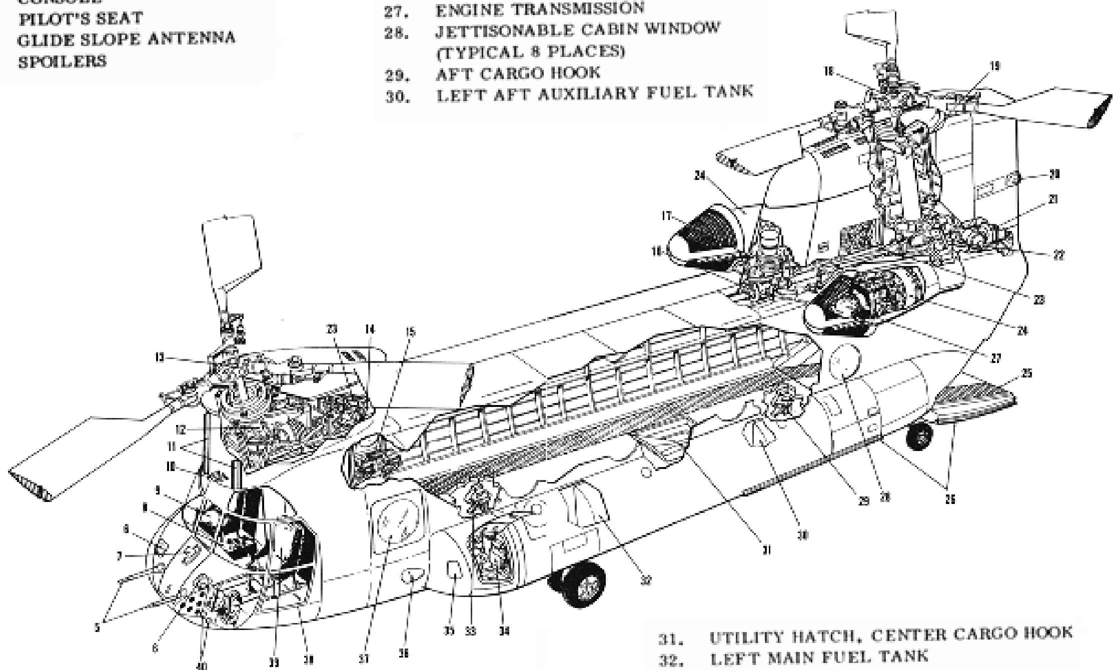
Helicopter Operating Handbooks

The average modern flight manual is broken down into a standard set of sections. Although the order and therefore the numbering will be different from one manual to the next, generally speaking each manual will have each one of these sections. One case where this is often not true is with older aircraft. The FAA standardized flight manuals at one point, but aircraft which were certified before that occurred will often have very non-standard handbooks. Some older airplanes have handbooks only a few pages long!

- *General* which normally provides overview type information about the aircraft and the manual itself. For instance, in this section the Robinson manual has descriptive data about the helicopter, a list of abbreviations and definitions used in the manual, and units conversion tables. Here is an excerpt from the Boeing Vertol CH-47 operating handbook showing an exploded view of the aircraft
- *Limitations* is that section of the manual which is basically an extension of the FARs. Each item in the limitations section has the force of law, and you break the law if you exceed anything in this section. Examples of the sorts of things you will find in here are airspeed restrictions, powerplant restrictions, weight and balance restrictions, and maneuver restrictions.
- *Emergency Procedures* is the section which gives you the manufacturers recommendations on how to handle certain emergencies you are likely to encounter in the particular aircraft.
- *Normal Procedures* is the section which gives you the manufactureres recommendations on how to fly the aircraft during normal usage. This is commonly where you will find the airspeeds the manufacturer recommends for best climb, best range, etc. The preflight inspection sequence is usually given in this section.
- *Performance* sections you charts and other information which will help you to determine before or during flight whether the intended operation is likely to be possible give conditions of density altitude, gross weight, etc. For example, the Robinson R22 handbook gives us an airspeed calibration chart, a chart for determining density alititude, in-ground-effect and out-of-ground-effect hover ceiling charts, and the height velocity diagram (dead man's curve).
- *Weight and Balance* gives us general procedures for weighing the aircraft, information as to the longitudinal and lateral stations of important places in the aircraft (such as seats, baggage compartments, fuel tanks). It also gives us some charts which can be used to determine whether the CG is within limits.
- *Systems Description* is a section which gives a quick description of major systems in the aircraft and how they should be used.
- *Handling, Servicing, and Maintenance* is a section which outlines the manufacturers recommended procedures for ground handling, complying with inspections and maintenance, and general servicing that the pilot can perform such as adding oils, cleaning the exterior and interior, etc.
- *Supplements* is the section which describes optional equipment available from the manufacturer or third parties. For each option, there is a minature section of the pilot operating handbook including limitations, emergency procedures, performance, etc. I find it can get pretty confusing to tell the impact of performance when you have multiple options installed on the aircraft.
- *Safety Tips* gives some dos and don'ts, and in the case of the Robinson R22 handbook includes the Robinson Safety Notices, which are descriptions of things to do or not do based on accidents which have occurred. Very useful.

5. PITOT TUBES
6. RADAR WARNING ANTENNA
7. TRANSPONDER ANTENNA
8. CONSOLE
9. PILOT'S SEAT
10. GLIDE SLOPE ANTENNA
11. SPOILERS

22. AFT TRANSMISSION
23. HYDRAULIC POWER UNITS AND TANKS
24. ENGINE AND SCREEN
25. RAMP
26. STRAKES
27. ENGINE TRANSMISSION
28. JETTISONABLE CABIN WINDOW (TYPICAL 8 PLACES)
29. AFT CARGO HOOK
30. LEFT AFT AUXILIARY FUEL TANK



12. FORWARD TRANSMISSION
13. FORWARD ROTOR
14. DRIVE SHAFT
15. CABIN DOOR
16. COMBINING TRANSMISSION
17. ENGINE AND COMBINING TRANSMISSION OIL COOLER AND DUCT
18. AFT ROTOR
19. AFT ROTOR DRIVE SHAFT
20. RADAR WARNING ANTENNA
21. AUXILIARY POWER UNIT

31. UTILITY HATCH, CENTER CARGO HOOK
32. LEFT MAIN FUEL TANK
33. FORWARD CARGO HOOK
34. LEFT ELECTRICAL COMPARTMENT
35. EXTERNAL POWER RECEPTACLE
36. NO. 1 FLIGHT CONTROL HYDRAULIC SYSTEM GROUND TEST CONNECTIONS
37. CABIN ESCAPE HATCH
38. JETTISONABLE DOOR
39. COPILOT'S SEAT
40. AFCS PORTS

Semi-Rigid Main Rotors

A semi-rigid main rotor is always a 2 bladed rotor system. It gets its name from the fact that it does not have a lead-lag hinge, the way a fully articulated rotor system does. The rotor system can be said to be rigid in-plane, because the blades are not free to lead and lag, but they are not rigid in the flapping plane (through the use of a teeter hinge). Therefore the rotor is not rigid, but not fully articulated either, so we call it semi-rigid. The rotor systems we will look at here are 2 bladed teetering systems. The Robinson and the Bell teetering system differ because the Robinson includes coning hinges in addition to the teeter hinge, while the Bell system simply cones by bending the blades.

