7
Inverted flight

INVERTED FLIGHT IS OPERATING THE AIRCRAFT UPSIDE DOWN FOR A sustained period of time. It is a negative-G maneuver, and can therefore be performed only in aircraft equipped with inverted fuel and oil systems. In terms of our definition, the inverted portions of such maneuvers as rolls and loops do not constitute true inverted flight. While in inverted flight, the student is expected to be able to fly straight and level, climb and descend, and perform turns. It is an essential aerobatic skill, to be acquired by all aspiring aerobatic pilots.

While aerobatic sequences consisting entirely of positive G maneuvers can be flown in aerobatic aircraft that are not equipped with inverted systems, a botched positive-G maneuver in any aircraft might result in negative-G inverted flight, a compelling reason for all aerobatic pilots to learn to fly inverted. Inverted flight is an important building block of competition aerobatic sequences.

Typical inverted cruise speeds

Aerobatic trainer:	125 mph
Intermediate aircraft:	145 mph
Unlimited monoplane:	170 mph

UNDERSTANDING IT

The most obvious question regarding inverted flight is how a wing, especially one that is asymmetric, is able to generate lift in the inverted position. A very basic review of how a wing generates lift is in order. First, consider the airflow over an asymmetric wing. The greater curvature of the wing's top surface provides a longer distance for the air particles to travel in the same time that particles travel along the wing's underside. In upright straight-and-level flight, the air particles flowing over the top surface speed up in comparison to the particles flowing along the underside of the wing. As per Bernoulli's principle, the faster airflow results in lower pressure along the top surface in comparison to the bottom surface, and the wing is suspended in the airflow by the combined effect of the two pressure zones.

Now we have to once again talk of angle of attack. If we increase the asymmetric wing's angle of attack, we displace on the leading edge of the wing the point where the airflow separates to traverse the wing's upper and lower surfaces. By increasing the angle of attack, we have further increased the length of the top surface and decreased the length of the bottom surface along which the air particles have to travel. The airflow along the upper surface speeds up further relative to the airflow along the lower surface, and the result is increased lift.

So, what about a symmetric wing, the wing found on most high-performance aerobatic aircraft? If the upper and lower surface curvatures are the same, the pressure zones on the two sides should be equal and the wing should never be capable of ascending. Yet it is, and the answer is angle of attack. A 2–3° angle of attack will sufficiently move the point on the leading edge where the airflow separates to create a difference between the length of the wing top and bottom surface over which the air flows, resulting in an increase in lift.

Now consider the asymmetric wing inverted. The task is to increase the distance over which the air particles have to flow along the top surface to exceed the distance traveled by the airflow along the bottom surface. This is done by increasing the angle of attack. The increase has to be substantial, which is why aircraft with asymmetric wing profiles can maintain inverted level flight only in a noticeably nose-high attitude.

The principle is the same for the symmetric wing, but the angle of attack required is small and equivalent to that required right side up. The symmetric wing performs equally well either side up, which is the reason why it is found on high-performance aerobatic aircraft.

FLYING IT

Inverted flight can be entered in several ways. You can roll inverted, you can pull up inverted through the first half of an inside loop, or you can push over into inverted flight through the first half of an outside loop. Rolling inverted is the easiest and least stressful way to enter inverted flight, so it is taught here. Once you feel comfortable flying upside down and have learned to do inside loops, you will routinely pull up through a half loop into inverted flight. Pushing over into inverted flight through an outside half loop is an advanced maneuver and should be left to the advanced stage of your aerobatic training.

Another important aspect of inverted flight is recovering from it. You can roll upright, which is the preferred recovery technique, or you can pull through the second half of the loop, which is the instinctive reaction but is emphatically not recommended as a standard recovery technique because of the rapid airspeed buildup, high acceleration load (Gs), and loss of altitude.

Let's learn the maneuver, how to roll into it, and how to recover from it.

1. Rolling inverted. We have already learned how to do rolls. There is nothing more to rolling inverted than simply stopping a roll by neutralizing aileron and rudder control when the aircraft reaches the inverted position.

   As we emphasized in the sections covering rolls and in the presentation above, you need a high angle of attack (especially with an asymmetrical wing) in the inverted position to maintain level flight (i.e., to stop the nose from dropping). There are two options in establishing this angle of attack. You can roll inverted and push the nose up, which is an uncomfortable negative G procedure, or you can pitch up before you start the roll and as you reach the inverted position you will be already at the appropriate angle of attack. This latter method is more comfortable and highly recommended.

   Thus, the simplest entry is a half aileron roll. Pitch up, neutralize controls, apply full aileron and momentary rudder in the desired direction of the roll, and neutralize aileron when you reach the inverted position.

