NBSIR 88-3807

Lights of New York Harbor

James A. Worthey

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Environment Division
Lighting Group
Gaithersburg, MD 20899

June 1988

75 Years Stimulating America's Progress
1913-1988

Sponsored by

Coast Guard Research and Development Center
U.S. Department of Transportation
Avery Point
Groton, Connecticut 06340-6096

NBSIR 88-3807

LIGHTS OF NEW YORK HARBOR

James A. Worthey

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
National Engineering Laboratory
Center for Building Technology
Building Environment Division
Lighting Group
Gaithersburg, MD 20899

June 1988

Sponsored by
Coast Guard Research and Development Center
U.S. Department of Transportation
Avery Point
Groton, Connecticut 06340-6096

U.S. DEPARTMENT OF COMMERCE, C. William Verity, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

ABSTRACT

This report presents photometric measurements on shore lights of the New York harbor area, taken from three observation points. In particular, measurements were made of the illuminance at the observation point due to distant lights, considered to be point sources. This is a measure of point source intensity appropriate to this situation, and quantifies what a mariner will see sailing into or out of New York harbor at night. The measurements are of interest because lights on shore make it hard to see the lights maintained by the U. S. Coast Guard as aids to navigation. One conclusion is that most of the interfering lights are high-pressure sodium vapor lamps used to light the streets, roads, and docks. The distributions of the lights in intensity, position, and color are presented graphically.

KEY WORDS: Aids to navigation; Aiming device; Buoy; Lighthouse; Photometry; Signal lights.

DISCLAIMER

Where commercial products are mentioned by brand name, this is for identification only, and does not imply that they are endorsed by the government, or are the best available.

ACKNOWLEDGEMENTS

Special appreciation is due to Charles Bulik who assisted in the development of the apparatus and took part in every measurement. Thanks are due as well to Noel Nazario who put in one long night on the beach at Sandy Hook, and to Dr. Marc Mandler, the sponsor's technical representative, who lent us apparatus, visited the observation sites, and was extremely helpful at every stage of the work.

FOREWORD

This report documents the results of National Bureau of Standards (NBS) in support of the United States Department of Transportation Coast Guard, in fulfillment of USCG/NBS Contract # Z51100-7-00003. This report summarizes work done from February 1987 to February 1988.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter 1. Overview

1.1. Background - Visual Clutter in Big City Harbors. Vessels entering a harbor such as New York must steer to their destination, while avoiding obstacles such as shoals and the shore, and possibly staying within dredged and marked channels. To help them do this, the Coast Guard maintains numerous "aids to navigation," such as buoys of different sizes, traditional lighthouses, and lights on shore towers. At night, these aids are visible as point light sources.

To help mariners identify them, lighted aids differ in color and flash characteristic. White, red, and green are the most common colors, while typical flash characteristics are "fixed" (100 percent duty cycle) or flashing once every few seconds. For instance, Volume 1 of the *Atlantic Coast Light List* tells us that along Sandy Hook Channel, south of New York City, at 40° 27′.2 north latitude*, 73° 56′.3 west longitude, Lighted Gong Buoy 1 flashes green at intervals of 2.5 s. This buoy is visible at up to 4 nautical miles. Other aids which are brighter and on taller structures may be visible at ranges up to 19 nautical miles.

Clearly in the dark of night these aids provide important information at distances which are far too great for the mariner to see the supporting structure. They appear as point sources on a black field, distinguished only by their color and flash characteristics. Since most of these aids are not "mighty beacons," but may have only a 30-watt incandescent bulb with a high-quality Fresnel lens, they are not consistently brighter than sources on the shore behind them, such as streetlights. In urban areas, where lights on the shore are numerous, mariners report that at night it is often difficult or impossible to distinguish the aids from shore lights.

The U. S. Coast Guard is concerned about increasing the visibility of aids at night, by making them more visually dissimilar from the shore lights. An important first step is to gather information regarding shore lights in a harbor where visibility of aids is a problem.

1.2. Nature of this Report. The larger responsibility for studying what makes a light visually distinctive from its background, and of inventing and testing improved aids, rests with the Coast Guard Research and Development Center at Avery Point, Connecticut. The present report concerns only the limited task of physical measurements on the lights of New York harbor. The raw data are presented in Chapter 2; some simple graphical analysis of the data appears in Chapter 3; and the underlying theory, apparatus, and data-taking software are described in Chapters 4-7.

---

*In nautical usage, latitude and longitude are usually given in degrees, minutes, and decimal fractions of a minute, with seconds of arc not being used. The usual precision is 0′.1, that is a tenth of a minute. It is common for the minute symbol to be applied to the whole number, and written over the decimal point, as in 3′.3 or 3!3.

1.3. Observation Sites. Data were taken in three sets, from locations around New York harbor. The exact spots were found through on-the-spot searches, in consultation with Dr. Marc Mandler from the Coast Guard Research & Development Center. The intention in each case was to get a view similar to that which might be seen from a ship entering New York. Two of the locations were actually in the same building on the west side of Governor's Island. One of these gave a view similar to that seen in sailing past Governor's Island and the Statue of Liberty and up the Hudson River between New Jersey and Manhattan Island. The other gave a view that might be seen in following this same course the other way. The third location, on the beach at Sandy Hook, New Jersey, gave a view similar to that which might be seen in sailing from the open Atlantic toward Staten Island or toward the Verrazano-Narrows Bridge and points north.

Chapter 2. Data

2.1. General Description of Data-Taking method. For the benefit of impatient readers, the data will be presented in this chapter, ahead of the detailed description of the apparatus and so forth. Hence, a brief description of the method is needed here. (Extremely impatient readers may want to skip ahead to Chapter 3 on the analysis of data, but this is *not* recommended.)

2.1.1. Instrument and its Sensitivity. The measuring instrument used was a telephotometer, a model 1980 version of the Spectra-Pritchard photometer[1], made by Photo Research Division of Kollmorgen Corporation. Simple manipulation of handbook data and the instrument specification shows that the instrument with its normal lens can give a *full-scale* response to the dimmest visible signal light. (The original specification for the current project said we should measure lights down to 2×10^{-8} footcandles illuminance at the observation point, in close agreement with the working threshold for lighthouses given by Wyszecki and Stiles[2], 0.5 photopic mile-candles. When the Pritchard is used to measure point sources, its best full-scale sensitivity is 2×10^{-8} footcandles.)

2.1.2. Objective Lens and Apertures. The Pritchard photometer is a telescopic instrument, which in its general appearance and method of aiming resembles a camera. Most of the light entering the objective lens simply passes through and out an eyepiece. By looking in the eyepiece, the operator can aim and focus the lens, based on the image which he sees of the object to be measured. In the center of that image, the operator sees a black spot which is actually a hole ("aperture") in a mirror that is part of the through optical path. The light that falls through the aperture strikes the photomultiplier tube and is measured.

The standard objective lens of the photometer used has a focal length of 7 inches. With this lens, the apertures which can be rotated into place give circular measurement fields having diameters of 3° (180 minutes), 1° (60 min), 20 min, 6 min, and 2 min. There is also one rectangular aperture which was not used. The lens actually used for all measurements was an 84 inch Cassegrain objective; the magnification gained by this telescopic objective is (84 inches/7 inches) = 12, therefore the actual measurement field diameters were 1/12 of the nominal values. Of course, the aperture wheel on the instrument is labelled with the nominal values. Therefore, the apertures will always be referred to by their nominal sizes, but in calculations, the magnification must be accounted for.
Note that if the resolution of human vision is 1 minute, any lights that were measured with the 6 min or 2 min apertures had actual subtenses of less than 0.5 min or 0.17 min and were true point sources to the naked eye. Even lights measured with the 20 min aperture were near the limit of resolution.

