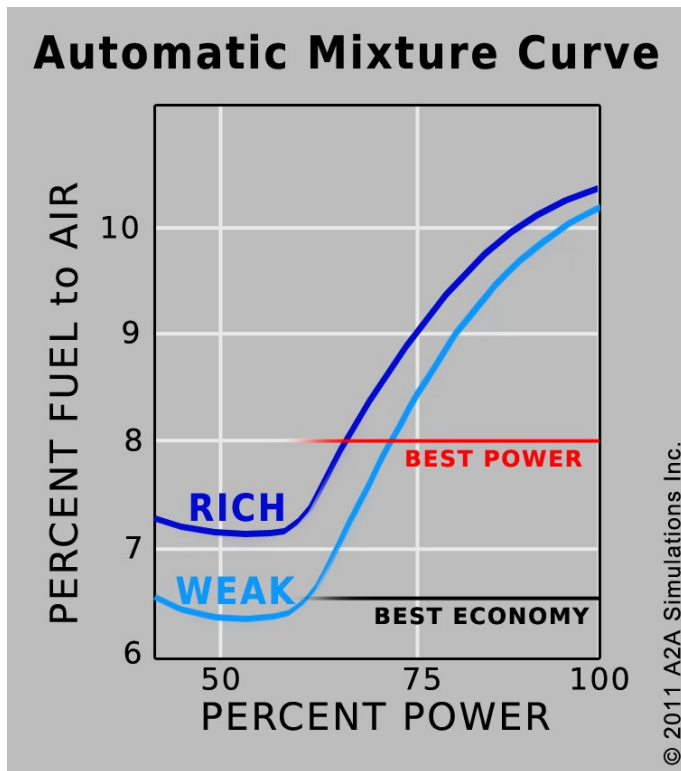
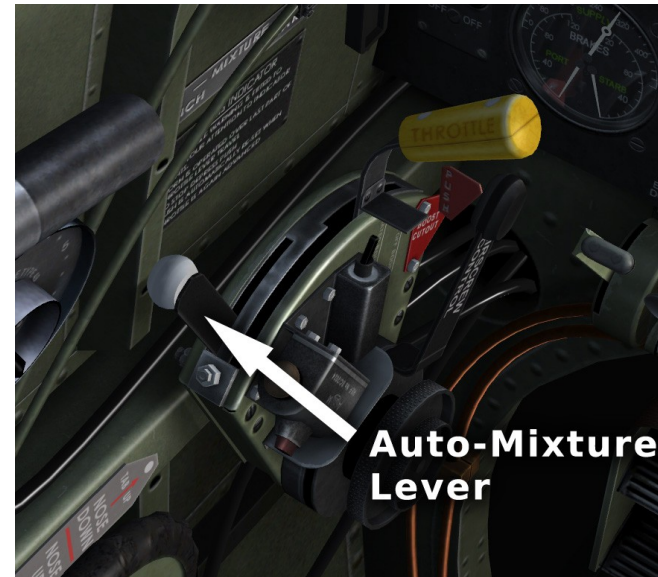
Accu-Sim has secret and subtle ways to let you know you are starting to experience hypoxia. At some point, you may notice your breathing is heavy. If this happens, make sure your oxygen is working properly. If not, **IMMEDIATELY** dive to lower altitudes. If you end up not responding to these signs and pass out, you will lose complete control of the aircraft. Only when you return to lower altitudes will you awaken.

Auto Mixture

Your engine is equipped with an automatic mixture control, which can be set to RICH or WEAK via a lever next to your throttle (WEAK means the same as LEAN).

Both settings automatically adjust the mixture based on air density and engine power. This allows for a more accurate mixture than is possible through manual mixture settings.

In general, you should use a RICH setting (lever back) for all operations except when you are throttled back in cruise for the longest range / best fuel economy. You should avoid high power with a WEAK mixture, as this can lead to high engine temperatures.



You can see that the LEAN setting gives you about a 6.5% fuel mixture, which is ideal for maximum efficiency (and maximum heat) when at a lower, cruise power. RICH scales the entire curve upwards giving more fuel, and greater power.

Also notice how both curves exceed the 8% best power mixture. Above 8% is entering what is called a RICH RICH condition, which is used to help keep your engine cooler at these higher power settings. This is actually producing less power than if an 8% mixture was held, however, the engineer's adjust this curve to suite each engine.

All of our Accu-Sim aircraft, including our Boeing 377 use a mixture curve similar to what is shown here. If you ever notice black smoke under very high power settings, do not be alarmed, this is normal. You can see from the graph that high power settings use a very high fuel mixture which cannot all be burned off in the combustion process, therefore unburned fuel (black smoke) is ejected from the engine. Later, with the introduction of water injection (on our P-47), this RICH RICH condition was bypassed as the water was adequate for engine cooling.

Coolant and Oil Temperature

Engine temperatures will rise based on the power, air temperature, and the air flow through the radiator. Use common sense and make gradual adjustments with power and speed. Avoid high power, steep climbs, and low power descents with the radiator flap opened.

Also, being a water-cooled engine, it takes time for the coolant to travel through the engine, through coolant lines to the radiator, then to your temperature gauge, so the temperature gauge tends to lag behind the actual heating of the engine. For example, you may perform a run up, and only at the end of the run-up, you will notice a sharper increase in coolant temperatures. Then as you are idling, temperatures may continue to rapidly climb as that heated water from the run-up is now reaching your temperature gauge. This is normal behavior, but you do need to understand why this is happening to anticipate heating and cooling. Also understand that both your landing gear and flaps obstruct the flow of air through your radiator, so your time on the ground is limited. Your engine WILL overheat, so either get it in the air, or get it to its parking spot and shut it down. When in the air, get those flaps and gear up as soon as possible.



Coolant Pressure Release Valve

If your coolant system pressures are too high or your coolant temperature exceeds 120° C, a pressure relief valve will open allowing high temperature air to escape. This relief valve helps prevent damage to your coolant system due to extreme pressures.



Persistent Aircraft

Every time you load up your Accu-Sim Spitfire, you will be flying the continuation of the last aircraft which this includes fuel, oil, coolant levels along with all of your system conditions. So be aware, no longer will your aircraft load with full fuel every time, it will load with the same amount of fuel you left off when you quit your last flight. You will learn the easy or the hard way to make, at the very least, some basic checks on your systems before jumping in and taking off, just like a real aircraft owner.

Additionally, in each flight things will sometimes be different. The gauges and systems will never be exactly the same. There are just too many moving parts, variables, changes, etc., that continuously alter the condition of the airplane, its engine and its systems.

NOTE: Signs of a damaged engine may be lower RPM (due to increased friction), inconsistent manifold pressures, or possibly hotter engine temperatures.

Electrical System and Battery

Accu-Sim installs an authentic period battery into a feature-rich electrical system, thanks to close consultation with our own on-staff electrical engineer and high time pilots. Batteries suffer from reduced capacity as they age, have a limited output (40 amp hours), can overheat if you demand too much from them, and can even load up your entire system if you have a brand new, but dead battery on-line. (ever try to jump start a car with a dead battery and nothing happens? You have to disconnect the dead battery and try again, since the dead battery is stealing all the electricity). The physical laws governing electricity are inexorable as those which govern running water. Our latest and most sophisticated version of version of Accu-Sim accurately replicates those physical laws and permits you to see the electrical system at work, via voltmeters on both models and an additional ammeter on the Mk Ia.

Volts, amps, watts, what does this all mean?

Without getting too technical, the pilot really need to understand the basics of what is happening in the aircraft's electrical system and components. Volts X Amps = watts. If we use a water hose as an analogy, volts would be the water pressure, amps would be the hose width, and watts would be the amount / rate of water coming out the end. You could have, for example, a 120 volt, 1 amp light bulb would be the same brightness as a 12 volt, 100 amp bulb. The high voltage system is sending high pressure down a small pipe, and the low voltage system is sending low pressure down a large pipe, but each putting out the same amount of water (watts).

So when you look at your voltmeter, you are seeing how well your electrical system is holding up against the load. If you take a huge draw, in this case your direct drive electrical starter on the MkIa, voltage will plummet as the battery struggles to supply this enormous draw. Your Ammeter is showing the current draw. In this case, the starter pushes it off the scale. However, play with your lights, pitot heat, etc. and

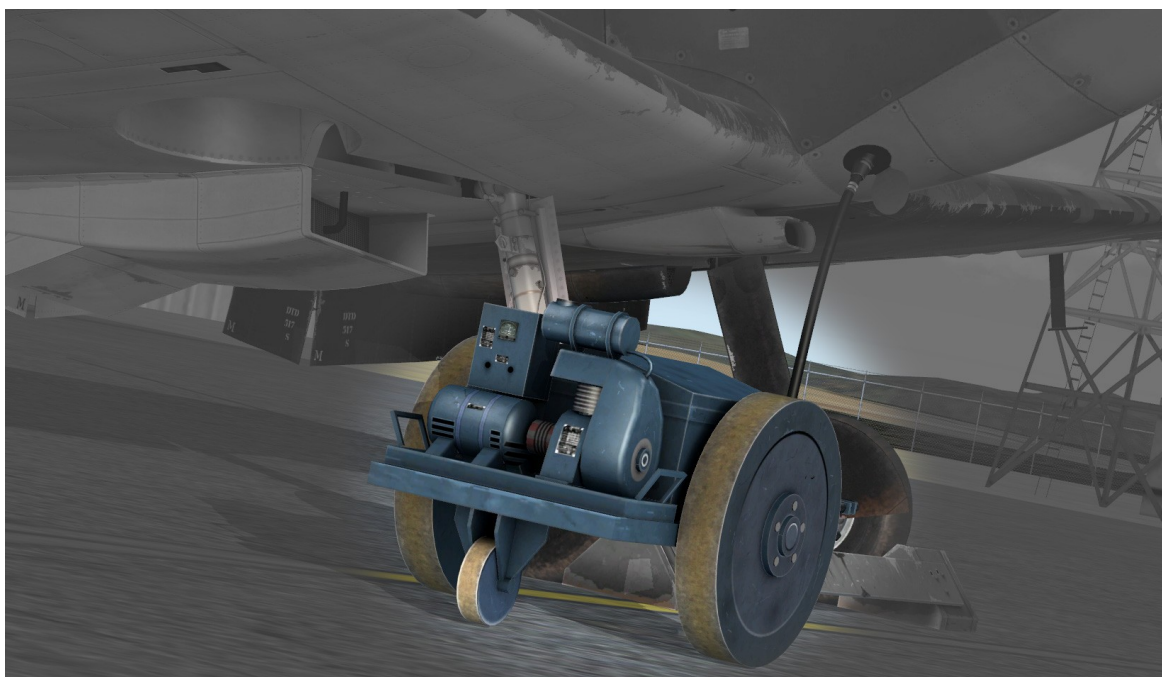
watch how these little changes affect these systems.

Remember, your electrical system has a battery and an engine driven electrical generator. The battery puts out about 12 volts, while the generator puts out a little more (about 14 volts). This allows your generator to not only drive all of the systems, but charge the battery at the same time. Remember, your generator is powered by the engine speed, and it does not reach it's full capacity until about 1,800 RPM. Watch your meters, and you will see and enjoy a genuine electrical system in action.

In addition, weather affects a battery's performance. Fortunately, you can always visit your maintenance hangar for a quick charge or replacement. If you use your battery wisely and correctly, it will last a long time. And speaking of using your battery wisely...

When starting with an electric starter in your MkIa, use your APU (in your CONTROLS menu – Shift-3).

This is a battery cart with a generator that supplies about 2X the power of your internal battery, and while you can start your engine with your internal battery, why not use the APU and give that little on-board battery a well-deserved break?



