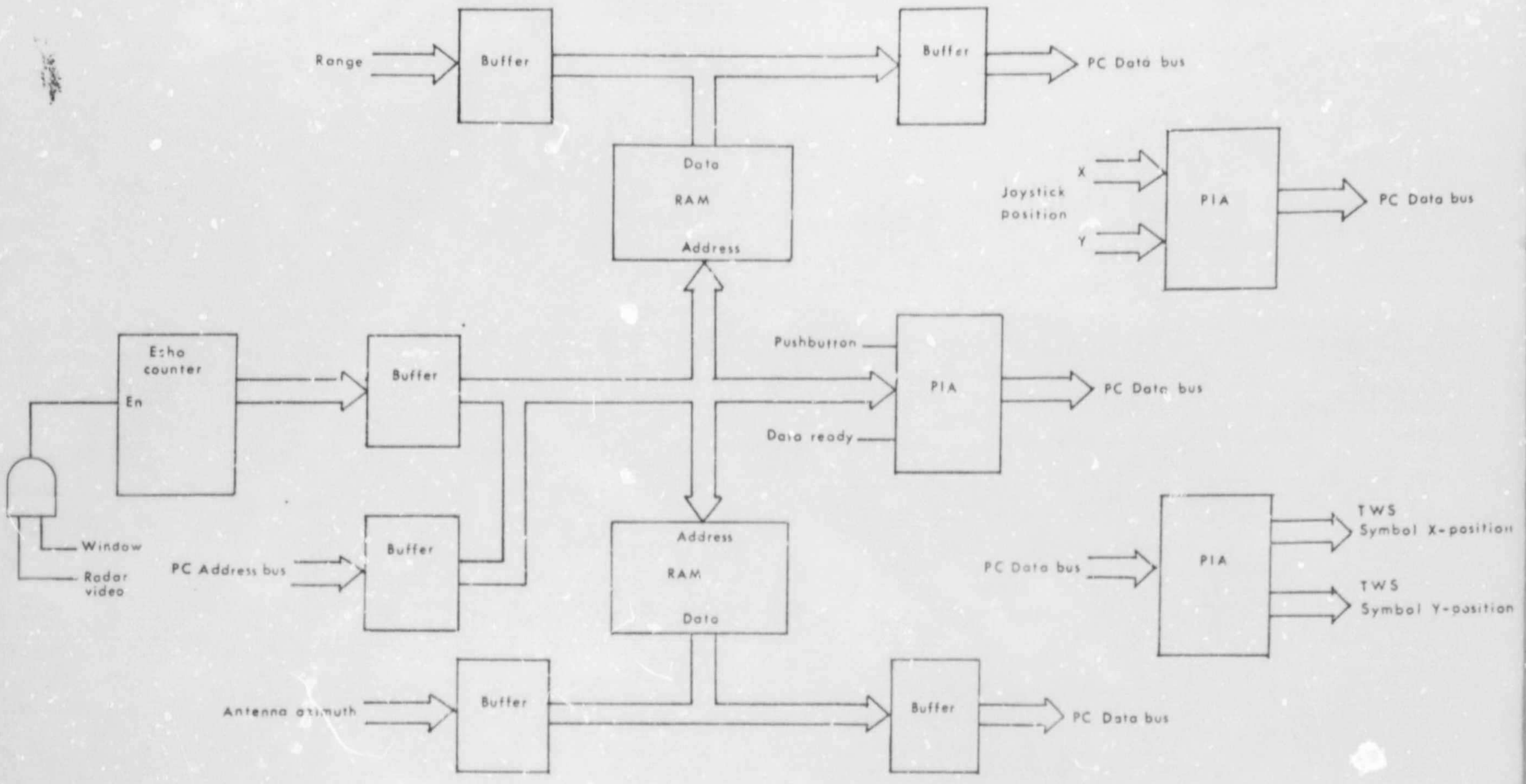

Figure 6.15 Basic Block Diagram of the Memory Card

6.4.2 The TWS Algorithm

The algorithm forms the main part of the system. Figure 6.16 details an overview of the software program.

6.4.2.1 The Setup Process And Main Calling Routine

Figure 6.17 details a flow chart of the setup process and main calling routine.

When the program is initiated at system power-up, the first process required is the setting up of the PIA ports, the clearing of all flip-flops and flags and the initiating of constants. The static position of the tracking symbol on the display has been chosen to lie just outside the maximum range in the top left hand corner. This position is output to the symbol position generator and the latching pulse clocks the position into the latches.

The program now enters the main loop. It will continue in this loop until either the pushbutton is depressed or the window generator indicates that data is ready for processing. Flags are used to indicate the status of the tracking algorithm. When the program was iniated the INITIATED flag was reset, as was the DATA READY flag from the tracking window generator and the

