AN OVERVIEW OF THE NLRS RANGING SOFTWARE

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ABSTRACT

The Division of National Mapping in co-operation with NASA have undertaken an upgrade of the National Mapping ranging facility to enable Satellite Laser Ranging as well as a Lunar Ranging to be performed at the site. Because the new system was to be so dramatically different from what existed, this upgrade provided a unique opportunity to design from basics a complete integrated system to fulfil this dual role. This paper provides a brief outline of the ranging system hardware used and an overview of the software system to control it. It should not be taken as a recipe for instant success or necessarily the best way but as an outline of the approach taken by National Mapping to achieve the goal of routine high accuracy ranging.

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Introduction

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Because the new system was to be so dramatically different from what existed, this upgrade provided a unique opportunity to design from basics a complete integrated system to fulfil this dual role.

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Ranging System Hardware

Telescope and Telescope Control:

The telescope is a 60 inch clear aperture Cassegrain telescope mounted in an X-Y configuration. The telescope control electronics consists of a Contraves-Goerz MPACS system with an absolute encoding system providing a resolution of 0.36 arc seconds. The telescope's position can be read under computer control and it can be driven in both position and rate modes.

The MPACS system is interfaced to the computer system through a locally designed and built interface (MPACS Interface).

Automated dome control is implemented by means of this interface together with a guiding handpaddle which provides a manual offset of the computed telescope position. Four push buttons provide long and cross track corrections for satellite ranging. These same push buttons provide X and Y corrections when used for Flexure Mapping of the telescope. Incorporated in the Handpaddle is an 'on target' switch which is also used for Flexure Mapping.

Laser Ranging Controller:

The NLRS uses epoch determination rather than time interval measurements for establishing the time-of-flight. Coarse epoch consisting of days, hours, minutes, seconds and decimal seconds to the 100 nanosecond level is obtained from a locally designed and built Laser Ranging Controller. Fine resolution epochs to ten picoseconds are obtained by merging the coarse epoch with readings taken from 2 Lecroy 4202 Time to Digital converters which are controlled by the same pulses as the Laser Ranging Controller's clock. The Lecroy modules are housed in a standard Camac crate.

The LRC provides a) the Range Gate function for the system; b) in conjunction with a Hewlett Packard 5359A Time Synthesiser two software selectable off-line system calibration modes; c) a T/R system monitor; d) a Station Clock which can be used under computer control to determine epochs of selected events other than ranging operations together with Laser Control, Diode/PMT gating logic and the necessary computer hardware interface.

CAMAC Crate:

A standard CAMAC crate is used to house the following modules:

a) Kinetic Systems crate controller

b) Locally developed computer Interface

c) Dataway display module for diagnostic purposes

d) Discriminator and Logic modules for Timing System

e) Lecroy 4202 TDC modules

f) T/R stepping motor controller

g) A/D Converter module for Meteorological system.

Transmit/Receive System:

A T/R system of the same design employed by the McDonald Observatory MLRS is used in the NLRS. A spinning disc mirror with 2 diametrically opposed holes is used to switch the optical path between laser transmission from the telescope and returning signal into the PMT. A spinning 'dog-bone' is used as a protective shield for the PMT. The mirror disc and the 'dog-bone' have to be synchronised and rotated at the same speed for system operation.

Locally developed hardware is used to detect that the T/R system is in position for the Laser to fire. This is used in conjunction with a master Laser Enable signal generated by the computer through the LRC to fire the laser.

The T/R system is controlled by the computer via a module in the CAMAC crate.

Computer Hardware:

There are two Hewlett Packard A-Series computers on site.

The Ranging is currently run on the A-700 system which is configured with 1Mb of memory, hardware floating point, 65Mb Winchester disc drive, 400 lpm printer, 1600 BPI magnetic tape drive, graphics VDU, system console VDU.

The second system comprises an A-900 system with 1.5Mb memory, hardware floating point, 132Mb Winchester disc, 1600 BPI magnetic tape drive, 200 LPM printer, 2 graphics VDU's and a system console VDU.

All non-standard peripherals on both systems are interfaced using Hewlett Packard 16 bit parallel interface cards. Although Hewlett Packard supply a software driver for this card our approach has been to develop our own. This has allowed us to customise the drivers and provide a means whereby the complexity of the hardware control and interrupt routines are removed from the actual ranging and utility programs.

Both computer systems run the standard Hewlett Packard RTE-A Real Time operating system which is unmodified in any way. The relevant software drivers for the locally developed hardware interfaces are 'generated' into the system and these devices are accessed from then on as any other standard peripheral using high level language calls.

