ORIS — The Oak Ridge Imaging System Operation's Manual

P. R. Bell
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OAK RIDGE NATIONAL LABORATORY
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ORIS - THE OAK RIDGE IMAGING SYSTEM
OPERATION'S MANUAL

P. R. Bell and R. S. Dillon*

*Computer Sciences Division

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ABSTRACT

The Oak Ridge Imaging System (ORIS) programs are briefly described in this volume. It is intended as an operators manual but includes program abstracts and instructions for assembling the modules and adding new ones. The instructions are specifically for the RK8E version but apply with minor changes to versions for other OS/8 devices. The system provides for access, storage, processing and display of nuclear medicine images and for any other type of data displayable in image form. The system is not limited to square image arrays nor to any specific size of data arrays below 16K elements.

The complete code package for ORIS is available as MED-8/ORIS from the Biomedical Computing Technology Information Center (BCTIC), Oak Ridge National Laboratory, P. O. Box X, Oak Ridge, Tennessee 37830, telephone number (615) 483-8611, extension 3-0293.

1. Introduction to Volume II

The Oak Ridge Imaging System is intended to provide the small research group or nuclear medicine clinic with facilities to access, store, process and display nuclear medicine images, not inferior to those of the larger research groups with a large central computer. The system allows gradual introduction into a clinic without a large initial expenditure and without incurring a financial penalty for gradual introduction.

The system was designed with the realization that it would not be operated by the clinician, except while establishing new protocols, but by a technician. For this reason analog controls were avoided and objective digital commands used exclusively. By this means a photograph of a patient image using an identical set of commands will be exactly the same whether produced from the data just taken or after the lapse of weeks or months when made from the raw data recalled from tape.

Considerable attention was focused on making the system compatible with routine clinical use. The individual image processing methods run in less than 3 minutes and usually in less than 30 seconds in order to provide immediate processed output. A process that requires an hour will rarely find clinical application. Means are provided for the entry of patient names, numbers, dose and any other needed information in a comment file before the day's runs. These comments can then be attached to each study as it is completed by a short command. It was found that entry of this data between studies caused excessive delay in typing and a tendency

to error due to haste. The comments always accompany the data and are displayed with it so that photographs are pre-labeled. Image processing automatically adds a tag to the comments on the processed image so that photographs are properly identified.

Protection against loss or destruction of patient data is essential and precautions are taken to preserve the raw, unprocessed data by writing it to an image file and by working with copies of the data in separate working areas. Most commands do not modify even this copy permitting quick recovery from operator error. Commands are never "pushbutton" commands but require a definite commit action to execute. As a result of these safety measures only one patient image has been lost here in four years of operation (and that was lost with our earliest program).

An essential for successful image processing is an adequate display without excessive blockiness or confusing artificial patterns. Reasonable economy in data access and storage requires that no more than 2 or 3 data points be taken in each resolution width of the imaging device (camera or scanner). This data contains all the information but it produces a picture with an unsatisfactory degree of blockiness. A 64 x 64 element camera image is adequate to define the data without loss of statistical strength but is too coarse to give a good display. In ORIS the displays are interpolated on the fly during display providing 4 displayed points for every stored data point. The resulting display is smooth and easy to read without incurring the cost in time, core, disk and tape storage that would be required if the original data were accessed with 4 times as many points.

Image file storage for patient records is provided on DECtape, each small reel containing 11 4-view static camera studies, 3 to 5 dual image rectilinear scan studies or one dynamic sequence. Further economy for archival storage is provided by an image compression program that squeezes out the space in the images resulting in 2 to 4 fold storage reduction.

Functional or summary images may be produced to assist the clinician in the analysis of dynamic sequences. These often provide better information than can be seen in the original study. And, in addition, the images can be used to summarize most of the information of a dynamic sequence in 2 to 4 4K-images when storage space requirements do not allow long-time storage of the complete raw data file.

The ORIS system is not a closed system but may be extended to new access, processing or display methods with ease.

This volume of the report is intended as an operators manual describing briefly the procedures for each part of the system. There are many separate "programs" in the system, each providing some kind of access, processing or display process, with each program having also a large repertoire of standard commands as well so that it is generally not necessary to call another program to display, photograph or store the results of processing.

2. Program Overview

ORIS-V2 runs under the OS/8* monitor. The program segments reside on the disk and use of chaining permits extensive processing with essentially modular programs. The program modules are called from the ORIS program by keyboard commands.

The program is started by:

.R OR76(CR)**

ORIS V2 MARCH 76

The initial program contains the SCAN program module and also displays the calibration grid used for oscilloscope adjustment. This grid is dismissed and normal program operation begun by typing:

B(CR)

This BACK command is generally used as an exit from special displays.

Other program modules, area-of-interest tables, flood correction tables and HELP files are called by typing:

CTRL-PNAME(CR)**

where NAME is the 4 character or less name of the item wanted. Table 2-1 contains a partial list of modules. More program segments will be added and the user may add as many additional program modules, AOI maps, flood tables or HELP files as desired.

Any of these programs may be called from ORIS. The HELP files do not disturb the current program and are dismissed by giving any command. The current program resumes. The area-of-interest lists or Flood tables also

*Copyrighted program of Digital Equipment Corporation (DEC).

** Portions typed by the program are underlined. (CR) signifies typing the RETURN key. CTRL-P presents holding down the CTRL key while typing the P key.

† Except for the contour mode where exit must be made by any D or S command.

do not disturb the current program and are available for use after the command. The general programs (like SCAN, CAM4, GH53, etc.) replace the current program. ORIS programs cannot be called from the FOCAL* analysis programs however, and a return to the OS/8 monitor must be made and ORIS recalled by R OR76(CR).

The user may add programs of his own that may be called from ORIS. The programs should be prepared as OS/8 files with a suitable starting address. Note that the OS/8 CHAIN process starts a program at one more than the specified starting address and a suitable safe instruction should be located at the listed starting address so that the program may be called directly [R NAME(CR) from OS/8 or by CHAINing from ORIS].

These programs may be made compatible with ORIS and call other ORIS programs or they may be quite independent and exit by return to monitor. Suggestions for writing these programs are given in Appendix B.

* Copyrighted program of Digital Equipment Corporation. FOCAL is a high level language algebraic interpreter useful for performing mathematical calculations and analysis.

TABLE 2-1

<u>NAME</u>	<u>FUNCTION</u>
SCAN	Rectilinear scan access, process and display of any images larger or smaller than 4096_{10} elements.
CAM4	Static camera image access, formation of Flood tables from flood images and flood correction of camera images.
GS1	Gated static image access gated by any physiological trigger. Like CAM4 except that Flood tables cannot be prepared.
DYN4	Dynamic sequence access and serial repeating display. The NTMAX or FALL summary images are prepared from the dynamic sequence. Any consecutive set of the images may be summed into one image and image smoothing in the time domain can be accomplished. Symmetry images are also provided.
DNF1	An adjustable grid type AOI is provided to form time sequence curves from a dynamic study. Area-of-interest maps may be created or edited and automatic AOI location is provided for vertex brain perfusion studies. Smoothing or flood correction of any consecutive set of the image sequence is provided.
DNF2	Similar to DNF1 except that the independent rectangle AOI is used.
DHB1	Dynamic sequence access program for up to 180 frames of 32×32 element images with access times as short as 0.05 sec. or as long as 40 sec., commands for recovery of any frame, expansion by interpolation to 64×64 and for display of the sequence as a movie are available.
GHS3	Gated heart sequence program for the access and display of an averaged dynamic sequence covering one heart cycle in 12 unequal frames ($8\frac{1}{10}$ cycle and $4\frac{1}{20}$ cycle); any frame may be recovered and expanded by interpolation.

TABLE 2-1 (continued)

<u>NAME</u>	<u>FUNCTION</u>
GHF1	Heart sequence analysis program, determines ejection fraction by ellipsoid method.
FDYN,PLOT F645,P645	Analysis programs for time sequence curve sets formed by DNF1 or DNF2. Interpolates and smooths curves and makes counting loss correction. Hard copy curves are produced on the teletype or a line printer.
TWOD	Two-dimensional Fast Fourier Transform processing for camera images. Arbitrary radial filter functions may be used.
FFT	Produces the real and imaginary frequency images from a camera image.
FFF1	Examination and modification program for frequency domain images. Prepares filters for use by IFFT.
IFFT	Inverse Fast Fourier Transform program. Filters and inverse transforms frequency domain images produced by FFT.
FILE	File management program for storing and retrieving image files on disk and transferring files to DECTape. Types comment files from tapes, provides fast comment scans of image files. Provides for editing individual images onto a tape file.

3. System Layout on the RK8E Disk

The monitor part of the disk, SYS or RKAØ to OS/8, is built in the usual way from BUILD with the following exceptions:

After the \$ BOOT(CR) command has been given to BUILD and the new system starts, the first action must be to place certain blank programs on the first or SYS portion of the disk and on the second or RKBØ portion. An initialization program STORIS should be run to perform the action. The normal OS/8 system is then used to transfer all the normal OS/8 and ORIS programs to the disk. This process is detailed in Appendix A. The program will then be located as shown in Figure 1.

4. Program Command Methods

ORIS operations are controlled by commands given on the keyboard. The commands consist of a command character followed by any arguments required and terminated by a carriage return.* No action takes place until the carriage return key is struck, and an erroneous command may be deleted by striking the RUBOUT key at any time before the RETURN key has been typed. A question mark, carriage return and line feed will follow striking the RUBOUT key. There are two command modes, each with their own set of command characters. The data handling mode contains most of the commands, while the access mode contains only those commands that pertain to image access actions. The two mode arrangement prevents operator errors that might cause loss of a patient image since only those commands belonging to the current mode will be recognized. A command of the other mode or any non-command character will produce a question mark and will be ignored.

All programs start execution in the data handling mode and transition to the access mode is made by the command:

CTRL-A(CR)[†]

Exit from the access mode is secured by CTRL-O(CR) or CTRL-P(CR) depending upon the particular access program. Due to the large number of commands in the data handling mode a supplementary command list has

* An exception to this rule occurs in the comment mode when text is being entered, the CTRL-K and CTRL-FORM commands require no carriage return.

[†] CTRL-A means depressing and holding the CTRL key while typing the A key. (CR) means typing the RETURN key.

been provided. This list is entered by using CTRL-C as a command character followed by a command word, for example: CTRL-C MON(CR) produces a return to the system monitor.

Some commands require numerical arguments for their action, see for example, the Dn and Sn commands below. These arguments are entered as decimal numbers following the command character, then followed by a carriage return. A few commands require two arguments (Contour and Multiprocessor) which is accomplished by entering the command character, the first argument, carriage return, and then the second argument followed by another carriage return.

5. Command Lists

The main program segment contains many general commands concerning the display, the storage of images, image file management, processing by smoothing, anti-scatter and anti-penetration correction, edge sharpening by second derivative, adding or subtracting images, quantitation marks and entering, attachment or editing of image comments. These general commands are always available.* Each program module has in addition a number of commands of its own. These commands are listed in the following sections. Help files are supplied to remind the operator, should he forget, of the form and brief function of the commands.

* A very few general commands may be made unavailable by individual program modules due to incompatibility. This is controlled automatically by the command list of each module.

6. Image Display

While in the data handling mode, images are displayed by interpolation on the fly. That is, a data point is displayed, followed by a point that is the average of that data value and the next one, then the second data point is displayed and so on to the end of an image line. The next line consists entirely of interpolated points. Alternate points of this line are averages of the stored data for the neighboring lines. The points between are averages of the already averaged neighboring points on its line. In this way 4 points are displayed on the screen for every data point in core. This provides a very smooth image without the need for taking or storing a larger number of data points. Thus the data is sampled efficiently while the needs of the observer's eye are satisfied. Images displayed in the access mode are not interpolated since the computer is heavily loaded and the images are generally used for operator assurance only during this period.

7. Brief Command Lists

7.1 General Commands for ORIS Imaging Program

Most commands in this list apply to all the programs with the exceptions noted in other lists.

Note: Commands echo the character typed, except for control codes (e.g., CTRL-C, CTRL-D, etc.).

Display Commands

Dn(CR)	Display scale, D7 - data x 4, D6 - data x 2, D5 - as recorded, D4 - x 1/2, D3 - x 1/4...D0 - x 1/32.
Sn(CR)	Subtract n counts from each element.
En(CR)	Extend image to n units between points.
X(CR) or X-(CR)	Flip X coordinate of image X = Normal, X- = Reverse.
Y(CR) or Y-(CR)	Flip Y coordinate, Y = Normal, Y- = Inverted.
Yn(CR)	Invert and raise n units from bottom.
Pn(CR) or P(CR)	Photo, n sweeps. Remembers n. P(CR) uses remembered n. Initial value of n is 5.
Cn(CR)m(CR)	Contour, counts from n to n + m - full intensity, others 0. Exit by Dn(CR).
Vp(CR) or V(CR)	Drops contour by m every p sweeps, remembers p.
F(CR) or Fn(CR)	Forward, displays next 4 K of image. Fn-start current 4K image at line n. Not available in 4K only image programs like CAM4.

GENERAL

B(CR)	Back, return from forward, etc. Usual exit from special effects except contour.
T(CR)	Total, display all segments of image. Has repeating movie function in DYN4, DHB1, GHS3.
Zn(CR)	Profile of Z cut at line n (or column n).
Z100(CR)	Shift to ZY (column) cuts.
Z99(CR)	Shift to ZX (line) cuts.
M(CR)	Multicycle contrast enhancement mode exit by MM(CR).

GENERAL

All commands in this section cause a fresh image to be fetched from the working area except for the E, X, Y, and P commands.

Quantitation Marks

0(CR)	Light up marks.
1n(CR)	Move upper left corner of marks to line n.
2n(CR)	Move upper left corner of marks to element n on the line.
3n(CR)	Make mark rectangle n lines high.
4n(CR)	Make mark rectangle n elements wide.

Quantitation mark commands may be given repeatedly and in any order except for 0 which should be given first, once, whenever a new image without marks is showing.

K(CR)	Print sum of elements inside rectangle.
K (CR)	Type out elements in rectangle in array format.