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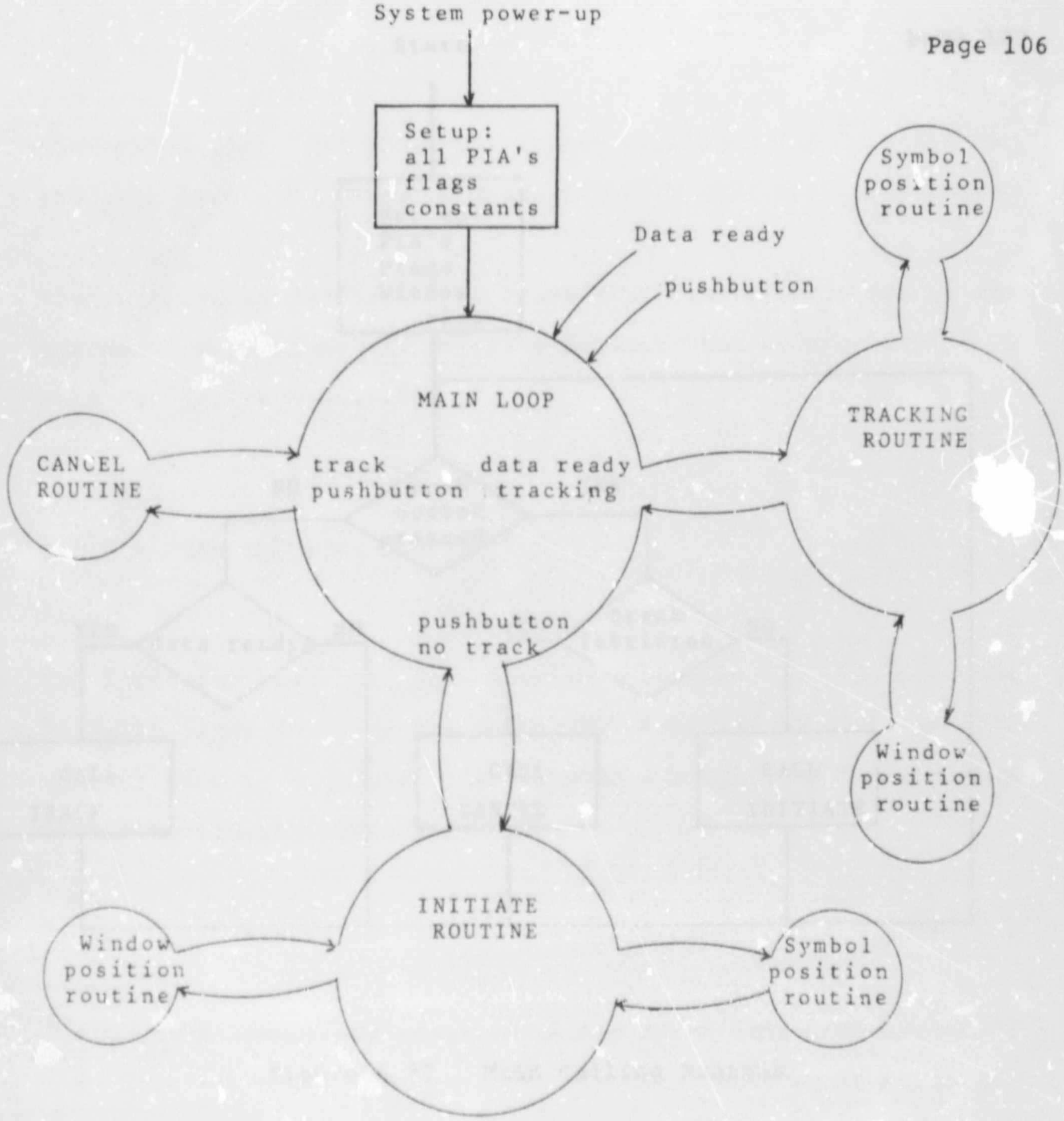

