AD-A055 266 MASSACHUSETTS INST OF TECH LEXINGTON LINCOLN LAB F/G 17/8
CALIBRATION AND POSITIONAL DETERMINATION OF BOLLER AND CHIVENS --ETC(U)
APR 78 L E EATON, R L IRELAN F19628-78-C-0002
UNCLASSIFIED ETS-29 ESD-TR-78-66 NL

| OF |

AD
A055266

END
DATE
FILMED
7 -78
DDC

AD A055266

/ /

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LINCOLN LABORATORY

CALIBRATION AND POSITIONAL DETERMINATION OF BOLLER AND CHIVENS 31-in. TELESCOPE B

L. E. EATON

Group 94

R. L. IRELAN

Manpower, Inc.

PROJECT REPORT ETS-29

10 APRIL 1978

Approved for public release; distribution unlimited.

LEXINGTON MASSACHUSETTS

78 06 09 025

ABSTRACT

ABSTRACT

This report describes the methods presently used to determine the position of the second Boller & Chivens telescope (telescope B) at the GEODSS ETS.

Also discussed is a system devised for auto-calibration of the telescope position.

ABSTRACT

ACCESSION for

NTIS White Section

DDC Buff Section

UNANNOUNCED

JUSTIFICATION

BY

DISTRIBUTION/AVAILABILITY CODES

Dist. AVAIL. and/or SPECIAL

A

PRECEDING PAGE BLANK-NOT FILMED

CONTENTS

PRECEDING PAGE BLANK-NOT FILMED

I. INTRODUCTION

Tests recently conducted at the ETS on telescope B have raised a question regarding the positional accuracy of the instrument. This may be defined as the degree of accuracy which can be expected of a differential measurement taken from a reference or calibration star to another object in the sky.

To better understand the difficulties encountered in any attempt to deal with pointing errors, this report describes the method by which the telescope's position is determined. This description starts at the drive train and follows through to the LED displays of Right Ascension, Declination and Hour Angle.

II. GENERAL

Before a detailed description of the positional determination of telescope B is given, a brief history is in order. This 31" Boller & Chivens telescope was delivered to the GEODSS ETS with some major modifications from the first telescope. First, a new drive system is used, consisting of a single D.C. motor servo system on each axis. Second, the shaft encoders used on telescope B have an accuracy of .2 arc sec as opposed to 1 arc sec on telescope A. The only electronics associated with the system, as received, were the pre-amps, power amps and tachometer feed-back circuitry for the servo system.

A complete telescope control system was designed by Lincoln Laboratory personnel using a Motorola M6800 microprocessor to calculate and display telescope position from shaft encoder pulses. The microprocessor also generates sidereal rate for the telescope drive system. Because of the extensive design modifications done by Lincoln at the ETS, this telescope has been much more thoroughly examined than telescope A to verify proper functioning of the hardware and software.

As a result of this careful examination, several shortcomings in the pointing accuracy of the telescope have come to light which, in our estimation, limit the degree of precision attainable with this particular instrument.

Bearing these limitations in mind, this report will explain and define the workings of the telescope to illustrate the method by which the position of the telescope is determined. It is important to remember that there are numerous areas in which errors may be introduced, and these will be brought to light as a description of the mechanical drive system is given.

The report also explains how the telescope is initially calibrated and the tests that have been conducted to examine the precision of this calibration.

III. TELESCOPE DRIVE SYSTEM

The Right Ascension drive system in this telescope is a worm/worm gear type in which a stationary worm gear is concentric with the center of rotation of the polar axle. The Declination drive is mechanically the same as the Right Ascension; however, the primary worm gear rotates with the axle, and the worm drive assembly is stationary.

Tangential to the worm gear and integral with each rotating axle is a drive assembly consisting of: drive motor, worm and worm housing, fly wheel, tachometer for servo loop and the optical shaft encoder (see Figure 1). The shaft encoder is positively connected to the worm shaft such that any rotation of the worm (hence the axle) transmits pulses from the shaft encoder.