   You will also find it easy to enter inverted flight through a half slow roll. As we have learned, the slow roll requires pushing the nose up as the aircraft rolls past the vertical, but forward stick is applied gradually, thus minimizing the effect of subjecting our body to negative G.
2. Inverted straight and level. When you are established in the inverted position, the first order of business is to get used to straight and level. Glance at the airspeed indicator to confirm stable and appropriate airspeed and look straight ahead at the horizon as you did when you first learned straight and level right side up. The negative G sensation might feel a bit weird (you will think you are hanging from your straps far more than you really are) and in a training aircraft the nose will be way above the horizon. The switched places of earth and sky will most likely seem more normal than you had expected.

   Practice maintaining straight and level flight. When you are used to the general view, glance more frequently at the airspeed indicator and the vertical speed indicator for backup confirmation of your attitude. Gently experiment with shallow climbs and descents. Note the strong stick forces necessary to keep the nose up, and the eagerness of the aircraft to descend. Should you retrim in inverted flight? Generally, you shouldn't. You will be spending only a few minutes inverted, and if you retrim, you will have to retrim again for the subsequent maneuvers of your session.
3. Inverted turns. Doing turns in inverted flight is confusing at first. You have to bank in the direction you wish to turn as you do in upright turns, which requires aileron deflection in the same direction; inverted or upright, your aileron input is always in the direction of the turn. To turn left, you need to apply left aileron, upright or inverted. So far, so good. Now you have to overcome the adverse yaw created by the wing outside the turn (the up wing). Upright, you would apply left rudder, the rudder on the inside of the turn. To

achieve the same effect upside down, you also have to apply the rudder on the inside of the turn; however, upside down, this rudder is the *right rudder*, which in mirror image is where the left rudder was upright.

To summarize: In an inverted turn you have to apply aileron in the direction of the turn and rudder opposite the direction of the turn. This is truly easier to understand and learn by doing than by reading about it. With some trial and error you will soon get the hang of it.

4. Recovering from inverted flight. The best way to recover from inverted flight is to roll right side up. You should practice this mode of recovery until it becomes instinctive. In emergencies, it is much safer than pulling down into the second half of a loop. The roll puts a negligible acceleration load on the aircraft, airspeed does not increase, and little altitude is lost even if the maneuver is done in a sloppy fashion.

   Pulling down into a half loop will, on the other hand, lead to a rapid speed buildup, it will require pulling a substantial acceleration load to control the speed buildup, and it will result in a substantial loss of altitude even if done correctly. You will learn to incorporate into aerobatic sequences a planned downward half loop from inverted flight, but as a standard or emergency recovery technique from inverted flight, stick to rolling upright.

   When you are ready to recover from inverted flight, smoothly apply full aileron in the desired direction of the roll accompanied by momentary opposite rudder to correct adverse yaw and wait for the horizon to turn right side up. Gradually neutralize forward stick as you roll around. If you want to be fancy, you may turn the recovery into the second half of a slow roll by adding top rudder as you approach the first 45° of roll and maintaining it until you are about 45° from the upright position.

COMMON ERRORS

Only one common error is committed by novices learning inverted flight: the failure to maintain a sufficiently nose-high attitude to maintain inverted straight and level. In training aircraft, the required attitude is extreme, and the control pressures are high. The discomfort of negative G does not help matters. To learn inverted straight and level, revert to what you did on your first instructional flight when you were learning to fly. Concentrate on the horizon and keep it where it belongs. Ignore the fact that the space above the horizon is now ground and the space below, sky. Remind yourself that whatever you feel is natural, however unusual it might initially seem to you.

IF THINGS GO WRONG

One reason pilots are initially reluctant to get the nose way up in inverted flight is their fear of an inverted stall, possibly developing into an inverted spin. From straight and level, an inverted stall might be encountered, but is about as benign as an upright stall. The nose will drop and the aircraft will soon be flying again. Remember, in inverted flight you need to apply *aft* stick (elevator) to get the nose down. So to recover from a stall, make sure the rudders are neutral and apply aft stick. The forward stick forces are so high that you will encounter plenty of prestall buffet in most training aircraft before experiencing an inadvertent inverted stall.

An inadvertent inverted spin is possible from inverted straight and level flight with the gross misapplication of controls (extreme uncoordination), but the chances of it developing are quite remote in most low-performance training aircraft. In a badly mishandled turn, the chances are slightly higher. The standard recovery technique from the inadvertent inverted spin is:

1. Power off.
2. Rudder opposite the *yaw* to stop the rotation.
3. Aft stick to unstall the wing.
4. When the spin stops, neutralize the controls and pull out of the dive.