Figure 6.16 An Overview of the TWS Program

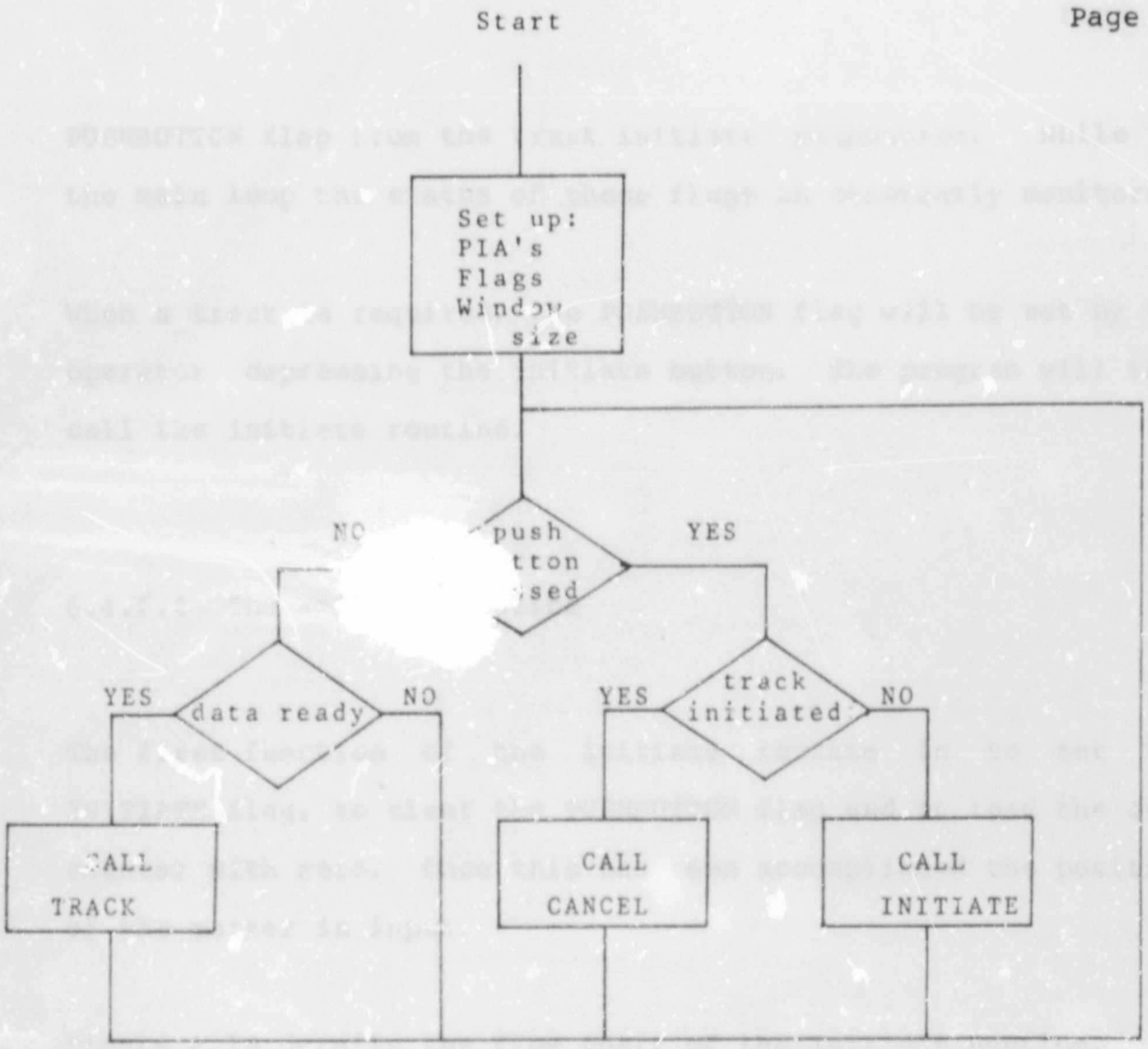

Figure 6.17 Main Calling Routine

PUSHBUTTON flag from the track initiate pushbutton. While in the main loop the status of these flags is constantly monitored.

When a track is required, the PUSHBUTTON flag will be set by the operator depressing the initiate button. The program will then call the initiate routine.

6.4.2.2 The Initiate Routine

The first function of the initiate routine is to set the INITIATE flag, to clear the PUSHBUTTON flag and to load the echo counter with zero. Once this has been accomplished the position of the marker is input.

Figure 6.18 details the flow chart of the Initiate Routine.

The program inputs the position of the lower left hand corner of the marker symbol. The processor is then required to calculate the position of the centre of the marker. This is a function of which quadrant the marker lies in and offsets need to be added or subtracted as required. Once the X-Y position of the centre of the marker has been calculated the position is translated from the (0,0) position on the grid to the (512,512) position, the coordinates then being converted to R-θ coordinates via simple trigonometric rules. The marker X-Y position relative to the (0,0) grid is used to initiate the filter as the first predicted value. The X and Y coordinate velocities are set to

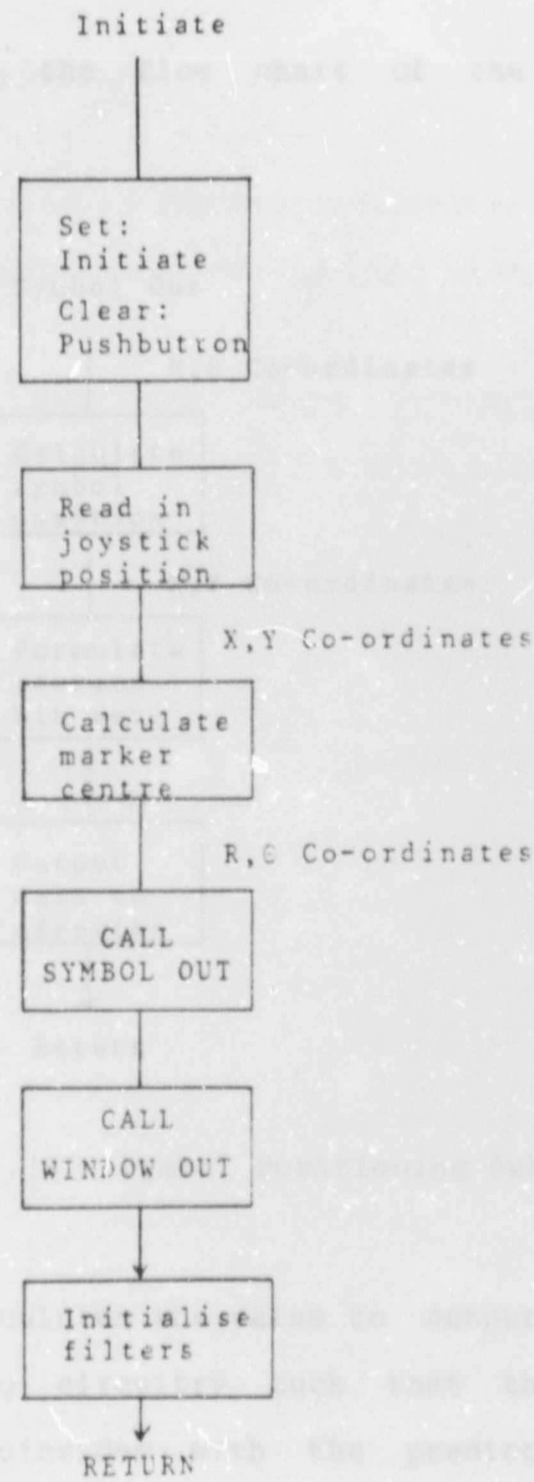

Figure 6.18 Initiate Routine

zero.

Once the range and theta values of the marker have been calculated the symbol positioning subroutine is called.

Figure 6.19 details the flow chart of the Symbol Position Subroutine.

