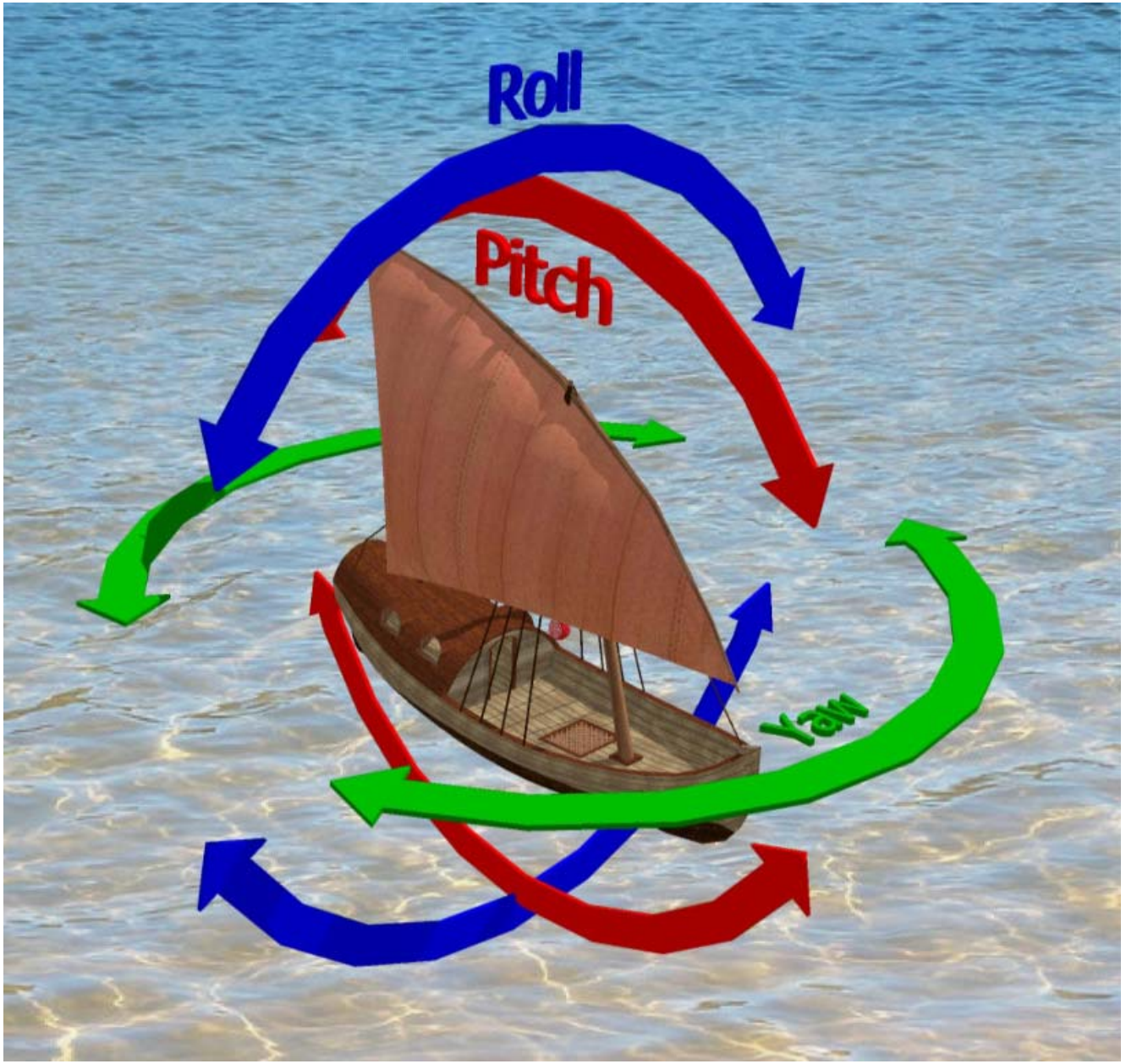
What did the Wright brothers invent?

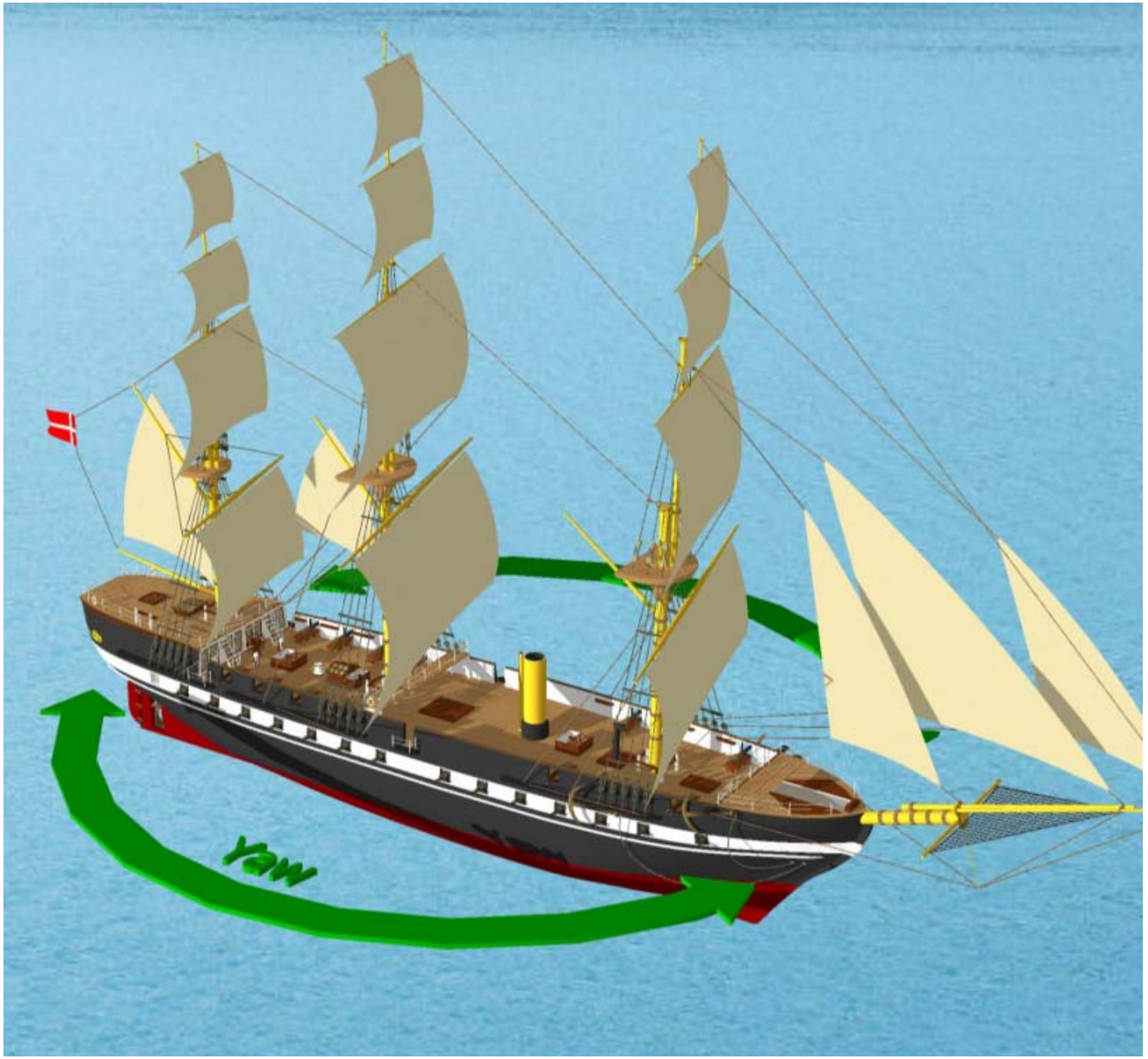
The airplane, right? Well, not exactly.

