N91-32715

IMPLEMENTATION OF THE FAA RESEARCH AND DEVELOPMENT ELECTROMAGNETIC DATABASE

R. L. McDowall
Computer Resource Management, Incorporated
FAA Technical Center, Atlantic City International Airport, NJ

D. J. Grush and D. M. Cook
EG&G Idaho, Incorporated
Idaho Falls, Idaho

M. S. Glynn
Federal Aviation Administration
FAA Technical Center, Atlantic City International Airport, NJ

ABSTRACT

The Idaho National Engineering Laboratory (INEL) has been assisting the Federal Aviation Administration (FAA) in developing a database of information about lightning. The FAA Research and Development Electromagnetic Database (FRED) will ultimately contain data from a variety of airborne and ground-based lightning research projects. This paper contains an outline of the data currently available in FRED. It also lists the data sources which the FAA intends to incorporate into FRED. In addition, it describes how the researcher may access and use the FRED menu system.

INTRODUCTION

A number of researchers throughout the world have conducted research on lightning. In general, once a researcher has published his data and conclusions, it is very difficult for other researchers to access that data. In the Proceedings of the 1988 International Aerospace and Ground Conference on Lightning and Static Electricity [1], Computer Resource Management, Incorporated (CRM) reported on the plans which the FAA had for the creation of a world-wide database of information on lightning. This paper presents the accomplishments made since that time.

The FAA has solicited data from a number of different sources to be compiled in a database. The aim of this database is to unite in one location information compiled by different researchers using different equipment with different research goals in mind.

At present, not all data sources contain information for all of the data fields in FRED. In addition, as other sources become available, new fields may be added to FRED. FRED's major function will be to provide a place to collect data gathered in lightning studies conducted throughout the world. The combined data will then be available to researchers in common format for analysis, allowing them to create and test lightning models.

The minimum objective for FRED will be to provide access so that users can see what information has already been collected. They can then use this

information to plan future physical or statistical research projects.

Functions currently available through FRED include average, mean, integration, differentiation, maximum, minimum, relative maxima, relative minima, waveform plots, and scatter diagrams of combinations of fields.

Functions anticipated to be available through FRED include fast Fourier transforms, standard deviation, correlations, and histograms of combinations of fields.

FRED will provide investigators with the ability to generate reports and perform statistical analyses. A number of pre-programmed reports and graphs are available to the user. These reports can be selected from the menus. Other reports may be available on request from the FAA Database Administrator (DBA):

FRED Database Administrator, ACD-230
Flight Safety Research Branch
FAA Technical Center
Atlantic City International Airport, NJ 08405 USA

DATA

Although a number of data sources have been identified, acquisition of the data has not proceeded as rapidly as anticipated. Data have been acquired from the FAA (the CV-580 program), from the National Aeronautical and Space Administration (NASA) (the F-106 program) and from the Bureau of Land Management (BLM). Each of these data sources will be discussed below. If a user has an existing body of data, the FAA would be very interested in reviewing it for inclusion in FRED.

There are three basic types of information contained in FRED: environmental, electromagnetic, and waveform data. At a minimum, for each strike, there will be both environmental and electromagnetic data. Although FRED allows for entry of various items of data, not all sources will have entries in all data fields.

The following sections describe the data fields in FRED. All possible data fields are listed along with a description of the data they may contain. In addition, the default value for each field is given. In general, the default value will be some value that is physically or logically impossible to obtain, or will be the letter "U" or the word "Unknown".

WAVEFORM DATA

Waveform data consists of data points recorded either by a digital or an analog recorder. If the waveform was recorded in analog format, it was digitized before inclusion in FRED.

ENVIRONMENTAL DATA

Environmental data consists of data describing the environment at the time of the strike. Items such as air temperature, or precipitation type and

intensity are examples of environmental data. Table I shows the possible environmental data fields and their default or unknown values.

TABLE I. ENVIRONMENTAL DATA

FIELD	DEFAULT VALUE	FIELD	DEFAULT VALUE
ALTITUDE	-9999	AIRSPEED	-9999
OUTSIDE AIR TEMPERATURE	-9999	LATITUDE	999:99:99
LONGITUDE	999:99:99	PRECIPITATION SEVERITY	U
TYPE OF PRECIPITATION	0	TURBULENCE	U
ATTACHMENT-DETACHMENT POINT	Not Available		

ELECTROMAGNETIC DATA

Electromagnetic data consists of those electromagnetic parameters which can be calculated from a waveform or which can be sensed directly. Table II shows the possible electromagnetic data fields and their default values. Those fields whose default value is marked with an asterisk (*) do not have default values.

