From the Till to the International Space Station: Josephine Jue and Spaceflight Computing

Jennifer Ross-Nazzal

Mathematician and aerospace technologist Josephine Jue spent more than thirty years working behind-the-scenes on computers and software at NASA, making giant leaps for humankind possible. One of the few professional women working at the Manned Spacecraft Center (MSC) in the 1960s, Jue literally changed the face of computing at the Houston Center as the first Asian-American woman in her division. Fresh out of college with a bachelor's degree in mathematics, she applied to work at NASA in 1963, a time when most MSC female employees worked in the clerical field, as they did in other government agencies and across the aerospace industry.[1] There was a general belief that women were better suited for these careers and tasks rather than other professional positions. For instance, when a male flight controller requested a typewriter to type up his notes, he was told, "engineers don't get typewriters. *The girls* get the typewriters."[2]

Although few in number, there were professional opportunities for women. NASA needed employees with technical training, and women with math degrees found exciting opportunities with the space agency. Jue became active in the Federal Women's Program (FWP) and in the American Federation of Government Employees.[3] As the lunar program wound down in the early 1970s, her work helped to usher in a new era of spaceflight with the development and testing of the avionics for the Space Shuttle Orbiter. Later, she oversaw the Center's efforts to provide all employees with workstations and desktop training. Jue's groundbreaking career is just one example of the types of contributions professional women made at the space agency in the field of computer science and beyond.

Jue was the child of Chinese immigrants. Like many Chinese people who immigrated to the Mississippi Delta, her parents ran a grocery store. Born in the back of that Vance, Mississippi, store in 1940, she was only three months old when her parents chose to relocate to Houston. They hoped for greater opportunity in Texas and

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Communicated by Notices *Associate Editor Laura Turner.*

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DOI: https://doi.org/10.1090/noti2642

[1] *Jue recalls arriving at MSC in 1963, but the telephone directories do not show her arriving until two years later. The Manned Spacecraft Center became the Lyndon B. Johnson Space Center (JSC) in 1973. For more information about the female experience at JSC, see Jennifer M. Ross-Nazzal,* Making Space for Women: Stories from Trailblazing Women of NASA's Johnson Space Center *(College Station: Texas A&M Press, 2022).*

[2] *Emphasis added. John R. Garman, interview by Kevin M. Rusnak, April 5, 2001, JSC Oral History Project, transcript,* https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/oral_histories/GarmanJR/GarmanJR_4-5-01.htm.

[3] *NASA,* Minority Profiles, *Google Books,* https://books.google.com/books?id=yck7SI23SbYC&newbks=0&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false.

purchased a store in Houston's Third Ward and renamed it Far East Grocery. They later opened a second market.[4]

It was here, at her parent's store, that Jue developed an interest in mathematics. Her parents expected her to help with the store when she came of age. Before she was ten, she worked at the cash register and learned how to count by twos, tens, and twenties. In an age when clerks had to add the price of items and compute the total sale, including sales tax, "math came in handy" Jue said, especially when customers only had a couple of items so she did not have "to use the adding machine." She also learned how to correctly count the change to give people. While in high school, Jue signed up for all the math classes her school offered including algebra, geometry, infinite series, and trigonometry.[5]

After high school graduation, she attended the University of Houston so she could continue to help her parents when she was not attending classes. She chose to major in math and minor in chemistry, not knowing what she might do with her degree. Jue did know one thing, however, she did not want to be a teacher, a nurse, or a secretary. In addition to her required courses, she also completed a computer programming class in FORTRAN (FORmula TRANslator) and another in MAD (Michigan Algorithm Decoder). "That was my start in computers," Jue recalled.[6]

While Jue worked on her degree, NASA announced it would be building a Center about twenty-five miles south of downtown Houston to achieve President John F. Kennedy's dream of sending a man to the moon and returning him safely by the end of the 1960s. The Manned Spacecraft Center would be home to the astronauts and Mission Control. Houstonians were thrilled with the decision to locate a Center in their community, and they welcomed employees with open arms. Newspapers, radio, and television reporters hailed the decision and covered the site construction.[7] To meet the president's ambitious goal, NASA needed engineers, scientists, technicians, and mathematicians, so after graduation Jue applied. "NASA," she explained, "opened up a new world" for her and the other women who worked outside of the pink-collar workforce.[8]