The shaft encoder generates 18,000 pulses in one complete rotation of its shaft, and there is a 360 to one gear ratio between the worm and the worm gear. This calculates to one pulse for each .2 arc second of rotation of the axle. Separate pulses correspond to clockwise or counter clockwise rotation of the worm.

In addition to the clockwise and counter clockwise pulses from the shaft encoder, there is a unique pulse that occurs once per revolution of the shaft encoder shaft (18,000 divisions). This pulse represents a one degree movement of the axle precise to .2 arc sec on the worm gear.

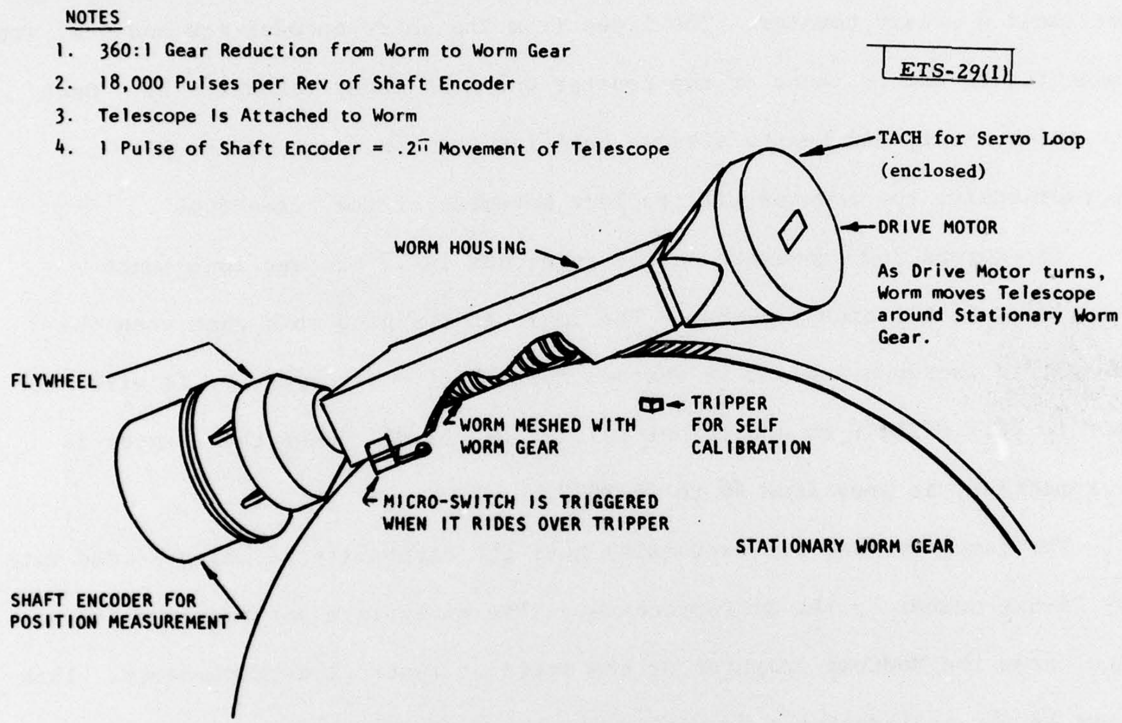

Fig.1. Worm on stationary worm gear.

IV. MEASUREMENT OF POSITION WITH LOGIC

The shaft encoder outputs pulses indicating a delta movement of the telescope. Each pulse represents .2 arc sec movement of the telescope. To accumulate these changes, the shaft encoder pulses are used to increment or decrement a binary counter. The lines from the shaft encoder (cw and ccw) are connected to the UP input of the counter and DOWN input respectively. Once the telescope is pointed to a known position and the counters are set appropriately, the counter will reflect movement of the telescope.

To express 360° movement of the telescope in .2 arc sec increments requires a 24-bit binary number. The logic is designed such that when the counter is incrementing and it reaches #62EØ7F (# = Hex symbol), it will roll over to #Ø. #62EØ7F is equivalent to 359° 59' 59.8". When the counter is decrementing, it goes from #Ø to #62EØ7F.

