On the Creation of ICASE: A Personal Retrospective View

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This talk is dedicated to Linda Johnson, Emily Todd, Etta Blair and the rest of the ICASE administrative staff that diligently contributed so much to the success of the institute.

For the past 25 years ICASE has been one of the very few places where one could engage in "strategic" research—the type of scientific inquiry which has all the attributes of basic research but which has an application horizon in the not-very-far future. As a result ICASE has left its mark in many areas of aero-space applications.

Saul Abarbanel, June 1997(private communication)

Abstract

The creation of ICASE and the emergence of Computational Fluid Dynamics during the late 1960's to early 1970's and its impact on NASA research are examined by one present at the creation.

Introduction

This workshop is primarily focused on the future. I find the future hard to predict and would like for you to indulge me while I look at the past, specifically at the creation of the Institute for Computer Applications in Science and Engineering, ICASE. ICASE was established with the primary objective of performing research in applied mathematics, numerical analysis, and applied computer science with particular emphasis on application areas of interest to the NASA Langley Research Center. The mechanisms envisioned for performing such research were through visiting appointments of leading university researchers in these fields, postdoctoral fellowships, and term appointments of younger scientists with no other affiliations. Appointees, whose training was primarily in mathematics and computer science, were encouraged to work in close collaboration with NASA scientists and engineers on problems of mutual interest. At the time, 1972, this was a classic example of *thinking outside the box* that required an understanding of both the weaknesses of the Center and the impending computational revolution.

To understand the forces that led to the creation of the institute we need to step back and look at the emerging science of computational fluid dynamics and the challenges that NASA faced in the late '60s early '70s.

The late 60's early 70's

Fifty years ago, in 1968 while at the Polytechnic Institute of Brooklyn, I had completed a code to solve the Navier-Stokes equations over a supersonic blunt body using the Lax-Wendroff scheme. The results were presented at the AIAA winter meeting in New York in 1969. In April of that same year, Bob MacCormack, working at NASA Ames, presented his two step variant of the Lax-Wendroff scheme that avoided calculating the Jacobians. Anyone that has programmed the Lax-Wendroff scheme knows what a significant improvement this was. I immediately proceeded to rewrite my code with the MacCormack variation.

At the same time, Julian Cole, see Fig.1, on sabbatical from UCLA, and Earll Murman, working at the Boeing Scientific Research Lab discovered the need for upwind differencing to solve the steady transonic small disturbance equation. Their results were published in 1970.

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[1] ICASE Director, 1996-2002.

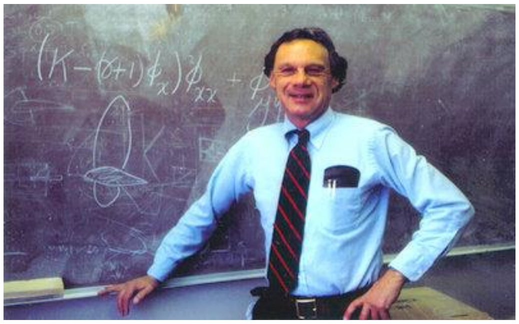

Figure 1. Julian Cole on his last visit to ICASE, late ‘90s.

Looking at NASA, we recall that the first moon landing took place in July 1969 and it was followed by 5 other landings, the last one in December 1972, so that by 1972 the Apollo program was coming to an end. It was to be followed by the development of a spaceplane, the Space Shuttle. Funding at NASA was coming down from its high levels of 1965-1966, but was still substantial, see Fig.2.

