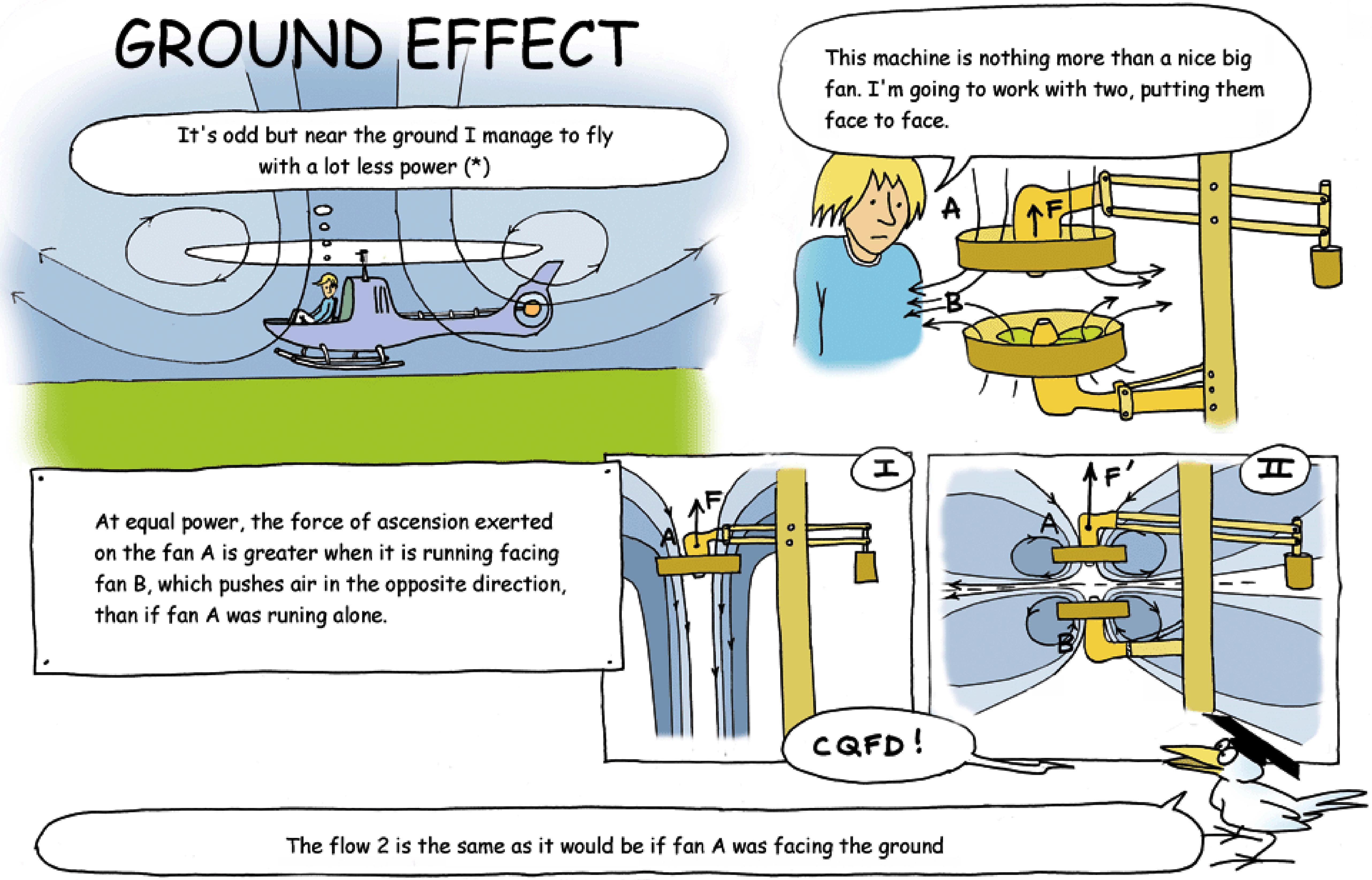
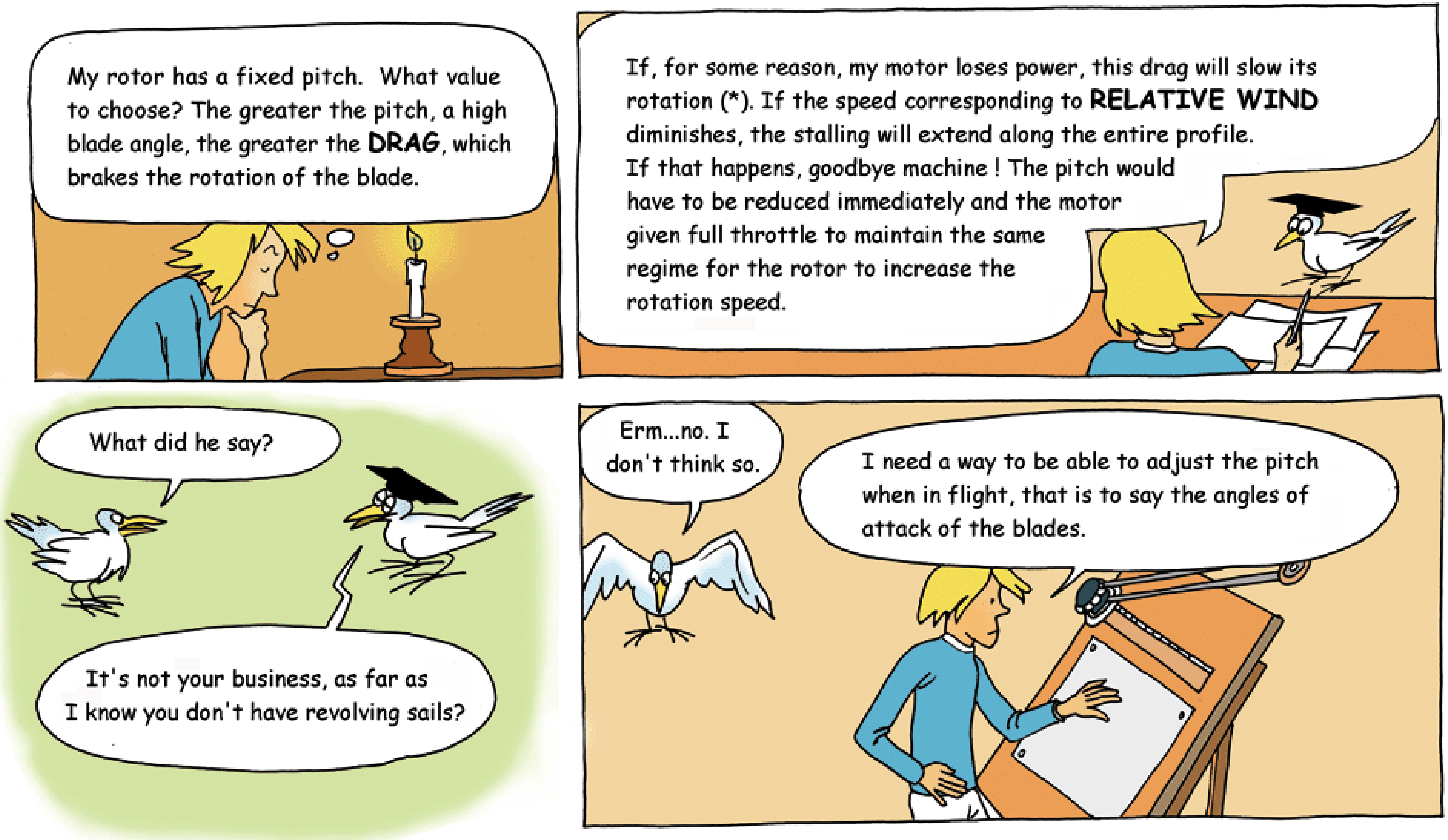
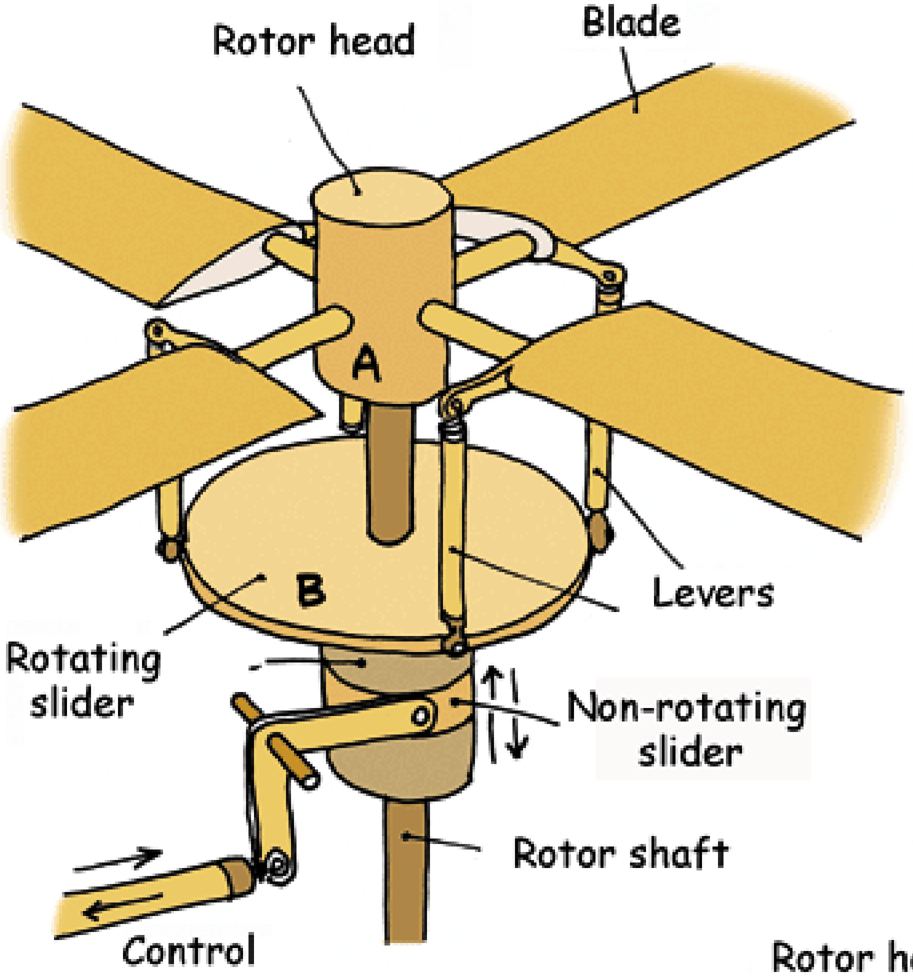