The counters (one for each axis) have the capability of being loaded with any 24-bit number by the microprocessor. The microprocessor receives its input from the ModComp computer or the operator controlled thumbwheels. This input is the calibration information for the position at the telescope. The position is usually obtained by boresighting a known star and loading its Right Ascension and Declination.

The two counters, Local Hour Angle (HrA) and Declination, will thus describe the actual position of the axes. Once the system is calibrated, i.e., counters loaded, movement of each axis will be reflected by the counters.

To ascertain Right Ascension, the microprocessor needs the Sidereal

Time. Thus, a third 24-bit binary counter was built which is incremented by a 1Khz sidereal clock. This counter, too, can be set.

With the microprocessor having both Sidereal Time and Hour Angle available to it, Right Ascension can be calculated:

$$RA = \text{Sidereal Time} - \text{HrA}.$$

Figure 2 gives the block diagram of this system. The microprocessor has control of reading and writing to the external 24-bit counters. The counters reflect the movement of the telescope via the incremental shaft encoder pulses. Calibration information for setting the counters can be obtained by the microprocessor from operator controlled thumbwheels or the ModComp computer.

With incremental shaft encoders, binary counters and a microprocessor, a system has been developed that is equivalent to an "absolute shaft encoder" system. As opposed to mechanical/optical absolute shaft encoders, which are always calibrated, this system is given a calibration reference. With this system, any point on the two axes can be found to within .2 arc sec.

