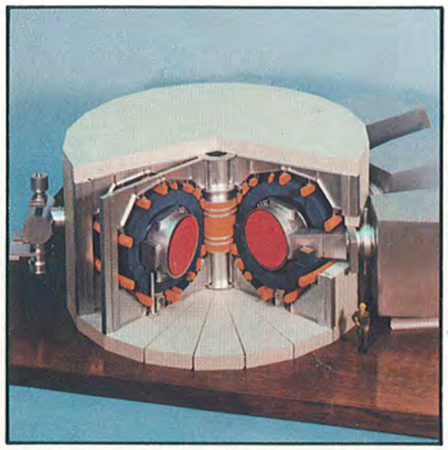
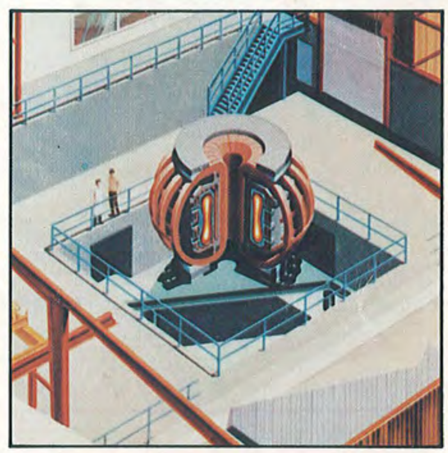
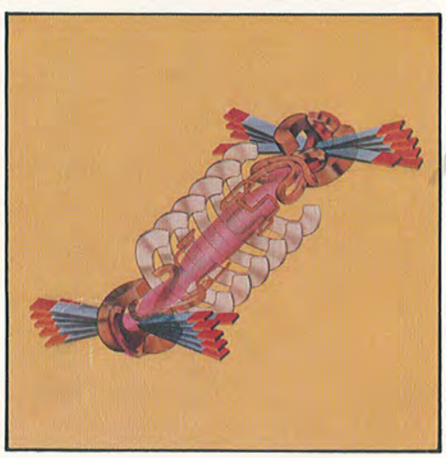
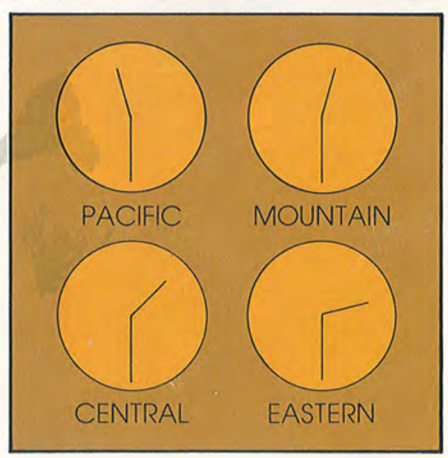
The National Magnetic Fusion Energy **Computer Center**