GENERAL

GENERAL

Image Manipulation

N(CR) or NN(CR)	View and use lower working area (N), or upper working area (NN). Lower working area usually contains the upper scan head (detector) image.
=(CR)	Copy image in view into other working area.
+n(CR)	Add to image in view and display tentatively, n times image in other work area, n = 1000 = 1.00 times. Limit 2.000.
-n(CR)	Same as above but subtract.
+ or - 4000(CR)	Commit full image to add or subtract using current factor.
Rn(CR)	Read image n from image file to viewed working area.
R(CR)	Report number of images and free 4K blocks in image file.
CTRL-W(CR)	Write image in view to image file. In this case, a W is echoed.
CTRL-Dn(CR)	Delete image n from image file, rewrite and renumber file to recover vacated space.
CTRL-CERASE	Reset image file index to empty. Not needed before refresh or dynamic sequence access.
\$(CR)	Refresh image file from file tape on Unit 1.
\$(CR)	Dump image file to file tape on Unit 1. Tape must be WRITE ENABLED.
CTRL-A(CR)	Go to image access mode. Some programs do not have an access mode.

GENERAL

Q(CR) Quit; stop action, wait for command.

CTRL-CMON Data handling mode only. Exit to disk monitor.

GENERAL

Image Processing

Processing commands are inserted as a stored command string. For example, CTRL-NA3,P4(CR). All processing commands or command strings must be preceded by CTRL-N.

An Average (smooth) with weighting matrix n, WEIGHT = 4. Table of matrices shown on HELP file HLAV.

Sn Same as An, except WEIGHT = 1. For floods, very intense images.

Bnm Bound at n standard deviations from average m. $n = 1:1/\sqrt{2}$ standard deviation, 2:1 standard deviation, 3: $\sqrt{2}$ standard deviations. Should be used on raw data only.

Fn Fine anti-scatter and anti-penetration correction. Uses matrix table n. The table is shown on the HELP file HLPR. "An" is usually used instead.

Pn Coarse anti-scatter and anti-penetration correction. Using table n shown on HLPR. When used with Fn, Pn must follow and n must agree in each or be omitted after P.

Vn Validate image. n sets standard deviation; see Bnm.

CTRL-CSC(CR) Execute prestored command list.

GENERAL

GENERAL

Comment Manipulation

The comment file is on the disk immediately following the image file and is unaffected by dumping or refreshing the image file.

"(CR)	Add comments in view to comment file.
"n(CR)	Get comment n from comment file and attach to the image in the working area in view. Overwrites any comment already there.
"32(CR)	Erase comment file index. Next "(CR) will put comment into file location 1.
CTRL-CNOTE(CR)	Enter comment mode. Available in data processing mode in all programs and in access mode SCAN. All input is entered as text and displayed. Maximum comment size is 127 characters including spaces, carriage returns, and the automatically entered line feeds.
CTRL-K	Kill buffer content.
RUBOUT	Delete one character with stroke.
CTRL-FORM	Leave comment mode, return to normal command mode.
CTRL-CPUT(CR)	Make comment permanent by attaching it to the image in view. The comment may be transferred to the comment file without making it permanent by the "(CR) command.

Comments entered from the access mode of SCAN are automatically attached to both images of the pair when exiting from access by CTRL-0 or by automatic exit. In data handling mode comments must be attached to the image in each working area separately by a CTRL-CPUT(CR) or by a "n(CR) command.

SCAN

SCAN

7.2 Commands for Rectilinear Scanner Program SCAN

Data Access (Acquisition or Scanning) Mode

CTRL-A(CR)	Enter access mode from data handling mode. Starts data access.
G(CR)	Start access again. Used after any interruption that requires the scanner to be returned to restart. All previous input is ignored.
Dn(CR)	Set display level. D3 = data x 1, D0 = data x 1/8. Does not affect data being recorded.
U(CR) or UU(CR)	View upper head (U) or lower head (UU) data. Does not affect data being recorded.
C(CR)	Enter comment mode. See CTRL-CNOTE above.
CTRL-FORM	Leave comment mode; see above.
O(CR)	Order scan in array format, enter comments, if any, give message: TYPE ID:, wait for ID number to be entered in the form INNN(CR) where NNNN is a decimal number less than 4096, and go to data handling mode. The images are only in the working areas of the disk, not yet on the image file. Each image must be saved separately by using CTRL-W and N commands.
CTRL-P	Stop, go directly to data handling mode ignoring any images being accessed.

CAM4

CAM4

7.3 Commands for Static Camera Access Program CAM4

Data Handling Mode

All data handling commands are standard with the addition of the following:

CTRL-CFLOOD(CR)

A camera flood image must be in the working area in view. A flood correction table is prepared in Field 2. An image showing those elements that are outside $\pm 15\%$ of the average is stored in the working area and displayed. When the program returns to display, type CTRL-CMON; to the monitor's dot, type SAVE SYS Fxxx 20000-27777; 4344(CR). This will save the flood table for later use. Alternatively, the table can be used at once for flood correction without saving it.

CTRL-CFC(CR)

Flood correct the image in view. The image must be in D5(CR), S(CR) and M(CR) display state and a suitable flood correction table must be in Field 2. A tag of FC is appended to the comments of the image in the working area.

H(CR)

Type out a histogram of the data within the quantitation rectangle. The data of the displayed image is used and the lowest 5 bits are all that are considered. The range of the image displayed thus should be reduced to $0-31_{10}$ before calling H.

Data Access Mode

CTRL-A(CR)

Go to data access mode, display image in non-interpolated mode and wait for command.

CAM4

CAM4

Tn(CR) Set prestored time for image in seconds. Limit 4095 seconds. This value is saved and does not need to be reentered. A default value of 20 seconds is present initially.

Kn(CR) Enter prestored count in thousands of counts. Limit 4 million counts. This value is retained for repeated use. A default value of 200 (200000 counts) is initially present.

GT(CR) Go for the predetermined number of counts. Exit is automatic for both modes. Time and counts are reported:
 NNNNNNNN COUNTS MMMM SEC
 TYPE ID:
 Enter the ID in the form: INNN(CR), where NNNN is a decimal number less than 4096. The image will then be transferred to the working area and the program will return to data handling mode. The printed counts will be 0 for the predetermined count.

CTRL-O(CR) Stop, give typeout and wait for ID as above.

CTRL-P(CR) Stop, go to data handling mode, abandon image in core.

Dn(CR) Change display scale, D5 - data x 1, D0 = data x 1/8. Does not affect the data being recorded.

GS1

GS1

7.4 Commands for Gated Static Access GS1

Data handling commands are the same as CAM4 except that a flood table cannot be prepared by GS1.

Data Access Mode Commands

CTRL-A(CR)	Enter access mode. Filling of the 16 word physiological trigger interval buffer begins.
KNNN(CR)	Number of thousands of counts to be accepted. Default is 200.
BNNN(CR)	Number of cycles to be counted, default is 320.
Hn(CR)	Number of 1/8 cycles to hold off before starting the access each cycle. Default value is 7.
On(CR)	Number of on 1/8 cycles for each access. Default is 1.
GB(CR)	Go for the predetermined number of beats (physiological signals).
GC(CR)	Go for the predetermined number of counts.

On automatic exit the number of counts and cycles is typed and an ID is asked for:

<u>TYPE ID:</u> INNN(CR)	Enter ID number NNNN.
--------------------------	-----------------------

DYN4

DYN4

7.5 Commands for Dynamic Access Program DYN4

Data Handling Mode Display Commands

Most commands are standard except that the T command is greatly altered and many image processing commands have been added.

Tn(CR)

Display images 1 through n as a repeating movie. A "bouncing ball" moves along the bottom edge of the image to indicate the position in the time sequence.

Image Manipulation

CTRL-C+(CR)n(CR)m(CR)

Images n through m are summed and the result is put in the working area in view.

Image Processing

On(CR)

NTMAX. Images 1 through n are searched and an NMAX image is formed in upper working area (NN), a TMAX image is formed in the lower working area (N). In NMAX each element contains the maximum value that element attained anywhere in the series, if it exceeded a count of 3. In the TMAX image, each element contains the time (frame number) at which the maximum was attained. The time is recorded inversely, maximum for the first frame 0 for the nth. The value is: (n - frame number of maximum)*4.

DYN4

DYN4

Fn(CR)

FALL. Form a normalized image in the lower working area whose elements contain the activity at TMAX + 5 frames divided by the activity at TMAX. Areas that clear slowly are brighter, areas that clear rapidly are darker. The FALL image is quite noisy and must be smoothed (typically by CTRL-NB13,A3(CR)) before evaluating. NTMAX must be executed just prior to FALL as FALL uses the NTMAX tables in Field 2 and 3 as data. The n parameter should agree with that used in the NTMAX command.

Jn(CR)

Time smooth (TSM). The sequence in the image file is smoothed (averaged) in time only. Each element in the n images is replaced by: $C(k) = C(k-1) + 2 \cdot C(k) + C(k+1)$. At the ends, $C(1) = 3 \cdot C(1) + C(2)$ and $C(n) = C(n-1) + 3 \cdot C(n)$. This smoothing, resulting in a weight of 4, is used for weak sequences to yield a good NTMAX.

*n(CR)

SYM. Form a symmetry image from the image being displayed. D and S should be adjusted suitably. Image should be in a multicycle mode (M(CR)). n is the number of the column of symmetry (usually near 32) and is remembered. Find this line by using the Z cut in ZY mode on the pseudo-static image at the end of the series. Symmetrical elements are compared, the larger is made bright, the smaller is set to Ø (black).

Dynamic Sequence Access

CTRL-A(CR)

Transfer to access mode; display image noninterpolated at a fixed size. Ready to set sequence timing or to go.

DYN4

DYN4

CTRL-P(CR)

Return to data handling mode.
Abandon any data taken. May leave
image file incomplete if given
during access.

G(CR)

Begin sequence. Exits to data
handling mode upon completion
with last image (pseudo-static
image) in the working area.
Attach comments ["n(CR)] and
save by CTRL-W(CR).

T(CR)

Enter access sequence numbers
and times. Answer each typeout
by a number and CR to enter new
value, by CR to keep default
value. Typeout is:

REPEAT 30	Number of first series images, default number is 30.
TIME 10	Number of tenth seconds, default 10.
REPEAT 14	Number of second series images, default number is 14.
2ND TIME 20	Number of tenth seconds, default is 20.
STAT 1000	Time of static images, default 1000 = 100 SEC.

Dn(CR)

Set access display level from
D0(CR), Data*1/32 to D5(CR),
Data*1.

DNF1

DNF1

7.6 Commands for Dynamic Processing Program DNF1

DNF1 has no access program and is used for processing dynamic image sequences. The display commands are similar to CAM4 except for extensive changes in the quantitation mark commands.

Image Manipulation

CTRL-C+(CR)n(CR)m(CR)* Images n through m are summed and the result is put in the working area in view.

Image Processing

1n(CR) Move upper left corner grid to line n.

2n(CR) Move upper left corner of grid to element n on present line.

3n(CR) Make each mesh of grid n lines high.

4n(CR) Make each mesh of grid n elements wide.

Ø(CR) Lights up mesh.

L(CR) LOCATE. Automatically center grid mesh on a vertex view brain image and display it. Ready for the Øn(CR) command.

Øn(CR) DYNFCN. Form AOI table in Field 3 from AOI list in 7600 page, Field 3; form double precision time function curves for each area-of-interest for n images, store curves in working area and display as an image. Includes a curve of the total count in each image. The AOI table must be present in Field 3. (see 1, 2, 3, 4, and Ø commands above.) The curves may be displayed by the Z profile commands and may be processed by FOCAL program FDYN.

DNF1

DNF1

ANM(CR)J

Mesh edit command. Enters letter J in mesh NM in image and in list in 7600 page of Field 3. J does not echo. If J is a space key, content of mesh is erased. When a mesh list is finished it may be saved by returning to monitor [CTRL-CMON(CR)] and typing: SAVE SYS A0In 37600;4344(CR).

!(CR)STRING(CR)

Enter prestored process command string. STRING is a series of process command characters and arguments separated by commas. Example: !A4,P2(CR) will command average with matrix 4 (sharp), followed by anti-scatter and anti-penetration processing with process matrix 2.

CTRL-Mn(CR)p(CR)

Process images n through p using the prestored command string.

CTRL-CMFC(CR)n(CR)

Flood correct n images. The appropriate flood correction table must be in Field 2.

DNF2

DNF2

7.7 Command List for Arbitrary Rectangle AOI (DNF2)

All commands except those involving the AOI table are the same as for DNF1. Thirty-one rectangles (1 through 31) may be entered and any number may be assigned to each of up to 31 areas of interest. Individual rectangles may have any size and may overlap. In the overlap, the highest numbered rectangle is written last and overwrites the previous entries on the overlap. Note that areas illuminated in the image remain, so that several areas may be examined together. The lit up areas are removed by typing S(CR) or any other command that replaces the image with a fresh copy from the working area.

Quantitation marks are as usual except that Ø(CR) and Øn(CR) are special.

Ø(CR)	Light up all rectangles at locations determined by the current 1 and 2 commands.
Q(CR)	Blackout the image in all areas covered by the rectangles.
L(CR)	Locate the AOI map automatically on the vertex view brain image.
Øn(CR)	Form time activity curves from n images for all rectangles and displays as an image.

Rectangle Editing Commands

An(CR)J	Enter current quantitation mark rectangle as number n, part (or all) of area J.
An(CR) (SPACE)	Erase rectangle n.

DNF2

DNF2

A(CR)@

Erase AOI list.

An(CR)@

Light up rectangle n.

A(CR)J

Light all rectangles of area J.

A(CR) (SPACE)

Light all rectangles.

FDYN,PLOT

FDYN,PLOT

7.8 Commands for FDYN,PLOT

FDYN and PLOT are FOCAL programs for the reduction of time activity curves produced by DNF1 or 2 and for plotting the curves on the teletype.

FDYN is called from ORIS by:

CTRL-P FDYN(CR)

The program types an asterisk and is ready for commands:

*G(CR)
NO. OF 1 SEC IMAGES: 30(CR)

Go.
Answer number of images (typically 30).

2 SEC IMAGES: 14(CR)

Answer number of images (typically 14).

LAST AOI: n(CR)

The number of the last AOI to be processed starting with A=1...M=13... The program proceeds to completion and types an asterisk. At this point return to the monitor by typing an asterisk and carriage return:

**(CR)

Return to monitor. The processed curves are now in the ORIS lower working area. If plots are wanted call PLOT:

.R PLOT(CR)

PLOT types an asterisk and is ready for command:

*G(CR)

Go.

