William Alfred Higinbotham: Scientist, Activist, and Computer Game Pioneer

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After reading an instruction manual that accompanied a Systron-Donner analog computer, William Alfred Higinbotham was inspired to design Tennis for Two, the first computer game to display motion and allow interactive control with handheld controllers. It was also the first game to be played by the general public—in this instance, attendees of a visitors day at Brookhaven National Laboratory (BNL) in 1958.

For Higinbotham, this was just an isolated incident in a distinguished career as a physicist and electronics expert that also encompassed spells at Cornell University, the Massachusetts Institute of Technology (MIT), and Los Alamos National Laboratory. Recruited from MIT in 1945 to work on the Manhattan Project, he developed the timing circuits for the first atomic bomb and witnessed the test detonation in Alamogordo, New Mexico. The following year, he helped found the Federation of Atomic (later, American) Scientists. A passionate advocate of nuclear nonproliferation, he worked tirelessly to educate government officials and the public about adapting atomic energy for peaceful purposes and implementing safeguards on weapons of mass destruction.

Early Years
William (Willy) Alfred Higinbotham was born in Bridgeport, Connecticut, to the Reverend Robert G. and Dorothea Higinbotham on 25 October 1910. His father was the minister of several churches in New York before settling at the “White Church,” or First Presbyterian Church in Caledonia, a small town located southwest of Rochester.

William’s interest in science emerged at the age of 14, when he began constructing and dismantling radios in an effort to pick up the frequency transmissions of the first commercial radio stations. At 16, he enrolled in a high school physics class and quickly discovered that he had a natural affinity for it. Higinbotham entered Williams College in 1928, majored in physics, and obtained a bachelor’s degree in 1932. Finding his employment prospects hindered by the Great Depression, he decided to pursue graduate studies. He was accepted at Cornell University but struggled there as an impoverished student. He explained:

I was not a promising experimentalist, much less a theoretician. I let my supervisor pick out a tough research project, which I was not able to complete, and did not look around for a better one, which I would do later in life. I had to earn room and board and $150 per year in tuition. I did all kinds of odd jobs, worked for my

Background of William A. Higinbotham

Born: 25 October 1910, Bridgeport, Connecticut
Died: 10 November 1994, Gainesville, Georgia
Education: Williams College, AB (physics), 1932; Cornell University, graduate studies (physics), 1932–1940.
Honors and Awards: Honorary doctorate in science, Williams College, 1963; IEEE Annual Nuclear Science Award, 1971; Distinguished Service Award, Institute of Nuclear Material Management (INMM), 1979; Fellow of the American Physical Society, IEEE, and the American Association for the Advancement of Science (AAAS).
room, etc. In 1936, I was offered two jobs in the Physics Dept.: night watchman, which gave me a room in the attic, and as a technician. The latter involved carpentry, glass-blowing, instrument repair, design and construction of electronic circuits, etc. This proved to be a life-saver. I discovered I was very good at electronics.2

**Massachusetts Institute of Technology**

Experimental physicist Robert Fox Bacher was pursuing post-doctoral studies at MIT in 1941 when he extended an invitation to Higinbotham to join its Radiation Laboratory to research and develop radio detecting and ranging (radar) devices for application during World War II. During this time, analog computers were being developed and adapted for military initiatives, particularly for simulations as a cost-saving measure by the US government.3 Higinbotham designed displays using cathode-ray tubes (CRTs) and gained experience converting transmitters and displays from airborne radars for use in antisubmarine activities.

According to David Mindell, the series of textbooks that were produced based on the research conducted between 1940 and 1945 at the Radiation Lab “laid foundations for a new era of communications, control, and computing.”4 Among the dozens of initiatives that the laboratory embarked on was a joint project with Bell Laboratories to develop the Eagle radar, a high-altitude bombarding system. Higinbotham was responsible for designing the indicator’s subsystem, including designing circuitry under the supervision of physicist Luis W. Alvarez.5 Colleague Clayton Washburn reflected on the significance of the research they conducted at MIT:

> Rad Lab not only provided an almost perfect subject by which to expound the range and breadth (sic) of electronics. It was also constituted to break the secrecy around ideas … they provided a quantum leap forward in electronics which was finally solidified by the Rad Lab series of books. So to me the most important historical result of Rad Lab (which must be properly shared with the war effort) was that it was the birthplace of electronics.5

