In the early 1980's, Raj Reddy, the founding director of the Robotics Institute at CMU, called up Ivan while he was at Caltech and said "Why don't you come back to Carnegie Mellon and run the Robotics Institute?".

Ivan thought about it, but decided not to. He knew he

wouldn't be any good at something he didn't think was fun. He was able to arrange an ideal situation instead, as a self appointed "Visiting Scientist". So, the Institute provided him with a garage on campus, and he began to build a machine. LEGGED LOCOMOTION

While at Caltech, Ivan met a young man named Marc Raibert.

They met in Pasadena, California, while Marc was working at the Jet Propulsion Laboratory there. According to Ivan, Marc was persistent in having an opportunity to meet with Ivan, and his persistence paid off, as they soon became good friends and colleagues.

Ivan and Marc mutually encouraged one another in their

research. Raibert told Ivan about his vision for "dynamic legged locomotion" and Ivan got excited. More than 40 years after his Machina versatilis, he returned to Carnegie Mellon to continue his investigation of "electric animals". Ivan decided to build a hexapod, inspired by insect locomotion. If you ask Ivan why he decided to do this, he will tell you, "because it was fun."



Raj Reddy in an Oculus Rift

THE TROJAN COCKROACH













Ivan had first thought it would be small, but he thought it would be more fun if a human could ride it. Having a human rider set the scale, Ivan says. Finished in 1983, Ivan's machine is significant in being "the first man-carrying computer-controlled walking machine". At eight feet long, with six hydraulically actuated legs, an 18 horsepower gasoline engine, three degrees of freedom for each leg, and a Motorola 68000 microcomputer on board, the hexapod was a sight to behold. And it worked.

Students nicknamed it "The Trojan Cockroach".

COLLABORATION

A young man named Michael Ullner was a graduate student at CalTech, and he came with Ivan to CMU to do a post doc Ivan's long term collaborator, Bob Sproull, was a professor at CMU. They had first met when Ivan taught at Harvard and Bob was an undergraduate years earlier.

Ivan's brother, Bert, was in charge of the cockpit. He was able to finagle a Navy F-4 jet control stick from an old flying buddy in San Diego. Marc Donner, a PhD student at CMU, asked to be involved, and Ivan suggested he work out a system for programming gaits.

Marc Donner wrote a custom language to program the Hexapod, named OWL. It treated each leg independently and coordinated a gait cycle between each leg. Donner's PhD thesis, titled "Real-Time Control of Walking", is considered by some to be the first "official" PhD in Robotics granted by CMU.

leg".



Diagram and gait studies for the Trojan Cockroach

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Donner provided compelling insight into the nature of insect nervous system and its parallels in robotic control systems. A major question in converting animal or insect locomotion to robotic movement is to discover the logic of the control system. A ganglion, a cluster of neurons, is associated with each leg in insects like ants and cockroaches. There is, however, a limited amount of connection between each leg to a common center. Instead, research suggests that control is distributed. Physiologists have shown that brainless and headless insects can still walk.

An observation from Ivan led to the concept of the "virtual

CONTROL, CONTROL, YOU MUST LEARN CONTROL

A built in microprocessor controlled the movement of the legs by switching valves on and off to regulate the flow of oil to the hydraulic actuators.

The sensors in each leg sent information to the computer to report their position in space. The Trojan Cockroach crawled at about two miles per hour.

Each variable displacement pump was attached to three cylinders. Each leg was actuated by two cylinders.

When the two cylinders moved in opposite directions, the leg would move in a horizontal plane.

When the two cylinders moved in the same direction, the leg would move in a vertical plane.



Cover of A Walking Robot

HIGGLEDY PIGGLEDY

Claude Shannon came to visit and stayed with Ivan. He came by the garage to watch the hexapod.

Afterwards, during dinner at the Sutherland's, Shannon remarked "I saw Ivan's walking machine do a pirouette".

Ivan found the description funny because of the machine's immense size, but it did move very elegantly.

Shannon wrote what Ivan calls "a bit of doggerel - a "Higgledy Piggledy":

> A Higgledy Piggledy by Claude Shannon

"Ivan E. Sutherland built a huge cockroach, 12 horsepower clout, but the roach. waxing vengeful for previous roach genocide, hexapodantally stamped lvan out"