Sounds Generated by Physics

Microsoft Flight Simulator X, like any piece of software, has its limitations. Accu-Sim breaks this open by augmenting the sound system with our own, adding sounds to provide the most believable and immersive flying experience possible. The sound system is massive in this Accu-Sim Spitfire and includes engine sputter / spits, bumps and jolts, body creaks, engine detonation, runway thumps, gear doors and flaps, dynamic touchdowns, authentic simulation of air including buffeting, shaking, canopy, broken flaps, jammed gear, oxygen sounds, primer, and almost every single switch or lever in the cockpit is modelled. Most of these sounds were recorded from the actual aircraft and this sound environment just breaks open an entirely new world. However, as you can see, this is not just for entertainment purposes; proper sound is critical to creating an authentic and believable flying experience. Know that when you hear something, it is being driven by actual system physics and not being triggered when a certain condition is met. There is a big difference, and to the simulation pilot, you can just feel it.

Gauge Physics

Each gauge has mechanics that allow it to work. Some gauges run off of engine suction, gyros, air pressure, or mechanical means. The RPM gauge may wander because of the slack in the mechanics, or the gyro gauge may fluctuate when starting the motor, or the gauge needles may vibrate with the motor or jolt on a hard landing or turbulent buffet.

The gauges are the windows into your aircraft's systems and therefore Accu-Sim requires these to behave authentically.



Propellers

The Spitfire: The birth of the Merlin engine and advanced propeller technology

Moving from the Spitfire Mk I to the Mk II propels you almost a full century ahead in propeller technology.

The very first seventy-seven Spitfire Mk I's to roll out of production were fitted with a fixed-pitch, 2-blade, wooden propeller. Just months later, a newer 2-pitch propeller became available and was fitted on every Spitfire starting with the seventy-eighth airframe.

When the Spitfire Mk II started to roll off assembly lines, they were fitted with the newest constant speed propellers that allowed almost every bit of horsepower to be put to the air.

That wooden prop on your Mk I is not much different than the propellers fitted to WWI biplanes, and the constant speed Rotol propeller isn't much different than those fitted on aircraft flying today. It's just astonishing how the explosion and need for creating the very best performing aircraft became a reality in not years, but months, and that same technology has survived to this modern day. But in those early days of WWII, major changes happened, and every pilot must have a solid understanding of these changes.

The propeller to an aircraft is like the tires to a race car.

The propeller is where the engine meets the air. Propeller technology and physics is the foundation of not only prop-based aircraft, but jets, and even ships. A lot happens when an engine drives a propeller to such a speed that it can move a multi-ton piece of machinery, especially through the thin air. The prop blades are basically little wings, biting and grabbing the air, sending it backwards over the airframe and moving surfaces. It torques and twists the aircraft, and twirls the air around it.

As a pilot, you don't need to be an aeronautical engineer to understand the basics of what is going on, so let's just go over the basics.



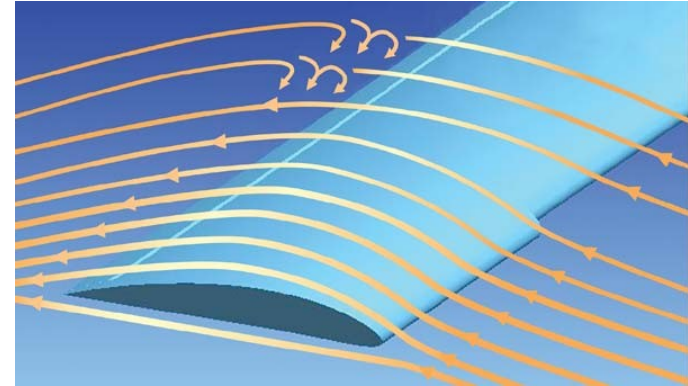
The Airfoil: How a wing creates lift

Before you learn about how different propellers work, first you must understand the basics of the common airfoil, which is the reason why a wing creates lift, and in this case, why a propeller creates thrust.

The Bernoulli Theory

This has been the traditional theory of why an airfoil creates lift:

Look at the image to the right which shows you how the shape of an airfoil splits the oncoming air. The air above is forced to travel further than the air at the bottom, essentially stretching the air and creating a lower pressure, or vacuum. The wing is basically sucked up, into this lower pressure. The faster the speed, the greater the lift.



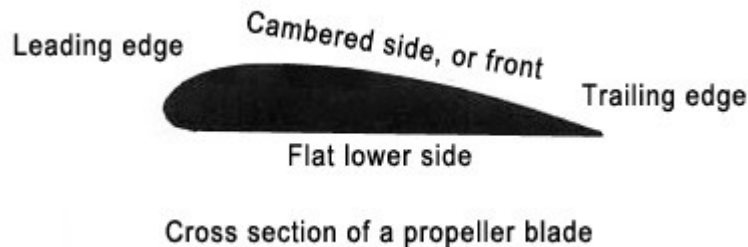
The Newton Theory

As the air travels across the airfoil's upper and lower surfaces, lift is created by shoving the air down with great force at its trailing edge, and to some degree, the Newtonian force of opposite and equal reaction apply.

What we do know (and what the pilot needs to know)

The airfoil is essentially an air diverter. Regardless of what role each theory plays, an airfoil's lift is dependent upon its shape, the speed at which it is traveling through the air, and its angle to the oncoming air (angle of attack).

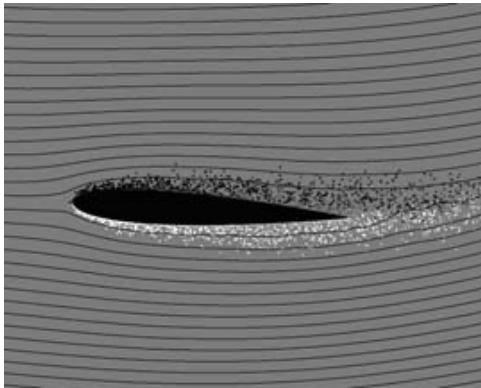
Look at the cross section of a propeller blade. Essentially, the same process creates lift.



Below are some graphical representations of an airfoil travelling through the air in various conditions:

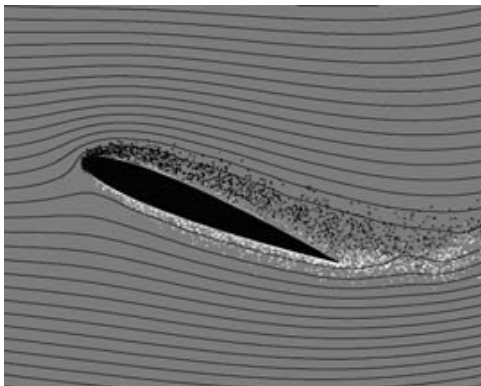
Level Flight

A wing creating moderate lift. Air vortices (lines) stay close to the wing.

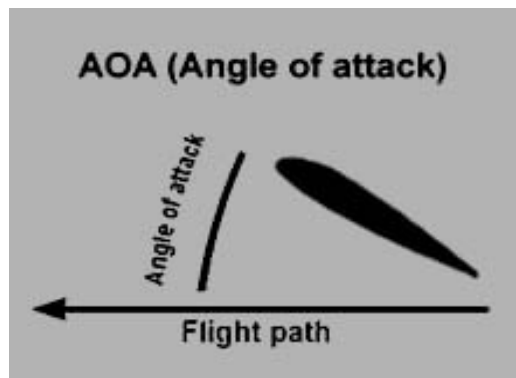


Climb

Wing creating significant lift force. Air vortices still close to the wing.



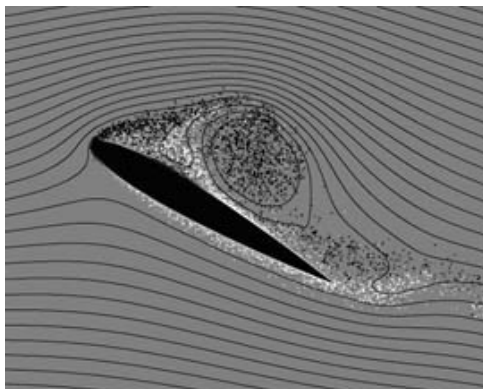
What is a stall? In order for a wing to produce efficient lift, the air must flow completely around the leading (front) edge of the wing, following the contours of the wing. At too large an angle of attack, the air cannot contour the wing. When this happens, the wing is in a “stall.”



Typically, stalls in civilian aircraft occur when an airplane loses too much airspeed to create a sufficient amount of lift. A typical stall exercise would be to put your aircraft into a climb, cut the throttle, and try and maintain the climb as long as possible. You will have to gradually pull back harder on the stick to maintain your climb pitch and as speed decreases, the angle of attack increases. At some point, the angle of attack will become so great, that the wing will stall (the nose will drop).

Stall

The angle of attack has become too large. The boundary layer vortices have separated from the top surface of the wing and the incoming flow no longer bends completely around the leading edge. The wing is stalled, not only creating little lift, but significant drag.



Can a propeller stall?

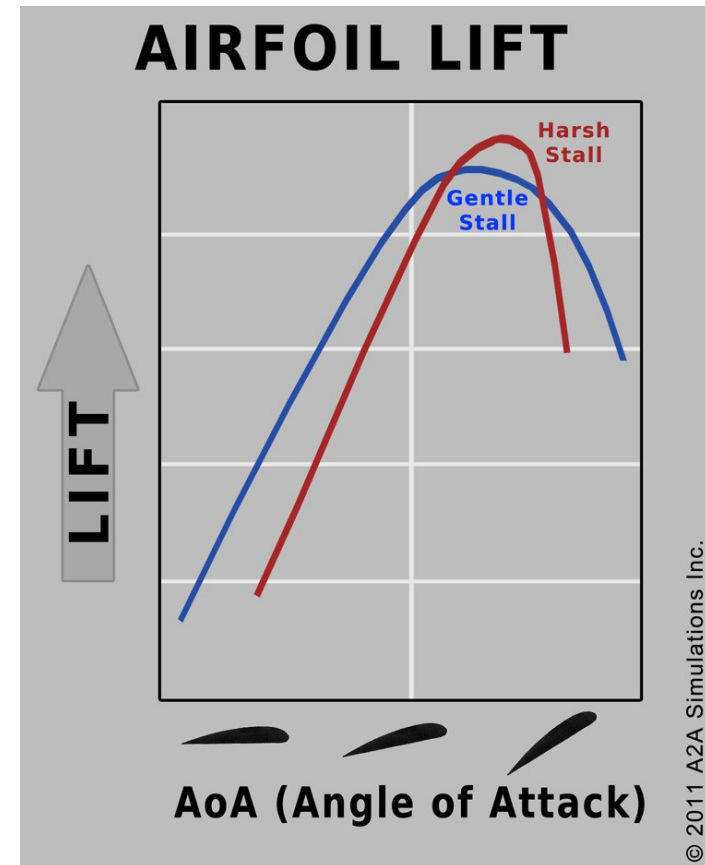
What do you think? More on this below.

Lift vs Angle of Attack

Every airfoil has an optimum angle at which it attacks the air (called angle of attack, or AoA), where lift is at its peak. The lift typically starts when the wing is level, and increases until the wing reaches its optimum angle, let's say 15-25 degrees, then as it passes this point, the lift drops off. Some wings have a gentle drop, others can actually be so harsh, as your angle of attack increases past this critical point, the lift drops off like a cliff. Once you are past this point of lift and the angle is so high, the air is just being plowed around in circles, creating almost no lift but plenty of drag. This is what you experience when you stall an aircraft. The buffeting or shaking of the aircraft at this stall position is actually the turbulent air, created by your stalling wing, passing past your rear stabilizer, thus shaking the aircraft. This shaking can sometimes become so violent, you can pop rivets and damage your airframe. You quickly learn to back off your stick (or yoke) when you feel those shudders approaching.

