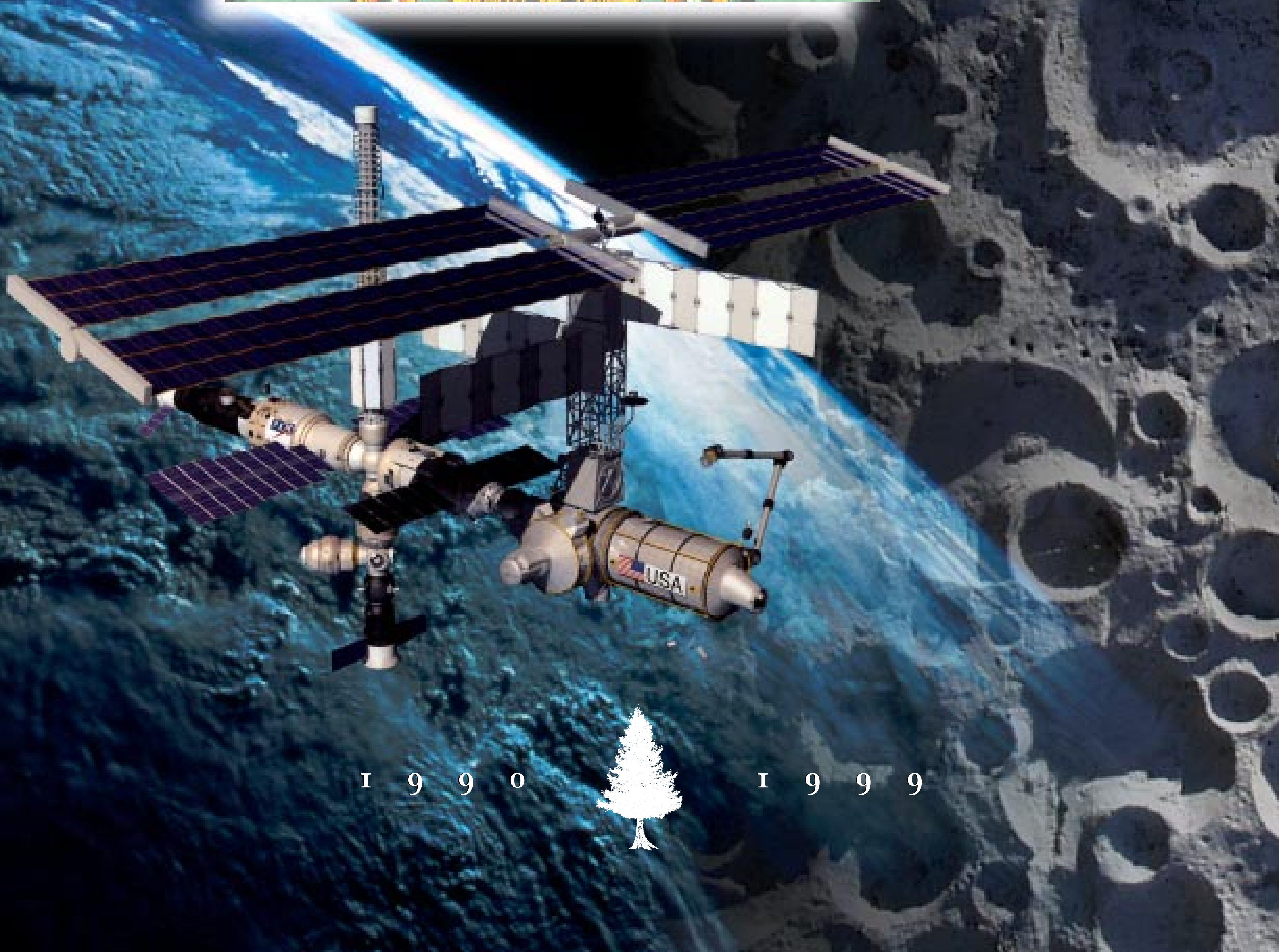
*Human centered computing is on the forefront of Information Technology at Ames.*



1990 1999

# A Center Reborn

## *Chapter 4:*
### *Ames in the 1990s*

Ames underwent more profound change in the mid-1990s than in any period since the end of the Apollo era. With the demise of the Soviet threat and shrinkage in federal research spending, Ames people had to face the reality that their Center might be shut down. Like NASA as a whole, Ames was swept up in changes imposed by headquarters: downsizing, quality management, reengineering, program shifting and outsourcing. However, Ames people took this dark period as an opportunity for self-discovery—of asking what was unique about Ames' historic strengths in science and engineering. They focused on expansive new missions in astrobiology and intelligent systems, and cleared away inherited structures to get at the essence of their work. By the end of the decade, as NASA as a whole reconfigured itself to shape America's aerospace future, the Ames approach—its cultural climate, managerial empowerment, collaborative spirit and fundamental scientific curiosity—increasingly stood as the model for what NASA wanted to become.

***Calothrix cyanobacteria isolated from Midway Geyser Basin in Yellowstone National Park. Analogous thermal spring features have been identified on Mars and are of interest as potential landing sites to search for ancient life.***

### THE GOLDIN AGE

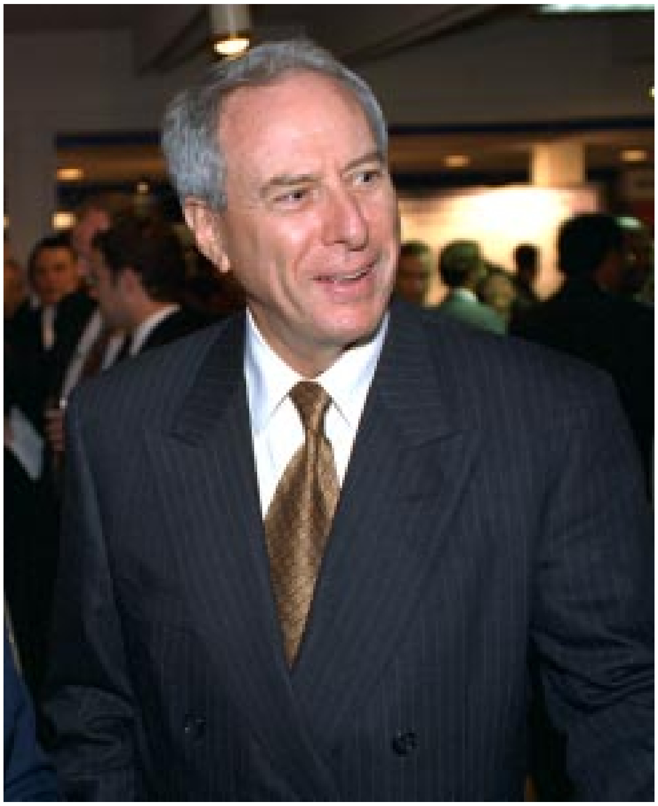
Three years into the Bush administration, Congress insisted more firmly that all federal laboratories, especially those in the departments of energy and defense, rethink their roles for the political realities of the post-Cold War era. Compared with the rest of NASA, Ames had lost little as Congress started cutting defense funds. Ames had already made plans to mothball all nonessential tunnels and simulators. Half of Ames' remaining tunnel time went to test military aircraft, though civil projects stood in line to buy any freed-up time. What military work that remained at Ames went toward technologies—like helicopters and navigation systems—needed to fight the now-expected strategic scenario of many battles on many fronts. In fact, the decades of quiet collaboration between Ames and the Soviets in life sciences was a key resource for the rest of NASA as it pursued a wider array of cooperative projects with the Russian space agency.

NASA headquarters, however, showed no inclination to squeeze out a peace dividend from the NASA budget. Plans for a Moon colony and a human mission to Mars were abandoned slower than the growing realization that the technology was too premature to do either safely or cheaply. Congress grew more impatient as NASA let the International

Space Station, the key cooperative project, soak up any funding liberated from NASA's defense-oriented projects. On 12 March 1992, Bush made a surprise announcement—that he had nominated Daniel Goldin to replace Richard Truly, whom he had asked to resign as NASA administrator.

Goldin was a vice president and general manager of the TRW Inc. Space and Technology Group in Manhattan Beach, California, which specialized in commercial, spy and early-warning satellites. During Goldin's five year tenure in that group, TRW had built thirteen such spacecraft—for the tracking and data relay satellite network, the Air Force defense support program, and the Brilliant Pebbles and Brilliant Eyes projects of the Strategic Defense Initiative Office. For NASA, TRW had built the Compton Gamma Ray Observatory and parts of the Advanced X-ray Astrophysics Facility. TRW won NASA's 1990 Goddard award for quality and productivity and was a finalist for the George M. Low trophy for excellence. Those who bought spacecraft from TRW knew Goldin as a very capable manager. Those in space policy knew nothing about him.

Goldin's early pronouncements showed him supportive of a smaller International Space Station, a human landing on Mars, and reliable operation of the shuttle. But mostly, he talked about applying an industrial perspective to shake up NASA. "He's a faster, cheaper, better kind of guy," said a Bush administration official. "He's obviously outside the NASA culture."[1]



***Daniel Goldin, NASA Administrator***

"My challenge," Goldin proclaimed in his first address to NASA employees, "is to convince you that you can do more, do it a little better, do it for less, if we use more innovative management techniques and if we fully utilize the individual capabilities of each and every NASA employee." Goldin also voiced, Ames people noted, distaste for how he perceived NASA's recent work in aeronautics: "We have to perform world class aeronautics research. Not leave it on the back-burners, not enjoy all the fun we're having writing TRs and TNs [technical reports and technical notes], but what we have is an obligation for America. The American aeronautics industry is counting on us and let's ask ourselves, have we really lived up to the expectations of American aeronautics?"[2] He was obviously a man of extraordinary energy, different views and, Ames people soon discovered, of strong personality.

Not the passage of time, nor changes of heart, nor the growing respect for Goldin's leadership—nothing softens the horror when Ames people tell the story of Goldin's first visit to Ames. There is no videotape that recorded what actually happened, so stories are told. Articles criticizing Goldin's intentions had just appeared in Bay Area newspapers and Goldin, one Ames manager remarked, "seemed to show up loaded for bear."[3] Rather than listen to welcoming speeches, he counted the number of women and minorities in a photograph of Ames executives, then made pointed comments about how few he found. Goldin challenged those he happened upon to defend their programs. People hid their name badges. In a meeting in the director's conference room, Goldin sent to the perimeter all those sitting around the table—mostly senior white males—and asked those sitting in perimeter chairs to take their place. Then Goldin heckled director Dale Compton as he reviewed Ames' strengths and goals, until Compton walked silently from the room, halfway through his presentation, to compose himself. Only then did Goldin's wrath subside.

Goldin himself has turned philosophical about how NASA people reacted to the force of his personality. Goldin's visit, in fact, foreshadowed that he really would push for a diverse workplace, for opening up NASA facilities to scientists outside the usual clubs, for imposing total quality management, and for tightening the NASA organization. But clearly, there was more to his displeasure with Ames.

NASA headquarters sent a surprise security review team that descended upon Ames on the evening of 31 July 1992. They sealed buildings, changed locks, searched file cabinets,

***Aerial view of Moffett Federal Airfield in 1995, looking straight on the main runway. In the background is the San Jose International Airport.***

took computers, interrogated hundreds of scientists, and sent ten researchers home on administrative leave. Only Compton was told, the day before, who they were, what they were looking for, and what prompted the raid. The team pointedly asked everyone about "management's judgment" on technology transfer matters.[4] Rumors circulated that they targeted scientists of Asian descent, especially those in the aerophysics directorate. In the end, the team discovered nothing illegal, and Ames altered some minor security procedures. But some good people decided to quit, and the Center was left with deepened concerns about the attitudes toward Ames that prevailed in NASA headquarters.

Whenever Goldin talked of Ames he used the word "revitalize," which Ames people considered better than "shut down." During the summer of 1992, as Bill Clinton made gains in the polls, Ames people thought a change in administration might remove Dan Goldin from their list of worries. But Albert Gore, as senator from Tennessee, chaired the committee that oversaw NASA matters and liked what he saw in Goldin. When Gore became Vice President, he asked Goldin to stay on.

### *Moffett Field, Quality, and Cultural Climate*

Compton won the next round of tensions between Goldin and Ames—over the reconfiguration of Moffett Field. The Navy had managed Moffett Field since 1931, except from October 1935 (following the crash of the dirigible Macon) to April 1942 when it was run by the Army Air Corps. In the 1950s, the Navy based supersonic fighters there until the community objected to the noise. In 1962, propeller-driven P-3 Orions arrived on base to fly patrols over the Pacific in search of Soviet submarines. With the collapse of the Soviet Union in 1990, the Navy said it no longer needed Moffett Field. The Base Realignment and Closure Commission (BRAC) agreed.

The Bay Area congressional delegation, led by Norman Mineta, a San Jose Democrat who chaired the Congressional Space Caucus, stepped into the fray. They convinced the BRAC that, even if the Navy left, Moffett should remain a federal

***Burrowing owls and least terns keep watch over Moffett Field wetlands.***

airfield. Efforts in 1990 to declare fifty acres at Moffett as protected wetlands, and to chart the presence of protected species like the burrowing owl, least tern, and peregrine falcon limited other developments at the field. In the October 1991 recommendations approved by Congress and the president, the BRAC said that NASA, as the next biggest resident agency, should become Moffett's custodian. The Navy had subsidized Moffett operations at $6 million per year, a cost NASA then would have to include in its budget unless it found other ways to generate revenues from field operations. Yet NASA administrator Richard Truly understood the opportunities for Ames. Goldin inherited a decision, however, that was not initially in line with his change agenda. NASA headquarters was already planning to trim Ames' flight operations. Furthermore, if Congress ever imposed a BRAC-type process on NASA, headquarters presumably would want nothing to get in its way of shutting down Ames. Compton and his executive staff understood this, marshalled the substantial goodwill toward Ames from its local community, and wrested control of the property on which Ames sat. Not until 23 December 1992, in a subdued signing ceremony at Ames, did Goldin concede that NASA would step up as custodian agency when the Navy officially decommissioned its station in July 1994.