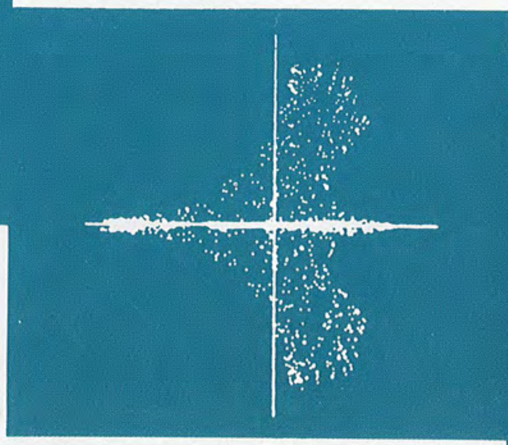
Livermore, California

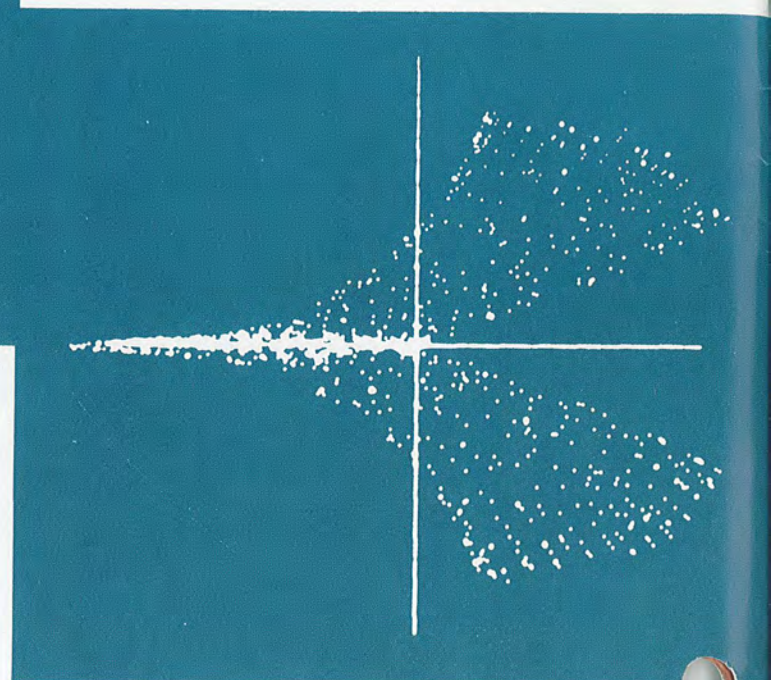







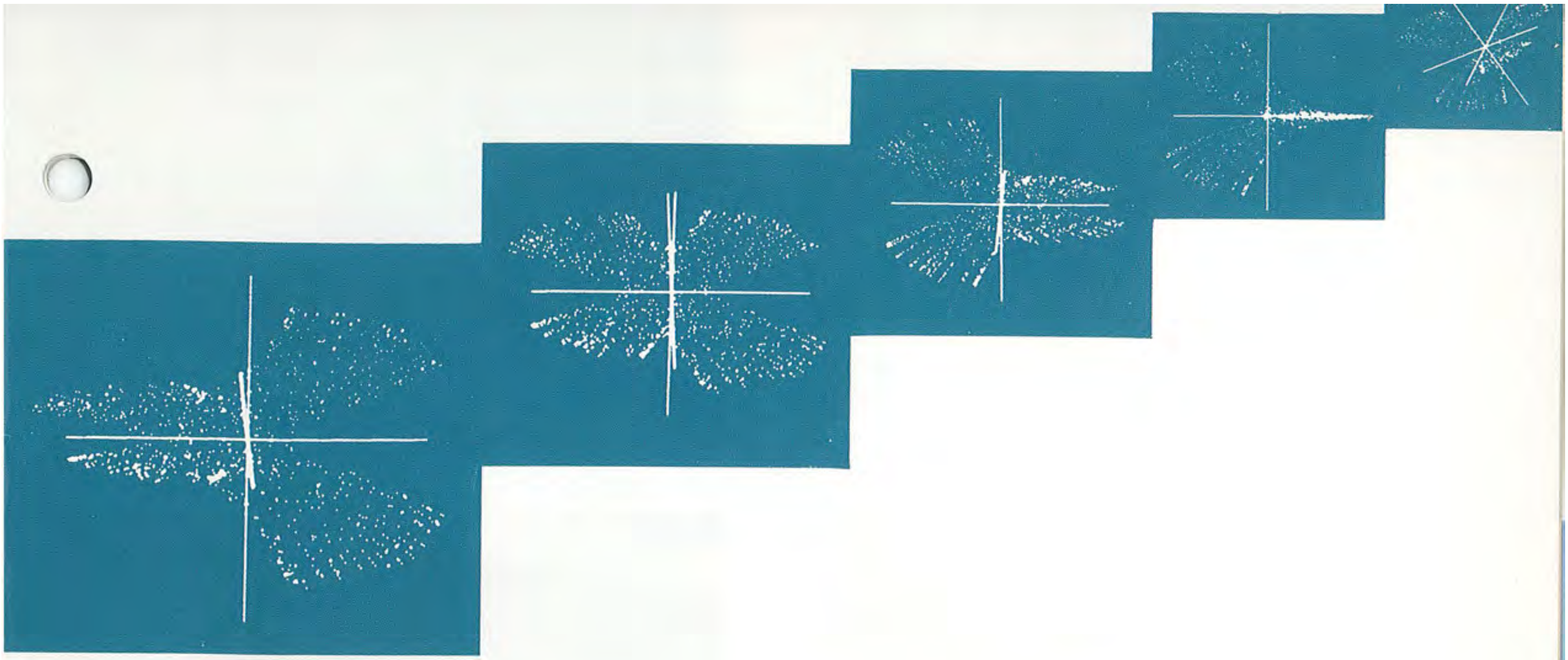


New Computer Graphics can simulate Plasma Configurations.
Frames from a computer-generated color motion picture hint at NMFECC's developing ability to represent plasmas in three-dimensions from varied perspectives.

FUSION

Fusion is a process in which atomic nuclei collide and join, thereby releasing prodigious energy. Fusing nuclei in the sun produce its light and heat. When materials are heated to high temperatures such as the 100 million degrees Celsius needed to produce fusion reactions, they become ionized gases. These hot gases made of electrons and positively charged ions are called plasmas. Fusion has been achieved in a plasma of gaseous hydrogen (the heavy isotopes deuterium and tritium are used) by first confining the fuel in strong magnetic fields. It is then heated, compressed, and injected with energetic particles to increase the number of fusion reactions.

To achieve controlled thermonuclear fusion using magnetic confinement, there are three major approaches: low-density closed systems (e.g. the ring-shaped tokamak at the Princeton Plasma Physics Laboratory), open systems (with ends capped by magnetic mirrors, e.g. the Mirror Fusion Test Facility at the Lawrence Livermore Laboratory), and high-density pinch systems (in which the magnetic field is pulsed rapidly). Computational studies at the National Magnetic Fusion Energy Computer Center were keyed from the outset to the research needs of these three



principal confinement schemes.

A second concept for creating controlled nuclear fusion involves tiny pellets of fuel, which are irradiated by intense beams of energy, such as laser light. The outer layer of the pellet is blown away, creating an implosion of equal and opposite force. The pellet is thus compressed and heated intensely, increasing the likelihood of hydrogen nuclei fusing. This concept is called inertial confinement.

ENERGY OVERVIEW

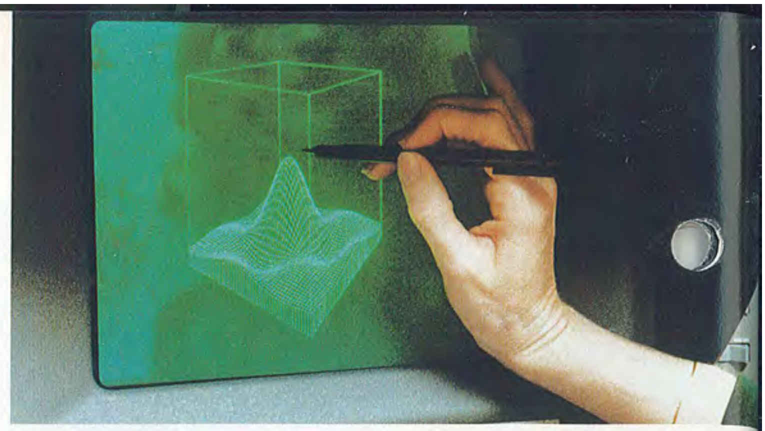
Alladin's magical lamp held oil. Today there may be a new genie in the bottle, one capable of supplying electrical power practically forever, able to materialize without any smoky folderol. That is, magnetic fusion energy could be the answer to those stark questions posed by dwindling reserves of fossil and fissile fuels and by the wastes they create.

The oil crisis and natural gas supply limitations are familiar to everyone by now. Coming more into public consciousness also are the environmental, political, economic and technical problems associated with any significant increase in the burning of coal, the safeguarding and disposal of radioactive wastes from fission reactors, and the utilization of solar energy.

The main fuel for fusion is deuterium, an isotope of hydrogen which can be easily extracted from sea water at minimal cost. This resource can be expected to last more than a billion years. Another type of hydrogen, tritium, also is used in certain kinds of nuclear fusion processes. Tritium is produced artificially from the abundant element lithium.

