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Lunar Laser Ranging Data Processing in a Unix / X Windows Environment

by

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In cooperation with the NASA Crustal Dynamics Project initiative placing workstation computers at each of its laser ranging stations to handle data filtering and normalpointing, MLRS personnel have developed a new generation of software to provide the same services for the lunar laser ranging data type. The Unix operating system and X-windows/Motif provides an environment for both batch and interactive filtering and normalpointing as well as prediction calculations. The goal is to provide a transportable and maintainable data reduction environment. This software and some sample displays are presented.

Introduction

The processes of reformatting, calibrating, filtering and normalpointing lunar ranging data has taken several shapes during the years of University of Texas McDonald Observatory participation in lunar laser ranging. During the days of the 2.7m ranging system, from 1969 to 1985, data was transferred on magnetic tape from the Observatory to Austin, where batch programs on the CDC Cyber computer systems were invoked on an entire month's data. After a good deal of interaction with line printer plots, listings, and punch cards, the data was finally processed and ready for mailing -- on punch cards or magnetic tape.

The part-time lunar ranging facilities on the 2.7m telescope were soon replaced by the dedicated lunar and artificial satellite ranging system MLRS (McDonald Laser Ranging System). From the first lunar observations in 1983 until mid-1990, data was processed interactively on Data General NOVA 4/X computers. There were restrictions as to the amount of computer memory and the speed of processing. Fortunately, the station contained 2 identical NOVAs sharing a hard disk, meaning that the lunar (or satellite) data could be processed on one computer while data was taken on the other. The reduction of the data was totally interactive and in no way automated. In addition, lunar predictions were produced on-site, another first in the effort to down-size historically mainframe-based applications. Extraction of earth rotation parameters was at one time attempted on site in near-realtime.

In 1988, the Crustal Dynamics Project SLR Computer Panel mandated the installation of Hewlett-Packard 9000/360 Unix workstations at each NASA-operated laser ranging station to relieve the aging controller computers of much of their data and communications handling responsibility and to provide on-site data filtering and normalpointing for a growing list of artificial satellite targets. This was seen by MLRS staff as an opportunity to provide a better lunar data processing environment as well.

A New Environment

One of the important goals of the computer panel was to provide a standard environment for data handling that would allow portable code to be written for a non-

proprietary system. To this end Unix as well as X windows were chosen for the software environment. Both of these products can be found on workstations and mainframes from many different vendors. Although there are many "flavors" of Unix, there is enough of a common thread, especially with POSIX, SVID , and other standards to allow fairly portable code to be written. In addition there are many useful tools generally available with Unix, from text editors to file manipulation utilities and operating system shells. The availability of shell scripts to create batch jobs has also eased the task of system development.

X windows (along with OSF/Motif) provide a network-oriented interactive graphical user interface that is quite portable and has been implemented on several operating systems. X-windows is policy free, meaning that there is no implied style imposed on code being written for this interface. The Open Systems Foundation (OSF) Motif graphical user interface was adopted to give a common style to this and other programs written for the X-windows environment.

Lunar Tasks

The process of obtaining lunar data requires several pre- and post-acquisition steps, which are at the heart of this discussion:

- 1) range and point angle predictions,
- 2) data calibration and reformatting,
- 3) data filtering,
- 4) data normalpointing.

Much of the software for tasks 1), 2), and 4) was implemented in a FORTRAN 66 variant on the NOVA as well as in FORTRAN 77, after a joint port with the Australian National Mapping organization. While the data filtering code also existed on the NOVA, it was not in a form that was readily usable on the Hewlett-Packard workstation. Common to all these steps is the need for a flexible user interface which handles entry of parameters, plotting of data, and display of processing results.

Predictions

The first task of any ranging system is to provide point angle and range predictions. Lunar ranging is no exception. Most of the code required to produce lunar predictions is also required in the production of the filtered lunar data and normalpoints, making the maintenance of code relatively straightforward. This software can use either the MIT/UT PEP ephemeris or the JPL DE-303 ephemeris and its successors. Lunar and planetary predictions as well as lunar librations are included in both of these packages. Since no fit of lunar or solar system parameters is made in the on-site processing, no partial derivatives are needed. Earth rotation data is updated weekly to provide the most accurate predictions possible.