***National Full-Scale Aerodynamic Complex (NFAC) wind tunnels and the Numerical Aerospace Simulation (NAS) building from across a springtime field of mustard and wild flowers.***

***"Finding a Cure for Cancer," a fanciful depiction by Clayton Pond.***

"Over the past five years in my prior job, I've become a true believer in the value of total quality management," said Goldin. "I believe deeply that if you can't measure it you can't manage it, and I intend to bring this philosophy to NASA."[5] Total Quality Management (TQM) was like a confusing new language. Throughout the 1970s, headquarters had asked Ames to undertake consultant-driven reviews and exercises—like quality circles—to make itself more efficient, and it was entirely Goldin's prerogative to impose the latest fashion in organizational improvement. But TQM was confusing. It demanded a focus on the "customer." "The space program doesn't belong to us," Goldin would say. "It belongs to the American people. They are our customers."[6] Lots of NASA people did not find that definition specific enough to clarify how they would use all the statistics and acronyms TQM demanded. But Ames people tried.

***Jana Coleman addresses the Ames all-hands meeting on 16 July 1992 to explain the process of total quality management.***


Compton called an all-hands meeting in July 1992 on the Ames flight line to say Ames would start implementing TQM with a year of education and training. Meanwhile a quality improvement team, chaired by Jana Coleman and Robert Rosen, worked with continuous-improvement consultants Philip C. Crosby, Inc., and wrote a report on the whole TQM process. In April 1993, Ames posted everywhere its carefully worded quality statement. Ames' management council approved the report in February 1993, and set about forming process action teams (PATs) to reduce the costs of nonconformance (CNC). Ames created a culture that naturally supported spontaneous quality teams and continuous improvement. Throughout the Center, teams defined their customers, used flow charting and process measurements, tore apart then rebuilt all their procedures, and began to report savings in costs and time. For example, in late 1993, the Unitary 11 foot transonic tunnel applied a TQM approach to test

***Ronald McNair Intermediate School in East Palo Alto has long hosted mentors from NASA Ames. Dale Compton visited in 1991 to encourage the students to prepare for careers in science and engineering.***

runs for the Navy's A/F-X competition by four contractor teams. By reviewing their procedures and listening to their customers, the tunnel group doubled the expected number of successful runs. Ames announced a $2 million investment in process infrastructure—like electronic forms and purchasing, computer peripherals, and a charge-back system for technical support—that helped all teams improve their processes. Ames made good progress, even though the Crosby literature trumpeted that continuous improvement is a cultural process that takes five to seven years to change—"so don't let impatience cloud your view of progress."[7] Ames undertook the Malcolm Baldridge Self-Assessment in the fall of 1993—less than eighteen months after starting TQM—because of a Clinton administration initiative to "reinvent government." The survey showed that, even though Ames people thought their work was very high quality, they knew little about Ames' formal quality process. Ames lagged well behind all other organizations actively implementing TQM.[8] Ames management, presumably, had not become true believers in TQM.

Another cultural review further widened the chasm between Ames management and NASA headquarters. In July 1992, Ames was visited by a NASA-wide Cultural Climate and Practices Review Team, led by General Elmer T. Brooks, deputy associate administrator for agency programs. The team gave Ames a glowing report, calling it "the best" of all NASA Centers. Ames employed higher percentages of underrepresented groups than any other NASA Center; the Ames Multi-Cultural Leadership Council was a model for other Centers; participation was strong in the Equal Opportunity Advisory Groups—African American, Asian American and Pacific Islander,

***Ames research contributed to the aerodynamics and thermal protection systems of all single-stage-to-orbit spacecraft under development in the late 1990s: (left to right) the Rockwell wing body; the Boeing/Bell vertical landing configuration, and the Lockheed Martin lifting body.***

***Michael Marlaire, chief of Ames' external affairs office, discusses plans for Moffett Field at a local town meeting.***

Disabled, Hispanic, Women and Native American; Ames won NASA's Equal Opportunity Trophy in three of the past nine years; and Ames' entire work force felt challenged and satisfied with their work.

However, there were problem areas. The percentages of minorities employed were lower than in the culturally diverse Bay Area as a whole. African Americans were especially underrepresented, indicating that Ames had failed to reach into the local community. Ames tended to hire experienced researchers rather than those fresh out of co-op programs. Any mentoring was too informal, and career development was haphazard. Higher wages in local industry made it tough for Ames to retain the leaders it did develop. Of forty top managers, only one was a woman and only two were minority males. Minorities and women perceived the senior executive service as a white male preserve. In fact, the Brooks team declared that all problems were caused by upper management. Despite being the best in NASA in affirmative action, the Brooks team reported, "everyone is looking to the Center Director for proactive leadership."[9]

Then, in October 1993, Congress pulled funding for the SETI (Search for Extraterrestrial Intelligence) program that Ames had nurtured for two decades and that had stirred up enormous scientific excitement around NASA. Some Ames staff felt that Goldin failed to stand up to congressional doubts, and sacrificed SETI to secure funding for the space station and for programs at other Centers. Goldin later said that NASA would focus instead on the far more promising search for dumb, organic life in the universe by developing the discipline of astrobiology. Eight civil servants and fifty contractors were affected by the $12 million cut. As other Ames projects were cut, and as Ames prepared for many years of flat or declining budgets, Ames opened a career-transition office to move its work force into a booming Silicon Valley economy hungry for such technical skills.

Compton and Vic Peterson, Ames' deputy director, increasingly felt that, as the lightning rods for some unarticulated displeasure from NASA headquarters, the best thing they could do for their Center was to retire. On 22 November 1993, both Compton—after 36 years of government service—and Peterson—after 37 years of government service—took the retirement they had earned. In declining to speculate on what his successor might consider Ames' major goals and challenges, Compton replied: "The long term goals of this Center have survived many directors."[10]

### *Ken K. Munechika*

***Ken K. Munechika, Director of Ames Research Center from 1994 to 1996.***

On 17 January 1994 Ken K. Munechika became director of Ames. Munechika was raised in Hawaii and earned a doctorate in educational administration from the University of Southern California. He had a distinguished career in the U.S. Air Force. He started as a navigator, flew 200 combat missions in Southeast Asia, moved into training as a professor of aerospace studies, then served as chief of satellite operations to recover space capsules deorbited from space. In July 1981 he moved to Sunnyvale to command the Air Force Satellite Control Facility (later renamed Onizuka Air Force Station), where he directed contractor teams in launch operations of more than fifty defense satellites, and all the defense payloads launched by NASA's Space Shuttle. He was also responsible for planning and budgeting a global network of satellite tracking stations. He retired in June 1989 to become executive director of the Office of Space Industry for the state of Hawaii (where he would return after being reassigned from Ames).

Munechika asked William E. Dean to serve as his deputy director. Dean, too, was a newcomer to Ames, having arrived in August 1991 as special assistant for institutional management. Prior to that, Dean served as president of Acurex Corporation of Mountain View, a privately held supplier of control and electronics equipment. Before then, from 1962 to 1981, Dean worked for Rockwell International, serving as group vice president responsible for the Global Positioning Satellite and the operational phase of NASA's space shuttle program. Compton had hired Dean to infuse business-like thinking into Ames, and Munechika asked him to stay on.

***Ames inscribed its name, again, on NASA's Equal Employment Opportunity Trophy in 1993.***

Though he had spent his entire career managing the highest technology in the Air Force arsenal, Munechika was the first to admit he was no scientist. His first priority was addressing the lingering factionalism from the Cultural Climate and Practices Plan. "Since aeronautics and space are for everybody," Munechika wrote, "I want Ames to look like America and the community we represent....Ames must have a work environment where everyone feels empowered, included, valued, and respected."[11] Jana Coleman was named to lead the newly created Center operations directorate, the first woman to head a directorate at Ames. Ames attracted good people, who in turn attracted good people, who then saw Ames as a great place to build their careers. This was a key part of Ames' success, so Ames people addressed their diversity with seriousness.

Ames people also put more vigor into their outreach efforts. Every year for two weeks thousands of students gathered for the JASON project to explore, through telepresence, the scientific mysteries of our Earth. Ames formed a docent corps to staff the Ames Aerospace Encounter, the Ames Visitor Center, and the Ames Teacher Resource Center. NASA distributed internet kits to area schools, and engineers volunteered to share with students the excitement of their work. Ames expanded its relationship with the National Hispanic University (which began early in 1993 with a space sciences program and would culminate in an historic collaborative agreement in October 1997). Interns and research fellows came from a wider variety of schools. Space Camp California opened just outside Ames' main gate.

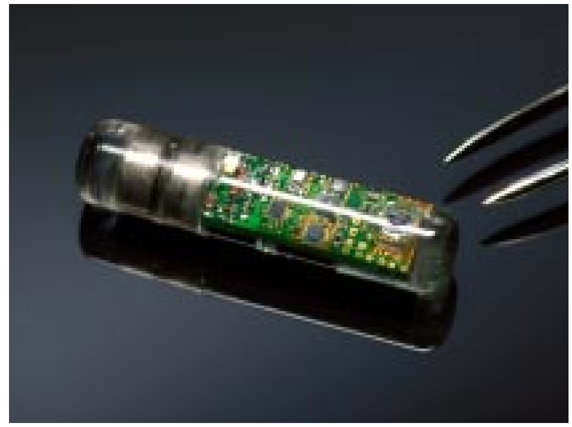
With Munechika to introduce them, headquarters staff showed up more regularly at Ames, praising its revitalization efforts. Many of the significant events and program activities that would follow—like the Zero Base Review, the information technology Center of Excellence, the Astrobiology Institute, Lunar Prospector, the SOFIA restart, and the absorption of Moffett Naval Air Station—were all started in a fairly short period of time during

***Ames tracking and telemetry station at Crows Landing auxiliary airfield.***

Munechika's tenure as director. Yet bolstered morale and coalescence of support from the external community only served to brace Ames people for program adjustments and structural changes still to come. The darkening funding picture and Goldin's agenda for change set the challenges for Munechika's period of leadership. The same day Goldin announced Munechika's appointment, he also announced the appointment of three other Center directors (two of whom, like Munechika, would be gone within three years). He further announced that, in March 1994, after twelve years as part of Ames, Dryden would become an independent Center. Ames management expected that, as Dryden asserted itself in NASA planning, programs and people would be shifted there from Ames.

Headquarters let Ames staff know that Moffett Field was their burden to bear. Countless details were ironed out in advance of the transfer, all coordinated by Michael Falarski and Annette Rodrigues of the NASA-Moffett Field development project. But change appeared gradually—access guidelines were redefined, security guards wore different uniforms, the Navy's P-3 Orions left, the Navy began environmental remediation, and historic preservationists surveyed the architecture. In 1993, NASA took control of the small naval airfield at Crows Landing in Stanislaus County,

***MD-900 helicopter in hover mode during noise-abatement tests.***



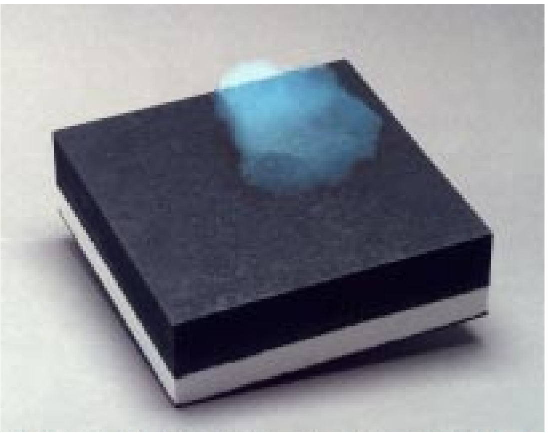
***Advanced telemetry devices such as this pill transmitter can monitor fetal health in the mother's womb.***

***Decommissioning ceremony on 1 July 1994, marking the transfer of Moffett Federal Airfield from the U.S. Navy to NASA.***

which Navy pilots had used for P-3 training flights and which NASA would use for low-speed flight research. The Onizuka Air Force Station took over the military housing that Navy families vacated. On 1 July 1994, while a Navy blimp and a P-3 Orion flew overhead, a 21 gun salute and taps sounded as Navy officers lowered their flags. "From Lighter than Air, to Faster than Sound, to Outer Space:" that's how the Navy commander described the changes seen at the Moffett Field Naval Air Station. NASA renamed it Moffett Federal Airfield to reflect its new organizational flexibility. It now could serve a wider array of tenants and customers—the Naval Air Reserve Santa Clara, the Army Reserve, the California Air National Guard, other governmental agencies like the U.S. Post Office and the Federal Emergency Management Agency, and private firms executing government contracts. Then Ames people started planning to make something new and exciting from their enormous facility and opportunity.