NASA needed employees with technical training, and women with math degrees like Jue found exciting opportunities with the space agency. Poppy Northcutt held a math degree from the University of Texas and worked for aerospace contractor TRW on trajectories to safely return the astronauts home from the moon. Ivy Hooks and Dottie Lee became engineers and were the only women to serve on the original design team for the Space Shuttle Orbiter in 1969.[9]

Given her background and their need, NASA offered Jue a position, and personnel asked about her interests before they placed her. She told them she liked math, so they offered her a job as a mathematician in the Computation and Analysis Division. Located in the Engineering and Development Directorate, the division handled computation and data reduction for the entire Center, and she served as one of eighty computer programmers and analysts. With the facility still under construction, Jue reported to one of NASA's fourteen temporary sites: Site 11 at the University of Houston. The building housed NASA's digital computers and would later become the site for KUHT, Houston's PBS station. Given the choice of scientific or business programming, Jue chose to focus on the latter. She recalled, "That [option] sounded better."[10] Later that year the division moved onsite when their building opened.

Her assigned branch, the Data Systems Development Branch, handled three systems: financial, procurement, and logistics as well as applied data analysis techniques and general management applications. Her supervisor knew that she had experience working with computers and offered her the choice of using either the IBM 1401 or the 7094. She chose the 1401, a much smaller computer specifically designed for processing and handling administrative and business tasks such as payroll, procurement, and managing of contracts. Jue learned to program in COBOL (Common Business Oriented Language) at NASA and designed a program for the library to check out books to employees. As NASA came closer to landing on the lunar surface, she helped provide "resource, time, [and] cost analysis" for the Gemini and Apollo Programs. Over the years she received promotions and eventually became a project lead.[11]

Merv Hughes, the coordinator of MSC's Federal Women's Program, credited women's promotions at the

[4] *Josephine Jue, interviewed by Daisy Chan Gee, circa 1980, audio,* https://hdl.handle.net/1911/63493; *Charles Reagan Wilson, "Chinese in Mississippi: An Ethnic People in a Biracial Society,"* https://www.mshistorynow.mdah.ms.gov/issue/mississippi-chinese-an-ethnic-people-in-a-biracial-society; *Josephine Jue, interview with author, August 4, 2021, JSC Oral History Project, transcript.*

[5] *Jue interview with author.*

[6] Ibid. *Programmers used FORTRAN, the first high-level programming language, for computing numeric calculations and scientific applications.*

[7] *Henry C. Dethloff,* Suddenly, Tomorrow Came: A History of the Johnson Space Center *(Houston: NASA, 1993), 44–45, 50–51.*

[8] *Jue interview with author.*

[9] *For more information on Hooks and Lee, see Ross-Nazzal,* Making Space for Women.

[10] *Jue interview with author; Major Test Facilities of the Engineering and Development Directorate, April 1966, Apollo Series, Box 066-64, JSC History Collection, University of Houston-Clear Lake.*

[11] *Jue interview with author; Major Test Facilities of the Engineering and Development Directorate, April 1966; The IBM 1401 Demo Lab and Restoration Project Computer History Museum, "The IBM 1401,"* http://ibm-1401.info/1401GuidePosterV9.html.

Figure 1. Josephine Jue in front of one of the Center's mainframe computers.

Center to a lack of discrimination in the agency. "When you've got your eyes on the stars," he said, "you haven't time for prejudice." *Los Angeles Times* reporter Ursula Vils highlighted the opportunities for women working in the space program in a series of articles featuring women who worked at some of the NASA Centers in 1969, the year the United States accomplished the nation's goal of landing on the moon. Jue was one of several professional women she interviewed. In her opinion, the benefits offered by NASA were excellent. "Our salaries are comparable to industry or better and we get twenty days leave after three years and thirteen days sick leave," Jue reported.[12]

Generous compensation did not mean improvements could not be made, however. In 1975 she joined the Federal Women's Program Committee to assist the Center's FWP coordinator and Equal Employment Opportunity Officer with problems faced by female employees.[13] Recognizing that women lacked access to certain career paths at NASA, the program set out to recruit and hire women and place them in fields for which they were qualified but underrepresented. The coordinator and committee also offered guidance about career advancement as well as training. Jue recalled that the committee met to "talk about what we could do" to ensure the Center avoided prejudice in the hiring or promotion of women employees and remembered they discussed how to move secretaries into positions with higher pay and greater authority.[14]