Parameters to run this software are set in the Lunar Data Editor program. The prediction software itself is run automatically on a daily basis from a Unix "cron" script. The program reads the date and time, recognizes whether predictions already exist and produces predictions as appropriate for the next day. The prediction program can also be run interactively from the command line of a terminal window as well as from XControl, the main user interface program, but that is never done in production. Lunar predictions are moved to the ranging system control computer over an RS-232 serial link in the same way as the artificial satellite predictions.

Batch Analysis

The reduction of the lunar ranging data after the moon is observed starts with the same suite of programs as do the artificial satellite reductions. Once the data has been transferred from the controller computer and preliminary reformatting and collating of data has been done a shell script is initiated to calculate and apply geometric and electronic calibrations, to filter the data using Poisson filtering techniques, and to normalpoint the data. (See figure 1.) The results of processing are then displayed using the Lunar Data Editor program, giving the crew can get an objective view of the quality of the ranging data.

Interactive Analysis

During the time when lunar data was being entirely reduced on-site with NOVA software, there was manpower available to scrutinize data. We no longer have that luxury. The lunar data is electronically transferred to Austin (using batch uucp over a dedicated line) for final filtering and lunar-network-oriented quality control.

To better interact with the data, the Lunar Data Editor (LDE) was developed. It uses X windows and OSF Motif to provide a modern environment in which to examine and process the lunar data. Pull down menus, pop-up windows as well as both histogram and scatter plots of the data are available for operator use. Figures 2-7 show portions of the user interface through which the user has control over the scale of the plots, the parameters used in the Poisson filtering and normalpointing and the sequence of reduction operations. Also included in the interface are provisions to manage up to 10 sets of station coordinates, lunar ephemeris parameters, and control parameters as well as 5 sets of lunar reflector coordinates. This capability permits easy changes among ephemerides and stations as the situation dictates.

LDE is comprised of several programs with distinct responsibilities. LDE itself is a C language program that handles the user interface, including parameter input and data display. The entire X-windows/Motif interface resides here. It in turn uses the Unix "system" call to invoke the lunar calibration program (C), the Poisson filtering program (FORTRAN), and the normalpoint program (which can also be called to recompute data residuals) (FORTRAN). This has the advantage of breaking up what would otherwise be a huge program into more manageable units. It also provides a way to integrate existing FORTRAN and new C programs in a portable manner. Error codes and messages returned by the called programs are used by LDE to provide pop-up error dialog boxes as needed. Results from each program's execution are shown in the scrolling text box at the bottom of the screen, as can be seen in figure 7. Each of the called programs can also be run individually from the command line, as they are in the batch file.

Since LDE is an X windows program, it can be run across a network. The program itself is run on the HP workstation, but the user can either be at the system console or, as is often the case, running the eXodus X windows server on a Macintosh connected to the workstation over the departmental ethernet network. One can even run this program across internet from thousands of miles away (with some degradation in speed) and still have the advantages of the graphics, pull-down menus and so forth.

It should be noted that none of the above discussion touches on performing quality control by comparing multi-run or multi-station data or the computation of earth orientation parameters from the data. Due to the origins and complexity of that code, it will remain on an IBM mainframe for some time to come.