The Wrights never claimed to have invented the airplane, or even the first airplane to fly. In their own words, they made the first sustained, powered, *controlled* flights. The key word here is "control." Wilbur and Orville's most important contribution to aviation was an effective control system for an aircraft and the skills needed to navigate it. Without control the airplane would never have been a safe or practical means of transportation.

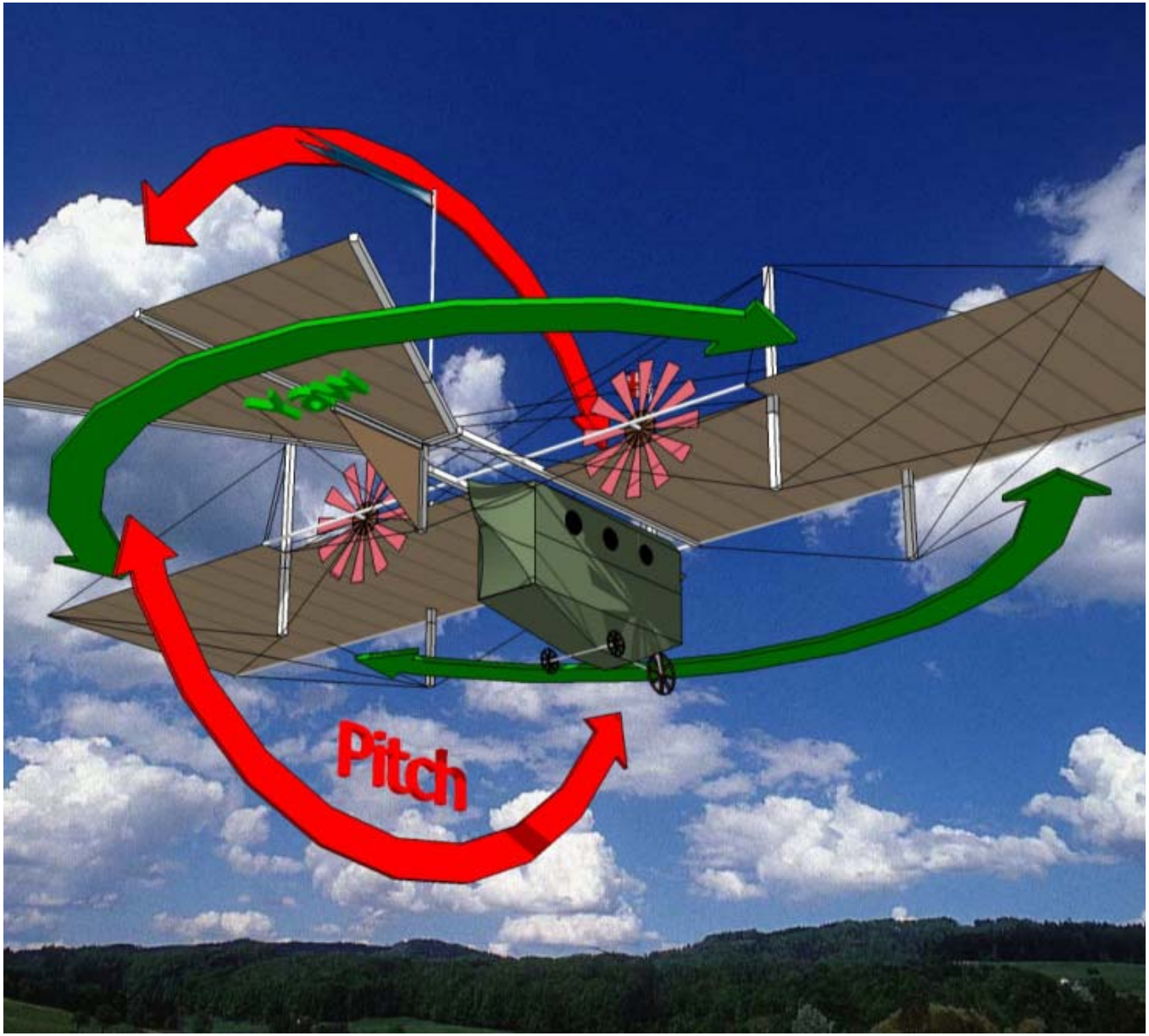
The first clues as to how to control an aircraft came from sailing ships. As soon as sailors put to sea, they found their vessels could be upset by three types of motion. A wave coming broadside at a ship would cause it to **roll** from side to side. A wave aimed at the front or back caused the bow and stern to **pitch** up and down. Finally, wind and waves could make the vessel **yaw** right and left.