2.1.3. Point Sources. If a point source is measured in the laboratory, it may be characterized by its luminous intensity in a given direction, defined as the flux over a small solid angle *subtended at the source*, divided by that solid angle. For point sources spotted through a telescope, the solid angle subtended by the entrance pupil of the measuring instrument at the source is unknown, because the distance is unknown; a different measure of point source intensity is needed. A practical one is *the illuminance at the measuring instrument due to the point source.*

In this context, illuminance means exactly what it always means: luminous flux incident on a surface, per unit area of that surface. The surface in this case is the entrance pupil of the measuring instrument. What is perhaps unfamiliar is that this is not the cosine-integrated illuminance routinely measured with a "foot-candle meter," but only that part of total illuminance which is due to one distant source. If you are standing on the beach at Sandy Hook, New Jersey, this illuminance is the answer to the question "how much is one of the mercury vapor lights on the Verrazano bridge going to help me read the newspaper?" The answer of course is "not much," and it is to be expected that these numbers will be in the range of tiny fractions of a lux. (1 lux = 1 lumen / m^2)

2.1.4. Measuring Point Sources with the Pritchard Telephotometer. The Pritchard photometer is designed to measure luminance of extended sources. Given one technical assumption and the proper interpretation of the data, however, it is perfectly suitable for measuring illuminance at the measuring instrument due to a point source. The raw data to be presented in this chapter include values of "luminance reading." This is the *actual reading* from the luminance readout on the photometer, and is **NEVER** a meaningful luminance. In a few cases, where the comments indicate that the "luminance calibration" was in effect, and the source filled the aperture, then actual luminance = 10.0×(luminance reading). Most data, however, are point-source measurements, and a more complicated calculation is required to recover illuminance due to the point source.Let L be the *luminance reading*, let B be the actual luminance, let E be the illuminance at the meter due to the point source, and let *Apert* be the nominal aperture diameter in minutes. Then, Table 2.1 gives the working formulas from which B and E may be computed:

Table 2.1: Working Calibration Formulas

Fills?	**Calibration**	**Working Formula**
Yes	Luminance	$B = 10.0L$
Yes	Point source	$B = 15.94L$
No	Luminance	$E = 4.625\times10^{-9}\ (Apert)^2$
No	Point source	$E = 7.373\times10^{-9}\ (Apert)^2$

The "Yes" or "No" is the answer to the question whether the light being measured fills the aperture, as seen in the eyepiece of the Pritchard. A special column of the data gives this information. The question of whether "Luminance" or "Point source" calibration was used is answered among the comments to the data. Most data were taken with the "Point source" calibration and the lights did not fill the aperture. *What makes a light a point source for present purposes is that it does not fill the aperture. It is incidental which calibration (gain setting) was used, so long as the proper formula from Table 2.1 is applied.* The derivation of the formulas in Table 2.1 appears in Chapter 4, along with some tutorial discussion of measuring point sources.

2.1.5. Data Collection Procedure. A special two-axis mount was devised for the Pritchard, with stepper motors to set azimuth and altitude. The steppers were interfaced to the computer used to collect the data. The data collection program incorporated a procedure for calibrating azimuth and altitude. The instrument could then be aimed by keyboard commands or by a joystick, and the computer always kept track of the absolute azimuth and altitude.

To measure a light, an operator generally spotted it first with the naked eye, then spotted it through the Pritchard with its telescopic objective, and finally, by watching through the eyepiece and making small moves with the joystick, covered the light's image with the measurement aperture.

2.2. The Raw Data. As will be explained in more detail later, all data were taken directly into a computer. This includes the date, time, azimuth and altitude, which the computer had direct access to, as well as numbers and text which were typed in by the operator. Although nearly all the information was written to disk in a standardized way via the interactive program used to aim the instrument, that program also allowed the operator to branch to a text editor and enter free-form comments, or correct errors in data.

The data were stored so as to create an orderly table, easily read into a spreadsheet program or perhaps into a specially written computer program, provided that the comments and directional calibration information are first deleted. The calibrations for azimuth and altitude, while obviously important, were given immediate effect in the recorded values and are only background information so far as the tabulated data are concerned. Comment lines are few, although the first file presented begins with one. Comments begin with an asterisk (*).

For convenience in printing out the data, one row of the data table was stored as two or three lines in the data file. Each logical row starts with an ampersand character (&). A short filter program, presented in Chapter 7, suffices to replace the ampersands with newline characters and eliminate all other newlines, creating a "wide" version of the file.

2.2.1. Detailed Format. The data as presented below have not been edited, except for the few changes that were made during the measurement session the night the data were taken. They were imported with the word processing program to become part of this report.

Lines beginning with an asterisk are comment lines.

Each calibration report occupies 5 lines. The first of these is just the line:

&"Calibration:"

Line 2 of the calibration report gives simple descriptions of the observation point ("Here:") and the distant point used as a direction calibration ("There:"). Line 3 gives the serial numbers and flash characteristics approximately as they appear in the Light List[3]. (As the light list computer file in Section 7.9 illustrates, real lights in the New York area have numbers in the range of 32000-33000; other points not in the Light List have arbitrarily invented serial numbers far from that range.) Line 4 gives the latitude and longitude of Here and There. Line 5 gives the vector from Here to There. Logically, the heights above mean high water should have been included for the calibration locations, but by an oversight, they are not given. They are available in Section 7.9.

Where a calibration appears in the file, it was given immediate effect in the calibration of the following data points. Points occurring prior to any calibration shown in the file are also calibrated, but the calibration was done before the file was opened.

The data set for a photometric measurement begins with an ampersand and a blank, then the following:

1st line: date and time; azimuth [decimal degrees]; altitude [decimal degrees]; a terse description of the light;

2d line: color; nominal aperture diameter [minutes]; did the light fill the aperture? [yes or no]; luminance reading; flash rate; duty cycle; comment.

Luminance reading is recorded in power-of-10 notation. With just a couple exceptions, significant figures and exponent are exactly as displayed on the instrument, the point being to avoid a false appearance of precision. The stated precision is fictitious anyway, however, because of the large fluctuation of many of the lights. No attempt was made to document this fluctuation, but it is probably due to the atmosphere and increases with distance.

By convention, a steady light ("fixed" in Coast Guard parlance) has flash rate 0.0 and duty cycle 1.0. If the comment would make the second line too long, it appears by itself on a **third line**.

All recorded colors are judgments of one human observer with normal color vision.

Because the Governor's Island data include some questionable values, demanding discussion, the easier-to-understand Sandy Hook data will be presented first. Otherwise, data will be grouped in files and kept chronological. The following paragraph headings include the file name and the last date and time the file was closed---the MSDOS "time stamp."