All locally developed drivers are written in Assembler language (H.P. MACRO). The Ranging software and all other utility software is written in FORTRAN 77.

Ranging System Software

Satellite Prediction System:

The NLRS prediction software is based on that used at McDonald Observatory. Ephemeris data arrives at the site on magnetic tape in the form of daily IRV's for about a 6 month period. They are read from tape and stored in a variable record length disc file.

As required program FORMIRV is run against this disc file to create a random access binary file or IRV's to cover the desired period. FORMIRV performs checksum verification and the necessary reformatting. It is capable of accepting IRV data from either Goddard or U. of T. Experience at the McDonald site leads us to believe that the U. of T. IRV's have a better long term stability.

Periodically the SATPREDICT program is run to produce an ALERT file for a period as well as a PREDICTION file for each satellite pass where the satellite will rise above a 20 degree horizon. Data in the prediction file consists of a file header containing the relevant IRV from which it was generated, daily time bump information as supplied by the network (U. of T.) and for every 1 minute point in the pass a satellite position in Azimuth, Elevation and Range.

Operator inputs to program SATPREDICT are:

a) File name of checked daily IRV's

b) Starting date and number of days predicts required

c) Whether program can expect a new IRV for each day's processing or has to extrapolate from only one IRV

d) Whether PREDICT files are required

e) Whether an ALERT file is required.

Where there is a missing IRV the program can extrapolate across the gap.

Ranging Software:

The Ranging system comprises 3 separate programs, INITIAL, RANGE and CLEANUP.

Program INITIAL performs the following sequence of operations:

a) Initialise the inter-program communication memory area.

b) Access the ALERT's file to determine which pass is the relevant one, obtain the name of the PREDICT file and create and initialise the observation data file.

c) Read in from a disc file the current flexure parameters for the telescope.

d) Obtain the current weather parameters from the meteorological system.

e) Loop through the PREDICTION file data applying refraction corrections to predicted elevation and range; azimuth corrections for dome positioning; corrections for X-Y axes offset and optical path lengths to system fundamental point; corrections for telescope flexure.

f) Store in the inter-program communication area the corrected prediction data together with all other default parameters such as range gate window width, firing repetition rate, real time display parameters etc.

Program RANGE is the actual data acquisition program. It is basically a supervisory program which directs the various hardware systems to perform the requested actions in a sequential fashion. This sequence is as follows:

a) Initialise all hardware modules, position dome for start of pass.

b) Synchronise T/R stepping motors.

c) Initialise real time display.

d) Verify all variable parameters with user.

e) Ramp up the T/R system to require repetition rate.

f) Determine theoretical telescope and dome positions. Output them to MPACS. Wait 100msec then read in telescope position from MPACS. Evaluate new theoretical position and calculate error vector. If error vector is less than 0.02 degrees then proceed otherwise repeat this step.

g) Issue the Master Laser Enable signal to the LRC.

h) Read in from the LRC and CAMAC timing modules the epoch of the laser diode pulse and PMT calibration pulse.

i) Evaluate predictions for theoretical range.

j) Output Range Gate Epoch to LRC.

k) Read in from MPACS the current telescope position, time and handpaddle data.

l) Determine theoretical position, drive rates and dome azimuth.

m) Calculate actual drive rate for ensuing period by adding in to base rate corrections for handpaddle.

n) Output pointing information to MPACS.

o) Read in current weather details from CAMAC module.

p) Read in from the LRC and CAMAC timing modules the epoch/s of returning photons.

q) Calculate and display Residuals on real time display.

r) Journal data to disc file.

Steps (h) through (r) are repeated for the duration of the pass. The system can be halted at any time to enable the user to vary such things as firing rate, range gate window width, range gate offset, real time display parameters and also to display a histogram of the current real time calibration data. Once this is done control goes back to step (h) and ranging is resumed.

The one minute IRV's held in the inter-program communication area are interpolated using Bessel's Central-Difference Formula of degree 5 to provide theoretical range at step (i) and telescope position and dome azimuth at steps (f) and (l).

Steps (h) and (p) are the only occasions when the software system has to wait for a hardware interrupt from an external device.

Program CLEANUP is true to its name. Essentially it filters the ranging data and reformats it to make up the QUICKLOOK, MAILING and ARCHIVING files. It operates in the following manner:

Low noise passes

Three iterations of a two step stripping process are employed on each 1 minute block of returns. The two steps are:

a) Residuals are histogrammed (at a bin width of 10 nanoseconds on the first iteration an 1/2 sigma on subsequent iterations). The highest bin is determined. Data in bins of height less than a nominated fraction (typically 25%) of this maximum are rejected.

b) A straight line is fitted through the remaining residuals. Results more than 3 standard errors away are rejected.