***Toni Ortega and Lisa Hunter evaluate a mock-up of the Space Station centrifuge facility in July 1994.***

*"Solid Smoke" aerogel insulations developed for the Space Shuttle have found uses on Earth such as insulators for refrigerators, furnaces and automobiles.*



Ames started by assessing community needs in the adjacent cities of Mountain View and Sunnyvale and in the Silicon Valley region. San Jose International Airport was congested, with any expansion limited by its proximity to downtown and its location amid residential neighborhoods. Moffett Field offered a superb airfield—twin runways 9,200 feet and 8,900 feet long, ample tarmacs, three very large hangars, aircraft fuel and wash facilities, and more than seventy structures for aircraft operations. It had round-the-clock crash and rescue service, sixteen hour air traffic control, instrument landing equipment, world-class communication links, and easy access to Highway 101. What it lacked was air traffic, so Ames facility managers suggested using the airfield for business and freight flights. Specifically, the San Jose airport could no longer fit in jumbo jets ferrying electronics back and forth from Asia. Furthermore, Bill Dean, Ames' deputy director and the person most responsible for base planning, thought that Ames should keep the airfield as the Navy left it. Like so many others, he thought that some day soon Russian submarines would again patrol the Pacific and the Navy would return its P-3 Orions. Converting Moffett Field into an air cargo base best kept it in mobilization shape, so that was the plan he proposed.

But local residents had gotten used to quiet (even though the P-3 and C-130 flights were never very noisy). Rather than decide themselves, the Mountain

*Chris McKay explores for life in the harsh environment of Dry Valley, Antarctica.*

***The Slender Hypersonic Aerothermodynamic Research probe (SHARP-L1) is an example of a revolutionary lifting body concept.***

View and Sunnyvale city councils asked for a nonbinding vote on the plan to make Moffett Field a freight airport. Voters advised against the plan, Munechika respected the vote, and Ames was left to devise another plan while shouldering the costs of running the base. Though the derailing of momentum behind the Moffett Field plan was a loss, far more significant losses came in the wake of NASA's Zero Base Review.

### *Zero Base Review*

Goldin arrived at NASA proclaiming that NASA was bloated. He imposed a new type of discipline to NASA's budget process and, in time for the fiscal 1994 appropriations, submitted a budget that reduced NASA's five year budget by $15 billion. Two years later, by cancelling programs and redesigning the International Space Station, he reduced NASA's long-range budget by thirty percent. He called this process "a fiscal declaration of independence from the old way of doing business." But by 1995, when Congress asked NASA to absorb an additional $5 billion in cuts from its $14 billion budget, starting in 1997, Goldin realized that the loss of more research programs would jeopardize NASA's leadership in aerospace technology. So in response to the Clinton administration's call for a National Performance Review, instead of cutting programs Goldin focused on streamlining NASA's infrastructure through a Zero Base Review (ZBR).

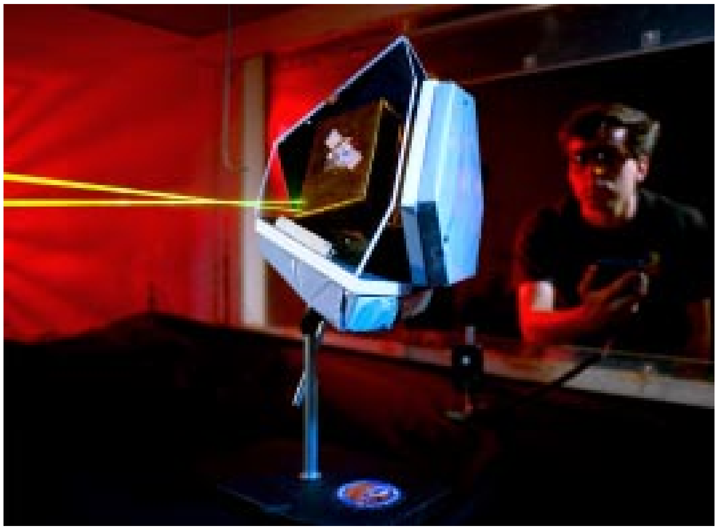
Rather than starting with last year's budget to develop the next, zero base budgeting means starting from zero every year, and asking whether each program is essential to an agency's core missions. This was different from the national laboratory review of 1992, which focused mostly on eliminating duplication of functions. A headquarters "red team" visited in 1994 and asked Ames people to ponder the prospect of being shut down. The preliminary ZBR white paper of April 1995, drafted by NASA deputy chief of spaceflight Richard Wisnieski, translated this vague recommendation into a specific budget planning document. Nancy Bingham, the Ames manager on whose desk the faxed ZBR draft landed, called it "inflammatory."[12] It presented numbers that dropped Ames civil servant cadre from 1,678 to below 1,000 within five years—below the point of viability. Aerospace facilities would be transferred to Dryden, and the space station centrifuge would go to Johnson Space Center. What remained of Ames could then easily be shunted into a GOCO—a government owned, contractor operated facility. Ames had in the past confronted efforts to shut it down—in 1969 at the start of Hans Mark's tenure and during the 1976 reductions in force before he left. The draft ZBR white paper made it most clear—in dollars and headcounts—that if people in Washington wanted to rebuild NASA from scratch, they would rebuild it without Ames.

To stave off the threat that the entire Center would be shut down immediately, Ames mobilized support within the community, among California legislators and Ames' friends in Washington. Congressman Norm Mineta protested that the people of Ames "are too valuable to be left to the underestimation of NASA bureaucrats in Washington."[13] With the small amount of time they won, they dove head first into the challenge of zero-base thinking. NASA headquarters had started by defining its five strategic enterprises—mission to planet Earth, aeronautics, space science, space technology, and human exploration and development of space. They intended to declare each Center a center of excellence in some area to help all of NASA execute those missions. Each Center would take on lead center programs, and administrative functions would be consolidated agencywide. Deciding which Centers should execute a mission and which were "overlap" got intensely political.

Many at Ames believed their Center did not fare well in the grab for assignments. Ames lost its leadership in Earth sciences to Goddard, in biomedical sciences to Johnson, in space technology to Marshall Space Flight Center, and in planetary sciences to the Jet Propulsion Laboratory. Significantly, Ames lost its leadership in aerodynamics and airframes to Langley, and Langley would also manage Ames' tunnels and simulators, which were mostly staffed by contractors but made up sixty percent of Ames' budget. Ames faithfully eliminated programs declared redundant, and executed its plan for 35 percent attrition during 1996: buyouts reduced the number of civil servants by 300, layoffs almost halved the number of contractor personnel to 1,400. Most importantly, Ames lost its aircraft to Dryden.

In December 1990 NASA headquarters had appointed long-time Dryden researcher Kenneth Szalai to the position of "Director" of the Ames-Dryden Flight Research Facility. Marty Knutson, who had managed the facility for five years and guided Szalai's development as a manager, returned home to Ames. Goldin visited Dryden in September 1992 and announced that "the right stuff" still lived there and, indeed, Szalai proved adept at bringing new projects to Dryden—from industry as well as from other NASA Centers. By March 1994, after thirteen years of direction from Ames, Dryden again became an independent NASA Center. In a note to Ames employees, Szalai wrote "Many professional associations and friendships were developed and I intend to work hard to sustain these….Please consider Dryden as your flight research center, too."[14] Then, on 19 May 1995, NASA announced that for cost savings every aircraft in the NASA fleet—operational as well as experimental—would be consolidated at Dryden.[15] Ames had the most to lose. Of the seventy aircraft in NASA's fleet, Ames then serviced twelve—three ER-2s, one DC-8, one C-130, one Learjet, one C-141 and five helicopters. Moving the airborne science airplanes provoked the most controversy. Ames management argued that these airborne laboratories relied on input from an active scientific community simply not found in California's high desert, and that they used equipment made in Silicon Valley. "This consolidation could mean the end of valuable environmental programs," wrote California Congresswoman Anna Eshoo, "I'm also concerned NASA is fudging its fiscal homework on the consolidation plan.

Its numbers are incomplete and its economic justifications are questionable."[16] The flight operations branch, the first branch established at Ames, was disbanded. Some support staff moved with the aircraft; some retired, like long-time flight operations chief Martin Knutson and pilot Gordon Hardy; most took new assignments at Ames. In November 1997 the last Ames aircraft flew off to Dryden. A disconcerting quiet hung over the Ames hangars. Researchers at Ames who had dedicated their careers to improving aircraft and who wanted to see them in flight, now had to shuttle south to the desert on a little commuter airplane.



***Mars Pathfinder model being installed by Chris Cooper in the Mars wind tunnel at Ames.***

Amid all these program losses, however, Ames had constructed a bold new strategy. Ames' response to the ZBR fell on the shoulders of a mid-career group of technical leaders—most of whom had hired into Ames during the 1970s and had honed their advocacy skills in the strategy and tactics committee meetings called by Bill Ballhaus and Dale Compton. Despite the mandate of zero-based thinking, they refused to believe that Ames had no history. They knew the people there, how fluidly they worked together, and how ingeniously they used the research tools available. But Ames management had not done a good job marketing these capabilities. Coordinating efforts from the Ames headquarters building, Nancy Bingham, Bill Berry, Mike Marlaire, Scott Hubbard and George Kidwell pulled together comments from their colleagues around Ames, and gradually a strategic response emerged. Ames polished this story by talking to community leaders, to the Bay Area Economic Forum, and the local press. The final NASA ZBR white paper of May 1996 showed Ames' headcount at 1,300 and that Ames would lead NASA in information technology, astrobiology, and aviation system safety and capacity.

Ames' response to the ZBR marked its rebirth. In the same way that so many scientists and engineers had reinvented themselves to address new national needs,

**Henry McDonald, Director of Ames Research Center since 1996.**

by the end of the ZBR exercise the Center had also redefined itself. It coincided with the arrival of a new leader, who understood Ames' past and its future.

## HENRY McDONALD

Harry McDonald remembers that when he first met Goldin, Goldin said that he "gave Ames one plum assignment—to become a center of excellence in information technology—and that Ames hadn't executed it well."[17] Munechika's plans for the newly created information systems directorate were largely derailed when David Cooper, the information system director he appointed to replace Henry Lum, left and many of his staff left with him. Consolidating all of NASA's computing and communication systems should have shown a savings of 1,200 positions nationwide, but the systems were still burdened by disorganization and redundancy. More and more NASA projects revolved around imaging, robotics, data crunching and internetworking, and NASA people had a hard time finding the expertise they needed. Moreover, Ames was stagnant. Since becoming a part of NASA, Ames had always had about seven percent of NASA staff and about five percent of its budget. If Ames expected to grow it had to take a bold stance. Thus charged with implementing Ames' information technology mission, McDonald arrived as Ames director on 4 March 1996.

A native of Scotland with a doctorate from the University of Glasgow, McDonald had spent the previous five years as professor and assistant director of computational sciences in the Applied Research Laboratory at Pennsylvania State University. Before that, McDonald was president of Scientific Research Associates, Inc., of Glastonbury, Connecticut, a company he founded in 1976 to do contract research in computational physics and gas dynamics. The state of Connecticut awarded McDonald its small businessman of the year award for high technology because of a ventilator he invented and developed. And before that he worked as a research engineer for British Aerospace and then for United

*Yuri Gawdiak displays a personal satellite assistant prototyped at Ames in 1999 for future spaceflights. The PSA is an autonomous robot based on Ames' work in telepresence, artificial intelligence, and research in microgravity. It hovers behind an astronaut, monitors environmental conditions, collects data from onboard experiments, provides video conferencing, and otherwise serves as a wireless link between the astronauts and ground crews.*

Technologies where, along with colleagues at Ames, he developed the linearized block implicit methods for solving compressible flow equations. McDonald joined Ames on an interpersonnel agreement (IPA) that allowed him to keep his university tenure, and he kept his house in Glastonbury, where his wife had her medical practice.

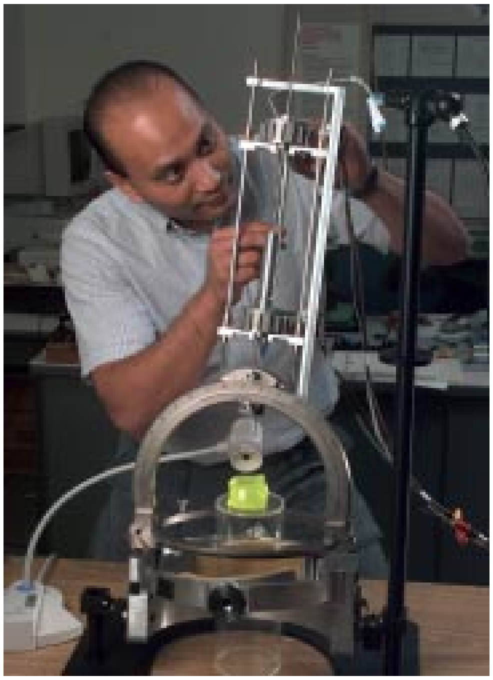
McDonald was an expert in computational aerodynamics, and people around Ames knew and respected his work. As his deputy director, he named William Berry who had built a strong reputation for management in the space and life sciences side of Ames. McDonald also brought in new managers from the outside—like Robert "Jack" Hansen as deputy director of research, and Steve Zornetzer as director of information sciences and technology. He also invited back an old hand as his advisor, John Boyd.

Intellectually, McDonald understood the entire range of work at the Center and could thus represent it effectively outside. He tempered what many perceived as the traditional arrogance around "Ames University." (While speaking at Ames, General Sam Armstrong once opined that NASA was a place, "where a direct order is seen as an open invitation to debate.") McDonald tapped in to the desire of Ames researchers to embrace change rather than fight it, and to constantly reinvent themselves by applying their skills to new challenges. Most important, McDonald focused Ames on implementing the strategic opportunities posed by the Zero Base Review.