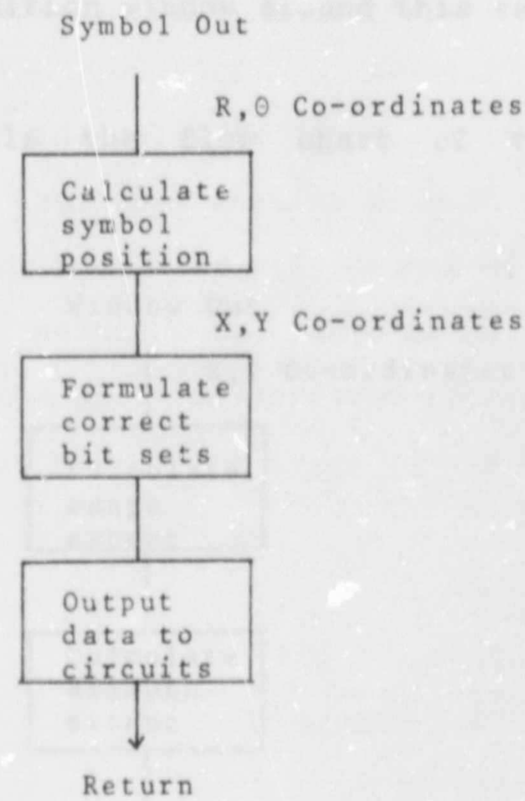

Figure 6.19 Symbol Positioning Subroutine

This subroutine calculates the value to output to the symbol position generating circuitry such that the centre of the tracking symbol coincides with the predicted R-Θ value. Initially the predicted R-Θ value is converted to X-Y coordinates referenced to the (512,512) point on the grid. The point to be output to the symbol position generating circuit is the lower left hand point. This point is calculated based on the quadrant in which the symbol is required to lie. Once this point is calculated it is translated so that it is referenced to the (0,0) point on the grid. This X-Y position is output to the symbol generator circuits.

The next process is to use the R-Θ coordinates of the marker to set up the acquisition window around this value.

Figure 6.20 details the flow chart of the Window Position Subroutine.

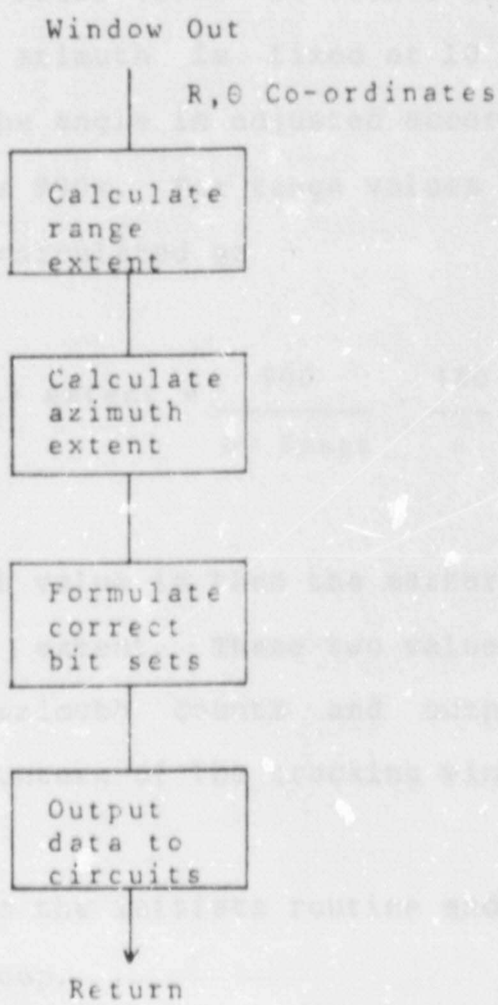

Figure 6.20 Window Positioning Subroutine

The window size is fixed at 900m in range and 900m in azimuth, as described in section 5.6. So the range increment is 15 counts of the range counter. The range start value is then the marker range value (expressed in range counts) minus half the range extent. The range start and range extent are output to the window generator comparator and counter respectively. The azimuth value is calculated using simple trigonometry. The azimuth extent is specified in metres. However the window generator requires the value to be output in digital values in the same format as the antenna azimuth information. If the range is less than 5040m (i.e. 84 counts of the range counter) then the window azimuth is fixed at 10 degrees. For ranges greater than 5km the angle is adjusted accordingly so that the azimuth extent is 900m. For range values greater than 5km the azimuth extent is calculated as

$$\text{Azimuth extent} = \frac{900}{60\ \text{Range}} \cdot \frac{180}{\pi}\ \text{degrees}$$

The initial azimuth value is then the marker azimuth value minus half the azimuth extent. These two values are then converted from degrees to azimuth counts and output to the azimuth comparators and counters of the tracking window generator.

This then completes the initiate routine and control is passed back to the main loop.

6.4.2.3 The Cancel Routine

To cancel a track the operator is required to depress the initiate button once again. The INITIATE flag is set (a track is in progress) and the PUSHBUTTON flag is set. These two conditions cause the main loop to execute the cancel routine.

The first process executed is the resetting of the INITIATE flag and the resetting of the PUSHBUTTON flag. Once this is done the static position of the tracking symbol is output to the symbol position generating circuitry. Control then returns to the main loop.

Figure 6.21 details a flow chart of the cancel routine.