2.2.2. **File SANDY.001 10-28-87 11:41p.** *All the data at Sandy Hook were taken in one night, from a high point on the beach, some 300 feet back from the water, using power from a portable generator. Height of eye for this location was taken to be 12 feet. (See Section 3.19.) The first four data points evaporated when power to the computer was momentarily lost; after that, care was taken to back up the files frequently. The file begins with a terse statement that this is the second attempt to get going:*

```
*Second try 21:57
```

```
& "87-10-28, 22:12:46" 325.130 -0.185 "1 Light"
 "Orange" "60" "no" 10.00E-2 0.00 1.000 ""
&"Calibration:"
"Here:  Beach I - along path           There:  Romer Shoal Light            "
"Serial: 99999  Chr:  NA               Serial: 32370  Chr:  Fl (2) W 15s    "
"Loc:   40° 28!100 N    73° 59!900 W   Loc:   40° 30!800 N    74°  0!800 W  "
"Vector, Az:  345° 46!792 E of N, Alt:    0°  7!178, Dist: 2.8 naut. mi."
& "87-10-28, 22:23:45" 325.215 0.125 "1 Light"
 "Orange" "60" "no" 5.75E-2 0.00 1.000 "another similar; pt src cal"
& "87-10-28, 22:24:59" 325.275 0.085 "1 Light"
 "Orange" "60" "no" 14.70E-2 0.00 1.000 "another similar; pt src cal"
& "87-10-28, 22:27:45" 325.270 -0.130 "4 lights"
 "Orange" "180" "no" 0.97E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:30:27" 325.510 -0.130 "4 lights"
 "Orange" "180" "no" 0.60E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:33:26" 325.675 -0.130 "1 light"
 "Orange" "60" "no" 2.50E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:34:33" 325.800 -0.130 "1 light"
 "Orange" "60" "no" 5.20E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:38:03" 326.085 -0.145 "1 light"
 "Orange" "60" "no" 4.40E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:38:35" 326.205 -0.145 "1 light"
 "Orange" "60" "no" 3.60E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:39:50" 326.345 -0.145 "1 light"
 "Orange" "60" "no" 4.20E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:40:40" 326.500 -0.145 "2 lights"
 "Orange" "60" "no" 5.10E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:42:49" 326.800 -0.135 "1 light"
 "Orange" "60" "no" 2.00E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:43:36" 326.920 -0.135 "1 light"
 "Orange" "60" "no" 5.25E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:44:21" 327.010 -0.135 "1 light"
 "Orange" "60" "no" 9.80E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:45:37" 327.150 -0.135 "1 light"
 "Orange" "60" "no" 6.90E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:46:35" 327.295 -0.145 "1 light"
 "Orange" "60" "no" 11.60E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:48:25" 327.455 -0.145 "1 light"
 "Orange" "60" "no" 2.45E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:49:24" 327.720 -0.145 "1 light"
 "Orange" "60" "no" 12.00E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:51:14" 327.935 -0.115 "5 lts"
 "Orange" "180" "no" 1.53E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:53:40" 328.390 -0.135 "1 lt"
 "Orange" "60" "no" 2.90E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:55:20" 328.870 -0.115 "4 lts"
 "Orange" "180" "no" 0.65E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:57:59" 329.230 -0.125 "3 lts"
 "Orange" "180" "no" 1.25E-2 0.00 1.000 " pt src cal"
& "87-10-28, 22:59:50" 329.470 -0.165 "1 lt"
 "Orange" "60" "no" 5.40E-2 0.00 1.000 " pt src cal"
```

```
& "87-10-28, 23:00:31" 329.610 -0.165 "1 lt"
 "Orange" "60" "no" 2.70E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:01:12" 329.825 -0.165 "1 lt"
 "Orange" "60" "no" 6.60E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:02:51" 330.015 -0.150 "4 lts"
 "Orange" "180" "no" 2.00E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:07:21" 330.315 -0.165 "2 lts"
 "Grnsh+Orng" "60" "no" 1.50E-1 0.00 1.000 " pt src cal"
& "87-10-28, 23:09:20" 330.670 -0.165 "4 lts"
 "3 orng + grnsh" "180" "no" 2.25E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:12:20" 330.920 -0.160 "5 lts"
 "2 orng, 3 grnsh" "180" "no" 2.80E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:14:41" 331.195 -0.140 "6 lts"
 "2 orng, 4 whitsh" "180" "no" 1.90E-1 0.00 1.000 " pt src cal"
& "87-10-28, 23:17:33" 331.385 -0.180 "3 lts"
 "2 whtsh, 1 orang" "60" "no" 2.00E0 0.00 1.000 " pt src cal"
& "87-10-28, 23:20:50" 331.680 -0.190 "3 lts"
 "1 yelsh, 2 orng" "180" "no" 1.30E-1 0.00 1.000 " pt src cal"
& "87-10-28, 23:23:31" 331.910 -0.195 "4 lts"
 "Orange" "180" "no" 2.85E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:24:51" 332.190 -0.195 "sm cluster (5?"
 "Orange" "180" "no" 2.70E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:26:23" 332.470 -0.195 "several lts"
 "Orange" "180" "no" 1.45E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:28:43" 332.870 -0.195 "cluster"
 "Orange" "180" "no" 3.00E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:30:12" 333.430 -0.145 "cluster"
 "Orange" "180" "no" 1.65E-2 0.00 1.000 " pt src cal"
& "87-10-28, 23:35:56" 334.090 -0.050 "rotating lt"
 "White" "60" "no" 7.00E0 6.00 0.333 " pt src cal"
```