LAST AOI: n

Answer with the number of the last AOI to be plotted. When the plots are complete, return to monitor by:

**(CR)

F645,P645

F645,P645

7.9 Commands for F645,P645

F645 is a FOCAL program like FDYN. It uses the same commands as FDYN. It stores the processed time-activity curves in the lower working area but it also leaves a set of scaled curves and scale labels in Field 2 for the use of P645.

Commands for P645

There are no specific commands for P645. After F645 has run return to monitor by: **(CR). Then turn on the line printer, type: .R P645(CR). The plots will be printed on the line printer and the program will exit to monitor.

GHS3

GHS3

7.10 Commands for Gated Heart Sequence Program GHS3

The commands in the data handling mode are standard with the following exceptions:

1. The T command has been changed to display the 12 image sequence as a repeating movie.
2. The GETNTH and Interpolate commands have been added to select and expand any member of the sequence.

The new data handling mode commands are:

Tn(CR)	Display the 12 image sequence as a repeating movie. Each frame is displayed n times before going to the next.
Gn(CR)	Get the nth frame of the sequence into the current working area. This should not be done from the T mode. The original image must be recovered from the image file before another Gn command is given.
I(CR)	Expand by interpolation the 32 x 32 image in view to 64 x 64 elements.

Access Mode Commands

CTRL-A(CR)	Go to access mode, start filling the beat buffer. This command, of course, is a command of the data handling mode.
G(CR)	Go, begin accessing an image. Exit is automatic at the end of the preset number of beats (currently 320).
Dn(CR)	Display intensity, same as for CAM4.
CTRL-P(CR)	Exit from access mode retaining the image so far collected.

GHF1

GHF1

7.11 Gated Heart Sequence Analysis Program GHF1

GHF1 has no access mode.

Editing of the independent rectangle list is the same as for DNF2.

Area-of-Interest Commands

1n(CR)	Move the area-of-interest reference point to line n.
2n(CR)	Move the area-of-interest reference point to element n on the current line.
Ø(CR)	Illuminate the area-of-interest.
Ø1(CR)	Set all points of the image <u>outside</u> the area-of-interest to zero. The area inside is retained at the current D, S, and M conditions.
+ (CR)	Transfer the image in view to the current (active) working area at the conditions set by the current D, S, and M commands. This overwrites the current content of the working area.
CTRL-CAREA(CR)	Type the total of all non-zero elements within the quantitation mark rectangle.
CTRL-CDIAG(CR)	Type the length of the diagonal of the quantitation mark rectangle.
CTRL-CCUT(CR)	The elements of the image inside the current quantitation rectangle are set to Ø.

DBH1

DHB1

7.12 Commands for the Fast Dynamic Access Program DHB1

Image Handling Mode Commands

Tn(CR)m(CR)	Display in movie mode from image 4(n-1)+1 to 4(m-1)+4. That is start with frame n (containing 4 images) and display through frame m then repeat. B(CR) is exit from this display.
Gn(CR)	Get image n from the file n=1 to 180.
I(CR)	Expand the 32 x 32 image to 64 x 64 by interpolation. This image replaces the previous contents of the working area.

Access Mode

CTRL-A(CR)	Enters access mode.
T(CR)	Start dialog to enter times and frame numbers for access.
<u>REPEAT</u> : n(CR)	Take n frames of 4 images each.*
<u>TIME</u> : XY(CR)	Time per image in units of .01 sec. Values below 5 (0.05 sec) are illegal.
<u>REPEAT</u> : m(CR)	Number of frames of second section in units of 4 images).
<u>2ND TIME</u> : VW(CR)	Time per image in units of 0.01 sec.
<u>STAT</u> : AB(CR)	Time per frame for each of the 4 "static" images in units of 0.01 sec limit is 4095 = 40.95 sec.

*Number of first + second + one static frame must not exceed 45.

DHB1

DHB1

G(CR)

Start access. Exit is automatic to data handling mode. The 4 static images have not been written to the file. Attach comments and write to file CTRL-W(CR).

CTRL-P(CR)

Return to data handling mode and abandon sequence.

TWOD

TWOD

7.13. Commands for the Fast Fourier Transform Program, TWOD

This is an ORIS preliminary program. The TWOD program does a direct two-dimensional Fast Fourier transform on the image in the current working area. It then multiplies the transformed data by a radial filter function, then performs an inverse two-dimensional transform and writes the transformed image back to the current working area. The radial full field filter is formed by the program from a list of radial values located in the 2600 page. Calculations are done in integer arithmetic with automatic scaling of data to prevent overflow. The average value of the image is determined and subtracted before processing and it is restored following inverse transformation.

The program is called by:

CTRL-PTWOD(CR)

when processing is complete the previous program is recalled and the image is displayed. The program expects a radial filter function list to be present in the 2600 page of Field 0. This filter must be called before TWOD by:

CTRL-P XXXX(CR)

where XXXX is the name of the filter wanted.

FFT

FFT

7.14 Commands for the Direct Two-Dimensional Fast Fourier Program - FFT

This is an ORIS preliminary program. It is a subset of TWOD. The subtraction of the average value of the image is not performed. The real part of the transform is written to the current working area but the imaginary part is left in Field 2. The companion program FFF1 provides for manipulation of these images.

The program is called by:

CTRL-PFFT(CR).

The program returns to the calling program with the real part image on display and the imaginary part still in Field 2.

IFFT

IFFT

7.15 Commands for Inverse Two-Dimensional Fast Fourier Transform Program - IFFT.

This preliminary ORIS program is a subset of TWOD. It multiplies the real part of the transform in the current working area and the imaginary part of the transform in Field 2 by the full field filter function it finds in Field 3. After the multiplication the inverse two-dimensional transform is performed and the real part image is stored in the current working area, overwriting the previous contents. The imaginary part of the result is left in Field 2. Negative values in the real part have been set to zero. The companion program FFF1 may be used to store or examine the imaginary part.

The filter function in Field 3 is formed by FFF1 or may be called from the disk before calling IFFT.

The program is called by:

CTRL-PIFFT(CR)

Upon completion, it returns to the previous program.

FFF1

FFF1

7.16 Commands for Frequency Image Manipulation Program - FFF1

This is a preliminary program module for ORIS. The real and imaginary images produced by FFT have negative as well as positive values and cannot be adequately displayed by the usual programs. Special commands convert negative values to zero or make negative values positive so that normal displays result.

CTRL-CNEG(CR)	Make negative values in image zero. Does not affect the data in the working area.
---------------	--

CTRL-CPLUS(CR)	Make negative values positive. Does not affect data in the working area.
----------------	--

The program contains the standard independent rectangle quantitation mark arrangement (see DNF2). A filter for use by IFFT can be created in Field 3 by the commands below.

CTRL-CKILL	Zero Field 3 to prepare for a filter.
*(CR)	Set filter factors within quantitation mark area to "1" in Field 3.
**(CR)	Set filter factors within quantitation mark area to "0" in Field 3.

The location of the filter segments may be ascertained by:

%(CR)	Clears all image except AOI areas.
%%(CR)	Clears AOI areas of image.

FFF1

FFF1

The current image or the imaginary part in Field 2 may be stored in the current working area by:

+ (CR)

Save current image, as it is being viewed, in the current working area.

++ (CR)

Save the image in Field 2 in the current working area.

FILE

FILE

7.17 Commands for the File Management Program - FILE

The FILE program is used to transfer whole image files between the active image file IF0 and the file save areas IF1 - IF6 on the disk. It also provides for transferring image files from the save areas to DECtape, transferring individual images from the working areas to tape, for typeout of all the comments of a file on the tape and for quick examination on the CRT of all the comments of images in the active image file IF0.

The program is called by:

CTRL-PFILE(CR)

and return to the previous program is done by:

RE(CR).

All commands for FILE require two letters with or without arguments.

GE _n (CR)	Get file in save area <i>n</i> into IF0, the active image file. Previous contents of IF0 are overwritten and the content of IF _{<i>n</i>} is unaffected.
GE(CR)	Type numbers of occupied save areas.
PU(CR)	Put the file in IF0 into the first unoccupied save area, type number of area used.
DE _{m,n,o,p} (CR)	Delete files <i>m,n,o,p</i> from the save areas. Only the index is changed. If a file has been deleted in error, the file may be recovered if a new one has not yet been written over it by using the GE _{<i>n</i>} command which does not consult the index.

FILE

FILE

WRn(CR)	Write save file n onto DECTape on unit 1, the tape must be write enabled. Content of save area n is not changed.
TP(CR)	Append the image in the current working area to the DECTape on unit 1, the tape must be write enabled.
TP1(CR)	Write an empty index block on the tape unit 1, tape must be write enabled.
TY(CR)	Type out all the comments on the tape on unit 1.
RRn(CR)	Read image n from the active image file IF0 into the current working area. Same as Rn(CR) in the other programs.
NN(CR)	Change to the lower working area.
NN1(CR)	Change to the upper working area.
CO n(CR)	Display the comments of the active image file starting at image n. In this mode striking the space bar advances to show the next comment. A carriage return is used to exit from this mode.
RE(CR)	Return to the previous program.

8. Program Description and Operation

There are roughly two classes of commands in the ORIS system: those that are standard throughout all the programs, and those that are specific to one individual program. The dividing line between these two command classes is not precise, but does allow a reasonable basis for presenting the operational aspects of the system. Consider first the general commands.

8.1 General Commands for ORIS

When ORIS is called, it starts by typing the current version of ORIS on the teletype followed by a display of the calibrating grid on the CRT. The grid display allows adjustment of the display for focusing and size adjustment. The grid should delineate squares (not rectangles). The program is now ready to accept commands from the teletype. Commands require a carriage return to start execution. A rubout commands the program to disregard the entire command. The first subclass of the general commands are the ones altering the display. These affect only the image stored in the display buffer (Field 1 of the computer). They do not affect the working areas or the image file.

Display Commands

B(CR)

Back. Usual exit from special display effects, such as Z-Cuts, Total, Forward, Isometric or Time sequence displays. Calls a fresh image from the disk.

Dn(CR)

Display Scale. Sets the scale factor for the data being displayed. The scale factors are given in the table below. Causes a new image to be read from the current working area.

<u>n</u>	<u>factor</u>
0	1/32
1	1/16
2	1/8
3	1/4
4	1/2
5	1
6	2
7	4

Sn(CR)

Subtract. n counts are subtracted from each image element. This is in effect a background erase or thresholding. The scale factor (Dm) is applied to the data after the subtract is done. Causes a new image to be read from the working area.

En(CR)

Extend. The image is displayed with n spaces placed between each data point or interpolated point. Does not cause an image read, but does reset the X and Y commands back to normal. If too large an E value is requested, wrap around will occur.

X(CR) or X-(CR)

Flip X. Image is reversed right to left. X = normal, X- = reverse. Does not cause an image read.

Y(CR) or Y-(CR)

Flip Y. Image is reversed top to bottom. Y = normal, Y - = reverse. Does not cause an image read.

Yn(CR)

Perform a Y- and raise display n units from bottom of CRT.

Pn(CR) or P(CR)

Photo. Provide a means of taking a picture. After command is given, the screen will go blank for a short time, and teletype bell will ring, signaling operator to open the camera shutter. n sweeps of image then occur after which the bell is rung again to signal shutter closure and the screen blanks temporarily. Extra sweeps of the comments are to aid when photographing small (low E value) images. n is remembered so that once given, only P need be commanded again.

Cn(CR)m(CR)

Contour. Display at full scope intensity an image of those elements whose values lie between n and n+m. All other elements are displayed at zero intensity. The data is reduced by the current subtract value, but is not scaled according to the current D-level. Exit from this mode is by any D command.

Vp(CR) or V(CR)

Variable Contour. Display successive contour images made by decreasing the contour level n (from contour command) by m counts each p sweeps. Uses arguments provided by most recent contour command. Once sequence has reached the lowest contour, it will remain at this display level until ordered otherwise. The p value is remembered and need not be given again. This level regression permits the whole image to be examined for contour irregularities without missing any region. When the level has ceased to fall, the display is still in the contour mode and exit to the normal display is secured by a Dn command.

Zn(CR)	Z Profile. Display an intensity versus position plot of line n (or column n). A line of full intensity through the image at line n is also displayed to indicate exactly where the cut was made. The current D and S levels determine the magnitude of the plot.
Z100(CR)	Change Z-cut mode to produce vertical (column) cuts.
Z99(CR)	Change Z-cut mode to produce horizontal (line) cuts.
M(CR)	Multicycle contrast enhancement mode (MCCE). In the non-MCCE display mode, the data is limited to 37_8 units in the display, i.e. all image elements greater than 37_8 are reset to 37_8 , which is the maximum intensity that can be displayed on the CRT. MCCE inhibits this limiting process so that the data in the display buffer (Field 1) are their proper value for the prevailing D and S levels. However, since only the low order 5 bits determine the CRT intensity, the data is displayed modulo 40_8 . For example an image element of 37_8 would be represented by a full intensity dot on the scope, but an image element of 40_8 would have zero intensity. Thus a pattern of cycles are displayed providing a better quantitation of the image intensities. When the program is first started it is in the MCCE mode.
MM(CR)	Return to limited mode. Both M and MM cause a read from the working area.

N(CR)	Display the contents of the lower working area and use this image for picture display and processing.
NN(CR)	Shift to the upper working area.

Quantitation Marks

The quantitation marks are available in most, but not all, programs. They provide a means of specifying a rectangular portion of the image for some special process. The marks delimit the four corners of the rectangle with the upper left hand mark lying inside the rectangle.

Ø(CR)	Light up the marks. This action also saves the values of the four data elements which were used to display the marks.
-------	---

The following commands move the rectangle (1 and 2) and change its size (3 and 4). They also restore the image values saved by the Ø command and save new values at the new location.

1n(CR)	Move the upper left corner of the rectangle to line n.
2n(CR)	Move the upper left corner of the rectangle to element (column) n of the current line specified by the 1 command.
3n(CR)	Make the rectangle n lines high.
4n(CR)	Make the rectangle n elements wide.

The commands may be given in any order, except the Ø command should be given first when using a new image without any marks displayed. None of the commands cause a read from the working area.

Print commands using the rectangle made from the marks:

K(CR)	Print the decimal sum of the elements inside the rectangle (at the current D and S levels).
K1(CR)	Type out the decimal value of the elements within the rectangle in array format (at the current D and S levels). The full value at which the data was accessed may, of course, be obtained by setting D5, m, and S0, then giving the 0 command before K or K1.