*AME-2 airplane, designed to be unfolded and flown through the atmosphere of Mars, in flight demonstrations at Moffett Field.*

### Center of Excellence for Information Technology

"The future of NASA lies in information technology and information systems," proclaimed Goldin in May 1996 in a ceremony designating Ames as the NASA Center of

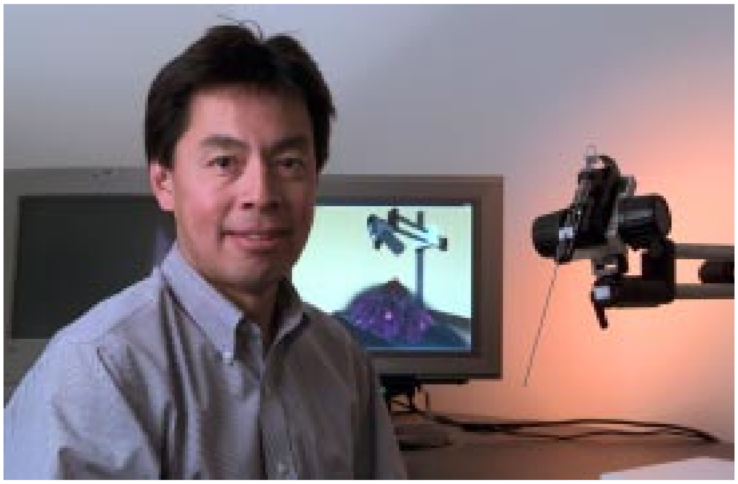


***Michael Guerrero works with the robotic neurosurgery apparatus, a computer controlled motor driven smart probe with a multisensory tip.***

Excellence for Information Technology (CoE-IT). The CoE-IT developed rapidly, directed by Jack Hansen and then Kenneth Ford, as the center of a virtual corporation that linked NASA Centers, industry, and academia into tight-knit teams. These teams developed "enabling technologies" in modeling, database management, smart sensors, human-computer interaction, and supercomputing and networking. These enabling technologies then supported key areas of NASA's missions — integrating aerospace design teams, networking data to improve simulations, improving efficiency in aviation operations, and developing autonomous probes to make space exploration more frequent, reliable and scientifically intense. Ames led NASA efforts to incorporate advanced information technologies into all NASA space and aeronautics programs in support of faster, better, cheaper programs.

The CoE-IT consolidated resources at Ames and from around NASA. Ames became NASA's lead center for supercomputer consolidation, overseen by the Consolidated Supercomputing Management Office (CoSMO). Consolidation began with an inventory of all of NASA's supercomputers—including the central computer facilities, the NAS facility, and the test beds in the high performance computing and communications program—and identified forty systems with a total purchase price of $300 million. Consolidation continued as Ames matched the right computer to the right job within NASA's enterprises. For example, the NAS and the computational chemistry branch together pioneered new ways of designing nanotechnology—machines built at the molecular level.

From there, Ames information technologists set about building NASA's information power grid, a system of interlinkages



***A surgical robot, designed to probe breast tumors and to be controlled over the internet, developed by Robert Mah of the Ames bioinformatics center.***

***Christine Falsetti and Kevin Jones review Ames contributions to building the next-generation internet.***

that enabled distributed supercomputing to support the entire range of NASA research and decision-making. The tools they developed for the seamless integration of computing and data archiving also underlay NASA's contributions to NREN, the national research and education network. Ames' CoE-IT was also named to represent NASA as the federal government invested $300 million to build the next-generation internet. Christine Falsetti led a group of thirty Ames people designing and integrating new network technologies that would allow data to flow a thousand times faster than in 1997.

One Ames effort integrated into the CoE-IT was the NASA center for bioinformatics, opened in August 1991 with a dazzling display in the Ames auditorium by Muriel Ross. A biologist specializing in the neural networks around the vestibular system, Ross joined Ames in 1986 for access to its supercomputing infrastructure. She suspected, and later experiments would confirm, that exposure to microgravity caused the inner ear to add new nerve cells. She also suspected, rightly, that this rewiring could only be accurately depicted in three-dimensional models. Reconstructing the architecture and physiology of this expansive neural network was painstaking work.

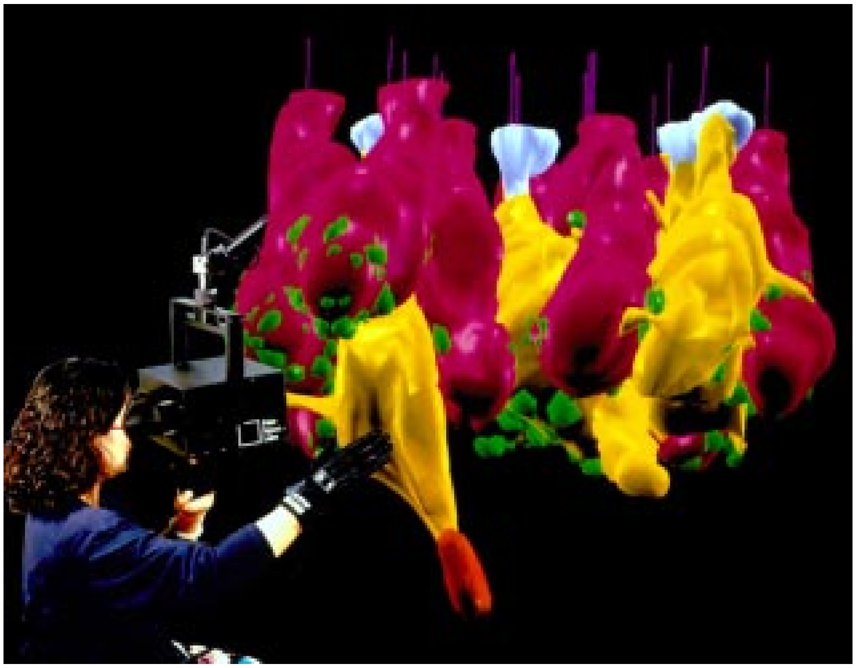
***Muriel Ross and Rei Cheng looking over the immersive work bench in 1996 showing a skull for facial reconstructive surgery.***

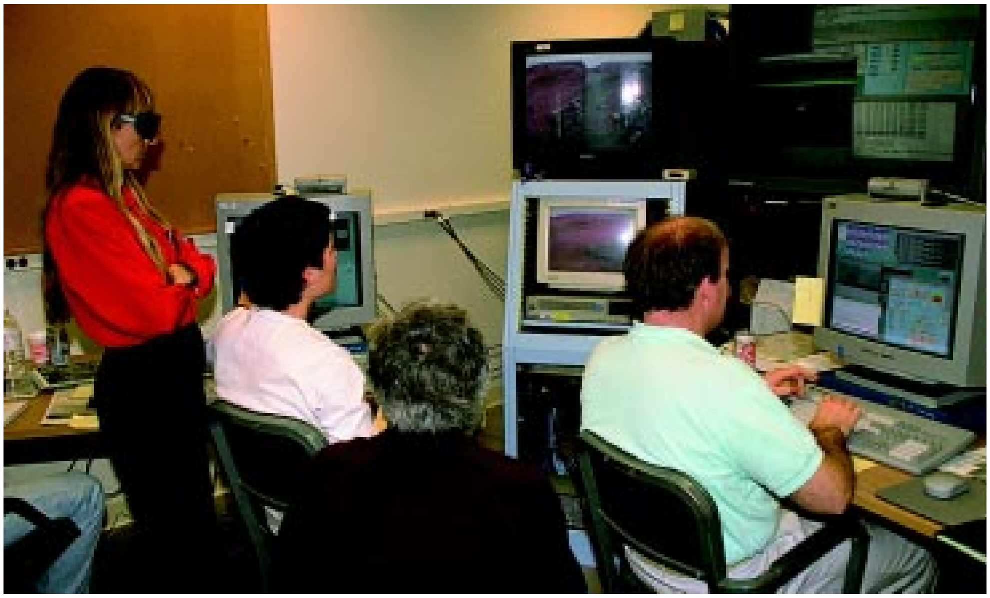
***Daryl Rasmussen working in Ames' Mars map laboratory. Ames provided much of the visualization technology that helped Mars Pathfinder grab headlines around the world.***

So Ross worked with programmers in the NAS to devise a technology for reconstructing serial sections of a rat's vestibular system into a three-dimensional computer model. Ames' artificial intelligence experts explored this model for clues about building neural networks with computers. Ames experts in virtual reality, led by Glenn Meyers of Sterling Software, bought a prototype virtual boom from Fakespace Corporation and linked it with Silicon Graphics workstations to project reconstructed images into the first immersive workbench. There, surgeons could rehearse difficult procedures before an operation.

The next step for the bioinformatics center was to build collaborative networks with other NASA centers using emergent Silicon Valley networking technology. Stanford University Medical Center was first, followed by the Cleveland Clinic Foundation, then the Salinas Medical Center, and the Navajo Nation. With each new collaborating clinic—each more distant and less sophisticated in computing—Ames tested technologies for doing remote medicine, preparing for when astronauts many days distant on the space station might need to respond to medical emergencies. In the meantime, the center is a national resource that allows investigators to apply advanced computer technology to the study of biological systems. When challenged to apply its skills to a national initiative in women's health, the Ames center for bioinformatics developed the ROSS software (for reconstruction of serial sections) to provide very precise three-dimensional images of breast cancer tumors.

***Virtual reality applied to neuroscience. Rei Cheng of the Ames bioinformatics center shows a model made to study motion sickness and balance in the inner ear.***

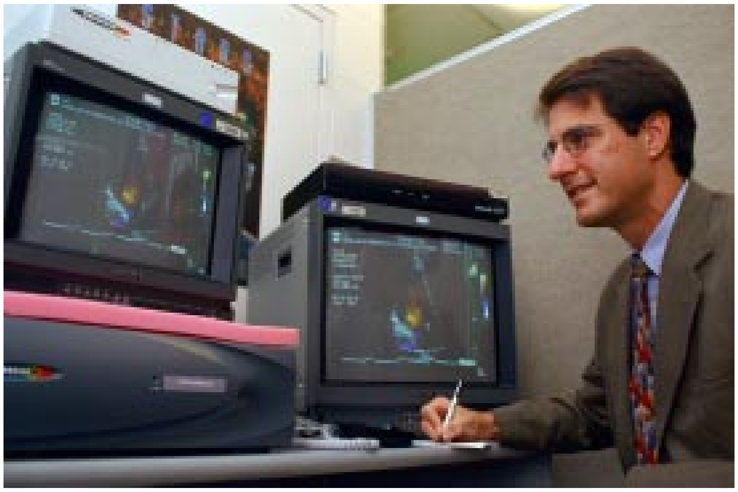




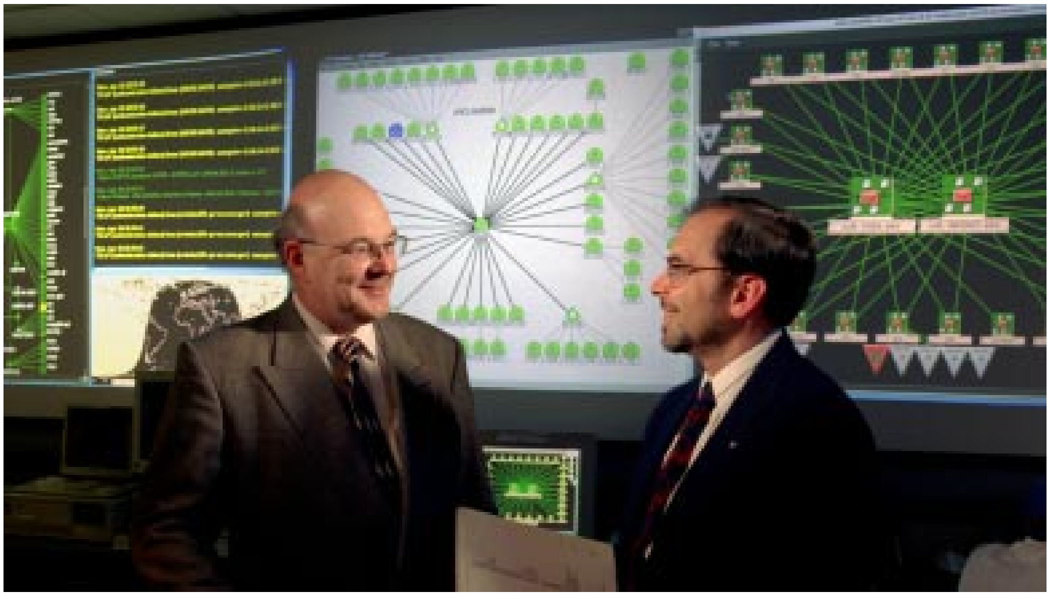
***Ames' telepresence control room, in practice for robotic exploration of distant planets.***

Ames made telepresence the key to NASA plans for planetary exploration. In 1990, the Ames space instrumentation and studies branch, led by Scott Hubbard, developed mission plans for the Mars environmental survey (MESUR). The plan was to build a global network of sixteen landers around the Martian surface—each capable of atmospheric analysis on the way down and, once on the surface, of performing meteorology, seismology, surface imaging, and soil chemistry measurements. Because the network could grow over several years, the annual costs would be small and the landers could be improved to optimize the scientific return. With the data, NASA could pick the best spot to land a human mission to Mars. However, in November 1991, NASA headquarters transferred MESUR to JPL, where it was trying to centralize work in planetary exploration. JPL invented the idea of a single MESUR lander, renamed it and developed it into Mars Pathfinder, which roved across the Martian landscape in July 1997.