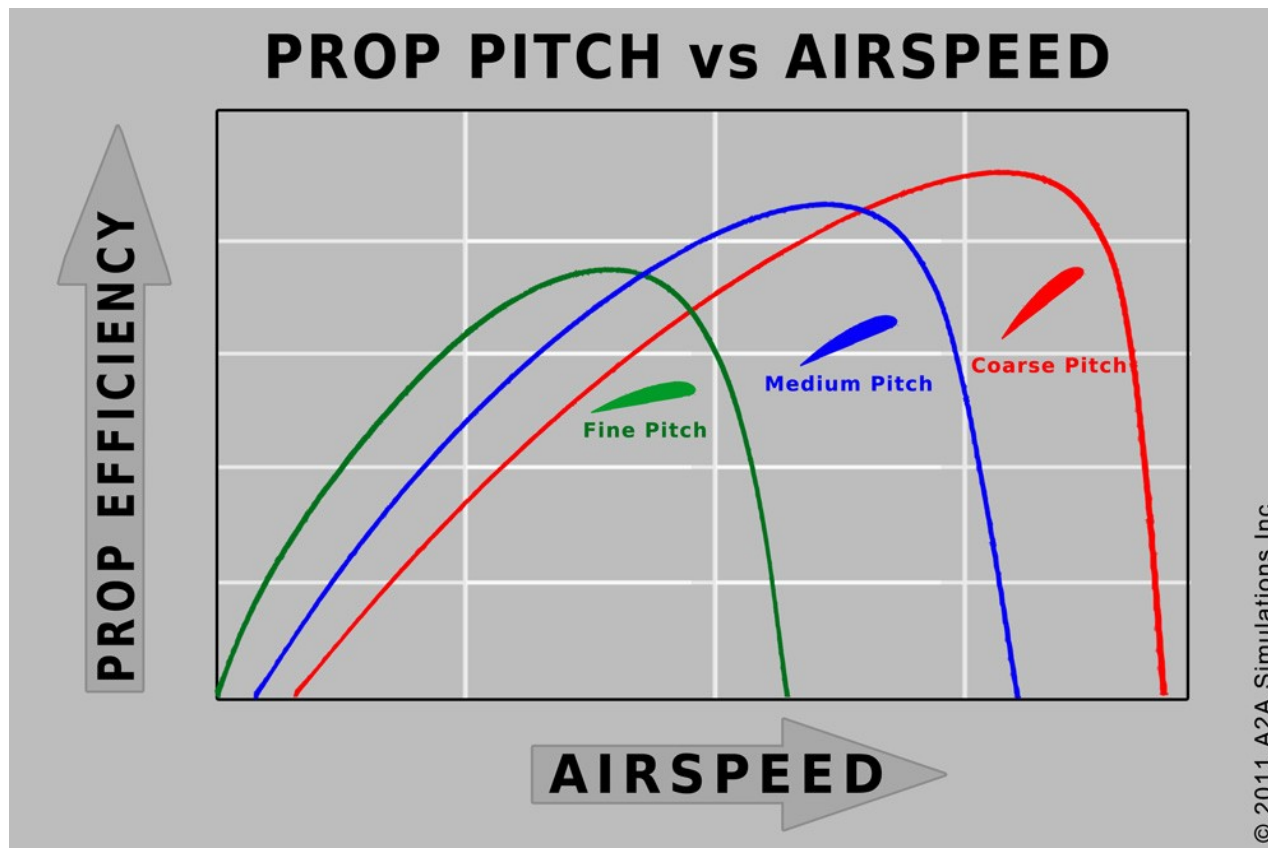
Look how, in the diagram to the right, how the airfoil creates more lift as the angle of attack increases. Ideally, your wing (or propeller) will spend most of its time moving along the left hand side of this curve, and avoid passing over the edge. A general aviation plane that comes to mind is the Piper Cherokee. An older version has what we call a "Hershy bar wing" because it is uniform from the root to the tip, just like an Hershey chocolate bar. Later, Piper introduced the tapered wing, which stalled more gradually, across the wing. The Hershey bar wing has an abrupt stall, whereas the tapered wing has a gentle stall.

A propeller is basically a wing except that instead of relying on incoming air for lift, it is spinning around to create lift, it is perpendicular to the ground, creating a backwards push of air, or thrust. Just remember, whether a propeller is a fixed pitch, variable pitch, or constant speed, it is always attacking a variable, incoming air, and lives within this lift curve.



Propeller Efficiency

Higher RPM, bigger diameter (faster tip speed), and higher angle (referred to as coarse angle) all contribute to the propeller moving more air, faster. Now remember as the incoming air increases in speed (airspeed), the propeller has to increase in either speed or pitch to keep up with this incoming air. If the prop is too slow or the pitch is too shallow (also called FINE), then the prop will act as a brake as the faster air rams into the slower prop. As the prop speed and / or angle increases, it surpasses the incoming air and starts to bite the air and pull the aircraft forward. So a higher angle (coarser pitch) will work better at higher speed. A lower angle (finer pitch) will work better at slower speeds (create more thrust). This relationship of the prop speed and angle to the speed of the incoming air helps to determine how efficient the propeller is operating. The Spitfire's fixed pitch wooden propeller is designed to be most efficient at the very highest speeds, therefore it is set to a very coarse pitch. Look at the red “coarse pitch” line below, and look how inefficient it operates at lower airspeeds. This is why it takes so long to get the plane rolling and airborne, and is only a mediocre climber.



The Fixed Pitch Propeller

This, like an aircraft wing, is set at a fixed angle. The prop is directly connected through a shaft, usually through a reduction gear, to the engine crankshaft. More power means more engine speed which means more propeller speed. A fixed pitch propeller is basically the art of compromise. The propeller engineer chooses an angle that typically does one thing fairly well, but has no choice to accept everything else it does is either fair or or just flat out poor. For example, if you are looking for a “climb prop” you will typically want a propeller with a more shallow angle, allowing for higher RPM's to be achieved at slower climb speeds. If you wish to have a 'cruise prop' you will typically choose a prop that has a larger angle, to be able to take larger grabs of air at higher altitudes, and when the RPM is low.

The wooden prop for the Spitfire was designed to create the best top speed (remember, this is a racer). The engineer's took the altitude at which the Merlin engine created the most horsepower, then pitched the prop so the aircraft arrived at it's top speed when the engine RPM was at it's maximum RPM (3,000 RPM). This is sort of like predicting when two changing lines converge, as the engine speed gives power, and the power gives speed, and the speed pushes the prop. They didn't have the convenience of modern computers; they had to do things the hard way, but they knew what they were doing and they delivered the prop which does exactly what it was meant to do – provide the highest possible speed at 18,000 feet. However, you have traded this top speed performer for very poor takeoff performance.



The Variable Speed Propeller

Unlike the fixed pitch propeller that is just what it says it is, fixed, the variable speed prop allows the pilot to change the prop pitch (angle) with a lever in the cockpit. So now, at takeoff, a pilot can choose a shallow pitch for higher RPM and thrust at these very low airspeeds, and when up high in the thinner air at faster airspeeds, the pilot can choose a coarse pitch allowing the propeller to keep up and continue to be efficient.

2-Pitch

The 2-pitch prop is what it says it is. It has two settings, high and low. The fine pitch is made for slower airspeeds (takeoff or climb), and the coarse pitch is made for higher airspeeds (cruise, high altitude flight, top speed). The Spitfire MkIa is fitted, by default, with a De Havilland 2-pitch propellor.

Variable

Unlike the 2-pitch propeller, the pilot no longer has to choose between two settings, but to smoothly change the pitch from fine to coarse. This is better than a 2-pitch because it allows for the perfect pitch in almost any situation. However, this can be a lot of work. As the conditions can rapidly change in the air (especially in a life or death combat situation), the variable requires the pilot to also respond as quickly as the situation changes.

NOTE: Interestingly, the 2-pitch De Havilland fitted to the Spitfire MkIa actually worked as a variable pitch in reality. Pilot's found, if they moved the prop pitch lever very carefully in that middle band, when it was switching between high and low pitch, you could actually get pitches in between. We have modeled this behavior in our Accu-Sim MkIa Spitfire. You will soon understand why pilots loved this little side effect of this prop system.



Constant Speed

This constant speed prop represents the ultimate solution, as all the pilot needs to do is set the prop lever to the “desired” speed, and the prop constant speed governor does the rest for you. Lets say, for example, the pilot moves the lever $\frac{3}{4}$ forward, where he knows this is about a 2,600 RPM speed. As he throttles up, the propeller “governor” turns the prop to it's lowest pitch to allow for the highest possible RPM. As it approaches this desired RPM, it begins to coarsen the pitch, adding more drag / thrust, and slowing the engine down. The pilot has not moved either the throttle or prop lever, but the prop has, all by itself, adjusted it's pitch to maintain the RPM the pilot has set with his prop lever. So, at almost any flight regime, takeoff, cruise, top speed, dive, or landing, the constant speed prop will try maintain the desired RPM. Notice that I used the word “try” because even a constant speed has it's limitations, of which you the pilot must understand.

The only situation when a constant speed prop cannot deliver the pilot requested RPM is when the prop reaches it's max or min pitch stops, or limit. For example, when static and on the ground, lets say you move your prop lever to it's highest speed, which is 3,000RPM on the Spitfire. The prop is hitting still air, creating huge amounts of force as the RPM increases. The constant speed unit continues to flatten the pitch in its effort to reach the requested RPM. However, with many constant speed props, it its the stop for the minimum pitch before it can reach the desired RPM. So, what you the pilot will noticed is the RPM stopping somewhere short of the 3,000 RPM you requested. As you start to roll down the runway and get some help from the incoming air feeding it, the prop can slowly reach it's goal. Conversely, on a high speed dive, the speed can become so great that the propeller reaches it's coarse pitch stop, essentially becoming a fixed pitch prop. If the speed continues to increase, the RPM will exceed the desired RPM. Finally, when on final, and with a high RPM being requested, as your aircraft slows and you start to pull the RPM back, your engine is now wanting to slow down, yet the incoming air is now pushing the propeller. When you start to notice your RPM drop on final, this is your constant speed unit hitting it's fine pitch stop.

NOTE: If you look closely, you can see the Rotol constant speed maintains a nice fat width, right to the inner hub, whereas the 2-pitch De Havilland is generally a thinner prop. It's just good to know the visual differences, so when you look at your spitfire parked on the ramp, you not only see a prop, but you see what prop is on your plane.



From Stall to Full Power

With brakes on and idling, the angle at which the prop attacks the still air, especially closer to the propeller hub, is almost always too great for the prop to be creating much lift. The prop, is mostly, behaving like a brake as it slams it's side into the air. In reality, the prop is creating very little lift while the plane is not moving. With your Accu-Sim Spitfire, you can achieve higher power without nosing over than in most FSX aircraft because prop stall is part of the Accu-Sim prop physics suite. You can, just as the manual recommends, have two men sit on the tail to hold it down, so you can achieve and test full power without nosing over.

Once done with your power check, you can order the men off your tail, and then prepare for takeoff. Once you begin your takeoff run, you may notice the aircraft starts to pull harder after you start rolling forward. This is the propeller starting to get is proper “bite” into the air, as the propeller blades come out of their stalled, turbulent state and enter their comfortable high lift angles of attack it was designed for. There are also other good physics going on during all of these phases of flight, that we will just let you experience for the first time yourself.

The bottom line is when you open up that Merlin engine, you will see, hear, and feel a lot of new things going on. It is our hope that all of this new feedback not just helps you become a more capable pilot, but you will simply enjoy the experience that much more.