In practice this procedure converges satisfactorily and the final histogram has a reasonably normal distribution out to 3 sigma. The standard error is often 0.3 nanoseconds and 67 - 80% of all data points are accepted.

High Noise Passes

A preliminary estimate of the starting point and slope of the real trace in the first minute of the data has to be obtained from the real time ranging display. All data points more than 32 nanoseconds away from this line are then stripped out. The low noise procedure outlined above is then performed. The resulting straight line is then used as the reference for the next 1 minute of data.

Future Development

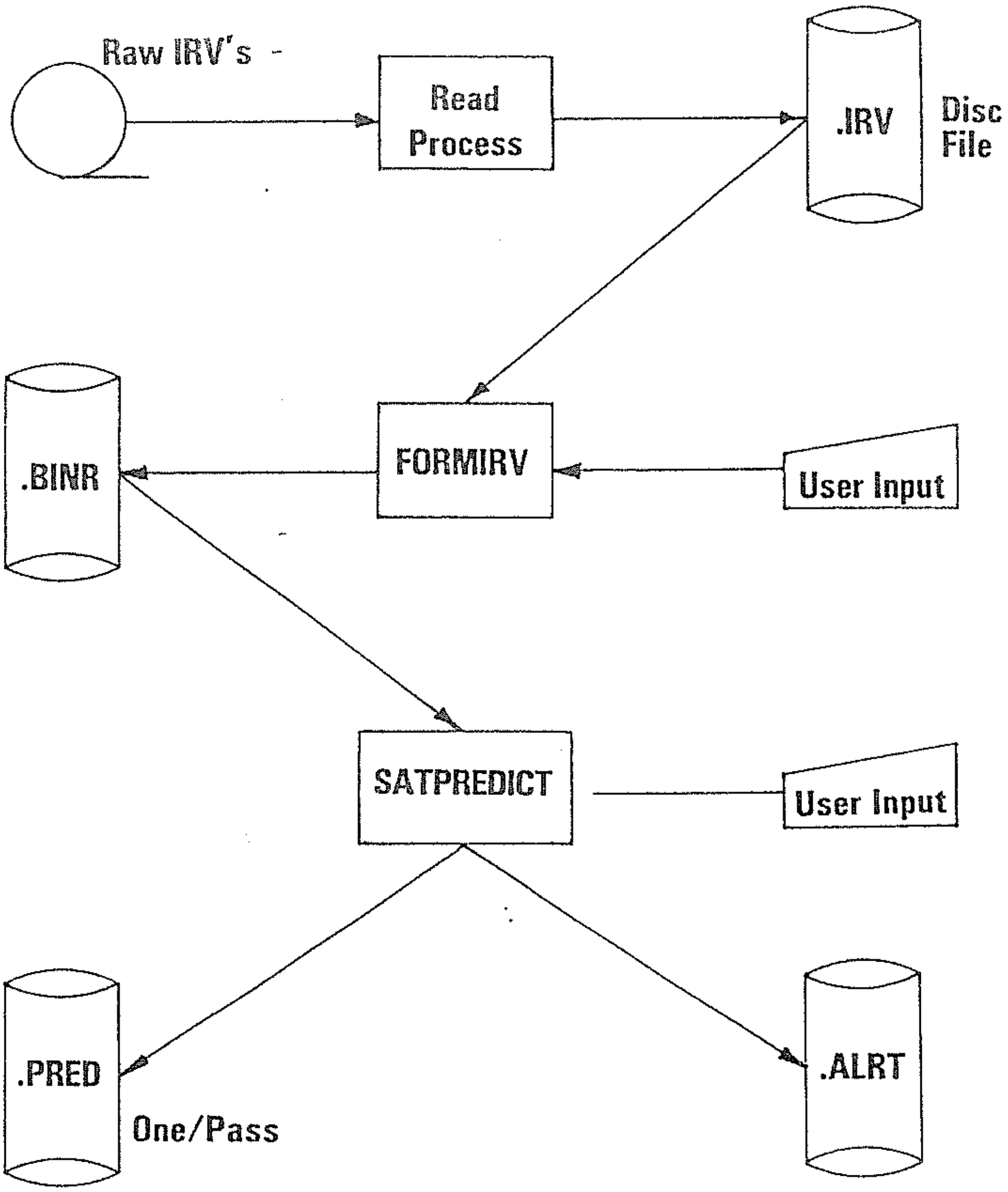
The system described is the satellite ranging software system. For Lunar ranging the same concepts - indeed almost the same programs - are being used. The inter-program communication area will be expanded to hold data for the several lunar targets, some of the internal loops of program RANGE will need to be modified to allow for multiple photons in flight and the user will be given the ability to switch from one target to the other without having to reinitialise the system. The hardware will require no modification nor will the software drivers that interface them to the computer. It is intended to include into the system one or two video monitors for the real time display instead of using the graphics VDU. This will enable the display of both residuals and calibration simultaneously.