Ames continued developing the technology to support robotic missions to Mars after MESUR had been moved. In January 1992, Geoffrey Briggs was appointed scientific director of Ames' new center for Mars exploration (CMEX). Since the Viking missions of the mid-1970s, Ames maintained a world-class group of scientists specializing in Martian studies across a broad spectrum. CMEX brought all of this expertise—especially expertise in robotic spacecraft and data



***At the distant end of an internet line a physician, at the Cleveland Clinic Foundation working in partnership with Ames to develop telemedicine technologies, checks an echocardiogram displayed in real time.***



**Bohdan Cmaylo and Russ Wertenburg in the Ames Network Operations Center.**

processing—to bear on key questions in the geographical and atmospheric evolution of Mars. Ames paleontologist Jack Farmer and exobiologist Christopher McKay led studies on the best strategies and locations to search for life on Mars.

"Antarctica is the most Mars-like environment on Earth," said Carol Stoker of the Ames telepresence technology project. "We're taking this technology to a hostile environment to conduct research that has direct application to NASA's goal of exploring Mars."[18] In December 1992, Stoker and Dale Anderson tested telepresence technology on mini-submarines exploring the sediments under the permanent ice covering Antarctic lakes. The next Antarctic summer they returned with a rover with stereoscopic vision, not only so they could generate a three-dimensional terrain model of the McMurdo Sound but also so the teleoperator had depth perception to better collect samples with the rover's robotic arm. Back at Ames, Butler Hine controlled it using a teleoperations headset developed by Ames' intelligent mechanisms group. They were linked via a powerful satellite and internet connection put together by Mark Leon and the NASA science internet engineering team.

Ames' artificial intelligence software guided the Deep Space 1 spacecraft, launched on 24 October 1998. It was the first mission under NASA's new Millenium program to test in spaceflight the many innovative technologies that will lead to truly "smart" spacecraft. One new technology was Ames' AutoNav remote agent that made the spacecraft capable of independent decision-making so that it relied less on tracking and remote control from the ground. In May 1999, for the first time, an artificial intelligence program was given primary control of a spacecraft. On 28 July 1999, after getting a brief instruction to flyby the asteroid 9969 Braille, the DS-1 remote agent evaluated the state of the aircraft, planned the best path by which to get there, and executed a flyby no more than ten miles from the asteroid.

The Ames CoE-IT, managerially, was increasingly integrated into the Ames information science and technology division as ways of applying this expertise became a more normal part of Ames' operations. Ames assumed oversight of the NASA Independent Verification and Validation Facility in Fairmount, West Virginia that independently tests and validates new software for space projects. Ames is applying its skills to test Shuttle avionics software, to make commercial software compatible with proprietary software already used in the Shuttle, and to create an integrated vehicle health management to further expedite Shuttle maintenance. Ames also applies its expertise to help NASA develop aerospace hardware quicker and cheaper, with less technical risk. Integrated design systems, for example, let engineers see and test a system before metal is ever cut. Ames information technologists have systems to translate, in real time, massive amounts of data into visual images and useful information. This has already proved useful in monitoring environmental changes—like fires, hurricanes and ozone holes—from space.

Harry McDonald especially encouraged everyone at Ames to inject intelligent systems and information technology into their work. Revolutionary computing—that is, computing with nanotechnology or neural networks—opens up new opportunities in intelligent flight controls. Ames is developing autonomous systems—essentially an array of sensors, robots, and artificial intelligence systems for non-human space exploration. And Ames information technologists still apply their expertise to solve the logistics and information problems of the airspace system.


***Ames has a long tradition of basic research on ways to fight pilot fatigue.***

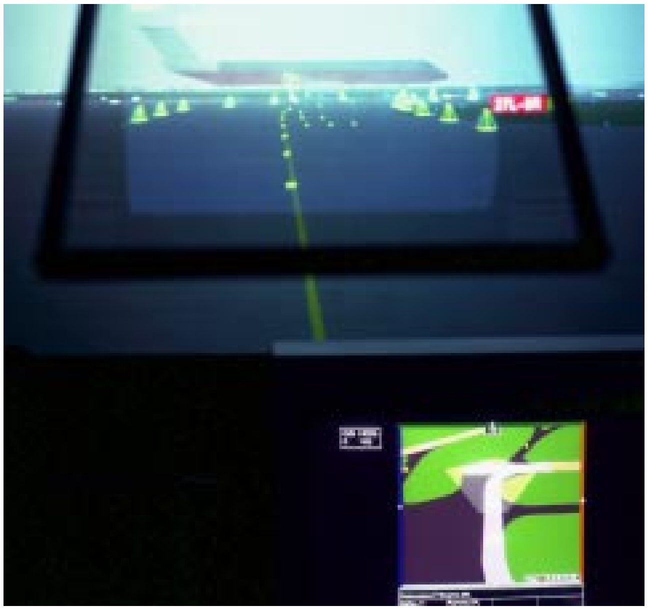
**Operation trials of the Ames Center TRACON Automation System installed in 1996 at Dallas/Fort Worth International Airport.**

### Lead Center Mission in Aerospace Operations Systems

Ames' collaboration with the Federal Aviation Administration (FAA) grew more vibrant in the 1990s. As the federal agency responsible for the national airspace system, the FAA often turns to Ames for technologies to infuse that system with greater safety, efficiency and timeliness. In November 1996, Ames announced a NASA/FAA integrated plan to focus the various facets of Ames' air traffic management research and technology. In June 1997, NASA announced a $450 million aviation system capacity program, with Ames as the lead center to make bold technological leaps forward in air traffic control.

Previously, Ames had focused on human factors in air traffic control and pilot workload. For example, a long running experiment by Curtis Graeber proved that short periods of rest dramatically improved pilot performance during long-haul international flights. Ames' aerospace human factors research division, in October 1993, installed a Boeing 747-400 simulator in its crew vehicle systems research facility (CVSRF). The cockpit simulator was identical to those used to train airline pilots, except that the new displays were reprogrammable and

**Heinz Erzberger displays the complicated algorithms he devised as part of Ames' work to improve air traffic safety.**



***Ames combined its expertise in graphics and air system safety to develop this system for pilots to visualize what's around them even in dense fog or heavy rain.***

stocked with equipment for collecting computer, audio and video data. "Our goal is to find ways to improve human capabilities using automation," said CVSRF manager Robert Shiner. Indeed, one of the first experiments evaluated how to replace voice communication between pilot and controller with a digital datalink.[19]

"Modern flight management systems in today's aircraft help pilots do their jobs much better. The CTAS program is about providing the same benefits to air traffic controllers," noted Heinz Erzberger, the Ames research scientist who conceived much of the technology.[20] Ames had been working on traffic control issues since the early 1970s, but they took their research into development with the advent of graphical computers. Programming started in 1991, in consort with the FAA and a team of contractors. In May 1997, Ames released its Center TRACON Automation System (CTAS), a suite of software that generates new types of information to "advise" air traffic controllers. The traffic management advisor picks up aircraft when they are still twenty minutes from landing, and develops an optimum plan for them all to land. The descent advisor graphically depicts the time and

***Ames' FutureFlight Central, dedicated in December 1999, is the world's most sophisticated facility for basic research on movement into and around airports.***

***The high bay of the crew vehicle systems research facility: to the front is the Boeing 747-400 cab and to the rear is the advanced cab flight simulator for basic human factors research on pilot workload.***

space relationships between incoming aircraft as they converge on an aerial gate forty miles from the airport. The final approach spacing tool lets controllers quickly make corrections to aircraft spacing as they approach the runway.

CTAS quickly proved its value in both time and cost savings at some of America's busiest airports. As quickly as May 1992, Ames installed the simplest version of CTAS at the Stapleton International Airport in Denver, then continued to refine the more complex parts. It passed a major test at the Dallas/Fort Worth International Airport in 1994.

Once aircraft are on the ground, a different set of advisors chime in. The surface movement advisor (SMA) is a simple client-server computer system that collects data so controllers can provide the airlines with automated data on when aircraft will arrive on the ground or at the gate. This relatively simple idea improved gate and crew scheduling, reduced voice traffic over radios, and got aircraft onto the ramp and into the air more quickly. From a go-ahead in March 1994, Ames got a rapid prototype of the SMA working and installed at the Hartsfield Atlanta International Airport in time for the 1996 Olympics. After eighteen months of operations, taxi-time reductions for all aircraft averaged one minute each. Delta Airlines calculated that SMA saves them $50,000 a day in fuel costs alone. The FAA is now exploring ways to make the SMA standard equipment at all airports.

Increasingly, the Ames approach used new information technologies to integrate air-based and ground-based traffic systems. Ames researchers explored unrestricted flight routing, or free flight, which allows more aircraft to safely share airspace under all weather conditions. Ames' advanced air transportation technology branch developed an integrated block-to-block planning service that allows each aircraft to choose its own

***From the control room of the crew vehicle systems research facility, Ames experts in human factors study how to improve pilot workloads.***

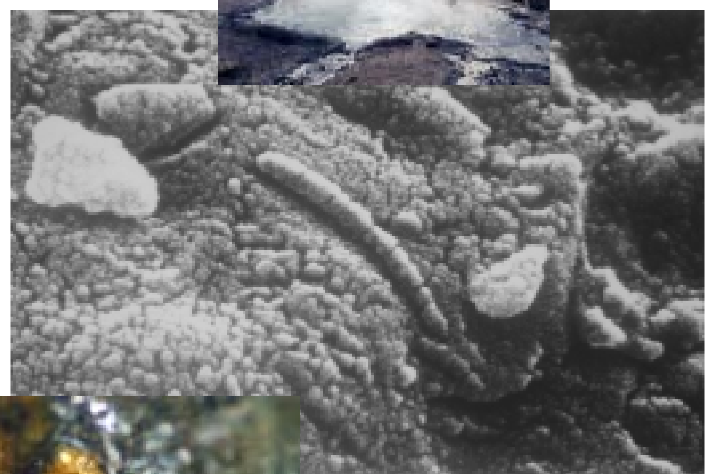
best flightpath, saving minutes of air time per trip and millions of dollars in aggregate.

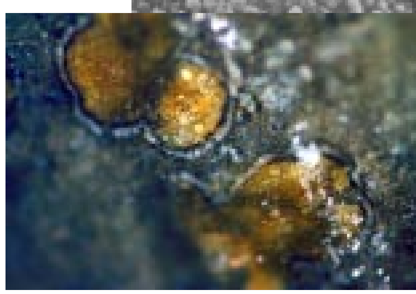
Another spectacular example of the application of information technology to solve safety issues is the Future Flight Central facility (FFC, though it was first named the surface development test facility). "Surface movement around airports," said Stanton Harke, manager of the Ames program, "is really the bottleneck to making the air transportation system more safe and efficient."[21] Originally conceived to test new versions of Ames' surface movement advisor, the Ames information technology staff saw ways to make something better, faster and cheaper. They used off-the-shelf video and the latest in Silicon Graphics imaging computers to provide a high resolution display with a 360 degree view out the window. Coupled with a sophisticated and changeable console design, for less than $10 million the FFC became the world's most sophisticated test facility for air and ground traffic control simulations. The FFC can be configured to look like the air traffic control tower of any of the world's major airports—both in the arrangement of modular equipment inside the tower and in the view out the window. By reprogramming the display, airport designers can see how well aircraft can move around a proposed airfield, and evaluate any technical innovations, or revise procedures, before concrete is poured.

***The reconfigurable cockpit interior of the advanced cab flight simulator.***

**Lake Hoare, Antarctica, and Beryl Spring, Yellowstone National Park.**

Ames also completed a system to automatically record and process huge amounts of real-time flight data from new aircraft. "We can detect accident precursors that we didn't know existed," said Richard Keller of his work on the FAA/NASA aviation safety reporting system. Alaska Airlines and United Airlines helped Ames demonstrate the recorder, beginning in 1998, and reported that the data returned could be used to not only improve safety, but also aircraft performance and maintenance scheduling.

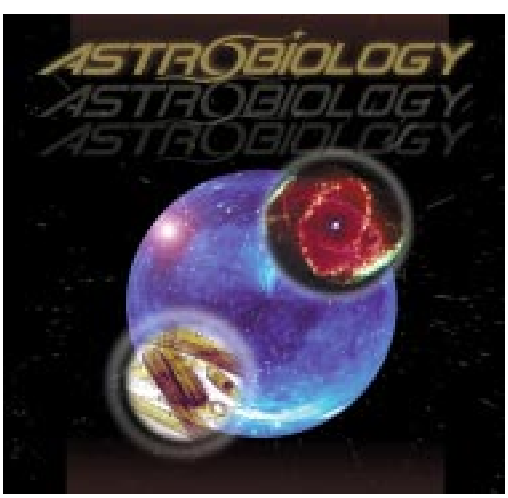




**Martian meteorite.**

### Astrobiology Program and Institute

In addition to its leadership in information technology and air traffic control, Ames accepted the lead center mission in astrobiology—defined as the multidisciplinary study of life in the universe. Astrobiology incorporated the issues early explored as exobiology—the origin of life within the context of evolving planetary systems, and how life evolved, specifically within Earth's harshest environments. Astrobiology also addresses the distribution of life, and how we might search for other biospheres in our solar system. It addresses the destiny of life, how life might adapt to environments beyond Earth, and how life might end as it may have on Mars or Venus. And it includes any scientific approach to these issues—observational, experimental and theoretical.