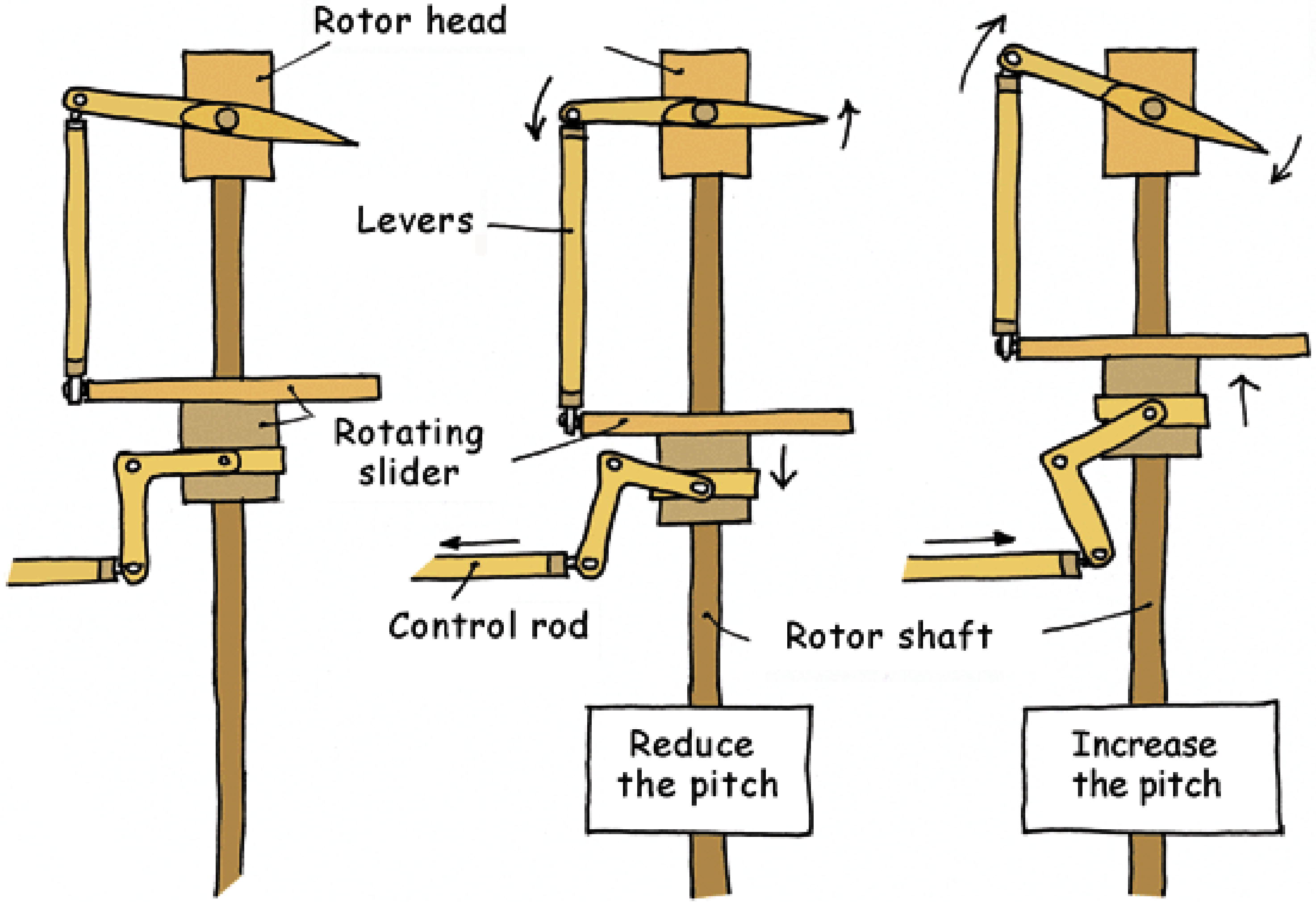
(*) The ground effect becomes important when the rotor is at a distance from the ground equal or inferior to half its diameter.

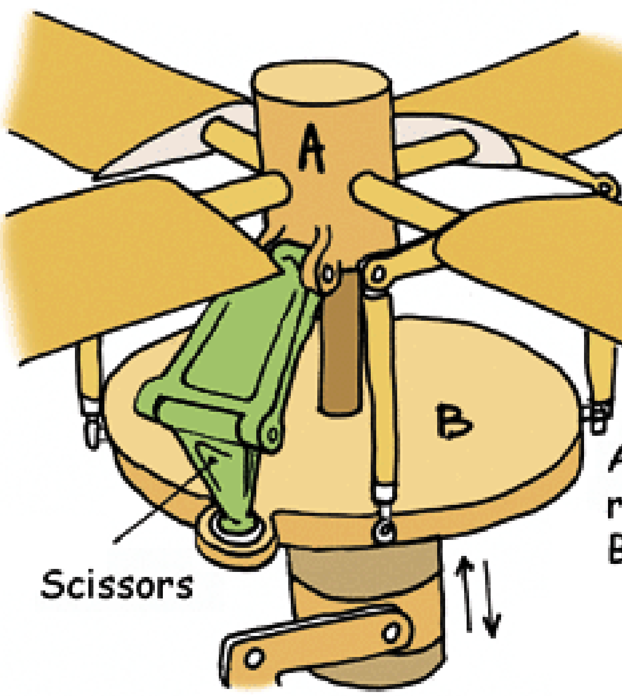
INCREASING RPM

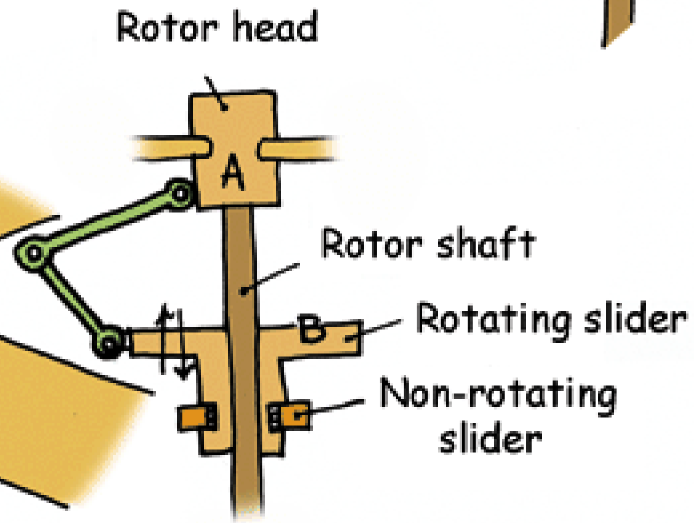


(*) A rotor whose motor stopped suddenly would be dangerously slowed within...one second.