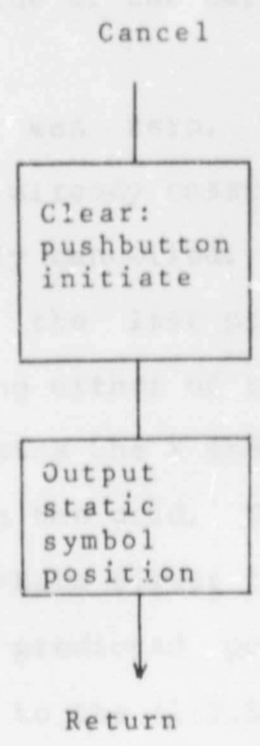

Figure 6.21 The Cancel Routine

6.4.2.4 The Track Routine

When the data captured while the antenna scanned through the window is ready for processing, the READY flag was set. As the INITIATE flag is set by the initiate routine, the main program calls the track routine.

Figure 6.22 details the flow chart of the Track Routine.

The first process is to reset the READY flag. The output of the echo counter containing the number of echoes received while the beam was within the window is input from the window generator. If the number input was greater than zero, then the processor calculates the mean of the range extremeties of the target and the mean of the azimuth extremeties of the target. These values form the measured value of the target position.

If the number input was zero, then the processor has two choices. If it has already coasted for five previous scans the track is automatically cancelled. If not, the filter coasts for this iteration and the last predicted value becomes the next measured value. Using either of the two measured values above the processor calculates the X and Y measured positions relative to the (0,0) point on the grid. These measured values are then used by the Alpha-Beta filter to predict the next position of the target. This predicted position is converted to R-θ coordinates relative to the (512,512) point on the grid.

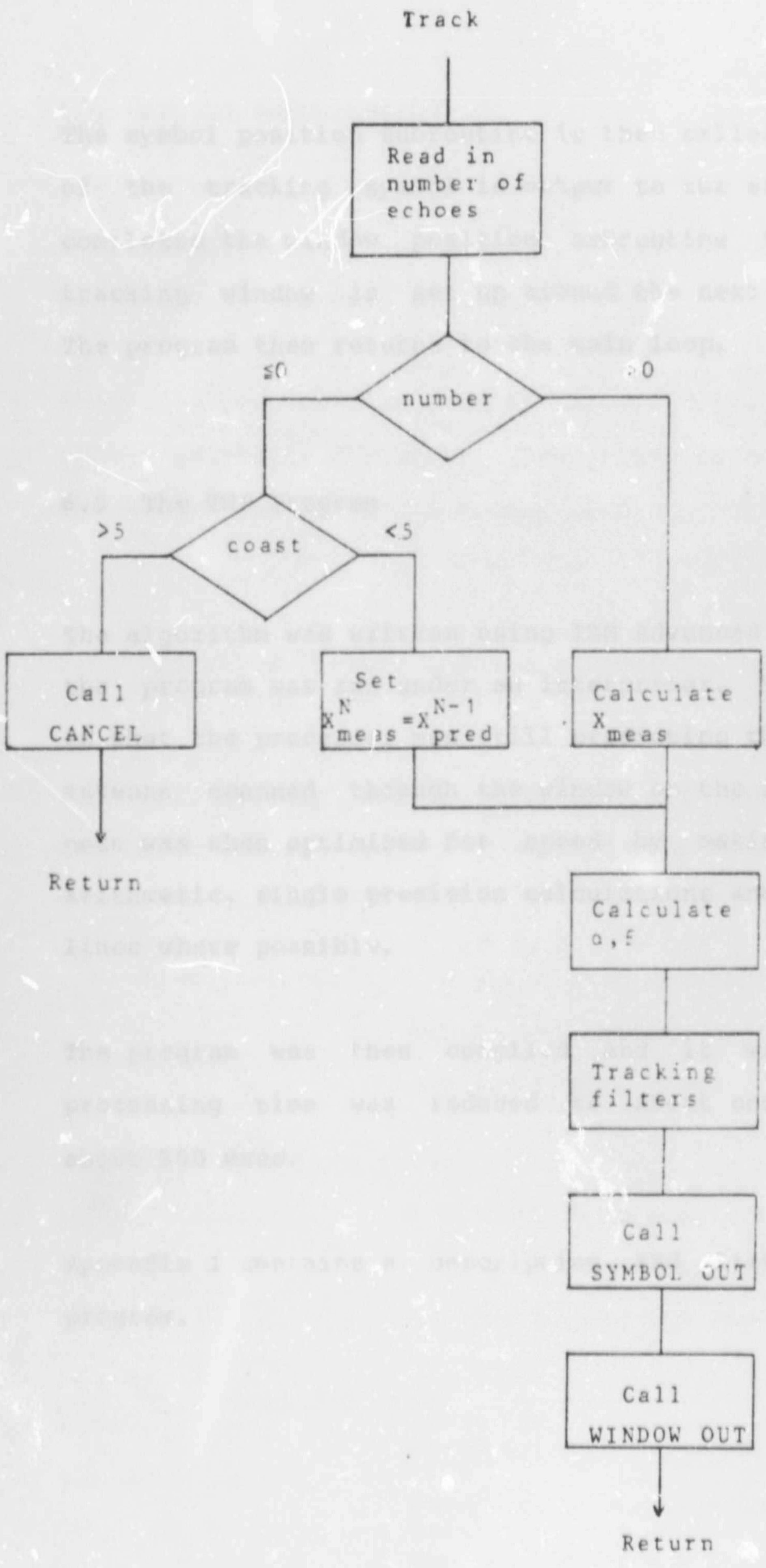

Figure 6.22 The Track Routine

The symbol position subroutine is then called and the position of the tracking symbol is output to the screen. Once that is completed the window position subroutine is called and the tracking window is set up around the next predicted position. The program then returns to the main loop.