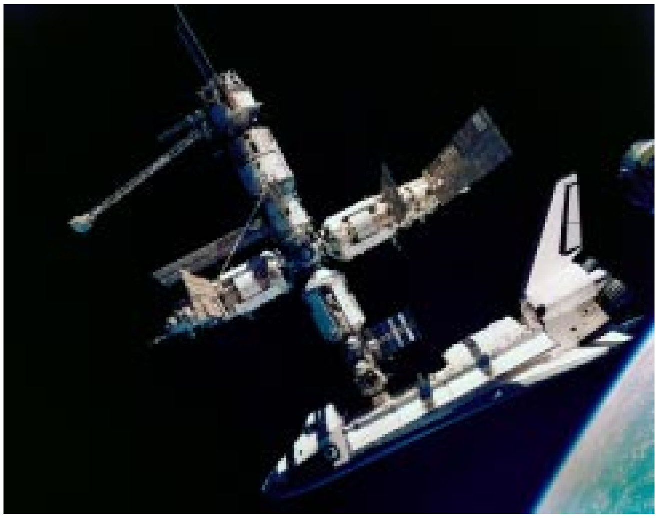

The term "astrobiology," as well as revolutionary plans to pursue it, were sparked to life in the intense pressure and complex chemistry of the primordial zero base review. The future of space science at Ames looked especially bleak, since Ames would likely get no

***Assembly of the International Space Station.***

new space missions to manage. NASA headquarters had decided that it could support only two centers pursuing space exploration missions—and that Goddard was best established in Earth orbit missions and JPL in planetary missions. NASA chief scientist France Cordova chaired discussions on the role of science within NASA, which were very sensitive to the excellent work done at Ames. She suggested—given the chronically, and now acutely, threatened status of the space, Earth, and life sciences at Ames—that those scientists be privatized outside of Ames in association with a local university.

The idea of a privatized institute, however, hit roadblocks. David Morrison and Scott Hubbard contributed to an agency-wide review, led by Al Diaz of NASA headquarters, of possible approaches to the institute form, but each encountered problems over how to move civil servants into a private institute. Congress balked at passing legislation that eased post-employment restrictions for NASA employees or allowed them to transfer their pensions. Without it, the universities balked at undertaking so big a task as that of integrating an entire research directorate with 600 civil servants and 1,000 support contractors. More important, the institute science plan lacked a cohesive vision. It would be called simply, the Institute for Space Research. In a continuing series of meetings to define a forward-looking agenda for this institute, NASA associate administrator for space science, Wesley Huntress, first suggested the term "astrobiology."

Exciting new scientific announcements in 1996 fueled interest in astrobiology—the discovery of new planets around other stars and hints of fossils in a meteorite from Mars. In August, data from the Ames-managed Galileo probe returned data on Jupiter's climate drivers. The Galileo orbiter returned photos that showed that Jupiter's moon Europa may harbor "warm ice" or even liquid water—both key elements in sustaining life. Goldin saw biology as a



***The Space Shuttle orbiter undocking from the space station Mir in April 1996. The Ames life sciences division designed many biological experiments that were transported to Mir's microgravity environment during these encounters.***

science with a future, and appreciated all that Ames had done to define the field. He named Ames as NASA's lead center in astrobiology, and tasked it to continue exploring ideas to promote collaboration with larger communities through an institute. The result was a "virtual" astrobiology institute led by Scott Hubbard as interim director.

The NASA Astrobiology Institute (NAI) is in essence creating a new discipline. Ames people created the disciplines of computational chemistry and computational fluid dynamics in the 1970s, driven by the need to theorize the experimental work they had begun. Based on that experience, they took a more deliberate approach to creating astrobiology. A series of astrobiology roadmap conferences identified the holes in the discipline they would need to fill, and established a "virtual" institute that linked universities and research organizations across the United States. In June 1998, the Institute director's office opened at Ames, and accepted competitive proposals to fund research projects. One of the eleven funded projects was from Ames, extending its tradition of research into organic astrochemistry, planetary habitability and early microbial evolution. Plans are to wire this virtual institute into a new and separate building at Ames, where researchers can come to use sophisticated laboratories that most directly support the government's interest in astrobiology—the quarantine and analysis of planetary samples, and mimicking the harsh vacuum, radiation and chemical environments of space. To recognize the major integrative role of astrobiology in Ames' future, in August 1999 McDonald renamed the Ames directorate overseeing all space, earth and life sciences to the astrobiology and space research directorate.

***Gabriel Meeker examines her crop in the Ames gravitational biology facility.***

McDonald decided that the Institute should be led by a scientist with a world-wide reputation as sterling as what the Institute intended to accomplish. In May 1999 the

***Dan Goldin and Harry McDonald introduced Barry Blumberg.***

Institute announced that its new director would be Baruch S. Blumberg, who shared the 1976 Nobel prize in physiology and medicine for his work on the origins of infectious diseases that led to the discovery of the hepatitis B virus and discovery of the HBV vaccine. Blumberg would be the first Nobel laureate ever employed by NASA. Goldin turned Blumberg's appointment into an opportunity to make a major address on NASA's vision of exploration, and capped the day by signing an agreement between NASA and SGI, Inc. on a long-term plan to develop new supercomputers. Goldin exclaimed: "It doesn't get much better than this."[22]

### *Lead Center for Gravitational Biology and Ecology*

Likewise, NASA headquarters named Ames its lead center for gravitational biology and ecology to recognize its reputation in life science payloads. Though it appears to be "small science," compared with the "big science" of most other NASA projects, gravitational biology is very management-intensive. Microgravity can only be sustained in space, where it is expensive to send living things. If a space-borne animal is to be sacrificed, every tissue from its body will be studied for microgravity effects. Careful management is needed at every step: to select the experiments from hundreds of proposals; to oversee the very precise construction of habitats and biosensors; to ensure that tissues are carefully prepared and distributed equitably around the

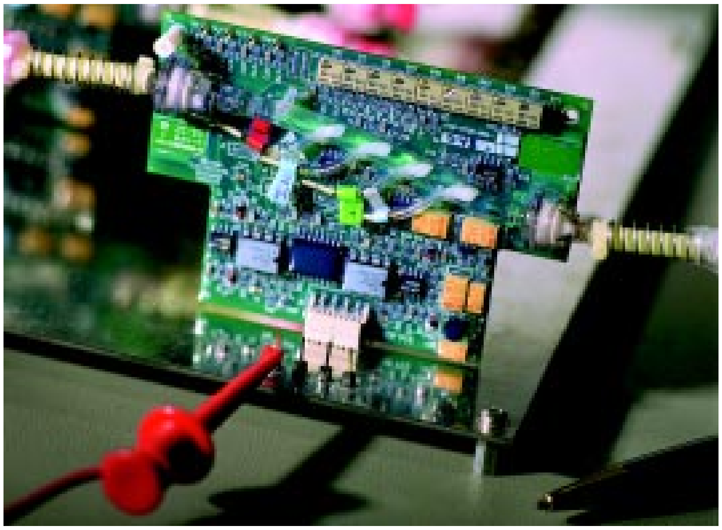
***Simulated microgravity test for the Space Station gravitational biology research facility.***

***The research animal housing facility being prepared at Ames for Neurolab.***

world; to involve every interested biologist in reviewing the data; and to make sure the results are repeatable from flight to flight with very small numbers of subjects.

In the mid-1990s, Ames' work in gravitational biology shifted to the Shuttle/Mir program. These experiments continued the collaboration begun with the Cosmos/Bion missions (which NASA cancelled in 1997) and preceded the biological research to be done on the International Space Station. From June 1995 to January 1998, Ames managed several experiments transferred during the eleven dockings between the Shuttle and the Russian Mir space station. For the first time, a complete life cycle (seed-to-seed) of plants was lived in space. Desert beetles, previously flown on Cosmos/Bion flights, demonstrated the effects of extended space travel on the body's internal clock. Ames researchers swapped tissue cultures with their Russian counterparts, gave the Russians a strain of wheat to grow aboard Mir, and supplied cardiac monitors and bone measuring devices for Mir cosmonauts. Meanwhile, Ames flew a number of experiments collaboratively with the European Space Agency using its Biorack hardware.

Neurolab was NASA's primary contribution to the "Decade of the Brain," as Congress declared the 1990s. The Neurolab mission was launched on 16 April 1998 for 17 days aboard STS 90 and included a variety of experiments to explore neurological and behavioral changes in space. The laboratory contained a



***The Biona C—a miniature, computerized blood analyzer developed by Ames' Sensors 2000! program.***

An experiment package to study zebrafish in microgravity is tested in the Ames aquatic centrifuge.


variety of organisms—crickets, fish, mice and rats, as well as monitors for the Shuttle astronauts. Neurolab was one of the most complex missions ever flown in the NASA life sciences. All the non-human experiments—15 of the 26 total experiments—were managed by Ames. In addition, Muriel Ross designed one of the experiments—her third experiment on a Spacelab mission—which led to exciting new reinterpretations of neural plasticity in space. Neurolab was to be the last life sciences mission NASA planned to launch—Shuttle flights would focus on construction of the space station—until the opening of the space station itself.

The space station biological research facility (SSBRF) someday will be the world's first complete laboratory for biological research in microgravity. Ames began designing the SSBRF in the late 1980s as a major scientific module for the International Space Station, though the SSBRF module has been redesigned as often as the space station itself. Meanwhile, the Ames SSBRF project team, led by John Givens, continued to test and perfect the research tools and scientific plans for the facility. A centrifuge measuring 2.5 meters in diameter rotates at selectable rates from 0.01 g forces to 2 g forces, allowing for experiments or experimental controls in artificial gravity. A set of self-contained habitats—with the entire environment remotely monitored from Ames or aboard the space station—will completely support a variety of life forms: rats and mice, insects, plants, small fresh water and marine organisms, avian eggs, and one-celled organisms. A glove box will allow two biologists to perform dissections, transfer samples, and conduct photomicroscopy while keeping the biological samples immobilized and isolated from the rest of the space station. Flash freezers will preserve samples for return to Earth. And a sophisticated data collection system will telemeter data back to scientists at Ames, who will then convey it to university biologists around the world. Ames continues to solicit proposals for experiments from collaborating biologists, so that the experiments run on the SSBRF will study the effects of microgravity on virtually every physiological system. All together, Ames is applying its expertise to enable human exploration of space by understanding a major force—gravity—that differentiates life on Earth from life in space.

### Lead Center for Rotorcraft Research and Technology Base

When NASA headquarters transferred other Ames aircraft to Dryden, the Army aeroflightdynamics directorate insisted that its research helicopters should stay at Ames. After several years of negotiation, in July 1997 NASA headquarters signed a directive that Ames would continue to support the Army's rotorcraft airworthiness research using three helicopters. One UH-60 Blackhawk configured as the RASCAL (Rotorcraft Aircrew Systems Concepts Airborne Laboratory) remained as the focus for advanced controls. The NASA/Army rotorcraft division, led by Edwin Aiken, used it to develop programmable, fly-by-wire controls for nap-of-the-earth maneuvering. Another UH-60 Blackhawk was rigged for air loads tests, and an AH-1 Cobra was configured as the Flying Laboratory for Integrated Test and Evaluation (FLITE). In addition, the rotorcraft division made good use of the refurbished wind tunnels. For example, Stephen Jacklin led load and efficiency tests in the 40 by 80 foot wind tunnel of the advanced rotor hub, without hinges and bearings, designed by McDonnell Douglas for its new generation of helicopters.

### FASTER, BETTER, CHEAPER

Even in areas where other NASA Centers provided management, Ames has been named leader of specific, important projects. Ames had the history, capability, and people for doing things faster, better, and cheaper. The Pioneer series of space probes, launched in the early 1970s, stand as the best examples of this tradition. This tradition combined well with its ability to craft cooperative arrangements with private firms and other research organizations. Three projects especially demonstrate this capability—Lunar Prospector, the X-36 and SOFIA.

### *Lunar Prospector*

Goldin launched NASA's Discovery Program in 1992 to fund highly focused missions with lower costs, shorter timelines, and less risk, by giving the science investigation teams a great deal of freedom. Discovery series projects were meant to reinvigorate the space sciences, which had dwindled as NASA funded Shuttle projects, and to spark public enthusiasm for the continued exploration of space. Discovery mission hardware should be built in less than 36 months, and cost less than $150 million ($250 million including launch costs). Ames' Lunar Prospector was the first competitively selected mission funded under the Discovery Program.