2.2.3. File SANDY.002 10-29-87 2:56a. *The file wasn't open when the calibration was done, so a comment line notes the calibration. A later comment calls attention to the fact that the mercury vapor lights along the cables of the Verrazano-Narrows Bridge were switched off at 01:00 hours, leaving only some red aircraft warning lights near the towers, and the streetlights along the roadway.*

```
*Recalibrated on Romer Shoal Light
& "87-10-29,  0:22:26" 334.755 -0.060 "small lts"
 "orange" "180" "no" 2.60E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:25:27" 334.935 -0.060 "2 lts"
 "grn + orange" "60" "no" 8.90E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:26:48" 335.415 -0.100 "1 lt"
 "orange" "60" "no" 6.35E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:28:00" 335.900 -0.100 "grp little dots"
 "orange" "180" "no" 2.25E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:31:22" 336.925 -0.110 "grp little lts"
 "orange" "180" "no" 3.20E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:33:21" 337.330 -0.110 "grp little lts"
 "orange" "180" "no" 2.30E-2 0.00 1.000 "pt src cal"
```

```
& "87-10-29,  0:36:40" 338.330 -0.110 "group of lts"
 "orange" "180" "no" 5.70E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:38:37" 339.125 0.085 "array on pole"
 "orange" "60" "no" 12.50E-1 0.00 1.000 "pt src cal"
& "87-10-29,  0:40:00" 339.285 0.085 "1 lt"
 "greenish" "60" "no" 1.75E-1 0.00 1.000 "pt src cal"
& "87-10-29,  0:41:11" 339.390 0.075 "array on high pole"
 "Orange (Na)" "60" "no" 10.25E-1 0.00 1.000 "pt src cal"
& "87-10-29,  0:42:47" 339.480 0.080 "array on high pole"
 "Orange (Na)" "60" "no" 8.10E0 0.00 1.000 "pt src cal"
& "87-10-29,  0:44:02" 339.755 0.055 "array on high pole"
 "Orange (Na)" "60" "no" 14.30E0 0.00 1.000 "pt src cal"
& "87-10-29,  0:44:44" 340.075 0.060 "array on high pole"
 "Orange (Na)" "60" "no" 16.80E0 0.00 1.000 "pt src cal"
& "87-10-29,  0:46:31" 340.340 0.060 "array on high pole"
 "Orange (Na)" "60" "no" 10.70E0 0.00 1.000 "pt src cal"
& "87-10-29,  0:47:44" 340.780 -0.070 "group of lts"
 "White" "180" "no" 2.70E-2 0.00 1.000 "pt src cal"
& "87-10-29,  0:49:41" 341.165 -0.050 "group of lts"
 "Greenish" "180" "no" 0.74E-2 0.00 1.000
 "pt src cal; at Staten Island end of Verrazano bridge."
& "87-10-29,  0:52:56" 342.065 0.115 "lts on VZ cable"
 "Greenish" "180" "no" 1.70E-2 0.00 1.000
 "pt src cal; at Staten Island end of Verrazano bridge."
& "87-10-29,  0:55:43" 342.885 0.470 "11 lts on cable"
 "10 Grnsh, 1 red" "180" "no" 1.77E-2 0.00 1.000
 "pt src cal; on cable leading to west tower."
& "87-10-29,  0:59:20" 343.030 0.540 "10 lts on cable"
 "Greenish" "180" "no" 1.57E-2 0.00 1.000
 "near west support (top of the cable). After this reading, grnish lts out."

& "87-10-29,  1:14:00" 343.705 0.135 "2 lts on roadway"
 "Greenish" "20" "no" 1.86E-1 0.00 1.000
 "These are 2 on a pole; a sample of lights all across the bridge."
& "87-10-29,  1:19:07" 343.750 0.420 "2 lts on cable"
 "red" "20" "no" 1.30E-2 0.00 1.000
 "These red lights remain on after green lights were turned off."
& "8 lts"
 "whtsh & orng" "180" "no" 4.80E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:45:04" 349.715 -0.045 "group lts"
 "whitish" "180" "no" 2.35E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:47:18" 351.695 -0.030 "group lts"
 "orng & whtsh" "180" "no" 2.60E-2 0.00 1.000 "In Brooklyn."
```

```
& "87-10-29,  1:49:27" 351.920 0.030 "group lts"
 "whitish" "180" "no" 6.20E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:51:16" 352.170 -0.065 "streetlights"
 "greenish" "180" "no" 3.50E-2 0.00 1.000 "In Brooklyn."
& "8 lts"
 "whtsh & orng" "180" "no" 4.80E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:45:04" 349.715 -0.045 "group lts"
 "whitish" "180" "no" 2.35E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:47:18" 351.695 -0.030 "group lts"
 "orng & whtsh" "180" "no" 2.60E-2 0.00 1.000 "In Brooklyn."
```

```
& "87-10-29,  1:49:27" 351.920 0.030 "group lts"
 "whitish" "180" "no" 6.20E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:51:16" 352.170 -0.065 "streetlights"
 "greenish" "180" "no" 3.50E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:53:39" 353.505 -0.055 "streetlights?"
 "orange" "180" "no" 2.70E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  1:58:17" 354.630 -0.035 "group of lts"
 "orange" "180" "no" 1.98E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:01:52" 355.110 -0.025 "4 lts"
 "whitish" "180" "no" 6.50E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:03:34" 355.830 -0.060 "6 lts"
 "orange" "180" "no" 1.30E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:05:06" 356.220 -0.055 "8 lts"
 "orange" "180" "no" 1.55E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:06:19" 356.540 -0.060 "2 lts"
 "orange" "60" "no" 1.46E-1 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:08:30" 356.925 -0.050 "6 lts"
 "orange" "60" "no" 1.53E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:10:54" 357.310 0.010 "1 streetlight"
 "greenish" "60" "no" 1.60E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:11:55" 357.370 0.010 "1 streetlight"
 "greenish" "60" "no" 7.40E-2 0.00 1.000 "In Brooklyn."
& "87-10-29,  2:14:39" 357.420 0.755 "2 on world trade"
 "red" "60" "no" 1.50E-2 0.00 1.000 "Now in Manhattan."
& "87-10-29,  2:16:06" 357.460 0.755 "4 lts + windows"
 "red, white" "180" "no" 1.94E-2 0.00 1.000
 "Row of red warning lts + some windows, nr top of World Trade."
& "87-10-29,  2:20:23" 358.400 0.395 "lited crown bldg"
 "whitish" "60" "no" 8.02E-2 0.00 1.000 " Cone shaped."
& "87-10-29,  2:23:00" 358.495 -0.030 "9 streetlight"
 "orange" "180" "no" 6.90E-2 0.00 1.000 ""
& "87-10-29,  2:24:39" 358.930 -0.025 "14 streetlights"
 "orange" "180" "no" 4.20E-1 0.00 1.000 ""
& "87-10-29,  2:26:16" 358.965 0.205 "4 lts"
 "orange" "60" "no" 2.21E-1 0.00 1.000 "high on building."
& "87-10-29,  2:28:13" 359.410 -0.015 "group"
 "orange" "60" "no" 6.70E-2 0.00 1.000 "streetlights."
& "87-10-29,  2:29:38" 359.735 -0.070 "streetlights"
 "orange" "60" "no" 3.40E-1 0.00 1.000 ""
& "87-10-29,  2:32:38" 359.880 -0.030 "streetlights"
 "orange" "60" "no" 1.95E-1 0.00 1.000 ""
& "87-10-29,  2:35:14" 0.630 -0.055 "1 streetlight"
 "orange" "60" "no" 6.65E-1 0.00 1.000 ""
& "87-10-29,  2:36:55" 0.850 0.195 "light atop bldg"
 "whitish" "60" "no" 6.50E-2 0.00 1.000 ""
& "87-10-29,  2:40:43" 0.870 -0.055 "streetlights"
 "orange" "60" "no" 1.90E-1 0.00 1.000 ""
& "87-10-29,  2:42:16" 1.165 -0.050 "streetlights"
 "orange" "180" "no" 6.20E-2 0.00 1.000 ""
& "87-10-29,  2:45:06" 1.485 -0.050 "streetlights"
 "6 orange, 1 whts" "180" "no" 3.40E-2 0.00 1.000 ""
& "87-10-29,  2:51:15" 1.965 0.290 "lt on bldg"
```

```
 "orange" "60" "no" 12.60E-2 0.00 1.000 ""
& "87-10-29,  2:53:00" 2.085 0.610 "Empre St 1 lt"
 "orange" "60" "no" 6.65E-2 0.00 1.000 ""
```