Basic R22 Head

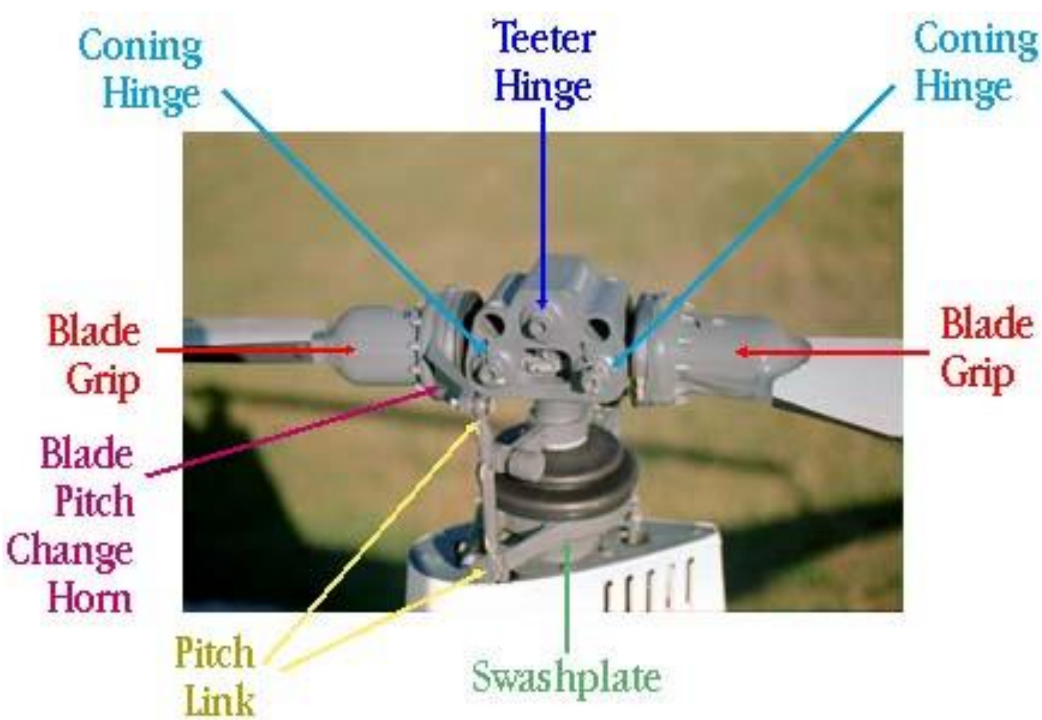
Teeter Hinge

The dark blue arrow is pointing to the teeter hinge. This central hinge allows the entire rotor head to tilt left and right in order to allow the blades to flap. When one blade flaps up, the other flaps down. The entire mechanical arrangement works like a child's see-saw (teeter-totter) toy.

Coning Hinge

The light blue arrows point to the two coning hinges. These hinges allow each blade to move up and down independently of the other blade. This would normally happen during coning, when each blade moves up until centrifugal force balances lift. During times of high lift, or low RPM, the blades will be coned quite high, while during low lift or high RPM, the blades will tend to be lower.

The holes in the rotor head above the coning hinges serve no purpose except that they may be used to hoist the rotor system.



Blade Grips

The light red arrows point to the blade grip. The grip attaches the rotor blade to the rotor head, and includes a pitch change mechanism used to change angle of attack by feathering the blade (with the cyclic control). In the case of the R22, the grip has multiple bearings, and is filled with a fluid similar (identical?) to automatic transmission fluid.

Pitch Horn

The dark red arrow points to the left hand blade pitch horn. The pitch horn on the right blade is behind the head in this photograph can cannot be seen, but does exist. The purpose of the pitch horn is to give the feathering pitch change mechanism (cyclic/swashplate) a place to attach to the blade. By sticking out from the blade, the pitch horn works as a lever, decreasing the force it takes to change the angle of the blade. Note that it also has the effect of changing the location on the swashplate where the pitch mechanism attaches. Rather than attaching to the swashplate directly under the blade, it attaches to the swashplate almost 90 degrees earlier in rotation. This is how the control system corrects for the almost-90 degree lag in rotor response due to Gyroscopic Precession.