Prop Overspeed

A fixed speed prop spends almost all of it's life out of it's peak thrust angle. This is because, unless the aircraft is travelling at a specific speed and specific power it was designed for, it's either operating too slow or too fast. Lets say you load up your fixed-pitch wooden prop, and you manage to reach your optimum altitude of 18,000 feet. This is where your Spitfire Mk Ia, at full power, will be creating roughly +6psi of manifold pressure (thanks to your supercharger and additional ram air), about 3,000 RPM, and settle somewhere between 270 and 280 mph indicated airspeed. OK, you are now at max speed, max power, and max RPM, just like the engineer's intended. Now you pitch down, what is going to happen? You will immediately go into a prop overspeed condition. If you pitch up your RPM will drop, losing engine power and propeller efficiency. You really don't have a whole lot of room here to play with, but you can push it (as many WWII pilots had too).



Now, take a constant speed prop. You may think, “No problem, it will change pitch and keep the speed proper.” Well, theoretically you are correct, but in reality, things don't happen instantly in life (and airplanes), they take time. The governor in your constant speed hub, has to strike a happy medium between being too responsive, or too sluggish. If it was engineered for immediate response, you would run into oscillation problems (can get dangerous very fast, ending up in destroying your engine as it is yanked from one extreme to the next). If it is too sluggish, well then it is just always behind you, the pilot. So, consider your unit it tuned to deliver the most response with the lowest risk of oscillating. So, if you throw your throttle forward at takeoff, or even in flight, you will likely see your propeller surge ahead, then back off. If you pull the throttle back suddenly, the RPM will drop down, then as the pitch starts to flatten, creep back to your desired RPM.

It is important to know how this unit works, as a pilot, because this is your critical connection of your engine to the air, as said above, just like a car is connected to it's tires.



Types You Can Fly

We have three Spitfire models available, the Mk Ia, fitted with a Merlin III engine designed for 87 octane fuel, +6 psi max boost, or a Mk II with a Merlin XII, designed for the higher 100 octane fuel, beefier block, slightly increased supercharger, and capable of a higher +12 psi. The Mk IIa is fitted with eight .30 cal machine guns and the Mk IIb is fitted with four 20mm cannons.

In the maintenance hanger, you can load either the Weybridge 2-blade, fixed-pitch wooden prop or the De Havilland 2-pitch prop. The Mk II can be fitted either with the Weybridge or the heftier Rotol 3-blade constant speed unit.

Takeoff and Acceleration

Look at these statistics for these props. Knowing what you read above, what does this tell you?

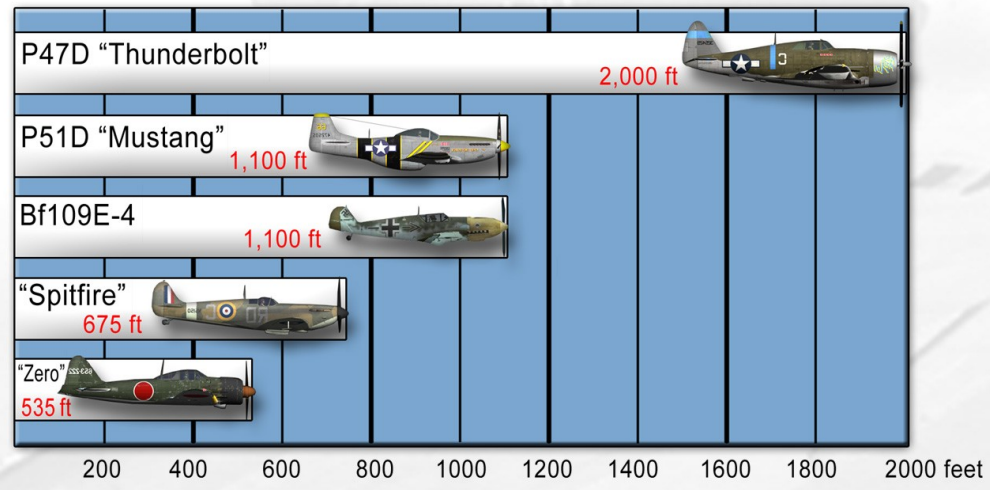
<u>Airscrew (prop)</u>	<u>Take-off run (yards)</u>
Rotol Constant Speed	230
2-Pitch Metal	322
Wooden Fixed Pitch	415

Well, you can see, the Rotol will have the quickest takeoff times, and the Weybridge the slowest. This is because the Rotol can achieve a very shallow pitch which gives almost a full 3000 RPM, max power down the entire runway. The De Havilland 2-Pitch minimum pitch is coarser than the Rotol, so there is more drag, so it can only achieve about 2,600 RPM on the takeoff roll, and the Weybridge can only muster about 2,000 RPM on it's takeoff roll. However, once the aircraft gets airborne and picks up speed, the good old wooden prop doesn't perform all that badly, partially due to the enormous weight savings over it's more complex variable pitch counterparts. In fact, if you were to own a Spitfire, operating it with a fixed pitch propeller would likely save you a lot of money on maintenance and upkeep of an advanced, and heavy constant speed unit. So, looking at these props for what they were, it depends what your goal is. If it is maximum performance, climb, and top speed, then the constant speed cannot be beat. If it is simplicity and reliability, the wooden fixed pitch is the propeller of choice.

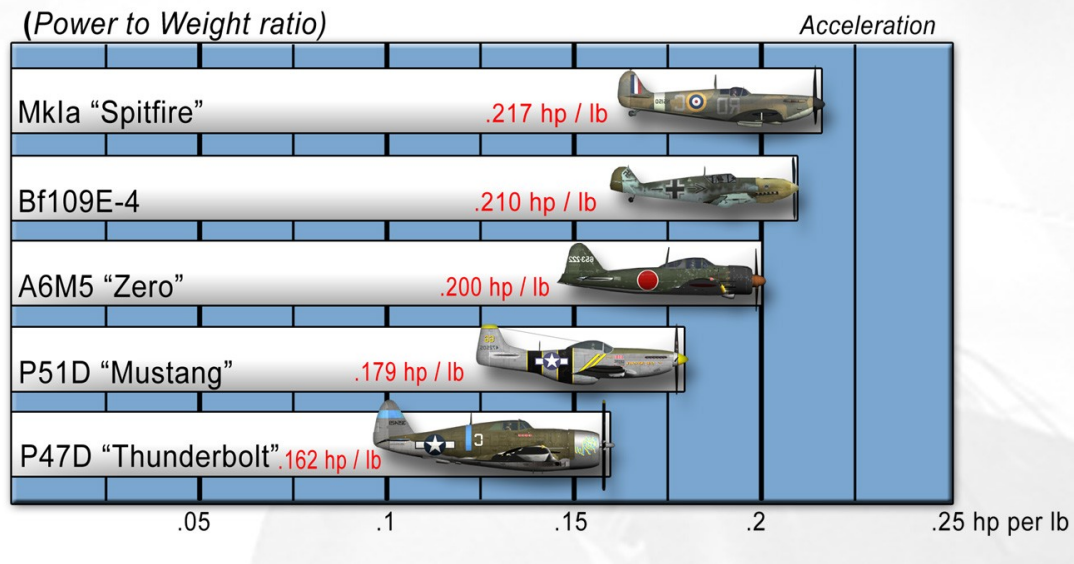
Just for comparison, take a look at how an early mark Spitfire compares to other aircraft in terms of how fast it can get off the ground. This is partially due to the high wing lift at low airspeeds, but also due to the high power to weight ratio.

The lightweight airframe also allows you to get the tail off the ground, almost immediately as your takeoff run begins.

Minimum Takeoff Distance (Combat weight, no stores)



(Power to Weight ratio)

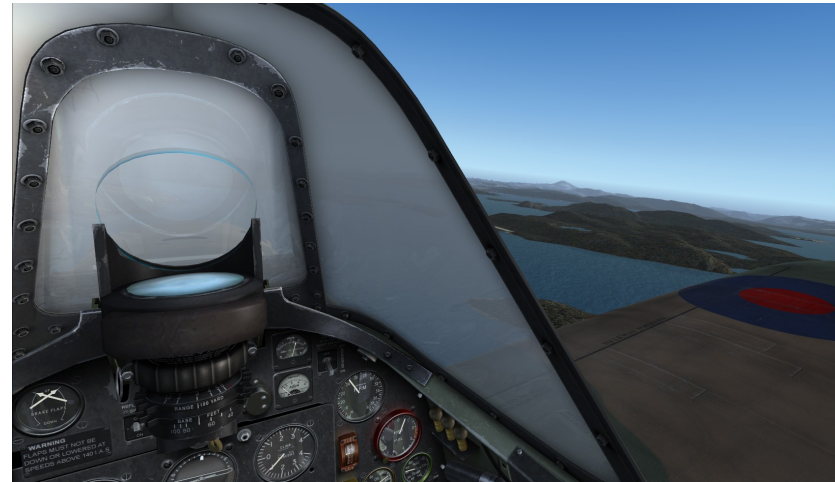


A power to weight ratio is determined simply by dividing the aircraft's power by it's weight. This tells you how much acceleration an aircraft has by determining how much horsepower per pound an aircraft has. Look below, and you can see how the Spitfire with about 65% the horsepower of the larger P47, has a much higher acceleration due to it's low weight. This is another reason why these early Spitfires were and still are so much fun to fly.

Air, Humidity, Visibility

Your new Spitfire doesn't have many things we take for granted in a modern airplane. For example, a heated air defroster. Modern airplanes (and cars) go one step further, and have automated climate control. While this is all very good, it puts that much more distance between you, the pilot, and the airplane. This Spitfire doesn't even have a heater. Flying the Spitfire is kind of like taking a hike, in the sense that when it is cold, you dress warm. The Spitfire is not your long range hauler, it's a thrilling ride. But it can take you places, both high and low, in a hurry, so you need to be prepared for what it is truly like moving from the frigid, dry high altitudes to the warm, moist air at lower altitudes.

Think of air as a wash cloth. The warmer the air, the thicker the wash cloth, and the more water it can hold. Down low, the wash cloth is thick and heavy. Take it up high, it's thin and dry. Now imagine, you are flying at 15,000 feet, and the temperature is about -10 degrees Celsius. The aircraft is cold, the seats, and most importantly, the windows. You now make a dive for that warm, moist air below. In just minutes, that warm moist washcloth is being slammed on your icy-cold window, just wringing out its water because, your window is still frigid and dry. If you want to experience this yourself, put a perfectly dry mirror in your freezer for just 10 minutes. Take it out, and what happens? It immediately fogs up. It's now wet. Hello morning dew. Well, the mirror didn't absorb any water from your freezer, but it basically sucked the water out of the air that was in your kitchen. The warm air in your kitchen hit that cold mirror, the air was then cooled to the point where it could no longer hold the water, and it deposited it on that mirror. In just a few minutes the mirror is clear, why? Well, the mirror slowly returned to room temperature, and the water was then absorbed back into the air.



So when you dive to lower altitudes, your thick canopy will fog up, largely because it is thick enough to hold onto its cold temperatures. No heat in the cabin means the whole cabin is like an ice cube.

However, they certainly weren't cavemen in the 1940's, far from it, and you do have a defroster, that throws hot glycol on the windshield. So, before you decide to lose 10,000 feet in a hurry, reach over and turn on your defroster.

Well, here at A2A, we don't believe in re-inventing the wheel, or faking it for that matter. We also don't like tricks. These are all short term gains with long term headaches. So what we do is model the air with proper meteorological properties. When your canopy fogs up, it could be the above, or it could be your own breath fogging up the inside. Ever sit with a special someone in a car, with the windows up? It's amazing how us humans can act as humidifiers. Well, this is an entire car interior. It takes a lot less to heat up a small, cramped cockpit. When on the ground, at the very least have your vent opened, as even just a 5mph breeze will help exchange that air with the outside (remember, we're talking Accu-Sim here :)) Better yet, do what the pilots do and keep that canopy opened until you start your motor. Then you will have plenty of air passing over the cockpit to flush out any humidity you are putting out.