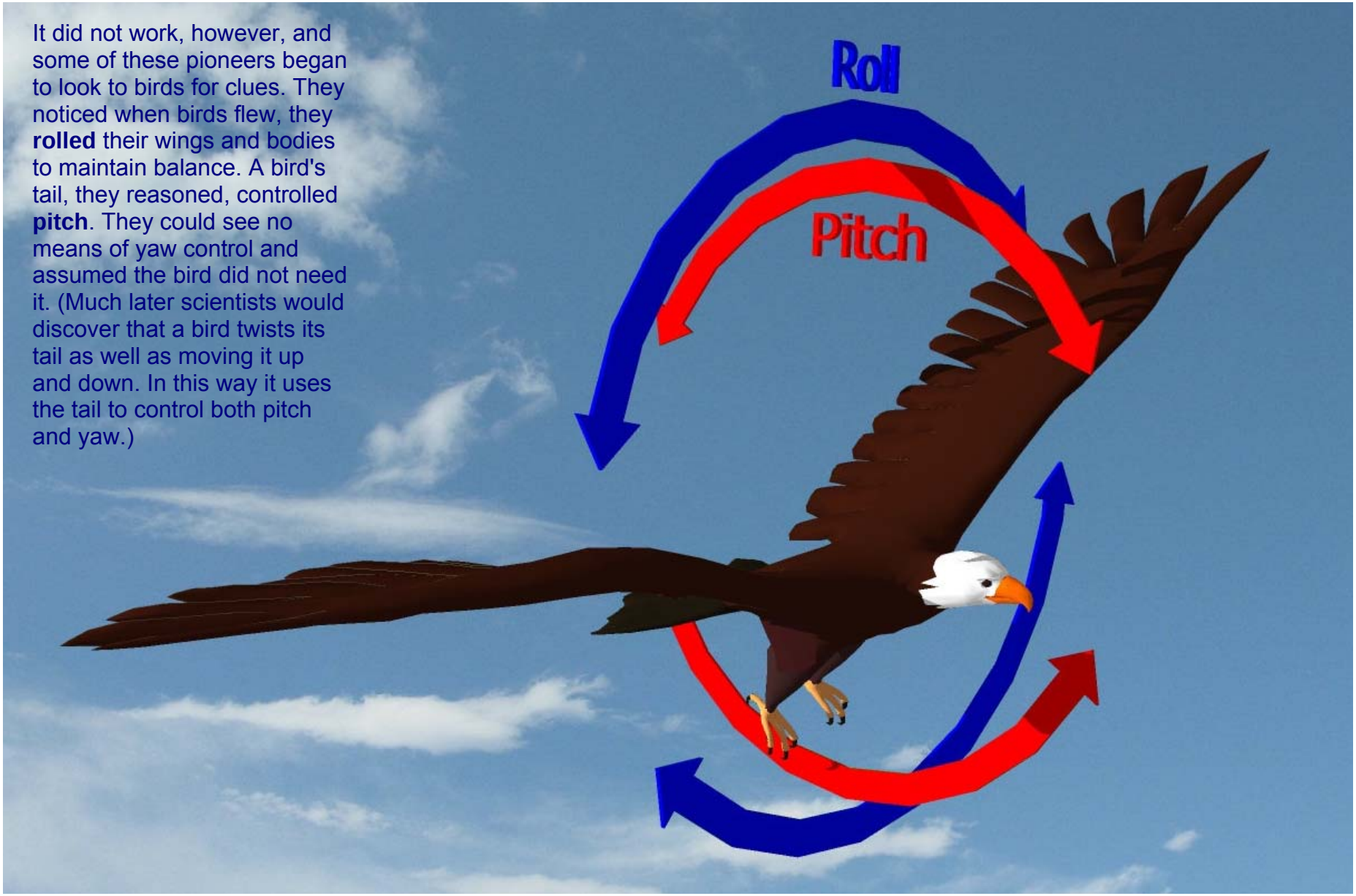
Ship builders found they could reduce pitch and roll with ballast (weights) and hull design. Sailors could not control these two motions, but the improvements made ships **stable**. To control yaw, builders developed the **rudder**. This one control was all the sailors needed to navigate a ship and point it where they wanted it to go.



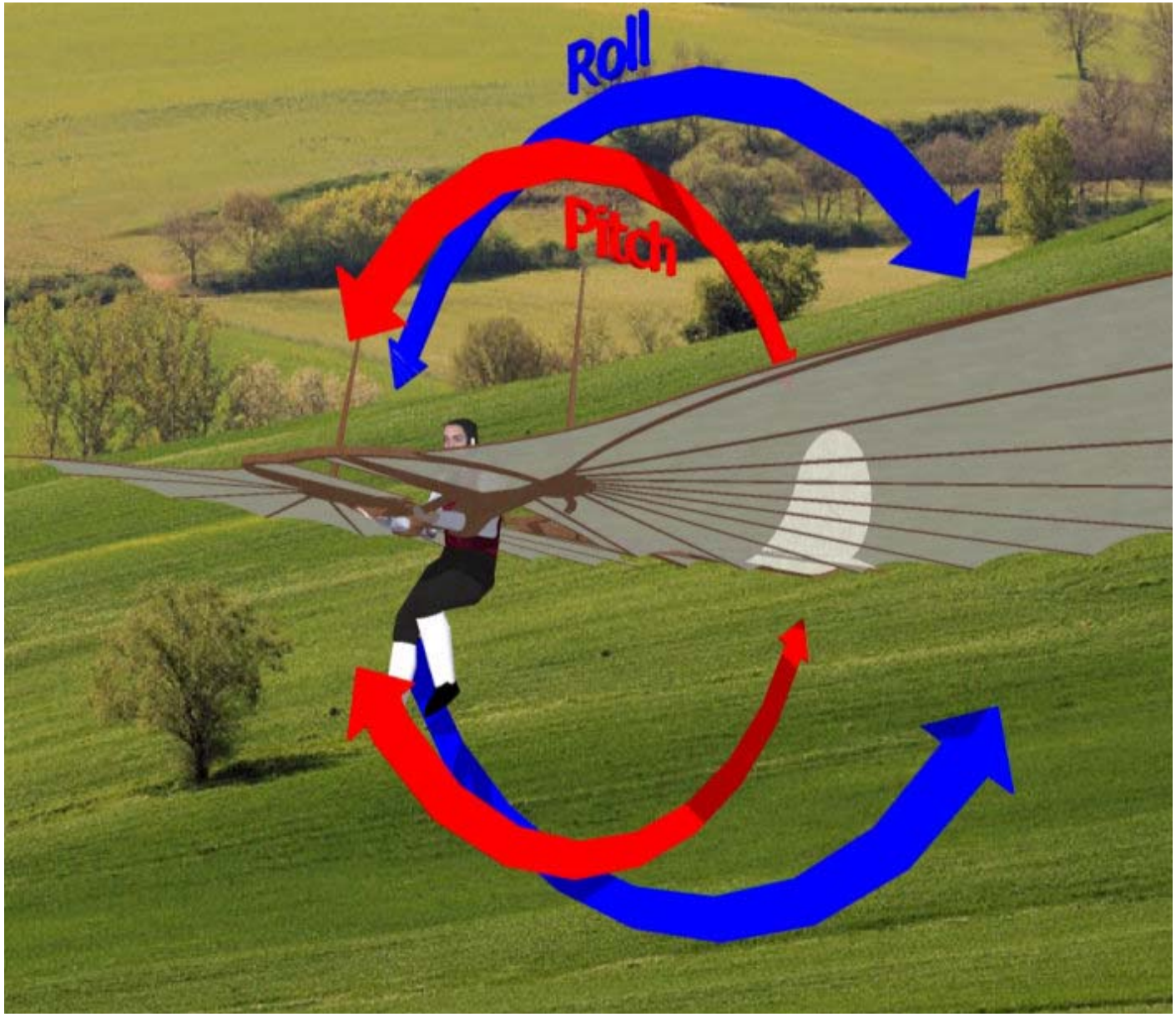
Many of the earliest aviation pioneers (1800 to 1890) were sailors and their aircraft designs where drawn from their experience with ships. They reasoned that to navigate the air, they would need a rudder to yaw the airship right and left, much like a sailing ship. But aviators would also have to point the airship up or down to take off and land. So they designed a horizontal rudder (later called an **elevator**) to control the pitch of the airplane. They were certain they could make a flying machine stable in roll with clever weight distribution and design, much the same way sailing ships were stabilized.