**Los Alamos National Laboratory**

Higinbotham’s professional relationship with Bacher would continue for several more years. Bacher recruited Higinbotham in 1943 to Los Alamos National Laboratory in New Mexico to work on a classified military assignment: researching and developing design components for the first atomic bomb as part of the Manhattan District Project. Higinbotham was given the rare opportunity to first visit the site. Although ethically conflicted, he decided to pursue the offer because he felt his work on radars at MIT was concluding, and more importantly, he was “anxious to make sure that what I did would contribute to ending war.”7 At Los Alamos, his work concentrated on developing the timing circuits that would control the bomb just prior to detonation and developing electronic amplifiers, counters, and recorders.

When I first arrived in December 1943, I found that the electronics there were very primitive compared to M.I.T. I built triggered sweeps for the oscilloscopes, fast amplifiers, and low capacity probes. I also invented diode-steering for reliable triggering of bitable circuits, before x-mas. In the spring of 1944, D.K. Frohman asked to step down as head of the electronics division, and I took that on.7

On 16 July 1945, he and several of his colleagues boarded a bus to witness the test detonation of the first atomic bomb, which had been given the code name Trinity by director J. Robert Oppenheimer. Their location was situated approximately 18 miles from the site in Alamogordo, New Mexico. Higinbotham established the radio contact that allowed the group to listen and monitor signals.8 A bomb was dropped over Hiroshima on 6 August 1945 and another on 9 August 1945 at Nagasaki. Higinbotham was appointed chairman of the Association of Los Alamos Scientists a few days later.

**Federation of American Scientists**

Witnessing the test of the atomic bomb in Alamogordo and viewing images of their effects in Hiroshima and Nagasaki took an emotional toll on Higinbotham, deepened by the deaths of brothers Philip and Frederick during the war.9 After leaving Los Alamos, he was eager to share his deep convictions about nuclear nonproliferation. Several of Higinbotham’s colleagues from the bomb program had expressed distress and apprehension about the implications and consequences of scientific endeavors on the global community. On 1 November 1945, the Federation of Atomic Scientists was formed to address these issues.10
In December 1945, Higinbotham persuaded his colleagues to consider expanding the membership scope of the organization, and it was subsequently renamed the Federation of American Scientists. Higinbotham moved to Washington, D.C., to incorporate the nonprofit organization and serve as the first executive director, the chairman, and in other capacities. FAS activities included lobbying, presenting educational lectures, producing the Bulletin of Atomic Scientists, and testifying at official government hearings. Major successes of the FAS were the defeat of the May-Johnson Bill, which would have given the military control of nuclear research, and the passage of the McMahon/Atomic Energy Act of 1945, which established the US Atomic Energy Commission (predecessor of the US Department of Energy), a civilian commission under which atomic energy policy and nuclear power development was managed (see http://www.fas.org/about).

Higinbotham was enthused by the idea of working at BNL due to its institutional focus on responsible and peaceful uses of nuclear power. He was offered the Physics Department’s associate division chief position in experimental nuclear electronic instrumentation and officially joined the laboratory on 8 December 1947. Higinbotham stated that it “looked like the best place for me for what I wanted to do. I wanted to be involved in instruments and also be at an institution that wouldn’t complain if I continued to be active in arms control.”

At BNL, he developed safeguards for instruments in the disciplines of medicine, high and low energy physics, nuclear chemistry, and biology. By the end of 1948, he had already received a series of promotions and achieved tenure.

Higinbotham married Julie Ann Burritt on 9 June 1949, settled in Bellport, New York, and had three children: Julie, Robin, and William B. He was appointed the division head of the Instrumentation and Health Physics Department in 1952, a rank he would hold for 17 years. His division produced the electronic equipment used in Brookhaven’s particle accelerators and research reactors and conducted pioneering work on digital computers.

**Tennis for Two**

Visitors Day was an annual community event at Brookhaven National Laboratory. Each division was expected to prepare an exhibition that showcased its current R&D projects (see Figure 1). In the fall of 1958, the Instrumentation Division planned to display its latest contributions to science, including a sodium-iodide detector, a multichannel pulse height analyzer, and the Chase-Higinbotham linear amplifier. However, anticipating that the display would not be dynamic enough to generate interest, Higinbotham and his colleagues began to brainstorm about ways to draw attention to it.