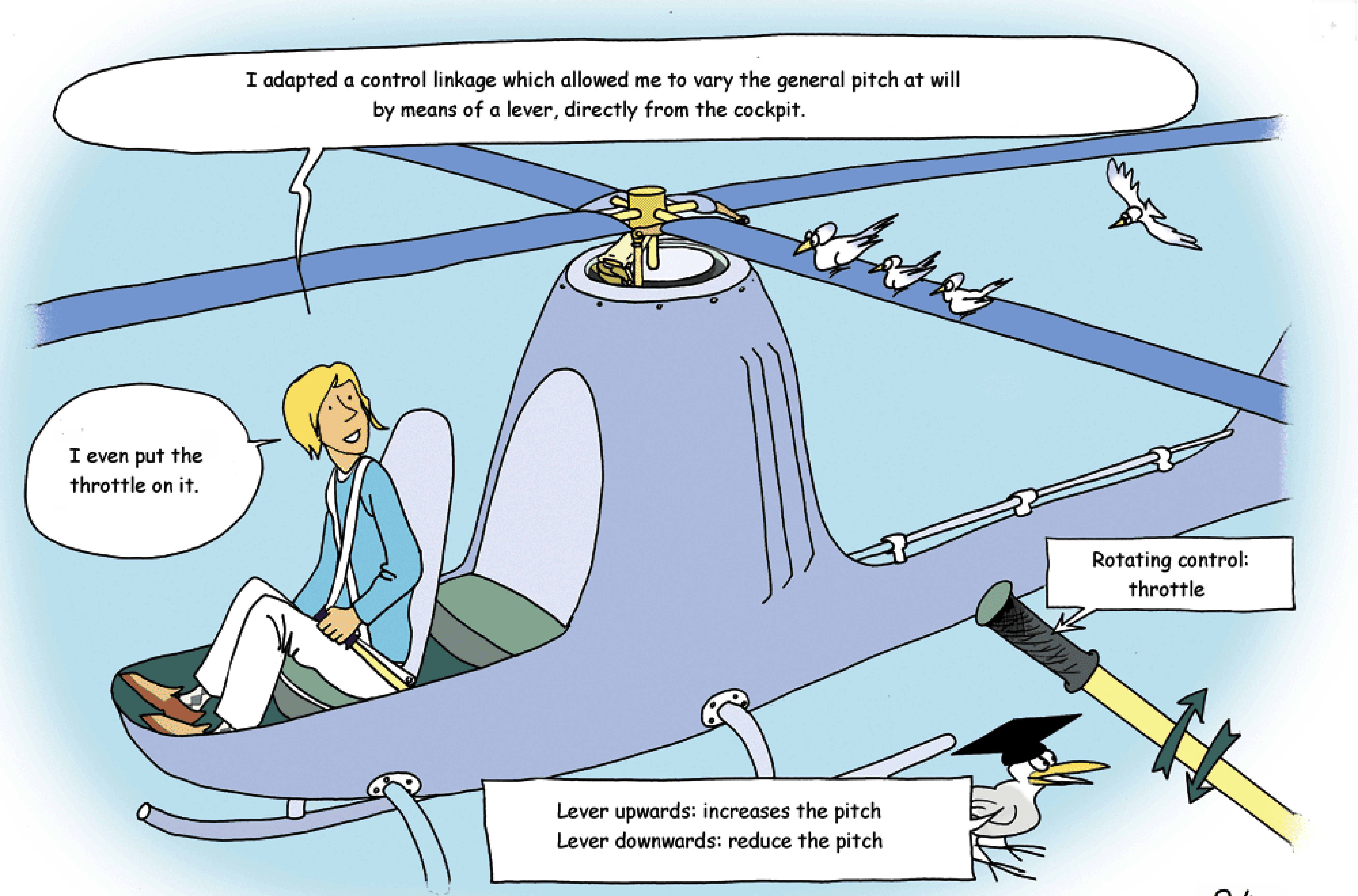


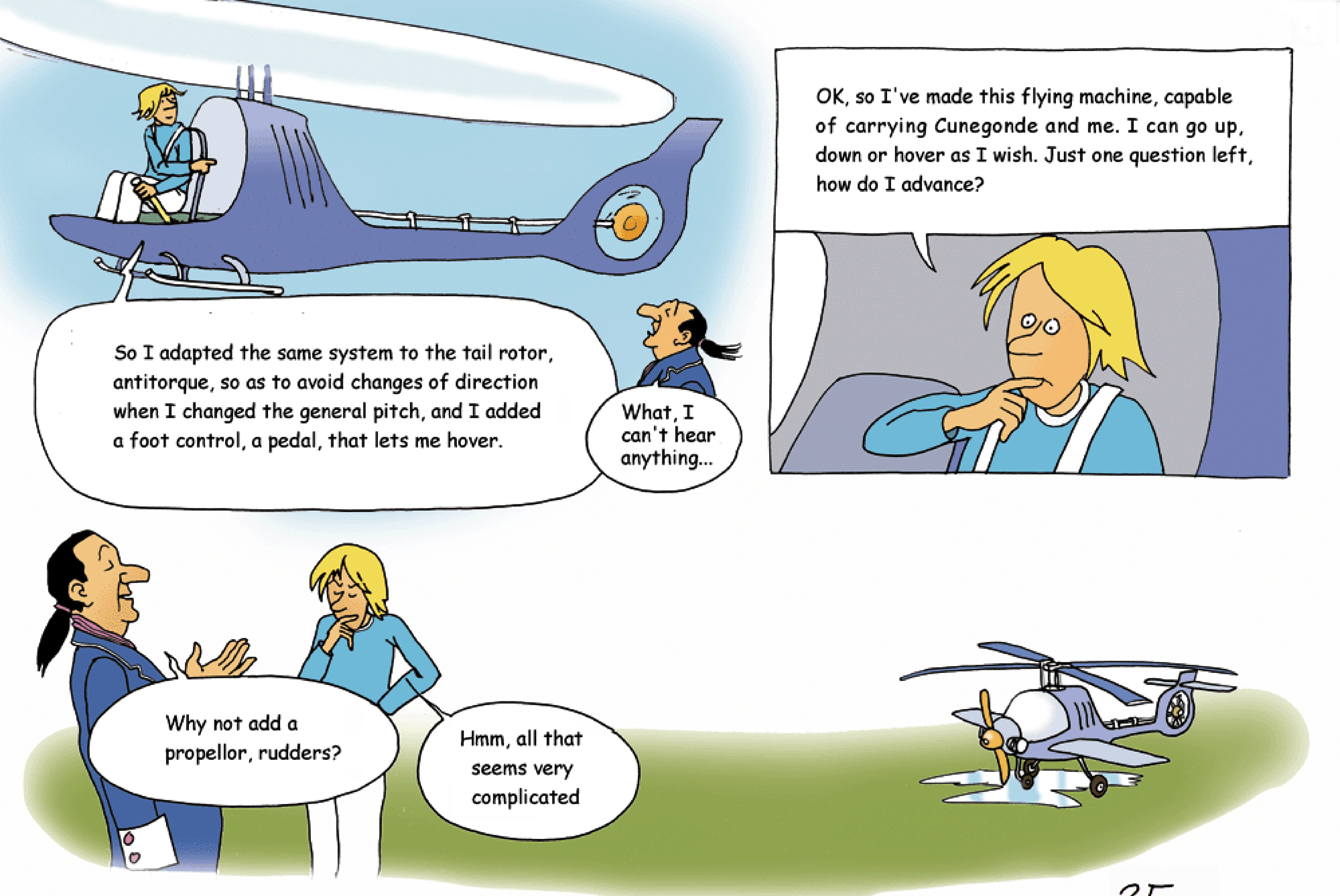


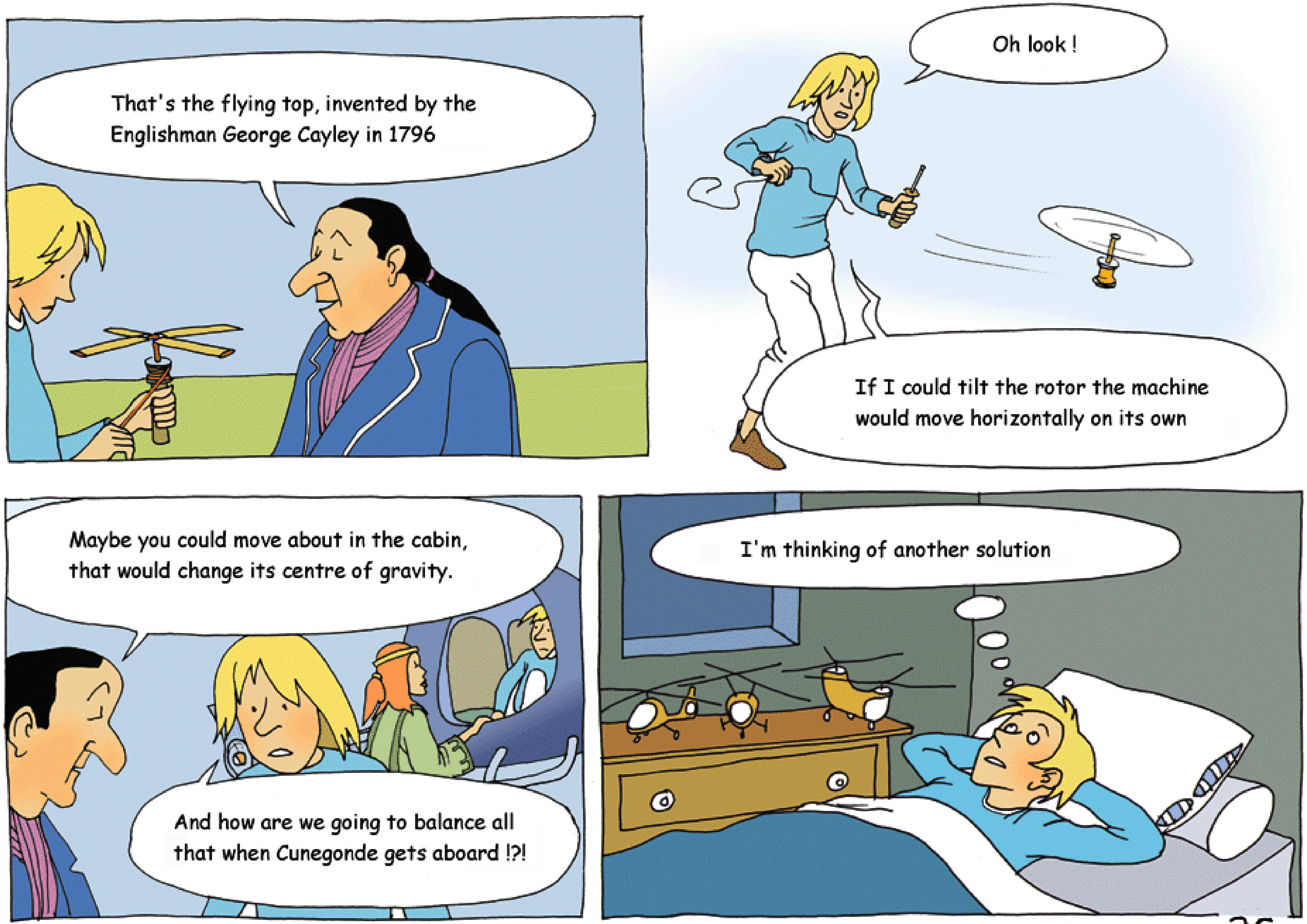
Articulated "scissors" oblige the rotor head A and the rotating slider B to turn at the same angular speed.

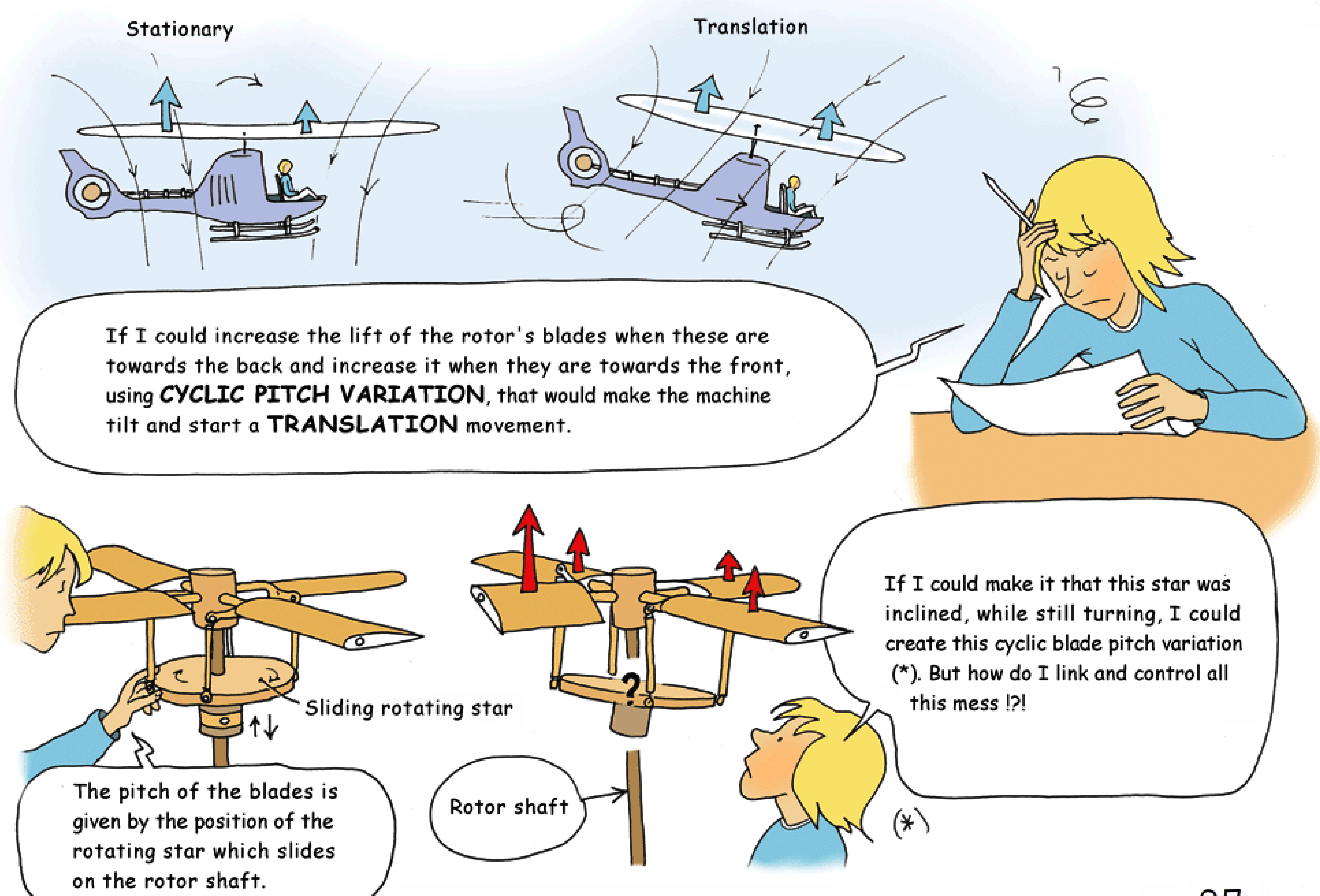
With such a system we can vary all the blades of a rotor at the same time by acting on the non rotating slider, linked via a ball-bearing and a rotating slider A, which retransmits the order to the blades via levers.

The Management.

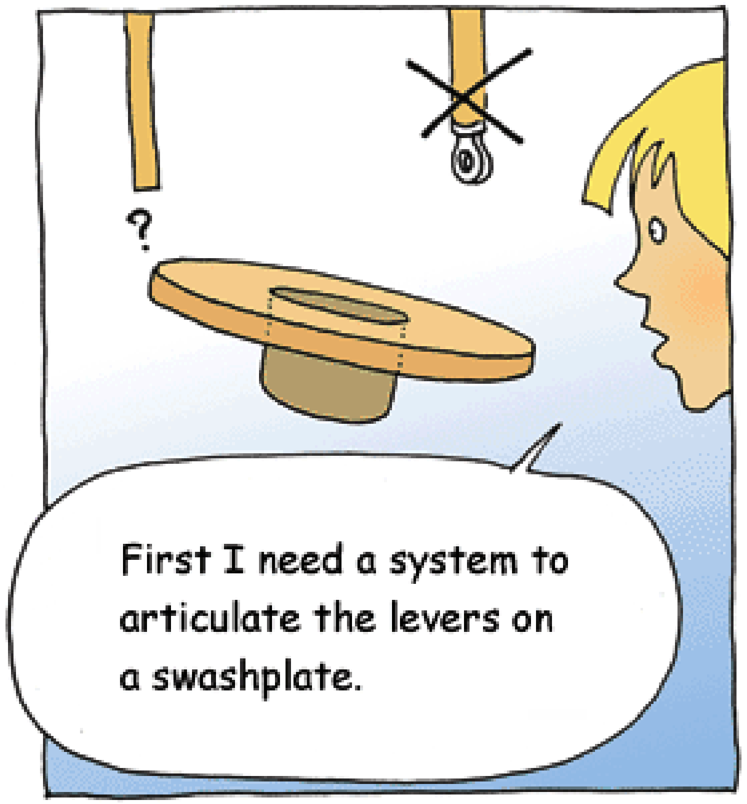

I adapted a control linkage which allowed me to vary the general pitch at will by means of a lever, directly from the cockpit.
I even put the throttle on it.
Rotating control: throttle
Lever upwards: increases the pitch
Lever downwards: reduce the pitch