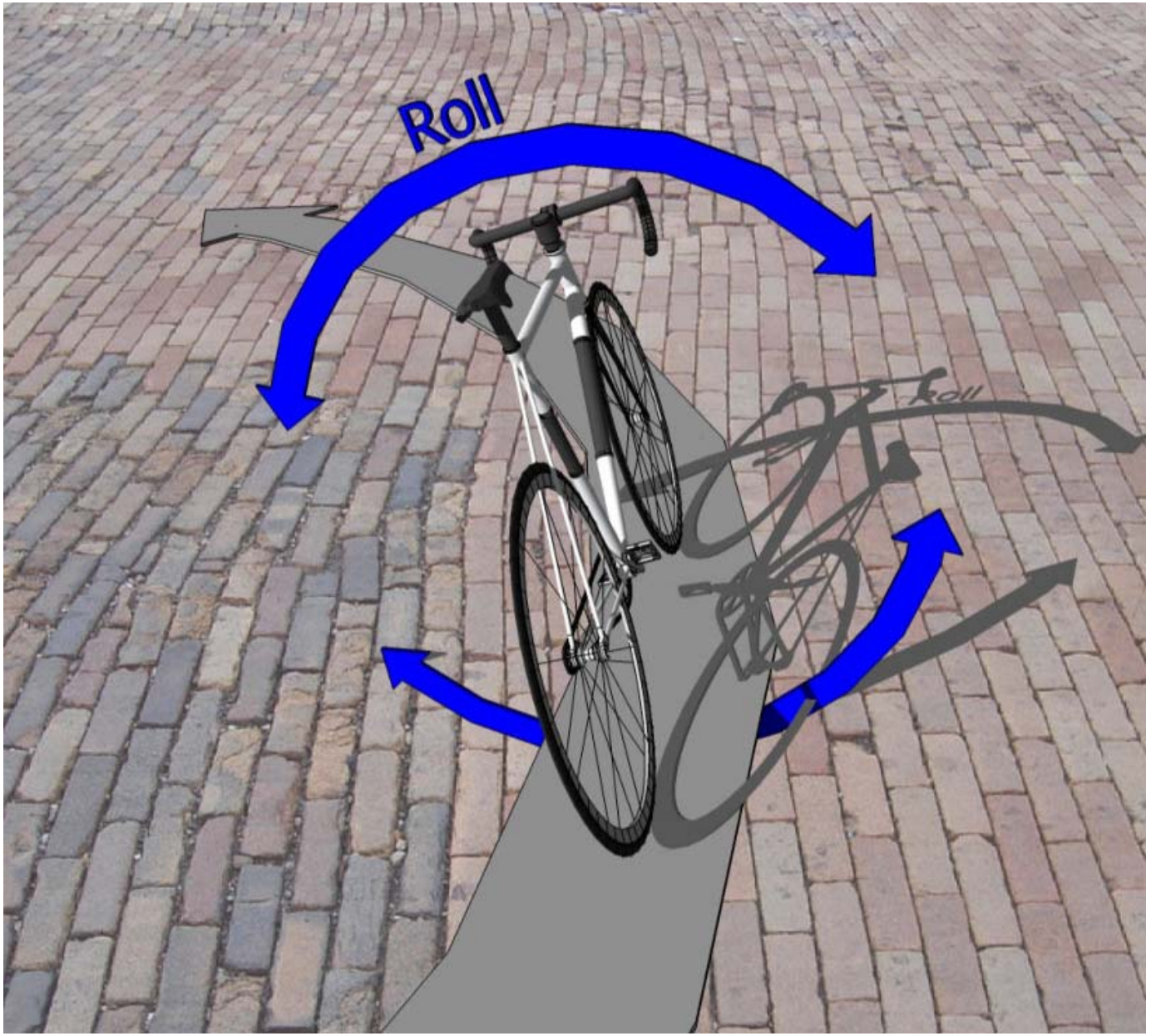
It did not work, however, and some of these pioneers began to look to birds for clues. They noticed when birds flew, they **rolled** their wings and bodies to maintain balance. A bird's tail, they reasoned, controlled **pitch**. They could see no means of yaw control and assumed the bird did not need it. (Much later scientists would discover that a bird twists its tail as well as moving it up and down. In this way it uses the tail to control both pitch and yaw.)



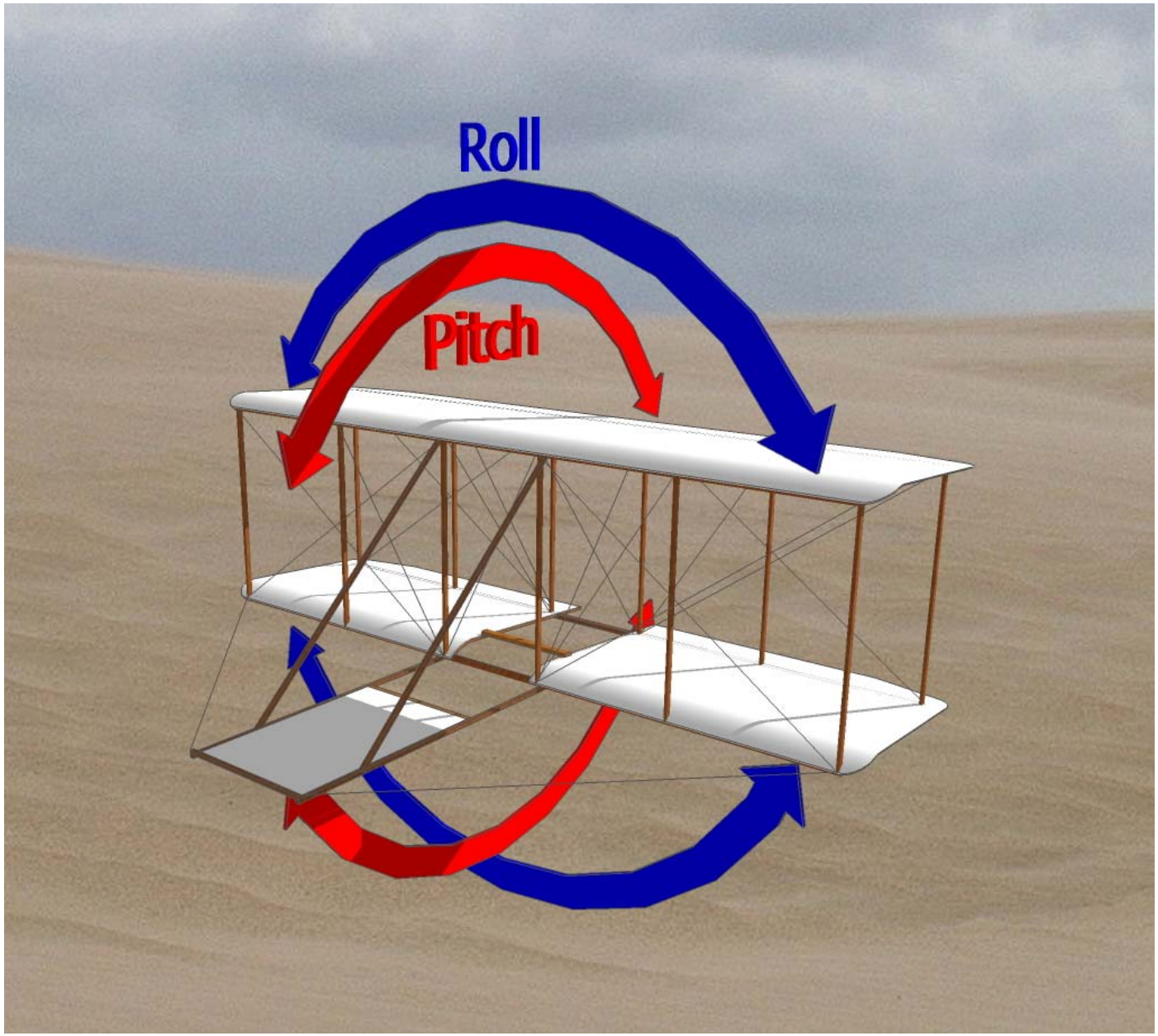
In the 1890s several pioneer aviators developed gliders in which they shifted their weight to control **roll** and **pitch**. They hung beneath their flying machines and swung their bodies this way and that, shifting the **center of gravity** to maintain balance. This primitive control system worked — sort of — but it was not very responsive when the pilot needed to restore balance quickly. Some of these pioneers were killed or hurt when they got into trouble and could not bring the aircraft back to level quickly enough. Note that these first glider pilots were not trying to navigate their aircraft – turn it in the air. At this juncture, flights were simply straight ahead (more or less) as the pilot fought to control balance.