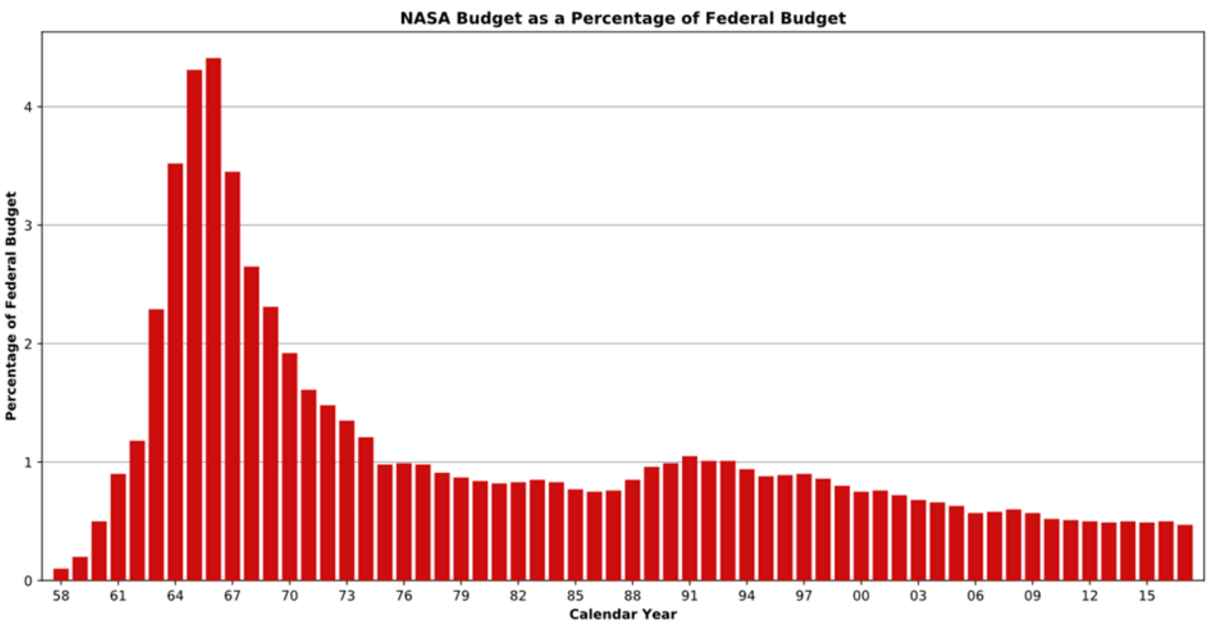

Figure 2. NASA’s budget as a percentage of the federal budget from 1958 to 2017.

In 1972 NASA Langley awarded a contract to Grumman Aerospace to develop a code to study the flow field around the Space Shuttle. I joined Grumman to work on this code with Frank Marconi. A few feet away from my desk at Grumman, Antony Jameson was working on a code to solve the steady full potential equation for transonic flows. Nearby, David Korn was also working on transonic flows using the method of complex characteristics. David would move to Bell Labs to develop the Korn shell in the early 80’s. Soon after I joined Grumman, North American Rockwell, who had been competing with Grumman to develop the Space Shuttle, was awarded the contract. The first Space Shuttle, The Enterprise, rolled out in September 1976.

By 1973 I realized that, with the loss of the Shuttle contract and no prospects beyond the Navy’s F14 Tomcat, Grumman was in the decline. I decided to join NASA Langley.

During the period of 1969 to 1971, NASA Ames faced the threat of closure and reduction in force. This has been a common theme throughout the years post the Apollo program for the three NASA aeronautics research centers. In response to this threat, Hans Mark, the newly appointed Ames Director, began to take steps to strengthen the viability of the Center. Together with Dean Chapman, Director of Astronautics, and Harvard Lomax, Chief of the Theoretical Branch within the Thermo- and Gas- Dynamics Division, began to strategize on a dominant role for Ames in the emergent field of CFD. So in 1970, the Theoretical Branch was renamed the CFD Branch, Harvard Lomax was appointed Branch Chief and Bob MacCormack was recruited from the Hypersonic Free-Flight Branch as his assistant. Those two, plus two graduate students, were the sum total of CFD research at Ames in 1970[2]. A strong recruitment effort was initiated to augment their ranks. In 1969, Ames had the weakest computer facility of the Agency consisting of a 1960 era IBM 7090 (by contrast Langley had 5 CDC 6600s). When an Air Force IBM 360-67 was about to be declared surplus, Mark was knocking at their doors to have the computer moved to Ames. Similarly a CDC 7600, also an Air Force surplus, was moved to Ames.