Pitch Link

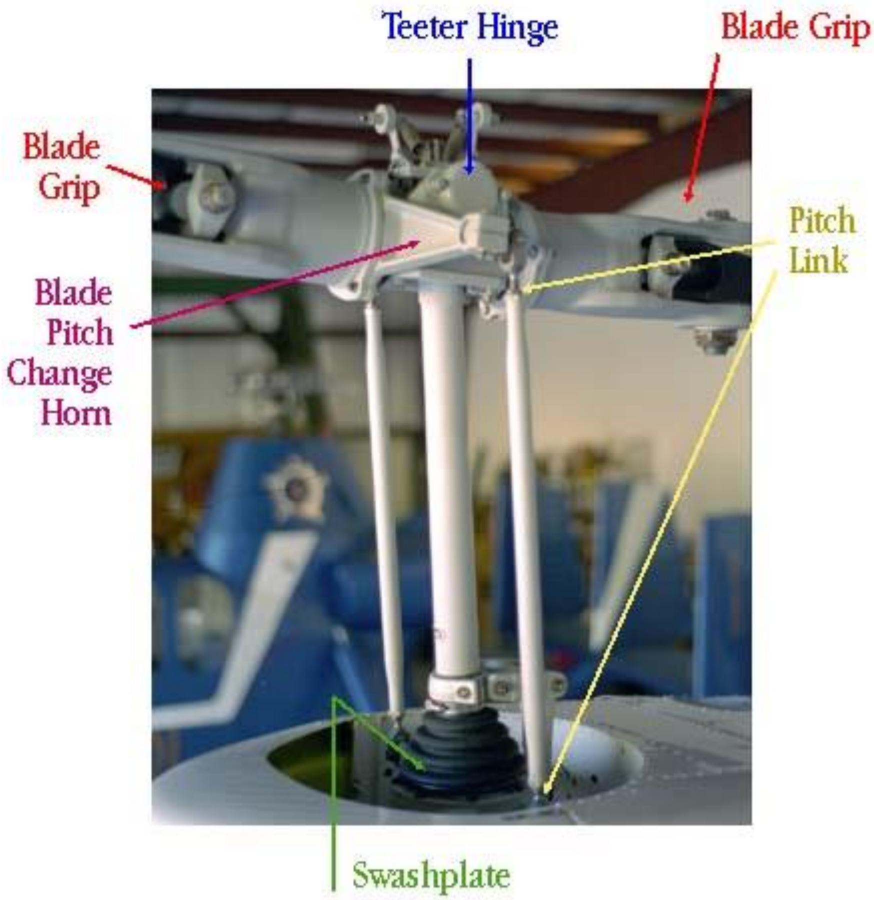
The yellow arrow points to the pitch link, which connects the pitch horn to the swashplate. These length of these pitch links can be adjusted to set the angle of incidence of the blade during track and balance of the rotor system.

Rotating Star (Swashplate)

The green arrow points to the rotating portion of the swashplate, which attaches to the pitch links. Below that is the non-rotating part, which connects to the pitch control rods coming up from the cyclic/collective mixer.

Basic JetRanger (Bell 206) Head

The design of the Bell 206 rotor head is not that different from that of the Robinson. Note that in this picture, there are no light blue arrows, because the 206 head does not include coning hinges. Instead, the rotor head is designed with a pre-cone angle to the blade retention system, and other coning forces are simply dealt with by bending of the blades (which must be built stronger to deal with the extra stress).



Blade Grips

The light red arrows point to the blade grips. The design is slightly different than the Robinson. The inside of the grips is filled with a light grease, rather than a fluid. Also, note on the right hand blade that there is a vertical bolt attaching the blade to the grip. The blade can be set with some fixed lead or lag as part of the rotor system rigging, compared to the Robinson where the lead/lag position of the blade is fixed by the design of the rotor head, and can not be adjusted, even at the factory.

What is Teetering (Flapping) versus Feathering?

On any rotor system, flapping occurs when the blade moves up and down. On a rigid rotor system, this occurs when the blade bends. On an articulated system, the blade flaps up and down around a *flapping hinge*. On a 2 bladed, semi-rigid teetering system, the blades flap in unison around the flapping hinge such as in these pictures of a Robinson R22:

Notice that the angle the airfoil makes with the horizon here does not change. Flapping changes the angle of attack not by pitching the airfoil up or down, but by changing the direction of the wind relative to the blade. For a more in-depth discussion see Relative Wind, Flapping and Angle of Attack.

Compare this to the following picture which shows the blade being feathered by the pilot's controls via the swashplate:

In this picture, you can clearly see that the angle of the blade with respect to the horizon has changed, from a nose up angle on the left side, to a nose down angle on the right side. In this case, the swashplate has moved in response to either the cyclic, collective, or both, and has moved the pitch links up or down. Since the pitch links are connected to the blade via the pitch horn, the blade is forced to rotate around the blade grip bearing into a different angle of incidence.

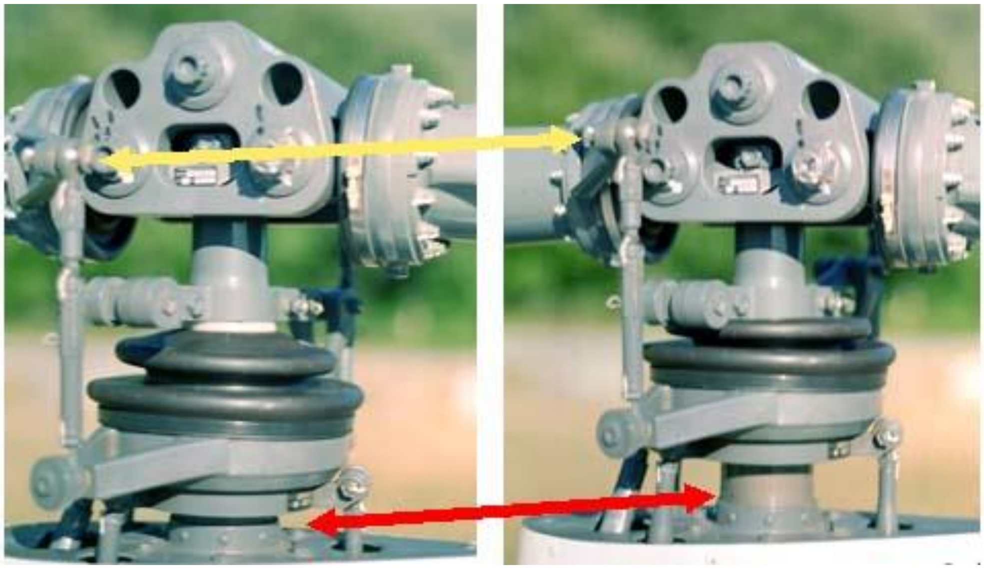
How does the Rotor System Teeter?

The rotor system teeters around the central hinge. The position of the blades is due to the balance between centrifugal force which is trying to hold the blades "straight out", versus lift which is trying to make them fold straight up. The balance of the forces will cause the blades to fly at some angle. If one blade starts to develop more lift, while the other blade starts to develop less lift, one blade will want to climb while the other will want to descend. The result will be that the rotor head will teeter, allowing one blade to go up while the other goes down.

It is important to understand that teetering happens "automatically", as a result of aerodynamic and centrifugal forces. The pilot does not command flapping with the control system.