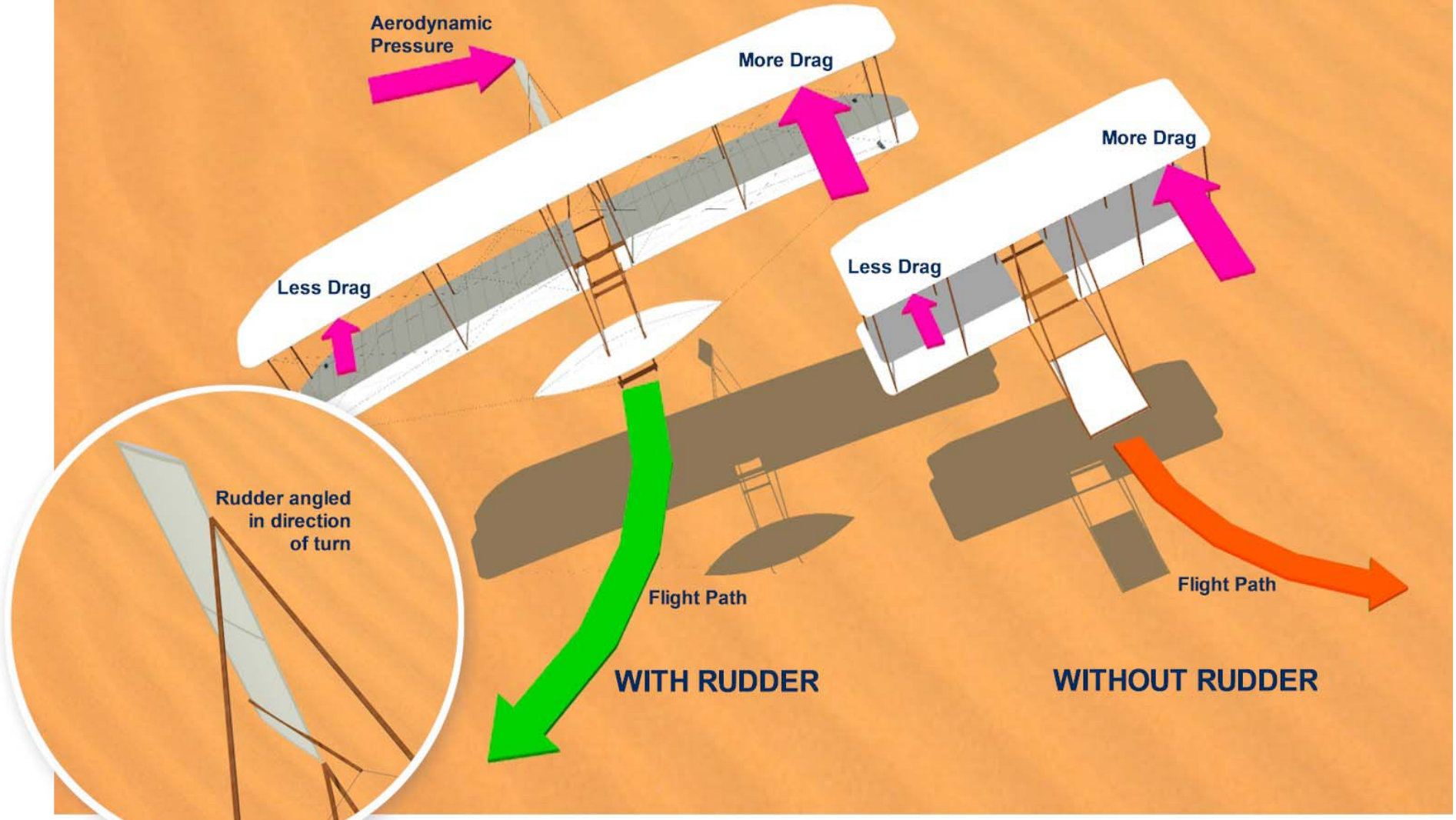
About the same time, the Wright brothers were making bicycles, a relatively new form of transportation. This was the first-ever vehicle that the operator had to **roll** into a turn. The cyclist leaned the bicycle right or left to navigate. The Wrights also observed that birds roll or bank when they turn in the air. From this, they reasoned that the same thing might work to control an aircraft in flight. Roll control might not only be necessary to balance an aircraft in flight; it might also be a way to navigate.