TABLE II. ELECTROMAGNETIC DATA

FIELD	DEFAULT VALUE	FIELD	DEFAULT VALUE
SENSING PARAMETER	*	PEAK VALUE OF PARAMETER	*
PEAK RATE OF RISE OF PARAMETER	0E0	TIME TO PEAK VALUE OF PARAMETER	*
FULL WIDTH AT HALF MAXIMUM VALUE	*	TIME TO HALF MAXIMUM VALUE	*
SATURATION FLAG SET	U	ACTION INTEGRAL	blank
CHARGE TRANSFER	blank	TRIGGER THRESHOLD	-9999
SATURATION THRESHOLD	-9999	F LL SCALE	-9999

OTHER DATA

In addition to the data described above, FRED carries other information important to the understanding of the lightning event and its measurement. There are two basic types of other data, data describing the data source and data describing the data collection equipment. These data fields are shown in table III. Those fields whose default value is marked with an asterisk (*) do not have default values.

DATA SOURCES

CV-580 DATA

During 1984, 1985, and 1987 the FAA conducted a program to take electromagnetic measurements of strikes to an aircraft which was flown in thunderstorms in Florida. This program was conducted jointly with the Air Force, the Navy, NASA, the National Oceanic and Atmospheric Administration (NOAA), and the Offices Nationales des Etudes et Recherches Aerospatiales

(ONERA). The program employed a Convair 580 aircraft specifically hardened against lightning. During the course of the program, the aircraft was struck approximately 60 times.

TABLE III. OTHER DATA

FIELD	DEFAULT VALUE	FIELD	DEFAULT VALUE
SOURCE TYPE	blank	MODEL NUMBER	*
SOURCE NAME	*	SENSOR TYPE	*
PRIMARY RESEARCHER	blank	LOWER FREQUENCY RESPONSE LIMIT	*
RESEARCHER'S AFFILIATION	blank	UPPER FREQUENCY RESPONSE LIMIT	*
DATE OF FLASH	*	ACCURACY	*
TIME OF FLASH	*	MANUFACTURER	*
TIME OF INITIAL SAMPLE POINT	*	MODEL NUMBER	*
PENETRATION	U	NUMBER DISCRETIZATION LEVELS	*
SENSOR LOCATION	*	NUMBER OF CHANNELS	*
DIGITIZER ID	*	MAXIMUM FM BANDWIDTH	*
SAMPLING INTERVAL	*	MAXIMUM DIRECT RECORD BANDWIDTH	*
SAMPLING WINDOW	*	FULL SCALE	*
ANALOG RECORDER ID	*	DYNAMIC RANGE	*
MANUFACTURER	*		

Three types of data were collected under this program: digital recordings, analog recordings, and manually written log sheets. The log sheets contain information about the environment: the altitude, temperature, airspeed, and precipitation and turbulence conditions. They also contain the date and time of the strike and the longitude and latitude of the aircraft when it was struck.

The CV-580 was instrumented with a variety of sensors throughout the aircraft. The number, kinds, and locations of the sensors varied from one year to the next. These sensors fed both analog and digital tape recorders. The analog recorders ran continuously during the flight, except when a tape ran out and a new tape was being mounted. Analog recordings were made for 48 of the strikes to the aircraft. The analog signals were converted to digital representations by Electro Magnetic Applications, Incorporated (EMA). This effort is described in an internal FAA report [2]. The digitized analog data and the data from the log sheets were entered into FRED by the staff at the INEL.

NASA F-106 DATA

Between 1981 and 1986, NASA conducted a program to study lightning at high atmospheric levels. An instrumented F-106 aircraft was flown into storm clouds. Data was collected on strikes near the aircraft, as well as strikes directly to the aircraft. Although both analog and digital waveforms were collected, only the digital will be incorporated into FRED. Additional data consists of environmental and other data similar to that collected under the CV-580 program.

BLM DATA

The BLM collects lightning location data on strikes in 11 western states of

the United States. This data consists of date, time, location, and peak current. As a result there is no waveform data from this source. Data for 1985 through 1990 will be included in FRED.

FRED

FRED will be housed on equipment at the INEL Supercomputing Center (ISC) in Idaho Falls, Idaho. Figure 1 shows the relationships among the various components used to store or access FRED.