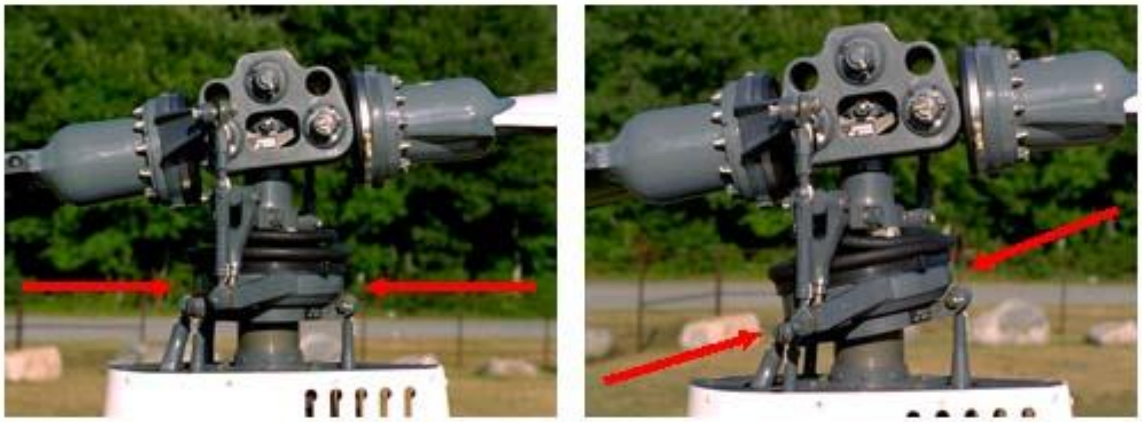
How does (the R22) Control System Transmit Pitch to the Blades?

There are many different mechanisms for transmitting cyclic and collective inputs to the main rotor system. The Robinson R22 and R44 mount the swashplate on a *monoball*. This allows the entire swashplate to slide up and down on the rotor mast (for collective inputs) and tilt (for cyclic inputs). These two pictures show how the swashplate slides up and down to transmit a collective pitch change:



You can see that the red arrow is pointing to the bottom of the swashplate in the left hand picture, but that in the right hand picture the entire swashplate has moved up the mast. Notice the effect that has on the pitch links: the yellow arrows show that in the right hand picture, the pitch link has moved up along with the swashplate (compare the top of the pitch link and the left hand coning hinge bolt in the two pictures). Since the entire swashplate has moved up without changing its tilt, the pitch links have all moved up a set amount, but will continue to move up and down during rotation in response to the tilt of the swashplate.

In comparison, look at the following picture to see how cyclic input is transmitted to the blades:



Notice that the swashplate in the left hand photograph is basically level, while in the right hand photograph it has been tilted. The tilt will cause the pitch link to have to move up as it travels to the right hand side of the picture, and move back down as it travels to the left hand side of the picture. As it moves up and down the blade pitch will increase and decrease.

Helicopter Tail Rotors

The problem with Torque

One of the very first problems helicopter designers encountered when they tried to create a machine that could hover was the problem of torque reaction. Newton's third law of motion requires that for every action there is an equal and opposite action. A typical single main rotor helicopter has a rotor system mounted on a rotor mast. The helicopter engine supplies power so that the helicopter can turn the mast, and thus the rotor system connected to it. When the helicopter applies torque to the mast to spin it, there is an equal-and-opposite torque reaction which tries to turn the helicopter in the opposite direction.

Eliminating the torque reaction

Counter Rotating Rotors

Most of the early designers seemed to use multiple rotors spinning in opposite directions as a way to cancel the torque. The advantage of these types of systems (co-axial, tandem, intermeshing) are that the torque is countered with no loss of power. When 50% of the torque is used to turn one rotor clockwise, and 50% of the torque is used to turn a second rotor counter-clockwise, the torque reactions balance out. 100% of the engine power goes into turning the lifting rotor systems.

There are still several production helicopters which use multiple counterrotating rotors as a way to cancel out torque. Examples are the Boeing-Vertol tandem rotor helicopters which evolved from

Frank Piaseki's designs, Charles Kaman's intermeshing rotor system, and the Russian co-axial helicopter (Hocum or Havoc I think it is, I'll have to look up the correct name I'm afraid). The V22 tilt-rotor uses counter-rotating proprotors in order to cancel out torque. It is similar to a tandem rotor system when in helicopter mode.

Tail Rotors

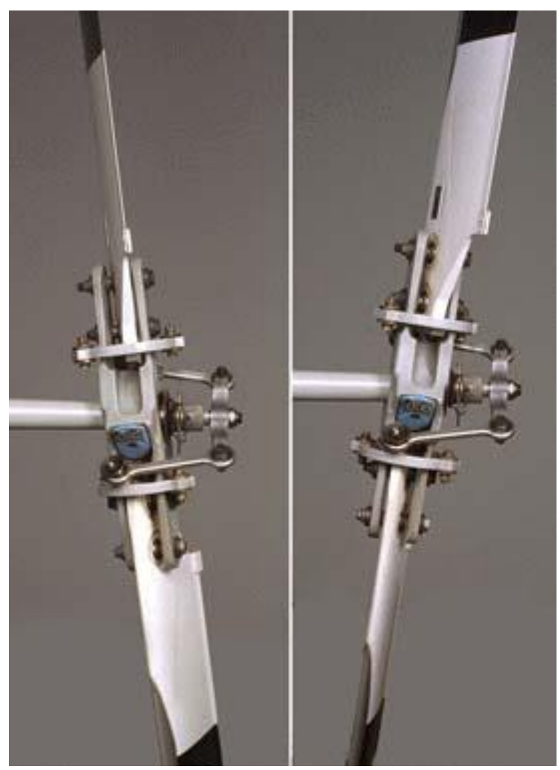
Igor Sikorsky seems to be the first to settle on using a single rotor mounted at the rear of the helicopter as a way to counter the torque. This is the most popular arrangement today. Sikorsky actually experimented with many different arragements before selecting a single tail mounted rotor.

It seems strange that the majority of helicopters produced use this method of countering torque, given that there are several major problems with this method which are not encountered with counter-rotating rotor systems.

One major problem with tail rotors is that they rob an enormous amount of power. As a rule of thumb, tail rotors consume up to 30% of the engine power.

Another probem is that due to size and weight constraints, tail rotors are fairly delicate compared to main rotors. This means that they cannot survive an encounter with very large obstacles. Because they are mounted at the rear of the helicopter, out of the pilot's sight, a fairly common cause of helicopter accidents is hitting an obstacle with the tail rotor, losing all anti-torque capability, and crashing due to the rotation of the entire helicopter.

Still another problem with tail rotors is that they are fairly difficult to control accurately. Turbulence and crosswinds make it extremly difficult to hold a constant heading in a tail rotor equipped helicopter. The workload is very high, and good results are difficult to achieve. Many larger helicopters end up being designed with a yaw stabalization system, which is essentially an autopilot for the tail rotor.



