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CARINE - A MULTI-USER REAL-TIME SYSTEM FOR CONTROL AND DATA ACQUISITION OF NEUTRON BEAM EXPERIMENTS

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CARINE is dedicated to automatic control and data acquisition of neutron diffractometers at the High Flux Reactor of the ILL at Grenoble (France). The system represents a major effort in respect of special developments realized in Hard- and Software for a medium sized computer (CAMAC-interface, Real-Time DOS). User programs for computation, control and data acquisition are written in FORTRAN and can be stored in individual or shared libraries. Compilation, library management and debugging are possible in background mode. Standard routines are available for all I/O as well as CAMAC functions or as more conventional peripheral devices (disk, magnetic tapes, display). Each instrument has individual disk files for temporary data storage. Output data are recorded on magnetic tape for further data handling and displayed on the graphic computer terminal. A description is given of the essential instrument characteristics and requirements. The design objectives are presented, followed by a description of the computer hardware configuration and the implemented software system. The evolution of the whole computer system project concerning management, personnel and financial effort is outlined.

1. INTRODUCTION

The scientific activities of the ILL lie in the field of solid state physics, nuclear physics, neutron physics, molecular chemistry and molecular biology by use of the intensive neutron source of the Institute's High Flux Reactor (1.5×10^{15} n/cm^{2}s at the reactor core) [1] [2]. In solid state physics the experiments with neutron beams are an improvement and complement experiments with X-rays, gamma-rays, electron-rays and optical methods, because neutrons have a very weak electric charge and a magnetic moment, and are similar to the hydrogen atom. Depending on their energy, neutron beams have a wavelength in the order of the distances between the atoms in a crystal or in a molecule. Neutron beams from the High Flux Reactor, which has a hot and a cold neutron source, have wavelengths between 0.5 and 50×10^{-8} cm.

The instruments coupled to the computer system, with which neutron beam experiments are done, are diffractometers and 3-axis spectrometers. Studies on crystallographic and magnetic structures are done with the diffractometers using elastic scattering of neutrons on the sample (without energy transfer between neutron and sample). The 3-axis spectrometers are used to study problems of pure crystals, using inelastic scattering. The essential mechanical parts of these instruments are the monochromators for the selection of the wavelength used by means of Bragg reflexion on a well-known crystal, the sample to be studied, mounted on a two circle goniometer or on a Eulerian cradle, auxiliary equipment for cooling, magnetic fields, mechanical tensions etc., the analysor for the selection of the scattered neutron wavelength (on the spectrometers only) and the detector. All mechanical parts are driven by step motors or DC-motors coupled with shaft encoders with a resolution of 1/100°. The electronic parts are the motor drive units, the 100 Hz-clock, the incoming neutron counter (monitor), the scattered neutron counter (detector) and the associated amplifiers, discriminators, ratemeters and scalers (preset scalers for the monitor and the time).

The data rates on an instrument are 0.25 - 2500 counts per sec, the measurement times per measurement point are 10 - 500 sec and the data volume on the final support is between 12000 and 470000 bits per day and instrument.

2. DESIGN OBJECTIVES

For the user a computer system must be a tool which allows him the best utilization degree of the reactor and the instrument with regard to the extremely high installation and running costs. Therefore the computer system must allow a quick setting up for the preparation of the experiments, have high availability during the 40 days reactor running period and on-line facilities for the data checking. Data outputs are needed on support which can be handled in other computing centers. Moreover experiments are carried out by visitors and experimental requirements change frequently. This requires a command system easy to understand and a high level program language for uncomplicated modifications of application programs.

2.1 Requirements on the computer system

Generally a measurement can be broken down into several typical steps which will be executed sequentially with looping on subsequences of one or several steps. These normally will be
- calculation of instrument setting from physical parameters
- check of settings for violation of physical limitations
- setting of the instrument
- starting of the measurement
- control of valid measurement conditions
- stopping of the measurement
- data acquisition
- pre-evaluation of quality and consistency of data