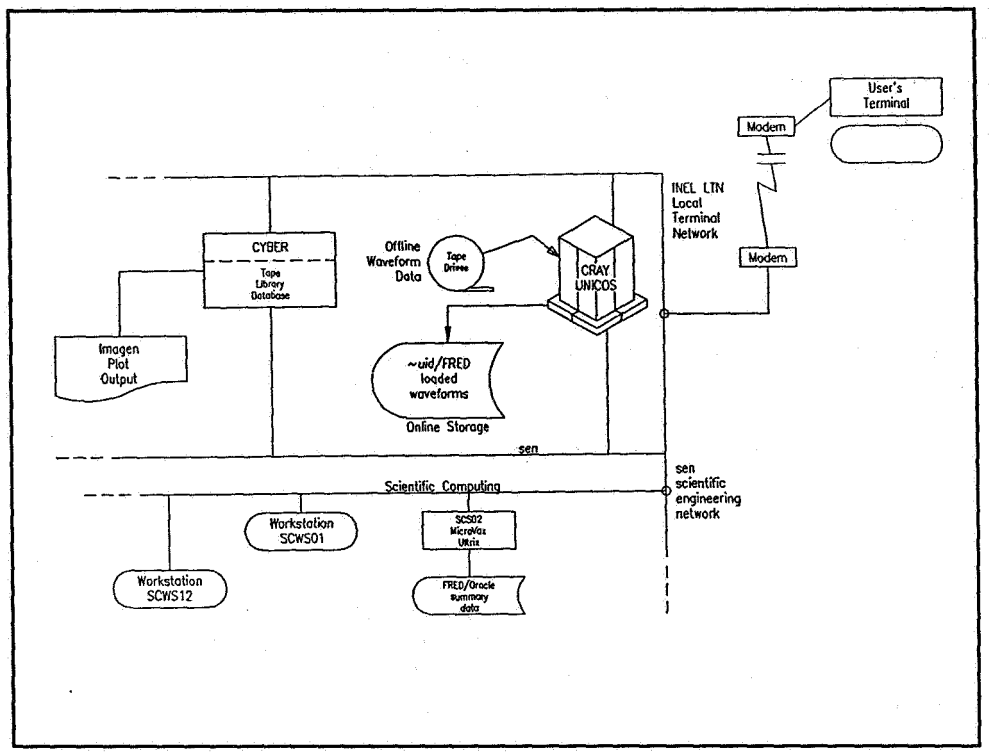

FIGURE 1. FRED ENVIRONMENT

The environmental data reside on a MicroVAX system and are accessed through the ORACLE relational database management system. The waveform data are stored offline on nine-track magnetic tapes. The user may request that waveforms be mounted for his review. The CYBER/Imagen system is used to generate waveform and statistical plots at the INEL. These waveform requests are handled through FRED.

To gain access to FRED, the user will request permission from the FAA DBA and complete the forms for INEL computer access.

FRED is a completely menu-driven system. The user makes selections and enters information on menu screens. Through FRED the user may view the environmental data for individual strikes, generate reports covering many or all strikes, plot data from selected strikes, and view or plot waveforms.

WELCOME SCREEN

The access to some of the data provided to the FAA for inclusion in FRED has been restricted by the original data owner. If a user's access to some data has been restricted, the user will see a restriction message in the Welcome Screen.

The Welcome Screen will also show the last time FRED was accessed by this User-ID and the last time FRED was updated. These dates allow the user to determine if the database has been changed since his last access, or if someone else is using his ID. From the Welcome Screen, the user can go to the User Menu or exit the system.

USER MENU SCREEN

The User Menu Screen (shown in figure 2) allows the user to select browsing, querying, and listing functions. These functions are selected by typing the appropriate number in the Selection field. Pressing the <EXIT> key causes the user to be logged off the system.

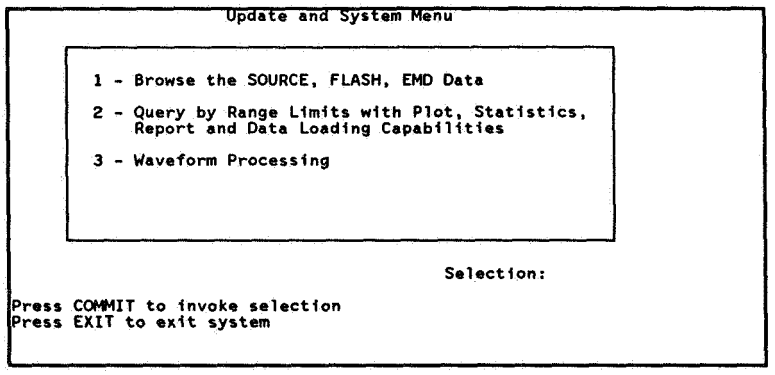

FIGURE 2. USER MENU

The first function on the User Menu allows the user to browse among the records which are available to him in FRED. Selecting this option causes the system to display the Summary Data screen (shown in figure 3).

The user may scroll through the information about sources of data available in FRED. When the user has selected the source he wishes to use, he may scroll up and down through the flashes for that source. For each source there will be many records in the Flash file. Each record will correspond to one strike of lightning.

When the user has identified the flash in which he is interested, he may move to the Electromagnetic Data block. When the curser is positioned in the Electromagnetic Data block, the user may scroll through the electromagnetic data records for the selected flash. For each flash there may be many records in the electromagnetic data file. Each record will contain information collected by one sensor from this one strike of lightning.