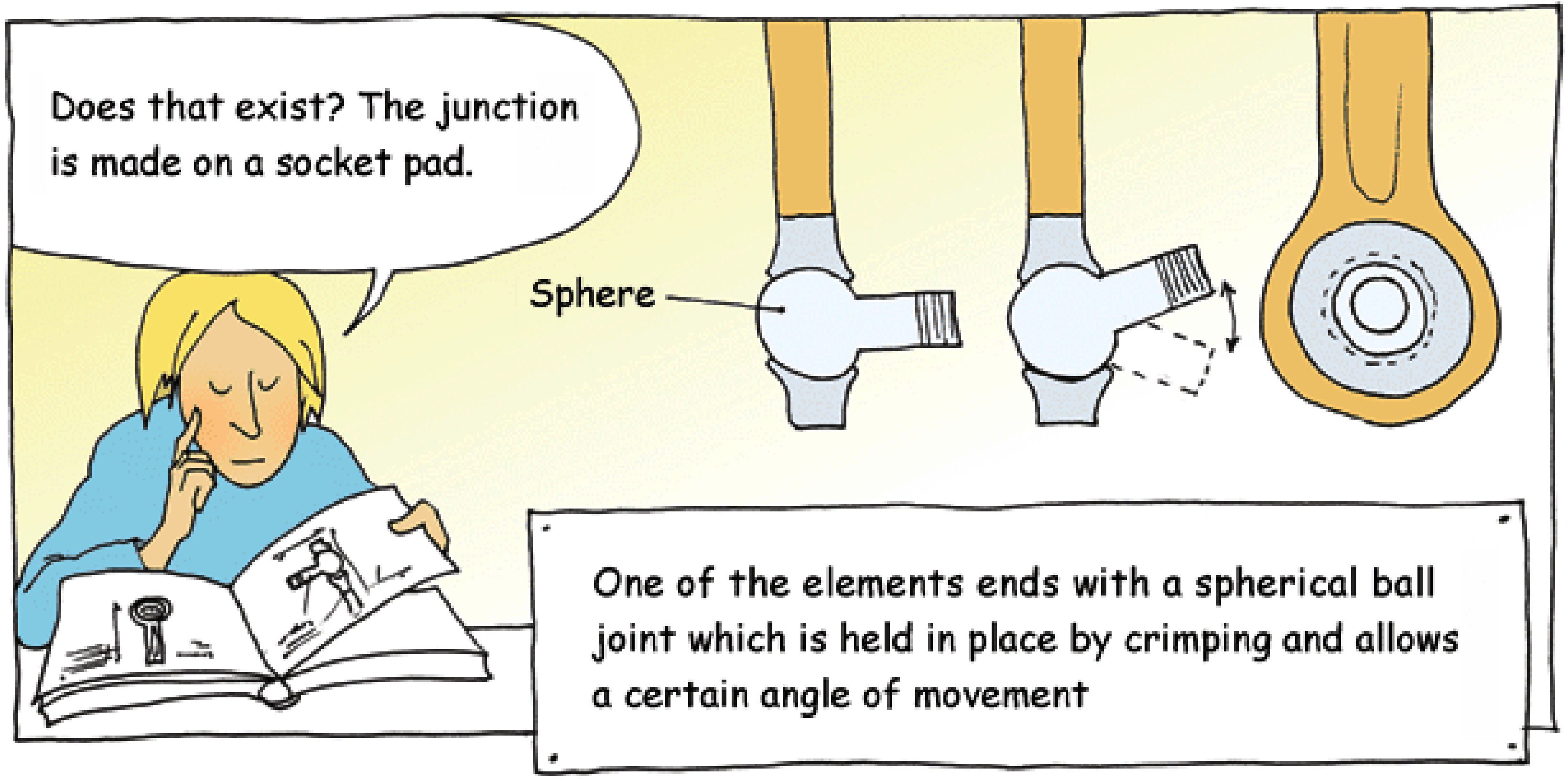

So I adapted the same system to the tail rotor, antitorque, so as to avoid changes of direction when I changed the general pitch, and I added a foot control, a pedal, that lets me hover.
What, I can't hear anything...
OK, so I've made this flying machine, capable of carrying Cunegonde and me. I can go up, down or hover as I wish. Just one question left, how do I advance?
Why not add a propellor, rudders?
Hmm, all that seems very complicated


That's the flying top, invented by the Englishman George Cayley in 1796
Oh look !
If I could tilt the rotor the machine would move horizontally on its own
Maybe you could move about in the cabin, that would change its centre of gravity.
And how are we going to balance all that when Cunegonde gets aboard !?!
I'm thinking of another solution

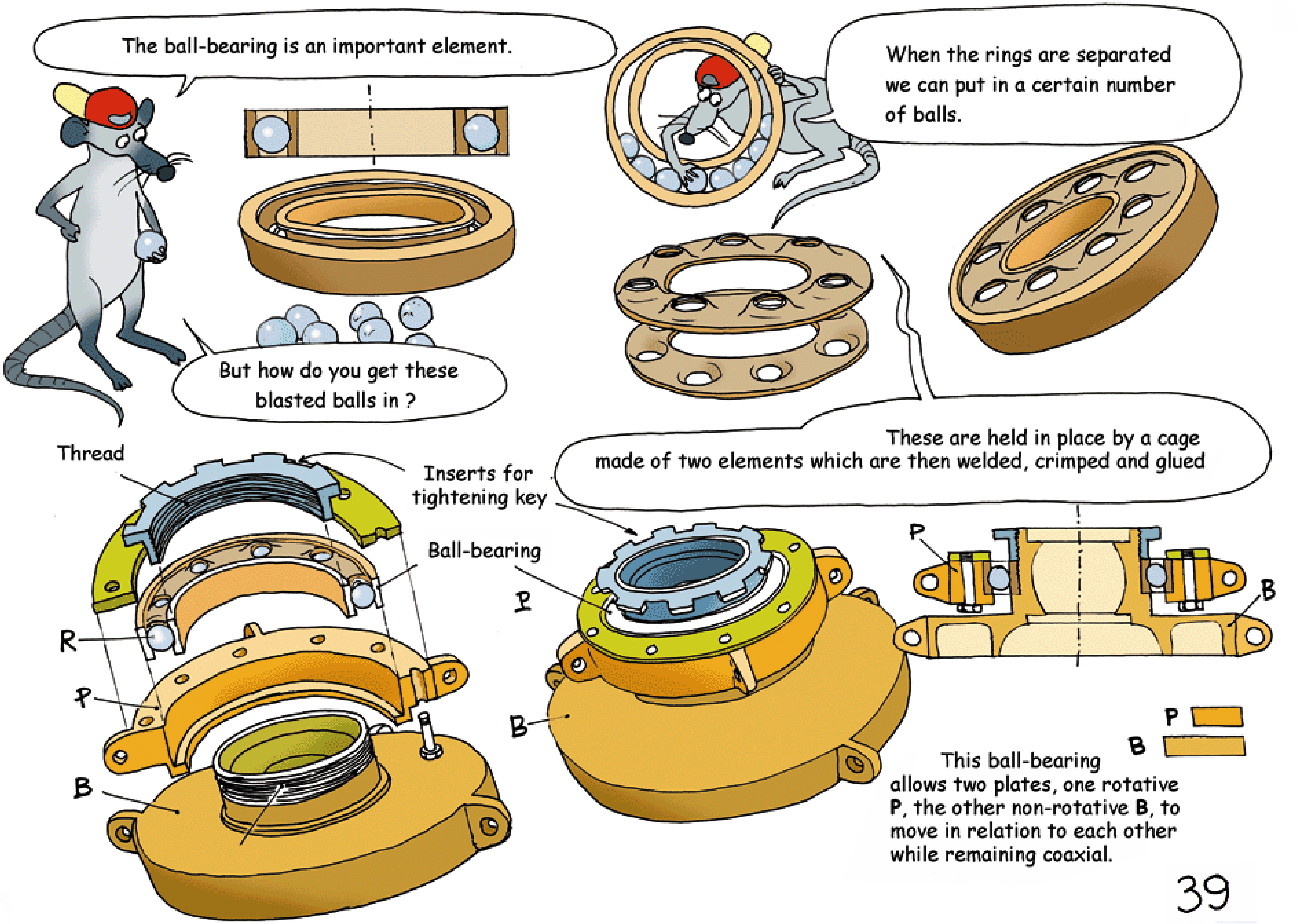


(*) Invented by the Spaniard Pescara, who introduced the idea of autorotation.