- output of data on appropriate support for further data handling

An inspection of the program size necessary to do all preparatory and evaluation calculations for the measurements revealed demands up to several 100 K bytes for Fortran source programs on IBM 360/67. For this reason the complete data handling for a measurement should be split into a "control and data acquisition part" to be done with a dedicated system and a "numerical part" to be done on a central computing facility. The estimation of the daily average data volume produced for all instruments clearly indicates that the magnetic tape would be the right support for output data. It was also evident that each counting operation for single or multiple detectors for reasons concerning distance and transmission speed were to be confined to the hardware. Even if the numerical part of a measurement were done elsewhere, it was always found that there were enough computing demands left, which had to be done on-line. The selection of the instrument electronics was consequently influenced, in the sense that all routine functions, consisting of a repeated sequence of elementary actions, e.g. for a control loop determining periodically the input value of an action device from the actual and desired value, should be realized by hardware, to take off from the computer unnecessary timing constraints to realize simple actions. This is even more true as, when the system was projected, economic reasons indicated a multiprogramming system supporting several instruments which would demand to be served in a complicated time schedule. For control loops it was decided that the computer should indicate to the device only the final setpoint and get a status information following an interrupt, when the desired setting was done. The preliminary check of data is done in a convenient way by visual inspection. The display is only needed from time to time so that the display facility may be time-shared. The graphic information most used is the representation of an x-axis and the presentation of some channel contents of the y-axis, the spectrum. For several applications it is interesting to be able to make comparisons between several spectra. Other functions which are quite often used are the determination of a peak and the integration of a spectrum between two x-values. A hardcopy output of the image presented is useful.

2.2 System facilities

It was the intention to create a system which combines high availability in the sense of security against crash-down of components or errors of utilization with high flexibility but low running cost i.e. staff costs. Flexibility and low staff costs can be achieved by utilization of a High Level Language, for example FORTRAN. This enables the users of the instruments, on condition that they can always integrate their program into the system, to realize directly and at any time the measurement program desired. High Level Languages normally are toorestrictive in respect to the standardized input-output function for the use of instrument control and data acquisition. Additionally it is difficult to execute subroutines which are conditioned by the external events. The input-output operation for instrument - control and data acquisition shall be done principally with one generalized write/read function. The system must permit the introduction of new or modified programs into the measurement programs at any time without danger for the whole system. The use of a High Level Language gives here the advantage that for a tested compiler the execution of object programs normally does not give rise to problems which might endanger the system. The computer time which is not needed for instrument control or data acquisition should be free for the compilation and integration of new programs, into the library. Particular attention must be paid to the convenience of testing the instrument electronics. It should be possible to write particular test routines in a High Level Language and these test routines should be executed on-line.

2.3 Monitor system

The specification of the system properties was done in view of different independent and partially contradictory demands. A multiprogramming system with 4 to 6 instruments on one computer seemed at the time when the project was made to be a compromise between system costs and reliability demands. Each measurement done with an instrument coupled to the computer means, for the multiprogramming system, the sequential execution of different subroutines which are organized in one main program. The number of instruments coupled to the computer is not the only factor determining the number of quasi simultaneously running programs. On the one hand if there are several system users one has to scope permanently with programming work i.e. modifications, development and test. On the other hand, especially for long term measurements users want besides the running of their instrument to run asynchronously other programs in order to prepare new measurement or set-up parameters or to check the incoming measurement data. The asynchronous execution of programs independent of the experiment program in order to check incoming measurement data necessitates the possibility of communication between these programs. The job mix of a typical instrument is supposed to put equal weight on the input-output operations and on numerical computations. Input-output operations are characterized by the fact that not only conventional computer peripheral equipment must be supported but in addition the rather extensive instrument electronics. This leds to the combination of two normally used strategies for the distribution of system resources. Re-distribution of system resources can be made accordingly to interrupt priorities or lapse of time intervals. Programs which become blocked during their execution time must liberate the system resources. The properties of the instruments for which the system was designed suggested the existence of a rich specialized numerical program library, even if the main part of the numerical work is done elsewhere. It is expected that the programs can be stored completely in the system memory. The system must offer the possibility of overlay for very large experiment programs. The existence of an interrupt handling system will be evident for the two groups:

- unexpected interrupts, e.g. an operator, a user or a device wants to establish communication with the computer and get some service;

- expected interrupts. These are interrupts which originate in consequence of some actions initiated by the computer.

The first class of interrupts normally should initiate some action on system program level, the second class of interrupts will be used after being analyzed in the input-output system.