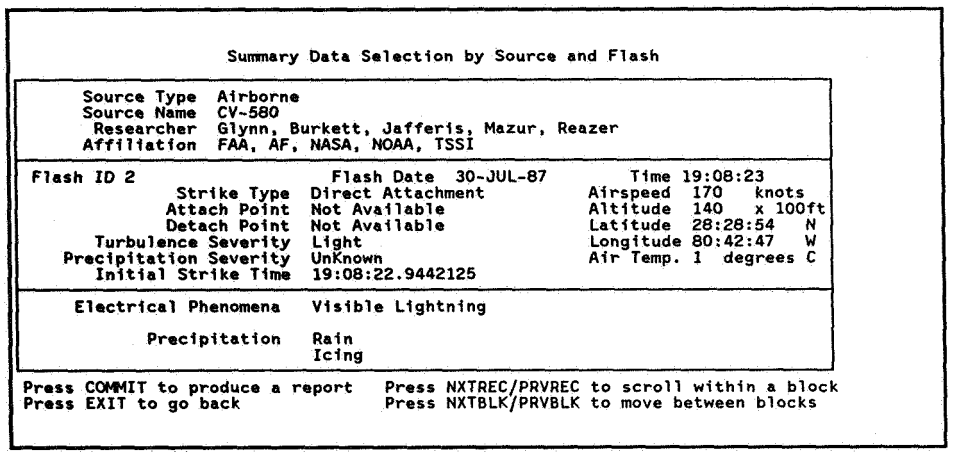

FIGURE 3. SUMMARY DATA SCREEN

If a waveform has been recorded for this sensor, the user may also elect to look at information about the waveform. Invoking the waveform information calls the Electromagnetic Data screen, shown in figure 4.

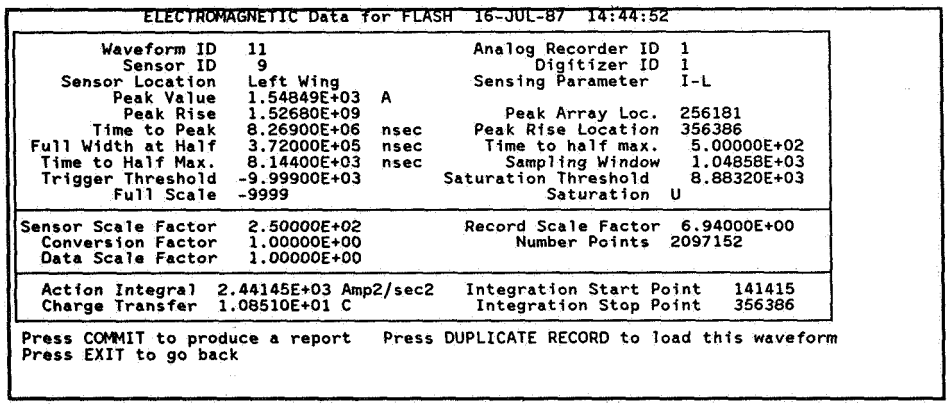

FIGURE 4. ELECTROMAGNETIC DATA SCREEN

The Electromagnetic Data screen shows the user information about the waveform selected in the Summary Data screen. The bottom block contains information only if the sensor for the selected waveform is a current or "I" sensor. The other blocks will contain information for all waveforms. After viewing the data, the user may return to the previous menu to select another Source, Flash, or Electromagnetic Data record. The user may also produce a report of the waveform or request that the waveform be loaded onto the CRAY from the Electromagnetic Data screen.

Query Screen

The second function on the User Menu allows the user to select data from FRED. The selected data may then be viewed, plotted, reported, or used for

statistical analysis. Selecting "2" causes the system to display the Query screen (shown in figure 5).

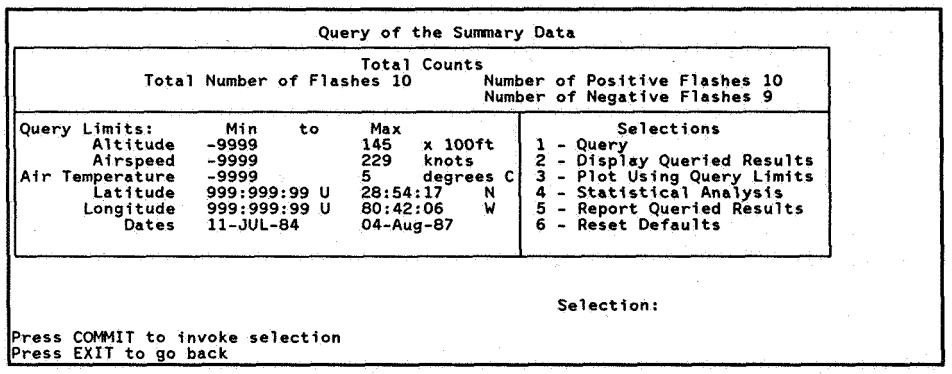

FIGURE 5. QUERY SCREEN

When this screen is invoked for the first time, the total counts reflect the total number of strikes of the relevant type in FRED. In addition, the query limits for each parameter are set to the minimum and maximum values in FRED. In general, if a numeric value is not known, it is set to the most negative value possible for the field. Alphabetic values are set to blank or "U" if unknown.