Tail Rotor Aerodynamics

Tail rotors share many of the aerodynamics of the helicopter main rotor system. They are essentially identical to a main rotor which is mounted sideways and is controllable in collective pitch, but is not capable of cyclic feathering. Some of the same problems which designers encountered with main rotors occur with tail rotors. Often the solution is similar or identical to the solution used on a main rotor.

Tail Rotor Dissymetry of Lift

Tail rotors experience dissymetry of lift just as a main rotor system does. (tail rotor dissymetry of lift is discussed specifically in in the dissymetry of lift aerodynamics section). This lift dissymetry would cause a torque around the tail boom which would tend to roll the fuselage in the same direction as main rotor lift dissymetry. While cyclic pitch could be used to counter the rolling tendancy, the tail rotor blades are typically allowed to flap, eliminating the lift dissymetry. Here is a picture of a Bell 206 JetRanger tail rotor flapped to right and left extremes:

Tail Rotor Translational Lift

Just as a main rotor produces more lift when it moves into clean air, a tail rotor develops extra thrust when the helicopter moves it into clean air. Unfortunately, the pilot sees this as a change in anti-torque force which results in an uncommanded yaw of the aircraft. The pilot is forced to make an adjustment to his anti-torque pedals as the tail rotor goes in and out of translational lift.

There is no aerodynamic solution to this problem, and this is just one of the items which makes a tail rotor helicopter more difficult to fly. One solution which is sometimes used is a yaw-damper, essentially an auto-pilot which uses a gyroscope to detect uncommanded yaw, and which changes tail rotor pitch in order to prevent uncommanded yaw.

Tail Rotor Settling with Power

Just as a main rotor can get into a Ring Vortex State by settling into it's downwash, yawing the helicopter such that the tail rotor settles into it's downwash (sidewash?) can induce the same ring vortex state. Indeed, a crosswind can induce the ring vortex state without any yaw being present. While this may seem unlikely, I personally know someone who crashed a helicopter as a result of this.

The solution to this problem is similar to that for the main rotor: try to prevent it from happening, but if it does either move the tail rotor into clean air (by moving the helicopter), autorotate (to eliminate the torque) or try to get out of the ring vortex state by a very rapid and large increase in thrust (but if the pedal is already at the stop, this probably isn't possible). A hover auto is probably the safest, most reliable way to get out of this situation.

Tail Rotor Coning

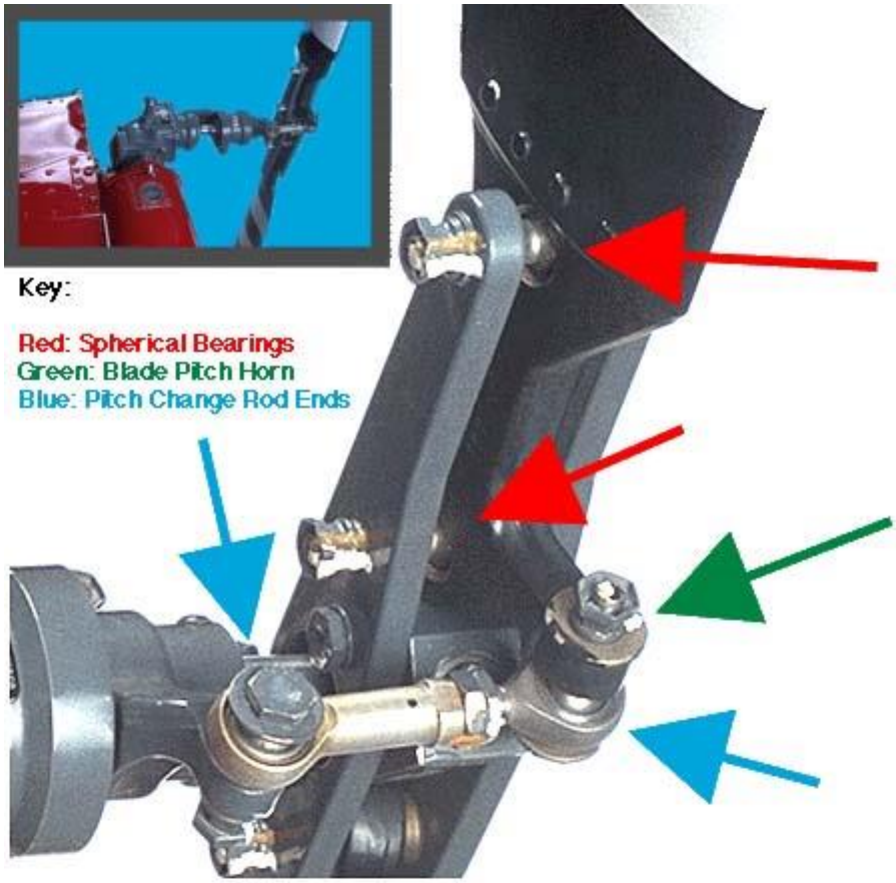
While some tail rotors may be designed to allow coning, all tail rotors that I am familiar with simply pre-cone the blades and don't worry about coning in the design. Helicopters with more than 2 blades (or more than 2 double stacked blades like the Hughes/MDHC-500) probably have a flapping hinge which acts as a coning hinge. I'll have to ask my friends at Sikorsky as they tend to build helicopters with large numbers of blades.

Changing the Pitch

In order to be able to yaw the aircraft both right or left, the tail rotor blades need to be able to be set to both negative and positive angles of attack, unlike main rotors which are normally only capable of positive angles of attack.

The angle of attack of the tail rotor is controlled by the pilot's anti-torque pedals (they're not "rudder pedals" in a helicopter). The pedals are typically connected to the pitch change mechanism by either push pull tubes, or by cables. From the standpoint of controlling pitch, a tail rotor requires collective pitch control, but not cyclic feathering. This makes the pitch control mechanism of most tail rotors much simpler than that of the main rotor system.

The tail rotor blades must be mounted, and there must be a mechanism to change the pitch of the blades. This picture is of a Robinson R22 tail rotor. You can clearly see how the blades are attached, and how the pitch change mechanism can pivot the blades.