Fusion reactors will be safe, creating neither long-lived radioactive poisons nor material which could be used in nuclear weapons. Plasmas in MFE devices need to be isolated from physical materials, including air, even to reach fusion temperatures. If the magnetic confinement system of a fusion reactor were, improbably enough, to fail, the plasma would cool so much upon striking the inner wall that the fusion process would be immediately quenched.

It seems that the world's long-term energy needs can possibly be met by three sources: fusion, solar, and fission breeder reactors. The way to go is not clear. A narrowing of options now would be premature. Strong research and development programs must be supported in order to determine commercial viability of these energy technologies.



Tektronix Terminal.
It took only seconds for the computer to display this graphics plot. A million bits of data make up a grid this size.

SERVICES

About the System–The National Magnetic Fusion Energy Computer Center concentrates hardware and software resources for research. Fusion scientists across the country can easily collaborate and share their work, thereby reaping the benefits of a group research effort. File privacy can also be maintained as desired.

Operating on a time-share as well as a batch basis, the system hardware relieves many institutions of costly equipment purchases, while guaranteeing the best in computational power and speed.

The main worker computers, a CRAY-1 and a CDC 7600, are modern, powerful, accurate, quick, and reliable. They run the timesharing system, and primarily handle large scientific calculations and large code development and debugging.

User Service Centers at key MFE research centers enable local handling of smaller problems. The USCs have direct hard-copy output.

Even users at remote locations interact directly with the NMFECC system, via dial-up access over voice-grade telephone lines. Like other users, remote users can interrogate the system.

About FILEM–FILEM (file management system) features convenient, fast, reliable file storage and retrieval, accessible interactively by users and by batch jobs. FILEM allows either permanent or temporary storage, privacy, the ability to share files with other users, and the ability to group files under directories. FILEM is used for storing codes, data, or any information the user wants saved longer than 24 hours. It also holds the entire user documentation for the NMFECC software system.

About LIBRIS–With LIBRIS, a user can instantaneously obtain descriptions of codes or search for codes pertinent to a given research problem. In submitting a code abstract to LIBRIS, an author puts his or her entire code into the data base. Any user may then retrieve the code. LIBRIS is compatible with the Argonne Code Center operation.

About Documentation–Up-to-date documentation is available online. Users can refer to any one of approximately 100 documents, the equivalent of 6,000

Versatec Printer-Plotter.
In ten seconds, one of NMFECC's staff physicists obtains a hard-copy of a plot. The high-speed (1,000 lines per minute) Versatec can print anything the Tektronix screen displays.

DICOMED Graphic Film Recorder.
Full-color or black-and-white graphic film images in a full range of sizes can be had from the DICOMED D48. Quick process time usually means a product ready for the user within one day.

pages of instructions. The documentation data base (DOCUMENT) covers practically all aspects of the system services.

DOCUMENT is human-engineered: it will guide a user in a step-by-step manner concerning use of the system, or the user may choose a set of highlighted procedures. The information can be viewed online with a terminal, using the DOCUMENT routine. DOCUMENT will also print (and plot) hard copies on various printing devices, e.g. printers and microfiche.

About Graphics–A general-purpose graphics software library serves users of the NMFECC, on either the CRAY-1, the CDC 7600, or the User Service Center PDP-10 systems. Included in this extensive graphics package are simple routines for drawing lines, points and characters, as well as complex routines for drawing contours, grids, shaded areas and three-dimensional objects. Various utility routines allow the user to view pictures on Tektronix terminals or to print them on any of the User Service Center Versatec electrostatic printer/plotters.

The NMFECC recently acquired a Dicomed D48 Graphic Film Recorder. The D48 is designed for high performance black-and-white and full-color graphic film recording. This system produces vectors and characters of high quality for graphic COM (Computer Output Microfilm) and, in addition, provides equivalent quality production of raster grey-scale images. The Dicomed D48 at NMFECC can produce 35mm film in both black-and-white and full-color, 16mm film and 105mm microfiche.

About Computational Physics–A small group of computational physicists are on the staff of the National Center. Their work basically seeks to predict plasma behavior reliably. The first of two areas of major endeavor concerns the use of the Fokker-Planck equation and the transport equations (calculation of the distribution of particles and energy).

By utilizing the Fokker-Planck and the transport process equations on the same problem (a hybrid code), a wide view of the particle collision effects (in a reasonable plasma geometry) can be obtained. The collisional effects of high-energy particles are simulated with the Fokker-Planck calculation, with the transport process simulating those of low-energy particles. This dual approach provides predictive ability for particle and energy distributions, which can be followed in the plasma simulation as a function of space and time.

Magnetohydrodynamics (MHD) calculations draw the other major chunk of attention from staff computational physicists. For some time now they have been developing codes to solve fully non-linear MHD equations in two and three dimensions. These calculational methods are available to study the evolution of large-scale waves and instabilities in the plasma. This work is facilitating researchers' ability to construct more realistic and more general plasma configuration models. The computational physics group is also newly developing a calculation of linear MHD stability using a more sophisticated plasma model. Linear equation models simulate small perturbations of the plasma.

Fig.1 Fig. 2,

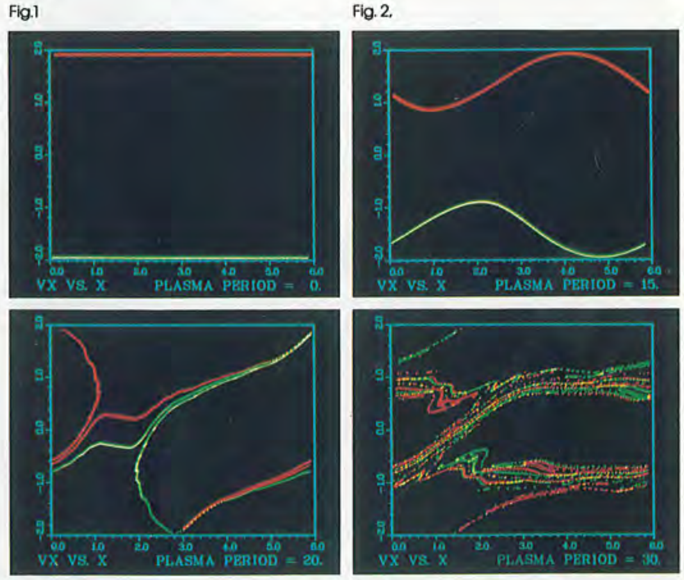


Fig. 3 Fig. 4

Looking at Plasma Behavior Predictions.
This sequence of plots illustrates a plasma instability caused by the electrostatic interaction of two cold electron streams.