In addition to the six selections offered on this screen, the user may change values in any of the parameter fields. After changing any of the limiting parameters, the user may restore the original defaults by typing a "6" in the Selection field. This results in the restoration of the screen to the original values, but does not perform a query. As a result, the data which has already been retrieved is not reset. If the user resets the defaults and then tries to display the queried results without invoking a query first, the data will remain the same.

Typing a "1" in the Selection field of the Query screen issues a "query" to the database management system. An ORACLE query selects data from the database using the selection criteria and the limits displayed on the screen at the time the query is invoked. When the query is invoked, FRED will count the total number of flashes and the number of positive and negative flashes resulting from the query. These numbers will be displayed in the top block of the Query screen.

Typing a "2" in the Selection field will display the queried results by invoking the Source and Flash screen (shown in figure 6). If no query has been made, the Source and Flash screen will be displayed, but it will contain no data. It is imperative, therefore, that the user issue a query by invoking selection "1" before selecting this option, even if the user is interested in browsing through the entire set of FRED data.

Typing a "3" in the Selection field of the screen invokes the Graphics Menu screen shown in figure 7. This screen allows the user to plot the data

contained in the displayed limits. (The user need not execute a query to select the data.) The user may select a number from one to eight corresponding to the plots listed on the screen.

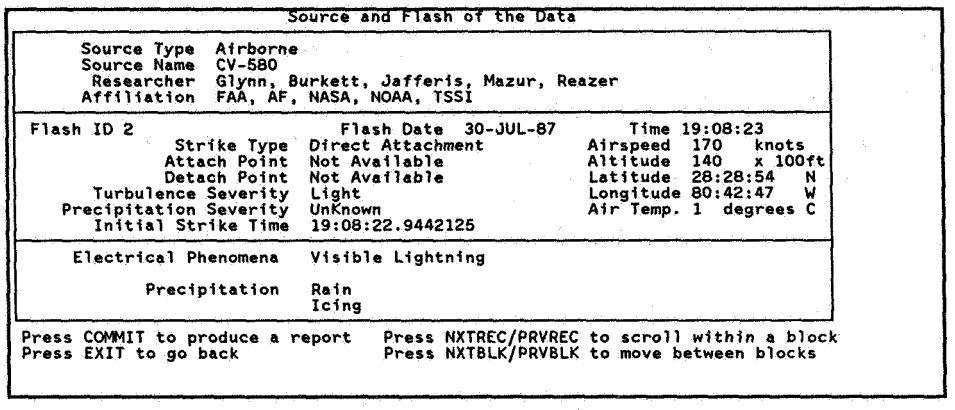

FIGURE 6. SOURCE AND FLASH SCREEN

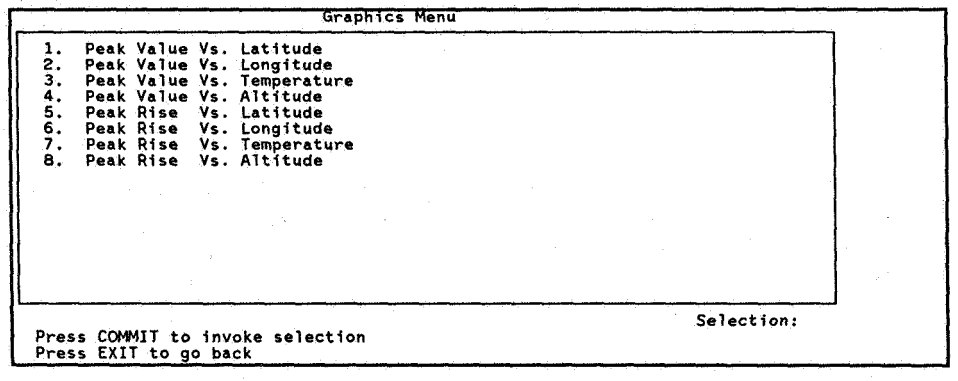

FIGURE 7. GRAPHICS MENU

When the user has made his selection, the system displays a Plot Customization screen. This screen allows the user the change the defaults used in creating the plot. When the user is satisfied with the information on the Plot Customization screen, the system will ask the user to select the device on which the plot is to be displayed. If the user wishes to display the plot on his terminal, the terminal must be compatible with Tektronix equipment.

When the plot is completed, the user returns to FRED by typing "quit" and "logout". A sample plot is shown in figure 8.

Typing a "4" in the Selection field of the Query screen and pressing <COMMIT> invokes the SQL environment. This environment allows the user to write his own SQL queries. Two sample queries are shown in figure 9. The resulting reports are shown in figures 10 and 11.