3. COMPUTER CHARACTERISTICS AND CONFIGURATION

The system implemented is based on a digital computer TELEMECANIQUE T 2000 with a core memory of 32 Kwords of 20 bits (19 bits + 1 parity bit); the cycle time is 1.5 μs and there are 56 basic instructions. The interrupt system includes up to 16 hardware levels. The system uses a fixed-head magnetic disk memory SAGEM MS 300 (256 Kwords, 20 bits, 10 msec average access time, 200 Kbytes/sec transfer rate) and the following peripheral devices:

- 8 teleprinters TELETYPE ASR 33 (10 char/sec) 2 teleprinters are installed in the computer room, 6 near the instruments;
- 2 magnetic tape recorders AMPEX-TMZ1 (9 tracks, 800 Bpi, IBM compatible);
- 1 paper tape reader TALLY 464 A(120 char/sec)
- 1 paper tape punch DATA DYNAMICS DD110 (110 char/sec);
- 1 card reader MDS 6002 (400 cards/min);
- 1 graphic computer terminal TEKTRONIX T 4002 with a hardcopy unit T 4601 and a closed circuit TV system with 7 TV monitors, one on each instrument and one in the computer room.

A closed interphone system allows conversation between the users and the computer room. The interface between the electronics of the instruments and the computer is realized in the CAMAC standard. [3] One system crate includes the branch drivers, the logical interface CAMAC T 2000, the interrupt (LAM) sorter and the system controller. The branch highway allows distances up to 200 m from the system crate.

4. THE SYSTEM IMPLEMENTED

The system software is based on the manufacturer's software packages

- Real Time Disk Monitor System (RTDMS)
- FORTRAN Package (FORTRAN II)
- Assembler (ASMAT)

and the following packages of the system software group

- Real Time FORTRAN and Library Management
- Real Time Executive
- Command System
- CAMAC I/O Control System
- Display Package
- Magnetic Tape Package

4.1 Manufacturer's Software

4.1.1 Real Time Disk Monitor System

The Real Time Disk Monitor System (RTDMS) uses the central processor and a disk to process both real time foreground and background programs. RTDMS monitors the chaining of jobs according to a hardware and a software priority. The memory is divided into a protected and an unprotected zone. The protected zone contains the supervisor and its modules, the drivers, the foreground resident programs and a swapping zone shared by the non-resident foreground programs. The unprotected zone contains the background monitor and a zone for the background programs. The background monitor is the lowest priority job and its function is to load into the memory programs from the disk requested by the user (ASMAT, FORTRAN etc.). RTDMS also provides management of sequential files with file protection. This can be used by the foreground and background jobs. An interrupt activates directly a core resident program which is executed with the priority of the interrupt. The monitor saves and restores the content of the registers of the interrupted program. The input-output handler MONES ensures the recognition and the management of the transfer requests on the peripheral devices. It also assumes and checks the execution of these transfers. The symbolic form of the calls to MONES facilitates the use of peripherals for the programming work. Certain MONES functions such as chaining of data transfer and commands to peripherals ensure an optimal transfer speed.
Requests for exchanges may be sequential or not, and may be put on a waiting list for a peripheral already occupied. Exchanges with disks may be made either directly by means of MONES or by means of the filing system. A scheduler gives control to the highest priority task whose execution has been requested. Each task has its software priority. If the task is not in the memory the scheduler makes a request to a module which liberates the fixed memory zone (384 words) by swapping out the occupying task on the disk and loads from the disk (fixed location) the priority task. During the transfers other tasks can be activated. Controls are made to limit the frequency of transfers. In the system implemented RTDMS occupies 4 Kwords for instructions and 3.5 Kwords for tables.

4.1.2 FORTRAN Package

The manufacturer's FORTRAN package, not integrated into an operating system includes:

- a conversational type compiler which generates an interpretable code. The FORTRAN source program may be read either from a teleprinter keyboard or from a paper tape reader; the compiler works in one simple pass, statement by statement. In the case of a syntactic error the compiler accepts the correction of the erroneous FORTRAN statement; this operation of correction is carried out in general with the teleprinter keyboard. The

product of the compilation of a program or a subroutine is a generated code, which is the image of the FORTRAN statement and a certain number of tables containing information relative to the units compiled, the variables and the labels used. The compiler occupies nearly 4 Kwords in the memory.
- The FORTRAN executive which is a re-entrant module of about 3.5 Kwords with the prime objective of interpreting the generated code and of executing the different FORTRAN statements. In the case of execution error an error message is printed out with the exact location in the program where the error was occurred.
- The floating point arithmetic and mathematical functions library which handles the arithmetic operations and the FORTRAN conversions. This module occupies about 2.5 Kwords.
  It is further to be noted that this FORTRAN package permits definition of the information supports by symbolic names for the peripheral devices either in the utilization of the compiler or at the level of the executive for input-output operations. From this fact the assignment of these symbolic names to the peripheral device numbers of the source program gives great flexibility in the utilization of the different peripheral devices.