Image and Image File Manipulation

The following commands, in general, change either the contents of the working area or the image file. The current values of D and S are applied to the image in the active working area when the display is resumed but do not otherwise affect the data transferred.

=(CR)	Copy. The image in the area being displayed is copied into the inactive working area. Note that the display values (e.g., D, S) do not affect the contents of the working area.
+n(CR)	Using the display buffer, add n times the image in the inactive working area (area not being displayed) to the image currently being displayed. The fractional addition takes place between the actual values in the working areas and the result is displayed at the prevailing scales (D-level and S value). The resulting display image is tentative in that the active working area has not been changed, only the display buffer. Any command

that requires a read from the working area will cancel the addition. n is scaled by a factor of 1000 so that $n = 1000$ will yield a multiplying factor of 1.00. The maximum range allowed is $0 < n < 2000$. Since the multiply routine is used regardless of the value of n supplied, some roundoff error can result even when adding 100% of one image to the other.

-n(CR)

Same as above, except the image in the inactive working area is subtracted from the image in view.

+ or -4000(CR)

The current addition or subtraction factor is applied to the complete image, with the resultant image being stored in the active working area. The modified image can now be manipulated by any of the usual commands. One should avoid many successive additions and subtractions because of the accumulation of roundoff errors. The image sum and difference is used to correct an image for source decay, differences in dose or for differences in scanning speed or access time. Better comparisons may be made in this way of images of a patient obtained at different times.

Rn(CR)

Read. Image n is read from the image file into the working area being viewed and is displayed.

R(CR)

Type the number of images in the image file and the number of free 4K blocks. This typeout is also produced if a value of n greater than the number of images in the file is specified.

CTRL-W(CR)	Write. The image in the active working area is written onto the end of the image file. The content of the working area is not changed.
CTRL-Dn(CR)	Delete. Image n is deleted from the image file and the file is rewritten so that the space gained by the deletion is placed at the end of the file. Thus all images greater than n are renumbered. The CTRL-D is not echoed.
CTRL-CERASE	Reset the image file index to empty, thus in effect deleting the entire image file. This is not needed before a refresh or a dynamic sequence access.
#(CR)	Refresh. Refresh the disk image file from the DECTape mounted on Unit 1. The tape does not need to be Write Enabled. The contents of working areas are not affected.
\$(CR)	Dump. The contents of the image file are written onto the DECTape on Unit 1. The tape must be Write Enabled. The current contents of the image file on the disk are not disturbed.
CTRL-A(CR)	Transfer to the image access mode and activate the access command list. This is not available in those programs with no access routines.
Q(CR)	Abort. Stop the current action and wait for a command. This action is sacrificed in some of the programs.

CTRL-CMON(CR)

Call the Monitor; abandon the current program.

CTRL-PNAME(CR)

Call from disk the program module NAME. The name must be 4 or less characters long. The current special program module is saved. Programs thus called may use some or all of the current program which is still in core unless overwritten. The called program may remain in core, may exit recalling the previous program (by going to RECOVER) or may CHAIN to another program module as needed.

CTRL-TNAME(CR)

Call the program NAME from the DECTape on unit 0. Tape need not be write enabled, otherwise same as CTRL-PNAME above. For users with small disks.

8.2 Image Processing

8.2.1 Command string and tag insertion

Perhaps the most fundamental technique ORIS has to offer is its matrix image processing capability. By means of a set of symmetric 7×7 matrices, many different processes may be accomplished, including smoothing (or averaging) employing least squares fitting, bounding, anti-scatter and anti-penetration correction, and edge sharpening. The commands are entered via a string which permits a variety of different processes to be carried out sequentially on the image. Processing changes the data in the active working area and displays the results when the process is completed. A tag is appended to the image comments describing what processing was done.

An example of a processing command string is:

CTRL-NB13,A3,P2(CR)

With the current assignments in the matrix tables, this command causes the image in the working area being viewed to be bounded within 0.71 standard deviation of the fitted value using a 5×5 element matrix giving a least-squares fit to a two dimensional quadratic. The image is then smoothed by a fit to the same matrix (No. 3) with a weight of 4. After this action, the anti-scatter and anti-penetration processing is carried out using coarse processing Table 2. The image is then displayed. The processed data has replaced the previous content of the working area on view. The previous comments of the image will have the following tag appended:

B13A3P2

It is not necessary or economical to save the processed image on the image file since the raw data is already there and the process may be repeated with identical results if it is needed again.

If the operator has forgotten which numbers correspond to what he has merely to type:

CTRL-PHLPR(CR) for the anti-scatter, anti-penetration correction matrices, or

CTRL-PHLAV(CR) for the averaging matrices
to display the list. Give any command to continue.

Averaging or Smoothing

ORIS processing is done in integer arithmetic and the image files are integer files. When smoothing is done in regions of low image intensity the smoothed value is not well represented as a small integer. That is, if the smoothed value in a region is about 3 it can only be set to 3 or 4. To permit a smoother average the whole image is increased by a factor of 4. The smoothed value then may be 12 to 16 giving a better range of values. This is generally possible since nuclear medicine images rarely have large maximum values. An occasional image (intense static or a flood image) will have data above 1777 octal. For these images the S character is used rather than A yielding a weight of 1, that is, the sum of the counts in an image area is not changed.

An

Average (smooth) with either a Gaussian matrix or a two dimensional polynomial least

squares fit, depending upon which matrices are present in each slot. Currently we have all least squares fit to two-dimensional polynomials:

n=1	7x7	quadratic, weight = 4
n=2	7x7	quartic, weight = 4
n=3	5x5	quadratic, weight = 4
n=4	5x5	quartic, weight = 4
n=5	3x3	quadratic, weight = 3.598
n=6	7x7	second derivative quadratic, weight = 16
n=7	5x5	second derivative quadratic, weight = 16

Sn

Same as An except that the weight of the matrix is divided by 4, resulting in a weight of 1 for most matrices. This is useful for floods and other very intense images.

8.2.2 Data bounding

The purpose of bounding is to correct data points that are statistically improbable. Such points may be due to electrical interference or perhaps only to an improbable count. When bad points are left unmodified they give bright or dark patches in the image. It is of course necessary to avoid suppressing real data increases or decreases. Since true high or low regions always must involve more than one picture element a distinction can be made by comparing a fit to a moderate sized area with the data point in question.

A least squares or gaussian fit is obtained for each image element according to the averager selected (m). At each image element the difference between the image value and the least squares or gaussian fit is then compared with the specified standard deviation range (of the least squares or gaussian fit) and if the difference exceeds the range, the image value is replaced by the fitted value. If the difference does not exceed the range the value remains unchanged. This should be used on raw data.

Bnm

Bound at so many standard deviations from averager m as specified below.

<u>n</u>	<u>standard deviations</u>
1	0.71
2	1.00
3	1.41
4	2.00

8.2.3 Anti-scatter and anti-penetration processing

This process removes the effects of Compton scattering and collimator septum penetration from the image. It is necessary to image a point source of the nuclide to be used with a collimator of the type used for the patient image. The source should be immersed in a suitable scattering medium of adequate size. The point source image is converted into a fine and coarse matrix by the matrix former program (MATR). This process need be done only once and the resulting matrix table is used thereafter. The correction process is a one step deconvolution that removes from the image the broad skirt part of the point source response.

Fn

Fine anti-scatter and anti-penetration correction. Uses matrix table n shown on HLPR display. An averager (An) is usually used instead in order to speed up processing. The fine correction depends upon the point source response close to the central peak and the correction is much smaller than the coarse correction. Smoothing combined with coarse correction yields almost the same result as fine correction combined with coarse correction followed by smoothing and requires only about 1/2 the time.

Pn

Coarse anti-scatter and anti-penetration correction. Uses matrix table n shown on HLPR display. When used with Fn, Pn must follow, and n must agree in each or be omitted after P.

8.2.4 Image validation

Vn

Validate image. Mark each data point with a landmark and leave them unchanged if they exceed the number of standard deviations set by n (see Bnm) from a ring average around each point; otherwise replace the point with this average. Validation locates regions of statistically sound deviation from their neighbors, that is, regions of abnormally high or low activity.

8.3 Comment File and Comment Manipulation

The last field on the RF08 disk or the field following the image file on the RK8E is reserved for the disk image file index and the comment file. Thus, there is room for 31 one-page comment entries * and one one-page image file index.

The comment file entries are unaffected by refreshing the disk image file and are, of course, not preserved on the image file tape. DDAR does not disturb the comment file unless a complete two-tape dump or refresh is requested.

8.3.1 Entering comments in the file, file index erases.

After an appropriate comment has been entered from the keyboard (via CTRL-CNOTE) and is being displayed on the CRT, it can be saved in the comment file as follows:

"(CR)	Enter the comment being displayed in the next available slot in the comment file.
-------	---

At any time the comment file may be erased for the entry of new comments by:

"32(CR)	Erase the comment file index, thus forcing the next entry to go into the first slot.
---------	--

8.3.2 Attaching comments to images.

Comments may be attached to the image in the working area in view by:

"n(CR)	Get comment n(n = 1, 31)* from the comment file and attach it to the image in the working area being viewed. This comment overwrites any existing comment already there.
--------	--

*On the RF0 disk only 27 comment entries are available.

Comments can also be directly attached to an image without using the comment file from the comment mode described next and are attached automatically to both images from the access mode of SCAN (see section 8.6.4).

8.3.3 Comment mode

The comment mode allows the keyboard to be utilized for entering image comment text. It is always available in the data handling mode and available in the data access mode in SCAN.

CTRL-C NOTE(CR)	Enter the comment mode. Subsequent data entered from the keyboard is treated as text, entered into the comment buffer (7000 page) and displayed on the CRT.
CTRL-K	Delete the contents of the comment buffer, thus erasing the current comments. This does not affect the comments stored in the working area, only those in core.
RUBOUT	Delete one character (or CRLF combination) with each stroke.
CTRL-FORM	Leave the comment mode, return to the data handling mode with the new comments stored in core.

Note: The preceding three commands are the only valid comment mode commands available, all other characters typed will be accepted as text. Note that the characters: +/ #& are illegal and will not produce the intended display character.

CTRL-C PUT(CR)

Make the comment permanent by writing it into the image in the active working area. The comment may be transferred to the comment file without attaching it to the working area by the "(CR) command.

8.3.4 Comment file maintenance

The index or pointer to the comment file is stored at location 6517 and is not changed whenever the disk image file index is read (e.g., during a refresh). The comment index indicates the last comment file entry made, and thus determines where the next entry will be made.

8.4 Exit to the Monitor

The disk monitor may be called from ORIS providing it is resident on disk.

CTRL-C MON(CR)

Clear TELSW (location 163) then
call the monitor.

8.5 Program Restart After a Fault

The program may cease to respond to the keyboard command. This may be due to a computer hardware failure, the result of a large electrical interference pulse or may simply be due to halting the computer while certain processes are being carried out. Generally the program is undamaged and the following procedures should be tried.

8.5.1 Normal

Assuming there has been no permanent damage done to the program,

- (1) Halt the computer
- (2) Load address 2000 IF=0 DF=0
- (3) Start

The program is now in a wait loop awaiting a command:

B(CR) if in data handling, or

CTRL-P(CR) if in access mode.

8.5.2 Return to monitor

Should the program be seriously damaged, the only course of action is to return to the monitor and recall the program. This may be accomplished by one of the following:

- (1) Activate the MI8E by the SW switch, should you have a PDP-8/E so equipped.
- (2) Start ORIS at location 3547 which is a monitor call.
- (3) Start EXIT running at location 7400 in field 3 (or wherever you generally store EXIT). A CTRL-0 in response to the > will get the monitor.
- (4) If EXIT is not in core, the disk bootstrap should be toggled in and started.
- (5) In the event of a disk catastrophe as well, the DEctape bootstrap should be used to boot onto a system tape, then call DDAR from the system tape, and refresh a monitor from an appropriate dump tape.

8.6. SCAN: Rectilinear Scan Access

The rectilinear scanner access program is capable of accepting data from each head of a dual scanner or from two energy channels from one head. The image being taken from either head or energy channel may be inspected on the CRT, comments may be added during the scan, and the display intensity levels may be changed. Either a reference line or an end of line signal may be utilized to determine lines, with the reference line being the recommended method. Program overlays are available to adjust the picture element size to that of the scan steps if corresponding sizes are not supplied by the hardware.

8.6.1 Compress element sizes

Overlay CMPELE can be used with SCAN to sum adjacent elements to yield an image containing twice the element size of the actual scanner settings, but only half the number of elements. This is useful, for example, when the element signal generator is set for 1/4 inch elements, but a 1/2 inch line step is being used. CMPELE will then sum adjacent 1/4 inch elements, forming 1/2 inch elements to correspond to the 1/2 inch steps.

8.6.2 Compress step sizes

Overlays CMLNS can be used with SCAN similarly to CMPELE, except adjacent lines are summed. Thus, again with the scanner unit producing 1/4 inch elements, if the step size is set to 1/8 inch steps, CMLNS will sum adjacent lines to produce 1/4 inch steps to agree with the 1/4 inch element sizes.

8.6.3 Entering access mode

The command: CTRL-A(CR) enters access mode and starts the acceptance of data from the scanner. This command is valid only from the data handling mode, but when given, allows only commands from the access command list to be executed.

8.6.4 Access commands

C(CR)

Enter the access comment mode. This is identical with the CTRL-C NOTE command of the data handling mode, except CTRL-FORM returns to the access mode and CTRL-C PUT is not available. At the conclusion of the scan, the comments entered under the C command are automatically added to each of the two working area images. The first letter of each image is automatically inserted as either an L (Lower) or a U (Upper) depending upon which scan head is providing the data for that image.

Dn(CR)

Display scale. This is similar to the D command of the data handling mode except n has a more limited range:

<u>n</u>	<u>scale factor</u>
3	1
2	1/2
1	1/4
0	1/8

Changing the display scale has no affect on the data being accessed.

G(CR)

Go. Start the image access again. All previously accessed data is ignored. This should be used when, for any reason, it is necessary to restart the scanner.

U or UU(CR)

Display the image being accessed from the upper head (U) or the lower head (UU). This does not affect the data being gathered, only the display.