Fig. 1) vx-x phase space during initial period. Fig.2) vx-x phase space during linear growth. Fig.3) vx-x phase space nearing saturation. Fig. 4) vx-x phase space after saturation.

The CRAY-1 Computer.
This machine's compact size belies its speed and power. Actually, great pains were taken to build this state-of-the-art computer small. It thus better accommodates the limitation placed upon it by the speed of light. Electrical signals travel in wire at about the speed of light, 1 foot per 1½ nanoseconds (1.5×10^{-9} sec.).

About Consultants–What happens at a User Service Center when a researcher has trouble making some software or a piece of hardware do exactly what he or she wants it to do? How can a person cope, as a dial-up user at a remote location, when stymied by a balky program they've written?

No matter where a problem arises, the NMFECC has experienced software and hardware people on hand to respond quickly. The National Center in Livermore employs consultants to serve all NMFECC users. These professionals may be contacted either in person, by telephone, or by sending a message via the computer network's mail system.

Questions? Programming problems? Call a Consultant.

THE NATIONAL CENTER

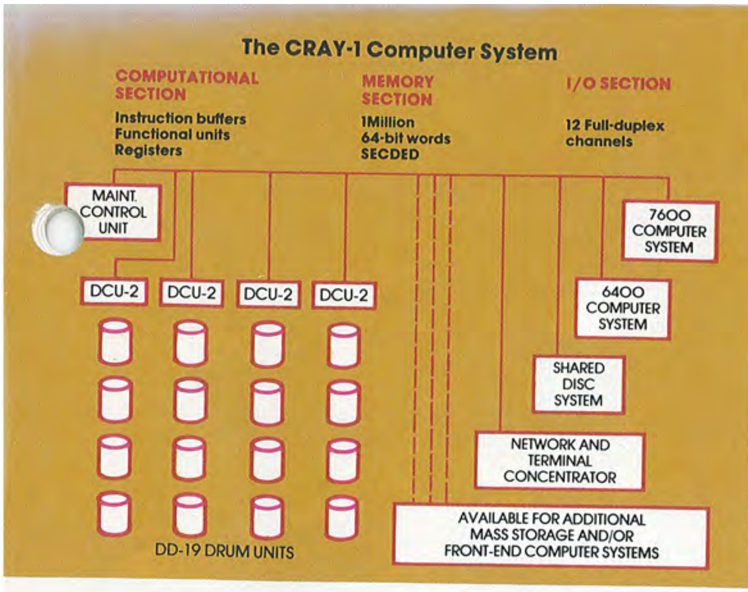
The main worker computers, a CRAY-1 and a Control Data Corporation 7600, handle large-scale scientific jobs and the time-sharing system.

The CRAY-1 especially suits the needs of MFE researchers because its design focuses on the simulation of complex physical processes such as magnetohydrodynamics. This advanced vector processor owes much to experience gained by computer designers while developing earlier models.

In one second (the time it takes to pronounce those four syllables) the CRAY-1 can perform 138 million floating-point operations (MFLOPS). This computational rate can be maintained for sustained periods. Even higher rates, up to 250 MFLOPS, can occur in short bursts. The internal architecture of this computer makes possible such high performance: the architecture accommodates the need to carry out many calculations in discrete steps. Based on a technique called chaining, the vector functional units, in combination with scalar and vector registers, generate interim results and use them immediately, without making the additional references to memory which slow down the computational process in other contemporary computer systems.

Some other features enhance the CRAY-1's computational capabilities: 1) its compactness reduces the distances electrical signals must travel within the computer's frame, allowing a 12.5 nanosecond clock period, 2) its one-million-word semiconductor memory equipped with error detection and correction logic (SECDED), 3) its 64-bit word size, and 4) its optimizing FORTRAN compiler.

The disk storage subsystem consists of four Cray Research DCU-2 disk control units, each controlling



four DD-19 disk storage units. These storage units hold 2,424,276,640 bits of useful data. They're set up so that a second controller can be called into play, with communication over an independent pathway.

The staff at the National Center is diligently at work, integrating the CRAY-1 into more and more of the network system, expanding the processor's usefulness.

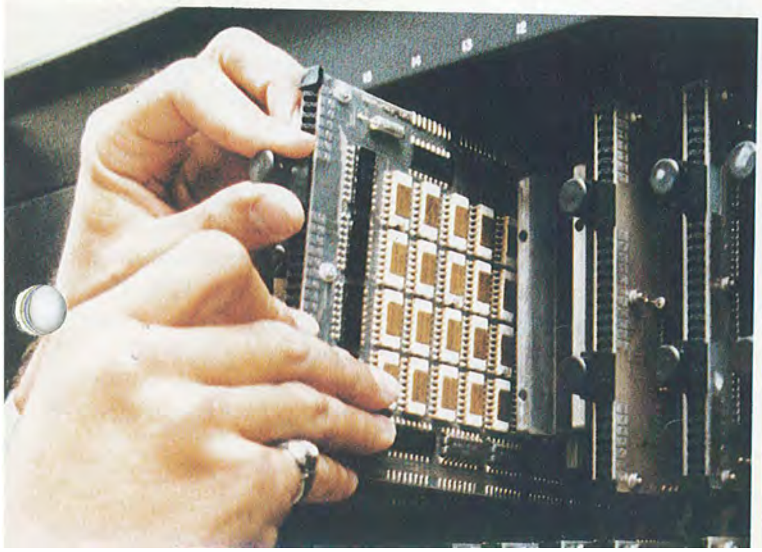
The CDC 7600 computer system processes the same type of jobs as does the CRAY-1. It does not work as fast as the CRAY-1 nor does it have as large a memory. However, its capability of 20 million mathematical operations per second and its 65,000 words of semiconductor memory and 512,000 words of magnetic core memory easily qualify the 7600 as a major computational resource.