4.2 System Software

4.2.1 Real Time Fortran and Library Management

To integrate the FORTRAN package under the system, a certain number of developments were realized with the cooperation of the manufacturer. The new performances of Real Time FORTRAN are the following:
- Execution of FORTRAN tasks in the foreground or the background under the monitor RTDMS:
  The background task controls the compilation and execution of FORTRAN programs and the management of the FORTRAN program libraries. The foreground tasks allow the execution of programs stored in the library and called by user request of the command system.
- Compatibility of the FORTRAN I/O with the I/O handler of RTDMS.
- Integration of peripheral devices not included in the FORTRAN package such as disk and card reader.
  The user has access to a sequential access file (accessible by the READ/WRITE statements) and several direct access files (accessible by a call to the standard functions R/WFILW) on the disk.
- Implementation of a package for the management of the FORTRAN program libraries. A number of disk's files is available to store user programs in a common library or a library for each user. The package makes it possible to save or to delete programs, to list the directory and to load programs into the core memory as background work. A dynamic control of the available area in the core memory (8 Kwords) is done by means of a link editor. Subroutines are loaded in the core memory only if they are called. The area is liberated following a RETURN statement.
- Integration of new standard functions for specialized I/O's like CAMAC interface, magnetic tapes and graphic computer terminal.

4.2.2 Command system

The command system allows a dialogue between the 6 users of the system and the computer. By means of the instrument teleprinter the user may
- load a stack of user program names
- start the execution of the user programs
- suspend the execution
- stop the execution
- access to the display
- access to the "background"

The requests are analyzed by tasks which themselves activate the execution, the background and display packages. The command system occupies 100 words in the resident area for tables and 2.4 Kwords for tasks on the disk.

4.2.3 Real Time Executive

The real time executive is a group of swappable tasks controlled by the monitor with the aim of allowing the simultaneous execution of the FORTRAN user programs. These tasks handle the different internal and external events during the execution of the FORTRAN programs.
- User requests and FORTRAN statements (PAUSE,STOP)
- "Time sharing" interrupts which limit the execution time of each FORTRAN program to 4 seconds
- I/O requests with the standard peripherals
- I/O requests with the CAMAC interface
- Errors of the CAMAC interface

The status of the FORTRAN programs is controlled by one task. During the I/O with standard peripherals or with the CAMAC interface the program is in a waiting status and can be swapped on the disk. The measured data are stored on the disk if the program is swapped out. The control of the swapping area for the FORTRAN program and the background program is done by an other task, depending on the time sharing interrupts and the active status of the programs. The real time executive occupies 300 words in the resident area and 1.8 Kwords for tasks on the disk.

4.2.4 CAMAC I/O Control System

The control of the instrument electronics via the CAMAC interface is done by means of swappable tasks, one task for each user. Depending on the CAMAC function the task calls a re-entrant subroutine for code conversion, check of software limits, consideration of zero shifts, etc. and makes a request to the I/O handler for the CAMAC interface. Immediate execution of CAMAC functions like the readout of a CAMAC station register (Q-response) does not change the active status of the FORTRAN program. Long time execution, like moving a motor or starting a measurement, will set the program in the wait status, until an interrupt is received(L-response).
The system may be restarted after a power failure by an operator request. In this case, the program

is continued from the point where it was interrupted and data already acquired are not lost. The CAMAC I/O control system occupies in the resident area 2.1 Kwords for instructions and 1.3 Kwords for tables and on the disk 5.2 Kwords for tasks.

4.2.5 Display package

The visualisation system consists of a control monitor and a certain number of swappable tasks corresponding to the various requests. The user has several alternatives:
- to display one or several of the disk files created by the user FORTRAN program
- to determine the coordinates of points of the spectra
- to integrate a spectrum
- to extend a spectrum
- to command a hardcopy-output of the image currently on the display.

