This facsimile reproduces a piece I wrote for The Virtual Reality Casebook, edited by Carl Loeffler et al. Due to its neglect by almost everyone who produced the book, and therefore its intended audience, nothing came of its publication. So, here is my contribution:

LEONARDO'S FLYING MACHINE AND ARCHAEOPTERYX

Fred Truck

The Model

For Leonardo da Vinci, swimming under water was the original flight simulator. In *Codex Atlanticus*, he notes: "Write of swimming under water and you will have the flight of the bird through the air." Nowadays, we can use computer technology in the form of virtual reality to create credible flight simulations for jet fighter pilot training. What, I wondered, could I do with virtual reality techniques to construct an artist's flight simulator based on one of Leonardo's flying machines?

I based my computer model of Leonardo's ornithopter on one of his early designs, from the 1490s. Rather than try to model in detail all the ropes and pulleys that provide Leonardo's machine with avionics, I eliminated them, emphasizing instead its spare, geometric lines, and of course, the batlike wings he drew so often.

Leonardo's Flying Machine and Virtual Reality

The three-dimensional computer model of Leonardo's ornithopter exists in two forms. The first form is in several animations with solid-modeled wings, which flap realistically, allowing the model to go through basic flight patterns. In the second form, the ornithopter has only the wing spars without the fleshed-out bat wings; this model has been successfully loaded in the Sense8 Virtual Reality Development System. Defying gravity, it floats, motionless, in a landscape containing nine telephone poles. As such, this work is a virtual sculpture that can exist only in the mind, and in interior computer space. The purpose of my virtual sculpture is to explore in a conscious state the common human experience of flying dreams, as reflected in the currently less common experience of flying through a virtual world. The array of nine telephone poles represents the obstructions to completely free flight often found in dreams of flying. The virtual sculpture is called *The Flying Dream*, and its exploration by technical assistants John Harrison and Colin Griffiths

is the subject of a video of the same name.

Several directions are planned for the future. These include, but are not limited to: 1) testing texture-mapped wings and animation in the virtual environment; 2) comparison of third-person virtual reality, in which the user sees himself or herself, and immersive virtual reality, in which the user experiences the virtual environment directly; and 3) construction of a hardware interface for the Leonardo computer model, which will give the user the physical experience of piloting the flying machine. The name of this interface is Archaeopteryx (see figures 3-1 to 3-2 and color insert # 12).

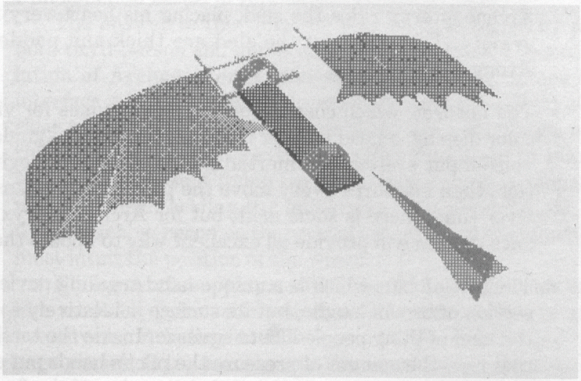

Figure 3-1. The solid-winged animation model was the project's starting point. • Credit: Fred Truck, 1992

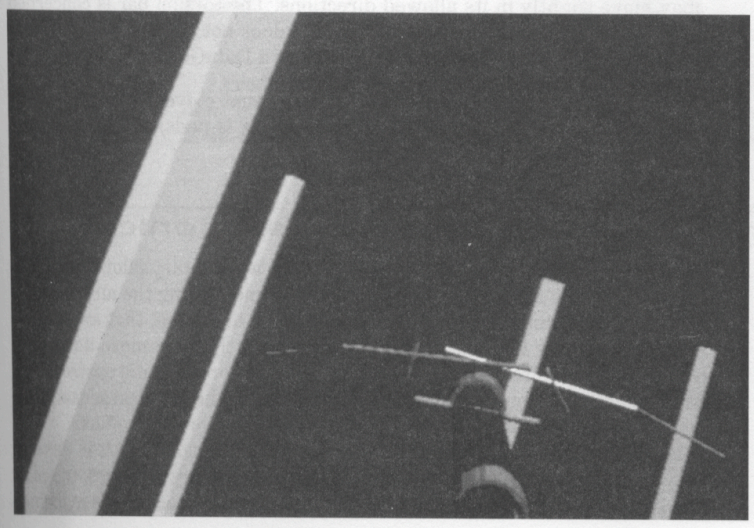

Figure 3-2. The Flying Dream, the model without wings, is a study for future projects. • Credit: Fred Truck, 1992.