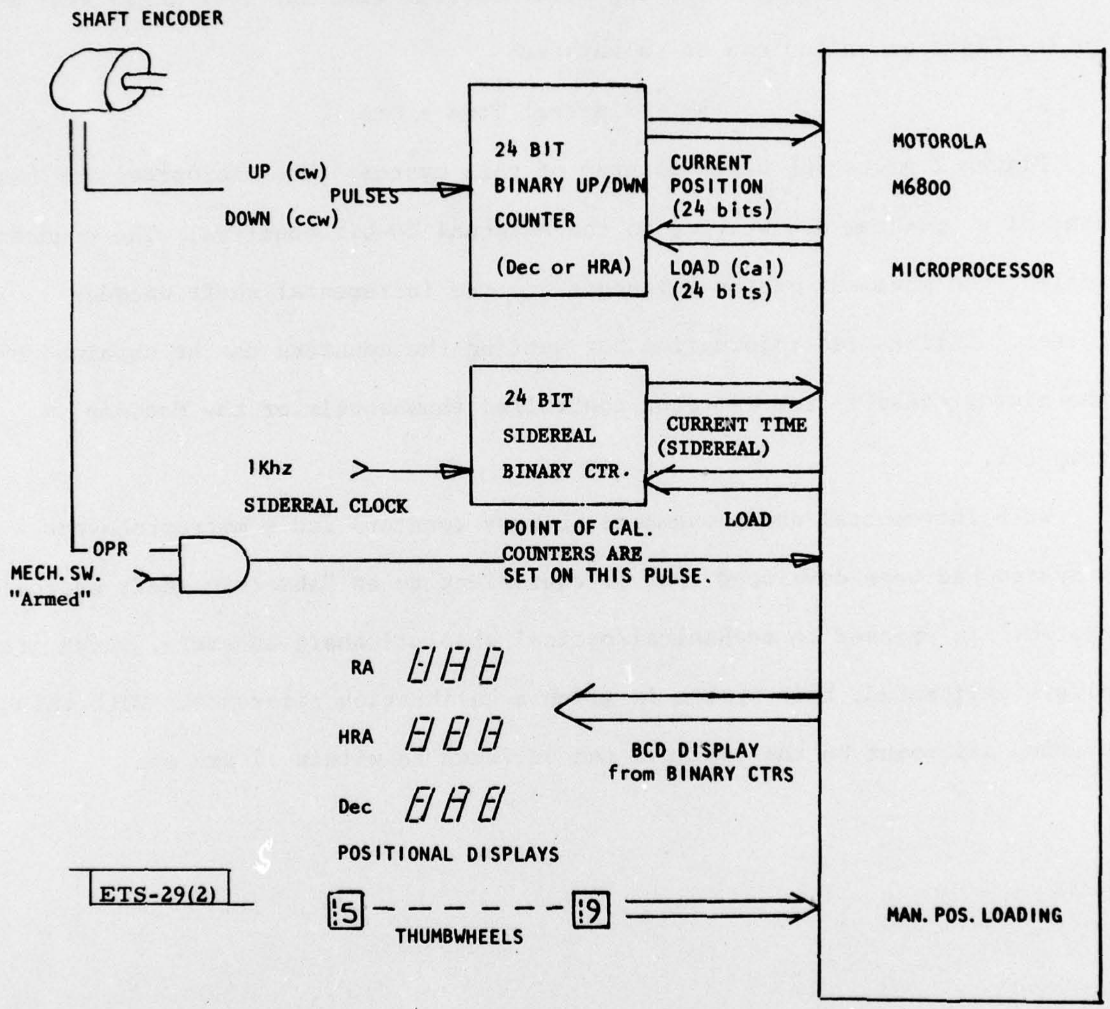

Fig.2. Block diagram of data flow from the shaft encoders to the displays.

V. DISPLAYS OF ASTRONOMICAL POINTING

The microprocessor processes the internal binary information to obtain BCD Right Ascension, Declination and Hour Angle. This information is displayed at the telescope console and sent to the ModComp.

The Right Ascension is calculated by a 24-bit binary subtraction of the Hour Angle from the Sidereal Time. The Sidereal Time is in units of milli-sec, and the Hour Angle is in .2 arc sec increments. This conversion is based on 1 sec of Sidereal Time being equal to 15 arc sec of Hour Angle. Thus, the proper conversion is made before the Right Ascension is calculated.

From the resulting binary number of Right Ascension, a binary to BCD time conversion is made. This number is displayed at the telescope console and also sent to the ModComp.

Declination and Hour Angle displays are simply a binary to BCD conversion properly formatted for the telescope console and the ModComp computer.

The precision with which this information is available at present is given below in Table 1.

TABLE 1

PRESENT PRECISION OF TELESCOPE POSITION AVAILABLE TO USER.

Position	At ModComp	At Tel. Console
RA	1/15 sec of RA	1 sec of RA
HrA	1/15 sec of RA	1 sec of RA
Dec	1 arc sec	6 arc sec

The microprocessor, however, has available the position precision of .2 arc sec, but present software structure does not make this available.

VI. METHODS OF CALIBRATING THE TELESCOPE POSITION

There are two methods employed here at GEODSS for initially calibrating the telescope's position. One is to allow an operator to manually boresight a star of known Right Ascension and Declination in the telescope's field of view. The star's coordinates are then set into the system via the operator thumbwheels or the ModComp computer.

Table 2 gives the precision with which the system can be initially calibrated by this method.

TABLE 2

PRECISION WITH WHICH THE TELESCOPE CAN INITIALLY BE CALIBRATED VIA THE MODCOMP OR TELESCOPE CONSOLE

Position	From ModComp	From Telescope Console
RA	1 sec of RA	1/75 sec of RA
HrA	1 sec of RA	1/75 sec of RA
Dec	6 arc sec of angle	.2 arc sec of angle

The second method of calibration is an automated procedure via the microprocessor. This is accomplished by knowing an absolute and accurately relocatable point on each worm gear. The microprocessor loads predetermined constants in the Declination and Right Ascension counters when the respective points are found. Appendix 1 gives the operator procedure for implementing this auto-calibration.

Figure 3 shows the diagram of the auto-calibration design. The design makes use of a mechanical tripper and the once-per-revolution pulse from the shaft encoder.