Landings

Bumps, squeaks, rattles, and stress all happens in an aircraft, just when it is taxiing around the ground. Now take that huge piece of lightweight metal and slam it on the pavement. It's a lot to ask of your landing gear. Well, remember, this is a race horse we are talking about, and so every pound counts. They don't make the landing gear any more rugged than they have too. This is one delicate piece of machinery in this sense, so treat it with kid gloves on your final approach. Kiss the pavement. Anything more, is just asking a lot of this lightweight, narrow landing gear. The same goes for the air forces in the air. Remember, these are air forces in excess of a hurricane. Keep it well under the airspeed limits, in this case 160mph, before dropping your landing gear (or flaps for that matter).



Accu-Sim watches your landings, and the moment your wheels hit the pavement, you will hear the appropriate sounds (thanks to the new sound engine capabilities). Slam it on the ground and you may hear metal crunching, or just kiss the pavement perfectly and hear just a nice chirp or scrub of the wheels. This landing system part of Accu-Sim makes every landing challenging and fun.

Your Turn To Fly

You may not be as strikingly good looking as the pilot is in your Wings of POWER 3 Spitfire (where does A2A get their source?), but what we want you to do is fire up your plane and take advantage of today's technology, just as WWII-era engineer's could only dream about. Start up your Mk Ia with the De Havilland 2-pitch. Idle, then swap in the wooden Waybridge beast and watch that idle drop. Takeoff, and know what it feels like to endure that painfully long takeoff run. Now imagine, you are on a short field with an obstacle at the end. You can see, how even if the wooden prop has some obvious weight advantages but understand through experience why the 2-pitch De Havilland unit eventually replaced all of the wooden units.



Final word on props and simulations.

In a simulation, you know when these forces are wrong, faked, or when they feel right. This is why it is so exciting, as pilot's ourselves, to experience this transition to advanced technologies in a simulation. You will come to realize that changing a props is like changing an engine. Your takeoff roll with a wooden prop is about two times as long as with a constant speed. However, as amazing as a constant speed propeller is, and how it so efficiently squeezes every bit of power out of that engine in almost every situation, the simplicity of a wooden propeller, being about 400 lbs lighter than it's more sophisticated alternatives, is still a marvel. Mastering both units will push your piloting skills to a new level. You will learn respect for what these pilots had to endure with the wooden props, and fully appreciate how a constant speed transitions what was once a tame engine into a screamer. This is what we want to deliver to you, this experience and knowledge to make you a the best pilot you can be, and perhaps most importantly, just have fun flying a wonderful airplane.

Enjoy

Accu-Sim is about maximizing the joy of flight. We at A2A Simulations are passionate about aviation, and are proud to be the makers of both the A2A Simulations Spitfire, and its accompanying Accu-Sim expansion pack. Please feel free to email us, post on our forums, or let us know what you think. Sharing this passion with you is what makes us happy.



Presenting the A2A “Accu-Sim” Supermarine Spitfire MK Ia and IIa and b For FSX

By: Mitchell Glicksman © 2010



“SPITFIRE!”

The very word evokes a unique moment in time, a desperate conflict against implacable, evil forces which were ultimately defeated, one of the highest achievements in aerodynamics and aviation science in its time, a feared foe, a dependable steed, a pilot’s dream machine, an effective and terrible weapon, and one of the most famous and recognizable aircraft in history.

The graceful and elegant Spitfire is all of these things, and more. It is an enduring emblem that uniquely and materially represented a nation at war, desperately fighting for its life, alone, against the odds, and against a more powerful and a more determined enemy than more benevolent Fates might have provided.

Like the Piper “Cub”, the Republic P-47, and the Boeing B-17, no one would dispute that the Supermarine Spitfire is one of the very few aircraft in history which can truly be called a “classic”. The Spitfire takes its rightful place along side of these other aircraft in the A2A hanger as a worthy addition thereto. It is, according to many, including this author, possibly the most beautiful aircraft ever designed. Those often-mentioned elliptical wings, the sharp spinner leading the long and graceful fuselage and tailplanes, the artfully sculptured compound curves, the proportions which look so “right” to the eye; all of these features working together in harmony result in what is a truly salient and outstanding design. The Spitfire looks like what we imagine when we think: “fighter airplane”.

The Spitfire’s greatness as a fighter aircraft was not solely due to its initial design, inspired and brilliant as it surely was. R.J. Mitchell’s Type 300, the Vickers/Supermarine appellation for the Spitfire I went on to be refined, improved and in some cases redesigned in forty major variants over the entire span of WWII and shortly thereafter. Mitchell was not at all impressed with the name “Spitfire” for his creation, and it is reported that he commented when he heard that it had been so named that “Spitfire” was, *"just the sort of bloody silly name they would choose."* Operated by both the R.A.F. and the Fleet Air Arm (Seafire), It was built in greater numbers than any other British airplane, and it appeared in every theatre and in every major conflict that the military forces of Great Britain and those of the nations of the Commonwealth participated in during the war. Esteemed and revered by its pilots, feared and respected by its foes, the Spitfire proudly takes its place at the very top of the pantheon of the greatest aircraft of all time.

Yes, the “Spit” is a legend, mythologically, at least, a “perfect” airplane with no flaws. However, as is so often the case, reality tells us a different story. If you ask a random person who knows anything at all about the Battle of Britain which aircraft saved the day for Great Britain, the answer would invariably and confidently be “the Spitfire”. The truth is that it was the more numerous Hawker Hurricane, a fine aircraft in it own right, which was responsible for the majority of German aircraft shot down in that conflict. Unfortunately, and perhaps unfairly not nearly as well publicized nor as glamorous in appearance as the Spit, the “Hurri” accounted for 1,593 of the 2,739 Luftwaffe aircraft claimed to have been destroyed in the air, almost 60% of all Luftwaffe aircraft destroyed between 10 July and 31 October, 1940. While the exact victory/loss figures continue to be disputed in some circles on both sides, there is no dispute that the Hurri downed the clear majority of German aircraft destroyed in the air in that seminal, history-changing aerial battle.

An Imperfect Work of Inspired Aeronautical Art and Science

As a flying machine the Spit was beloved of its pilots for its responsiveness and performance and properly so; however, as is necessarily true of all of those things which human beings create, it was not perfect. The controls were moderately well- harmonized, but only at middle and lower airspeeds.

The ideal for control harmony is that the order of sensitivity is: ailerons, then elevator, and then rudder. In the early Spit Marks, the elevator at all airspeeds and the rudder at higher airspeeds were far more effective than the ailerons, violating the aforementioned control harmony concept. In fact, in all Spitfire Marks the elevator, in particular, was very sensitive, resulting in many cases of unintentional and sudden accelerated stalls as well as inadvertently over-stressed airframes and pilots at high speed.



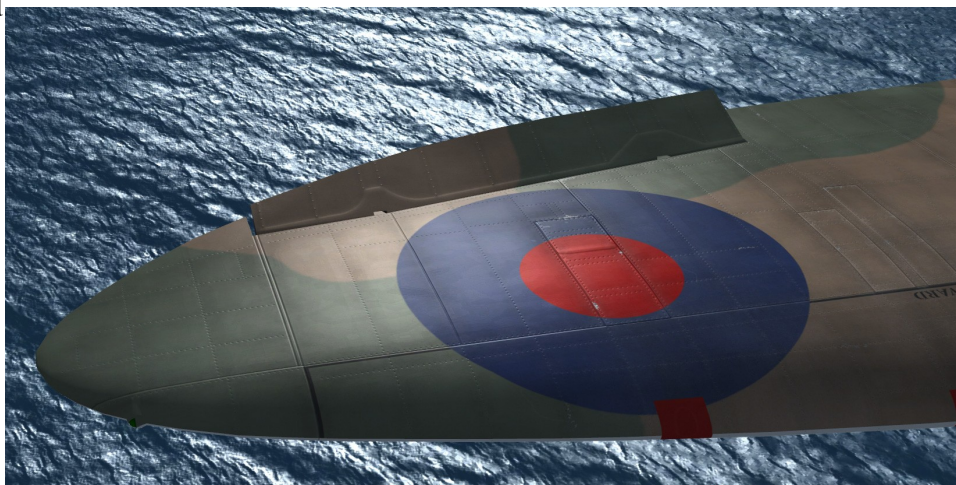
The Spit's ailerons gradually became heavier and less and less effective as airspeed increased until they were almost completely ineffective at airspeeds approaching and beyond 380 m.p.h., and very heavy during mid-to-high speed high aerobatics. Interestingly, the Spitfire shared this characteristic with another famous, nimble aircraft, the Mitsubishi Zero-Sen. As was a common aviation practice in the mid-30s and early 40's, Spitfire Mk I-IV had fabric covered control surfaces, including the ailerons - and therein lay the problem. (Mks III and IV were experimental models and were not put into production).

In the late 1930's and throughout WWII, Alex Henshaw was, first, a test pilot for Vickers/Supermarine, Weybridge, and then Chief test pilot at Castle Bromwich, Birmingham (the main Spitfire MK II manufacturing plant). In this position, he worked closely with the R.A.E. (Royal Aircraft Establishment) located at Farnborough Airfield, Hampshire, a government run group of scientists and test pilots, created to do scientific aviation research and which was primarily responsible for testing and making suggestions for improving all British service aircraft. In the spring and summer of 1940, Mr. Henshaw extensively flight-tested Spitfire Mk I and II aircraft along with his associate, Vickers/Supermarine's Chief test pilot and Spitfire prototype pilot, Jeffrey Quill. Regarding the Spitfire Mk I's ailerons, Henshaw wrote:

“I had hoped that the aileron control on the new Mark IIs would be better. On my earliest flights in the Spitfire I felt the controls were light and well-harmonized. I had no reason to change my mind until I started to use combat manoeuvres at high speeds or perform aerobatics and then I found the ailerons excessively heavy.”

(Henshaw: “Sigh for a Merlin”; 1996 p. 58)

Concerned and puzzled by the Spit’s aileron deficiency, Vickers/Supermarine, in association with the R.A.E., began to do intensive tests on the Spitfire at high airspeeds. A number of modifications to the Spit’s ailerons were tried with no substantial improvement until the ailerons were covered with thin aluminum. On 19 November 1940 Sandy Johnstone, a Vickers/Supermarine test pilot flew a Spitfire I (R6718) with metal ailerons and thin trailing edges at high airspeed; and, as Jeffrey Quill, remarked “The aeroplane was transformed.” The metal covered ailerons vastly improved the Spitfire’s roll axis at all airspeeds.



Quill further remarked, “After ‘Sandy’ Johnstones's flight (19 November) at Westhampnett, the word swept round Fighter Command like wildfire and in no time the air around Hamble was thick with the Spitfires of Wing Leaders and Squadron Commanders all trying to jump the queue to get their aircraft fitted with the new metal ailerons - Douglas Bader leading the hunt!”

Fabric covering is lighter than aluminum and the idea was that an aileron covered with fabric would be lighter aft of the hinge line, thereby fostering lighter lateral control stick pressures for the pilot. The aluminum covered ailerons would also require limited or no external mass balancing, which would increase their efficiency and reduce drag. Fabric covered ailerons were fine at relatively low airspeeds; but for all of the reasons stated above it was discovered that as airspeed increased the negative pressure of the airflow over the aileron’s surface also increased, causing the fabric covering to balloon outward from the top and underside of its metal frame, changing the aileron’s aerodynamic shape, creating drag, and greatly decreasing aileron control displacement. This was somewhat, but not entirely solved by changing the fabric covering for a thin aluminum covering. While the problem with the ballooning fabric covering was thereby eliminated, and aileron effectiveness was greatly improved at all airspeeds, particularly at airspeeds near or above 380 M.P.H., the Spitfire’s aileron’s control displacements remained somewhat reduced at higher airspeeds. Interestingly and ironically, it was judged at the time that the metal covered ailerons actually produced a lighter control feel than had the fabric covered ones.