2.2.4. File GOVISL.002 10-20-87 4:43a. *This first night on Governor's Island served as a shakedown for our measuring techniques. Some time was spent just in finding a light to calibrate on. As indicated in the comments, many of the measurements were taken through one or another window pane. Apart from the obvious loss of light to reflection at the surfaces of the glass, varying with the angle of incidence, this was terribly unsatisfactory because of the distortion of images. The Cassegrain objective lens has an entrance pupil perhaps 250 times larger than that of the unaided eye; the window pane's undulations over this area distort a point source into an unrecognizable shape. In the analysis in Chapter 3, these data are not lumped with the better data taken on later nights.* Height of eye for this location was taken to be 77 feet.

```
&"Calibration:"
"Here:  High rise #877-room 516        There:  Battery Light                 "
"Serial: 99998  Chr:  NA               Serial: 15     Chr:  Iso R 6s         "
"Loc:   40° 41!247 N    74°  1!493 W   Loc:   40° 42!017 N    74°  0!928 W
"Vector, Az:   29°  5!733 E of N, Alt: -  0° 40!878, Dist: 0.9 naut. mi."
& "87-10-20,  2:38:19" 29.095 -0.680 "Battery red light iso 6s"
 "red" "6" "yes" 10.00E1 6.00 0.500
 "Time on = 3s, lum. value is during on-segment of cycle."
& "87-10-20,  2:52:19" 29.095 -0.680 "Battery red light iso 6s"
 "red" "2" "yes" 2.60E2 6.00 0.500
 "Time on = 3s, lum. value is during on-segment of cycle.  Note better overfill."
& "87-10-20,  3:11:55" 24.535 -0.595 "Typical orange streetlight (Na?)"
 "orange" "2" "yes" 1.30E3 0.00 1.000
 "Many of these lights in the battery.  Reading fluctuates 1-1.6"
& "87-10-20,  3:16:37" 24.535 -0.595 "Typical orange streetlight (Na?)"
 "orange" "6" "yes" 6.00E2 0.00 1.000 "Same as prev., still appears to fill."
& "87-10-20,  3:18:19" 24.535 -0.595 "Typical orange streetlight (Na?)"
 "orange" "20" "no" 7.17E1 0.00 1.000 "NOW, the dot eclipses the light"
& "87-10-20,  3:22:38" 23.880 -0.545 "Streetlight with branch"
 "orange" "20" "no" 3.30E1 0.00 1.000 "NOW, the dot eclipses the light"
& "87-10-20,  3:50:34" 344.630 -0.080 "2 Na lamps in Jersey"
 "orange" "60" "no" 13.50E-1 0.00 1.000 "Through the window pane."
& "87-10-20,  4:10:06" 350.260 1.075 "1 light atop bldg"
 "red" "2" "yes" 0.04E2 0.00 1.000
 "Through the window pane, 'nearly' fills aperture."
& "87-10-20,  4:13:52" 350.355 1.075 "1 light atop bldg"
 "red" "2" "yes" 0.04E2 0.00 1.000
 "Through the window pane, 'nearly' fills aperture.  Next in row."
& "87-10-20,  4:16:20" 350.530 1.075 "1 light atop bldg"
 "red" "2" "yes" 0.04E2 0.00 1.000
 "Through the window pane, 'nearly' fills aperture.  Next in row."
& "87-10-20,  4:17:18" 350.660 1.075 "1 light atop bldg"
 "red" "2" "yes" 0.04E2 0.00 1.000
 "Through the window pane, 'nearly' fills aperture.  Next in row."
```

```
& "87-10-20,  4:18:28" 350.900 1.075 "1 light atop bldg"
 "red" "2" "yes" 0.04E2 0.00 1.000
 "Through the window pane, 'nearly' fills aperture.  Next in row."
& "87-10-20,  4:20:34" 350.205 0.585 "Avg lum of 7 stories"
 "yellowish" "180" "no" 0.55E-1 0.00 1.000 "Average lum. of bldg.  Thru pane."
& "87-10-20,  4:25:52" 349.565 0.585 "Avg lum of 8 stories"
 "yellowish" "180" "no" 0.62E-1 0.00 1.000 "Average lum. of bldg.  Thru pane."
& "87-10-20,  4:33:37" 349.680 -0.085 "2 of row of lights"
 "orange" "60" "no" 0.83E0 0.00 1.000 "Average lum. of 2 lamps."
& "87-10-20,  4:37:41" 349.680 -0.225 "Water reflection of previous"
 "orange" "60" "yes" 0.14E0 0.00 1.000 "Not a sharp image, right?"
& "87-10-20,  4:40:21" 349.515 -0.080 "2 lamps (street?)"
 "orange" "60" "no" 1.32E0 0.00 1.000 "Through window, avg lum 2 lights."
```

2.2.5. File GOVISL.003 10-21-87 4:45a. *This second night, we stopped looking through the window glass, but it was raining. This is also a poor way to take data, and these numbers should be considered as a separate group from those taken under clear conditions. The remainder of the nights---Wednesday, Thursday, and Friday---were fortunately clear. Note that the formula given for point source calibration is NOT CORRECT. It has the right form, but the wrong constant in front. See Section 4.4 for a discussion of point source measurements.*

```
&"Calibration:"
"Here:  High rise #877-room 516        There:  Battery Light                "
"Serial: 99998  Chr:  NA               Serial: 15     Chr:  Iso R 6s        "
"Loc:   40° 41!247 N    74°  1!493 W   Loc:   40° 42!017 N    74°  0!928 W  "
"Vector, Az:   29°  5!733 E of N, Alt: -  0° 40!878, Dist: 0.9 naut. mi."
& "87-10-20, 20:38:12" 16.070 3.620 "1 lt of horiz row atop bldg"
 "white" "6" "no" 18.00E-1 0.00 1.000
 "Pt source calib!  Illuminance = 0.00023 *(lum rdg) ; No window glass.  W of
Worl"
& "87-10-20, 20:44:22" 16.070 3.590 "1 lt of horiz row of 24, lower."
 "white" "6" "no" 3.20E0 0.00 1.000
 "Pt source calib!  Illuminance = 0.00023 *(lum rdg) ; No wndo gls; E side of
bldg"
& "87-10-20, 20:48:11" 15.825 3.640 "1 lt of horiz row, S side bldg."
 "white" "6" "no" 10.00E0 0.00 1.000 "Pt srce calib!; No wndo gls;"
& "87-10-20, 20:50:00" 15.825 3.640 "Same light, different ap"
 "white" "20" "no" 11.70E-1 0.00 1.000
 "Pt srce calib!; No wndo gls; illum = 0.00023 * rdg * (20/6)^2"
& "87-10-20, 20:56:32" 15.670 3.675 "Upper row, fcng S, 1 of 24"
 "white" "6" "no" 8.30E-1 0.00 1.000
 "Pt srce calib!; No wndo gls; illum = 0.00023 * rdg"
& "87-10-20, 20:58:57" 15.670 3.675 "Same lt, 1 of 24"
 "white" "20" "no" 1.16E-1 0.00 1.000
 "Pt srce calib!; No wndo gls; illum = 0.00023 * rdg * (20/6)^2"
& "87-10-20, 21:07:56" 16.415 2.450 "Brt isolated lt (wndo?)"
 "white" "2" "yes" 10.00E1 0.00 1.000 "Pt srce calib!; (incorrect appl.)"
& "87-10-20, 21:10:49" 16.415 2.450 "Brt isolated lt (wndo?)"
 "white" "6" "yes" 3.00E1 0.00 1.000
```

```
 "Pt srce calib!; light ALMOST fills aperture."
& "87-10-20, 21:12:23" 16.415 2.450 "Brt isolated lt (wndo?)"
 "white" "20" "no" 3.67E0 0.00 1.000
 "Pt  srce  calib!;  lt  DOES  NOT  fill  ap;  but  slight  add'l  lt  reflected  from
windows?"
& "87-10-20, 21:14:29" 16.415 2.450 "Brt isolated lt (wndo?)"
 "white" "60" "no" 3.90E-1 0.00 1.000
 "Pt srce calib!; lt DOES NOT fill ap; rdg now more stable over time."
&"Calibration:"
"Here:  High rise #877-room 516        There:  Battery Light                    "
"Serial: 99998  Chr:  NA               Serial: 15     Chr:  Iso R 6s            "
"Loc:   40° 41!247 N    74°  1!493 W   Loc:   40° 42!017 N    74°  0!928 W      "
"Vector, Az:   29°  5!733 E of N, Alt: -  0° 40!878, Dist: 0.9 naut. mi."
& "87-10-20, 21:59:59" 16.415 2.450 "Brt isolated lt"
 "white" "180" "no" 6.52E-2 0.00 1.000
 "Last of test series - stepping aperture."
& "87-10-20, 23:01:31" 14.960 2.830 "Window as pt src"
 "white" "20" "no" 8.45E-2 0.00 1.000
 "All windows on this bldg look yellowish;  tinted glass?"
& "87-10-20, 23:07:55" 14.955 2.505 "Another wndo as pt src"
 "white (yellowish" "20" "no" 12.83E-2 0.00 1.000
 "All windows on this bldg look yellowish and alike."
& "87-10-20, 23:14:28" 14.795 2.305 "A brighter wdo as pt src"
 "white (yellowish" "20" "no" 6.78E-1 0.00 1.000
 "All  windows  on  this  bldg  look  brighter.  Illum = rdg * .00023 * (20/6)^2 we
thin"
& "87-10-20, 23:19:10" 14.790 2.870 "2d wdo, same bldg"
 "white (yellowish" "20" "no" 9.80E-1 0.00 1.000
 "Still all data this evening taken with the pt src calibration."
& "87-10-20, 23:27:08" 14.715 -0.400 "Streetlight"
 "white (Hg?)" "60" "no" 12.45E-1 0.00 1.000
 "Still  all  data  this  evening  taken  with  the  pt  src  calibration.  Clearly  see
glob"
& "87-10-20, 23:32:07" 14.675 -0.325 "Streetlight"
 "white (Na?)" "20" "no" 6.69E1 0.00 1.000
 "Lt almost fills aprt.  Still pt source!"
& "87-10-20, 23:39:47" 20.645 -0.550 "Streetlight"
 "white (Na?)" "60" "no" 2.09E0 0.00 1.000
 "Well defined in telescope; 27 of these in a row in Battery Park."
& "87-10-20, 23:44:28" 21.620 -0.575 "Streetlight"
 "white (Na?)" "60" "no" 4.49E0 0.00 1.000 "Another of the 27."
& "87-10-20, 23:52:42" 16.280 -0.420 "Fluor lt in window"
 "white (greenish?" "20" "no" 9.11E-1 0.00 1.000
 "To the naked eye, this looks like it might be a green nav. aid!"
&"Calibration:"
"Here:  High rise #877-room 516        There:  East twin stack                  "
"Serial: 99998  Chr:  NA               Serial: 17     Chr:  Dark                "
"Loc:   40° 41!247 N    74°  1!493 W   Loc:   40° 42!857 N    74°  2!120 W      "
"Vector, Az:  343° 33!267 E of N, Alt:    0°  6!924, Dist: 1.7 naut. mi."
& "87-10-21,  0:42:04" 343.630 0.550 "Isolated lt nr E twin stack"
 "yellowish" "20" "no" 5.84E-1 0.00 1.000
 "Still pt src calib.  Altitude zeroed by spirit level just previously."
```