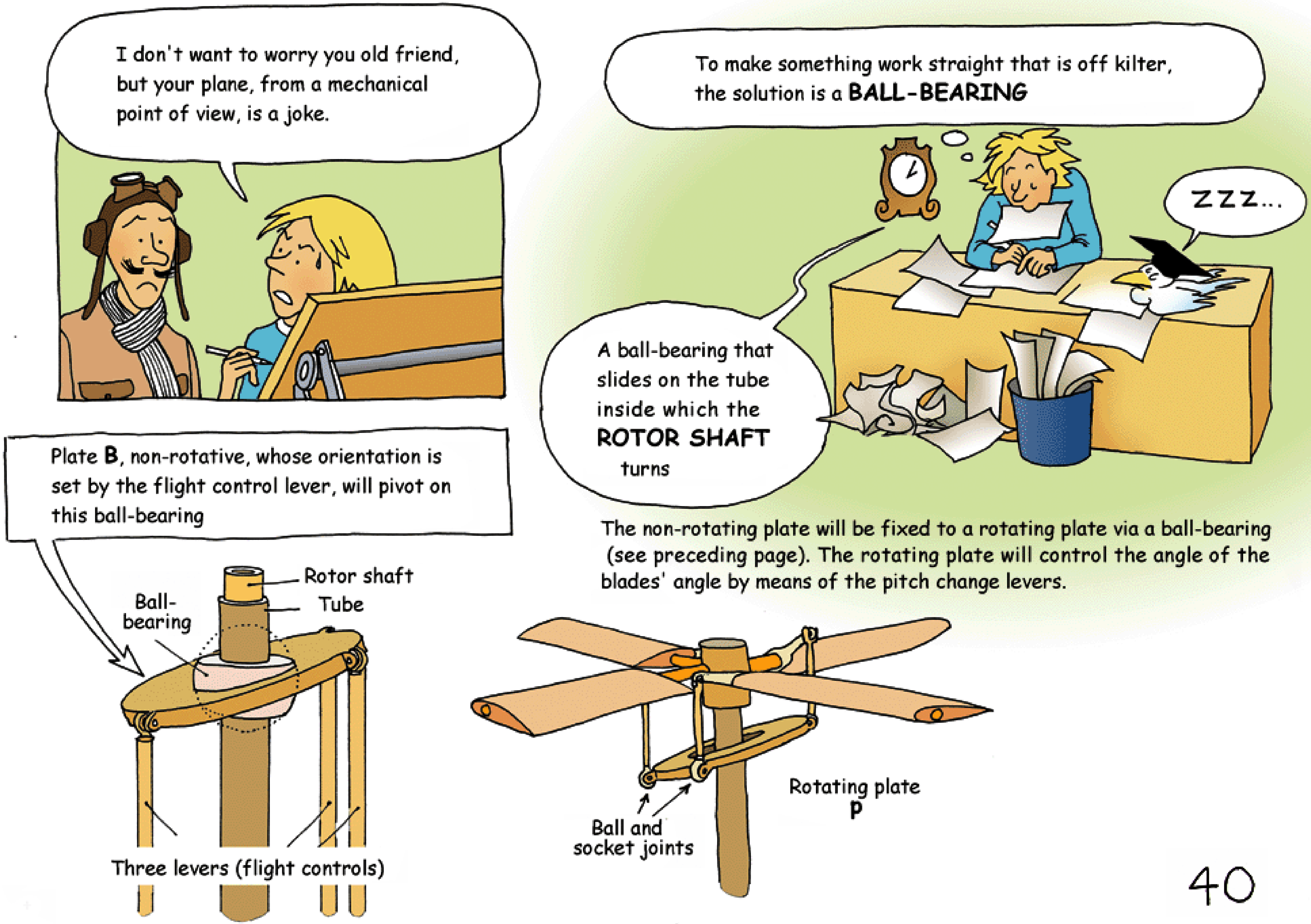


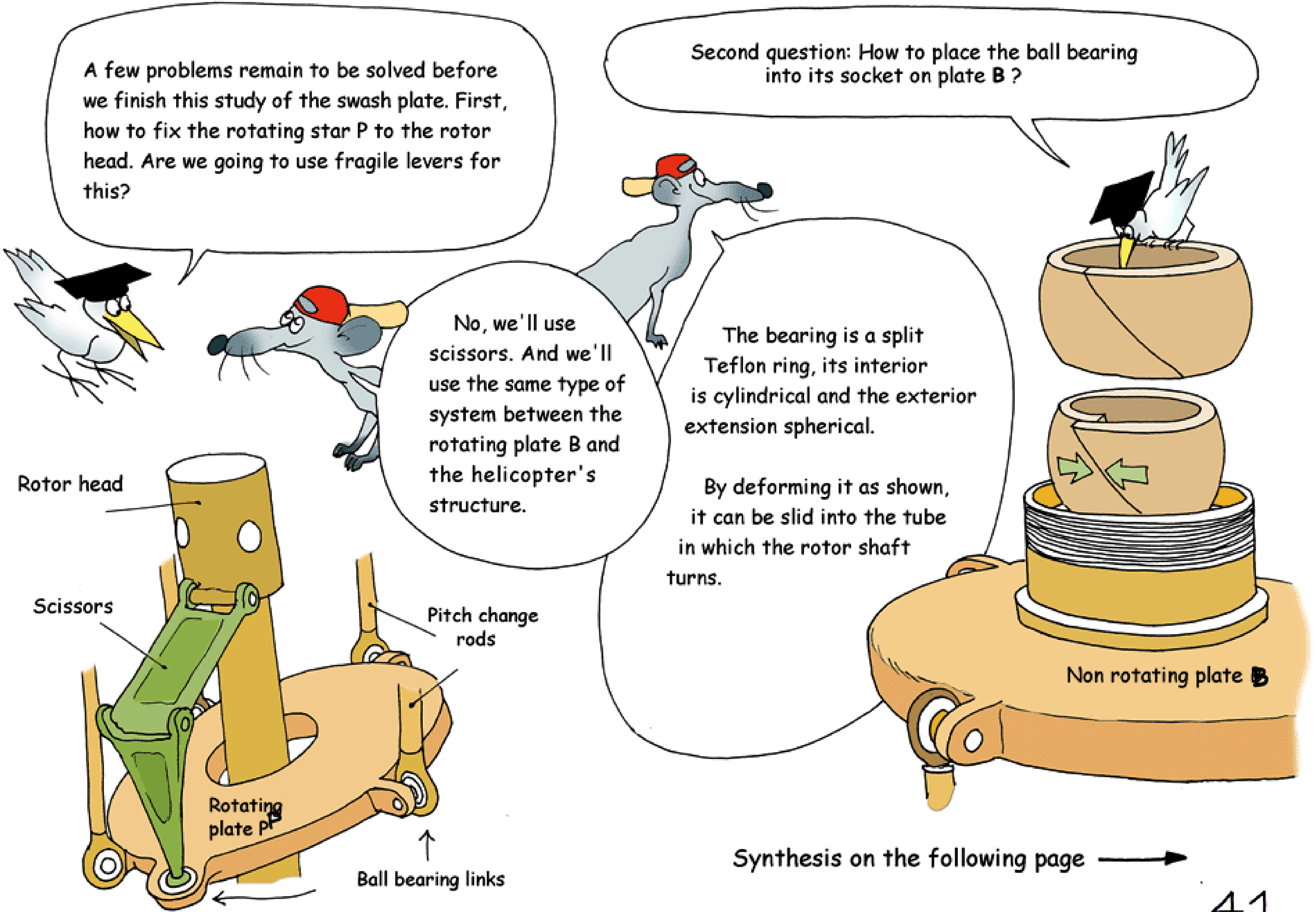


The life of a helicopter pilot hangs on a complex mechanical system bringing into play a set of levers of this type, cogwheels, ball-bearings. All these elements must be machined to the highest precision. Construction and maintenance costs are higher than for a plane. Since the 70s, new materials have been used, composites, elastomers and self-lubricating components, which have helped reduce their complexity, weight, construction costs and the maintenance schedule while improving reliability. But this is outside the scope of this book.



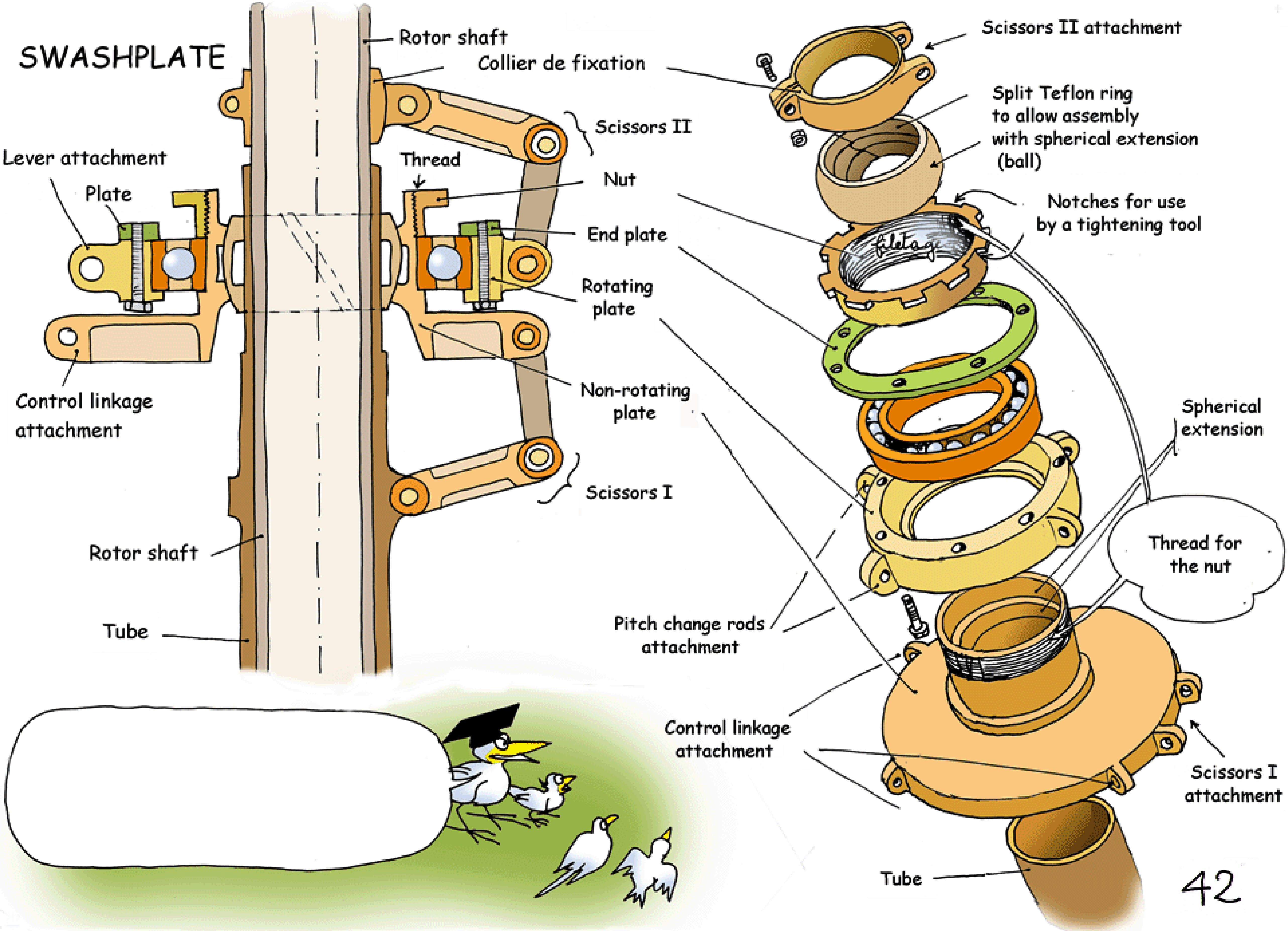
The ball-bearing is an important element.
But how do you get these blasted balls in ?
When the rings are separated we can put in a certain number of balls.
These are held in place by a cage made of two elements which are then welded, crimped and glued
Thread
Inserts for tightening key
Ball-bearing
R
P
B
P
B
P
B
P
B
This ball-bearing allows two plates, one rotative **P**, the other non-rotative **B**, to move in relation to each other while remaining coaxial.

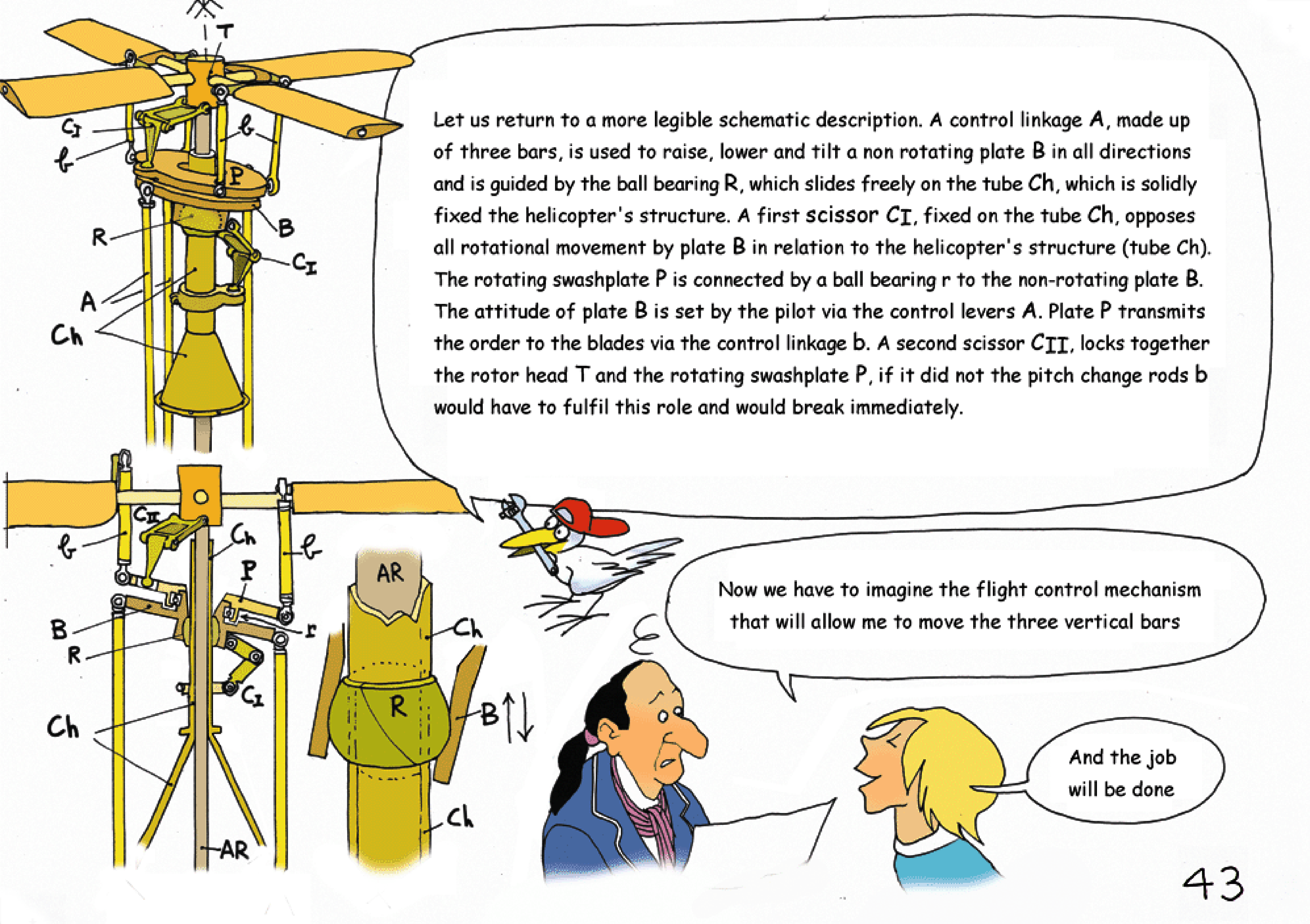

I don't want to worry you old friend, but your plane, from a mechanical point of view, is a joke.
To make something work straight that is off kilter, the solution is a **BALL-BEARING**
ZZZ...
A ball-bearing that slides on the tube inside which the **ROTOR SHAFT** turns
Plate **B**, non-rotative, whose orientation is set by the flight control lever, will pivot on this ball-bearing
Rotor shaft
Tube
Ball-bearing
Three levers (flight controls)
The non-rotating plate will be fixed to a rotating plate via a ball-bearing (see preceding page). The rotating plate will control the angle of the blades' angle by means of the pitch change levers.
Ball and socket joints
Rotating plate P