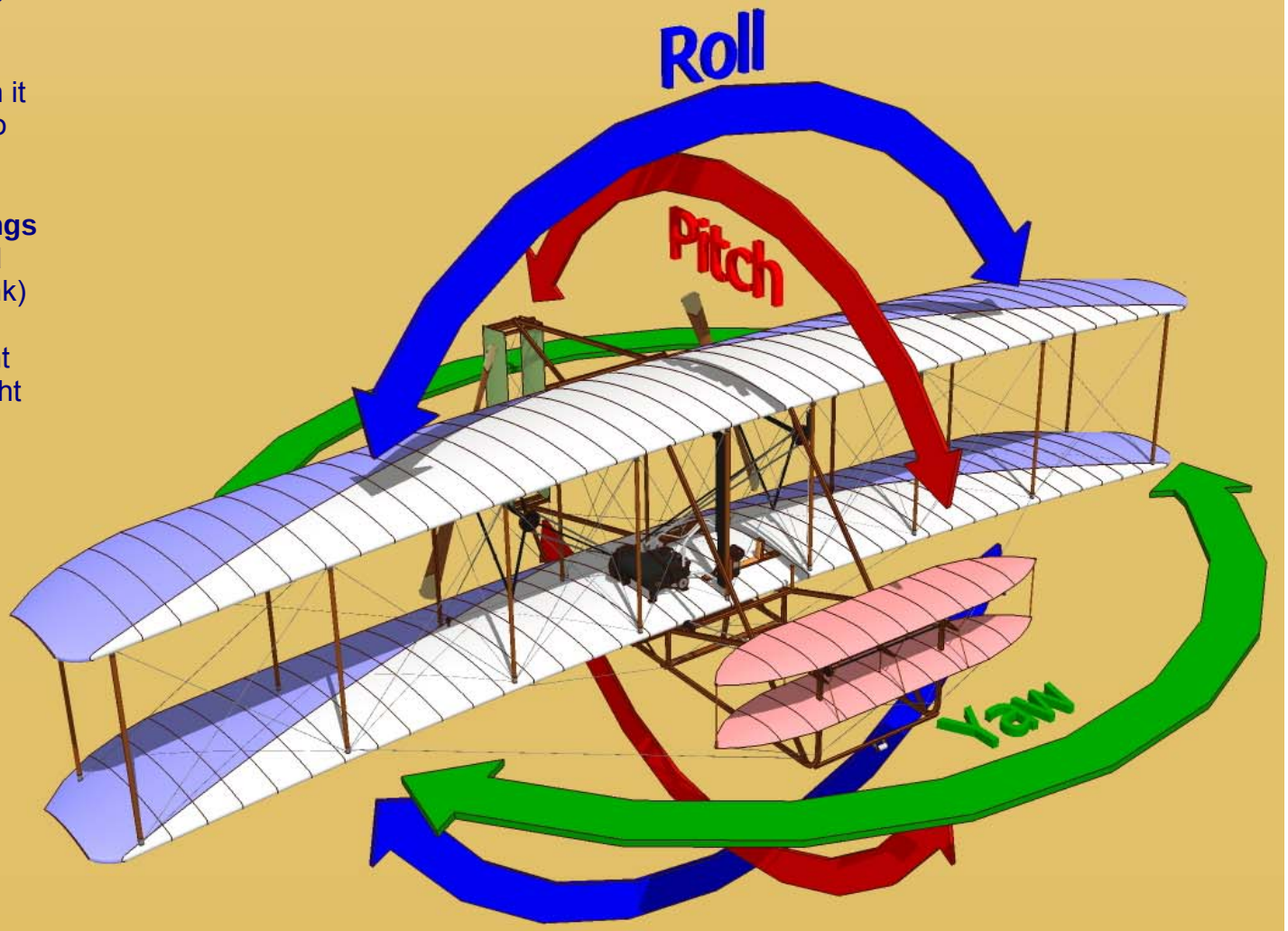
They were wary of weight-shifting, however. The Wright brothers suspected that the early glider pilots ran into trouble because they relied *solely* on shifting their weight to maintain balance. Birds, they observed, could twist their wings or change the position of their tail. It seemed to Wilbur and Orville that birds had **aerodynamic controls** — movable surfaces that could be angled in the wind. So the Wrights built their first gliders with twisting wings and a movable elevator for aerodynamic **roll** and **pitch** control. Like many other scientists at the time, they thought yaw control was unnecessary.



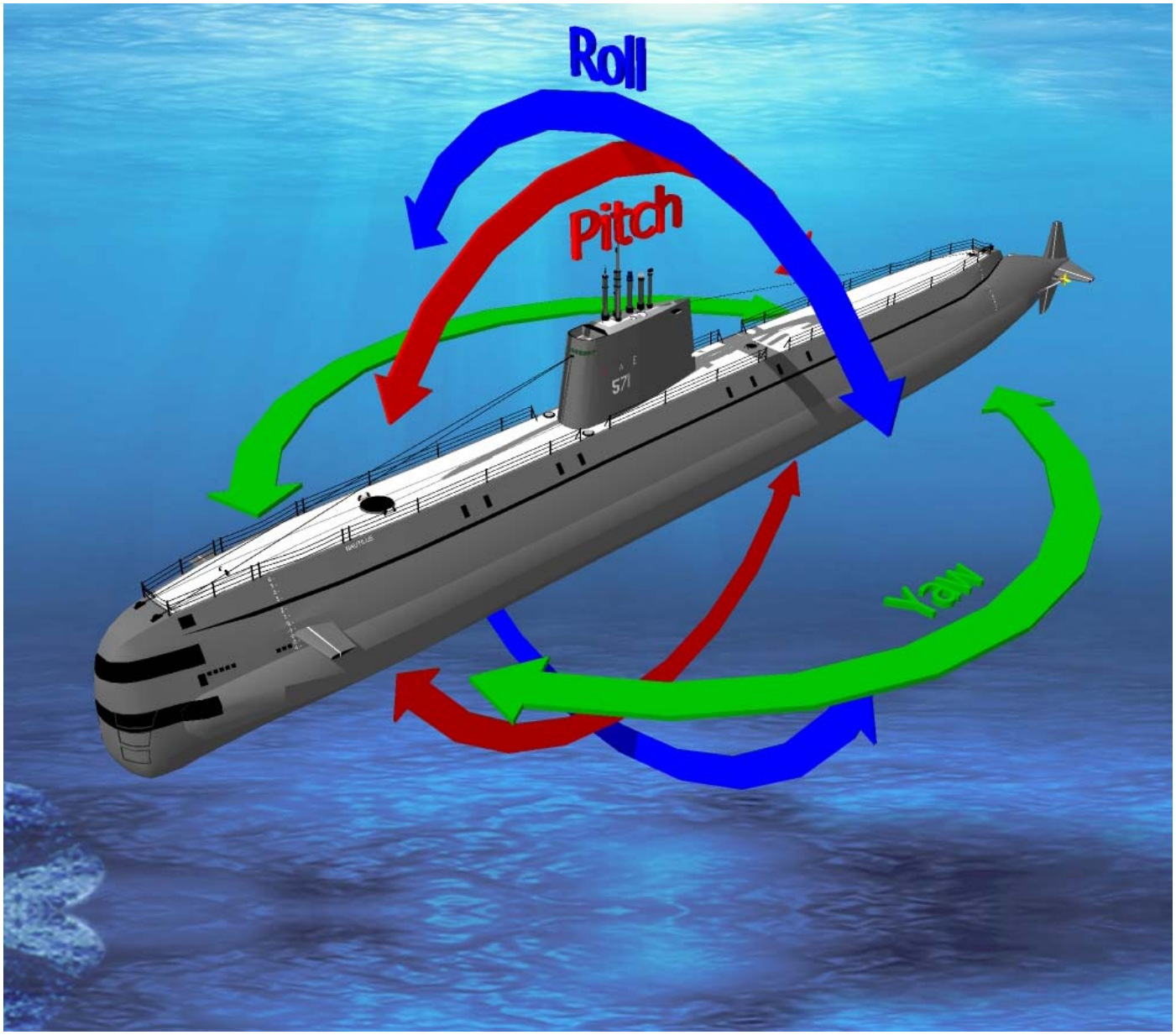
And they were wrong. They could fly straight ahead well enough, but when the brothers rolled into a turn the high wing would create more drag than the low wing. The imbalance in drag made the glider yaw in the opposite direction of the turn. After a few years of experiments, the Wrights finally hit upon the idea of using a **rudder** to counteract the drag. The rudder added aerodynamic yaw control and their 1902 glider was to first machine ever with **three-axis control — roll, pitch** and **yaw**.