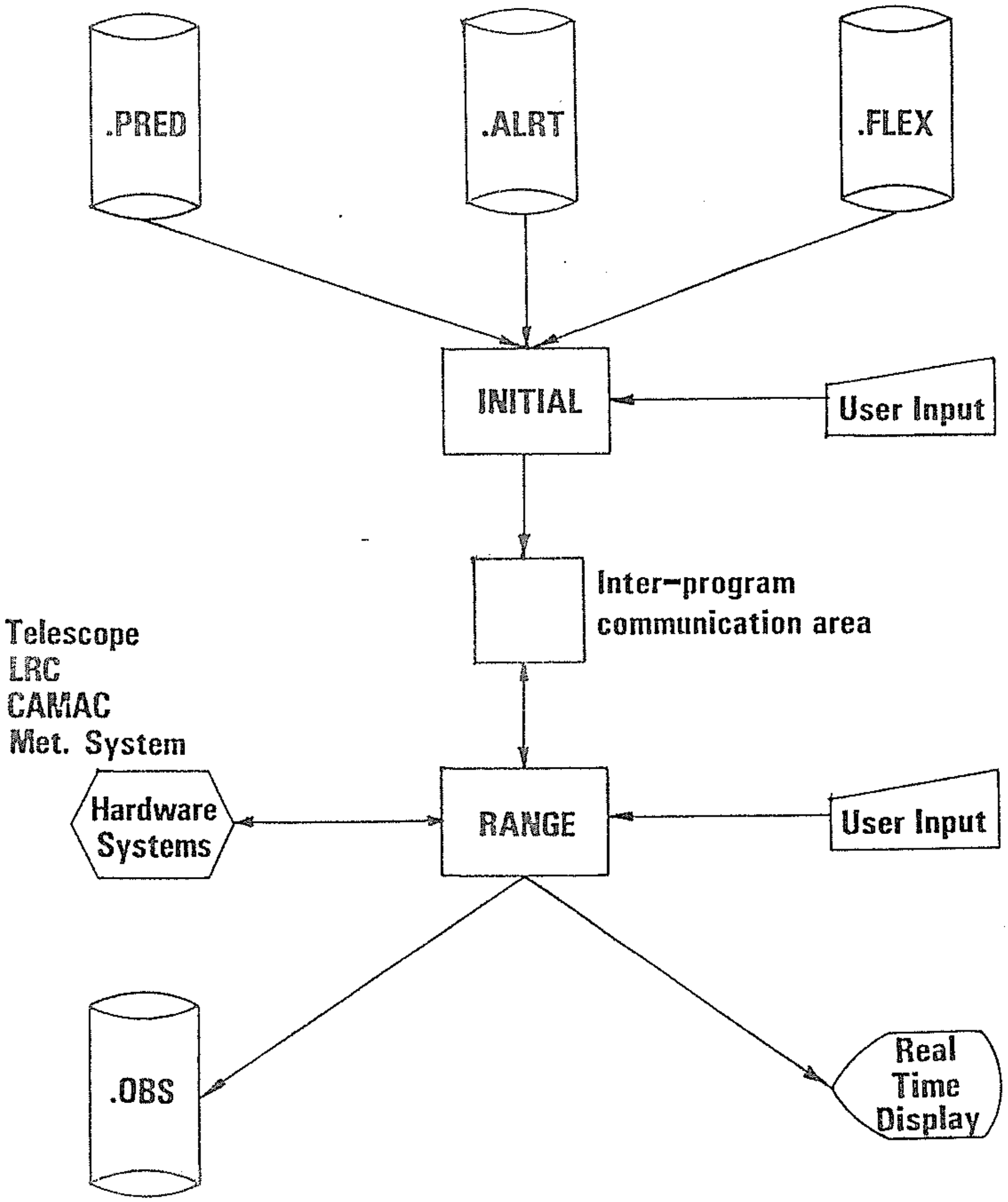
Conclusions

The Hewlett Packard computer system used has proven adequate. Once an integrated hardware/software design for the system was reached both streams were able to proceed in parallel. The ability to 'hide' the complex hardware control within the operating system makes the high level code easy to write and maintain. If software drivers need to be changed then a new system has to be generated but since this takes on average half an hour it is not seen as a problem. It facilitates the testing of individual parts of the system using various locally written high level utility routines which proved extremely helpful in the debugging phase of the project.