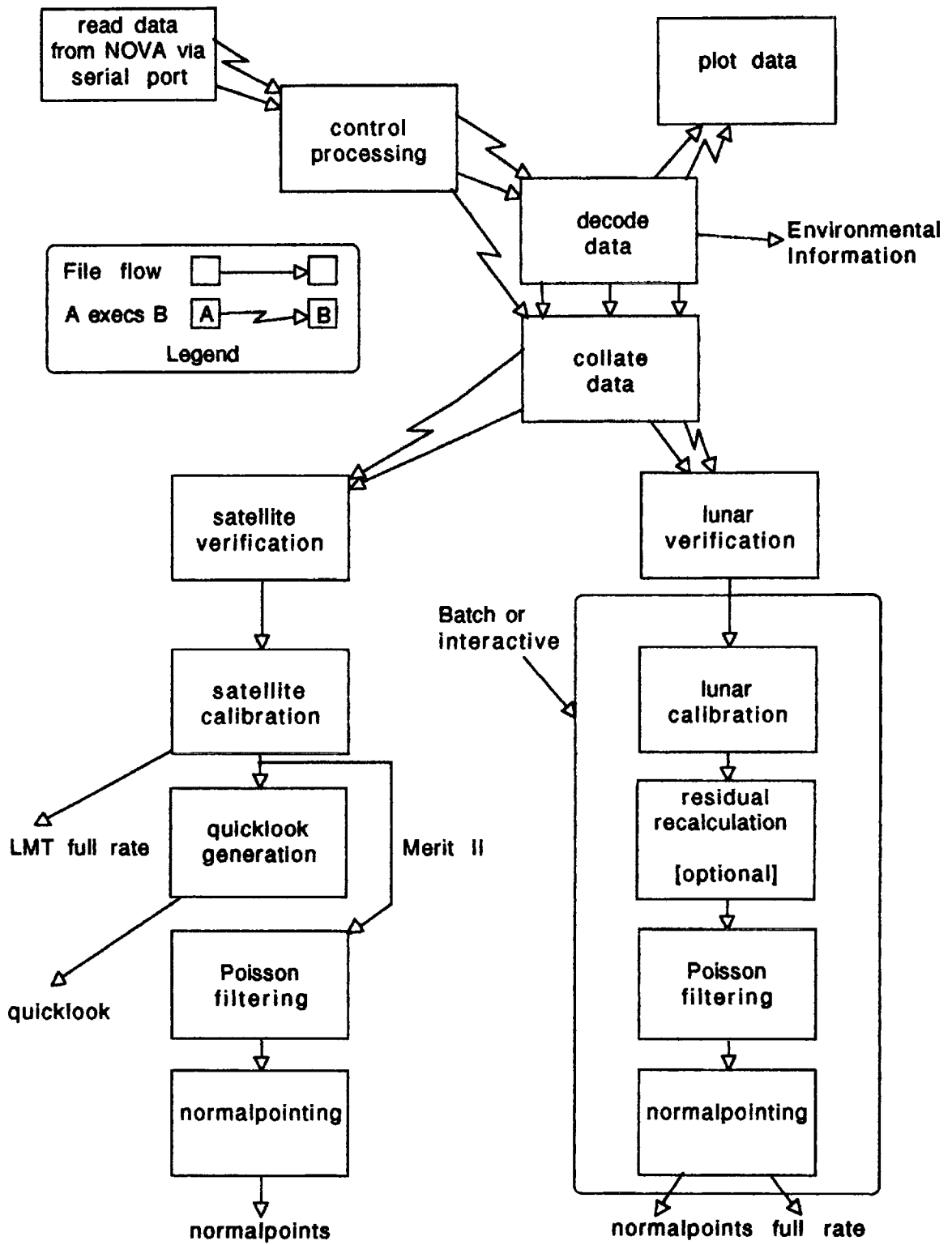


Figure 1 - MLRS Data Flow - HP Workstation

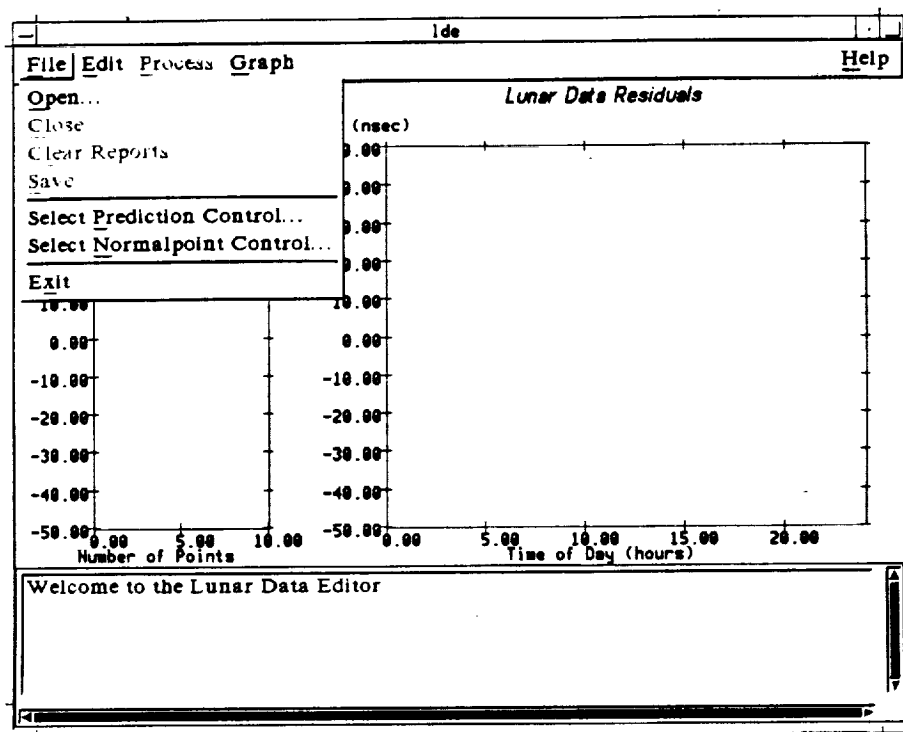


Figure 2 - Lunar Data Editor file menu

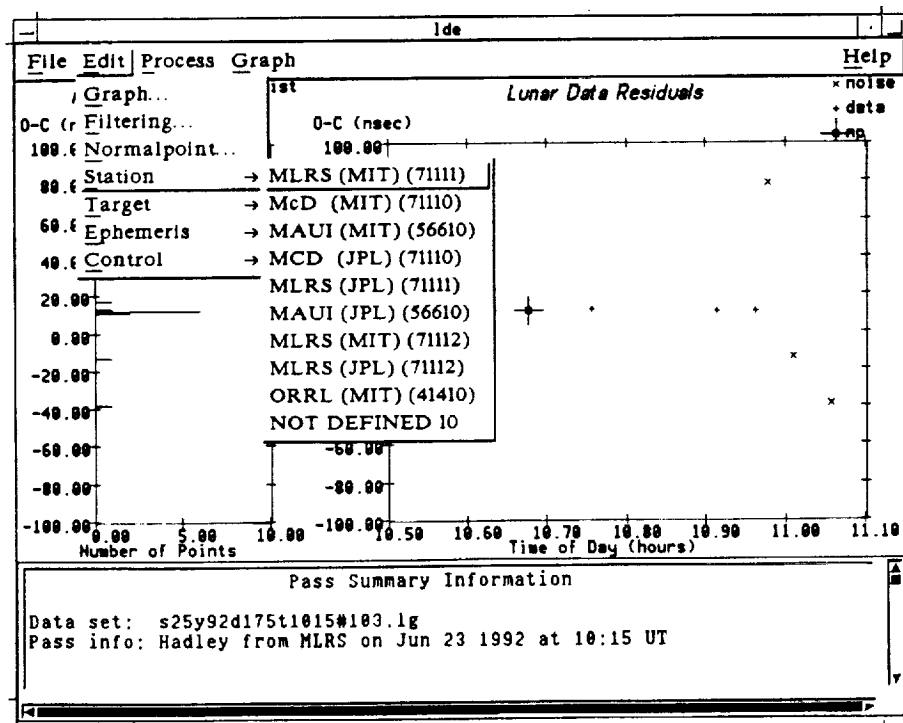


Figure 3 - Lunar Data Editor edit menu