The Beggs/Müller emergency recovery technique also works in most aircraft:

1. Power off.
2. Let go of the stick.
3. Rudder opposite the *yaw* (step on the rudder that offers the greater resistance).
4. When the spin stops, neutralize the controls and pull out of the dive.

It is imperative that you get comprehensive inverted stall/spin instruction from a qualified aerobatic instructor prior to solo inverted flight.

Things can go very wrong if for whatever reason you decide to abandon inverted flight and decide to pull through in a split-S instead of rolling upright. The altitude loss and airspeed gain in a split-S can be tremendous and a hazard to safety. Always roll upright to recover from inverted flight.

A WORD ABOUT INVERTED SYSTEMS

An inverted system is essential for prolonged negative-G flight, such as inverted flight, and an aircraft has to be specifically approved for inverted flight to be deliberately flown inverted, so a few words about inverted systems are worthwhile.

The direction of the flow of fluids circulating in an aircraft is affected by the force of gravity. In inverted flight, the fluids will flow in a different direction relative to the aircraft than in upright flight. Unless the systems using these fluids are specifically designed to take this difference into account in inverted flight, the flow of fluids will be interrupted and the systems will cease to function.

Fuel and oil are a problem in inverted flight on every aircraft, and on some sophisticated (mostly military aircraft) hydraulic fluid can also cause a problem. If there is no inverted system, when an aircraft is turned upside down, fuel and oil will cease to flow through the appropriate parts of the engine, which will stop and could even be damaged.

Fluid flow can be maintained many ways when flying inverted, but inverted systems generally fall into two broad categories: *time-limited* systems and *continuous* systems. Time-limited systems are based upon an inverted auxiliary tank. Fluid collects in the inverted tank during upright flight, and the tank is so positioned that when the aircraft is turned upside down it is able to supply fluid to the appropriate systems until it runs dry. These systems are simple and usually provide fluid for not much more than 5–10 minutes at a time, which is more than it might seem considering that the average length of an unlimited competition sequence is only about 8 minutes.

The more complex inverted systems innovatively combine a network of pumps and plumbing to provide a continuous supply of fluid equal to the supply available right side up. You should be intimately familiar with your aircraft's inverted capabilities and system. Consult your aircraft manual.

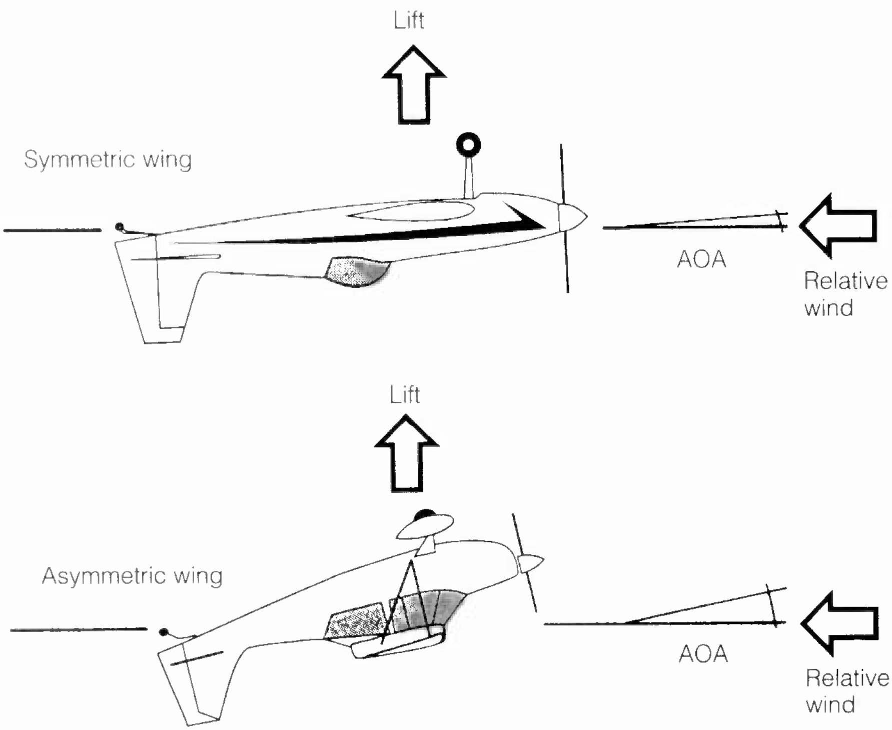

Fig. 7-1. *Inverted straight and level flight. The asymmetric wing is less efficient, requiring a higher angle of attack (AOA) to maintain straight and level.*