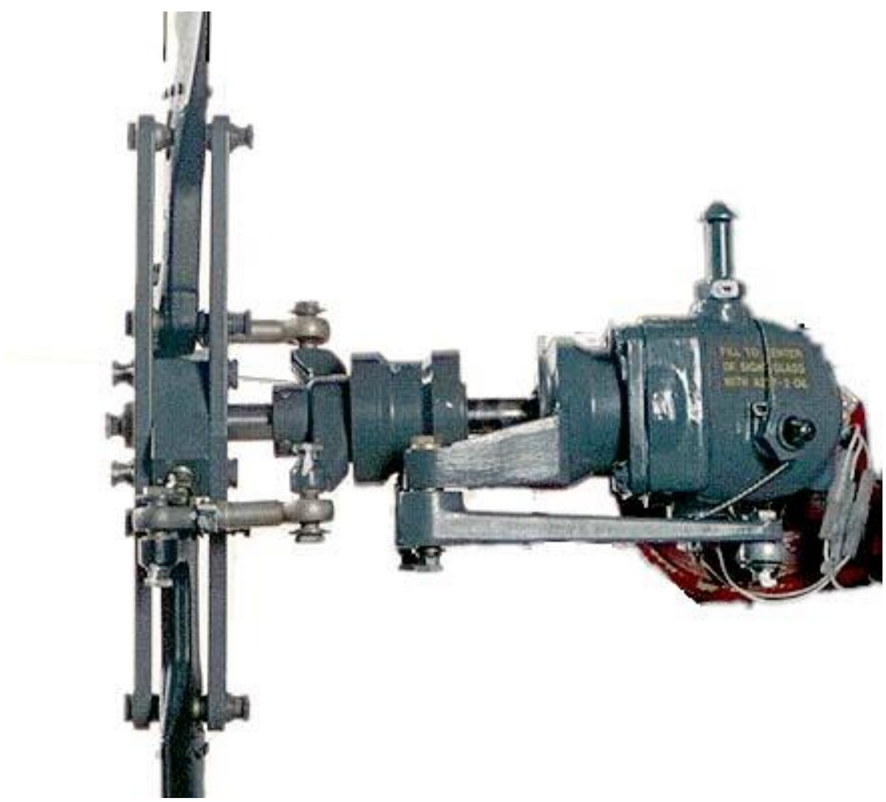
The red arrows point at the attach points for the blade itself. These attach points are a bolt which goes from one side of the yoke, through the blade, and into the other side of the yoke. The spherical bearing itself allows the blade complete freedom to rotate around the ball, which the upper red arrow is pointing at. Because there are two of these spherical bearings (you can just see the second one that the lower red arrow is pointing at) the blade is constrained to only move around an axis which is aligned between the two bearings. This allows the blade's pitch (angle of attack) to be changed, but allows no other motion of the blade with respect to the yoke.

Notice that the bottom of the blade makes an "L" shape, with the green arrow pointing to the end of the "L" where a bolt goes through it. The "L" part of the blade, which I call a "Pitch horn", gives us some leverage to move the blade in pitch.

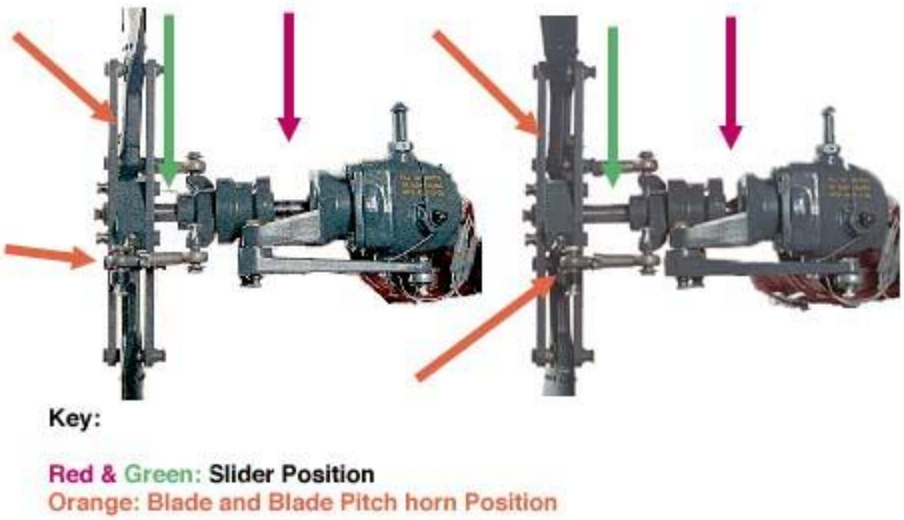
The bolt which goes through the "pitch horn" also goes through a pitch change rod end (right hand blue arrow) which has one of those spherical bearings in it. This allows the rod end to push and pull on the pitch horn, thereby changing the pitch of the blade.

The other end of the rod end (left side blue arrow) is attached to the pitch change yoke. This is examined in a later picture. Here is another picture of the same assembly, from a very slightly different angle. You can see the "L" shaped bottom of the blade better, and it's a little more obvious how it attaches to the pitch change rod.

Here is the same assembly, except that now we are standing behind the helicopter looking directly forward at the tail rotor assembly:



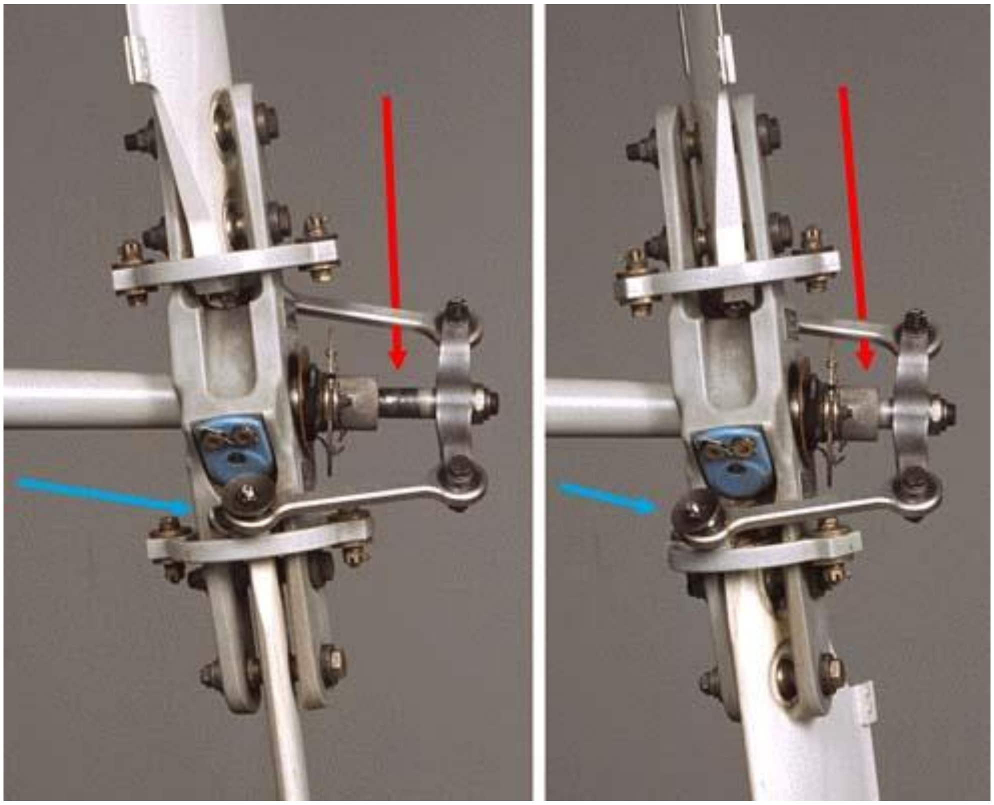
This picture shows how the pitch change mechanism works:



The red and green arrows show how the slider slides left and right on the shaft. The pitch change rods are connected to the slider, and so as the slider moves to the right, the pitch change rods move to the right, and take the blade pitch horn with them. If you look carefully at the bottom orange arrows, you can see that the pitch change rod and the blade pitch horn have been moved to the right. The upper orange arrow just points at the blade, which you can see is at a different pitch angle in the two pictures.

Here is the Bell 206 JetRanger tail rotor. Notice that the pitch change mechanism is quite different than the R22. The pitch change rod is actually a shaft which goes through the hollow shaft the tail rotor is mounted on:

Here is a closeup of the tail rotor hub at two extreme pitch settings. In the left hand picture, the red arrow shows that the inner shaft has been extended all the way to the right. The right hand picture shows the same shaft has been retracted:



As the inner shaft slides left and right, the pitch change rods are dragged along, and pulls the blade pitch change horn along with it. The blue arrow points out how far the rod end has moved, taking the blade's leading edge with it. Like the Robinson, the blade is mounted on two spherical bearings, which cause it to rotate only in the pitch axis.

This is the Enstrom F28A tail rotor assembly. In the lower left corner of the picture, you can see the cable attaching to the pitch change mechanism. The Enstrom blades don't attach with spherical bearings the way the Robinson and Bell do, they utilize a bearing pack to allow the blade to feather.

Cyclic Control

The cyclic is used to tip the rotor disk, and thus move the helicopter either forward, backward, or sideways. Here is an Enstrom F28A cyclic:

The arrows are pointing to 3 controls on the F28 cyclic.

The red arrow on the left is pointing at the trigger switch. This is used for transmitting on the radio. Normally, the first click would activate the intercom so the pilot could talk to the other people on board the helicopter, and the second click (i.e. all the way in) would actually transmit on the radio. In our F28, the first click doesn't do anything because we have a voice activated intercom, and so the switch isn't required.

On the right side, the upper arrow which is blue points at the trim switch. This is called a "coolie hat" because it has a shape similar to that of an asian peasant's hat. It is like a joystick, and can be moved up, down, left and right. The pilot uses this to neutralize stick force. If air loads from the rotor system are holding the cyclic to the left, the pilot can push the trim switch to the right. This runs an electric motor which will tension a spring which will tend to hold the stick to the right. If the pilot uses the trim correctly, the cyclic will stay where it is even if the pilot were to let go. Everytime the airspeed is changed, or a different cross wind is encountered, the pilot must retrim to remove the stick forces.

The bottom arrow on the right side points to the cargo release switch. This could be used for other things if no cargo hook is installed. We don't have a cargo hook on this helicopter, but we haven't bothered to hook this button to anything else, so it doesn't do anything for us. If this was connected to a cargo release hook, pushing this button would cause an external load suspended beneath the helicopter on a cable to be released from the hook.

The curve in the cyclic allows it to move back quite a few inches before it hits the seat, yet the handle is right where it is comfortable for the pilot to reach.

Compare the Robinson R22 Cyclic, which is a radically different design than most other cyclics:

There are a few things to note, which is why there are so many arrows! The orange arrows point to the hand grips. The green arrow points to the pivot point for the cyclic. The hand grips can be teetered up and down around this pivot, like a see saw. If one hand grip goes up, the other has to go down, they can't move independently.

The blue arrow points to the pin which allows the left hand grip assembly to be removed. (The left hand collective and pedals can also be removed).

The red arrows point to each set of *intercom* and *transmit* buttons. Unlike the Enstrom, the Robinson R22s do not normally have a voice activated intercom. You have to push your intercom button in order to speak to the other person in the helicopter. On the left hand floor, there is a foot switch which allows the person in the left hand to either use the cyclic or floor mounted switch to activate the intercom. The foot switch allows use of the intercom when the left hand grip is removed from the cyclic. It is also used by instructors sitting on the left side, so that they can talk to the pilot receiving instruction without the instructor having to push on the cyclic.

The second switch on each side of the cyclic is the radio transmit button. When the left hand cyclic assembly is removed, there is no way for the person in the left hand seat to transmit on the radio.

Most people react negatively to the Robinson style cyclic at first. However, as you get used to it, you realize that there are several advantages to this arrangement. Personally, I like having the column coming up from the floor where it is, away from hitting my legs. I just wish that each hand grip could move up and down independently so that each pilot could set the hand grip height to a comfortable position. As it is, instructors end up learning to fly with their arm high in the air so that the student pilot can rest his arm on his leg.

Collective Control

The collective is used to increase main rotor pitch simultaneously at all points of the rotor blade rotation. It increases or decreases total rotor thrust, whereas the cyclic changes rotor thrust *direction*. In a hover, changes in collective pitch will result in a different height above the ground. In forward flight, changes in collective pitch change the amount of thrust available, which can result in either a change in altitude or speed depending on how the pilot moves the cyclic.

Robinson R22 Collective

The yellow arrow on the right points to the twist grip throttle control. This works like a motorcycle twist grip. The Robinson R22 incorporates a throttle *correlator* which automatically rolls some throttle on and off as the collective is raised and lowered. The pilot does not feel the twist grip move, as the correlator is connected later on in the linkage.