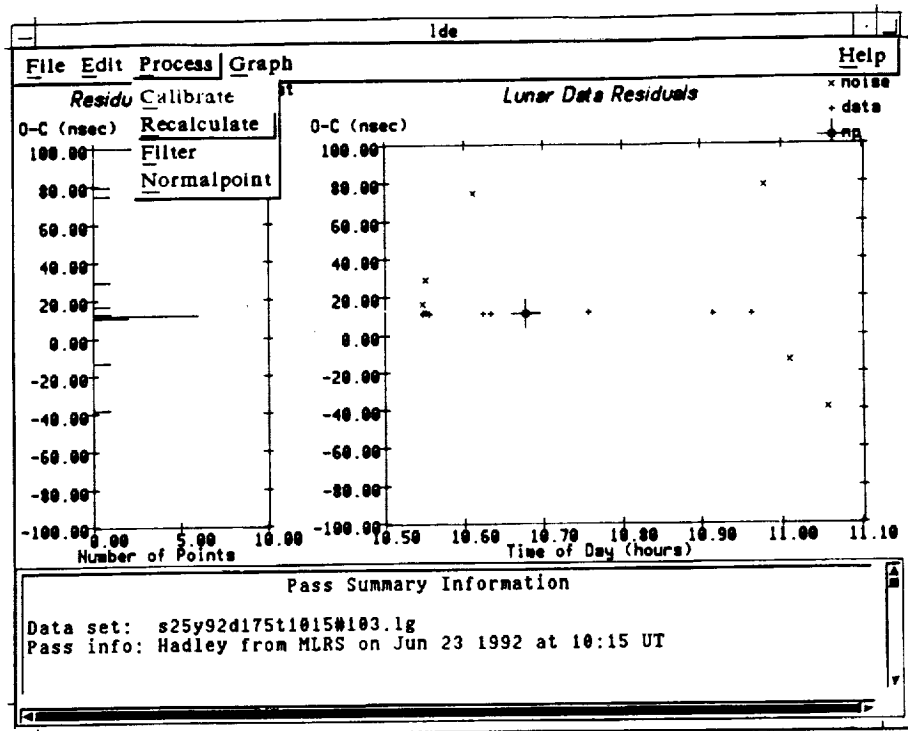


Figure 4 - Lunar Data Editor process menu

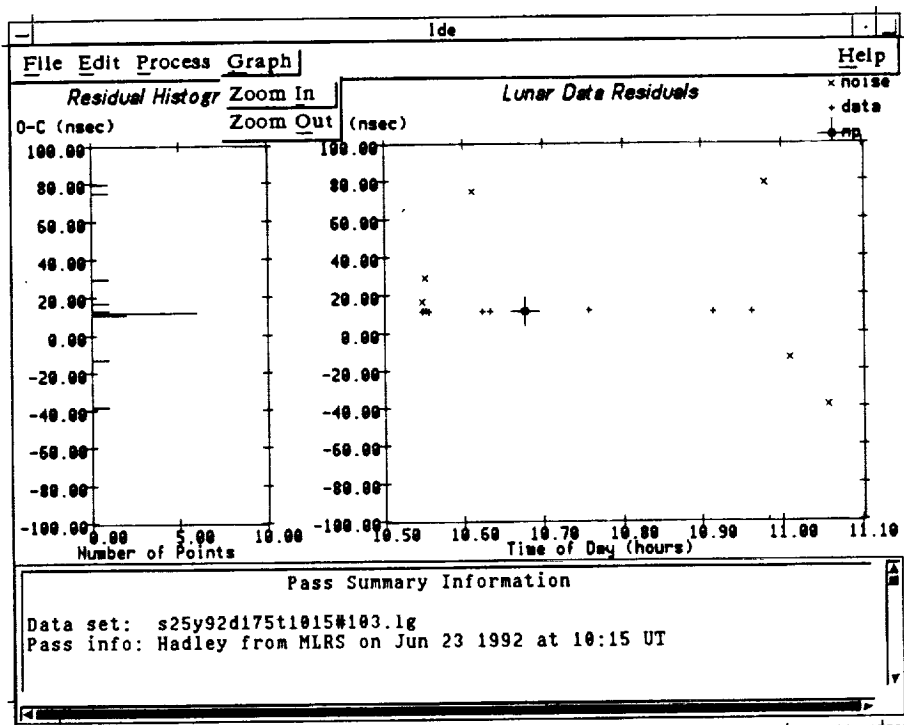


Figure 5 - Lunar Data Editor graph menu

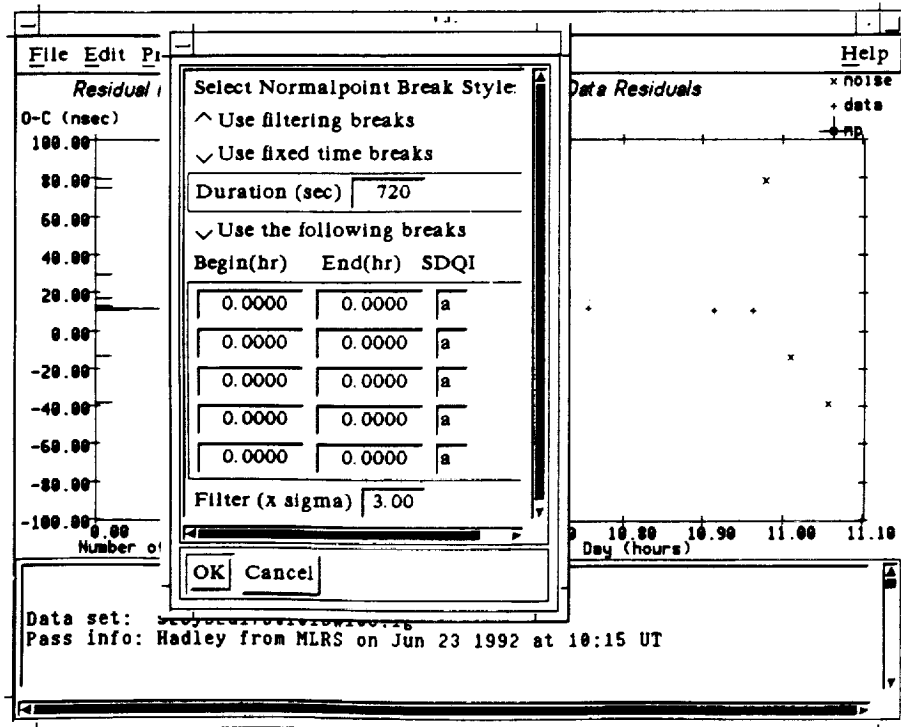


Figure 6 - Lunar Data Editor dialog box for normalpoint parameter edit