6.5 The TWS Program

The algorithm was written using IBM Advanced Basic. Initially the program was run under an interpreter. This proved too slow in that the processor was still predicting the position when the antenna scanned through the window on the following scan. The code was then optimised for speed by making use of integer arithmetic, single precision calculations and multiple statement lines where possible.

The program was then compiled and it was found that the processing time was reduced to about one fifth of a scan or about 300 msec.

Appendix I contains a description and listing of the Basic program.

7.0 SYSTEM CONSTRUCTION

For the purposes of implementation and construction the system was built in two main sections.

The first section consisted of the PPI drive circuitry and the symbol generator circuitry. The second section consisted of the TWS window generator and memory card.

7.1 PPI Drive Circuit And Symbol Position Generator Circuit

The PPI display driver circuits and the symbol position generator circuits were implemented as follows:

- A control card: a digital card generating the range count, the various sequencing signals and the symbol data.
- The X-position card: a digital card generating the symbol X-deflection voltage using inputs from the TWS boards and the joystick.
- The Y-position card: a digital card generating the symbol Y-deflection voltage using inputs from the TWS boards and the joystick.

- The seperate D/A cards: the digital symbol X-position, the digital symbol Y-position and the range counter all need to be converted to analog form for mixing to form the deflection voltages laid out on an analog printed circuit board.

- Video card: contains the Vector Generator, the deflection voltage switches and the video summing network.

All the digital cards were wired on Double-Eurocard sized wire wrap boards and interconnected via a dedicated backplane layout. The D/A cards and the Video card were all laid out on Double-Eurocard size printed circuit boards allowing good noise immunity. Extensive use was made of ground planes on the cards to lessen the effect of noise. All analog signals were distributed along the backplane in shielded co-axial cables. Figures 7.1 and 7.2 illustrate examples of the wire-wrap and printed circuit cards and figure 7.3 is a photograph of the cards installed in the 19" rack system.

All interconnections to the radar system, these being the clock, the trigger and the processed video were routed through high-speed opto-isolators to prevent noise from the radar system leaking into the display drivers. The interconnection to the joystick was via a ribbon cable conveying the digitised joystick position in parallel format.