Jue, like many other professional women at the Center, insisted that she did not face any discrimination because of her sex. Other women involved in computing agreed. "If you write a computer program," Northcutt said, "either it works or it doesn't. There's no opportunity for anyone to be subjective about your work." Jue admitted she "was just glad to have a job and working and earning money and making more money than [her] parents in the grocery store." NASA might not have had many professional female employees, but the agency did offer job opportunities that women did not have elsewhere.[15]

As part of the 1975 International Women's Year and the FWP week activities, Jue and the committee put together a program for Center employees to be held in the Center's large Teague Auditorium. The "Space for Women" program included a series of talks with Harriett Jenkins, NASA's Assistant Administrator for Equal Opportunity, Secretary Renee I. Hall from nearby Ellington Air Force Base, and two professors from the University of Houston. University professor Bette Stead spoke about how organizations could utilize female employees "to their fullest potential" so that they would be "accepted on an equal basis." Dr. Dale Hill addressed the issue of women's visibility in the workplace and programs designed to help women become more assertive. Hall spoke directly to the secretaries in attendance, encouraging them to set goals early in their career and to work toward accomplishing them. Center Director Christopher C. Kraft called the day an important step in advancing women's opportunities within NASA and emphasized the importance of using the talents of female employees "to the maximum extent for the benefit of the space effort."[16]

Throughout the 1970s, more women were increasingly involved in NASA's follow-on human spaceflight vehicle, the Space Shuttle, the world's first reusable spacecraft. Jue was one of those who found herself immersed in the

[12] *Ursula Vils, "NASA Women Behind Man on the moon,"* Los Angeles Times, *October 6, 1969.*

[13] *President Lyndon B. Johnson signed Executive Order 11375 in 1967, which created the Federal Women's Program. His order added sex to other prohibited forms of discrimination in the federal government. In 1972, NASA hired its first agencywide Federal Women's Program Manager to advance opportunities for women in the space agency.*

[14] *Jue interview with author.*

[15] *Jue interview with author; "The Personal Views of Eight Women Who Succeeded in It,"* Life Magazine, *September 4, 1970, 20.*

[16] *"FWD Program Committee Will Sponsor 'Space for Women,'"* Roundup, *May 9, 1975, 2; "Goals of FWP emphasized,"* Roundup, *May 23, 1975, 1–2; Bette Ann Stead, "Women in Management,"* Vital Speeches of the Day *(July 1975) 41, no. 19: 589.*

Figure 2. Jue sits in the front row at the "Space for Women" program. She is the third woman on the left.

program when, in 1975, she turned her attention to the development and testing of Shuttle software; that year she became part of the Spacecraft Software Division headed by Richard Parten. At the time the Shuttle "was one of the most complex software systems ever produced," an expensive and time-consuming endeavor. Compared to the relatively simplistic Mercury capsule, which had no onboard computer, the Shuttle could not have been developed or operated without onboard computers and their associated software. As John Garman, an engineer who monitored the Apollo Guidance Computer software and managed the Space Shuttle software development, explained, "virtually no component in [the vehicle] could be checked out without some form of software in the computers. And that's a first."[17]

As development of the Space Shuttle ramped up, Jue found herself no longer writing computer programs, because NASA opted to contract out the work. "We [civil servants] were out of the programming business," she said. In 1975, when she joined the Spacecraft Software Division, she served as a contract monitor, chaired the HAL/S Language Definition and User Coordination Group, and managed operations in the Software Development Laboratory (SDL), one of several facilities that tested Shuttle software.[18] For its latest spacecraft, NASA chose to program the Shuttle's Primary Avionics System using a high-order language known as HAL/S, and Jue came on board just before the software's configuration inspection in Cambridge, Massachusetts. While the bulk of the vehicle was built by Rockwell International, the agency let another contract for the design, development, and testing of the Shuttle's flight software. IBM received that contract, with Intermetrics supplying the compiler for the software. (The compiler translated the code used by the Orbiter's General Purpose Computers.) The Spacecraft Software Division closely monitored the software's development and Jue specifically approved any modifications to HAL/S as chair of the HAL/S Language Definition and User Coordination Group.[19]

As a contract monitor, she evaluated and graded IBM and their Intermetrics counterparts. Jue reviewed their ability to meet the technical requirements as required by NASA and evaluated their performance. Did they submit quality work? Did they meet all deadlines and come in at or under cost?