& "87-10-21, 0:58:53" 6.055 0.060 "Highway lt in haze"
"orange (Na?)" "20" "no" 2.65E-2 0.00 1.000
"Steady drizzle puts this light in haze. Apparently a highway up the Jersey shor"
& "87-10-21, 1:02:44" 5.630 0.055 "Brighter lt in same string"
"orange (Na?)" "60" "no" 3.61E-2 0.00 1.000
"Steady drizzle puts this light in haze. Apparently a highway up the Jersey shor"
& "87-10-21, 1:11:04" 0.450 0.405 "Bright lt in Jersey"
"white" "60" "no" 19.80E-1 0.00 1.000
"Shower is blowing away; still pt src calib."
& "87-10-21, 1:15:44" 358.030 0.010 "Lt on Jersey shore"
"green" "20" "no" 7.66E-1 0.00 1.000
"Shower is blowing away; still pt src calib."
& "87-10-21, 1:21:11" 357.395 0.000 "Lt on Jersey shore"
"greenish white" "20" "no" 17.96E-2 0.00 1.000 "Still not clear; pt src cal."
& "87-10-21, 1:30:38" 349.760 -0.045 "Na streetlight"
"orange (Na)" "20" "no" 2.34E0 0.00 1.000
"Still drizzling; pt src, no glass; same lt last nt thru glass."
& "87-10-21, 1:34:23" 349.680 -0.040 "Na streetlight"
"orange (Na)" "20" "no" 10.54E-1 0.00 1.000
"Still drizzling; pt src, no glass; same lt last nt thru glass."
& "87-10-21, 1:36:29" 349.570 -0.040 "Na streetlight"
"orange (Na)" "20" "no" 2.25E0 0.00 1.000 "Drizzle; another in a row."
& "87-10-21, 1:37:55" 349.535 -0.040 "Na streetlight"
"orange (Na)" "20" "no" 17.52E-1 0.00 1.000 "Drizzle; another in a row."
& "87-10-21, 1:39:46" 349.480 -0.040 "2 streetlts seen as 1"
"orange (Na)" "60" "no" 2.57E-1 0.00 1.000 "Lts overlap in this view."
& "87-10-21, 1:41:49" 349.395 -0.040 "3 streetlts as 1"
"orange (Na)" "60" "no" 4.63E-1 0.00 1.000 "Lts overlap in this view."
& "87-10-21, 1:43:39" 349.330 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 11.29E-1 0.00 1.000 "Still in row near water."
& "87-10-21, 1:46:22" 349.245 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 7.65E-1 0.00 1.000
"Still in row near water. Rain picking up. May quit for night."
& "87-10-21, 2:09:19" 349.175 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 3.32E0 0.00 1.000
"Still in row near water. Rain letting up; note time gap. Pt src cal."
& "87-10-21, 2:11:35" 349.125 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 2.79E0 0.00 1.000
"Still in row near water. Rain letting up."
& "87-10-21, 2:13:26" 349.090 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 3.89E0 0.00 1.000
"Still in row near water. Rain letting up."
& "87-10-21, 2:14:50" 349.100 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 3.89E0 0.00 1.000
"Still in row near water. Rain letting up."
& "87-10-21, 2:15:52" 349.075 -0.040 "2 streetlts as 1"
"orange (Na)" "20" "no" 10.37E0 0.00 1.000
"Still in row near water. Rain letting up."
& "87-10-21, 2:17:18" 349.045 -0.040 "1 streetlight"
"orange (Na)" "20" "no" 3.01E0 0.00 1.000

```
 "Still in row near water.  Rain letting up."
& "87-10-21,  2:18:47" 348.990 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 7.75E0 0.00 1.000
 "Still in row near water.  Rain letting up."
& "87-10-21,  2:20:32" 348.925 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 18.20E-1 0.00 1.000
 "Still in row near water.  Rain letting up."
& "87-10-21,  2:21:58" 348.920 -0.040 "1 streetlight"
 "orange (Na)" "6" "yes" 18.43E-1 0.00 1.000
 "Still in row near water.  Rain letting up."
& "87-10-21,  2:23:32" 348.875 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 2.94E0 0.00 1.000
 "Still in row near water.  Rain has nearly stopped."
& "87-10-21,  2:26:07" 348.825 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 8.00E-1 0.00 1.000
 "Still in row near water.  Rain getting heavier."
& "87-10-21,  2:32:58" 348.725 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 11.83E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:34:27" 348.665 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 2.70E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:35:52" 348.620 -0.035 "1 streetlight"
 "orange (Na)" "20" "no" 2.96E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:37:04" 348.500 -0.035 "1 streetlight"
 "orange (Na)" "20" "no" 12.22E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:38:23" 348.450 -0.035 "1 streetlight"
 "orange (Na)" "20" "no" 2.26E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:39:24" 348.400 -0.035 "1 streetlight"
 "orange (Na)" "20" "no" 2.27E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:41:07" 348.290 -0.035 "1 streetlight"
 "orange (Na)" "20" "no" 12.38E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:42:35" 348.250 -0.030 "1 streetlight"
 "orange (Na)" "20" "no" 2.37E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:43:50" 348.205 -0.030 "1 streetlight"
 "orange (Na)" "20" "no" 12.63E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:45:31" 348.085 -0.030 "1 streetlight"
 "orange (Na)" "20" "no" 11.15E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:47:07" 348.045 0.085 "1 streetlight"
 "orange (Na)" "20" "no" 16.62E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:48:33" 347.990 -0.030 "1 streetlight"
 "orange (Na)" "20" "no" 2.69E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
```

```
& "87-10-21,  2:50:18" 347.880 -0.030 "1 streetlight"
 "orange (Na)" "20" "no" 11.09E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:52:03" 347.765 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 11.94E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:53:13" 347.580 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 17.24E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:54:33" 347.480 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 2.08E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:58:04" 347.425 0.070 "1 streetlight"