In 1970 the Advanced Research Projects Agency (ARPA), now known as DARPA, and the University of Illinois, were developing a new massively parallel supercomputer, the Illiac, with a theoretical peak performance rate of 200 mflops. The original plan was for the Illiac to be located and operated from the university. But as student unrest over the Vietnam War grew during the late ‘60s early ‘70s, ARPA became increasingly nervous about locating the Illiac at the university. The atmosphere of unrest and the very real threat that students represented at the time is discussed by Peter Lax in the article *The Mathematicians Who Ended the Kidnapping of an N.Y.U. Computer*[3]. Mark again acted decidedly and promised protection for the Illiac at Ames. The Illiac IV arrived at Ames in the summer of 1972. With the arrival of the Illiac, Ames had established itself as the leading NASA center in CFD research.

In September of 1970, NASA Langley went through a painful restructuring by Edgar Cortright who had been appointed Center Director in May of 1968. The appointment of Cortright and the restructuring of the Center were two of the many pieces that had to fall into place for the creation of ICASE. The new organization replaced an informal and obscure organization maintained by the previous Director, Floyd Thompson, whose organization philosophy was to make *“it hard for outsiders to know exactly what was going on inside the laboratory, thereby making it harder for them to exploit or manipulate its resources”*[4]. The new organization consisted of four research directorates. One was the Electronics Directorate under which resided the Analysis and Computation Division (the Division mentioned in Margot Lee Shetterly’s book Hidden Figures) where all mainframe computers were hosted. The primary emphasis of this Division was data acquisition and reduction and although “computation” is in its title it had little to do with computation as we know it. Another Directory was Aeronautics which was organized by speed regime. In 1971, Cortright brought his college fraternity friend, Robert Bower, from Grumman to head the Aeronautics Directorate. At Grumman, Bower was Director of Advance Development, the office I worked for while I was at Grumman.

Another important change made by Cortright had to do with Langley's recruitment policy. Cortright found that Langley had been recruiting in the ‘60s almost exclusively from a handful of universities, notably Virginia Tech, NC State, and Georgia Tech. Cortright asked the personnel officer Townsend Johnson why the center was following this policy. Johnson replied: *"Well, Mr. Cortright, we're sort of partial to*

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[2] Elizabeth A. Muenger, *Searching the Horizon: A History of Ames Research Center 1940-1976*, NASA SP-4304, 1985, p. 174. [https://history.nasa.gov/SP-4304/ch8.htm]
[3] *The Mathematicians Who Ended the Kidnapping of an N.Y.U. Computer*, James Barron, The New York Times, Dec. 6, 2015.
[4] James R. Hasen, *Spaceflight Revolution: NASA Langley Research Center From Sputnik to Apollo*, NASA SP-4308, 1995, p. 402. [https://history.nasa.gov/SP-4308/ch12.htm]

southern boys."[5] That did not sit well with Cortright, who wanted a broad recruiting policy in line with the ICASE model.

When I arrived at NASA Langley to work in the High-Speed Aerodynamics Division of the Aeronautics Directorate, I found that computational research was decentralized with small uncoordinated efforts in various divisions. The largest concentration was perhaps in the Theoretical Aerodynamics Branch of the Subsonic-Transonic Aerodynamics Division. Unlike NASA Ames there was no recognition by the center's management of the impending computational revolution. Experimental research based on wind tunnels and flight tests was deeply-rooted in the Langley DNA. Computational simulations were tolerated, but mistrusted and the notion that one day computations could replace wind tunnel testing was completely abhorrent. This sentiment was not totally groundless and it forced us doing CFD to improve our research.