One of the main design aims in the software has been to make the system user friendly to the extent that specialists are not required for the routine operation of the site. For satellite ranging this goal has been achieved and National Mapping's Laser Ranging System is now in full production.

NLRS Data Flow

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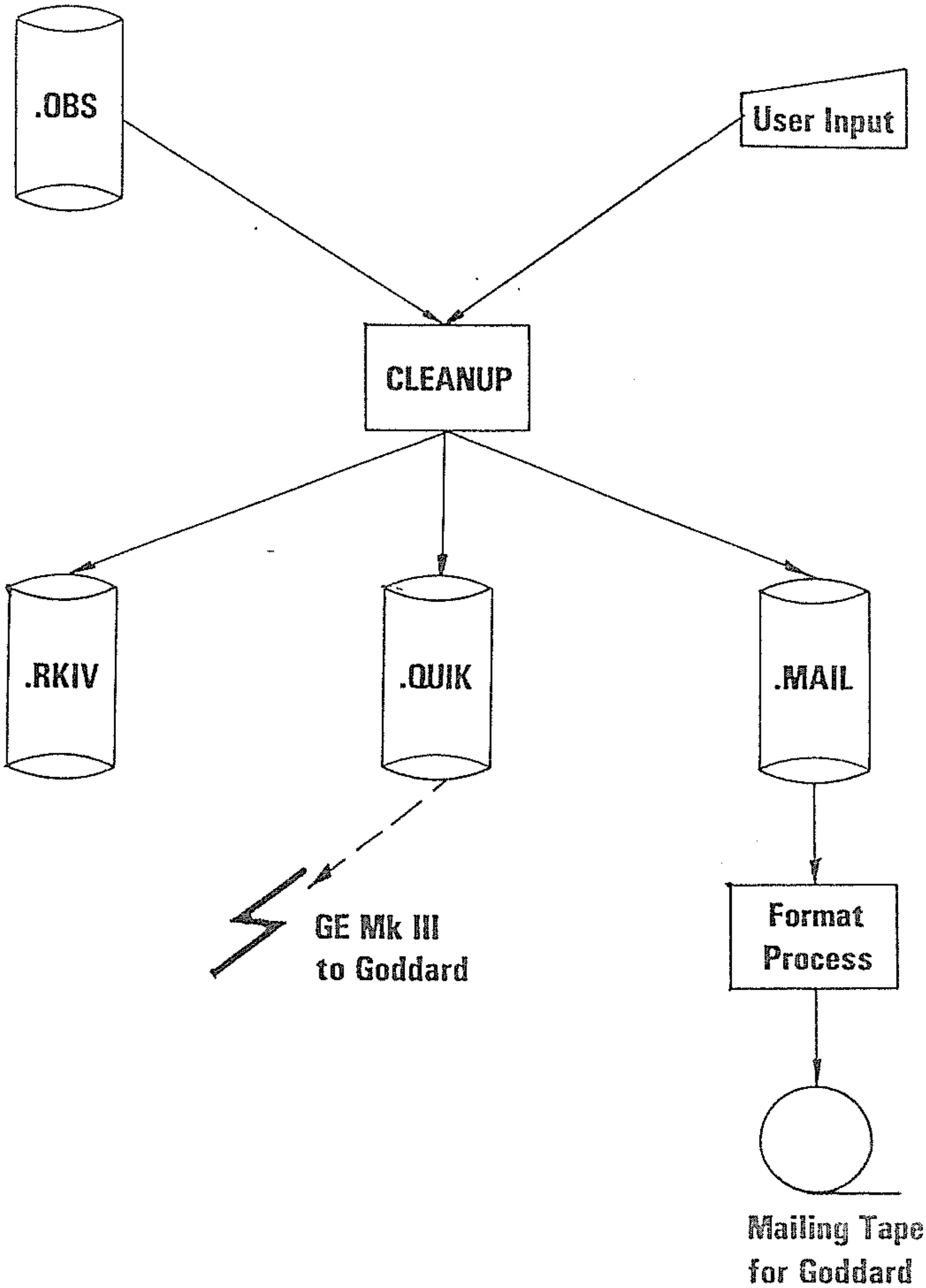
.ALRT
.FLEX
INITIAL
User Input
Inter-program
communication area
Telescope
LRC
CAMAC
Met. System
Hardware
Systems
RANGE
User Input
.OBS
Real
Time
Display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User Input
CLEANUP
.RKIV
.QUIK
.MAIL
GE Mk III
to Goddard
Format
Process
Mailing Tape
for Goddard