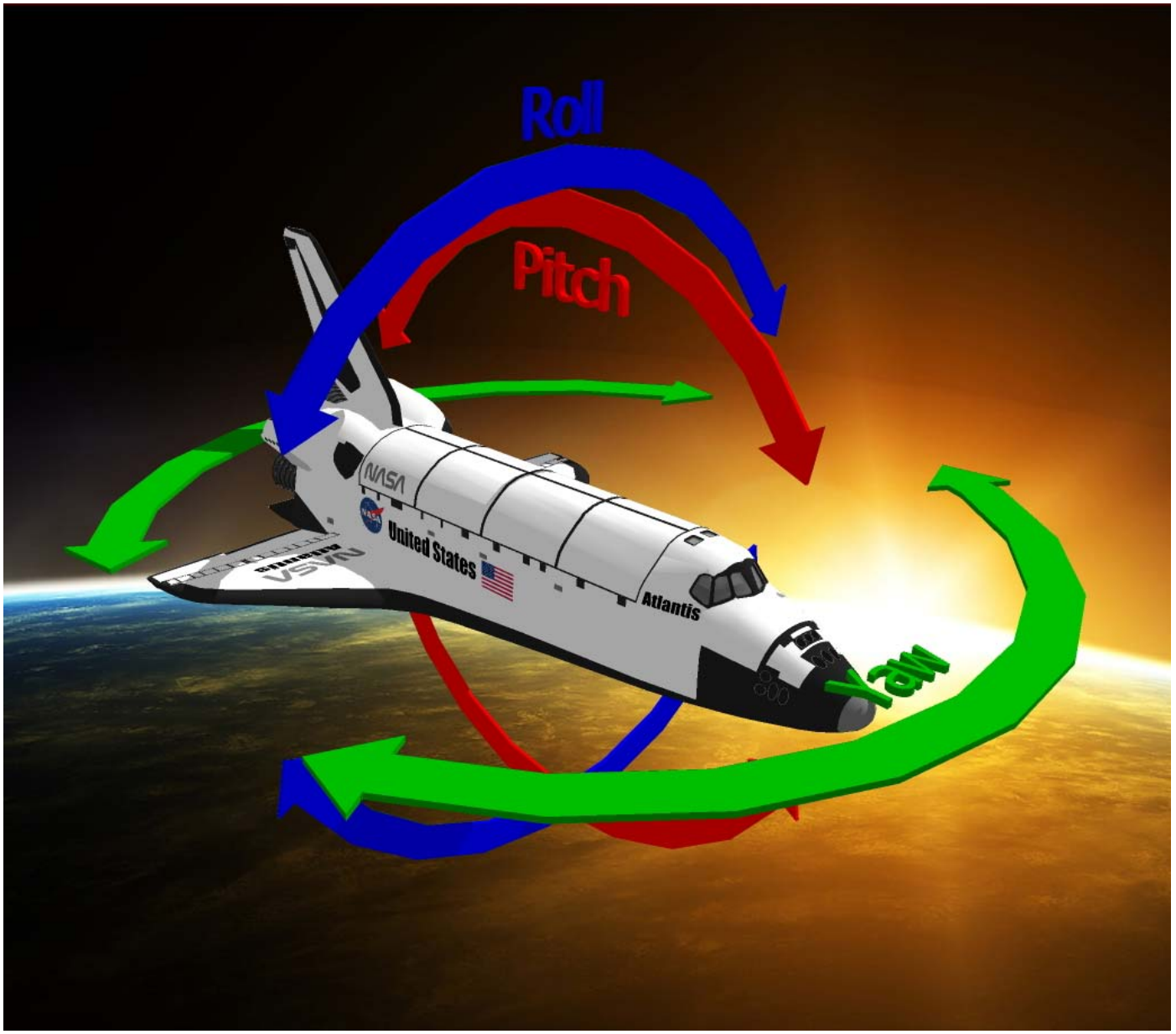
The 1903 Wright Flyer was the first *powered* flying machine with three-axis control, and for that reason it became the first airplane to make a controlled and sustained flight. The **twistable parts of the wings** (shown in light blue) **rolled** the Flyer; the **elevator** (pink) **pitched** the nose up and down, and the **rudder** (light green) **yawed** the nose right and left.