Inspiration soon arrived; the manual that accompanied a Systron-Donner analog computer described how to “program it to simulate a ball bouncing or a ballistic missile trajectory,” according to Peter Takacs, a physicist in the Instrumentation Division at BNL. Higinbotham began to conceptualize an interactive game because he thought “it might liven up the place to have a game that people could play, and which would convey the message that our scientific

**Brookhaven National Laboratory**

The Atomic Energy Commission founded Brookhaven National Laboratory in Yaphank, New York, in April 1947 with the mission to advance research in the atomic sciences and to develop scientific machinery of the highest caliber (see http://www.bnl.org). The site was formerly Camp Upton, a US Army installation during World War I and II.
endeavors have relevance for society.” He envisioned a 2D tennis game displayed on a screen (oscilloscope), one in which two players could compete by controlling the volleying action of a ball being lobbed over a net. He sketched the plans for *Tennis for Two* in a matter of hours. The design evidenced his vast knowledge of computers, electronics, circuits, and physics.

Historically, it [*Tennis for Two*] goes back to the fact that I had, during World War II, had spent a better part of three years at MIT in the Radiation Laboratory working on radar indicator sets—which are cathode ray tubes—and so I developed, and had asked for a number of circuits including circuits to integrate and differentiate wave forms, which were used in analog computers in those days. So I was using my old experience from way back then and my experience since then designing circuits—and we had, as it says in that report—the laboratory had several analog computers and they [inaudible] a book which tells you how to do a bouncing ball and some other things. And I look at it and say, well, obviously, with this machine I can fix it so instead of having it pre-programmed, I can fix it so people can control it, you know, what’s going on—so it was a great invention, if you want to call it that, and it didn’t strike me as the least bit novel. All the circuits I used were circuits that have been used by people before, except for putting these hand controls in—and a game which would go with that.15

Design engineer Alexander Elia of the Instrumentation Division produced the blueprints based on Higinbotham’s drawings and in less than three weeks, colleague Robert V. Dvorak, technical specialist at BNL, constructed *Tennis for Two*.

Joe Gettler of BNL described the process:

Higinbotham used four of the computer’s operational amplifiers to generate the ball’s motion while the computer’s remaining six amplifiers sensed when the ball hit the ground or net and switched controls to the person in whose court the ball was located. In order to generate the court and net (an upside down “T”) and ball on screen, it was necessary to time-share these functions.16

The game consisted of the following components:

- a Systron-Donner analog computer;
- a graphical display device made up of a DuMont CRT vector oscilloscope with a five-inch, phosphor-coated screen that displayed different voltages as visible light on its Cartesian coordinate display;
- an electronic network that included resistors, capacitors, relays, and germanium transistors/transistor switching circuits; and
- handheld controllers, where a potentiometer (a rheostat or variable resistor) was used to regulate the amount current moving through a circuit.

At MIT, Higinbotham had patented “circuits using operational amplifiers like those in the analog computer which was used in the tennis game.”17 Hank Campbell explained:

Higinbotham created a circuit that plotted the deflection of the ball proportionally to the input voltages. The plot of these functions simulated the trajectory of the bouncing ball—when the ball hit the ground, a relay would be thrown, reversing the polarity, and then the ball would reflect its previous path, while another relay would sense if it hit the net—the upside down T in the middle… [D]rag from wind was simulated with a 10 megaohm resistor.18

Each handheld controller consisted of a small metal box that had a dial and one button.

On 18 October 1958, *Tennis for Two* made its debut. The game challenged players to judge the angle and time at which to hit the ball. They needed to adjust the dial to either “up, down, or level” to control the angle of the invisible racket, which determined the ball’s trajectory over the net, while concurrently depressing the button to initiate the striking of the ball (and also game play).19 As the ball was “struck,” a trail of light followed it as it sailed back and forth on the screen. “You could actually hit the ball into the net,” recalled colleague David S. Potter, “see it bounce into the net and see it bounce onto the floor back to you. So it was a very clearly designed game Willy came up with.”20

Takacs recounted that “it was a big hit at Visitors Day. People were lined up out the door of the gymnasium where it happened to be set up.”13

(Lack of) Impact and Influence

*Tennis for Two* was dismantled in 1959 because “it didn’t seem likely that anyone would want to spend much time twisting
the dials on the rheostats to play this two dimension form of tennis." The game was not patented. Higinbotham later acknowledged that ‘although many of people played this game at Brookhaven National Laboratory in 1958 and 1959, it received no publicity then, and it only began to attract attention in the 1970s, when video games became big business.’