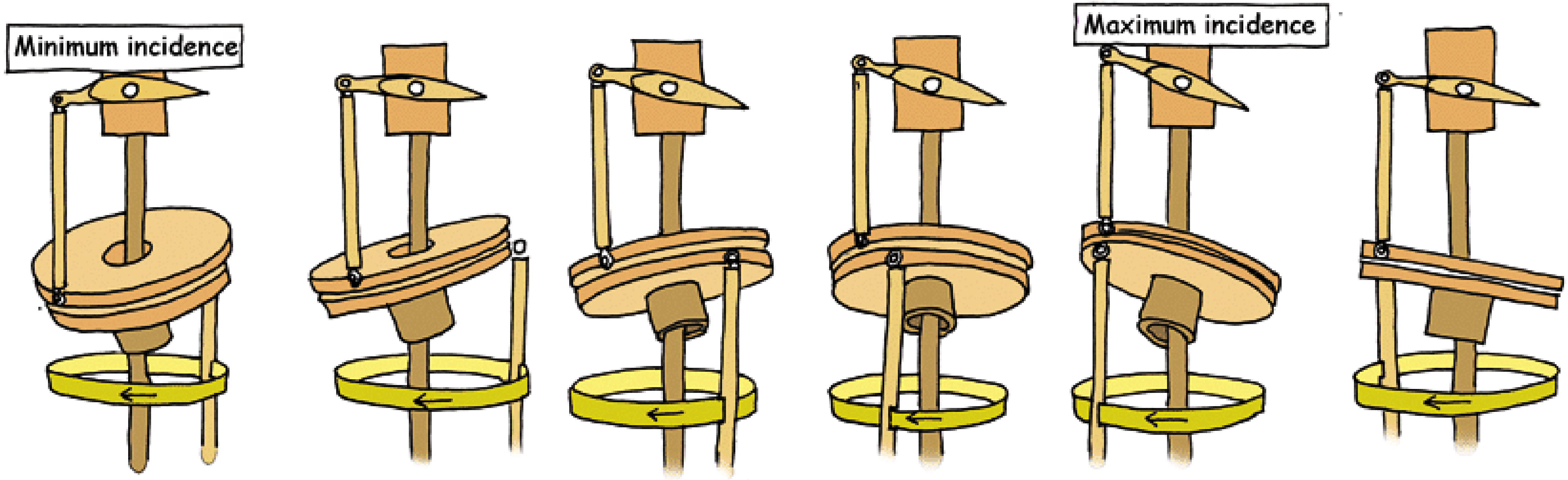


Synthesis on the following page →

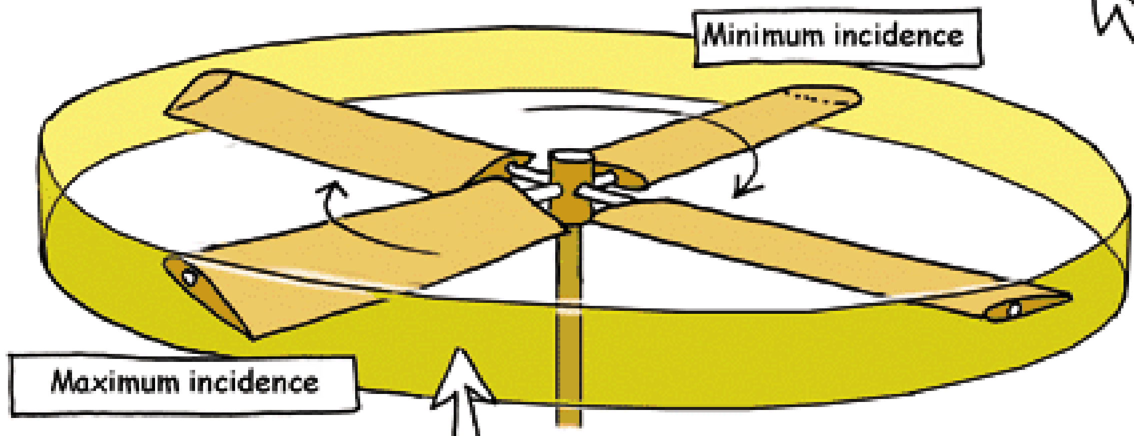
SWASHPLATE


Rotor shaft
Collier de fixation
Scissors II
Lever attachment
Plate
Thread
Nut
End plate
Rotating
plate
Control linkage
attachment
Non-rotating
plate
Scissors I
Rotor shaft
Tube
Scissors II attachment
Split Teflon ring
to allow assembly
with spherical extension
(ball)
Notches for use
by a tightening tool
Spherical
extension
Thread for
the nut
Pitch change rods
attachment
Control linkage
attachment
Scissors I
attachment
Tube


Let us return to a more legible schematic description. A control linkage A, made up of three bars, is used to raise, lower and tilt a non rotating plate B in all directions and is guided by the ball bearing R, which slides freely on the tube Ch, which is solidly fixed the helicopter's structure. A first scissor CI, fixed on the tube Ch, opposes all rotational movement by plate B in relation to the helicopter's structure (tube Ch). The rotating swashplate P is connected by a ball bearing r to the non-rotating plate B. The attitude of plate B is set by the pilot via the control levers A. Plate P transmits the order to the blades via the control linkage b. A second scissor CII, locks together the rotor head T and the rotating swashplate P, if it did not the pitch change rods b would have to fulfil this role and would break immediately.
Now we have to imagine the flight control mechanism that will allow me to move the three vertical bars
And the job will be done

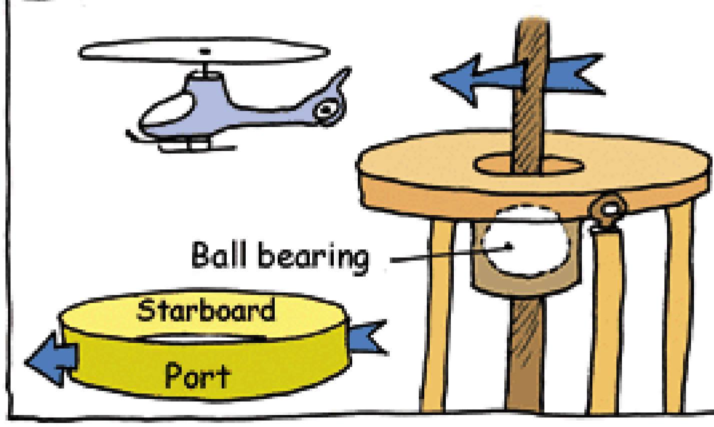


Etc...
Below, the apparent movement of one of the control linkages



Above we follow one blade's movement. Its incidence varies periodically between a minimum and a maximum value

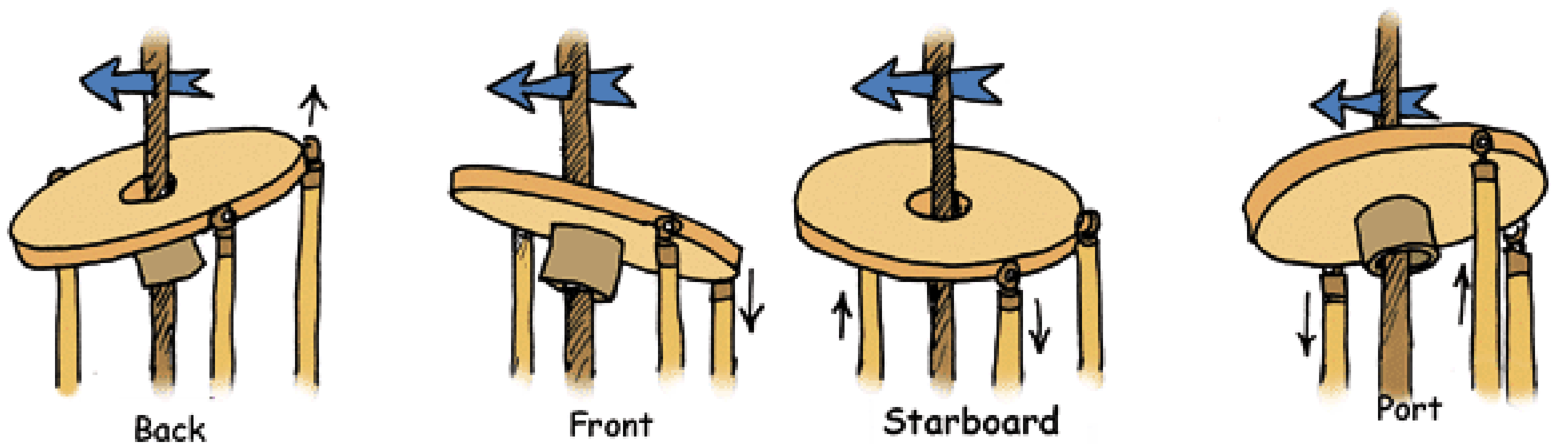
Here the blades occupy four different positions in the plane of rotation