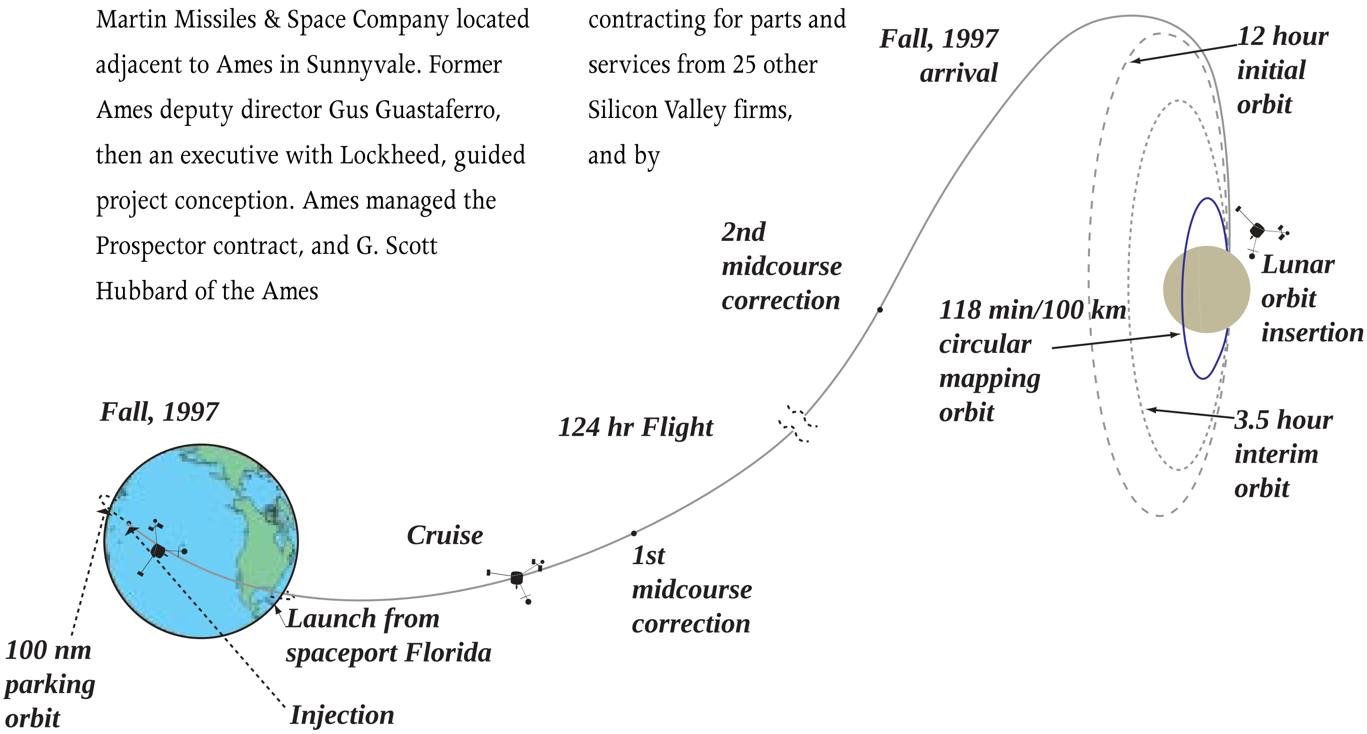
In the 25 years since Apollo, only a few spacecraft have flown by the Moon, and only one had a lengthy encounter. The Clementine spacecraft, built by the U.S. Department of Defense (with scientific management from NASA) to image the lunar surface, orbited the Moon for two months in 1994 in an elliptical orbit no closer than 250 miles to the surface of the Moon. Clementine returned radar signatures that provided indirect evidence of ice crystals at the lunar south pole. Since Apollo era samples showed the lunar regolith to be bone dry, scientists suggested that water was transported to the Moon on comets and asteroids, which created deep craters with permanent shadows that shielded the ice from the Sun's heat.

**_Lunar Prospector prototype in the Ames Space Projects Facility._**

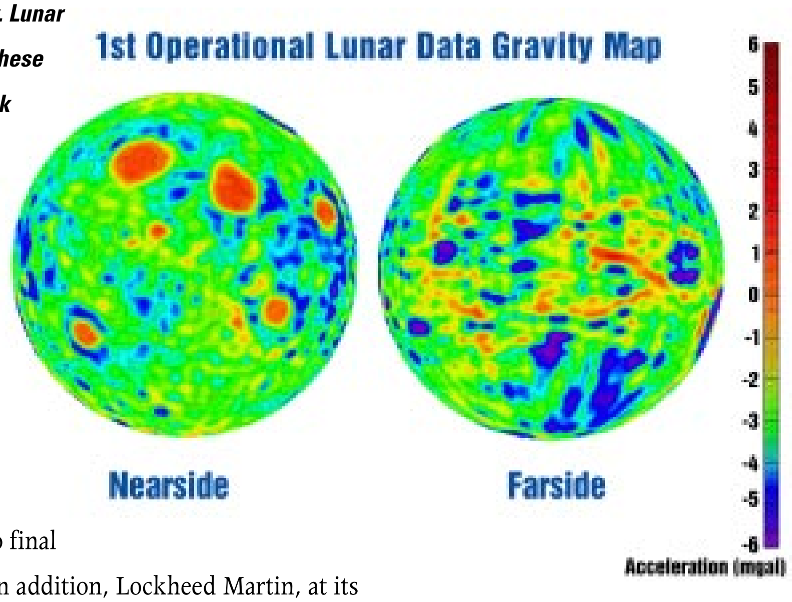
Spurred by these results, Ames developed plans for a spacecraft to lead NASA's

**Scott Hubbard, NASA mission manager for the Lunar Prospector.**

rediscovery of the Moon. Called the Lunar Prospector, it would orbit the Moon for a year, in circular orbit at an altitude of about 60 miles. The idea for the Lunar Prospector was initiated at the Lockheed Martin Missiles & Space Company located adjacent to Ames in Sunnyvale. Former Ames deputy director Gus Guastaferro, then an executive with Lockheed, guided project conception. Ames managed the Prospector contract, and G. Scott Hubbard of the Ames space projects division led all Prospector efforts as the NASA mission manager. The principal investigator was Alan Binder at Lockheed; Tom Daugherty led the team at Lockheed that designed and built the Prospector. (After launch, Binder moved to the Lunar Research Institute of Gilroy, California, to await return of data.) William Feldman of the Los Alamos National Laboratory led the design of three key instruments and the Hewlett-Packard Company built a custom test system using off-the-shelf components. By contracting for parts and services from 25 other Silicon Valley firms, and by



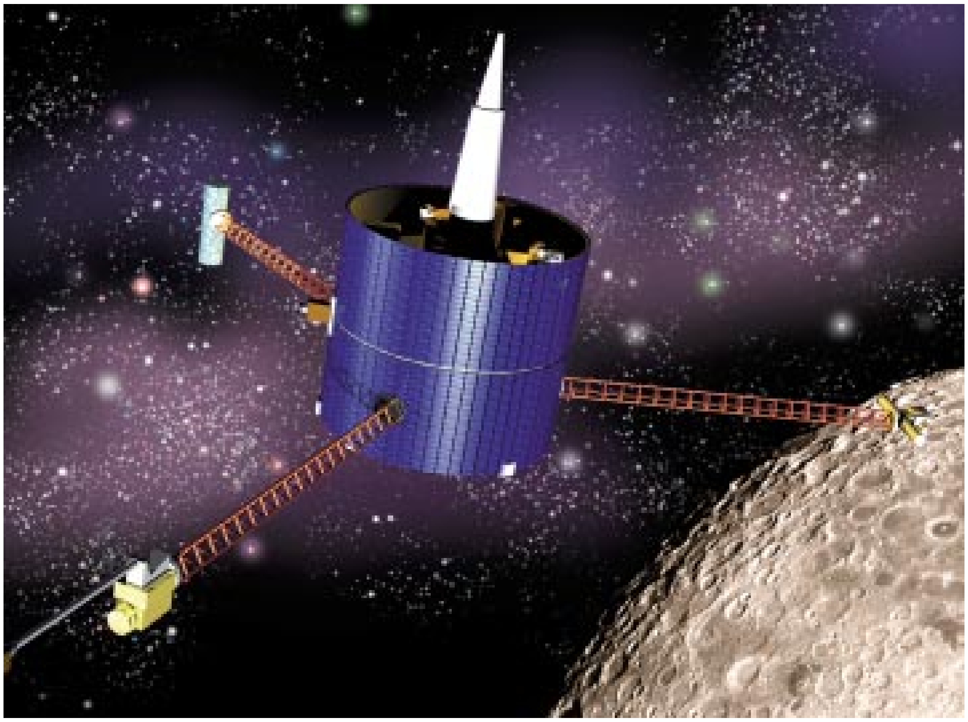
*The first operational maps of lunar gravity. Lunar Prospector's Doppler gravity experiment painted these portraits of the near and far sides of the Moon. Peak gravitation is shown in red and valleys in blue.*




designing Prospector as a simple spin-stabilized cylinder just 4.6 feet in diameter and 4.1 feet in length, Lockheed took the spacecraft and mission from go-ahead to final test in only 22 months. In addition, Lockheed Martin, at its facility in Colorado, built the Athena launch vehicle which was used for its first time to send Prospector skyward. The total cost to NASA for the mission, including launch, was $63 million. "Prospector has served as a model for new ways of doing business," said Hubbard. "This mission has made history in terms of management style, technical approach, cost management and focused science."[23]

Throughout 1997, Ames built a Prospector mission control room from the operations center that had so long served the Pioneer spacecraft. Mission controllers inserted the Prospector into lunar orbit on 11 January 1998 carrying five science instruments. A gamma ray spectrometer remotely mapped the chemical composition of the lunar surface, measuring concentrations of such elements as uranium, titanium, potassium, iron and oxygen. An alpha particle spectrometer looked for outgassing events that suggested tectonic or volcanic activity. A magnetometer and electron reflectometer probed the lunar magnetic fields for clues about the Moon's core. The doppler gravity experiment, managed by Alex Konoplic of JPL, returned the first lunar gravity map with operational specificity. And a neutron spectroscope, the first ever used in planetary exploration, detected energy flux emanating from the lunar regolith. Hydrogen has a unique neutron signature that is indicative of water ice at higher concentrations. Prospector

**Lunar Prospector in orbit around the Moon (artist conception).**



returned the first direct measurement of high hydrogen levels at the lunar poles, which Ames scientists believe can only be explained as the presence of water ice.

Ames held a press conference on 5 March 1998 to announce the first science results from Lunar Prospector, only seven weeks after it entered lunar orbit. The indication of water ice embedded in the permanently shadowed craters at the lunar poles made headlines around the world. Future lunar explorers could extract this water for life support or as a source of oxygen and hydrogen fuel. Rough estimates showed up to six billion metric tons of water mixed in fairly low concentrations. After its first year in orbit at sixty miles, Prospector was instructed to swoop down as low as twenty miles to map the Moon at even greater detail. Ames scientists then refined their scientific data and their estimates of water volumes. Mission controllers instructed the Prospector—its fuel now exhausted, its design life far exceeded, and after its 6,800 lunar orbits compiled a complete set of data—to crash into a crater at the lunar South pole on 31 July 1999. Although the impact kicked up no debris visible by ground-based telescopes, NASA scientists using space-based telescopes continued to look for signs of vapor that they could analyze for further evidence of water ice.

### NASA/Boeing X-36 Tailless Fighter Agility Research Aircraft

The X-36 proved, with dramatic efficiency, the concept of the tailless fighter. It was conceived in 1989 by researchers at Ames' military technology branch and McDonnell Douglas' Phantom Works in St. Louis (now part of Boeing). It embodied the results of a decade of Ames research into tailless fighters—using wind tunnels, simulators, supercomputers and flight controls. The X-36 lacks vertical and horizontal tails. Instead,


it gets directional stability and flight control through a split aileron and engine thrust vectoring. This innovative design should reduce weight, drag and radar signature and increase the range, maneuverability and survivability of future fighter aircraft.

Rather than build a full-scale piloted prototype, the Ames/Boeing team built a 28 percent scale remotely piloted model. Two X-36 prototypes rolled out in May 1996, only 28 months after go-ahead, at a total project cost of $21 million shared between Ames and Boeing. Each aircraft was 18 feet long, 3 feet high, had a 10-foot wingspan, and weighed 1,250 pounds. They were fully powered by turbofan engines providing 700 pounds of thrust, and flown by a pilot sitting in a ground-station cockpit, complete with a head-up display. By keeping a pilot in the loop, Ames eliminated the expense of complex, autonomous flight controls.

"When we saw this airplane lift off," exclaimed Rod Bailey, the X-36 program manager, "we saw the shape of airplanes to come."[24] Between May and November 1997, the X-36 prototypes flew 31 flights, for over 15 hours, in only 25 weeks. Four different versions of flight control software were tried out. The X-36 reached an altitude of


***The remotely piloted X-36 tailless jet fighter test bed in flight over southern California's Mojave Desert.***

20,200 feet, and a maximum angle of attack of 40 degrees. The flight tests clearly demonstrated the feasibility of tailless fighters, and showed that they could possess agility far superior to that of today's best fighters.

### SOFIA (Stratospheric Observatory for Infrared Astronomy)

SOFIA is the newest generation of airborne infrared observatories—in the tradition of the Kuiper Airborne Observatory, but built from a Boeing 747 and carrying a telescope 2.5 times stronger. Teams of astronomers will be able to observe the radiant heat patterns of space from the cold dark fringes of Earth's atmosphere. At its cruising altitude of 41,000 feet, SOFIA will fly above 99 percent of Earth's obscuring water vapor. Observations impossible for even the largest and highest ground-based telescopes will help answer questions about the birth of stars, the formation of solar systems, the origins of complex molecules in space, the evolution of comets, and the nature of black holes.