 "orange (Na)" "20" "no" 7.01E-1 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  2:59:39" 347.385 -0.040 "1 streetlight"
 "orange (Na)" "20" "no" 2.34E0 0.00 1.000
 "Still in row near water.  Rain has let up again."
& "87-10-21,  3:01:49" 347.375 -0.070 "1 streetlight"
 "white (Hg?)" "20" "no" 4.22E0 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:03:50" 347.300 -0.040 "2 streetlts as 1"
 "orange (Na?)" "60" "no" 8.99E-1 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:05:58" 347.195 -0.040 "1 streetlight"
 "orange (Na?)" "20" "no" 6.08E0 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:07:26" 347.135 -0.040 "1 streetlight"
 "orange (Na?)" "20" "no" 6.25E0 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:08:30" 347.085 -0.040 "1 streetlight"
 "orange (Na?)" "20" "no" 3.57E0 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:09:32" 346.970 -0.040 "1 streetlight"
 "orange (Na?)" "20" "no" 12.15E-1 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:10:52" 346.890 -0.040 "1 streetlight"
 "orange (Na?)" "20" "no" 3.57E0 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:11:56" 346.900 0.085 "1 streetlight"
 "orange (Na?)" "20" "no" 11.09E-1 0.00 1.000 "Still near water.  Pt src!"
& "87-10-21,  3:13:43" 347.040 0.660 "bright lt on bldg"
 "orange (Na?)" "20" "no" 7.68E-1 0.00 1.000
 "Up away from the water now.  Little rain."
& "87-10-21,  3:17:22" 346.680 0.755 "window (?) in vert line of 8"
 "yellow (incand)" "6" "no" 3.94E0 0.00 1.000
 "Up away from the water now.  Little rain."
& "87-10-21,  3:20:56" 346.855 -0.015 "bldg light"
 "white (Hg)" "20" "no" 9.71E-1 0.00 1.000
 "Up away from the water now.  Little rain."
& "87-10-21,  3:22:49" 346.790 -0.020 "bldg light"
 "white (Hg)" "20" "no" 10.68E-1 0.00 1.000 ""
& "87-10-21,  3:24:42" 346.795 0.025 "bldg light"
 "white (Hg)" "20" "no" 2.65E0 0.00 1.000 "Same bldg."
& "87-10-21,  3:25:51" 346.675 0.025 "bldg light"
 "white (Hg)" "20" "no" 2.99E0 0.00 1.000 "Same bldg."
& "87-10-21,  3:26:55" 346.680 -0.025 "bldg light"
 "white (Hg)" "20" "no" 9.21E-1 0.00 1.000 "Same bldg."
& "87-10-21,  3:28:14" 346.575 0.020 "bldg light"
```

```
 "white (Hg)" "20" "no" 2.71E0 0.00 1.000 "Same bldg."
& "87-10-21,  3:29:40" 346.575 -0.025 "bldg light"
 "white (Hg)" "20" "no" 2.84E0 0.00 1.000 "Same bldg."
& "87-10-21,  3:31:28" 346.605 -0.010 "bldg light"
 "greenish wht (Hg" "20" "no" 11.44E-1 0.00 1.000 "Same bldg."
& "87-10-21,  3:34:34" 346.225 -0.045 "outdoor light"
 "greenish wht (Hg" "60" "no" 2.73E-1 0.00 1.000 ""
& "87-10-21,  3:38:28" 345.795 0.270 "outdoor light"
 "orange (Na)" "60" "no" 9.90E-1 0.00 1.000 ""
& "87-10-21,  3:43:37" 345.415 0.060 "outdoor light on bldg"
 "greenish wht (Hg" "20" "no" 2.14E-1 0.00 1.000 "one of several on bldg"
& "87-10-21,  3:46:18" 345.245 -0.055 "outdoor light on bldg"
 "orange (Na)" "20" "no" 3.66E0 0.00 1.000 "another of several"
& "87-10-21,  3:49:09" 345.060 -0.065 "outdoor light on bldg"
 "orange (Na)" "20" "no" 6.29E0 0.00 1.000 "another of several on bldg"
& "87-10-21,  3:50:47" 345.040 0.040 "outdoor light on bldg"
 "orange (Na)" "20" "no" 2.09E0 0.00 1.000 "another of several on bldg"
& "87-10-21,  3:53:21" 344.620 -0.040 "outdoor light on bldg"
 "orange (Na)" "20" "no" 3.23E0 0.00 1.000 "another of several on bldg"
& "87-10-21,  3:55:51" 344.560 -0.040 "outdoor light on bldg"
 "orange (Na)" "20" "no" 12.56E-1 0.00 1.000 "another of several on bldg"
& "87-10-21,  3:57:47" 344.435 0.010 "outdoor light on bldg"
 "greenish (Hg??)" "20" "no" 4.65E0 0.00 1.000 ""
& "87-10-21,  4:01:09" 344.440 0.625 "Neon clock line @ 6 o'clock"
 "orangish red (Ne" "20" "no" 8.40E-2 0.00 1.000
 "Clock has lines not numerals.  Pt src cal & msmt."
& "87-10-21,  4:04:28" 344.735 0.690 "letter 'ate' of Colgate billboar"
 "white" "60" "no" 7.46E-2 0.00 1.000 "Billboard has 1 word Colgate."
& "87-10-21,  4:09:46" 344.150 0.005 "outdoor light"
 "greenish (Hg?)" "20" "no" 3.65E-1 0.00 1.000 ""
& "87-10-21,  4:11:47" 343.540 0.035 "outdoor light"
 "greenish (Hg?)" "20" "no" 4.63E-1 0.00 1.000 ""
& "87-10-21,  4:13:46" 343.135 0.035 "outdoor light"
 "greenish (Hg?)" "20" "no" 18.90E-2 0.00 1.000 ""
& "87-10-21,  4:15:32" 342.675 0.065 "outdoor light"
 "greenish (Hg?)" "20" "no" 2.57E0 0.00 1.000 ""
& "87-10-21,  4:17:46" 342.395 0.065 "outdoor light"
 "greenish (Hg?)" "20" "no" 2.08E-1 0.00 1.000 ""
& "87-10-21,  4:20:37" 342.125 0.105 "outdoor light"
 "greenish (Hg?)" "20" "no" 18.51E-1 0.00 1.000 ""
& "87-10-21,  4:22:07" 341.765 0.070 "outdoor light"
 "greenish (Hg?)" "20" "no" 19.13E-2 0.00 1.000 ""
& "87-10-21,  4:23:09" 341.535 0.025 "outdoor light"
 "greenish (Hg?)" "20" "no" 15.00E-2 0.00 1.000 ""
& "87-10-21,  4:26:26" 340.825 0.135 "light on pole"
 "greenish (Hg?)" "20" "no" 2.32E-1 0.00 1.000 ""
& "87-10-21,  4:28:57" 340.775 0.090 "light on pole"
 "greenish (Hg?)" "20" "no" 14.46E-2 0.00 1.000 ""
& "87-10-21,  4:31:19" 340.355 0.010 "outdoor light"
 "orange (Na?" "20" "no" 2.26E-1 0.00 1.000 ""
& "87-10-21,  4:33:21" 340.320 0.115 "outdoor light"
 "greenish (Hg)" "20" "no" 2.27E-1 0.00 1.000 ""
```

```
& "87-10-21,  4:35:11" 340.235 0.145 "outdoor light"
 "greenish (Hg)" "20" "no" 6.44E-2 0.00 1.000 ""
& "87-10-21,  4:37:00" 340.125 0.120 "outdoor light"
 "greenish (Hg)" "20" "no" 12.43E-2 0.00 1.000 "Still pt src cal."
& "87-10-21,  4:38:22" 340.120 0.015 "outdoor light"
 "orange (Na)" "20" "no" 2.22E-1 0.00 1.000 "Still pt src cal."
& "87-10-21,  4:40:20" 338.715 0.115 "outdoor light"
 "greenish (Hg)" "20" "no" 1.11E-1 0.00 1.000 "Still pt src cal."
& "87-10-21,  4:42:28" 338.140 0.235 "backlighted clock as pt src"
 "white" "180" "no" 10.44E-2 0.00 1.000 "Still pt src cal."
```

