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John Hockenberry reports from within the Mouse

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Imagine machines with gears the size of a grain of pollen, pistons 50 times thinner than a human hair and engines dwarfed by dust mites. Known as MEMS (micro-electromechanical systems), these tiny motors, sensors and pumps function on the micro scale but generate effects with a much bigger impact. These mini-machines are already in your car and at the hospital; soon they may be inside your body.

Ranging in size from micrometers to millimeters, individual or integrated groups of MEMS are fabricated in batches for pennies apiece using processes similar to those by which microchips are manufactured. To make MEMS, the form of the device to be manufactured is visualized as a stack of horizontal slices. The desired pattern, or shape, of each level is then drawn on the computer and transferred using lithography to a silicon wafer, where chemicals or gasses selectively etch the silicon in accordance with the original pattern. The process is repeated multiple times with different patterns on top of one another until the 3-D structure is built on the wafer. Considered to be "training wheels" for nanotechnology—manufacturing on the molecular level—the market for this new field of electromechanical design is expected to be greater than $8 billion by 2001.

"The next 10 years will be defined by a radical increase in the rate at which we make our computers aware of the environment around them," says Paul Saffo, director of the Silicon Valley–based Institute of the Future. "What MEMS really mean is the end of inert matter."

INVISIBLE CANTILEVER

Seeing isn't necessarily believing. Especially when you must peer through a powerful microscope for a glimpse of the Invisible Cantilever, a 1/1-millionth-scale MEMs model of Frank Lloyd Wright's landmark house, Fallingwater. Each of the mansion's three floors was etched as a separate layer from a CAD pattern based on Wright's original blueprints. "We wanted an art object that exists just at the threshold of human perception—something that strains the naked eye," says UC Berkeley engineering professor and techno-artist Ken Goldberg, who created the Invisible Cantilever with MEMS wizard Karl-Friedrich Böhringer, a postdoctoral researcher at the university.

With the building of Fallingwater in 1936, Wright pioneered the structural use of cantilevers—a method of distributing force now used in MEMS as a sensor in some automobile air bag triggers. Of course, you don't need to see firsthand the mechanics of the device to experience its, well, impact. But *art* in the age of electronic reproduction— especially on the microscale—raises questions about authenticity. The Invisible Cantilever can't be experienced with the naked eye—as a result, the viewing technology becomes part of the art.

"When the original artifact is distant either in space or in scale, the corporeal experience requires technologies such as telerobotics over the Web and electron microscopes," Goldberg says. "Rather than diminishing the aura of the original artwork, these technologies enable it."

Indeed, the Invisible Cantilever is an exercise in what Goldberg calls "telepistemology," the study of how distance influences belief, truth and perception. Invisible Cantilever: http://www.ieor.berkeley.edu/~goldberg/id/