The mechanical tripper cannot reproduce a point to an accuracy as great

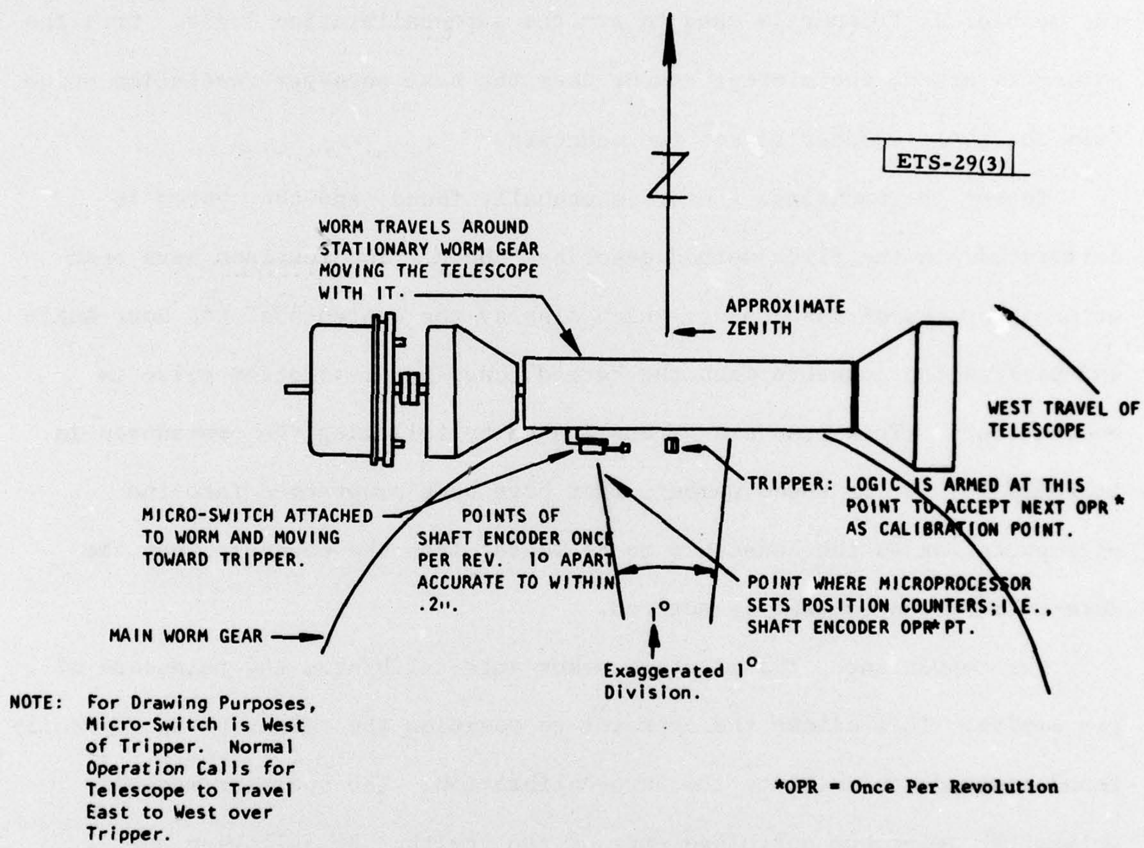

Fig.3. Set-up for calibrating telescope position.

as .2 arc sec, but it can easily "trip" within the same 1° slice of the worm gear. However, the once-per-revolution pulse from the shaft encoder is precise to within .2 arc sec and occurs every 1° movement along the worm gear. Thus, the mechanical tripper is used to arm the auto-calibration logic. Once the system is armed, the microprocessor uses the next once-per-revolution pulse from the shaft encoder to set the counters.

To set the counters, a star is manually found, and the system is calibrated via the first method described above. Two routines have been written for the microprocessor which display the contents of the Hour Angle and Declination counters when the "armed" once-per-revolution pulse is encountered. (This test can be duplicated by following the procedures in Appendix 1.) It is these numbers that have been programmed into the microprocessor as the constants to be loaded into the counters when the auto-calibration routine is entered.

For convenience, the microprocessor auto-calibrates the telescope at the zenith. This allows the operator to position the telescope in an easily found attitude to initiate the auto-calibration. The operator manually drives the telescope north and east of the zenith. By following the instructions in Appendix 1, the microprocessor will drive the telescope south and west until the two calibration pulses occur. Since the Sidereal Time is already known by the microprocessor, all three coordinate positions are calculated and the telescope is calibrated.