Managing operations in the SDL involved overseeing the design and testing of the software needed before the Space Shuttle could even take flight. Established in 1972, the lab used mainframes, old IBM-360s from Mission Control, to simulate and run early versions of test software. During simulations, three General Purpose Computers plugged into a specially designed Flight Equipment Interface Device (FEID) which allowed IBM programmers and NASA employees to test, start, stop, and view the development code's variables and parameters to look for software bugs. The SDL also ensured that the software met all of NASA's requirements. From 1975 to 1978, the lab was instrumental in providing the test software for the Center's crew trainers; simulators used by the astronauts and flight controllers to train for Shuttle missions; Rockwell's Palmdale facility, where the Orbiter was being manufactured and tested; the Shuttle Avionics and Integration Laboratory; and the Kennedy Space Center in Florida. Once technicians, engineers, and flight crews tested the hardware and software together to demonstrate their compatibility, changes to the software were necessary, which required hundreds of programmers to come up with multiple versions of software.[20]

In October 1977, about four years before the launch of *Columbia*, the first Orbiter to fly in space, the lab began releasing new flight software to be verified and certified in flight simulators. Change requests grew substantially between 1977 and 1980, and Jue was busy juggling changing requirements, overseeing the change orders, and monitoring the IBM team. Continual evaluation and testing of the

[17]*John Garman interview by Adam L. Gruen, May 9, 1988, transcript, NASA Headquarters History Division, Washington, DC; James E. Tomayko,* Computers in Spaceflight: The NASA Experience *(Washington, DC: NASA, 1988), 3, 86.*

[18]*The name HAL is a bit of a mystery. Jack Garman attributed the name to one of the early software developers named Hal; some say it stands for Higher Avionics Language. Jue said, "Some think it stands for Houston Aerospace Language." Tomayko,* Computers in Spaceflight, *92; Jue interview by author.*

[19]*Jue interview with author; John R. Garman, interview with Kevin M. Rusnak, March 27, 2001, JSC Oral History Project, transcript,* `https://historycollection.jsc.nasa.gov/JSCHistoryPortal/history/oral_histories/GarmanJR/GarmanJR_3-27-01.htm`; *Tomayko,* Computers in Spaceflight, *92.*

[20]*Garman interview by Rusnak, March 2001.*

software were important because the first National Space Transportation System mission, STS-1, would be the first test flight of the Space Shuttle in space. Called the boldest test flight in history, this was the first time NASA chose to test a new spacecraft on its inaugural flight with astronauts onboard. Everything had to work so that the crew could safely return home. The Shuttle's Primary Avionics Software System, "the most complex flight computer program ever developed," had to be free of bugs and went through an intensive testing program that involved the release of seventeen interim versions over a thirty-one-month period before NASA deemed it flight worthy.[21]

Richard Feynman, the famed physicist and later a member of the Rogers Commission investigating the Space Shuttle *Challenger* accident, described the meticulous process of software testing by IBM that Jue was monitoring:

> The software is checked very carefully in a bottom-up fashion. First, each new line of code is checked, then sections of code or modules with special functions are verified. The scope is increased step by step until the new changes are incorporated into a complete system and checked. This complete output is considered the final product, newly released. But completely independently there is an independent verification group, that takes an adversary attitude to the software development group, and tests and verifies the software as if it were a customer of the delivered product. There is additional verification in using the new programs in simulators, etc. A discovery of an error during verification testing is considered very serious, and its origin studied very carefully to avoid such mistakes in the future.[22]

Once all the subsystems had been successfully certified, NASA was ready to launch the Space Shuttle and the two-man crew.