“With metal covered ailerons the lateral control is much lighter than with the earlier fabric covered ailerons and pilots accustomed to the latter must be careful not to overstress the wings.”

(Excerpt from the British Air Council’s “Pilot’s Notes”, November 1940; provided to Spitfire pilots.)

While some existing Mk II aircraft began to be gradually and sporadically retrofitted with metal ailerons, they were not universally installed in the Spitfire until the Mk V entered service in February 1941. After a short while, it was speculated that a possible reason why, even with aluminum covering the ailerons’ effectiveness was still reduced at high airspeeds, was that wings themselves might be twisting torsionally when the newly efficient ailerons were operated at high airspeeds, thus causing not only a marked negation of the ailerons’ effect, but in some extreme cases, approaching actual aileron reversal. Jeffrey Quill, writing about how aileron reversal affected the Spitfire said,

“...had we, in 1941, been able to produce a design of aileron capable of allowing much greater control displacements at very high speed we should soon have been in serious trouble with what was known as ‘aileron reversal’ arising from lack of torsional stiffness of the wing.”

(Quill: “Spitfire: a Test Pilot's Story”; 1983 pp.272-273)

Quill further says that in the early Spitfire Mk's, the theoretical speed at which aileron reversal would have occurred was around 580 m.p.h. In the 1940s and even later, piston aircraft could not even approach this airspeed, except possibly in a near vertical power-dive, from which recovery was not likely. Quill goes on to say that the Spitfire with metal covered and thereby more effective ailerons was “teetering on the edge” of aileron reversal, but that the problem was not yet endemic or something to worry unduly about as the ailerons were not so effective as to actually twist the wing so far as to cause a reversal of roll control. Clearly, an attempted aileron turn at 580 m.p.h., if such was even possible due to the tremendous control forces present at such high airspeed (the early Spitfire Mk's did not have mechanically or aerodynamically boosted ailerons), would have likely resulted in the complete destruction of the aircraft, or as it has been more prosaically said, “the wings, fuselage and tailplane would adopt independent descent profiles.” (Thank you Darryl)

In any event, the Spit’s wing was not completely redesigned until the Mk 21 in which the airfoil and internal structure were entirely changed and the aileron reversal point was raised to an impossible to achieve, theoretical 825 M.P.H. The Mk 21 was an entirely new aircraft in many ways and was one of the later operational Spitfires which were flown during WWII. It entered service in December 1943, at which point the aileron control problems of the early Mk's were a thing of the past.

Negative “G” Means No Power

As engine design and engineering and advances in metallurgy made improvements to the Merlin engine possible, Spitfire Mk I-IV's performance continued to advance. However, all of these early Marks had one serious flaw, their Merlin engines would cut out when the aircraft was flown at a negative “g”, such as when pushing forward to commence a dive. German pilots knew of this flaw from when they encountered Hawker Hurricane Is over France in the spring and early summer of 1940 (10 May - 3 June) , and took good advantage of it thereafter. The Messerschmitt Bf109E, which the Spitfire Mk I and II encountered in the summer and early fall of 1940, had a fuel-injected Daimler-Benz engine which kept running perfectly under negative “g”. In France and in the Battle of Britain, the best way to get a Spitfire (or a Hurricane, which used the same engine) off your tail was to push forward into a power dive. The Spitfire could not immediately follow, since pushing forward from level flight meant that the aircraft would be at negative “g” for a few moments, during which time the engine would cut out and the aircraft would have no power. The only practical way for a Spit or a Hurri to follow the diving Messerschmitt without losing power was to do a half-roll and pull positive “g” to get the nose down. This was not usually an adequate solution since by the time this had been accomplished, the German fighter would often be long gone.



The problem was the SU- type float carburetor. Under negative “g”, fuel would be forced to the top of the float chamber and would not initially enter the engine. A moment more of negative “g” and the incoming fuel would push the carburetor float to the underside of the float chamber. The lower float position now opened the fuel supply valve regulating the entry of fuel into the carburetor, causing it to flood. Excess fuel in the carburetor would now enter the engine becoming an over-rich mixture which flooded the supercharger, causing an over-rich cut out and, accordingly, no power.

No solution for this was found during the Battle of Britain and one may only speculate grimly about how many British pilots and their

aircraft were lost due to this flaw in the design of the Merlin's carburetor. It seems incredible that an engine installed in a front-line fighter aircraft would be so fatally handicapped by such a primitive, inadequate, and thoughtless design, particularly when other options were available. As more and more complaints regarding this flooded the Air Ministry, who passed them on to Vickers/Supermarine, a solution to this engine cut-out problem was sought.

Beatrice Tilly Shilling, an Aeronautical Engineering graduate of Manchester University, worked as a systems analyst at the R.A.E. (see above). She was an unusual woman in her time, not only for her being an aeronautical engineer, but because she was also an avid, trophy-winning motorcycle racer. (see photo)

The negative "g" engine cut-off problem having come to the R.A.E. by the summer of 1940, activities to find a solution to it were commenced. Miss Shilling was assigned to the team investigating what might be done, and by late 1940 she came up with a brilliant solution: the fuel flow would be restricted by a metal diaphragm, a specially sized orifice, which would be fitted to permit just sufficient fuel to enter the carburetor (still the Su float-type) necessary to provide maximum power (at first 12 psi and shortly thereafter 15 psi) and to prevent excess fuel flow from causing an over-rich condition.

In early 1941, Beatrice Shilling and her team traveled to every airfield where Spitfires were deployed and oversaw the fitting of this device. It was installed in every Spitfire by March 1941 and was lauded as a great triumph. Fighter pilots, being the cheeky wags that they invariably are, named the new device "Miss Shilling's Orifice" or the "Tilly orifice", which must have greatly embarrassed Miss Shilling. The official name for the device was the far more conservative "R.A.E restrictor", which is descriptively correct, but not nearly as much fun.

(This is a photograph of the formidable looking Miss Shilling on her formidable looking motorcycle, pictured here in the mid-1930's with her Manx 500 which she often raced, and upon which became the first woman to lap Brooklands at over 100 M.P.H.)



Stay Cool, Man

Spitfire Mk I-VII have a single radiator mounted under the starboard wing. It has a manual shutter control and it's fine...in the air, and if the pilot carefully monitors the engine temperature gauges. On the ground, well, that's another story entirely. Spitfire pilots soon discovered that there is a very short window of time, five to ten minutes, give or take, depending, of course, on the outside air temperature, within which a Spitfire could be started, taxied and taken off before its cooling fluids boiled over.

As the Merlin engine was steadily improved and its power increased, Supermarine engineers soon realized that more radiator surface was required to keep the cooling fluids within proper operating temperatures. Accordingly, starting with the Mk VIII, a second under-wing radiator was installed under the port wing, adding a bit of drag (see below), but giving the old Spit a more symmetrical look. Even with two radiators, pilots still had to carefully watch their temperature gauges when the engine was running whilst on the ground, but the situation was now far more satisfactory.



(A2A Note: The heating/cooling system as well as all of the other systems and controls of the Spitfire Mk I and II have been faithfully and accurately replicated in the A2A Accusim Spitfire. We therefore highly recommend that you start the engine at a location close to the active runway or takeoff area, and that once the engine has been started that you commence the takeoff as soon as possible to prevent boiling over and the engine seizing. Monitor your engine temperature gauges at all times to prevent this from taking place. Periods of standing with the engine operating and/or taxiing for long distances should be avoided. With regard to this and all of the other aspects of operating the A2A Accusim Spitfire, you will be taking the same precautions, doing the same tasks, and sharing the same experiences of real-world Spitfire pilots.)

Draggy Radiators

In a report entitled: “Note On The Cooling Of Aircraft Engines With Special Reference To Ethylene Glycol Radiators Enclosed In Ducts”, communicated by the Director of Scientific Research, Air Ministry Reports and Memorandum No. 1683; 14 August, 1935, written by F. W. Meredith, B.A., an aeronautical engineer working at R.A.E., the concept that an aircraft’s radiator duct could not only cool fluids but also provide thrust, thus more or less offset the drag that the protruding radiator duct caused.

Spitfire Mk 1-VII had one such “Meredith duct” radiator mounted under the starboard wing; and thereafter, two, one under each wing. While this innovation was appreciated and widely adopted by aircraft designers and manufacturers world-wide, the design of the external, box-style aircraft radiator duct still produced a good deal of drag. It was reckoned that this kind of external radiator duct accounted for as much as a 30-35 m.p.h. penalty; perhaps more in some designs.

In April, 1940, North American Aircraft (NAA) designers Raymond Rice and Edgar Schmued designed what became what was arguably, but which is widely acknowledged to be the finest fighter aircraft of WWII, the P-51 “Mustang”. This aircraft came to light because the British Air Council Sub-committee on Supply (or “Supply Committee”), who were seeking to enhance the production of fighters for the R.A.F., authorized the British Purchasing Commission to approach North American Aviation with the intent of having them build P-40’s (Tomahawks) for the R.A.F. James H. “Dutch” Kindelberger, the president of North American Aviation, went to his engineers and designers and came back with a counter-proposal: NAA would build an entirely new fighter aircraft design which used the same Allison V-1710-39 engine as the P-40; but which aircraft would have far superior performance in every regime.



The rest is well-known history; the fabulous P-51 which NAA sold to the British incorporated a number of innovations which provided it with the superior performance that NAA had promised. Among these was a brilliant solution to the draggy radiator that plagued so many aircraft designs, including the Spitfire.

The P-40 that the British wanted NAA to build has a large air intake opening in the nose, just behind the airscrew, in which the radiator is

housed. The problem with this is that the extra area at that position on the aircraft causes a number of drag components to come into play, including interference with the efficiency of the airscrew itself. To avoid this and still have a large enough air intake opening to provide sufficient cooling, when designing the P-51, NAA engineers moved the radiator and oil cooler back, away from the front of the fuselage to a position at the underside of the fuselage, under the wing. The exact position of the air intake coincides with the same point where the wing's laminar airfoil (yet another NAA performance enhancing innovation) is thickest. The whole radiator/oil cooler housing was designed to be an integral part of the structure of the fuselage, and thereby creates no extra form or interference drag as does a box-type radiator duct rudely slung under a wing or fuselage, as was the common practice up to that time. The NAA engineers incorporated the Meredith duct thrust effect into this radiator design as well, giving the P-51's radiator the most efficient and least "draggy" radiator and oil cooler assembly known at that time.

As if this was not enough, the really clever and creative thing that was incorporated in to this already innovative radiator design was the way that the intake was designed. Up until the P-51, on every aircraft that had an air intake of any kind, whether it was mounted on the fuselage or on the wings, one side of the intake was flush with the surface it was immediately adjacent to as can be clearly seen when looking the front view of a Spitfire. The NAA engineers realized that this was the cause of the majority of the interference drag created by an air intake. To eliminate as much of this drag as possible, they offset the intake, dropping it away from the underside of the fuselage of the P-51 by a few inches and gracefully fairing it so that it smoothly flowed back into the main structure.