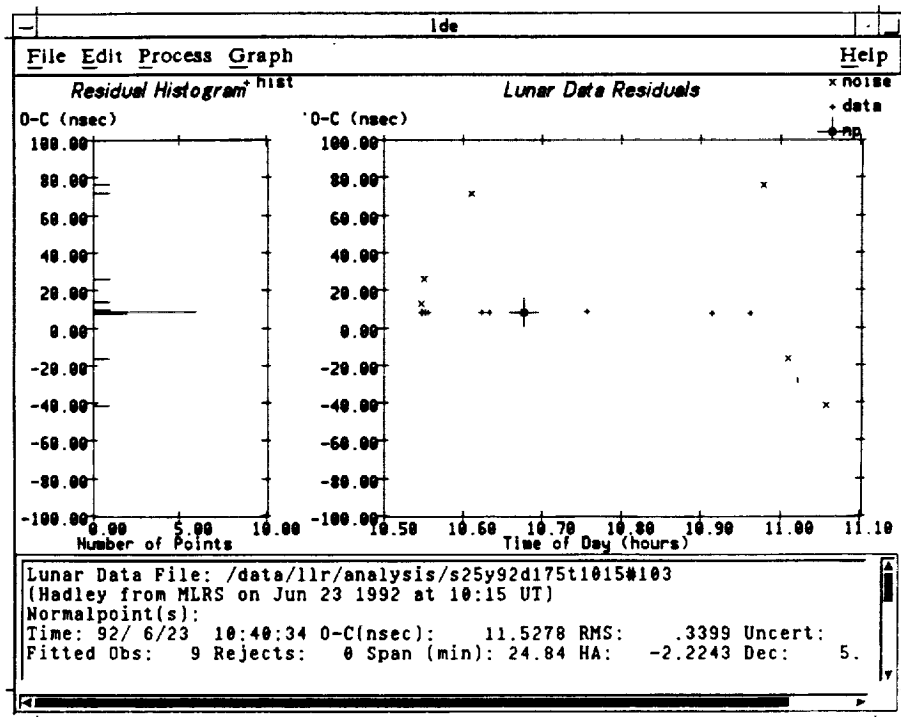


Figure 7 - Lunar Data Editor showing results of normalpointing

Conclusions

The lunar prediction and data analysis at McDonald Observatory have made several big transitions over the years, the latest being a successful move to a X windows/Motif graphical user interface and the Unix operating system. This move has proven to be worthwhile, producing more portable and flexible code and a network-based interactive data reduction environment.