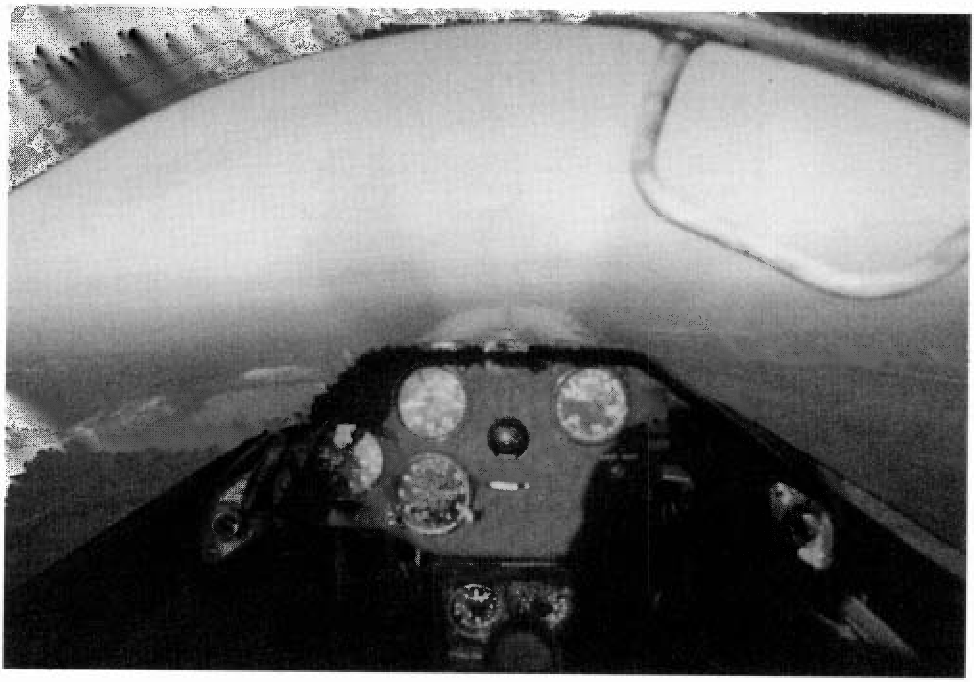

Fig. 7-2. *Upright straight and level cockpit view from an aircraft with a symmetric wing.*

Fig. 7-3. *Upright straight and level cockpit view from an aircraft with an asymmetric wing.*

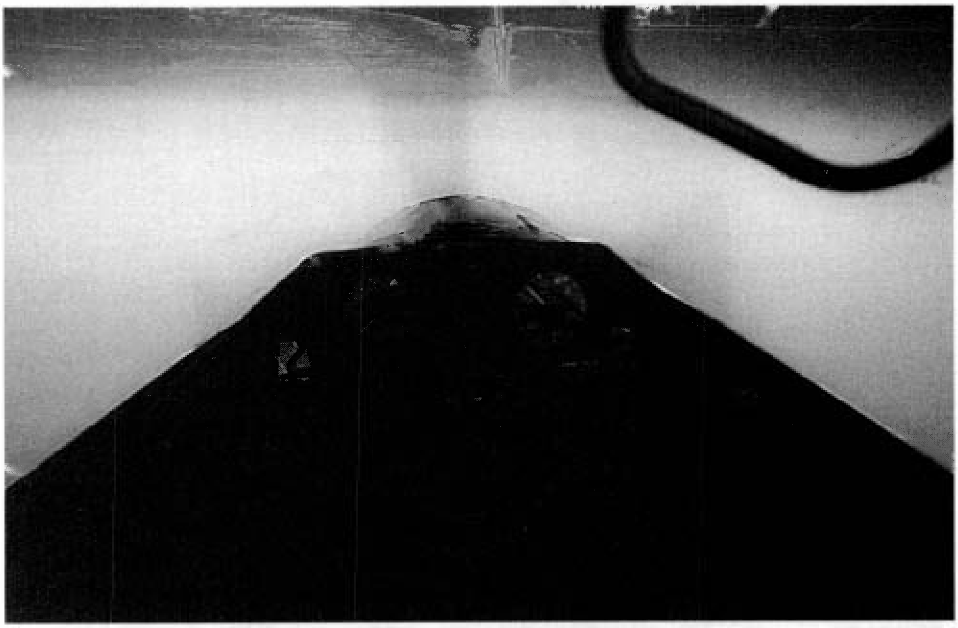

Fig. 7-4. *Inverted straight and level cockpit view from an aircraft with a symmetric wing. Note nose-high atltitude.*

Fig. 7-5. *Inverted straight and level cockpit view from an aircraft with an asymmetric wing.*