Around 1970, CDC started the design of a vector supercomputer, the Star-100, at the urgings of the Lawrence Livermore Lab. Shortly after, Langley started negotiations to acquire one of these computers for the lab. The then Assistant Director for Electronics Research, Barry Graves, see Fig. 3, soon recognized the lack of training within the centers research staff to utilize such a computer. He saw the need for a new institute to be focused on the science of computing. That started the ball rolling for the creation of ICASE.

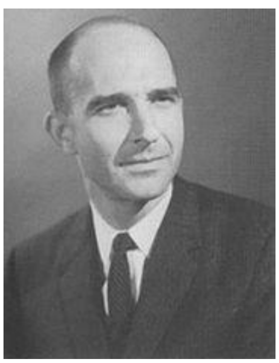

Figure 3. Barry Graves, Assistant Director for Electronics Research.

Graves retired in 1975, shortly after I arrived at Langley and I never had a chance to meet him. The only other thing I know about him is that he was responsible for setting up the tracking stations that monitored John Glenn's 3 orbits around the world in 1962, see Fig. 4. Eighteen relay stations covering three continents, seven islands, and two ocean-bound radar ships were erected. The stations were setup in such faraway and inaccessible places as the south side of the Grand Canary Island, 120 miles west of the African coast; Kano, Nigeria, in a farming area about 700 rail-miles inland; Zanzibar, an island 12 miles off the African coast in the Indian Ocean; a place called Woomera, in the middle of the Australian outback; and Canton Island, a small atoll about halfway between Hawaii and Australia.

ICASE is created

ICASE began operations at NASA Langley in July 1972 under an agreement between NASA Langley and the Universities Space Research Association (USRA), a university consortium of about 50 major universities at the time originally tasked with the management of the analysis of rock samples brought back from the moon. A temporary office was created at Langley while a search for the ICASE director was conducted. The institute was to have a small permanent staff for administration and the execution of its own independently developed research program. This was to be financed by core funding ($400K

[5] Ibid p.411

initially). The director was to be selected by USRA as well as a small council selected from the cooperating universities that was to meet at regular intervals to advise the director. Emphasis was placed on visiting research associateships of various lengths of visitation. This was desired in order to maintain a continuing exchange of new ideas and new research interests at the institute. Since the institute was to have an impact on the Center's own efforts at exploiting its computing capabilities, joint research with Langley staff members was encouraged.