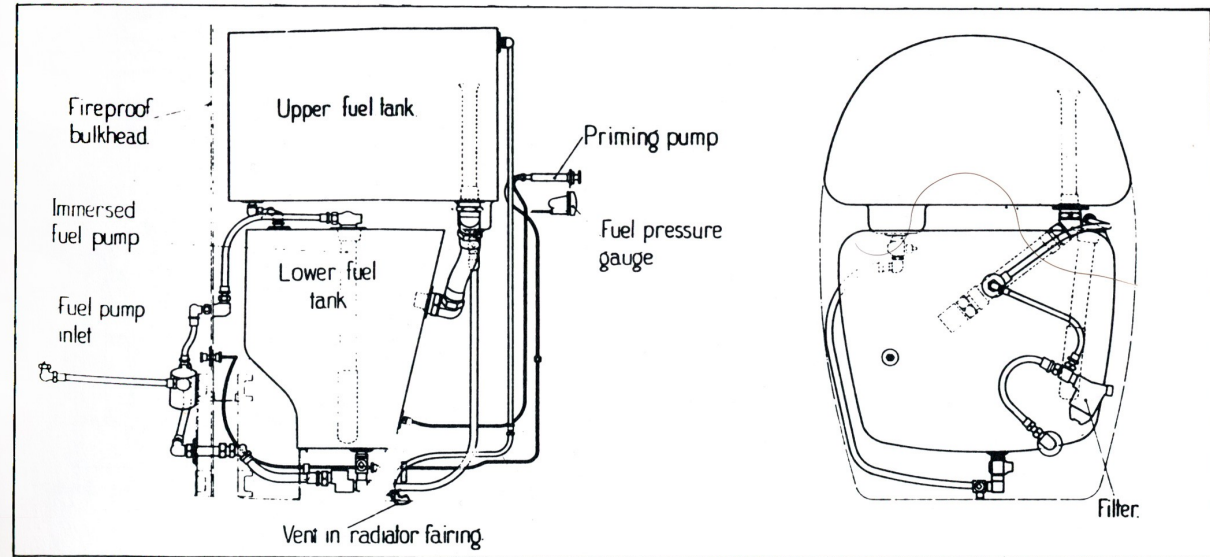
That this indeed reduced a good deal of drag was confirmed in the NAA's wind tunnel. NAA engineers also experimented with the shape of the intake, eventually making it a squashed horizontal oval that did not drop down too far into the slipstream. The combination of the offset air intake and its horizontal shape permitted the maximum volume of air to be taken into the radiator, while at the same time greatly reducing its form and interference drag.

In March 1940 the British Purchasing Commission gave NAA an order for 320 Mustang I's. Certainly, it is reasonable to expect that the B.P.C. inspected and went over every aspect of the new aircraft in detail, including its innovative radiator/oil cooler intake, before it was approved for purchase. The R.A.F. was familiar with and operated P-51s throughout the war. Why then did no one at Vickers/Supermarine or at R.A.E. take notice and adopt this new drag reducing aerodynamic technology for the Spitfire and other British aircraft? Placing the radiator at the middle of the underside fuselage of the Spitfire as on the P-51 would have required an entirely new aircraft design and was unfeasible given the R. A. F.'s desperate need for fighter aircraft to be delivered as soon as possible. However, slinging the under-wing radiator duct intake down a few inches from the underside of the wing would surely not have required much more than a little metal fairing work. Mysteriously, Spitfires never incorporated this design element and accordingly, they suffered an unnecessary and easy-to-eliminate performance-robbing drag penalty.

You Can't Get There From Here

Much has been said about the limited amount of internal fuel that the Spit could carry. While this was increased over time and some form of droppable external fuel tank was designed (the “slipper”); the fact is that the short duration and range of the early Mk's of the Spitfire did not come about by negligence or by accident.

It is common sense and a fact of physics (which are often the same thing) that an aircraft carrying less weight will perform better than one which is loaded down with more weight. Fuel weighs approximately 6.25 lbs. pounds per U.S. Gallon, 7.2 lbs. per Imperial Gallon, depending on temperature (lower temperature - heavier, warmer temperature - lighter). As you fill large wing or fuselage tanks the weight multiplies quickly. The Spitfire was designed from the first for point-defense. As opposed to area-defense aircraft or offensive aircraft, an aircraft designed for point-defense necessarily has a short duration and range, flying with as little extra weight as possible so that it can climb, manoeuvre and perform as effectively as possible.



When it was designed in the mid 1930s, the Spitfire's distinctly point-defense combat mission profile did not require it to be in the air for much more than an hour or two at most. Accordingly, the Spitfire and its stablemate, the Hurricane both had little on-board fuel capacity. As the war proceeded and the Allies went on the offensive, the Spitfire's limited range became a handicap. While still one of the best fighter aircraft of the war on any side, with only its internal fuel it just couldn't stay in the air long enough to perform many types of offensive missions. This is why Spitfire squadrons were usually based as close as possible to the active combat front in Europe, a situation that put them, their pilots and crews in substantially more jeopardy from German air attacks than other aircraft types.

The addition of external fuel to the Spitfire was never entirely successful. The “slipper” tanks and such that were used to increase the

aircraft's range reduced performance sharply, as do all external tanks. The necessary and practical practice of dropping external tanks when the enemy is encountered was not practical for the Spit if such an encounter took place too far away from home base. In such cases, with the slipper tanks dropped, the Spits might not have enough internal fuel to return home, which was, as mentioned above, often located just over the front lines. Falling short of getting home in this case was not just inconvenient; it meant certain capture or worse and the definite loss of the aircraft.

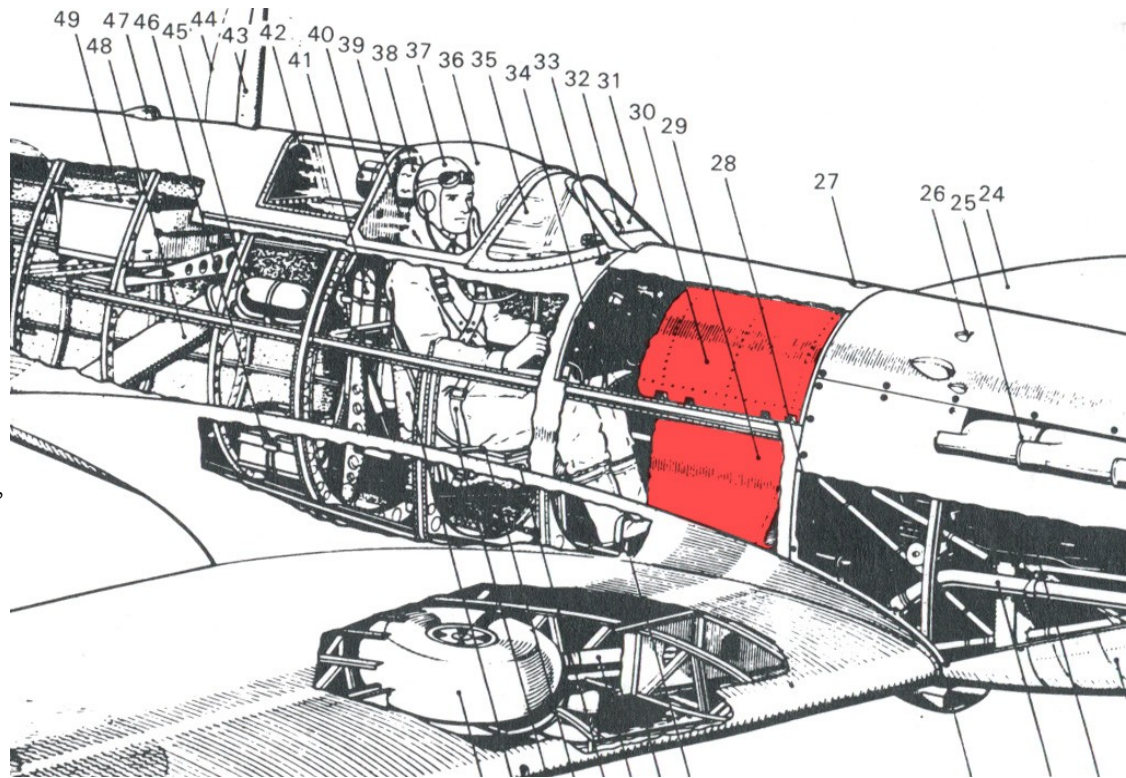
When comparing the great WWII fighters, no knowledgeable person ever denigrates the Spitfire's ability to fight and win. However, the prize for the best usually goes to the P-51 "Mustang". As it was said during the war, the Mustang can do for eight hours what the Spitfire does for two.

"The Faceless Few"

Your author respects and honours all of those who have fought and were killed or injured whilst in service, and does not intend in any way to make light of this subject. The above heading was taken from that which some of the victims of fire in the cockpit of Spitfires actually good-naturedly called themselves, darkly and ironically paraphrasing a part of Churchill's famous speech referring to the R.A. F. fighter pilots in the Battle of Britain: "Never in the course of human conflict has so much been owed by so many to so few."

In early Mk's of the Spitfire, all of the fuel was carried in two fuel tanks, one above the other, located just behind the engine, and just in front of the cockpit. The highly inflammable glycol cooling fluid tank was mounted near the front of the engine. Spitfire Mk's I and II had a very thin, virtually ineffective aluminum "firewall" between the two fuel tanks, the glycol tank and the cockpit. If during combat either fuel tank or the glycol tank were ignited by enemy fire, blue-hot flames would quickly stream back into the cockpit and engulf the pilot, usually too quickly for the pilot to bale out and escape the conflagration before serious burns were inflicted. The resulting burns, if not fatal, were invariably catastrophic to the hands and face.

There is little more to say about the unfortunate, foolish and possibly criminally negligent placement of so much volatile liquid where it would be most dangerous and where it would do and did the most damage to the pilot when set alight - not an entirely unexpected situation in a combat theatre where incendiary ammunition was commonly and copiously used by both sides. The Spitfire was not the only aircraft that had such a thoughtless fuel tank/cockpit arrangement; the Hawker Hurricane's glycol tank is located immediately ahead of the cockpit followed, in turn, by a large fuel tank. In the Chance-Vought "Corsair" the main fuel tank is also located just ahead of the cockpit. That the Spitfire shared poorly planned fuel placement with other great fighter aircraft did not in any way lessen the consequences to those unfortunate pilots who were so horribly burned thereby.



British and Commonwealth pilots were not the only ones to suffer from negligent fuel/coolant supply planning. The Bf-109 had its main fuel tank located under pilot's seat insuring a deadly result in the event of its ignition; and the Japanese Zero-Sen had wing tanks, but they were not self-sealing and the aircraft had absolutely no protective armour - anywhere. Accordingly, it has been said that Zeros could be flamed by a warm breeze.

While we accept and understand that those who participate in aerial combat are expected to, and do, risk their lives and bodies to accomplish the missions that they are called upon to perform, this author does not think that it is too much to expect that those who do so will be provided with machines that are not unduly likely to become fiery death traps.

“One Hit in The Wrong Place and You’re a Goner!”

All of the liquid-cooled aircraft of WWII shared one common flaw: a hit in the cooling system, no matter how small or from where, would likely cause the cooling fluid to leak and deplete, which in turn, soon caused the engine to overheat and stop. This made aerial combat and ground attack missions in particular more dangerous by a large factor when performed in an aircraft with a liquid-cooled engine than in an aircraft with an air-cooled one. The Republic P-47 “Thunderbolt” is considered by many to be the best ground attack aircraft of WWII partly because its Pratt and Whitney R-2800 radial engine was air cooled and would keep running even after it and its various systems had taken multiple hits which would have quickly caused the failure of any liquid-cooled engine.

The Spitfire’s Merlin engine was liquid cooled. Even in air-to-air combat such as the Spitfire Mk I and II primarily if not exclusively engaged in, any random, even accidental hit in the cooling system from a stray bullet from either the enemy or a friendly aircraft or from shrapnel and/or debris, would be sufficient to cause the stricken aircraft to soon have to land, or for the pilot to be compelled to bale out (note: the British spelling “bale” is used throughout herein). Fortunately for the R.A.F. pilots during the Battle of Britain, if they had to either land in a field or bale out over land, and if unhurt, they could shortly get back in the fight. If the same happened to a German pilot, he would surely be captured. (See “Mrs. Miniver”, a great, classic and stirring film about the home front in south-eastern England before and during the Battle of Britain in which a housewife, Mrs. Miniver, brilliantly played by Greer Garson, is at first surprised by a downed German airman, and eventually takes him prisoner.)