Planning for the SOFIA began a decade earlier when the Kuiper was the world's only airborne observatory. Edwin Erickson first nurtured plans to supersede the Kuiper with a bigger and more capable aircraft. Ames space scientists, led by James Murphy, also conceived and developed plans for the liquid helium-cooled Space Infrared Telescope Facility (SIRTF)—the infrared component of NASA's series of great spaceborne observatories. A unique technology group sprang up, led by Craig McCreight and Peter Kittel, to develop low noise

**Model of the SOFIA undergoing tests in the 14 foot wind tunnel.**

**_SOFIA during configuration test flights in March 1998._**


detectors for SIRTF. When NASA headquarters moved SIRTF management to JPL in 1991, McCreight and Kittel continued their work and Ames revised plans for the SOFIA to complement SIRTF capabilities. Ames aerodynamicists designed and tested ideas for the open air telescope port. During a major upgrade of the information systems for the Kuiper, completed in December 1991, Ames refined the computing and data collection equipment that would be included on the SOFIA. For the next five years, Ames struggled to get funding approved by headquarters and Congress as they reshaped the institutional structure to support SOFIA.

In December 1996, David Morrison, Ames' director of space, announced that Ames had awarded the $480 million SOFIA prime contract to USRA (Universities Space Research Association) of Columbia, Maryland, a private nonprofit corporation with eighty universities as institutional members. USRA was formed in 1970 under the auspices of the National Academy of Sciences to provide a mechanism for collaboration in space exploration. USRA has overall project management, and will later lead scientific operations. The SOFIA contract was a new type of contract—performance based and with full-cost accounting. Unlike previous contracts which specified the resources and personnel a contractor would devote to a project, Ames' contract for the SOFIA specified only the scientific work USRA must accomplish.

"The SOFIA program is a stellar example of NASA's new way of doing business," exclaimed Goldin, "We have taken the parts of a space science program that the private sector can do better and more cost effectively than the government, and had a competitive selection for the privilege of performing those duties."[25]

Modifications to the SOFIA Boeing 747 began in 1998 at Raytheon E-Systems of Waco, Texas, where the aircraft's open cavity was engineered and special equipment installed. Raytheon's lead subcontractor for communication and control software is the scientific systems division of Sterling

***Ames has always had world-class machine shops, where skilled workers can make intricate and reliable sensors or large panels of innovative composite materials. Here an aircraft part is being machined and mounted on a horizontal boring mill.***

Software, which brings years of experience in designing and operating computers for the Kuiper. The infrared telescope, 98 inches in diameter, was designed and built by a consortium of Germany's leading aerospace companies—Keyser-Threde GmbH and MAN Technology—managed by the German space agency. Specialized instruments, about 15 per year, will be built by scientists from Ames, the University of California, and other universities. SOFIA's education and outreach program will be conducted in alliance with the Astronomical Society of the Pacific and the SETI Institute. When SOFIA goes operational in 2001, United Airlines will operate and maintain the SOFIA aircraft, which once flew passengers as part of United's fleet. United will train pilots to fly the SOFIA, and will maintain it at its airline hangars in San Francisco or around the world as needed. USRA intends for the SOFIA to make about 160 flights per year of about eight hours each, and base it at Moffett Federal Airfield.

## PROCLAIMING THE AMES APPROACH

The success of Ames within the organizational culture of the new NASA was no accident. The Ames way of doing things always involved collaborative research, empowering scientists and engineers, doing things cheaper, getting your hands dirty, and working quickly. As NASA reshaped itself, it looked to Ames and to the leadership style of Harry McDonald as a model of how to do things right. Ames people were called upon to proclaim the reasons for their success, and they looked to their history.

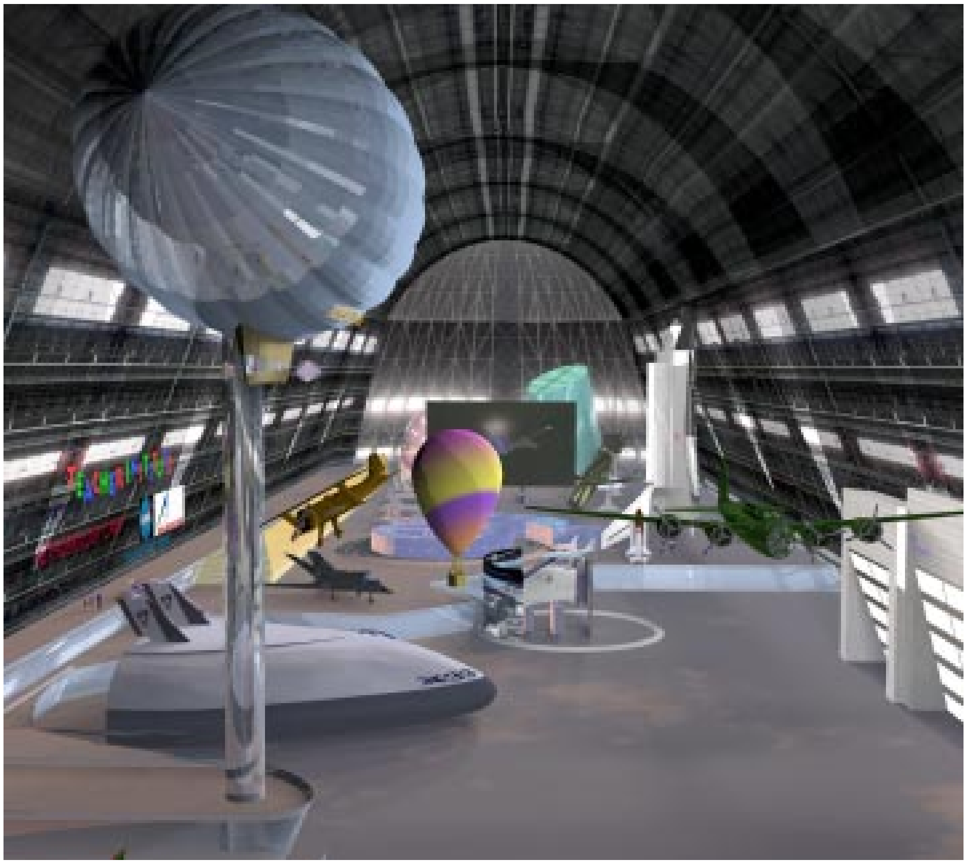
The history of Ames Research Center is reflected in the projects it does and the way it organizes its scientific and technical expertise. The history of Ames is also built into the place. The almost constant whirls and rushes sound out that Ames still operates, as it has for most of its sixty years, the world's greatest collection of wind tunnels. When the update of the Unitary plan tunnels is completed in 2000, all the major Ames simulation facilities will be able to meet the challenges of a new century.


***Bill Berry and Rick Serrano, in August 1999, raising the flag that proclaims Ames is ISO 9001 certified for meeting the highest standards of quality and customer satisfaction.***

Take a walk around Perimeter Road and see the sun glisten off the big vacuum balls, the vast welcoming sky above the Moffett field runways, and the huge mouth of the 80 by 120 foot wind tunnel ready to gulp air in service of ever-better helicopters. Peek into the high bays, where bustling teams of engineers, programmers, scientists, and human factors specialists build simulators to prove, again, that women and men can always go where they have never gone before if they just think through the trip. Stand at the broad doorways to the shops where skilled machinists craft models of aircraft just conceived, and lace them with incredibly sensitive instruments, while surrounded by racks bulging with the models and parts of the great aircraft and instruments of the past. It's been said that Silicon Valley happened here, because here you could get one of absolutely anything made. That quiet spirit of craftsmanship still thrives around Ames.

See the biologists huddled over sophisticated boxes that will let new generations of tiny ambassadors of earthly flora and fauna grow in space. Follow the glow of screens illuminating the young programmers driving computers ever further and faster. Wander about the library shelves bulging with the reports making even Ames' most abstract theories accessible to all. Glance up at the portraits of Joseph Ames, Smitty DeFrance, and the select members of Ames Hall of Fame, reminding all who enter that, above all, what its history has built into Ames is a respect for all who labor there.

Ames undertook ISO 9001 certification as a chance to align its tradition of excellence with the international standard for quality management. In June 1996, Ames' deputy director William Berry saw how certification benefited work at Great Britain's closest analog to Ames, the Defense Evaluation and Research Agency. When Goldin asked all Centers to fold their Total Quality Management into the broader and better-defined ISO 9001 process, the Ames aeronautical test and simulation division had already begun testing the implementation plan devised for Ames. By 1998, all of Ames embraced the ISO 9001 process as a chance to demonstrate categorically the quality they had so long, and often so quietly, provided to those they



***The proposed California Air and Space Center.***

served. In April 1999, after an intense review, Ames was ISO certified "without condition," a rare achievement. "When Ames needs to step up we can show superior management process," noted Harry McDonald. "We just don't want too much managerial process."[26]

Ames people started seeing Moffett Field less as a burden, and more as the physical endowment on which to build the Center of their dreams. With leadership from McDonald, Berry and Michael Marlaire, Ames' director of external affairs, Ames people began to view Moffett Field not as a problem to be managed or a collection of historical artifacts from another era of science and technology. Instead, they came to view the Moffett land as a once-in-a-lifetime opportunity—as a large, still-underdeveloped piece of land at the epicenter of the world's most dynamic industrial region. "Our Center's traditional agenda and structure were becoming fundamentally unstable because of the change in the world around us," noted Berry. "Today, no one would build huge wind tunnels here, on land this expensive, and where labor costs are so high. Nor would they surround a major research center with a fence."[27] The San Francisco Bay Area is the most prosperous metropolitan area in the nation. It is the nation's third leading exporter overall, producing more than one-fourth of America's high tech exports. A fifth of the 100 fastest growing global companies are located there—including most of the leaders in computing, communications and biotechnology that collaborate closely with Ames. For Ames to continue to flourish, to advance knowledge, and to contribute to the national well-being, the Center's leadership realized it must be firmly rooted in that community. They explored ways to use this endowment of land to bolster that connection.

Throughout 1998 Ames hashed out the details of a bold new development plan. The Ames portion of the base will remain fenced and operate as before. The airfield will remain intact though quiet. Then in the old Navy portion of the base there will emerge a new complex of research buildings. Stanford University needs research facilities and the University of California at Santa Cruz needs space for extension education. So these universities will help develop the land—perhaps into something akin to the Stanford Research Park—while Ames will control the improvements. The universities will also bring in industrial partners and, perhaps in the coming decades, take a larger role in managing the research done at Ames. "Reimbursable" Space Act tenants—mostly start-up companies helping to transfer NASA technology, will pay Ames for supporting the

***NASA Ames Research Center senior staff in January 1998: (standing, left to right) Kenneth M. Ford, associate director for information technology; Jana M. Coleman, director of Center operations; Robert Rosen, associate director for aerospace programs; Lewis S.G. Braxton III, chief financial officer; Robert J. Hansen, deputy director for research; David Morrison, director of space; Nancy J. Bingham, assistant director for strategic planning; (seated, left to right) Steven F. Zornetzer, director of information systems; Harry McDonald, director; William E. Berry, deputy director; John W. Boyd, executive assistant to the director.***

***At the September 1997 Ames Community Day and Open House, Ken Souza of the Ames life sciences division explains the need for spacesuits like those designed at Ames. More than 220,000 people—young and old—stood fascinated by the technology displays.***

infrastructure of the complex. The focal point will be the California Air and Space Center, a science education facility the size of Hangar One. Five acres were set aside for The Computer History Museum. The south gate will be reopened to allow easy, uncontrolled public access to an open campus.

Ames held its first open house community day on 20 September 1997. Thousands were expected; nearly a quarter million of Ames' closest friends streamed in. Ames displayed its latest technology at 17 sites around the Center, including demonstrations of the Mars rover and many of its wind tunnels. "Partnership" unified the 150 exhibits inside Hangar One, where local schools, companies, federal agencies, and community organizations bragged about all they had accomplished by working with Ames. Over 1,300 Ames ambassadors helped the crowd, describing the science behind the dazzling displays. "We all witnessed actions so extraordinary," effused Lynn Harper, who coordinated the space sciences exhibits, "that we thought we'd burst with pride."[28] As David Morse and Donald James, the Ames external affairs co-chairs who so quickly organized the open house, walked around to check on things, people applauded.

Morale at Ames had sunk low in recent years—budget cuts by Congress, the transfer of programs to other Centers, neglect and scolding from headquarters, and a lack of technical leadership within Ames. Most Ames people thought they had nothing to show the public but relics of its past. As they caught glimpses of the public interest in the open house, however, enthusiasm grew. Two weeks before the event it seemed like half the people at Ames were working on it. With the extraordinary turnout, employee morale skyrocketed and has risen steadily since. The open house displays and demonstrations let Ames shed the trappings of its past and embrace its future by declaring—loudly, visibly and harmoniously—how it was stepping up to its mission responsibilities in information technology, astrobiology and aviation capacity and safety. This time Dan Goldin, who had inspired the event after he met with local leaders six months before, had to compose himself as he welcomed the throngs so fervently interested in all Ames had contributed to its community. Ames director Harry McDonald reflected:

"September 20, 1997 was truly a momentous day in the life of Ames Research Center—a day when we made history and recast the course of our future. Together, as we transform this incredible Center, we are reinventing ourselves in the process. The sense of excitement is obvious and evident everywhere. Our workforce has a new sense of pride. A better, more robust Ames will be our legacy; effecting the transformation is our reward. Community Day did not initiate this process. But, as we look back, it will always stand as the most visible signpost on the historic pathway of change, and the point from which all future progress will be measured. Collectively, we have changed both the perception and reality of Ames."[29]