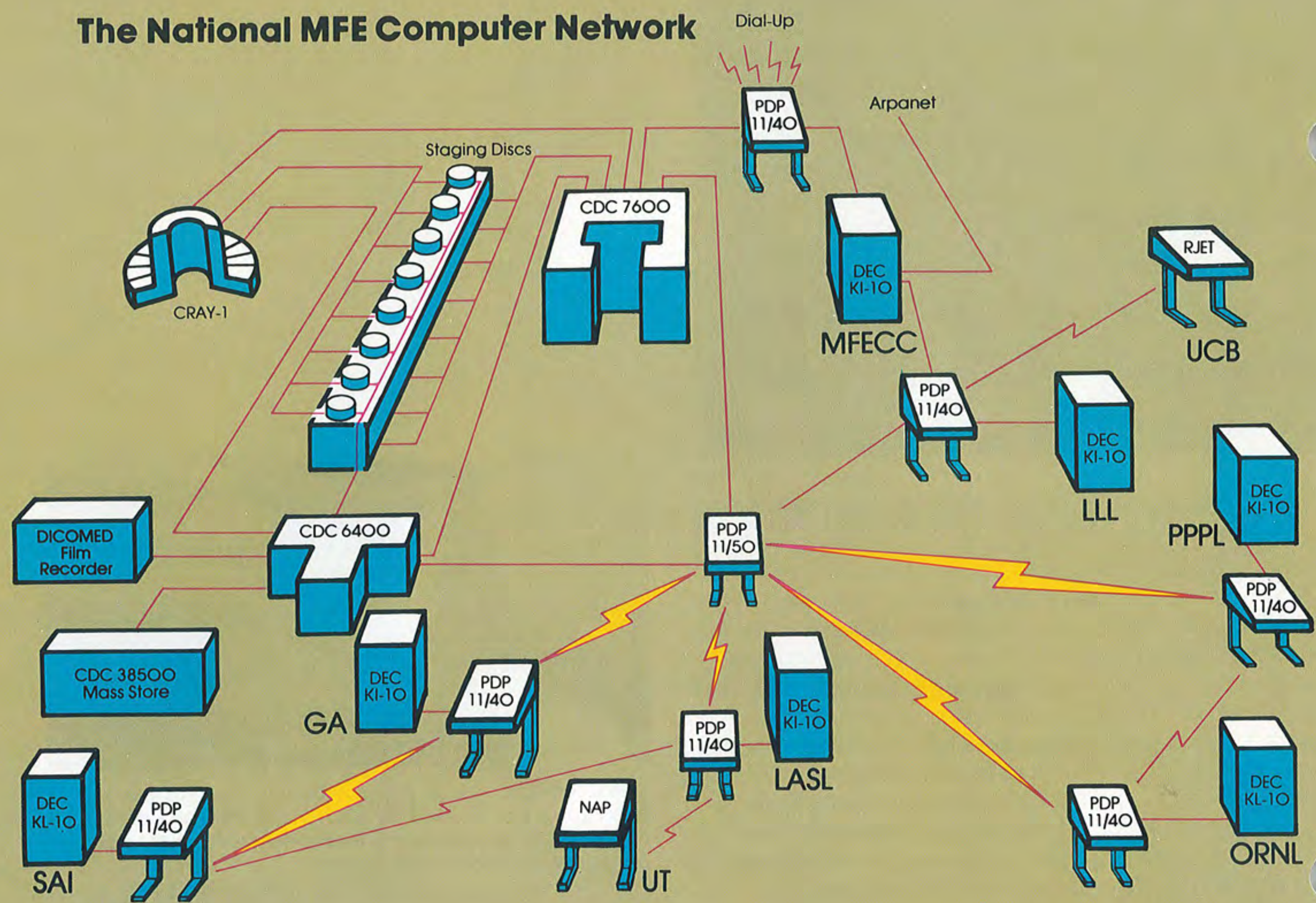
The operating system in use on the main computers is the Livermore Time Sharing System (LTSS) which is composed of a timesharing operating system which also supports batch processing, compilers, text editors, libraries, and utility routines which have been developed over the last fifteen years at the Lawrence Livermore Laboratory.

A CDC 6400 is responsible for performing file management functions associated with our file storage systems, called FILEM. The 6400 performs virtually all of the tasks associated with file custodianship, including indexing, storage, retrieval, and efficient management and allocation of the file storage media. Currently, FILEM uses rotating disks for medium-term file storage. In January of 1978, long-term storage began being converted from conventional magnetic tapes to a new 500-billion-bit CDC 38500 mass storage device.

One such disk pack holds up to 40 million 60-bit-words of data. Spinning at a typical speed of 3,600 rpms, reading at one time only one of 450 tracks on one of the 19 data-filled surfaces, the disk drive can transfer 38 million bits per second.

Two sides of a CDC 7600 Computer.
NMFECC computers receive regular maintenance. Easily testable and replaceable memory bank modules (such as in the picture on the left) mean more reliability and dependability for system users. Normally computers are run with their panels closed. However, these were opened to show how important miniscule segments of time are, to the functioning of these machines. Each wire must be a precise length, and larger ones simply are draped in the cabinet.





THE NETWORK

The NMFECC network is presently configured in a star pattern. An array of User Service Centers, mini-USCs, and telephone dial-up terminals all rely on the National Center, the nexus of the system.

Five of the seven User Service Centers (See map and listing on inside back cover, and the drawing above) communicate with the National Center over 50 kilobit-per-second full duplex synchronous wideband lines through PDP 11/40 remote communications control processors. A hard-wire connection was possible for Lawrence Livermore Laboratory's MFE division, since the National Center is located at LLL.