Because only one display terminal is available a period of 4 minutes is allocated to each user by the system following a request. The display package is completely independent of the real time executive and allows simultaneous execution of a user program and use of the display. The package occupies 3.7 Kwords for tasks on the disk.

4.2.6 Magnetic Tape Package

The access to the magnetic tapes is possible by use of standard functions in a FORTRAN program. These functions allow transfer of data from a user disk file to magnetic tape (write function), transfer of data from the magnetic tape to a user disk file (read function) and transfer of data from one magnetic tape to another. All these tasks use a magnetic tape input-output handler; this handler constitutes a specialized interface between these tasks and the monitor RTDMS for all elementary operations on the tape. It controls the storage of the tapes, treats function errors and faults, makes several attempts to perform I/O and renders a status report to the calling task. A special program informs the magnetic tape I/O handler that a magnetic tape physically has been mounted on the tape recorder. The magnetic tape package occupies 350 words for the I/O handler and 512 words for a buffer in the resident area and 2.4 Kwords for tasks on the disk.

4.3 Application Software

The application programs used on the system have a capacity of 112 Kwords, corresponding approx. to 11,200 FORTRAN statements. The elastic scattering programs occupy 55 K, the inelastic scattering programs 30 K and the utility programs including subroutines for the orientation matrix refinement 27 K.

4.3.1 Classic Scattering Instruments

In this area 3 different types of instruments are installed at ILL:
- 2-angle diffractometers: 2 types of programs are available. The first studies the diffraction of neutrons by crystals. In this case, the program calculates the angles from a first set of Miller's triplet HKL. The computer controls 2 motors with the associated shaft encoders and 3 scalers (time, monitor, detector).
- 4-angle diffractometer: The computer controls 4 angles and reads 3 scalers. One program calculates the orientation matrix and the corresponding values of the instrument angles, then corrects these angles, the wavelength and the cell dimensions from the results of two or more measured reflections. The orientation matrix and Miller's indices are used by another program to calculate the set-values of instrument angles, to execute scans about the central values and to determine the background, the intensity without Lorentz's correction and the ratio peak intensity to the background.
- a multidetector which allows simultaneous measurement of the 300 channels of a spectrum between two limits of the diffraction angle. One program calculates the sensitivity coefficients for the detector and another makes the acquisition of the whole spectrum with the correction for each channel. The data acquisition is made by use of an external buffer memory (multichannel analyser INTERTECHNIQUE, DIDAC 800 with a CAMAC interface).

4.3.2 Inelastic Scattering Instruments

The application programs for the 3-axis spectrometers consist of common programs (stored in the common program library) and special programs for each instrument. A common subroutine serves to input/output with any peripheral device, excluding magnetic tapes at the moment, the physical parameters for a certain number of phonon spectra to be measured. All parameters can be modified easily from the teleprinter keyboard and are stored on the disk. Another common subroutine calculates from these parameters the angle values to be set on the instrument. This involves the calculation of a transformation matrix (direct crystal lattice to reciprocal lattice) and elaboration of the scan parameters for the selected scattering plane under certain restrictive conditions for some parameters. Special subroutines set the calculated angle values on the instrument, scan with a given number of points over a spectrum and output the measured data. In these subroutines the data transfer from core memory to disk is done after each measured point of a spectrum and the transfer from disk to magnetic tape after each spectrum.

4.3.3 Utilities

The utilities stored in a common library are accessible by the 6 users and the background. These are programs for elementary instrument and system functions: CAMAC functions (initialize, read, write, position); subroutines to save data in the user's disk files; to transfer data between disk and magnetic tape; to print date and time; to scan over an angle and to display the measured spectrum (this program is useful for the calibration of the instruments). There are mathematical programs: an orientation matrix refinement program for the 4-angle diffractometers and mathematical functions which do not exist in FORTRAN II. The common library contains on-line test programs for the CAMAC-interface and for CAMAC stations (shaft encoders, motors, scalers etc.).

5. CRITICAL COMPARISON WITH OTHER SYSTEMS

Systems to be compared with the system presented should be dedicated to applications within a similar environment. Reference will be made to systems described in the papers [5], [6], [7], [8]. The common environment may be stated as [6]:

1. Experimental requirements change frequently
2. The computer system not only serves for data acquisition, but also for setting up an instrument and re-analysis of data taken during experiments.
3. Few users of the system will or can be expected to have detailed system knowledge, but most will have "FORTRAN" programming experience.
4. Experiments are carried out by visiting teams, who would like to use standard software procedures.
5. There is a frequent change of experiments with steady program preparation involving compilation and testing of new software.