Of course, not all of the combat in the BoB was over land. In such case that a Spitfire pilot had to bale out over the Channel, his chances of survival were small. The waters of the Channel are very cold even in the summer, and at that time the British had a very inefficient pilot rescue system, far less efficient than the Germans had for their pilots who found themselves in a similar circumstance.

Interestingly, the vaunted rearward placement of the radiator in the P-51 was both a good and a bad thing in this regard. In air-to-air combat the P-51's radiator was largely protected by the wing, unless the aircraft was attacked from below. However, in ground attacks, the P-51's radiator was more likely to be hit than a radiator located in the nose of the aircraft, such as in the P-40, or under the wing as on the Spitfire. This was because the nature of ground-defense fire against fast-moving incoming aircraft is that very often it does not properly or sufficiently “lead” the attacking aeroplane (to hit a moving target traveling at any angle across your path, you must fire sufficiently ahead of it, “leading” it, so that when the bullets reach the target they will hit it; otherwise they will fall behind the target). Accordingly, ground-fire hits are more likely to strike the middle to the aft section of the aircraft, right where the P-51’s radiator is located. In this sense, the Spitfire was the safer and better aircraft for ground attack than the P-51 as it was more likely to survive ground fire and make it home.

A Delight in the Air, a Dog on the Ground

The geometry of the Spitfires undercarriage is such that the struts are anchored and hinged at the wing root with the wheels outboard, retracting outward, away from the fuselage. This arrangement was necessary because the Spitfire's wing is so thin near its mid-span point that the undercarriage retract mechanism, motors, the substantial gear hinges, etc. will not fit into the wing where four machine guns and their ammunition are also located. Accordingly, the undercarriage hinges and retract motors had to be mounted in the thicker wing root. This, of course, means that the width of the undercarriage track is very narrow. If this were not bad enough, the fore-aft placement of the undercarriage in the Mk I and II is located fairly rearward in the wing, very close to the longitudinal centre of gravity (Lcg). Additionally, as mentioned before, the fuel and glycol tanks are located ahead of the cockpit, well ahead of the Lcg. What this means is that when these tanks contain any considerable amount of fuel, the aircraft will be loaded forward. This forward loading (nose heaviness), combined with the rearward location of the undercarriage struts means that the Spitfire is liable to tip up very easily.



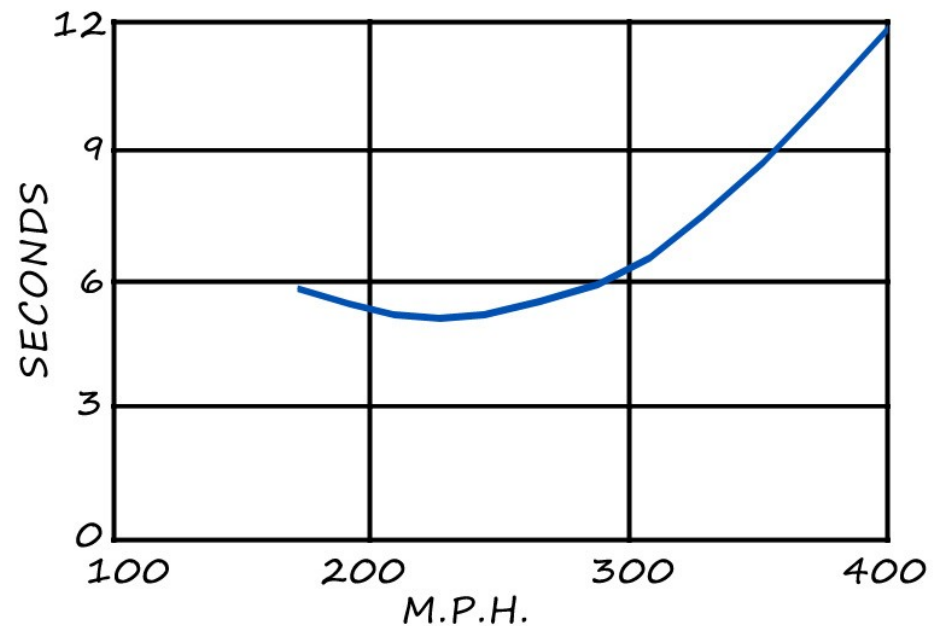
A too-hard application of the brakes while taxiing can easily cause the airscrew to strike the ground. With a running engine this usually causes serious if not catastrophic damage to the engine and the complete destruction of the airscrew. Pilots were forewarned about this situation and it was specifically emphasized in every manual and POH; nevertheless, many otherwise perfect Spits were seriously damaged on the ground, whilst taxiing, taking off and landing. Ironically, the Spitfire shared this sorry record of frequent damage on the ground with its arch-foe, the Messerschmitt Bf-109, which while it was, conversely, a tail-heavy airplane, it also had poor, often catastrophic ground handling characteristics. Starting with the Mk Vc (the suffix “c” indicating the “universal” wing which could mount eight .303in. machine guns, or four 20mm cannon, or two 20mm cannon and four .303in. machine guns), the undercarriage was strengthened and moved a few inches forward. This helped ground handling to some degree, but did not entirely eliminate the easy tipping-up that plagued all of the early Spitfire Mk's.

Wing Too Long – Roll Too Slow

The Spitfire was designed in 1934, a time when military flying fields were mostly grass and not all that large. After all, how much of a field did R.A.F. biplanes like the Hawker Fury or the Gloster Gladiator require, given their extremely slow take off and landing speeds? The new, retractable undercarriage, metal monoplanes of the mid 1930s were a great leap forward in technology and performance, however their pilots were mostly the same lot that had been recently flying Furys and Gladiators with their gentle, slow and forgiving landing characteristics. R.J. Mitchell was aware that the Air Ministry would not approve any new fighter design that tasked air service pilots too rigorously. A dirty (flaps and gear down), un-accelerated (one “g”) stall speed of around, and preferably less than 70 M.P.H. was the goal; and even that was considered to be pretty hot in 1934.

Accordingly, Mitchell drafted a very large wing with more than sufficient area for his new fighter to give it a low wing-loading which, accordingly, permitted it to stall at a low speed. The Type 300 (Spitfire I) had a wing area of 242 square feet and an average operating weight when kitted out for military use of around 6,000 lbs. at takeoff. This gave the Spit a wing loading (total wing area/ gross weight) that was no more than 24.79 lbs. /sq. ft., and less when fuel and ammunition had been spent as when landing after returning from a mission. To give a useful comparison of the wing loading of the Spitfire to other aircraft of WWII here is a short list:

The following figures for the wing loading of these aircraft have been calculated by dividing the average operating weight of each by the aircraft’s total wing area. It is well to remember that once the engine is operating and fuel is being depleted that the wing loading is, accordingly, always becoming smaller over time.



*Time to perform a 360 degree roll
Spitfire Mk1/II with fabric covered ailerons*

Supermarine Spitfire	24.79	lbs. /sq. Ft
Messerschmitt Bf109E	31.73	“
Focke-Wulf Fw-190A	41.62	“
North American P-51D	41.60	“
Mitsubishi Zero-Sen	23.20	“
Lockheed P-38J	61.30	“
Chance-Vought F4U	31.80	“

As the above list shows that of these fighter aircraft only the Mitsubishi Zero-Sen had a lower wing loading than the Spitfire. The Spitfire's generous wing area and low wing-loading provided it with some useful benefits: slower stall speeds permitting slower take off and landing speeds (but not necessarily better landing manners), better climb (for any given power), longer, shallower glide, more nimble handling, and tighter turning radii, better range (a moot point in early Spit Mk's); but worse stability and comfort in gusts and turbulence. Low wing loading does not usually affect the maximum speed of the aircraft except negatively in extreme cases where the aircraft's wing loading is so high that the aircraft's attitude at cruise is necessarily at a high alpha in order to maintain altitude. In fact, a medium-to- heavy wing loading is better for cruising and flying in turbulent conditions, and grants an airplane better landing characteristics, as well.

While the Spitfire's large wing gave it some positive benefits, its long span reduced the roll rate so much that the early Mk's suffered one of the slowest roll rates amongst its contemporaries. Starting with some Mk V's, the Spit's roll rate was improved somewhat by clipping 9 inches off of each wingtip, reducing the original wing span of 33 ft, 8 in. to 32 ft. 2 in. For Mk's I and II however, which did not have this modification, their roll rate suffered because the wing was too long. The standard, unclipped-wing Spitfire had a maximum roll rate of 105 deg./sec. Combat pilots in Europe agreed that the two best rolling a/c were the FW190 and the P-47. Pilots who flew P-47Cs against Mk V and Mk IX Spitfires in mock combat found that they could out-roll it by better than 2 to 1.

Even though the Spitfire had these many faults, most of which were eventually addressed and diminished or eliminated in later Marks, its stellar virtues far out-weighed them. It was considered by friend and foe alike to be one of the best flying fighter aircraft to ever take to the sky. Pilots loved it and said that flying a Spitfire was like “putting on wings” and that “you only had to think it, and it turned”. Once the relatively ineffective rifle caliber .303in machine guns were replaced and/or joined with 20mm cannon, and then entirely replaced with 0.5in. Brownings, the old girl got her substantial Sunday punch. Very few aircraft could match the Spitfire in a dogfight; and in competent hands she was a formidable, fearsome weapon indeed. A Nation and the whole world owes heartfelt gratitude to the Spitfire and to the undaunted, gallant pilots who flew her, who fought and sometimes perished in order to preserve liberty and freedom at a time when their future survival and existence were not at all certain.

So, here's to the gallant "Few", and to the Supermarine Spitfire. Cheers.

Reginald Joseph Mitchell - Commander of the Order of the British Empire (CBE), Fellow of the Royal Aeronautical Society (FRAeS) -
20 May 1895 - 11 June 1937

This photograph was taken in the last year of his all-too-short life.

Praecidam magnitudo numquam oblivione



Microsoft: Creators of Microsoft FSX and its excellent open-architecture system that allowed us to port in our Accu-Sim technology

Accu-Sim Systems Programming: Scott Gentile, Robert Rogalski, Michał Krawczyk

Technical Director and 3D Modeling: Robert Rogalski

C++ Programming: Michał Krawczyk

Aircraft Painting: Martin Catney

Audio: Scott Gentile

Public Relations, Web Design, Maintenance Hangar Concept: Lewis Bloomfield

Pilot's Notes and Operating Manual: Mitchell Glicksman and Scott Gentile (with special thanks to Darryl Hackett OBF)

Accusim Manual: Scott Gentile and Mitchell Glicksman

Manual Editing: Larry 'Tako_Kichi' Green and Mitchell Glicksman

Quality Control Beta Team: The world's most effective and knowledgeable flight simulation beta team, including Cody Bergland, Forest "FAC257" Crooke, Glenn Cummings (GlennC), Ryan "Hog Driver" Gann, Mitchell Glicksman, Captain Jakey, Erwin Schultze (dutch506), Guenter Steiner, Paul "Gypsy Baron" Stroger, Oskar Wagner.

Special Thanks to: Dudley Henriques for his extensive large piston engine flying experience and support; Darryl Hackett for his in-depth knowledge of the Spitfire and wealth of information; Vlado Lenocho, owner and operator of the Moonbeam McSwine, for his expertise on Merlin engine behavior and constant speed propellers; Glenn Wegman of Fighter Enterprises for his expertise on maintaining both Merlin-powered P51's and Spitfires; Don Anklin and Tom Singleton of Fighter Factory for their combined expertise on maintaining their operational Spitfire IX and its systems; Kevin Raulie of the Cavanaugh air museum for granting full access to their Spitfire V; and Dave Miller (Commemorative Air Force crew chief) for his on-going support and availability.

Very Special Thanks to our friends and families who stuck by us and worked hard to support our efforts

Very Special Thanks to our friends and families who stuck by us and worked hard to support our efforts

Get ready for takeoff, and for heaven's sake, use your checklists!