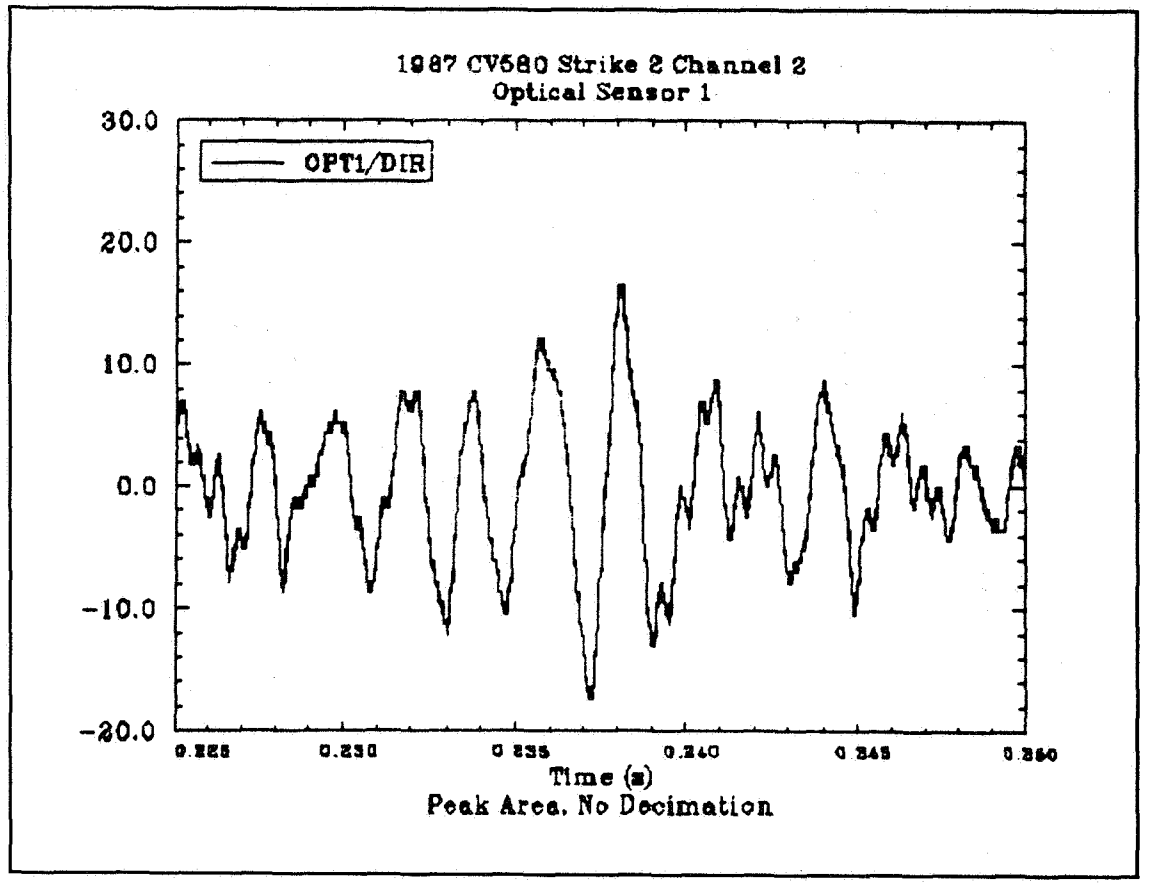

FIGURE 8. SAMPLE FRED PLOT

```
select action_integral,altitude,air_temperature
from i_param,flash,emd
where i_param.waveform_id=emd.waveform_id
and emd.flash_id=flash.flash_id
/

select action_integral,altitude,air_temperature
from i_param,flash,emd
where i_param.waveform_id=emd.waveform_id
and emd.flash_id=flash.flash_id
and action_integral=(select max(action_integral) from i_param)
/
```

FIGURE 9. SAMPLE SQL QUERY

ACTION_INTEGRAL	ALTITUDE	AIR_TEMPERATURE
494457	145	4
698.7231	145	4
2132.234	143	-9999
3266.51	143	-9999
20671.44	143	-9999
321279.8	145	4
438.3188	145	4
465.3078	145	4
250568.6	145	4
188269.5	143	-9999
327443.9	143	-9999

ACTION_INTEGRAL	ALTITUDE	AIR_TEMPERATURE
291.5429	-9999	-9999
218833.3	-9999	-9999
754749.2	140	5
811.6994	140	5
486.4361	140	5
422767.4	140	5
759333	140	5
523.8895	140	5
456.807	140	5
456773.4	140	-3
1055345	140	-3

68 records selected.

FIGURE 10. PARTIAL REPORT FROM FIRST SAMPLE QUERY

ACTION_INTEGRAL	ALTITUDE	AIR_TEMPERATURE
1055345	140	-3

FIGURE 11. REPORT FROM SECOND SAMPLE QUERY

Typing a "5" in the Selection field invokes the Report screen. This screen allows the user to select a report to be displayed and printed. The user will be prompted to enter the name of a file into which the report will be saved. This file will remain in the user's FRED directory. Management of these report files is accomplished through the waveform processing option. Files remain resident on the CRAY until the user chooses to delete them.

The report selected is displayed on the user's screen. This allows the user to capture the data for reprinting. A sample report is shown in appendix A.