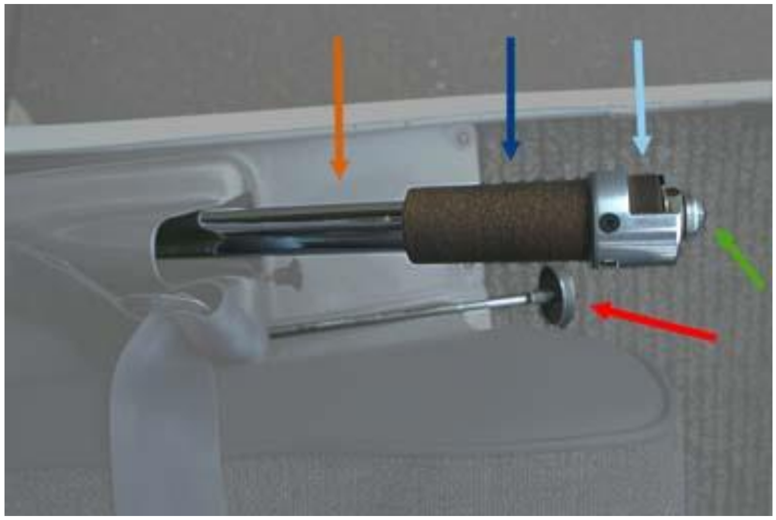
The Robinson R22 offers an optional RPM governor. When this is installed, the pilot will feel the throttle roll on and off as the governor attempts to maintain RPM. Not all R22s have governors, although some of us suspect that an AD (Airworthiness Directive) from the FAA may soon make them mandatory on all R22s. There are two types of governors available on R22s. The old style governor will both roll throttle on and off and move the collective in order to maintain RPM. The new style governor was originally designed for the R44, but is now being installed on R22s as well. This governor uses throttle, but not collective, to maintain RPM. It is extremely effective.

The blue arrow points to the collective lever (which the throttle twist grip is mounted on). The collective lever is connected to the swash plate by a series of push-pull tubes. Raising the collective lever increases the pitch on the main rotor blades, lowering the collective lever decreases the main rotor blade pitch.

The green arrow on the left points to the collective friction control. This control allows the pilot to control the amount of force it takes to move the collective control. The friction can be used on the ground and in flight in the Robinson helicopters.

Enstrom F28A Collective

The dark blue arrow points at the twist grip throttle control. In addition, the F28 incorporates throttle friction, which is the knurled knob pointed to by the light blue arrow. This control allows you to adjust the amount of force it takes to twist the throttle.



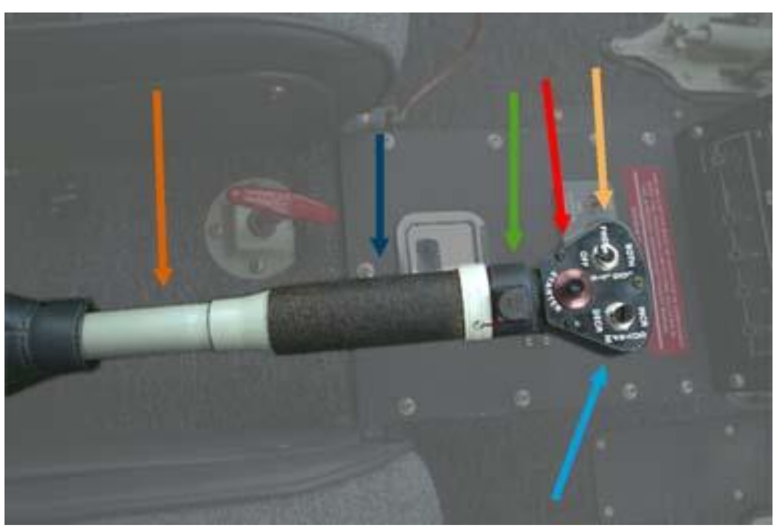
The orange arrow points to the collective lever, which works identically to the collective lever on the Robinson.

The red arrow points to the collective friction knob. Unlike the Robinson, Enstrom does not allow you to use collective friction in flight. The control is provided because during startup and shutdown the collective has a tendance to raise to the up position all on it's own. The friction is used to hold the collective down during these times.

The green arrow points to the starter button, which is on the end of the collective. This allows the pilot to activate the engine starter motor without having to take his hand off the collective. If the engine stalls during flight, he can enter autorotation while simultaneously cranking the engine to attempt to restart it. Contrast that with the Robinson which requires you to take your hand off the collective to crank with the key switch. The Enstrom only provides the starter on the left hand collective.

Bell 206BIII JetRanger Collective

Starting from the left, the orange arrow point at the collective lever. The collective lever is connected to the rotor system via push pull tubes. The 206 also has a *droop compensation* device which senses changes in the collective pitch lever and increases or decreases fuel to the engine somewhat in anticipation of a change in power required. This helps to minimize the RPM fluctuations during collective pitch change.



The dark blue arrow points to the throttle twist grip. This performs the function of an engine condition control, with positions for off, idle, and flight. In the flight position the throttle is rolled full open, and the fuel control (governor) controls the amount of fuel going to the engine in order to maintain proper rotor RPM. Between the flight and idle positions, the throttle can be used as a manual throttle, although this would only be done during an emergency (or simulated emergency) condition. This is useful during any event which would cause engine or rotor RPM to go too high, such as a high side governor failure or short shaft failure. The throttle can be rolled off to limit the amount of fuel going to the engine so that RPM is maintained in the green operating arc. Another time when this is useful is while landing after a tail rotor failure. The throttle can be manipulated to produce the amount of torque required to line the landing gear up with ground track during a running landing. The throttle can not be used to increase fuel flow over what the governor is commanding, which means it can not be used as a manual fuel control to correct for a low side governor failure.

The green arrow is pointing to the idle release button. When the throttle is rolled from "off" to "idle", the idle release button snaps into a detent which prevents the throttle from being rolled back to "off". This prevents the pilot from flaming out the engine when going from "flight" to "idle". In order to move the throttle from "idle" to "off", the pilot must hold down the idle release button while rolling the throttle to "off".

The red arrow is pointing at the starter button. Pushing this button causes the starter/generator to act as a starter motor, turning over the engine. The starter can also be used to motor the engine in order to cool it down by forcing cool air through it.

The yellow arrow points at the landing light switch, which is a three position switch. The three positions are "off", "forward" and "both". In forward, only the forward pointing light is activated. In "both", the forward and the downward angled lights are activated.

The blue arrow on the bottom points to the governor trim switch. By holding it in "increase" or "decrease" the pilot can set the RPM that the governor will attempt to maintain.