The Computer Assist

In less than 40 years, a novelty has grown into a mainstay of engineering practice. By John Varrasi

Sometime after the developmental programs for the lunar excursion module and the F-14 fighter jet, Thomas J. Kelly, a vice president at Grumman Aircraft Engineering Corp., summoned his engineers to find out the reason behind their repeated requests to install additional computing power in the engineering departments. After all, Kelly told his engineers, Grumman for years had been very successful designing and testing a wide range of aircraft and space systems on drawing boards using slide rules and other conventional tools. Why, then, would the company's engineers insist on bigger and faster computers?

Harry Armenia, who would later serve as president of ASME, worked as a structural engineer at Grumman and was one of the engineers at the meeting. Armenia told his boss that the engineering staff was responding to pressure from the US. Navy and other customers to upgrade the computational capabilities of both hardware and software in an effort to speed design processes and automate analytical techniques, with the aim of reducing developmental costs.

As ASME celebrates its 125th anniversary this year, Mechanical Engineering is running articles each month highlighting key influences in the Society's development. This, the 10th in our series, examines the emergence of computers in engineering in the 1970s.

"Our customer had become very sophisticated, and its higher performance requirements exceeded what we were able to do with standard tools on the drawing boards," Armenia recalls. "The company had no choice but to comply."

Pushed in many cases by systems users, particularly military and other government customers, the computer began arriving at corporate engineering workstations in the mid-1970s. Before then, the new technology was not widely used in the engineering department. Despite the promising demonstrations of Nastran, the powerful structural analysis system developed at NASA, and the presentations of the computer pioneer John H. Argyris at a series of conferences organized by the U.S. Air Force beginning in 1965, computer-aided engineering was not standard practice heading into the decade of the 1970s. The only computers at the disposal of engineers were mainframes such as the IBM 360 Series and pocket devices like the HP-35, which let practitioners perform routine calculations, store sales data, and process inventories.

Only a few forward-looking technology companies invested in computers, primarily mainframe systems. While bringing the benefits of data management and real-time processing to engineering, the mainframes were also a headache. Engineers spent countless hours correcting functional problems and writing programs.

The programs, particularly large-scale ones involving difficult computations, were executed in batch processing mode, meaning that the engineer had only one attempt each day to run the programs. In the days of the mainframes, "developing programs to execute the algorithms was a laborious task," said Karl S. Pister, former dean in the College of Engineering at the University of California, Berkeley.

Finite Element Analysis

UC-Berkeley in the early '70s was a focal point for the development of computer-based structural analysis. There, Edward Wilson, Ray Clough, Klaus-Jurgen Bathe,
and other pioneers worked on finite element methods, techniques that geometrically render a structure into a series of elements having prescribed properties.

Finite element analysis, or FEA, methods proved to be extremely useful in engineering. When the discrete elements were assembled to form a structure, or continuum, what resulted were sets of defined equations used to represent the behavior of a system under load. FEA tools involved the development of algorithms that helped engineers analyze such physical phenomena as deflections and stresses in complex structures. The pioneers of FEA carried out numerous applications, including analysis of aircraft components such as wings.

In 1973, Bathe developed the structural analysis program SAP IV, which was released at no cost to interested users. “The SAP IV source code offered numerical algorithms that engineers could apply to their own applications,” said Bathe, who is now a professor at the Massachusetts Institute of Technology. “The code was distributed worldwide.”

While military contractors and large corporations like General Electric and Hitachi could not ignore the role of finite element analysis in their technology programs, during most of the 1970s the general engineering community did not capitalize on the full potential of the computer. One main problem was lack of access. The prohibitive cost of the early mainframes and glitches in the software deterred many companies from investing in computer technology; those firms that installed systems often did not give priority to engineering departments. Another problem was education: In the 1970s, computers were relegated to the back burner as engineering schools instead earmarked funds for the construction of

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ultramodern laboratories and design centers.
Trends started to shift toward the latter part of the
decade. As computer speed and memory increased, finite
element analysis began to spread beyond research centers
and military labs to diverse industrial applications. Before
long, midsize firms and even small engineering consul-
tancies embraced this powerful tool that brought
speed and precision to systems analysis. By 1980, the
computer revolution finally had taken hold in engi-
neering, spurred by FEA.

The Emergence of CAD

The ASME Computers in Engineering Division was
established in 1980, and by then computer-assisted
engineering was gaining strongly in engineering practice. As engineers became increasingly adept at
using finite element methods for simulation, a group
of software companies was poised to take computer tech-
nology to the next level. These firms introduced com-
puter-aided design and computer-aided manufacturing
systems, enabling engineers to perform 2-D and 3-D
modeling on computer screens. Then, the vendors aug-
mented the CAD/CAM programs with powerful para-
metric systems to automate tasks associated with the
generation of geometry, signaling the beginning of
knowledge-based engineering.

“We see the development of computers in engineering
starting with finite difference and finite element meth-
ods, which support simulation and analysis, and progressing
to CAD/CAM, which supports design and manufacturing, and then to knowledge-based systems,” Harry
Armen said.

Knowledge-based systems allowed engineers to imple-
ment rules, which are entered in the computer’s database
to be used as constraints during the design of products
and systems. Such rules could be used for optimizing a
design against factors like cost, weight, manufacturing
constraints, and standards and regulations. Technology
firms that invested the necessary time and resources in
the development of knowledge-based engineering sys-
tems were able to integrate design, testing, and manu-
facturing, in the process automating tasks, saving time, and
reducing costs.

ASME members embraced knowledge-based engineering,
believing that there was great potential in knowledge-based
methodologies to support modeling, design, and manu-
facturability. Members conducted extensive research in
the field, and presented their findings at conferences as well
as in technical journals.

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The 1988 ASME Computers in Engineering
Conference had 23 ses-
sions on knowledge-
based engineering. Also,
the Society’s flagship
publication, Mechanical
Engineering magazine, de-
veloped “Computers in
Mechanical Engineer-
ing,” a regular feature
offering updates on
knowledge-based sys-
tems. Indeed, ASME
played a major role in ad-
vancing the field.

Computer capability in engineering has
grown exponentially since the 1970s. Engineers solve
hundreds of thousands of equations in minutes on lap-
top computers. Still, according to experts, engineers
have not realized the full potential of computers.

“A future challenge will be to integrate computer-
aided design and computer-based analysis and to ren-
der the two technologies fully compatible with models
embodying analysis and geometry,” said Farrokh Mis-
tree, associate chair of the George Woodruff School of
Mechanical Engineering at Georgia Institute of Tech-
nology in Savannah.

According to Armen: “The engineering community
must advance computer technology to the level where
engineers can validate a structure completely using com-
putational tools, without having to develop physical
models and prototypes. The next step is cognitive infor-
mation processing using the computer to actually mimic
the attributes of the human brain.”

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