Waveform Processing

The third function on the User Menu allows the user to review the waveforms which have been loaded into his directory. Selecting "3" causes the system to display the Waveform Processing Menu screen (shown in figure 12). The Waveform Processing Menu allows the user to see and manage a listing of the waveforms he has had loaded into his directory. Because of space and cost limitations, the waveform data is stored offline on nine-track magnetic tapes. If the user wishes to view or manipulate a particular waveform, he asks to have it loaded onto the CRAY computer. Depending on the workload at the time he issues his request, it may take an hour or more to process this request.

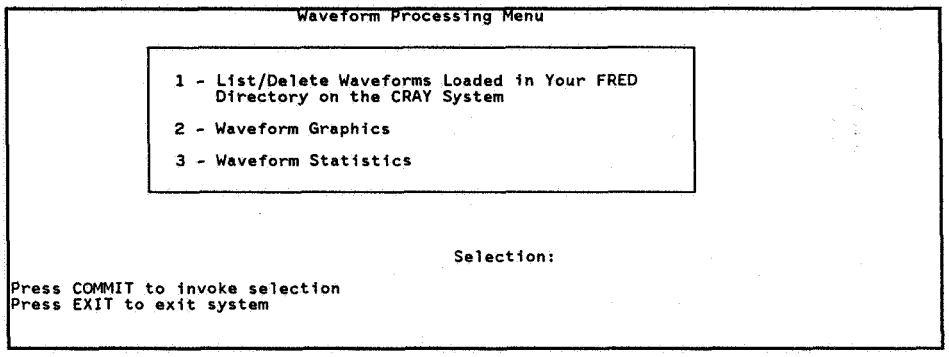

FIGURE 12. WAVEFORM PROCESSING MENU

ACRONYMS

BLM	Bureau of Land Management
CRM	Computer Resource Management, Incorporated
DBA	Database Administrator
FAA	Federal Aviation Administration
FRED	FAA Research and Development Electromagnetic Database
INEL	Idaho National Engineering Laboratory
NASA	National Aeronautical and Space Administration
NOAA	National Oceanic and Atmospheric Administration
ONERA	Offices Nationales des Etudes et Recherches Aerospatiales

REFERENCES

1. McDowall, R. L., and M. Glynn, "Lightning Information Database", Proceedings of the 1988 International Aerospace and Ground Conference on Lightning and Static Electricity, NOAA Special Report, 1988.

2. Elliott, J. R., and H. S. Weigel, "Digitization of CV-580 In-Flight Lightning Strike Analog Data from 1984, 1985, 1987", FAA Internal Report, 1990.