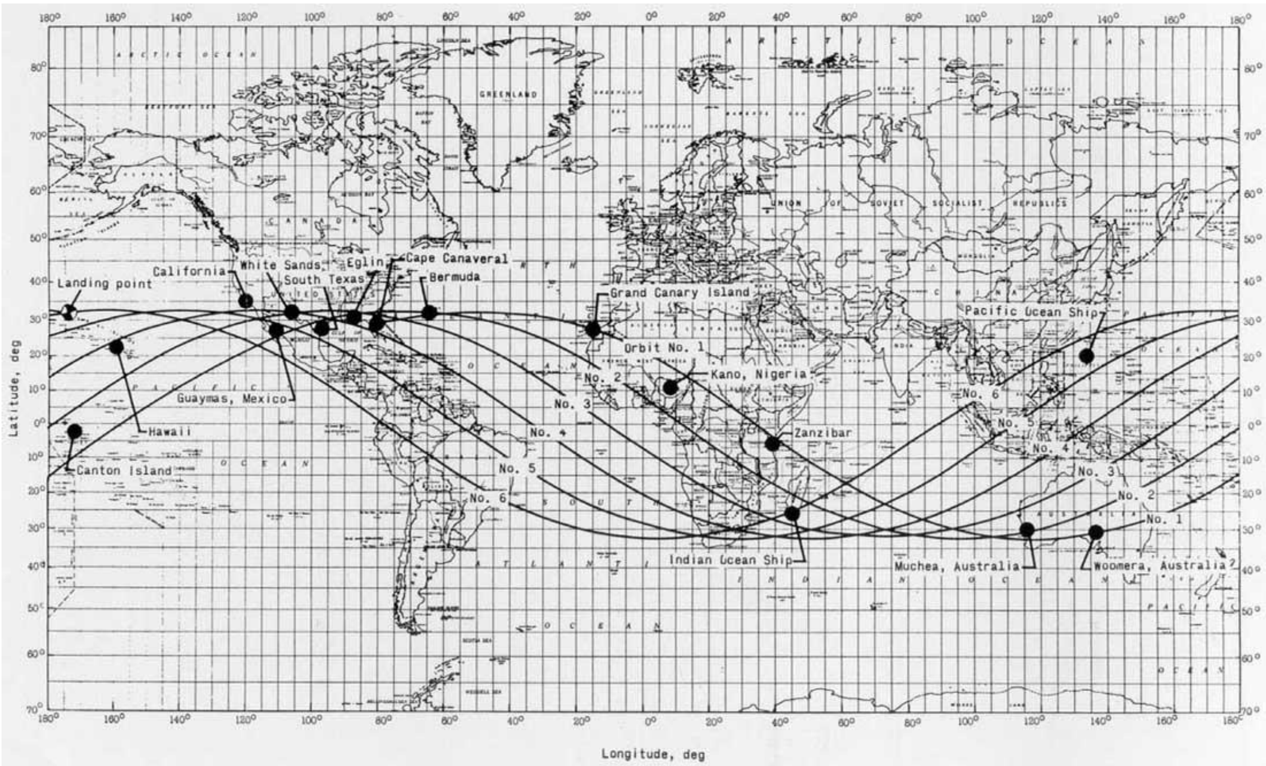

Figure 4. Mercury Project worldwide tracking network.

Core funding was central to the institute's efforts to sustain an independent long term research program and this was the Achilles heel of the institute. Core funding dependent on the initial commitment that both Langley's and NASA Headquarters' managers had made to support the institute. Initially the core research program was funded directly from NASA Headquarters. In 1997, Robert Voigt, Assistant ICASE Director, commented on the significance of this:

Dr. John Duberg [Langley's Chief Scientist and responsible for ICASE]… deserves a great deal of credit for his vision [on how to fund the institute]. We started out with core funding that was not at the expense of the Langley staff, at least not directly. The money flowed from NASA Headquarters with few strings. Thus if we wanted to explore a technical area or to interact with Langley researchers, we did not have to approach with our hand out. In fact, for several years there was no mechanism for Langley staff to provide direct support for activities at the institute.

But NASA's memory can be feeble and over the years the source for core funds changed several times. With changes in priorities, funding and personnel at both NASA Headquarters and at Langley it became a constant struggle for ICASE Directors to maintain a sufficient core fund for the institute.

After several months of consideration, the search committee selected Dr. James Ortega as ICASE's first Director, see Fig.5. Jim had a Ph.D. in Mathematics from Stanford University. In 1964 he joined the

University of Maryland and in 1969 became professor of Computer Science, Mathematics, and Applied Mathematics. He accepted the position of Director on a part-time basis in December 1972 and assumed full time duties in May 1973. In March 1973, Robert Voigt was selected as Assistant Director. Jim's expertise in applied mathematics, numerical analysis and computer science was the perfect mix for ICASE. Jim had the difficult job of setting the course of the new institute and formalizing the way the institute would interact with the Langley research staff. A strict disciplinarian, Jim sent home many ICASE staff scientists for wearing inadequate closing or shoes. One of Jim's creations was the ICASE reports series which was distributed freely to universities and research labs throughout the US. The first reports, 22 in total, were published in 1975.


Figure 5. Dr. James Ortega, first ICASE Director.