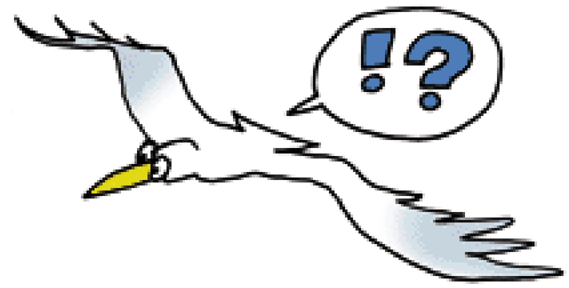


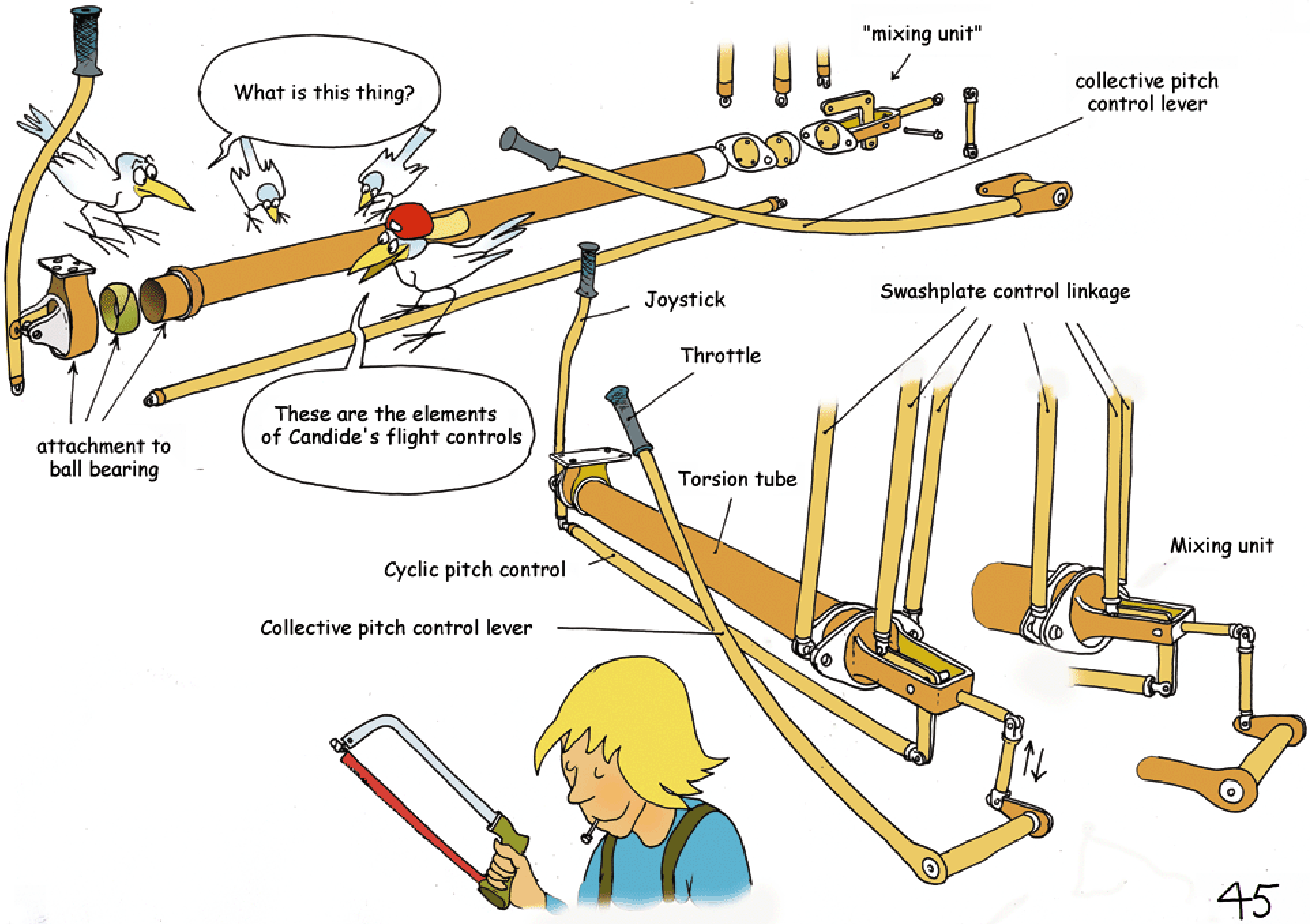
The arrow points towards the front of the aircraft.

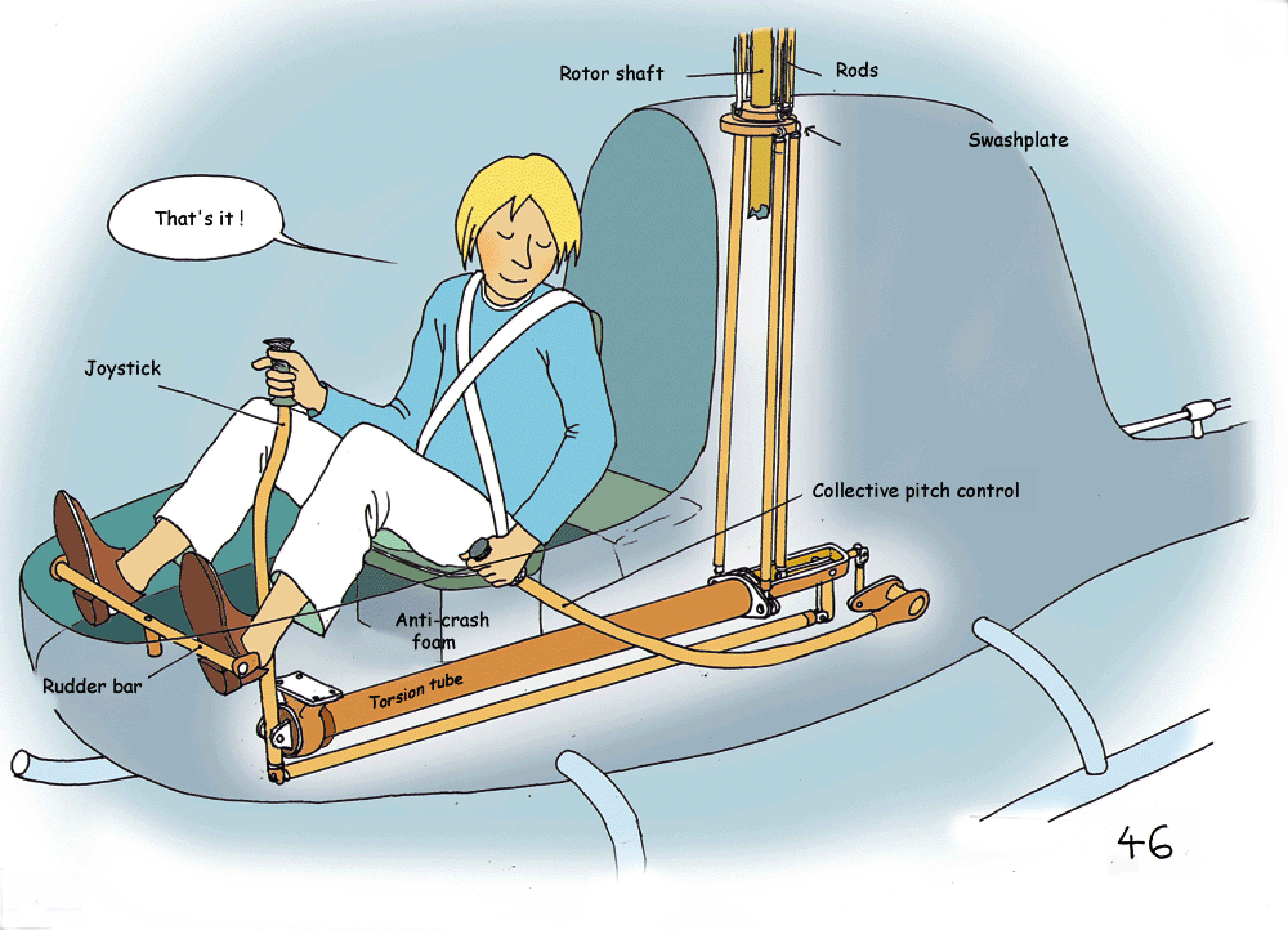
Three rods are enough to control the non-rotating plate's attitude.