User Service Centers: In conceptualizing the National MFE Computer Center network, planners determined that broader and faster service and more effective use of the main computers would be possible if some computing and output capability on a local basis was provided. MFE researchers in significant concentrations were to be found at locations like national laboratories, major universities, and certain private corporations. Thus, with the intentions of better serving the MFE researcher and holding costs down for the users, secondary computer centers were created (See map, inside back cover).

Each User Service Center harbors a PDP-10 KI or KL computer (made by the Digital Equipment Corporation). The PDP-10 is connected to the network, enabling any USC to function as a remote output or a remote job entry station. The USC also functions as a terminal concentrator, linking local hard-wired or dial-up terminal users to the main computers at the National Center in Livermore.

Capabilities of the UCSs include text editing, compilations, and running smaller programs not requiring the power of the CDC 7600 or the CRAY-1. Full print-out and plotting capabilities are furnished.

The typical PDP-10 system incorporates 192K of 36-bit/word Ampex memory, 2 disk drives, 2 tape drives, a Versatec printer/plotter, a card reader, 16 or 32 terminal lines, and an interface to the network.

A PDP-10 computer like this provides computational power at every User Service Center. The computer scientist in the foreground is responsible for network management software.

Remote Dial-Up Terminals: Dial-up capability gives non-network users direct access to the main computers. Thus, over voice-grade phone lines, researchers not at User Service Centers may still make full use of the interactively interrogatable feature of the NMFECC network. Complete on-line documentation can be put on terminal display. Consultation service may be had through the terminal via NEWS, or by personal phone call. Hard-copy output for remote users is printed in Livermore and posted with specially-contracted carriers.

Twenty-four dial-up phone lines can be answered automatically. Most of these lines operate at 300 bits/second. A few operate at 1,200 bits/second.

The long-range intent is to provide miniature USCs, with full in/out capabilities, to the largest of the non-USC laboratories.

OPERATION UPGRADE: CONDITIONS & RESPONSES

Expansion plans for the National Magnetic Fusion Energy Computer Center stem from the original purpose. Thus, the NMFECC wants to continue as a powerful computational resource—easy-to-use, up-to-date, and flexible—which is set up to facilitate and encourage sharing among MFE research scientists and engineers.

Conditions–The NMFECC is faced with some unique conditions:

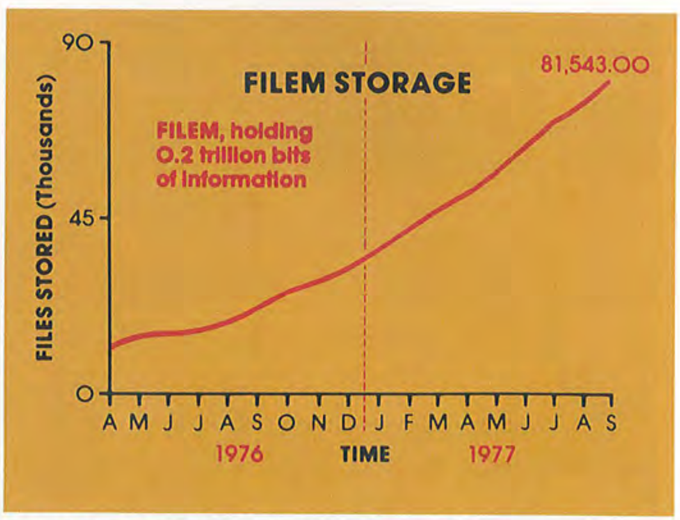
- A significantly increasing complexity in the codes and problems to be run.
- A fast-growing demand on computer time, from old and new users.
- Expiration of temporary and non-renewable support agreements, e.g. with the Lawrence Livermore Laboratory Computer Center.
- A substantial and increasing number of applications for service from remote users.
- Other computer services in MFE research exist in this and in foreign countries. It would be beneficial to share resources: hardware and software links need to be forged.

MFE researchers not at User Service Center installations may communicate with the network via a dial-up terminal like this one.

Responses– plans and proposals:

- A Mass Storage Device, an automated tape store-retrieve system, is being made available for NMFECC files. The machine, a Control Data Corporation 38500, will totally back up all files on the staging disks. It will hold all archival files too. A pneumatic mechanism of the system locates the proper tape cartridge and sends it to a read station where it is automatically mounted and started. This process should take about 15 seconds: conventional manual tape reading response time averages 1.5—2 minutes. The mass storage device will hold a half trillion bits, a capacity which can be doubled.

- Remote Job Entry Stations that function as mini-User Service Centers will be provided. A typical unit will have a mini-computer (with about 16K words of memory), a 1,000 line/minute printer/plotter, a 300 card/minute card reader, and several 30 character/second terminals. Access to the network will be gained using leased 4,800 or 9,600 BAUD lines to the nearest communications control processor. User costs would be less than for dial-up service, and there would be a broader band-width. A greater variety of I/O devices could be supported.



FILEM's dramatic yet orderly increase in stored files has been accompanied by a similar rise in the number of FILEM users. Around 600 individuals use FILEM (1/78). Clearly the new Mass Storage Device's .5 trillion bit capacity is appropriate.

...Conventional technology taking a back seat to the new tape-cartridge-loaded Mass Storage Device.

- A feasibility study for telecommunications via satellite is under consideration.

- The Advanced Research Projects Agency network (ARPA net) is another resource-sharing computer network which serves magnetic fusion energy research and other activities. NMFECC is implementing hardware and software links to ARPA net. In the future ARPA users will have access to the NMFECC.