With the anticipated arrival of the Star-100, ICASE, in collaboration with scientist at ACD, created a Star Linear Algebra Working Group and started research on algorithms for vector and parallel computers. Robert Voigt led this effort which included among others Gene Golub from Stanford University, William Poole from the College of William and Mary and Alan Cline from the University of Michigan.

In June of 1973, ICASE sponsored the First Langley Conference on Scientific Computing in conjunction with the 1973 National Meeting of the Society for Industrial and Applied Mathematics.

Alvin Bayliss, John Strikwerda, Heinz-Otto Kreiss, Joseph Oliger, Steven Orszag, Bertil Gustafsson, Max Gunzburger, Nic Nicolaides, Achi Brandt, John Knight, Stanley Rubin, George Fix, Bill Gear, Alan George, David Gottlieb, Eli Turkel and Thomas Zang were among the first ICASE staff appointees and visitors.

My office at Langley was just across the street from ICASE. A visit to an ICASE seminar led to discussions with some of the visiting scientists and soon I was spending more time at ICASE than in my own office. Early on I met David Gottlieb, see Fig. 5, and soon we developed a friendship that lasted a lifetime. A great deal of the ICASE research was conducted by visiting scientists on one of the many oversize blackboards on the ICASE conference room. Here visiting scientists, Saul Abarbanel was a prominent practitioner of this art, would discuss their research topic with whoever was at ICASE at the time or whoever just happened to walk by the conference room. Sometimes the discussions could get animated as when Ami Harten and I discussed the numerical treatment of shock waves. I was loud, Ami was louder. Just as the linear advection equation, $a_t + ca_x = 0,$ became known[6] as the ICASE equation, the "blackboard" became the symbol of ICASE and it was not long before someone had a blackboard installed in the ICASE restroom.

With the institute firmly established, Ortega left ICASE in 1977 to go to North Carolina State University as Head of the Mathematics Department. Two years later, he went to the University of Virginia as Chairman of the Department of Applied Mathematics.

Figure 5. The motley crew: David Gottlieb seated, from left to right Stan Osher, unknown, John van Rosendale, Stephen Davis and Bram van Leer. Summer of 1982.

I once was asked to quantify the success of the institute and its impact on CFD. I don't really know how to do this in a conclusive way. Perhaps we can get a sense of this from the following statistics. Over its 30 years of operation, ICASE hosted 178 staff scientists, 230 graduate students, 243 consultants, and 546 visiting scientists; it held 77 workshops and conferences; from 1975 to 2001 it published 1583 ICASE reports, 43 interim reports, 2 Pink Grundlehren[7] [Comprehensive] reports and 32 books and conference proceedings. It became the lifeblood of CFD research at Langley with every major Langley CFD code, TLNS3D, FUN3D, CFL3D, tracing its roots to ICASE research. A search in Google Scholar of "ICASE" (quotes included) yields 34,600 hits and if we restrict the search to "ICASE report" (quotes included) we get 8,550 hits. Among the topics to which ICASE made significant contributions are: multigrid methods, spectral methods, upwind schemes, parallel and vector computing, finite element methods, wavelets, total variation diminishing schemes, essentially non-oscillatory schemes, numerical implementation of near and far-field boundary conditions, large eddy simulation, turbulence modeling, design optimization, adjoint methods for PDEs, unstructured grids, lattice Boltzmann method, flow instabilities and transition, and Görtler vortices. But perhaps ICASE's most important contribution was the forging of life-long friendships among leading researches in overlapping regions of the fields of applied mathematics, numerical analysis, fluid mechanics and computer science.

[6] Xu Kun, *Direct Modeling for Computational Fluid Dynamics: Construction and Applications of Unified Gas-Kinetic Schemes*, Advances in Computational Fluid Dynamics, Vol. 4, World Scientific, 2015, p. 117.
[7] After the *Grundlehren der mathematischen Wissenschaften,* Springer's first series in higher mathematics founded by Richard Courant in 1920.