Fly the helicopter by increasing the blade indidence

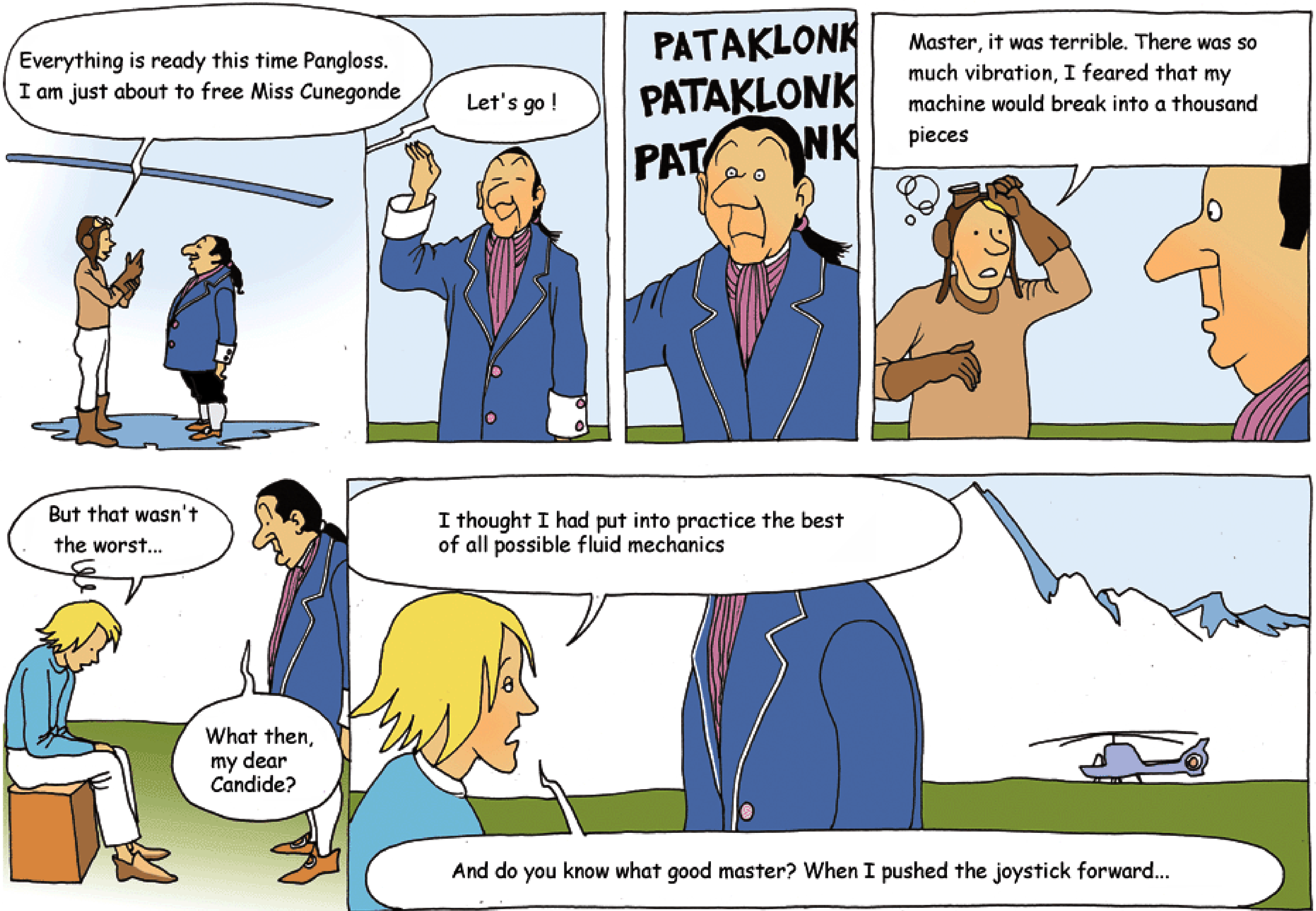




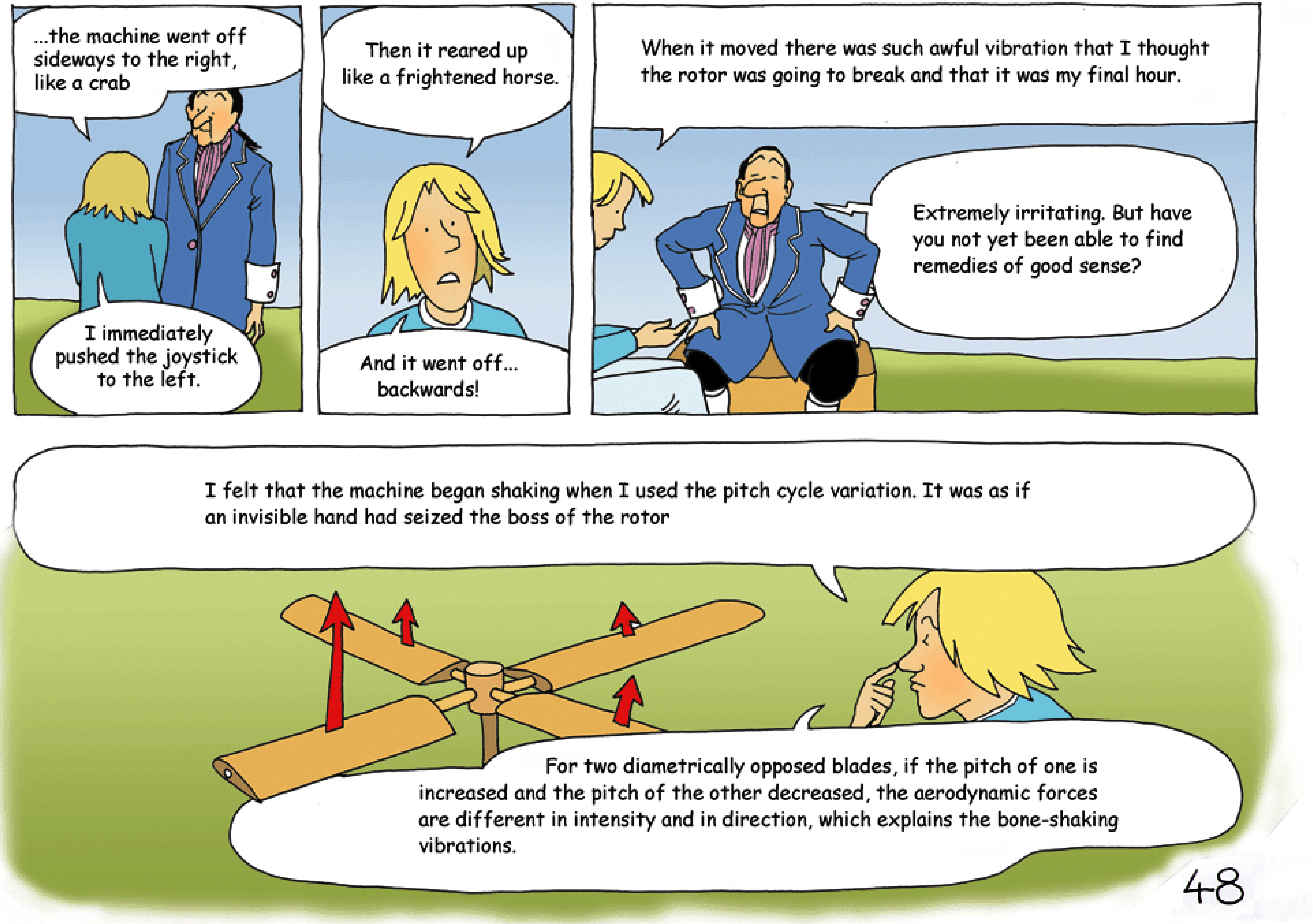

What is this thing?
These are the elements of Candide's flight controls
"mixing unit"
collective pitch control lever
attachment to ball bearing
Joystick
Swashplate control linkage
Throttle
Torsion tube
Mixing unit
Cyclic pitch control
Collective pitch control lever

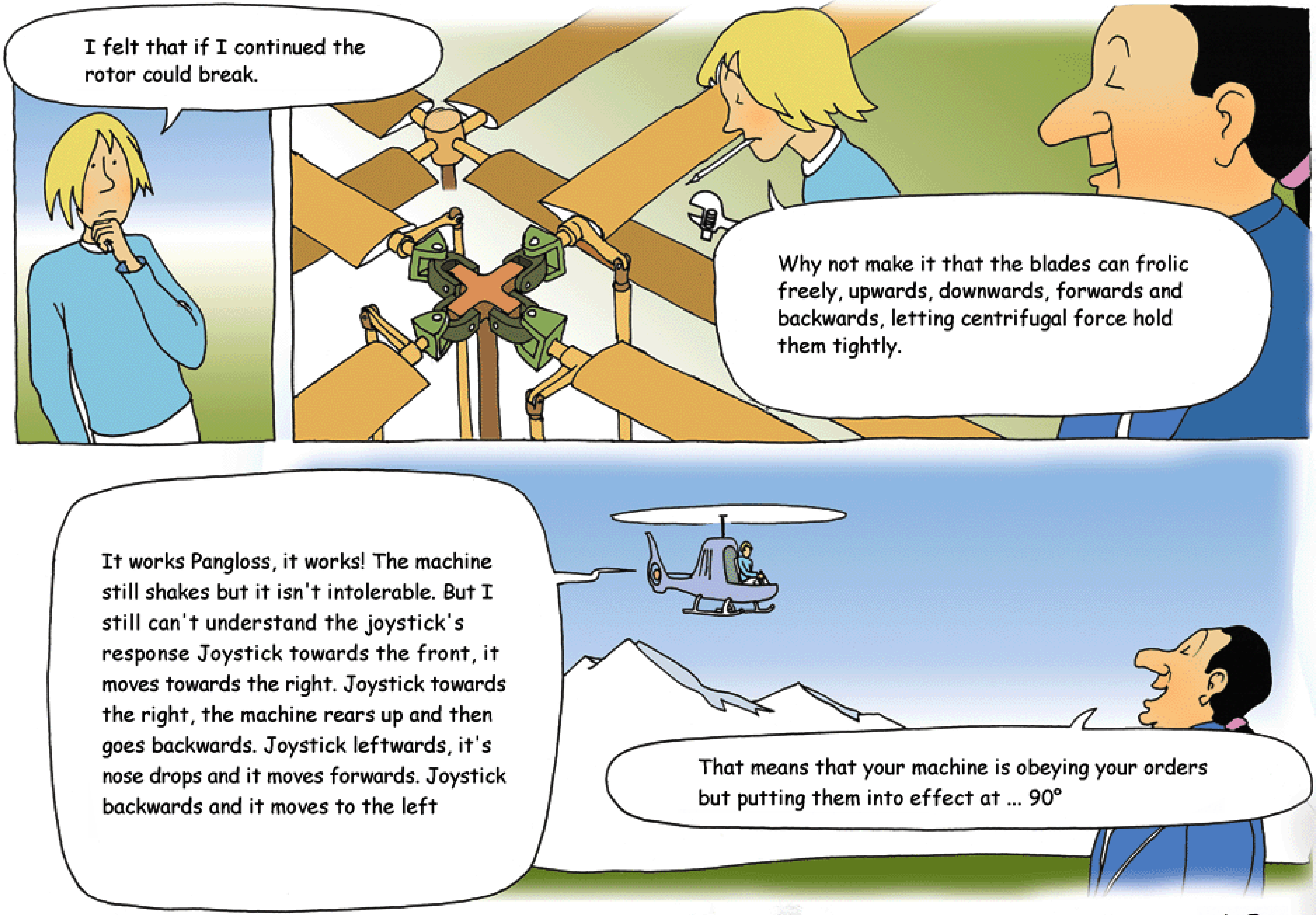


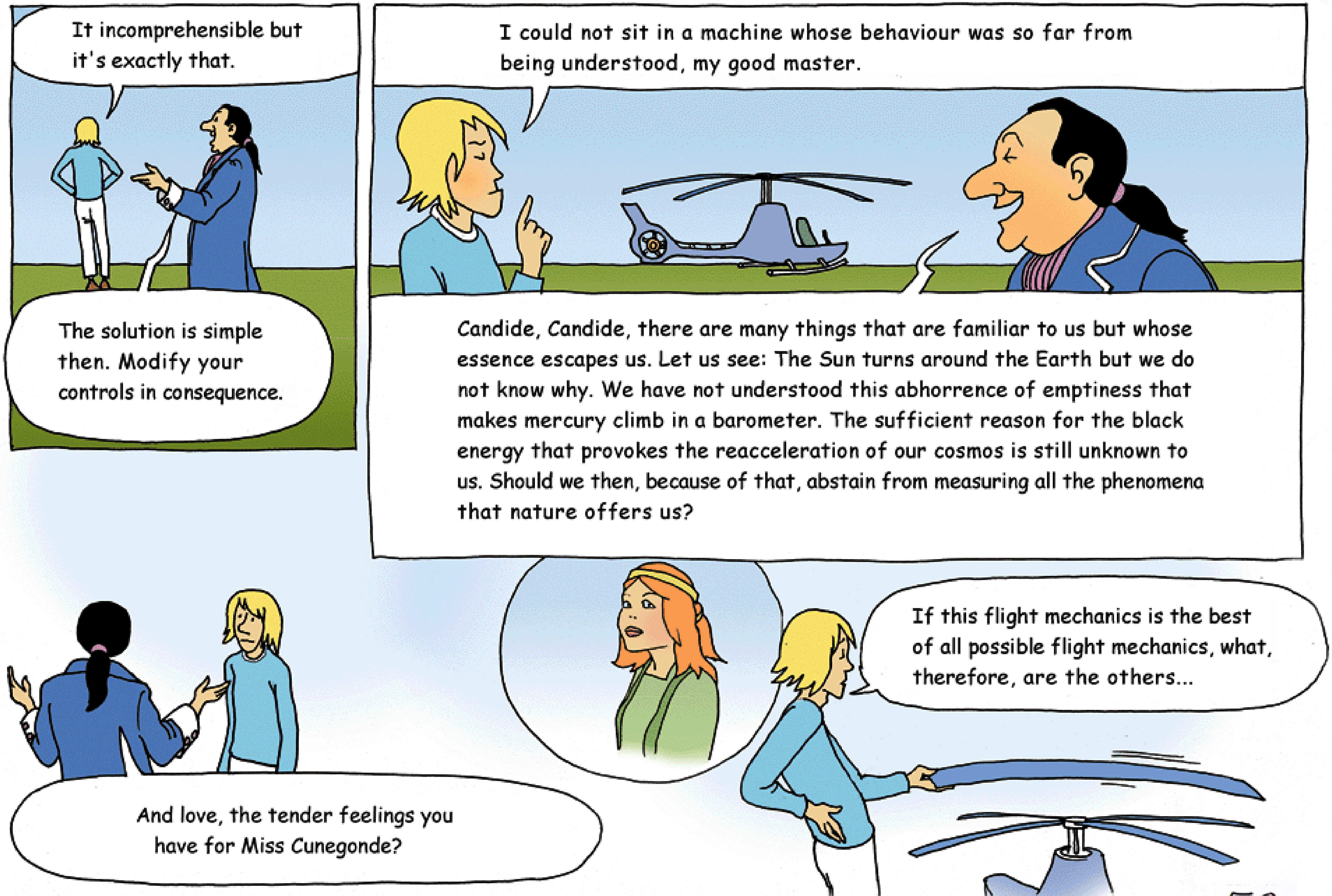
Rotor shaft
Rods
Swashplate
That's it !
Joystick
Collective pitch control
Anti-crash foam
Rudder bar
Torsion tube



Everything is ready this time Pangloss. I am just about to free Miss Cunegonde
Let's go !
PATAKLONK
PATAKLONK
PAT
NK
Master, it was terrible. There was so much vibration, I feared that my machine would break into a thousand pieces
But that wasn't the worst...
What then, my dear Candide?
I thought I had put into practice the best of all possible fluid mechanics
And do you know what good master? When I pushed the joystick forward...


...the machine went off sideways to the right, like a crab
I immediately pushed the joystick to the left.
Then it reared up like a frightened horse.
And it went off... backwards!
When it moved there was such awful vibration that I thought the rotor was going to break and that it was my final hour.
Extremely irritating. But have you not yet been able to find remedies of good sense?
I felt that the machine began shaking when I used the pitch cycle variation. It was as if an invisible hand had seized the boss of the rotor
For two diametrically opposed blades, if the pitch of one is increased and the pitch of the other decreased, the aerodynamic forces are different in intensity and in direction, which explains the bone-shaking vibrations.


I felt that if I continued the rotor could break.
Why not make it that the blades can frolic freely, upwards, downwards, forwards and backwards, letting centrifugal force hold them tightly.
It works Pangloss, it works! The machine still shakes but it isn't intolerable. But I still can't understand the joystick's response Joystick towards the front, it moves towards the right. Joystick towards the right, the machine rears up and then goes backwards. Joystick leftwards, it's nose drops and it moves forwards. Joystick backwards and it moves to the left
That means that your machine is obeying your orders but putting them into effect at ... 90°


It incomprehensible but it's exactly that.
The solution is simple then. Modify your controls in consequence.
I could not sit in a machine whose behaviour was so far from being understood, my good master.
Candide, Candide, there are many things that are familiar to us but whose essence escapes us. Let us see: The Sun turns around the Earth but we do not know why. We have not understood this abhorrence of emptiness that makes mercury climb in a barometer. The sufficient reason for the black energy that provokes the reacceleration of our cosmos is still unknown to us. Should we then, because of that, abstain from measuring all the phenomena that nature offers us?
And love, the tender feelings you have for Miss Cunegonde?
If this flight mechanics is the best of all possible flight mechanics, what, therefore, are the others...