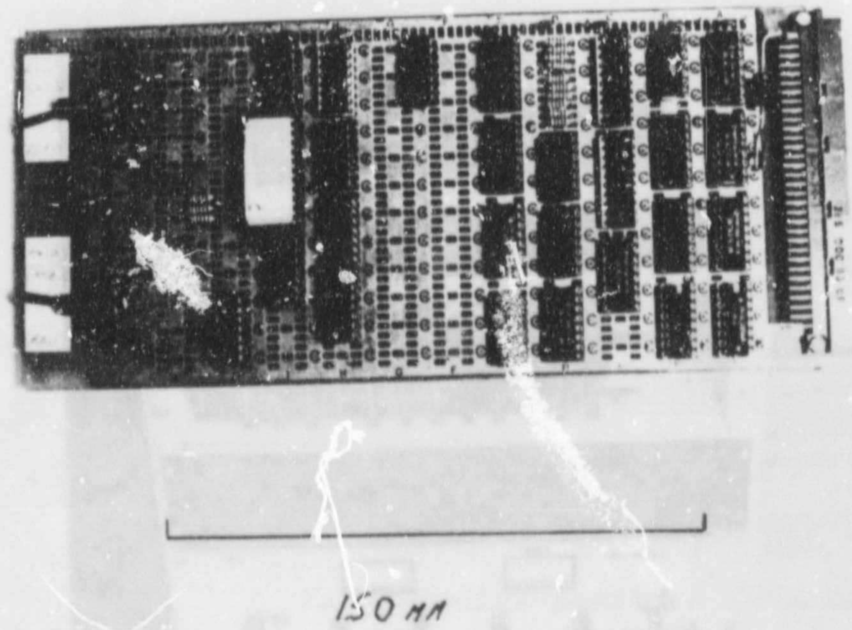

Figure 7.1 Example of a Digital Wire-wrap Card

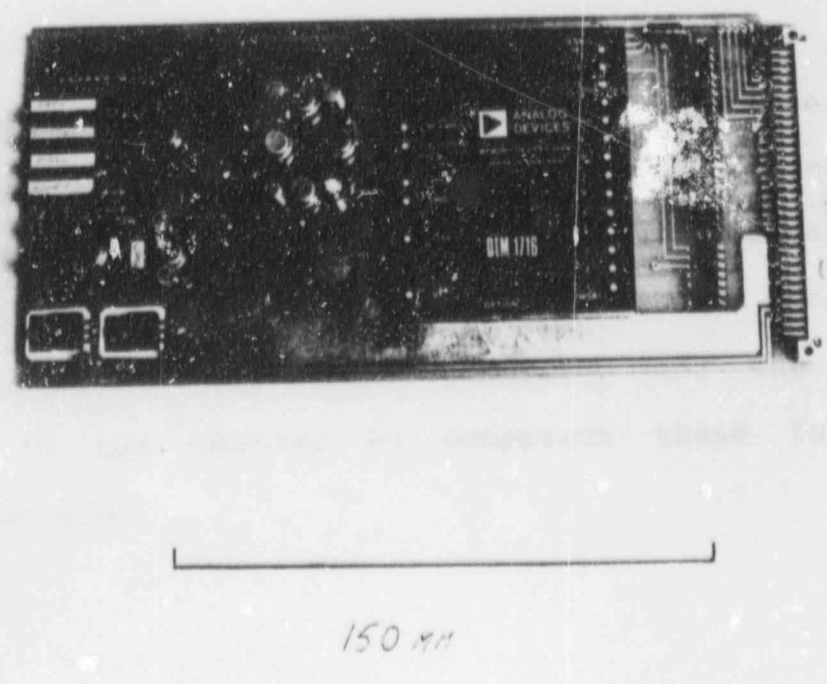

Figure 7.2 Example of an Analog Printed Circuit Board

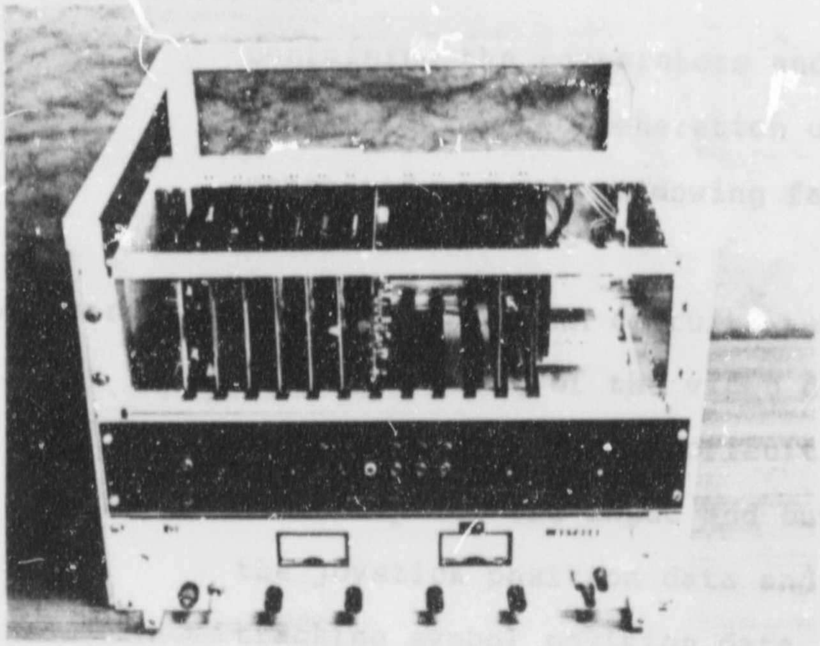

Figure 7.3 The 19" Rack System

7.2 TWS Window Generator And Memory Card

Dedicated wire-wrap cards were constructed for use in the IBM PC expansion slots. The window generator and memory card were constructed using wire-wrap techniques on these cards. Because of the large number of integrated circuits necessary for the implementation of the window generator and the data storage areas, it was decided to construct these functions on two seperate cards.

- Window Generator card: containing the comparators and counters necessary for the generation of the range and azimuth windowing facility.

- Memory card: containing the RAM circuits necessary for the storing of the video data, and the PIA integrated circuits necessary for the input and output of the joystick position data and the tracking symbol position data.

Figure 7.4 illustrates the memory and the window generator cards, with figure 7.5 illustrating the two cards positioned in the IBM PC mother-board.

All interconnections to the 19" rack are via a ribbon cable, with all symbol position data and joystick position data being transmitted in parallel format.