O(CR)

Order the scans in array format. Append the comments, if any, and print the following message:

TYPE ID

The program returns to the access display until the ID is entered.

In(CR)

Enter ID number, where n is a decimal number less than 4096. This forces a return to the data handling mode, with the two images left in the working areas. The CTRL-W (and N) command must be used to write each individual image onto the image file.

CTRL-P(CR)

Stop. Go directly to the data handling mode, ignoring any image data accessed thus far. Any additional scanner data will also be ignored.

8.7 CAM4: Commands for Static Camera Access Program

8.7.1 Data handling mode

All data handling commands are standard with the addition of the following:

CTRL-CFLOOD(CR)

A camera flood image must be in the working area in view. A flood correction table is prepared in Field 2. An image showing those elements that are outside $\pm 15\%$ of the average is stored in the working area and displayed. When the program returns to display, type CTRL-CMON(CR), then to the monitor's dot type:
SAVE SYS FXXX 20000-27777;4344(CR).
This will save the flood table for later use. Alternatively, the table can be used at once for flood correction without saving it.

CTRL-CFC(CR)

Flood correct the image in view. The image must be in D5(CR), S(CR) and M(CR) display state and a suitable flood correction table must be in Field 2. A tag of FC is appended to the comments of the image in the working area. If a flood table is not in Field 2 one may be called by:
CTRL-PFXXX(CR).

H(CR)

Type out a histogram of the data within the quantitation rectangle. The data of the displayed image is used and the lowest 5 bits are all that are considered. The range of the image displayed thus should be reduced to $0-31_{10}$ before calling H.

8.7.2 Data access mode

CTRL-A(CR)

Go to data access mode, display image in non-interpolated mode and wait for command.

Tn(CR)

Set prestored time for image in seconds. Limit 4095 seconds. this value is saved and does not need to be reentered. A default value of 20 seconds is present initially.

Kn(CR)

Enter prestored count in thousands of counts. Limit 4 million counts. This value is retained for repeated use. A default value of 200 (200000 counts) is initially present.

GT(CR)

Go for the predetermined time.

GC(CR)

Go for predetermined number of counts. Exit is automatic for both modes. Time and counts are reported:

NNNNNNN COUNTS MMM SEC
TYPE ID:

Enter the ID in the form: INNN(CR), where NNNN is a decimal number less than 4096. The image will then be transferred to the working area and the program will return to data handling mode. The printed counts will be 0 for the predetermined count.

CTRL-O(CR)

Stop, give timeout and wait for ID as above.

CTRL-P(CR)

Stop, go to data handling mode, abandon image in core.

Dn(CR)

Change display scale, D5 - data x 1, D0 = data x 1/32. Does not affect data being recorded.

8.8 GS1: Gated Static Camera Access Program

GS1 is a part of the ORIS system intended for the access of a static camera image gated by some physiological signal. The image access is based upon the period between physiological signals with data collected only during a portion of the cycle. It may be used to obtain an image of the heart without blurring due to heart motion or an image of the liver without blurring due to respiration. Electrocardiogram signals, respiration signals or other repetitive physiological signals are supplied to the computer and an average of the 16 most recent cycles (signal to signal intervals) is maintained. For gating purposes, the cycle is divided into eighths. Image access can be started at any preselected eighth and continued for any number of subsequent eighths. At the conclusion of the specified access period, data accumulation ceases and the computer waits for the next signal to prepare a new average period and repeat the cycle. At the end of the preset number of counts or number of cycles, access will terminate.

The program resembles CAM4 except that a flood table cannot be made. Flood correction, however, can still be done.

Operating Procedure

Electrocardiograph or plethysmograph leads should be placed on the patient so as not to interfere with the camera image. The signals should be established to the AX08 input (or DR8EA input for the PDP8/E). Call the program by:

CTRL-PFXXX(CR)

An appropriate flood table if flood correction is needed. This may be called at any time except during access.

CTRL-PGS1(CR)

The image currently in the working area will be displayed. To go to the image access mode type:

CTRL-A(CR)

Filling of the physiological period buffer begins. Wait at least 16 cycles before starting image access. The number of counts to be accepted may be entered by

KNNN(CR)

where NNN is the number of thousands of counts wanted. A default value of 200 (200,000 counts) is initially present.

The number of cycles to be counted is entered by:

BNNN(CR)

where NNN is the number of cycles.

A default value of 320 is initially present.

The physiological cycle is divided into eight sections. The delay or hold-off interval after a signal until access starts may be entered by:

Hn(CR)

where n is the number of 1/8 periods to hold off. A default value of 7 is initially present (suitable for myocardial infarct imaging).

The number of 1/8 periods to access data is entered by

$On(CR)$

where n is the number of 1/8 periods to be on.

A default value of 1 is present.

The sum of the hold-off and on intervals should be less than or equal to 8 but no damage is done if they exceed it, as access will be terminated by the occurrence of the next physiological signal and the cycle will restart.

Image access is begun by a GB(CR) or a GC(CR) command. The GB(CR) initiates collection for the preset number of beats or cycle periods while GC(CR) is used for a preset number of counts. At the expiration of the number of counts or cycles, the program types the number of counts and cycles accumulated and asks for an ID number.

Enter this in the form:

$INNNN(CR)$

where NNNN is a decimal number less than 4096. Exit to the data handling mode is then automatic. Other preparations of the program are identical with CAM4.

8.9 DYN4: Dynamic Camera Access Program

DYN4 is a part of the ORIS system intended for the access and processing of multiple-frame dynamic sequences using the gamma camera. The program can access up to 45 frames of 64 x 64 element images at frame rates up to 10/second. The frame sequence is divided into two groups of a variable number of frames each having a preset frame rate, plus a pseudo-static reserved for the end of the sequence. Thus the sum of the two variable frame-rate groups must not exceed 44 frames.

The access is double buffered, using Fields 1 and 2 alternately to hold the incoming data. As each frame is completed, it is written directly onto the image file, with the index being updated at each addition. The static at the end of the sequence is, however, left in the active working area so that comments can be added prior to saving on the image file. The particular frame-rate groups and times are saved for reference in a section of the 6600 page (6666) which is written on the tape when the image file is dumped.

The program can sum any contiguous group of images, including adding an image to itself, with the result stored in the working area. The dynamic series may also be displayed as a repeating movie.

Several processing modalities are provided including NTMAX which generates two summary images, one displaying the maximum perfusion achieved by each image elements (NMAX), the other displaying the time each image element reached its maximum (TMAX). An activity clearance function is also provided (FALL). Finally, a time-smoothing algorithm is available as well as a symmetry image.

8.9.1 Calling and operating procedure

The program is called from ORIS by:

CTRL-PDYN4(CR)

8.9.2 Accessing a dynamic sequence

Transfer from the data handling mode to the access mode is by

CTRL-A(CR)

The program is now ready to accept the time/frame sequence data. Frame durations are given in 0.1 second units. Type:

T(CR) and answer the following questions:

The program will type the underlined parts. The number is the default value present. If this is acceptable, reply by (CR). If a different number of images or times is wanted, enter it followed by a carriage return. The new values remain in force until a new copy of the ORIS main program is called from the disk [R OR76 (CR)] or until the image file is refreshed from tape or from the saved image files IF1-6.

REPEAT 30 (CR)

The first group will contain 30 images.

TIME 10 (CR)

Each frame will be collected for 10 x 0.1 second.

REPEAT 14 (CR)

The second group will contain 14 images.

2ND TIME 20 (CR)

Each frame will be collected for 2 seconds.

STAT 1000 500(CR)

The pseudo-static default value of 1000 = 100 seconds was replaced by 500 = 50 seconds.

The example numbers given above are the defaults and should these be desired, it is not necessary to execute the T command.

The program is now ready to access data. Upon receiving the signal to commence, the operator should type:

G(CR)

The program will collect the prescribed data, then exit to the data handling mode with the pseudo-static image in the active working area. Should it be necessary to abort the access, CTRL-P(CR) can be given, forcing a return to the data handling mode. The image file will be incomplete, but its index should reflect its current state. Comments should be added either through CTRL-CNOTE or from the comment file:

"n(CR)

and the image written to the image file,

CTRL-W(CR)

Image access is now complete, and after dumping the raw data to DECTape, or to disk files, processing can begin.

8.9.3 Displaying a dynamic sequence as a movie

The sequence can be displayed as a repeating movie by:

Tn(CR)

with images 1 through n utilized. A "bouncing ball" movies along the bottom edge (top edge if Y- or Yn is used) of the image to indicate its position in the time sequence.

8.9.4 Image manipulation

A sum of any contiguous group of images can be made by:

CTRL-C+(CR)

n(CR)

m(CR)

such that the sum of images n through m is placed in the active working area. Note: if an R45(CR) is given prior to the sum, the sequence comments will be displayed along with the summed image (assuming the pseudo-static is image 45).

8.9.5 NTMAX

An extremely useful pair of summary images may be produced from the image file and stored in the working areas by giving the command:

On(CR)

Images 1 through n are searched and an NMAX image is formed in the upper working area (NN), a TMAX image in the lower working area (N). In NMAX each element contains the maximum value that element obtained anywhere in the series, if it exceeded a count of 3. In the TMAX image, each element contains the time (frame number) at which the maximum was attained. The time is recorded inversely, maximum for the first frame, minimum for the nth. The actual value stored is (number of frames considered - frame number of maximum + 1) * 4.

8.9.6 FALL

A normalized image whose elements contain the activity at TMAX+5 divided by the activity at TMAX can be produced by:

Fn(CR)

Areas that clear slowly are brighter, areas that clear rapidly are darker. The FALL image is quite noisy and must be smoothed [e.g., CTRL-NB13,A3(CR)] before evaluating. NTMAX must be executed just prior

to FALL, as FALL uses NTMAX data provided in Fields 2 and 3. The n parameter should agree with that used in the NTMAX command. The FALL image is formed in the working area (N).

8.9.7 Time smoothing

Dynamic time sequences are often quite noisy, especially low dose, anterior/posterior view brain series. In order to yield an acceptable NTMAX, it is sometimes necessary to smooth such sequences in time. Each element in the n-image sequence is replaced by:

$$C(k) = C(k-1) + 2*C(k) + C(k+1)$$

at the ends,

$$C(1) = 3*C(1) + C(2) \quad \text{and} \quad C(n) = C(n-1) + 3*C(n)$$

where the subscripts refer to frame number. This smoothing results in a weight of 4.

8.9.8 Symmetry function

It is often useful to compare activity on each side of a symmetric image, such as the hemispheres of the brain in vertex view. The symmetry function compares each point of one hemisphere with the corresponding one of the other hemisphere, setting the lesser to zero and the greater to maximum. However, if the sum of the two points is less than 2, both are set to zero. The line of symmetry is found by using Z cuts in the ZY (column) mode on the pseudo-static image at the end of the series. For vertex view brain images, the superior sagittal sinus is the anatomic delimiter. Once the symmetry line is found, the image should be in multi-cycle mode [M(CR)] and the command

*n(CR)

given, with n being the line of symmetry, usually near 32 for a 64 x 64 image.

8.10 DNF1: Grid Multi-AOI Processing Program

DNF1 has no access program and is used for processing dynamic image sequences. The display commands are similar to CAM4 except for extensive changes in the quantitation mark commands.

8.10.1 Image manipulation

CTRL-C+(CR)n(CR)m(CR) Images n through m are summed and the result is put in the working area in view.

8.10.2 Image processing

1n(CR) Move upper left corner of grid to line n.

2n(CR) Move upper left corner of grid to element n on present line.

3n(CR) Make each mesh of grid n lines high.

4n(CR) Make each mesh of grid n lines wide.

Ø(CR) Lights up mesh.

L(CR) LOCATE. Automatically center grid mesh on a vertex view brain image and display it. Ready for the Øn(CR) command.

Øn(CR) DYNFCN. Form AOI table in Field 3 from AOI list in 7600 page, Field 3; form double precision time function curves for each area-of-interest for n images, store curves in working area and display as an image. Includes a curve of the total count in each image. The AOI table must be present in Field 3. (see 1, 2, 3, 4, and Ø commands above.) The curves may be displayed by the Z profile commands and may be processed by FOCAL program FDYN.

AMN(CR)J

Mesh edit command. Enters letter J in mesh MN in image and in list in 7600 page of Field 3. J does not echo. If J is a space key, content of mesh is erased. When a mesh list is finished it may be saved by returning to monitor [CTRL-CMON(CR)] and typing SAVE SYS AOIn 37600; 4344(CR).

!(CR)STRING(CR)

Enter prestored process command string. String is a series of process command characters and arguments separated by commas. Example: !A4,P2(CR) will command average with matrix 4 (sharp), followed by anti-scatter and anti-penetration processing with process matrix 2. After this command is given the screen will remain blank until the multi-process command below has been executed. One may abandon the action, however, by B(CR).

CTRL-Mn(CR)p(CR)

Process images n thru p using the prestored command string. The prestored command string must have just been entered.

CTRL-CMFC(CR)n(CR)

Flood correct n images. The appropriate flood correction table must be in Field 2. The flood correction table may be called by CTRL-PFXXX(CR).

8.11 DNF2: Independent Rectangle Multi-AOI Processing Program

All commands except those involving the AOI table are the same as for DNF1. Thirty-one rectangles (1 through 31) may be entered and any number may be assigned to each of up to 31 areas-of-interest. Individual rectangles may have any size and may overlap. In the overlap, the highest numbered rectangle is written last and overwrites the previous entries on the overlap. Note that areas illuminated in the image remain, so that several areas may be examined together. The lit up areas are removed by typing S(CR) or any other command that replaces the image with a fresh copy from the working area.

Entering an Area

(a) Form the desired rectangle using the quantitation marks by the commands: 1n(CR), 2n(CR), 3n(CR), and 4n(CR). See section 1.2. The Ø(CR) and Øn(CR) commands have special duties and should not be used with these marks; see below.

(b) After a rectangle is in place it may be entered in the AOI list as a rectangle n, a part (or all of) the area-of-interest J by the command:

An(CR)J

The area character (J) does not echo. All the rectangles assigned to the character J will be illuminated in the image.

(c) The AOI list may be cleared before entering any rectangles (or at any time) by command:

A(CR)Ø

- (d) A given rectangle m may be erased from the list by typing:

Am(CR)SPACE

where SPACE means striking the space bar.