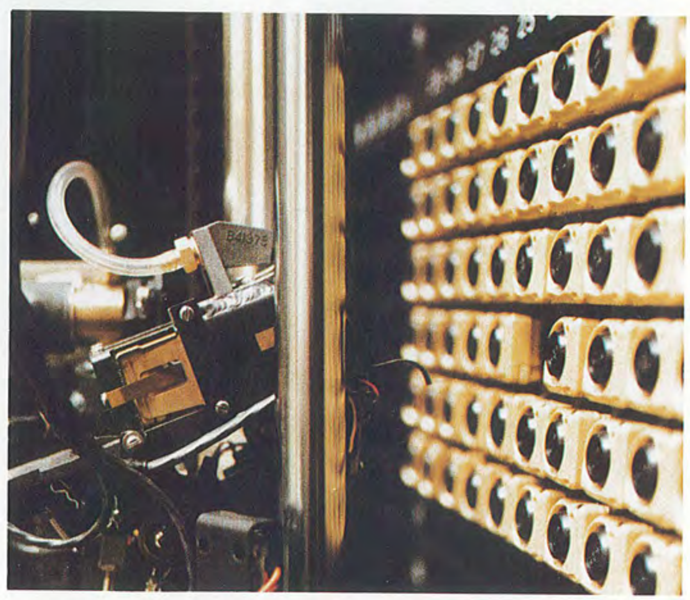
- The configuration of the NMFECC network is to be upgraded. Data currently flows in a star pattern: User Service Centers have no direct links among themselves. The National Center in Livermore is the hub of the system, and its sole connector. Plans call for establishing data transmission links among the USCs. Several premium benefits will be derived from these additions. For example, reliability increases with additional pathways available, because alternate routing, in case a line goes down, can be accomplished. This benefit grows in value when one keeps in mind that users need their output immediately. Much of the MFE work of the future will involve extremely complex codes and complicated engineering problems which will run many hours on even the CRAY-1 computer. Researchers need to be able to stop the process, get some output, check it, and restart their programs. It is essential that the data

Each 100" long tape from the CDC 38500 Mass Storage Device holds 64 million bits. The total installed capacity is .5 trillion bits.

going back and forth (and being held in memory) be always available at the remote location.

- Connecting computers and their peripheral equipment is no simple matter. Most machines actually operate internally by a numerical language quite unique, varying among makes, models and vintages. That means that these machines, even those of the same manufacturer, are not directly compatible. Sometimes commercial units are available to interface, say, a PDP-10 to a PDP-11. However, no commercial interfaces exist to link the PDP-10 or 11 and the CRAY-1 or the CDC 7600

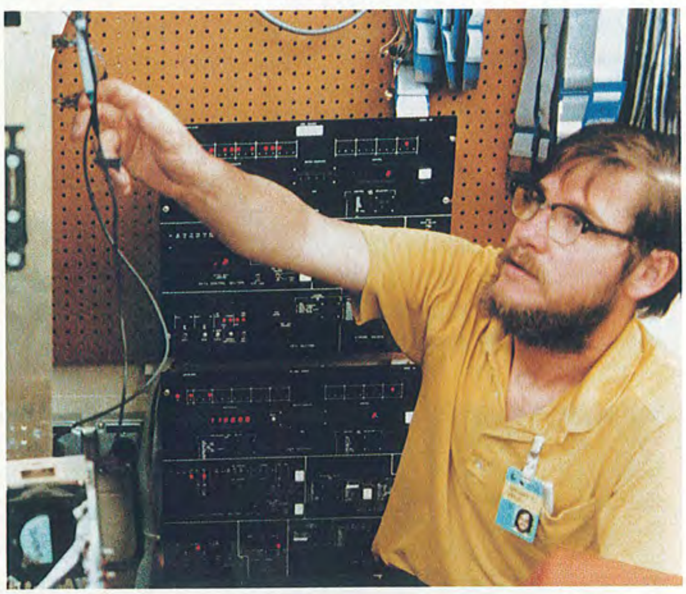
NMFECC engineers have come up with an interface design called Computer Standard Interface Channel, or CSIC for short. Now the computers, concentrators, printers, readers, controllers, and storage devices will be able to communicate via a standardized network format. This means also, that the NMFECC network can offer a standard connection, regardless of the new user's computer type.



In the worst case of cartridge access, eleven seconds would go by from request time before this selector mechanism of the Mass Storage Device had completed its job. The CDC 38500 had to meet the following primary design criteria: reliability, capacity, and performance.

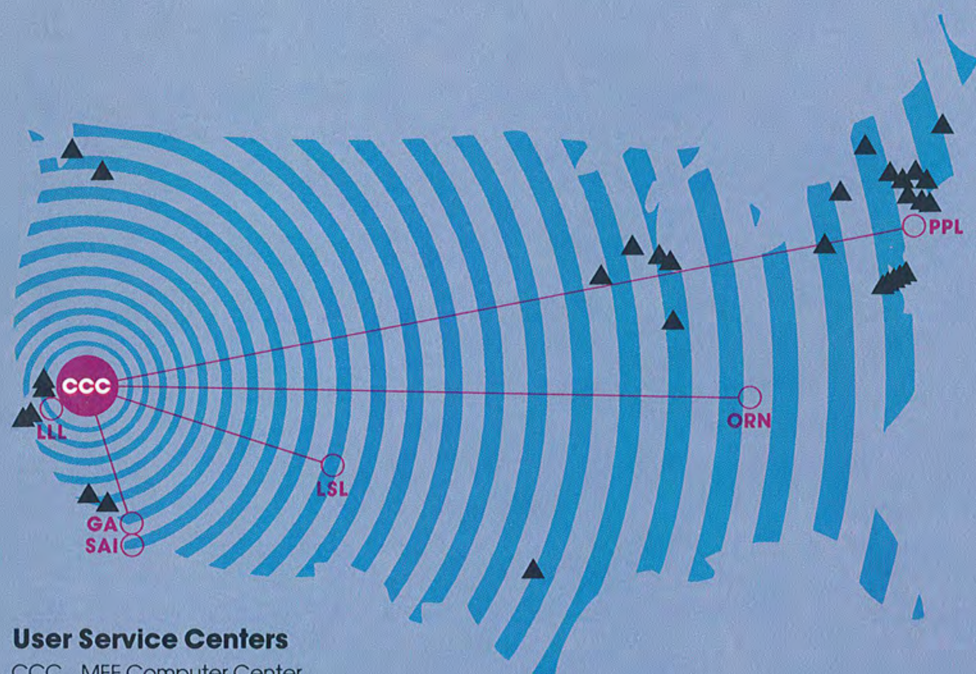
A BRIEF PERORATION

The **National Magnetic Fusion Energy Computer Center** looks to the day when research in this field produces a commercially viable power source. Computing service is provided under the assumptions that such service is indispensable, must be convenient to be useful, and is of increased value when members of the research community are encouraged to share resources with one another.