VII. AREAS THAT MAY INTRODUCE TELESCOPE POSITIONAL ERRORS

This report has given an explanation of the way the position of the telescope is determined. From a boresighted star's position to the actual displayed position of the telescope, several causes of error can be introduced. Some of these are listed here.

1. Refraction. This is the refraction of light through the atmosphere. The position of the real object and the pointing of the telescope will be different.

2. Telescope Bending. The barrel of the telescope can bend slightly depending, for one thing, on the attitude of the telescope. Telescope B has the heaviest barrel placed on this type of mount by Boller & Chivens.

3. Worm/worm Gear Drive. This type of drive requires the faces of the worm and worm gear teeth to be against each other at all times. If this is not consistent, errors can be introduced.

4. Reproducing the Auto-Calibration Point. By running the RA/Dec counter test described in Appendix 1, the consistency of reproducing the auto-calibration point can be determined. It was found that the Hour Angle and Declination counters would always contain the same count when the auto-calibration point was reached. However, an external reference point is required to determine the accuracy of the over-all system.

APPENDIX

AUTO-CALIBRATION OF THE TELESCOPE AND RA AND DEC COUNTER TESTS.*

A. <u>To Auto-Calibrate the Telescope</u>

1. The mode switches should be in the following state:

   Drives Enabled.

   Computer Inhibited.

   Thumbwheels Enabled.

   RA in Sidereal Mode.

2. Verify that the Time Code Reader is displaying the correct Sidereal Time.

3. Press RESET/START.

4. Drive the telescope a little north and east of the zenith.

5. Set the ID thumbwheels to a Ø4 and press ENTER.

6. The telescope should drive south and west and should return control to the operator after both zenith pulses have occurred.

7. The operator should verify that proper operation occurred by noting that the displays read approximately:

   RA = Sidereal Time

   $HrA = 0^h$

   $Dec = 33^o$

8. If any difficulty occurs, press RESET/START to regain control of the system.

B. <u>To Run the HrA (or Dec Counter Tests)</u>

1. Make sure mode switches are in the same state as A above.

2. Put the telescope a little east (north for Dec test) of the zenith

*L.E. Eaton, "Telescope B Users Guide", Project Report ETS-22, Lincoln Laboratory, M.I.T., (28 November 1977), DDC AD-A049685.

3. Press RESET/START.
4. Set a 33 for RA test (34 for Dec test) in the ID thumbwheels and press ENTER.
5. A variable track status code will come on for RA (Dec), and the telescope will drive east (south if in Dec test).
6. When the RA zenith calibration bit comes up (Dec zenith bit for Dec test), the microprocessor will display the contents of the HrA (Dec) 24-bit binary counter in the manual tracking LEDs. This number is a 6 digit hex number.

   (Note: For programming/logic reasons, there is a 3 second delay before the RA test starts.)
7. Press RESET/START to regain control of the system.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

18 19

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER ESD-TR-78-66	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 Calibration and Positional Determination of Boller and Chivens 31-in. Telescope B		5. TYPE OF REPORT & PERIOD COVERED 9 Project Report 6. PERFORMING ORG. REPORT NUMBER 14 ~~Project Report~~ ETS-29
7. AUTHOR(s) 10 Lawrie E. Eaton ~~and~~ Robert L. Irelan		8. CONTRACT OR GRANT NUMBER(s) 15 F19628-78-C-0002
9. PERFORMING ORGANIZATION NAME AND ADDRESS Lincoln Laboratory, M.I.T. P.O. Box 73 Lexington, MA 02173		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 63428F 16 ~~Project No.~~ 2128
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Systems Command, USAF Andrews AFB Washington, DC 20331		12. REPORT DATE 11 10 Apr~~il 19~~78 13. NUMBER OF PAGES 12 ~~22~~ 20 P.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Electronic Systems Division Hanscom AFB Bedford, MA 01731		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

None

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ETS	telescope
GEODSS	astronomical pointing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the methods presently used to determine the position of the second Boller and Chivens telescope (telescope B) at the GEODSS ETS.

Also discussed is a system devised for auto-calibration of the telescope position.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

207 650

hc