ELECTROMAGNETIC DATA INFORMATION

Strike Date	Strike Time	Sens Parm	Sense Loc.	Peak Value	Units	Peak Rate of Rise	Time to Peak (nsec)	Width at 1/2 Max. (nsec)	Full Time of 1/2 Max. (nsec)	S	Saturation Threshold	Action Integral	Charge Transfer	Trigger Threshold
30-JUL-87	19:25:50	BDOT	TB	-2.8E+02	A/m	3.2E+08	5.6E+05	2.1E+05	4.6E+05	U	2.0E+04			-9.999E+03
		I-H	TB	1.2E+04	A	5.7E+10	5.8E+03	2.8E+03	4.0E+03	U	1.7E+06	8.3E+04	-4.3E+01	-9.999E+03
		I-H	LW	6.7E+03	A	4.3E+10	3.3E+03	7.5E+02	3.0E+03	U	1.7E+06	2.8E+04	-1.8E+01	-9.999E+03
		I-H	RW	8.3E+03	A	5.3E+10	1.9E+05	7.5E+02	1.9E+05	U	1.7E+06	2.1E+05	-1.1E+02	-9.999E+03
		I-H	VS	4.2E+03	A	2.3E+10	1.0E+03	5.0E+02	8.8E+02	U	1.7E+06	3.8E+05	-1.5E+02	-9.999E+03
		I-L	VS	2.9E+02	A	6.4E+08	5.5E+03	2.0E+03	4.5E+03	U	8.9E+03	4.4E+02	4.5E+00	-9.999E+03
		I-L	LW	2.1E+02	A	4.4E+08	4.0E+03	1.0E+03	3.0E+03	U	8.9E+03	3.7E+02	2.0E+00	-9.999E+03
		I-L	TB	2.0E+03	A	3.8E+09	5.1E+04	6.7E+04	9.0E+03	U	8.9E+03	1.4E+03	9.5E-01	-9.999E+03
		I-L	RW	9.2E+02	A	4.9E+08	2.9E+06	1.8E+05	2.8E+06	U	8.9E+03	3.8E+02	3.0E+00	-9.999E+03
		IDOT	TB	-1.9E+09	A/s	1.3E+15	1.8E+04	2.4E+04	6.5E+03	U	1.1E+11			-9.999E+03
		JN	VS	-2.0E-06	C/m**2	3.9E+00	3.3E+03	2.8E+04	2.5E+03	U	5.0E-04			-9.999E+03
		JN	RW	-3.2E-06	C/m**2	1.4E+01	3.8E+03	4.5E+03	3.3E+03	U	5.0E-04			-9.999E+03
		JN	LW	-3.2E-06	C/m**2	4.9E+00	1.1E+05	5.5E+04	8.8E+04	U	5.0E-04			-9.999E+03
		JN-H	FF	3.2E-06	C/m**2	1.9E+00	3.5E+03	4.0E+04	2.5E+03	U	3.5E-05			-9.999E+03
		JN-L	FF	3.8E-06	C/m**2	2.3E+00	1.2E+05	4.1E+04	1.2E+05	U	6.9E-05			-9.999E+03
		JS	RW	4.4E+08	A/m/s	.0E+00	5.0E+03	4.8E+03	4.8E+03	U	2.3E+11			-9.999E+03
		JS	FF	1.2E+09	A/m/s	.0E+00	7.5E+02	7.5E+02	5.0E+02	U	2.3E+11			-9.999E+03
		JS	AF	5.6E+08	A/m/s	.0E+00	3.3E+03	7.5E+02	3.1E+03	U	2.3E+11			-9.999E+03
		JS	LW	5.6E+08	A/m/s	.0E+00	3.8E+03	7.5E+02	3.6E+03	U	2.3E+11			-9.999E+03
		OPT1	LF	-1.1E+01	V	1.6E+07	5.8E+05	6.2E+05	2.7E+05	U	5.7E+02			-9.999E+03
		OPT2	LU	-1.2E+01	V	1.9E+07	2.7E+05	6.8E+03	2.6E+05	U	5.7E+02			-9.999E+03
		OPT3	LA	-5.0E+00	V	1.0E+07	4.3E+05	1.6E+05	4.3E+05	U	5.7E+02			-9.999E+03
		OPT4	LR	-4.4E+00	V	1.0E+07	7.1E+04	2.8E+05	7.0E+04	U	5.7E+02			-9.999E+03
		OPT5	LL	-8.9E+00	V	1.6E+07	3.0E+05	8.3E+03	3.0E+05	U	5.7E+02			-9.999E+03
		OPT6	LD	-6.7E+00	V	2.0E+07	1.6E+05	4.5E+05	1.3E+04	U	5.7E+02			-9.999E+03
		TRIG	NA	-2.9E+00	V	6.4E+06	6.3E+03	9.7E+04	5.5E+03	U	5.7E+01			-9.999E+03
04-AUG-87	22:53:01	BDOT	TB	-3.3E+02	A/m	5.1E+08	4.8E+05	1.2E+05	4.8E+05	U	2.0E+04			-9.999E+03
		I-H	VS	-4.2E+03	A	2.7E+10	4.4E+04	6.0E+04	1.0E+04	U	1.7E+06	3.9E+05	-1.3E+02	-9.999E+03
		I-H	RW	4.2E+03	A	2.7E+10	2.1E+04	2.5E+04	5.5E+03	U	1.7E+06	2.5E+05	-1.2E+02	-9.999E+03
		I-H	LW	3.3E+03	A	2.3E+10	3.0E+05	3.8E+04	2.7E+05	U	1.7E+06	2.4E+05	-1.4E+02	-9.999E+03
		I-H	TB	2.5E+03	A	2.0E+10	5.0E+02	1.0E+03	3.8E+02	U	1.7E+06	2.7E+05	-1.4E+02	-9.999E+03
		I-L	VS	-1.6E+03	A	1.3E+09	5.9E+06	1.2E+06	5.4E+06	U	8.9E+03	3.5E+03	-6.1E+00	-9.999E+03
		I-L	TB	2.4E+02	A	4.5E+08	2.5E+03	1.5E+03	1.5E+03	U	8.9E+03	4.4E+02	2.5E-01	-9.999E+03
		I-L	RW	1.5E+03	A	9.2E+08	5.2E+06	6.0E+05	4.7E+06	U	8.9E+03	5.3E+03	7.4E+00	-9.999E+03
		I-L	LW	3.4E+02	A	5.6E+08	3.0E+03	3.0E+03	2.5E+03	U	8.9E+03	2.5E+02	-2.3E-01	-9.999E+03
		IDOT	TB	-1.9E+09	A/s	2.4E+15	1.2E+04	2.5E+04	1.0E+03	U	1.1E+11			-9.999E+03
		JN	VS	-2.0E-06	C/m**2	3.9E+00	5.3E+03	2.3E+04	3.5E+03	U	5.0E-04			-9.999E+03
		JN	LW	-3.4E-06	C/m**2	7.8E+00	4.5E+05	8.6E+04	4.4E+05	U	5.0E-04			-9.999E+03
		JN	RW	-3.9E-06	C/m**2	4.9E+00	2.9E+04	5.8E+03	2.6E+04	U	5.0E-04			-9.999E+03