The Design

Two tubular rings, placed at right angles to each other, represent the horizontal and vertical axes of Archaeopteryx. The single, mobile equatorial ring suspends a shortened fuselage based on Leonardo's flying machine design. The equatorial ring responds to the pilot's requests for directional change. The polar ring is fixed in position. It contains a complex head-tracking system, which updates the 3D world shown in the EyePhones as the pilot's head moves. The fuselage parts are:

- The sled, named after the Flexible Flyer sled, which it resembles. It consists of the headset, the torsion bar, and the pedals. The pilot of Archaeopteryx rides the sled, placing his heart very near the center of gravity. The straps of the sled are thick and padded, and extremely strong.
- The headset, which consists of VPL EyePhones for visual, stereoscopic, color display; a head tracker that cues the inertial guidance system; and a voice-input system. An inertial guidance system begins at a fixed position, then measures every move the pilot's head makes during the flight. Over time, there is some drift, but for Archaeopteryx, the inertial guidance system will provide an excellent way to update the virtual world.
- The torsion bar, which is a unique hand-tracking device that resembles a section of broom handle, but its surface is relatively soft and pliable. It is the kind of thing people like to squeeze. Inside the torsion bar are devices that read the amount of pressure the pilot's hands put on it, and the angle of force. To assist in clarifying the direction of the force, the torsion bar may move slightly in its allowed directions. The torsion bar is concerned only with hand tracking while flying, and does not preclude the integration of other forms of hand tracking, such as a DataGlove.
- The pedals, which are typical bicycle pedals that move the wings up and down when rotated. The faster Archaeopteryx is pedaled, the faster the wings beat.

Flight Simulation and Leonardo's Avionics

Microcomputer flight simulators usually present a sedentary pilot with a control panel including a number of instruments for monitoring the airplane, and flight controls for climbing, turning, engine speed, and so on, that are operated from a computer keyboard. Flight simulators that are more advanced, such as those the military uses, place the pilot in a more realistic environment that may manipulate him or her physically to create the physical sensation of the airplane bouncing off the runway during a landing, or other effects.

Leonardo's flying machine differs from conventional aircraft in several major ways. First, since the pilot's muscles provide energy for flight, the pilot cannot be sedentary. Additionally, the flight controls of Leonardo's machines

are based on bats or birds, which do not use the principles of fixed-wing aircraft. The wing flaps up and down, rather than being equipped with flaps. Second, Leonardo's designs have no instrument panel. Flying is done "by the seat of the pants." Finally, in Leonardo's design, the foremost object is the pilot's head, rather than a windshield, cockpit canopy, or engine and nose.

This raises a good question. How much of the 3D model needs to reside in the computer memory? If the pilot is immersed in the virtual world, he or she will see little, if any, of the model. If the virtual world is of the third-person variety, in which the pilot watches the performance of the craft, the model needs to be available at all times, in the correct attitude and position. Fundamental issues of representation are at stake.

The answer to this question may be determined by practice, working in both third-person and immersive virtual realities. I recently made a 3D simulation of Archaeopteryx, and some animations, to see how the hardware interface might actually work—a simulation of the flight simulator. It became clear to me that it would be valuable to use a simulation of Archaeopteryx in third-person virtual reality to allow the user to learn how to control Leonardo's unusual flying machine by watching it respond to various commands, before tackling the immersive, first-person flight, at which point the flying machine becomes the virtual extension of the pilot's body and he or she must intuit the position of the wings.

Flying Archaeopteryx should be a physically exhilarating experience, like aerobics, gymnastics, or dance. Archaeopteryx is capable of aerobatic maneuvers, including outside loops, hammerheads, and inverted and knife-edge passes. It is a machine for the adventurous, for those who want to swim through the air, for those who want to explore their flying dreams wide awake.

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