- (e) All of the rectangles belonging to a character (K) may be lit up by the command:

A(CR)K

- (f) All areas of the AOI are lit up by typing:

A(CR) SPACE

- (g) The rectangle n may be illuminated separately by typing:

An(CR)@

Saving and Calling a Prepared AOI List

- (a) When an AOI list has been completed, return to the monitor by typing:

CTRL-CMON(CR)

To the monitor's dot type:

._SAVE SYS AOIn 37600;4344(CR)

- (b) The series calling the AOI and the program from ORIS would be:

CTRL-PAOIn(CR)

CTRL-PDNF2(CR)

Adjusting the AOI to Fit an Image Sequence and Forming the Time Functions

- (a) Refresh the image file on the disk with the sequence to be used unless it is already there.

- (b) Call the pseudo-static last image of the sequence. If its number is not known, type R(CR). The typeout will tell the number of images (n).

Type:

Rn(CR)

and adjust the display to show the image at a low level.

(c) Type L(CR) and the AOI map will be placed automatically, then proceed to step (e), or if the fit of the map is unsatisfactory;

(d) Set a tentative initial position of the AOI map by typing:

15(CR)

21Ø(CR)

Ø(CR)

If the position of the areas does not fit the image satisfactorily, type S(CR) to erase the areas, type new values of the 1 or 2 commands or both, and Ø(CR) to light up the areas again. The Q(CR) command blacks out the area of the image covered by the map and may be used to examine the fit.

(e) When the areas are in position type:

Øn(CR)

where n is the number of images in the sequence, not counting the pseudo-static image at the end. The time function curves will be calculated and displayed as an image.

8.12 F645,P645: Dynamic Sequence Curve Processing and Plotting

Dynamic sequence time-activity curves produced by DNF1 or 2 are rearranged, smoothed, and corrected by the FOCAL program F645. The smoothed and corrected product curves are rewritten into the ORIS lower working area, ready to be displayed by any ORIS program. The program also leaves scaled curves in successive pages of Field 2 with scale labels in the last 20 (decimal) words of even numbered pages. This data is then in the form required by the program P645 which plots the curves on the Analox 645 line printer.

Method

The programs DNF1 and 2 store time-activity curves in double precision tables in successive pages of the image with the sum of the counts in each frame in the 3000th page. F645 corrects the values in each curve for camera counting loss using the total counts in each frame and a fixed dead-time of 7 microseconds. The values are then replaced as a single precision list and the values for the 2-second images are divided by two and placed at every other location with the in-between values filled by interpolation. The list of values is now smoothed by a 5-point orthogonal polynomial quadratic fit at each point. The processed curve is then written to the working area on the disk. After the curves have been processed, the complete image of all curves is scaled for plotting by P645 and left in Field 2.

Calling F645

From ORIS, type

CTRL-PF645(CR)

???.??

*

FOCAL is now running and the typical commands for F645 are:

*G(CR)

N: 30(CR) (30 1-second images)

M: 14(CR) (14 2-second images)

LAST AOI: 13(CR) (Area-of-interest thru M)

The program will run to completion and type an asterisk upon finishing. Scaled data are now in Field 2 for P645 and processed curves are in the lower working area.

Calling P645 to Plot Curves

After F645 has been run, return to monitor, prepare the line printer, and call P645 by:

* *(CR) (On older versions of modified FOCAL, the computer must be halted and restarted at loc. 7600).

. Monitor is running.

Press START on the line printer, type:

.R P645(CR)

The curves will be printed in sequence, the corresponding right and left areas on each curve. When the plots are finished P645 returns to the monitor.

8.13 FDYN,PLOT: Dynamic Sequence Curve Processing and Plotting

The two FOCAL programs FDYN and PLOT operate as do P645 and F645 to process and plot time-activity curves produced by DNF1 and 2 for those users who have no line printer (see F645, P645). The curves are produced on the teletype.

Calling and Processing with FDYN

From ORIS, type:

CTRL-PFDYN(CR)

?00.00

*

FOCAL is now running. The typical command sequence is:

*G(CR)

NO. OF 1 SECOND IMAGES: 30(CR)

NO. OF 2 SECOND: 14(CR)

LAST AOI: 13(CR)

The program runs to completion storing the processed images in the ORIS lower working area replacing the raw curves. The method is described for F645, P645.

Plotting Curves with PLOT

If plots are wanted, return to monitor and call PLOT by:

* *(CR)

(On older versions of the modified FOCAL it is necessary to stop the computer and restart at location 7600)

.R PLOT(CR)

?00.00

*G(CR)

AOI: 13(CR)

(if you want all plots)

When all plots have been completed, the program types an asterisk and remains running in FOCAL. You may return to the monitor by:

**(CR)

÷

Monitor is running and ORIS may be called in the usual way.

8.14 DHB1: Fast Dynamic Access Program

The fast dynamic access program DHB1 is a part of the ORIS system. It is intended for the access of up to 180 frames of 32 x 32 picture elements. Frame times as short as 0.05 second or as long as 40 seconds may be used. The sequence is divided into three successive segments each of which may have the same or different frame time. Each of the first two groups has any multiple of 4 images in such combinations that the total number of images does not exceed 176, while the last group always contains 4 images. The time for the images of each group is entered in units of 0.01 second. The sequence can be displayed as a repeating movie, and a routine is provided for the recovery of any frame of the sequence. The program must be regarded as preliminary and additional functions will be incorporated in it in later versions.

8.14.1 Calling procedure

The program is called from ORIS by:

CTRL-PDHB1(CR)

The program will display the image in working area.

8.14.2 Image handling commands

8.14.2.1 Displaying a time sequence

The sequence can be displayed as a repeating movie. The image can only be displayed in units of 4, for example, images 16 through 23 may be repeated but you cannot start at image 17, 18, or 19. The sequence is called with frame numbers each of which is displayed as 4 sequential images. The command is:

Tn(CR)m(CR)

This image will display 4 (m-n+1) images in repeating sequence. T6(CR)40(CR) would display image number 21 through 160 as a sequence.

8.14.2.2 Retrieving any image of the sequence

With the display not in the repeating movie mode, type:

Gn(CR)

This will put image n in the working area replacing its previous content. The argument n must be from 1 to 180.

8.14.2.3 Expanding a 32 x 32 image to 64 x 64

The 32 x 32 image in the working area (on view) will be expanded to 64 x 64 elements by interpolation by the command:

I(CR)

This is identical with the similar command in GHS3.

8.14.3 Access mode commands

The commands resemble those for DYN4 except that for each frame specified, four 32 x 32 images are collected and the times specified are the time for collecting each 32 x 32 image. The times are entered in 0.01 second intervals and times below 0.05 are illegal.

The access mode is entered as usual by:

CTRL-A(CR)

The image displayed will be a vertical bar containing space for 32 x 32 images.

The times and numbers of frames are entered by:

T(CR)

REPEAT 30 1(CR)

one frame, 4 images

TIME 10 100(CR)

100 x 0.01 sec = 1 second for each of the 4 images

<u>REPEAT 14</u> 43(CR)	43 frames, 72 images
<u>2ND TIME 20</u> 7(CR)	0.07 sec/image
<u>STAT 1000</u> (CR)	1000 x (0.01 sec) = 10 seconds for each of the static images.

When ready to begin the access type:

G(CR)

Exit to the data handling mode is automatic at the end of the sequence.

The four static images remain in the working area and have not been written to the image file. Attach suitable comments ["m(CR)] and write to the image file by:

CTRL-W(CR)

The access sequence is now complete.

Return to the data handling mode may be made during access of a sequence by typing:

CTRL-P(CR)

The sequence being taken is abandoned. The image file index may be incomplete however.

8.15 GHS3: The Gated Heart Sequence Program

The gated heart sequence program, GHS3, is a part of the ORIS system designed to collect a series of 12 sequential images spanning an averaged heart beat. The sequence begins at the R wave of the patient's ECG signal and ends at the next R wave. The R to R wave period is measured and is written into a 16 word circular buffer, overwriting the oldest entry. A new average time is then calculated. In this way a prediction of the next heart cycle is obtained with allowance made for the changing heart rate of the patient. When an R wave occurs incoming data is added to the images starting at the first image. Three 1/10 beat images are collected followed by four 1/20 beat images, then five 1/10 beat images. One of the 1/20 beat images should span end-systole. The twelfth image (end-diastole) is collected until the next R wave. In any case data taking ceases when an R wave arrives. The current beat duration is compared with the 16-beat average, and if it differs by less than 10%, data taking continues immediately. If the difference is greater than 10%, indicating an ectopic beat, data taking is suspended until the next R wave. The anomalous interval is not added to the beat buffer. When images have been collected for the predetermined number of beats (or when the action is terminated manually) the 1/20 beat images are scaled up to agree in intensity with the 1/10 beat images and the whole sequence is moved to the current working area.

The program has facilities for displaying the sequence as a repeating movie at a variable rate, for selecting any of the images of the sequence for processing, and for expanding a selected image from its 32 x 32 size

to 64 x 64 by interpolation. Selected images or the whole sequence may be smoothed or edge sharpened by the program.

8.15.1 Calling and operating procedure

The program is called from ORIS in the standard way:

CTRL-PGHS3(CR)

The current image will be displayed on the screen. The program has now available the content of the image file and the comment file. Images may now be examined or processed, or transfer may be made to the image access mode..

8.15.2 Accessing a sequence

Attach ECG electrodes to the patient and establish the signal from the ECG equipment to the AXØ8 (or DR8-EA for the PDP-8/E) input to the computer. Transfer to the data access mode by CTRL-A(CR). The beat buffer will now start to fill. Wait at least 16 beats to establish a rate average for the current patient before collecting any data. Data access is initiated by G(CR). Image accumulation will continue for the preset 320 beats and automatically exit to the data handling mode. The access may be terminated at any time by typing CTRL-P(CR), with the images accumulated to that point retained. The comments should now be added to the image sequence and it should be saved on the image file.

8.15.3 Comments and saving the image sequence

If comments have been previously entered for this sequence (at the beginning of the day's runs), say comment n, type:

"n(CR)

Verify that the correct comment has been attached to the image. If comments have not been previously entered, type:

CTRL-CNOTE(CR)

Enter comment, not more than three lines and not more than 127 characters, counting spaces, punctuation, and 2 for each carriage return. Leave the comment mode by:

CTRL-FORM (Note, no carriage return here)

Now attach this comment to the image by:

CTRL-CPUT(CR)

After comments have been made, add the image to the file by:

CTRL-W(CR)

The sequence is still in the working area and may be displayed or processed since the sequence is safely in the image file as well.

8.15.4 Displaying a gated heart sequence

The sequence is displayed as a repeating movie by the command

TN(CR)

where N is the number of repeats of each image before shifting to the next. The normal size and contrast commands for display apply to this display. Exit to the normal display is made by B(CR).

8.15.5 Extracting and expanding particular frames

With the sequence being displayed, type:

GM(CR)

The mth image ($m = 1, 12$) will be chosen and written into the working area, overwriting the sequence. This image can then be treated in the usual

way. When a different image is wanted, the entire sequence must be recovered from the image file by a READ command [Rn(CR)].

Any 32 x 32 image on display is permanently expanded into a 64 x 64 image in the working area by the command:

I(CR)

The image is expanded by interpolation between nearest neighbor data points as in the normal display.

8.15.6 Edge sharpening

Edge sharpening is produced by generating an image which at each point contains the average second derivative of the image to be sharpened. A fraction of this second derivative image is subtracted from the original image to provide a sharper result. To produce the second derivative image, get the desired image on view (D,S, and M commands do not count), then type CTRL-NS7(CR) to obtain the derivative using a 5 x 5 least squares two dimensional quadratic fit, suitable for a 32 x 32 image.

The command CTRL-NS6(CR) produces a second derivative image using a 7 x 7 point least squares fit of a two dimensional quadratic to the data at each point, more suitable to a 64 x 64 image.

After the second derivative has been produced, shift to the other working area [NN(CR) if you were in the lower working area]. Recover a copy of the image to be sharpened by a READ command. Adjust the D and S commands to suitable values then tentatively subtract some of the second derivative image, starting for example at -500(CR) (this is 1/2 of the subtracted image). Change values of S and the subtraction factor

until a satisfactory image is obtained. Make the subtraction permanent by typing -4000(CR). Remember that any change of S or D (or B) following a tentative subtraction erases the subtraction image, and the subtraction command must be repeated to recover the tentative subtraction image.

This sharpening procedure may be carried out on a single 32 x 32 or 64 x 64 image or upon the entire gated heart sequence as desired.

8.15.7 Changing number of beats collected

The number of beats over which data is collected is determined by the content of bin M500 at location 523. The accumulation count may be changed by inserting the appropriate binary negative number at this location.

8.16 GHF1: Gated Heart Sequence Analysis Program

GHF1 is a temporary analysis program of the ORIS system; it will be superseded by a permanent program after trials. It is intended to permit analysis of a gated heart sequence to yield ventricular volume and ejection fraction.

The method used involves obtaining the area and length of the left ventricle, and by assuming that the ventricle is a prolate spheroid, calculating the volume. The area of the elliptical cross section of the spheroid containing the major axis is

$$A = \pi ab$$

where a and b are the semiminor and semimajor axes respectively. The volume of the spheroid is

$$V = \frac{4}{3} \pi a^2 b = \frac{4}{3} \frac{(A)^2}{\pi b} = 0.85 \frac{A^2}{\ell}$$

since the length of the spheroid $\ell = 2b$.

The program contains an independent rectangle area-of-interest routine like that of DNF2. When this area of interest is located over the ventricle image, a command causes all of the image except that inside the area of interest to become zero. A command is provided that writes the image in core into the working area. In this way the desired part of the image can be isolated. The quantitation marks in this program have two new functions. When the command CTRL-CAREA is given, the number of non-zero elements within the rectangle is typed. In the

other new function, if one mark of the rectangle is located on the base of the ventricle, the diagonally opposite one is placed on the apex and the command CTRL-CDIAG is given, a typeout of the length of the ventricle results.