Flight controllers scrubbed the first launch attempt when there was a software glitch. Two days later the crew successfully launched into orbit where they spent nearly fifty-five hours in space, completed a lengthy list of systems tests, and returned home safely. In February 1982, after two successful Shuttle missions, Jue became the operations manager for the new Software Production Facility (SPF), pronounced "spiff." Like the SDL, the new facility continued to develop, verify, and produce flight software

Figure 3. Jue in the Software Production Facility.

for upcoming Shuttle missions. NASA anticipated flying multiple flights a month, up to fifty-two times a year, so using the old Apollo-era IBMs would be woefully inadequate as the agency moved from its first four test flights into operational missions. New technology was required. The 360s were updated to a single processor, the IBM 3033N, which had more capacity than those it replaced.[23]

In 1985, Jue learned of an opening in the Data Processing Systems Division and applied. NASA, like other federal agencies, recognized that employees needed personal computers, and Jue became JSC's User Workstation Manager. Computers were necessary to increase efficiency at the Center, and Jue was responsible for determining the user requirements and then overseeing the procurement and set up of the workstations across the Johnson Space Center. If machines required maintenance, her group handled those issues as well as training or troubleshooting. The staff also offered a Security Expo to help new computer users learn how to protect their hardware from viruses.[24]

In 1993, Jue heard the Space Station Program Office was "looking for somebody to head up the computer world

[21] *William A. Madden and Kyle Y. Rone, "Design, Development, Integration: Space Shuttle Primary Flight Software System,"* Communication of the ACM *(September 1984) 27, no. 9: 914–925; Gene D. Carlow, "Architecture of the Space Shuttle Primary Avionics Software System,"* Communication of the ACM *(September 1984) 27, no. 9: 926.*

[22] *R.P. Feynman, "Personal Observations on Reliability of Shuttle," in the* Report of the Presidential Commission on the Space Shuttle *Challenger* Accident, *Vol. II Appendix F,* https://history.nasa.gov/rogersrep/v2appf.htm.

[23] *Garman interview by Rusnak, March 2001; "Software Production Facility Now Operational,"* Roundup, *February 23, 1982, 3.*

[24] *Jue interview by author; "Users learn to protect, disinfect,"* Space News Roundup, *September 22, 1989, 1;U.S. Congress, Office of Technology Assessment,* Federal Government Information Technology: Management, Security, and Congressional Oversight *(Washington, DC: GPO, 1986), 30; Michael Schrage, "U.S. is Now Biggest Buyer of Computers,"* Washington Post, *September 11, 1985,* https://www.washingtonpost.com/archive/business/1985/09/11/us-is-now-biggest-buyer-of-computers/e1b12703-196f-49ba-bf27-953ddf8eada0/.

over there," so she decided to apply. The work was similar to what she had been doing for the Data Processing Systems Division, but she did not have to offer classes for Center employees or manage the help desk. She did, however, receive a promotion to a GS-15, the top of the pay scale for civil servants. Located in the brand-new home of the expanding Astronaut Office, Building 4 South, Jue found herself busy making certain the Space Station Program offices had the necessary computer connections, and she traveled to Japan to speak with the National Space Development Agency of Japan about their involvement in the International Space Station.

In 1997, she chose to retire from NASA when they offered her a buyout.[25] Having worked for thirty-four years, Jue had witnessed numerous changes in the workforce and in technology since her arrival. Women were no longer just secretaries or stenographers. They were astronauts and flight directors, and some served as branch or division chiefs. Just three years earlier, in 1994, Carolyn L. Huntoon, who also started at the Center in the sixties, became NASA's first female Center Director. Technology evolved over the years, and the mainframe computers employees once relied on were replaced with individual desktop computers. Jue made important contributions to the space agency in a mission support role, the type of work that if left undone, NASA would been unable to function. She provided vital services in the field of computer programming and as the technology evolved, in the procurement, distribution, and training of employees on personal workstations. Most importantly, she oversaw the dynamic development and testing of Shuttle software as manager of operations in the Software Development Lab and the Software Production Facility. Both were critically important to demonstrating and proving the reliability of the avionics system in flight.

Jennifer Ross-Nazzal

Credits

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[25] *Jue interview by author.*

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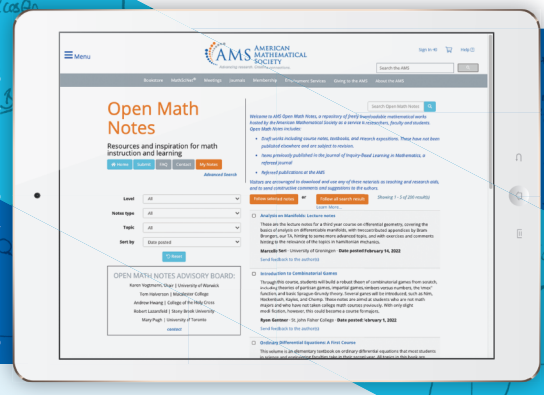

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