We must stress here the fact that many systems for laboratory or nuclear instrument applications which are described in various papers normally satisfy # 2 of the above demands but are mostly dedicated to single instrument, single user, steady state applications. The fact that these systems are normally programmed in assembly language puts in our view heavy restrictions on the ease of utilization and raises running costs for staffing reasons. The above cited papers [5], [6], [7] all describe multiprogramming systems which take into account the above mentioned environment providing high-level language support. Differences arise as to whether experiment programs may be integrated into the system and which program size can be supported by the system. All systems, except the NBS system [5] for which we think the fully specified and officially agreed CAMAC specification was not yet available are provided with a CAMAC multicrate interface bridging the distance between the computer and the remote instruments. The peripheral equipment of the different computer systems obeys different technical approaches of the same design philosophy, e.g. the Harwell system [6] relies heavily on magnetic tape for bulk storage. There are also different degrees to which control of real-time operations is possible. The NBS system [5] provides in a systematic way breakpoint switches and relays at the instrument site. To the authors' knowledge only the Harwell system [6] has been connected to a central computing facility IBM 360/75 via a high-speed data link, the other systems transfer their data via magnetic tapes to the main computer.

6. EVOLUTION OF THE COMPUTER SYSTEM PROJECT

6.1 Aspects of management

The specification, project study and implementation of the operating system was a contract awarded to the Laboratoire d'Electronique et de Technologie de l'Informatique (LETI) of the CEN Grenoble with the participation of members of the future operating group of the ILL. It was the intention to avoid a high manpower cost to ILL during realization of the project but also to guarantee good system knowledge. The user programs were created in close collaboration between members of the ILL software group and the responsibles of the different instruments with some effort on standardization.
During the realization period of 2.5 years for the whole system, the computer time had to be shared between the different electronic groups (development of the CAMAC interface, special CAMAC stations, the graphic computer terminal interface) and the groups for system and application software.
First only one computer T 2000 was available, later 3 computers. The mathematical part of the application software was checked partially on IBM 2740 terminals connected to IBM 360 computer using a simulation of the CARINE system environment.
During the debugging and set up period of 7 months, 2 computers T 2000 and the associated instruments were available. During the end of the system realization a maximum number of the application programs were executed in order to look for system failures. A 40 day acceptance test was performed under normal working conditions. The availability of the system in spite of system errors was better than 99 % of the runtime. Instruction manuals for the system and manuals concerning the use of the command system and the special functions for application programs were furnished by the system software group. The maintenance of the computer was done the first year by the manufacturers, later by members of the operating group.

6.2 Staff time

The system software group consisted of 3 engineers and 5 programmers. The operating group is composed of 2 engineers, 1 programmer and 2 technicians for the maintenance. The manpower was approx. 16 manyears for the system software and 2.5 manyears for application software (2 months for the specification and the debugging of the mathematical part and 1 month for the set up period per instrument).

6.3 Financial cost

The total costs for the system including hardware costs and staff costs for system software amounting to F 2.470.000 without taxes.
In detail:

2 computers T 2000 TELEMECANIQUE ELECTRIQUE with associated peripherals	F 1.450.000
1 graphic computer terminal T 4002 TEKTRONIX with hardcopy unit	F 100.000
1 CAMAC interface for 11 instruments	F 250.000
System software	F 670.000

The initial financial plan was exceeded by 23 % (18 % for the hardware and 41 % for the software).

6.4 Operating experience

Operating experience has been gained during more than 11 months of operation. The availability of the system is now 98.0 % including time for maintenance (1,8 %). The idle time of the monitor lies at 87 % of the runtime with a load of 6 instruments. The measurement times of the different instruments varies between 45 and 95 %. The background facility is used at 4 %. The system is running 24 hours a day without special operator assistance. An operator is only required for the daily change of the magnetic tapes with the measured data. For nights and week-ends a call service for technical assistance in the case of system failure has been organized. The total system recovery time is 5 minutes. User judgement about system performance is mostly positive and additional instruments (3 triple-axis spectrometers) will be connected in near future.

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