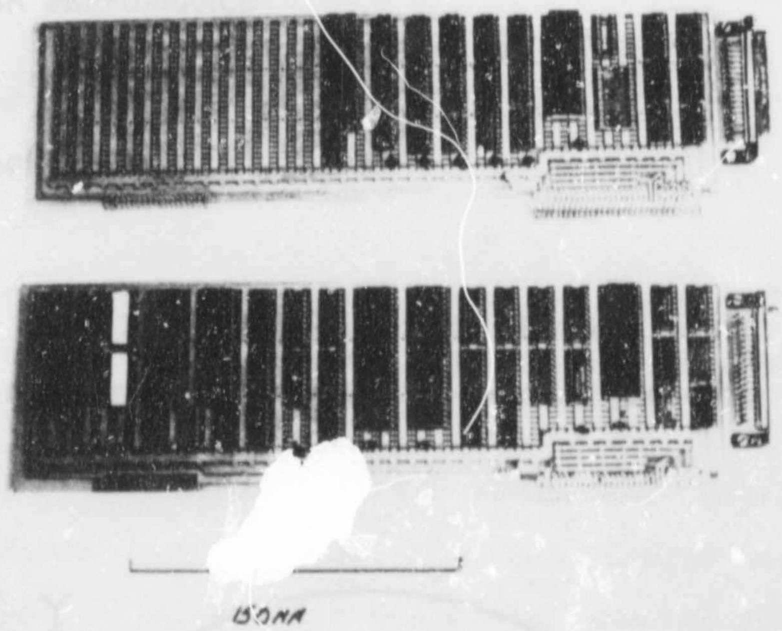

Figure 7.4 The Window Generator and Memory Cards

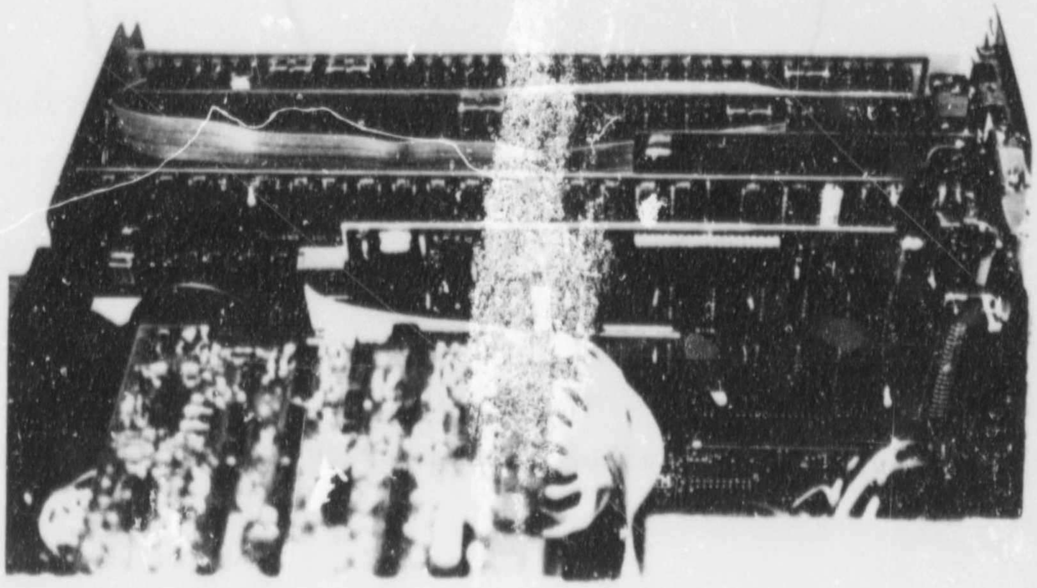

Figure 7.5 The IBM PC with Dedicated Cards Installed

8.0 SYSTEM PERFORMANCE

8.1 Predicted Results

Figure 8.1 details a typical PPI display with the tracking symbol, marker symbol and various echoes present.

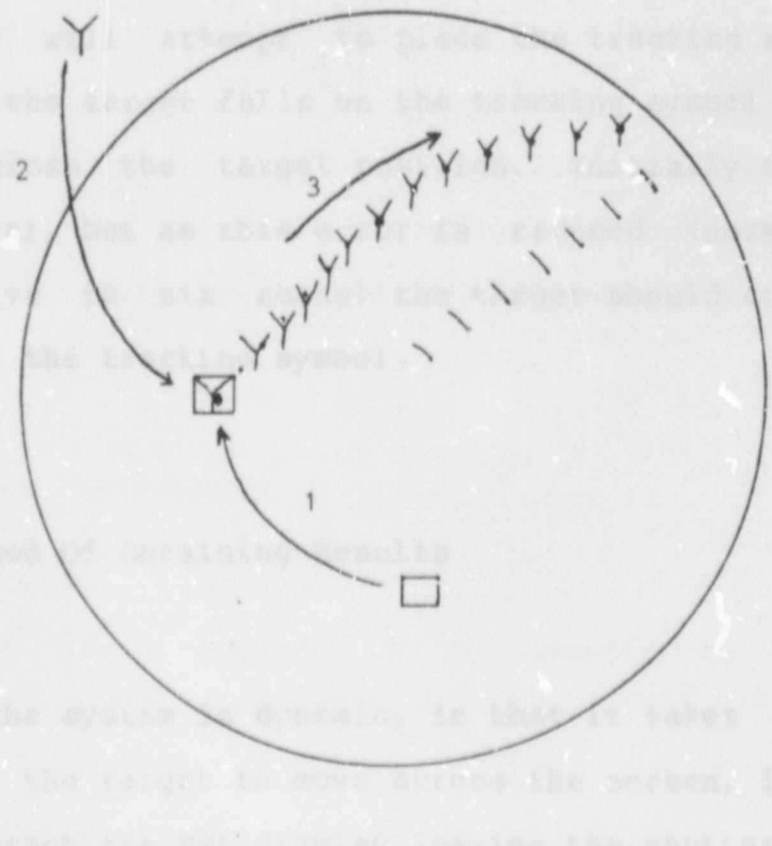

Figure 8.1 Typical PPI Showing Track Sequence

In practice one would not observe the whole series of tracking symbol positions out to the maximum range as indicated. Due to the persistence of the screen one would typically see the afterglow of the previous one or two symbols and no more. This figure thus serves to illustrate the expected operation of the TWS system only.

One can see that the first operation required is for the operator to place his designation marker over the target and to initiate the track. Once the tracking symbol has been placed within the designation marker symbol the operator is free to move the marker symbol away. On successive scans the TWS processor will attempt to place the tracking symbol in such a way that the target falls on the tracking symbol as the radar scans across the target position. Initially the filter has a large error, but as this error is reduced (normally it takes about five to six scans) the target should coincide with the centre of the tracking symbol.

8.2 Method Of Obtaining Results

Because the system is dynamic, in that it takes a fairly long time for the target to move across the screen, it was necessary to photograph the PPI display leaving the shutter open for the complete duration of the track.

A camera was mounted in front of the PPI display and the lens aperture and the intensity of the display were adjusted such that the photograph was correctly exposed for the expected period of the track.

When a target was detected the camera shutter was triggered and left open for the duration of the track. At the end of the track the shutter was closed. Because the lens was open for such a long time the random false alarms generated by the radar would be captured on the film. When viewed later the photograph would falsely indicate many clutter areas on the screen. Care should thus be taken in the interpretation of the photograph.

When the filter is indeed tracking the target, the target and the tracking symbol are coincident on the screen. The photograph will only show up the position of the symbol and the target will be masked. It is thus difficult to ascertain the actual position of the target in the photograph.

8.3 System Performance

Using the above method, it is possile to illustrate the performance of the system.

Figure 8.2 illustrates the PPI display containing the tracking symbol in the upper lefthand corner, the designation marker in the upper right hand corner of the display and a few clutter areas. The echoes at 14km and 11 o'clock are from large buildings in the area. The echoes at 11km and 12 o'clock are cars travelling along a small section of highway illuminated by