8.16.1 Operating procedure

Select and expand the frames of the gated heart sequence that contain end-systole and end-diastole, and perform edge sharpening. Write them to the image file (CTRL-W), then call the appropriate area-of-interest list and GHF1 from disk:

CTRL-PAOID(CR)

CTRL-PGHF1(CR)

Recover the end-diastole image and place the area-of-interest by typing:

14(CR)

21Ø(CR)

Ø(CR)

The area-of-interest will be illuminated. Recall the image by B(CR) and move the area-of-interest by using other arguments for the 1 and 2 commands until the area-of-interest is correctly located. Confirm this by recovering the image and typing Ø1(CR). Only the part of the image inside the area of interest will remain. If this is satisfactory, set D5, SØ, and M if these are not already current, then type Ø1(CR) to isolate a clean unmodified image.

Now transfer this image to the working area by:

†(CR)

This isolated image should be surrounded by a quantitation mark rectangle and the best display level and subtract found. Remember that all non-zero elements will be counted by the next command: CTRL-CAREA(CR), and the number of non-zero elements will be typed.

Move the quantitation rectangle so that the initial corner (upper left in normal display condition) just merges with the midpoint of the aortic valve line, adjust the length and width (3 and 4 commands) until the opposite point lies just outside the apex.

The command: CTRL-CDIAG(CR), will now type out the diagonal length. Calculate the volume of the ventricle by the relation.

$$V = 0.85 C^3 A^2 / \ell$$

Where A is the ventricle area in image elements, ℓ is the ventricle length in elements, and C is the camera calibration in cm/element.

Call the systolic area-of-interest table and GHF1 by:

CTRL-PAOIS(CR)

Now repeat the operation with the end-systolic image.

Ejection fraction (EF) is calculated by:

$$EF = \frac{V_{ED} - V_{ES}}{V_{ED}}$$

8.17 FILE: File Management Program

The RK8E disk has enough room for the active image file IF0.IF and for six image file save areas, IF1.IF...IF6.IF. The active image file may be transferred to one of these save areas or any one of these save areas may be transferred to the active file area. An index to these save areas is maintained on the disk so that it is independent of the program. The working areas, the comment file and the active image file are located in the disk file IF0.IF on the RKB0 part of the disk along with the save files IF1 to IF3.IF. The files IF4 - IF6.IF are on the SYS or RKA0 section of the disk (see Fig. 1). The save files have the image file in the first 45 4K-fields (1320₈ OS/8 blocks) with the file index following in the first 200₁₀ words of the last OS/8 block of the file. The image file index of IF0.IF is different since it is preceded by the one word comment file index and is followed by the comment file itself.

The FILE program provides for writing any one of the save files to DECTape and for deleting files to make room for others. FILE is also used to edit image files by transferring individual images onto a tape. The images are first transferred to the working area and then are appended to the file on the tape. An empty index may be written on the tape if desired so that a new file may be started. All the comments of the images on a tape may be typed out to provide a quick reference to the images on that tape. Comments of the images in the active file may be displayed on the CRT and leafed through rapidly to locate a wanted image. The FILE program is called by:

CTRL-PFILE(CR)

and can only be dismissed to return to the previous program by:

RE(CR)

All commands in the FILE program require a two character command and may or may not need an argument. More than one command may be given in a command string and DE (delete) may have more than one argument. Commands and extra arguments are separated by commas. For example:

PU,GE(CR)

will put the image in the active image file into the first unoccupied save area, and will type out all occupied save area members. The computer response to the above command string might be:

FILE 3 (the active file was written
to save area 3)

FILE 1 2 3 6 (save areas 1, 2, 3, and 6
are occupied)

ID: 4 (Return to current image)

A command then might be given:

DE1,2,6,GE(CR) (delete files 1, 2, 6 and
type out used files)

FILE 3 (only file 3 now occupied)

ID: 4 (return to displaying current
image)

The active image file cannot be refreshed from tape nor dumped directly to tape from FILE; a return to the previous program, [RE(CR)] should be made if this action is wanted.

The individual commands are:

GE(CR) type out a list of all files
occupied.

GEn(CR)

Move a copy of the image file
in save area n to the active
image file IF0.

The contents of IFn are not affected but the previous contents of IF0 are lost. The GEn command does not consult the index of save files which allows a file, which has been deleted by mistake, to be recovered if it has not yet been overwritten by a PUn command. If an n greater than 6 is asked for, an error message will be typed and the command and the rest of the command string, if any, will be ignored. The save file index is located on the disk in the last OS/8 block of the file SPACER.NO. When in core the index starts at location 1601. It is probably well, when a new disk is used for the first time, to do six successive PUn(CR) commands with an empty active image file and then delete all of them again. This writes an empty image file index into all the areas so that if a GEn is done on one of these before it has been used only an empty file will be found. If this is not done no damage will result however.

PUn(CR)

Copy the active image file
into the lowest number image
save area not occupied. The
content of the active file is
unchanged and the previous
content of the lowest unoccu-
pied save area is lost.

DEn(CR)

Mark save file n as not occupied.
Only the index is affected and
this area may now be used by
a PUn action. Any number of addi-
tional arguments may be used with
DE to delete more than one file
at a time. Each additional argu-
ment must be separated by commas.
Example: DE1,2,3,4,5,6(CR) will
delete six files.

WRn(CR)	Dump the image file in save area n onto the DECTape on unit 1, the tape must be write enabled. The contents of save area n are not changed.
---------	---

The DECTape image file editing commands are used by getting the image to be written into the current working area by a RRn(CR) command. An image file tape (or an empty but formatted tape) must be on unit 1 with write enabled.

TP1(CR)	An empty image file index is written on the tape. No other action is performed.
TP(CR)	The image in the working area is appended to the image file on the tape and the tape index is updated. If the index is empty the image is written as the first one.
RRn(CR)	Get image n from the active image file into the current working area.
COn(CR)	Display the comments for image n of the active image file on the CRT. CO(CR) starts at the first image. Striking the space bar causes the display of the next comment. If the comment block on an image is empty only the number will be shown. When the last image is reached, the last comment remains despite striking the space bar. Return from this mode is made by striking the RETURN key.
TY(CR)	The comments of all the images in the image file tape on unit 1 are typed out. This list may be kept with the image file tape for rapid examination of its comments.

NN(CR) and NN1(CR)

May be used to switch to the lower or upper working areas of the disk.

RE(CR)

FILE exits and the program that was running when FILE was called is restored in the condition existing when FILE was called.

8.18 TWOD: Two Dimensional Fast Fourier Transform Program

This is a preliminary program. It may be used for a variety of image processing procedures and may be used (as a subset FFT and IFFT) for the analysis of instrumental operation in cameras and scanners by displaying the real and imaginary parts of the transform of an image as images of the frequency domain. Scanner motion errors, camera digitizing errors and introduced noise may be found to assist in their correction.

The program is only applicable in its current form to 64 x 64 images, either whole camera images or segments of scanner images.

8.18.1 Arithmetic method

The computations are performed in integer arithmetic. The original data must not exceed 3777₈ at its maximum. This is a non-EAE program but an EAE version is in preparation for those who have an extended arithmetic element. The program is adapted from the original one-dimensional program of James Rothman, DECUS 8-144, August 1968. His automatic scaling method to prevent arithmetic overflow has been retained although modified considerably for the two-dimensional use.

8.18.2 Calculation procedure

The first operation is to expand the radial filter function list (in the 2600 page) into a full field filter in Field 3. This will be a radially symmetric filter matching the radial function list. the image is called into Field 1 and the average value of its elements

determined. This average value is saved and subtracted from all element values so that the DC term in the transform which is generally large, will be small or zero. This permits the transform to remain larger without arithmetic overflow. Alternate values in the image are then negated in a checkerboard fashion to shift the zero frequency term of the transform into the center of the array. Each line of the image is then transformed in one dimension. The process proceeds with one step to all lines followed by the next step to all lines to permit automatic scaling. The real part is stored in Field 1 replacing the original image while the imaginary part is stored in Field 2. After the complete one-dimensional transform is done, the data in fields 1 and 2 are transposed and the process is repeated again yielding the two-dimensional transform. Note that the resulting transform images are in transposed orientation, i.e. reflected about the diagonal as compared with the original image.

The real and imaginary parts are now each multiplied point-by-point with the corresponding element of the filter function in Field 3.

After the multiplication the inverse transform is performed in one direction, the images are each transposed and the inverse transform done again to finish the two-dimensional inverse transform. The elements of the real part of the transformed image in Field 1 are then negated at alternate elements as in the beginning to restore the image. The average value is then added, in taking account of any net change of scale that may have been used. A strong image will likely be at the same scale as the original but a weak image may be larger by one or more factors of two.

The imaginary part of the result is left in Field 2. The negation of alternate elements is not performed on it. It is generally rather small unless extreme filtering has been done.

The real part image is now written into the working area and TWOD exits to the previous program which displays the transformed result.

8.18.3 Subprograms FFT, IFFT and the analysis program FFF1

TWOD performs both the direct and inverse transforms and the frequency domain images are not retained. If the frequency domain images are wanted a subset of TWOD is used. The program FFT acts as TWOD does except that it does not prepare the filter in Field 3 nor find and subtract the average value of the image. When it has completed the two-dimensional direct transform it writes the real part of the frequency domain into the working area and exits to the previous program. The imaginary part remains in Field 2. The frequency image cannot be displayed properly by the usual programs since it has large negative parts.

The program FFF1 can be called to manipulate and display the frequency domain images. Two display modes are available, in one negative parts are set to zero [CTRL-CNEG(CR)] in the other, negative values are converted to positive values [CTRL-CPLUS(CR)].

FFF1 has provisions for forming a filter function in Field 3 which can then be used by the inverse transform program IFFT to filter the real and imaginary parts. IFFT performs the inverse transform and writes the real part result to the working area for use.

FFF1 contains quantitation marks and can enter 1's or 0's in Field 3 corresponding to the area within the quantitation rectangle.

The usual 1n(CR), 2n(CR), 3n(CR) and 4n(CR) commands form and locate the quantitation marks after which an *(CR) command will cause "1"s to be written to Field 3 corresponding to the area outlined by the marks. A **(CR) would cause 0's to be written similarly. Before forming the filter, the command:

CTRL-CKILL(CR)

will clear Field 3 removing any previous numbers there.

The command %(CR) causes all of the image being displayed to be cleared except those parts corresponding to the "0"s of the filter areas of Field 3. This makes clear which areas of the frequency domain will be used by IFFT. The corresponding command %(CR) clears the areas of the image corresponding to "1"s in the filter. The image is restored by any command that rereads the image such as B(CR), S(CR) or Dn(CR). The imaginary part of the frequency domain may be recovered for examination. If the real part is already in the lower working area, you may avoid overwriting it by shifting to the upper working area [NN(CR)]. The command ++(CR) moves the Field 2 area into the working area. The command with a single up arrow saves the image in view exactly as it is in core into the current working area.

When the IFFT program is called, the filter existing in Field 3 is used and the inverse transform is performed.

One may, for example, prepare a filter as above, that retains only those parts of the response that should not contain real image parts, that is, regions far from zero frequency. When inverse transformed, the result is mostly the defects in the imaging system and statistical noise. A filter

structured to retain only those parts of the frequency domain that contain proper image parts when inverted will give an image leaving out many system faults and some statistical noise. Do not forget, however, that filters prepared by FFF1 are "ideal" filters (that is, sharp edged) and will introduce some ringing in the images. Proper filters with gradual cutoffs should be prepared as radial functions and put in the 2600 page by a call from the disk for use by TWOD if artifacts are to be avoided.

8.19 MATR: Matrix Former

This program has the standard commands, has no access programs and has the matrix routines instead.

8.19.1 Methods of operation

(a) Load an image file containing the point source image of interest.

(b) Call the point source image into the working area by $Rn(CR)$. Clean up the comments if necessary as these will be part of the printed record for the new matrix.

(c) Set the display scale low $[D(CR)]$ and $M(CR)$ so that the point is small and set the quantitation marks to a 7×7 square centered on the point by commands:

37(CR)

47(CR)

1n(CR)

2m(CR)

where n and m are adjusted to center the square on the point.

(d) Prove the centering of the square by setting the display scale to 1(D5(CR)) and type out the data in the square by K1(CR). The maximum value should be in the center. If not, readjust the 1 and 2 command values.

(e) Determine which element in the 7×7 area is the last non-peak value. The elements are numbered as in Table 2. The expected optical (geometrical) resolution is a good guide to choosing this value. The

usual good collimators turn out to have about 3 or 4 as the last non-peak element. Determine also which set of tables (1 to 9) you wish to replace guided by the HLPR file.

TABLE 2
TYPICAL MATRIX ELEMENT LOCATIONS

0	X	X	X	X	X	X
1	4	X	X	X	X	X
2	5	7	X	X	X	X
3	6	10	11	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	X	X	X	X	X

All symetrically located elements have the same location number. For example, the third element in the top line is an element 2.

(f) Make sure the display is in multicycle mode and gain scale 1 by typing D5(CR) and M(CR), then type:

Jn(CR)

where n is the number of the last non-peak element. The program will type out the comment section of the point source image followed by 10 fine matrix element values and 10 coarse matrix values. The list will be followed by a statement of the MSHIFTS appropriate for these values at weight 4 and then will ask: REPLACE C+F and waits for the user to

type the single digit (1 through 9) designating which matrix table set is to be replaced. After typing the digit, not followed by a carriage return, the program types:

TURN ON PUNCH, TYPE KEY.

The user should then turn on the paper tape punch and strike any key. A paper tape will be produced containing the proper matrix table.

(g) Return to monitor by typing: CTRL-CMON(CR), put the paper tape into the teletype reader and type:

.R ABSLDR(CR)

*SYS:PROC.SV/I(CR)

*PTR:=1600\$

(The \$ was produced by using the ALT MODE key as a terminator instead of RETURN)

Start the teletype reader, the tape will read in and the monitor will give a dot, type:

.SAVE SYS PROC(CR)

.

(h) If it is desired to change the HLPR file to reflect the newly added matrix, do the following:

. ORIS(CR)

Get the program running again

CTRL-P HLPR(CR)

Call the matrix display

CTRL-CNOTE(CR)

Go to the comment mode.

CTRL-K

Erase current comments.

.....

Enter comments as described in Section 8.3.

CTRL-FORM Exit from comment mode.

CTRL-CMON(CR) Return to monitor.

SAVE SYS HLPR 7000;7367(CR) Save HLPR file.

Note that this procedure can be used to prepare any HELP file.

Whatever name is used in the SAVE command (up to 4 characters) is the name used to call that particular file with the CTRL-P command.