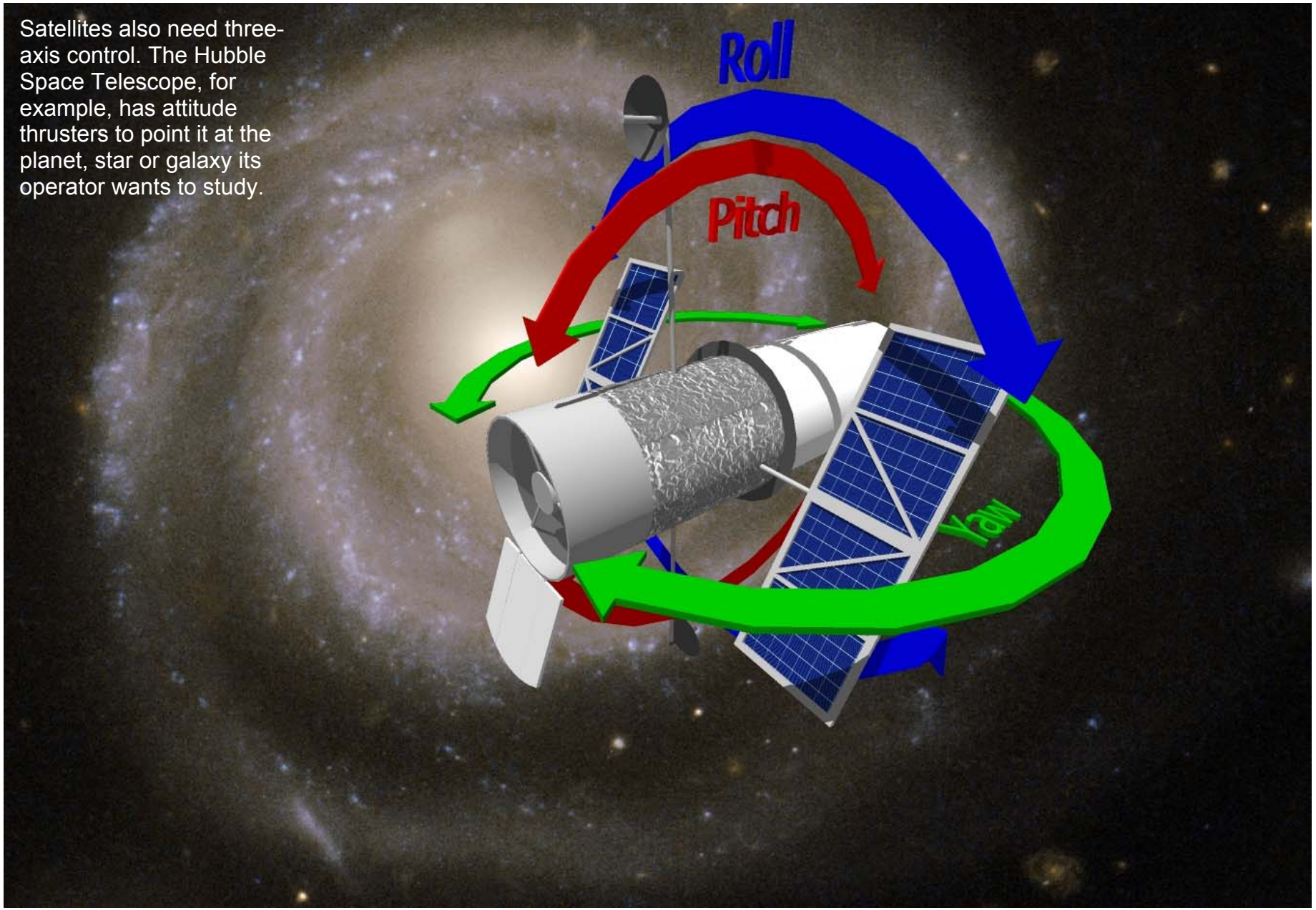
The Wrights' invention of three-axis control had far-reaching consequences. Not only did it make aviation possible and practical, this same system came to be used in submarine navigation. Piloting a submarine is like flying underwater.



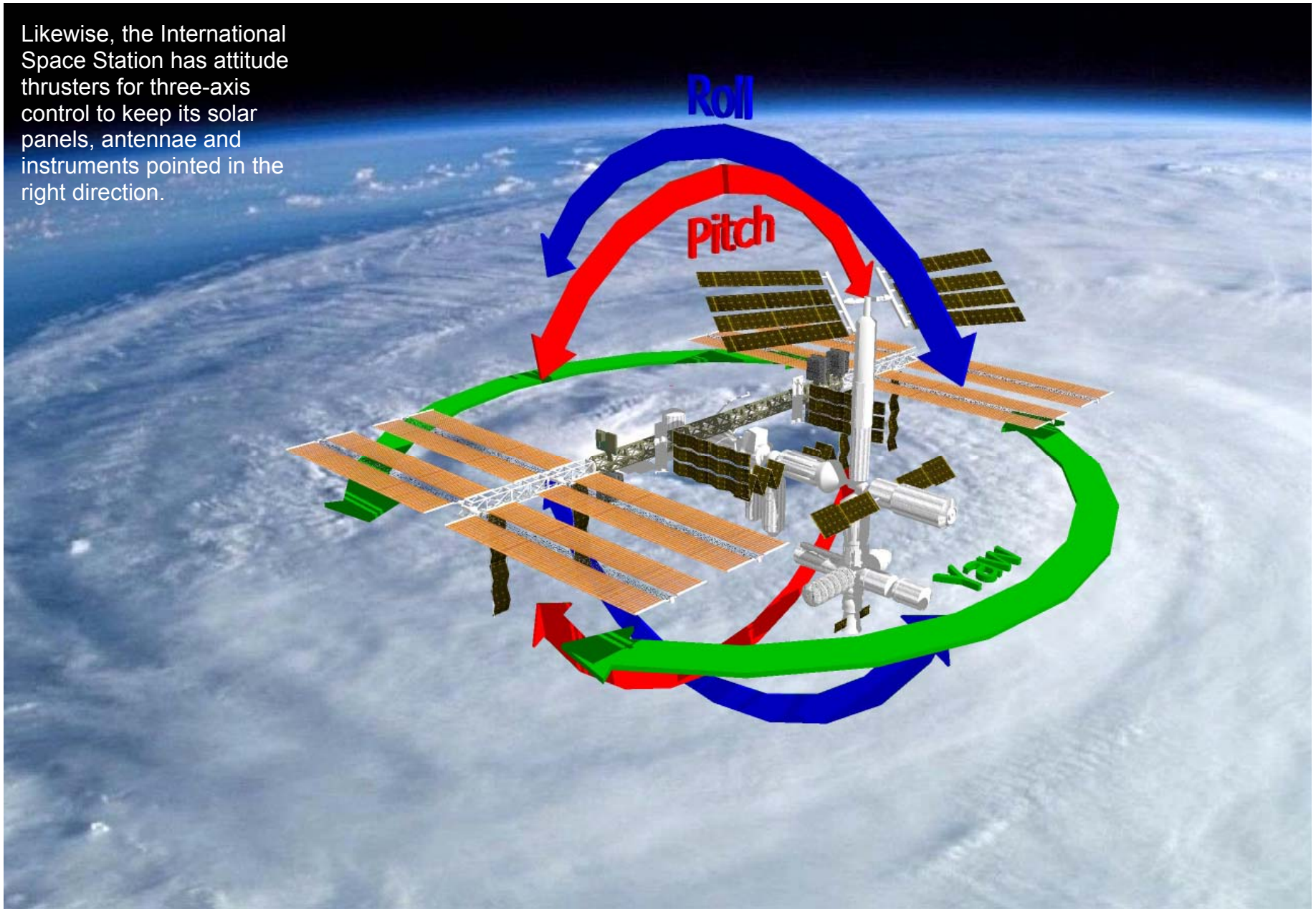
All space ships have three-axis controls. The Space Shuttle, in fact, had two separate control systems — a standard aerodynamic control system for when it flew in earth's atmosphere and a collection of attitude thrusters (small rocket engines) to adjust roll, pitch, and yaw in space.



Satellites also need three-axis control. The Hubble Space Telescope, for example, has attitude thrusters to point it at the planet, star or galaxy its operator wants to study.



Likewise, the International Space Station has attitude thrusters for three-axis control to keep its solar panels, antennae and instruments pointed in the right direction.



Three-axis control also made robotics possible. Industrial robots are programmed to roll, pitch, and yaw in precise patterns. In fact, many robots now have multi-axis controls, capable of precise movements around four, five, six, or more axes.

Finally, all the computer-aided graphics produced for this presentation were made in a drawing program with three-axis control. This computer software gives you total control over the three dimensional object you're drawing, allowing you to turn it and move it any direction. In this way three-axis control — the control concept invented by the Wright brothers to balance and navigate airplanes — is also essential to computer-aided design and computer animation.