The accepted history of computer and videogames includes a clear chain of influence from the 1960s onward. Game lineage and its impact on design can be traced from the PDP-1 computer game Spacewar! (1962) developed at MIT and from Ralph Baer’s television-based Brown Box (1966–1967) and Magnavox Odyssey (1972) to arcade games and later home console systems.

Whereas the significance of Spacewar! and Odyssey is well documented, Tennis for Two is generally relegated to the footnotes in histories of computer and videogames. It reached a limited audience and received limited publicity, so its direct influence on later developments is unclear. Henry Lowood commented on the importance of the ‘institutional contexts’ of early games because they were products of universities and laboratories experimenting with computer hardware and networks. At both BNL and MIT, computer games were used to lure the general public to exhibitions that underscored their respective institutions’ principal research projects. Although Tennis for Two demonstrated a novel way to employ analog equipment, it was never intended to be a main attraction.

The game received a modest amount of attention when Higinbotham was contacted by attorneys litigating patent lawsuits on behalf of Magnavox against Atari, among others. Although deposed on several occasions and questioned about the design of Tennis for Two, he never formally testified because the lawsuits were settled out of court.

Creative Computing magazine generated additional interest in the game when author John Anderson credited Higinbotham as being the inventor of the first videogame. Anderson came to learn about Tennis for Two from the magazine’s publisher and editor, David H. Ahl, who had attended one of BNL’s visitors days in 1958.

Later Career and Legacy

In 1967, Higinbotham and three of his colleagues submitted a proposal to the Atomic Energy Commission advocating for the establishment of a nuclear safeguards division at BNL to serve the federal government in an advisory capacity. Their lobbying efforts were successful; in January 1968, the Technical Support Organization (TSO) was formed at BNL. Higinbotham subsequently joined the TSO, which was later renamed the Safeguards and Materials Management Division of the Nuclear Engineering Department. He officially retired from BNL in 1984 but continued to serve as a consultant to the TSO and as the technical editor of the Institute of Nuclear Materials Management’s publication Journal of Nuclear Material Management.

William A. Higinbotham passed away on 10 November 1994. Prior to his death, the Federation of American Scientists, the organization he championed beginning in the 1940s, planned to rename its headquarters in Washington, D.C., Higinbotham Hall. FAS executives knew of his grave condition and sent to his immediate attention the text on the plaque. Higinbotham confirmed receipt of the document a day before his death and stated during a phone conversation with former FAS chairman Robert Stone that he was “well pleased” with the honor. The plaque features the quote, “Our efforts to move the planet rest on the fulcrum he fashioned.”

At the ceremony, a letter composed by Freeman Dyson, who served as FAS Chairman in 1962, was read:

In 1947, Willy was already a legendary figure, a symbol of the “ordinary guy” who changes history by doing the right thing at the right time. To me Willy was also a symbol of the good side of America, the open society where everyone is free to make a contribution. Willy just happened to make one of the biggest contributions.

Higinbotham was known for his kindness, generosity, and jovial spirit, which was often expressed through his musicianship. He often entertained his colleagues, friends, and family with his lively accordion playing and singing. One of his original compositions was titled, most apropos, “Atomic Power.”

Tennis for Two, an invention that Higinbotham devised within a matter of hours in 1958, purely for entertainment purposes, has made an indelible impact on everything from computer science to popular culture.
Later in his life, Higinbotham reflected on the game’s legacy:

I’m not very good at the new video games—my daughter beats the heck out of me…But I think that it’s a lot better than some of the other things we see on TV. It’s creative and participatory—and I like that.

The William A. Higinbotham Game Studies Collection at Stony Brook University, scheduled to open to the public in the fall of 2011, is named in his honor.

References and Notes
9. L. Waller and C. Waller, “Recollections (The Family at the Manse),” Willy Higinbotham, p. 35.

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