APPENDIX A

Building an RK8E System and Installing ORIS Programs

If the disk unit has never been formatted the formatter FRMT must be run. Next, run BUILD from the DECtape system. Insert:

```
RK8E    SYS, RKA0, RKB0
TD8A    DTA0, DTA1 (assuming you have a TD8E DECtape)
KL8E    TTY
KS33    PTR, PTP
```

and any other devices that may be present. This procedure is discussed in DEC OS/8 handbook DEC-S8-OSHBA-A-D starting on page 2-34. Verify the insertions by a PRINT command then give the command BOOT. The Disk system will start and print a dot. Before moving any other programs, initialization must be done.

The initialization program STORIS should now be run to store the field 1 monitor head into disk block 50 and to store the DECtape I/O program into XXTD8E.NO. Type:

```
._RU DTA0:STORIS(CR)
```

```
TD8E?
```

The user should answer Y if a TD8E tape unit is present or N if a TC08 is used.

The initialization actions are now complete and the image file areas have been entered on the OS/8 index.

Now the disk is ready to accept transfer of programs from the tape. Type:

```
._RU DTA0:FOTP(CR)
```

```
*SYS: DTA0:*.*/Q(CR)
```

FOTP will type the name of each program on the tape and the user should reply Y to each one he wants transferred and any other key to those he doesn't want. When the program at last types an * all programs have been transferred or rejected.

Note that all the programs with the file extension NO or IF should never be deleted and you cannot do a GET, R or RUN on them.

After these actions OR76 (ORIS) or any other program may be run.

APPENDIX B

Adding or Modifying Program Modules

The ORIS system has a principal section OR76 that fills field 0 from location 3000 to 6777 with only a few available locations. The area from 7000 to 7577 is a buffer used for displaying comments (7000 - 7177); for Z cuts (7200 - 7577) and for other temporary data. The DECTape I/O routine and its calls used for dumping or refreshing the image file also uses this area as do the Help files. The area from 0 to 2777 is used by other program modules. The user may wish to write modules like the Help files that occupy any or all of 7000 - 7577 but that do not use the command list or the normal command mode. Consult the listings of any of the Help files for an example. These programs cannot use the normal keyboard to give commands since their commands cannot be in the command list. They may of course use many of the normal subroutines as long as these do not use the teletype with the interrupt turned on.

Modules similar to the standard program modules are more complex. They must include a page 0 compatible with OR76 and must include a command list and the extended command list (CTRL-CXX) or at least a terminating word. The restart entry at 200 must also be present and provisions for the continuation of the interrupt chain at 400 must be included. These modules may be of two types: Those which retain control and remain in core until overwritten by another CTRL-PNAME(CR) command and those that exit either automatically (like PROC) or by command. These programs go to RECOVER at location 5507, recover the previous program and return to the display. It is of course possible to

call automatically a second program module from the first if a longer routine is needed. This may be accomplished by entering the second module's name (in sixbit) into WD1 and WD2 and jumping to GOCHN. Such programs that call another module may not exit to the previous ORIS program since the CHAIN action has also saved the current user program. The second program will recall the first one if an entry is made to RECOVR. Any of the programs may however CHAIN to any regular ORIS module in the above described manner.

A word is necessary about the interrupt operation to avoid difficulties. When a program is entered by CHAINing or from a keyboard command, the interrupt is off. It must be restored by an ION to permit the teletype to respond. Certain programs like MSG, BCDOUT, etc. use the command RETRN which causes control to go to the place from which it was last interrupted (generally the display). One must not therefore turn on the interrupt before giving a MSG since the teleprinter will be waiting to clear a line feed (from the command) and will cause an interrupt before the command MSG is reached. Control will return from MSG to the point of interrupt, establishing an endless loop. One must give the MSG before turning on the interrupt or one must send the program to the display or other interrupt enabled terminal loop like the wait loop at loc. 4000 and go to the section of the program wanted by a keyboard command. One may of course give DISPLA-1 as the starting address of the program

module and execute its functions by keyboard command. If one really must turn on the interrupts before the control has been safely passed to one of the terminal loops one can set a "safe return" for the MSG by:

TAD P4000

DCA 0

MSG

NAME - 1

etc.

This establishes the wait loop as the return location. The current working area is set by the content of location IUTR in page 0. If a new module is to continue to use whichever is the current working area, it will be necessary to recover the previous value of IUTR which has been stored in the entrance location of subroutine XPTCON by:

TAD I PUTCON

DCA IUTR

This action is not necessary if it is satisfactory to begin using the lower working area until commanded otherwise.

The locations 164-170 are not used by the OR76 part of the program and may be established by the page 0 of the program module or used as desired. Note that many locations in page 0 may not be altered without disturbing the normal functions of ORIS.

Program modules may be written in the usual manner and assembled with the page 0 ASCII on the system ASCII tape. The starting address may be inside the module or in OR76 (for example BACK). Do not

forget that CHAIN starts the program at the specified starting address + 1. The program name must be four or less letters long and must use the file extension .SV.

Your modules or the standard modules may be altered easily by OS/8 using ODT. A typical example would be:

<u>._GET</u> SYS OR76.SV(CR)	Get main program OR76
<u>._ODT</u> (CR)	Now call ODT
5746/ <u>0323</u> 0303	Ask for contents of loc 5746 put in new value, type LINE FEED.
<u>05747/0303</u> 0301	Get next location, enter new value, type LINE FEED.
<u>05750/0301</u> 0315	
<u>0571/0316</u> 0264(CR)	Enter last value, type carriage return.
<u>↑ C</u>	Type CTRL-C to recall monitor
<u>._SAVE</u> SYS OR76 (CR)	Restore modified OR76 to disk

The above sequence gets the program OR76 and examines and changes the content of locations 5746-51 which contain the name of the program which is automatically called when the program is started. The name was changed from SCAN to CAM4. When the program is called thereafter it will start with CAM4.

APPENDIX C

Equipment Requirements for ORIS-V3

1. Full operation with fast dynamic access:
 - PDP-8/E, 8/A or 8/I with teletype, 16 K memory
 - RK8E-(1600K), RF08-(256K) or DF32-(128K) disk
 - Dual TC08 or TD8E DECTape
 - Point plot control and CRT
 - Interface to camera and/or scanner
2. Full operation with dynamic access limited to 1-2 second/frame of 64 x 64 or 4 frames 32 x 32:
 - PDP-8/E, 8/A, or 8/I with teletype, 16K memory
 - No disk or 1-F32 (32K) for working areas only
 - Dual TC08 or TD8E DECTape
 - Point plot control and CRT
 - Interface to camera and/or scanner
3. Parial operation, slow dynamics 1-2 sec/frame and without NTMAX, Time smooth, flood correct or other operations requiring more core:
 - PDP-8/E, 8/A, or 8/I with teletype, 8K memory
 - Dual TC08 DECTape
 - Point plot control + CRT
 - Interface to imaging device.

APPENDIX D

Error Halts and Messages

There is one error HALT in the ORIS (OR76) resident module. This is at loc. 5430 and indicates an error in reading the field 1 monitor head from disk block 50.

The following error halts are found in the indicated program modules. All could well be replaced with ERROR (JMS I 75, 4475).

LOCATION	ERROR CONDITION	PROGRAM MODULE
2035	Error writing image to tape	DNF2
2050	Error writing comment to tape	DNF2
2220	Sum of squares too big	FFT,IFFT,TWOD
2505	Divide overflow	FFT,IFFT,TWOD
2510	Divided overflow	FFT,IFFT,TWOD

Error Messages

Error messages are of the form:

NNNN? (CR,LF)

Where NNNN is a decimal number giving the location in the program where the error occurred. If a question mark without a number is typed it indicates that a command character was entered that could not be found in the list.

LOCATION		ERROR CONDITION	PROGRAM MODULE
Decimal	Octal		
176	260	Error reading index	FILE
186	272	Error writing index	FILE
250	372	CTRL-CNAME command not found	GH53,SCAN,MATR
253	375	CTRL-CNAME command not found	CAM4,DYN4,DNF2, FFF1,GHF1,DNF1, DHB1
279	427	Number where letter expected	FILE
286	436	Number where letter expected	FILE
292	444	Command not in list	FILE
301	455	Letter where number expected	FILE
352	540	No Ø File	FILE
355	543	File no. too big	FILE
446	676	Error recovering FLD1 monitor	FILE
456	710	Lookup error (IFN not found)	FILE
465	721	Disk read error	FILE
470	726	Disk write error	FILE
519	1007	Error reading file index	FILE
528	1020	Too many images	DYN4,DHB1
529	1027	Table no. out of range	MATR
530	1022	Error writing index to disk	FILE
540	1034	Error reading tape (diskette) index	FILE
543	1037	CAN'T DO ZERO IMAGES	DYN4,DHB1
584	1110	Error writing image to tape (diskette)	FILE
598	1126	Error writing index to tape (diskette)	FILE
669	1135	Error fetching tape (diskette) handler	FILE
709	1305	ARITH overflow in divide	CAM4
712	1310	ARITH overflow in divide	CAM4
713	1311	Error reading index from tape (diskette)	FILE
725	1325	Error reading comment from tape (diskette)	FILE
1038	2016	Error fetching tape (diskette) handler	DNF2
1900	3554	Error recovering FLD1 monitor	OR76 RESIDENT PROGRAM
2834	5422	More than 4 characters in name	OR76 RESIDENT PROGRAM
2845	5435	Error saving program	OR76 RESIDENT PROGRAM
2850	5442	Error saving program	OR76 RESIDENT PROGRAM
2862	5456	Lookup error (no program that name)	OR76 RESIDENT PROGRAM
2892	5514	Error recovering program	OR76 RESIDENT PROGRAM
2897	5521	Error recovering program	OR76 RESIDENT PROGRAM
2911	5537	Error reading tape (diskette) handler	OR76 RESIDENT PROGRAM

APPENDIX E

Assembling ORIS program modules from the ASCII source programs.

Assembly of most of the ORIS modules is similar:

- (1) the assembler (PAL8) is called,
- (2) the binary output file and source file are specified,
- (3) the absolute loader (ABSLDR) is called,
- (4) the file BLANK.SV is loaded,
- (5) the previously assembled binary file is specified, and, finally,
- (6) the loaded program is saved.

Taking the module SCAN as an example:

- (1) . R PAL8(CR)
- (2) * SCAN.BN < R76K, SCAN(CR)

The .BN is optional; if omitted it will be appended automatically by the assembler. The R76K file contains needed symbol equalities and page 0 references.

- (3) . R ABSLDR (CR)
- (4) * BLANK.SV/I (CR)

This overlays a file of zeroes so that any unused program area is zeroed.

- (5) * SCAN.BN\$
(\$ = altmode key)

If more than one line of binary files is needed, use the carriage return; otherwise, use of the altmode key will yield an automatic return to the monitor.

- (6) . SAVE SYS SCAN 0-1377, 7000-7377; 7200 (CR)

Most assemblies require the page 0 file R76K for successful assembly; however, the main program, OR76K does not.

Table E-1 lists the save limits of the various modules and indicates by an asterisk (*) those that require R76K.

The STORIS ("store ORIS") program is somewhat different in that it consists of five separate program units, all of which must be assembled separately then loaded together. The following sequence must be completed:

```

. R PAL8 (CR)
* INIT < INIT (CR)

. R PAL8 (CR)
* TD7000 < R76K, TD7000 (CR)

. R PAL8 (CR)
* TD8EIN < TD8EIN (CR)

. R PAL8 (CR)
* TC7000 < R76K, TC7000 (CR)

. R PAL8 (CR)
* TC08IN < TC08IN (CR)

. R ABSLDR (CR)
* BLANK.SV/I (CR)
* INIT.BN, TD7000.BN, TD8EIN.BN, TC7000.BN, TC08IN.BN $

. SAVE SYS STORIS 0-1777;200 (CR)

```

The fast Fourier transform program (FFT) requires a multiple file, single assembly and appropriate save:

```

. R PAL8 (CR)
* TWOD.BN < R761, PBFFTC, FFT2A, P2D (CR)

. R ABSLDR (CR)
* TWOD.BN $

. SAVE SYS TWOD 0-2577;1600 (CR)

```

TABLE E-1

<u>Module</u>	<u>Save limits</u>
OR76	0,3000-6777; 5400
*SCAN	0-1377, 7000-7377; 7200
*DYN4	0-1777; 4343
*CAM4	0-1577; 4343
*GHS3	0-1477; 4343
*FFF1	0-1377; 4343
*DNF1	0-1577; 4343
*DNF2K	0-2177; 4343
*GHF1	0-1177; 4343
*DHB1	0-1377; 4343
*MATR	0-1577; 4343
*GS1	0-1171; 4343
*STORIS	0-1777; 200
TWOD	0-2577; 1600
*FILE	0-1377; 4343
*PROC	0-2777; 1600

* REQUIRES R76K FOR ASSEMBLY

APPENDIX F

Display Interface Functions

10T	NEM	FUNCTION
6050	DSM	SET MODE VIA AC 9, 10, 11
		000 POINT PLOT
		001 INTERPOLATE INC X BY 1
		010 INTERPOLATE INC X BY 2
		011 INTERPOLATE INC X BY 4
		101 INTERPOLATE DEC X BY 1
		110 INTERPOLATE DEC X BY 2
		111 INTERPOLATE DEC X BY 4
6051	DY1	INCREMENT Y BY 1
6052	DY2	INCREMENT Y BY 2
6053	DY4	INCREMENT Y BY 4
6054	DXL	LOAD X COORD. BUFFER (FROM ACCUMULATOR2-11)
6055	DXS	LOAD X COORD. BUFFER AND DISPLAY POINT
6056		
6057	DSB	LOAD BRIGHTNESS REG. FROM AC 7-11
6060	DX4	INCREMENT X BY 4
6061	DYM1	DECREMENT Y BY 1
6062	DYM2	DECREMENT Y BY 2
6063	DYM4	DECREMENT Y BY 4
6064	DYL	LOAD Y BUFFER (FROM AC 2-11)
6065	DYS	LOAD Y BUFFER AND DISPLAY POINT
6066	DLS	DISPLAY LOAD SEQUENCE. LOAD BRIGHTNESS REGISTER FROM AC 7-11, CLEAR AC, DISPLAY AVERAGE OF NEW DATA AND PREVIOUS DATA PTS., INCREMENT OR DECREMENT X, DISPLAY NEW DATA POINT, SHIFT X COORD AGAIN
6067	DIS	DISPLAY POINT

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