One of the engineers involved in creating the Computer Standard Interface Channel (CSIC) runs tests in the shop.

The National Magnetic Fusion Energy Computer Center devotes itself to providing its subscribers with the latest and best in computational resources. Installation of new equipment, debugging, and testing is a never-ending process.



User Service Centers

CCC	MFE Computer Center
GA	General Atomic
LLL	Lawrence Livermore Laboratory
LSL	Los Alamos Scientific Laboratory
ORN	Oak Ridge National Laboratory
PPL	Princeton Plasma Physics Laboratory
SAI	Science Applications, Inc.

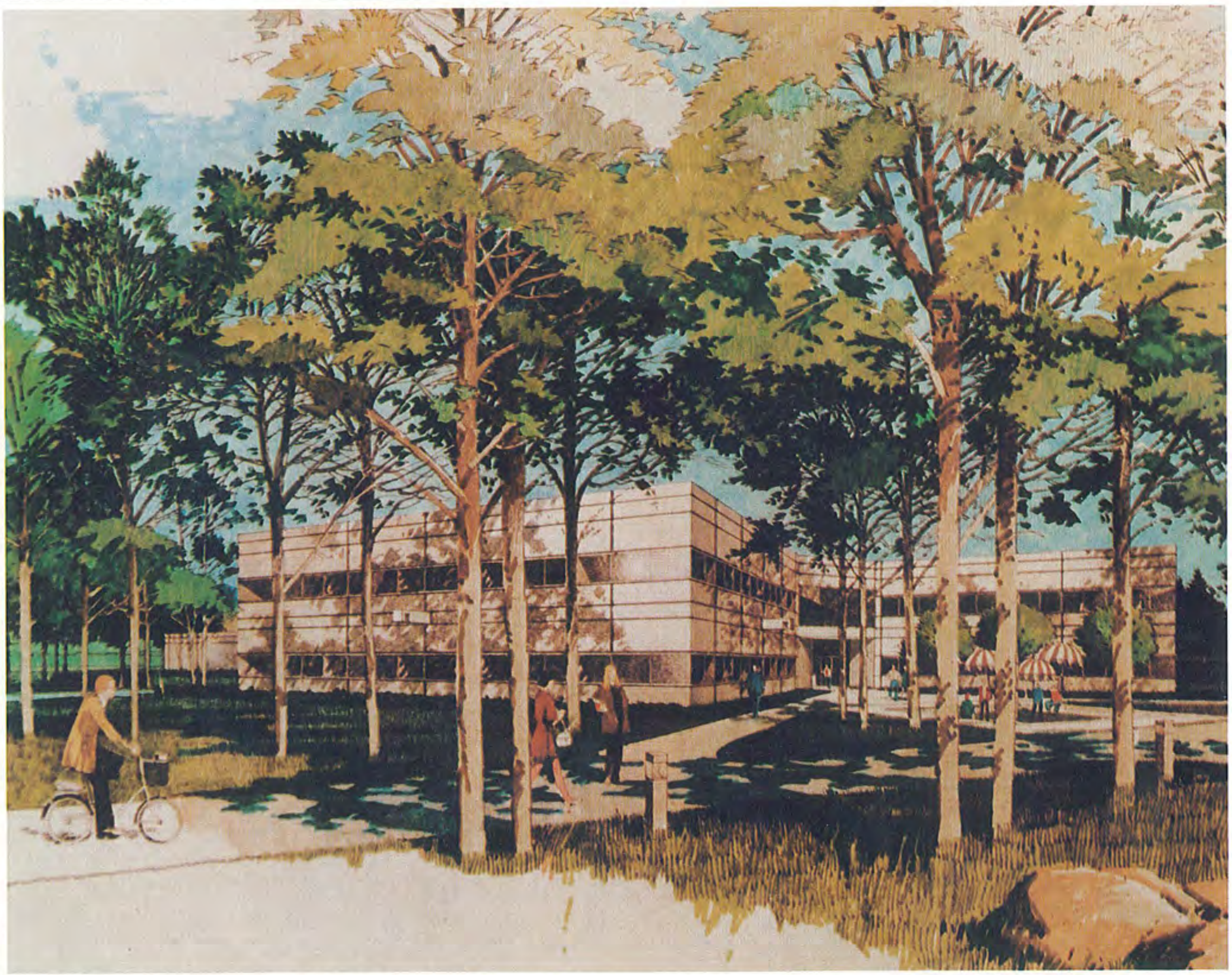
● MFE Computer Center
○ User Service Center
▲ RJETs or Dial-up users

Other User Groups

The National Magnetic Fusion Energy Computer Center serves over thirty groups of researchers in national laboratories, universities, and industry. In addition to the main computer installation and six secondary centers, dial-up terminals give remote users access to the full power of the network.

The following list cites those other groups using the NMFECC as of 3/78:

Argonne National Laboratory. Brookhaven National Laboratory. Columbia University. Cornell University. General Electric Corporation. Grumman Aerospace Corporation. International Nuclear Energy Systems Company, Incorporated. Johns Hopkins University. Lawrence Berkeley Laboratory. Massachusetts Institute of Technology. Mathematical Sciences Northwest. Naval Research Laboratory. New York University. Northwestern University. Rensselaer Polytechnic Institute. Stanford Research Institute. Stanford University. United Technologies Research Center. University of California, Berkeley. University of California, Irvine. University of California, Los Angeles. University of Illinois. University of Iowa. University of Maryland. University of Texas. University of Washington. University of Wisconsin. United States Department of Energy. Westinghouse Electric Corporation. Yale University.



December 1978 should see the NMFECC moved into a building specially designed for it.

If you would like to contact us, please call our
User Services Representative
415: 422-1544
FTS 532-1544

You may also write to us:

National Magnetic Fusion Energy Computer Center
User Services Representative
Lawrence Livermore Laboratory, L-402
Post Office Box 808
Livermore, California 94550

CROB-41 5M 3/78 BFK/TG