2.2.6. File GOVISL.004 10-22-87 3:35a. *Avoiding the shots through the window pane means that we must aim our fat telescope through the narrow open windows of the apartment we're using; only a narrow sector of the horizon can be sighted from a given tripod position. To get started on this file, we had to use a trick method of calibration, as the comment lines note:*

```
*Calibration done by a secondary std based on last night's data when
*we were calib'd on the red light at the Battery.  See handwritten notes.
*1987 Oct 21, 19:59
& "87-10-21, 20:07:10" 11.730 -0.320 "6 Streetlights in a row as pt"
 "Whitish (Hg?)" "60" "no" 3.13E0 0.00 1.000
 "W side Manhattan along roadway near water."
& "87-10-21, 20:12:50" 11.640 -0.295 "10 streelts in a row as pt"
 "Whitish (Hg?)" "60" "no" 3.12E0 0.00 1.000
 "W side Manhattan along roadway near water.  Clear nt.  Pt src cal since start."
& "87-10-21, 20:18:45" 11.570 -0.280 "5 streetlts in a row as pt"
 "Whitish (Hg?)" "60" "no" 13.71E-1 0.00 1.000
 "W side Manhattan along roadway near water.  Clear nt.  Pt src cal since start."
& "87-10-21, 20:21:16" 11.480 -0.265 "5 streetlts in a row as pt"
 "Whitish (Hg?)" "60" "no" 11.57E-1 0.00 1.000
 "W side Manhattan along roadway near water.  Clear nt.  Pt src cal since start."
& "87-10-21, 20:23:24" 11.275 -0.255 "2 streetlts"
 "Orange (Na)" "60" "no" 5.45E-1 0.00 1.000 "Near water on Manhattan W side."
& "87-10-21, 20:27:17" 11.035 0.010 "1 streetlt on high pole"
 "Orange (Na)" "60" "no" 2.14E0 0.00 1.000 "Near water on Manhattan W side."
& "87-10-21, 20:30:54" 11.315 0.085 "Strip of fluorescents as pt"
 "White" "180" "no" 15.50E-2 0.00 1.000
 "Recall illum = 0.00023 * rdg * (180/6)^2."
& "87-10-21, 20:42:22" 10.070 -0.060 "Front ct of apt bldg as pt"
 "Orange & White" "60" "no" 9.42E-1 0.00 1.000
 "Recall illum = 0.00023 * rdg * (180/6)^2.  A sodium and a mercury."
& "87-10-21, 20:55:13" 9.365 0.035 "Streetlight, 1st in a row"
 "Orange (Na)" "20" "no" 11.00E-1 0.00 1.000 ""
& "87-10-21, 20:58:50" 9.275 0.025 "Streetlight, next in row"
 "Orange (Na)" "20" "no" 5.45E-1 0.00 1.000 ""
& "87-10-21, 21:00:15" 9.150 0.025 "Streetlight, next in row"
 "Orange (Na)" "20" "no" 8.06E-1 0.00 1.000 "Following roadway in Jersey."
& "87-10-21, 21:01:49" 9.180 0.110 "Streetlight, parallel road"
 "Greenish (Hg)" "20" "no" 1.87E-1 0.00 1.000 "Road in back of 'orange' road."
& "87-10-21, 21:04:00" 9.015 0.010 "Streetlight"
 "Orange (Na)" "20" "no" 4.65E-1 0.00 1.000 "Back on orange road."
```

```
& "87-10-21, 21:05:53" 8.960 0.130 "Streetlight"
 "Greenish (Hg)" "20" "no" 1.92E-1 0.00 1.000 ""
& "87-10-21, 21:07:30" 8.855 0.020 "Streetlight"
 "Orange (Na)" "20" "no" 4.45E-1 0.00 1.000 ""
& "87-10-21, 21:09:16" 8.685 0.020 "Streetlight"
 "Orange (Na)" "20" "no" 4.18E-1 0.00 1.000 ""
& "87-10-21, 21:12:23" 8.310 0.020 "Streetlight"
 "Orange (Na)" "20" "no" 5.13E-1 0.00 1.000 ""
& "87-10-21, 21:13:49" 8.110 0.020 "Streetlight"
 "Orange (Na)" "20" "no" 4.96E-1 0.00 1.000 ""
& "87-10-21, 21:15:07" 7.920 0.030 "Streetlight"
 "Orange (Na)" "20" "no" 5.63E-1 0.00 1.000 ""
& "87-10-21, 21:19:41" 7.710 0.030 "Streetlight"
 "Orange (Na)" "20" "no" 7.25E-1 0.00 1.000 ""
& "87-10-21, 21:21:14" 7.505 0.030 "Streetlight"
 "Orange (Na)" "20" "no" 5.30E-1 0.00 1.000 ""
& "87-10-21, 21:22:21" 7.380 0.165 "Streetlight"
 "Greenish (Hg)" "20" "no" 18.00E-1 0.00 1.000 ""
& "87-10-21, 21:25:08" 7.340 0.030 "Streetlight"
 "Orange (Na)" "20" "no" 6.60E-1 0.00 1.000 ""
& "87-10-21, 21:27:28" 7.230 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 9.00E-1 0.00 1.000 ""
& "87-10-21, 21:29:10" 7.115 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 6.08E-1 0.00 1.000 ""
& "87-10-21, 21:31:21" 6.990 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 7.44E-1 0.00 1.000 ""
& "87-10-21, 21:32:18" 6.860 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 6.02E-1 0.00 1.000 ""
& "87-10-21, 21:33:59" 6.765 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 7.55E-1 0.00 1.000 ""
& "87-10-21, 21:35:15" 6.680 0.025 "Streetlight"
 "Orange (Na)" "20" "no" 7.01E-1 0.00 1.000 ""
& "87-10-21, 21:36:35" 6.625 0.035 "Streetlight"
 "Orange (Na)" "20" "no" 5.28E-1 0.00 1.000 ""
& "87-10-21, 21:39:55" 6.510 0.010 "2 streetlights as pt"
 "Orange (Na)" "60" "no" 4.10E-1 0.00 1.000 ""
& "87-10-21, 21:42:51" 6.445 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 6.72E0 0.00 1.000 ""
& "87-10-21, 21:44:40" 6.365 0.025 "3 streetlights as pt"
 "Orange (Na)" "60" "no" 3.40E-1 0.00 1.000 ""
& "87-10-21, 21:46:42" 6.300 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 12.75E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:48:53" 6.225 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 8.09E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:50:01" 6.155 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 4.92E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:51:19" 6.085 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 6.35E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:53:06" 6.000 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 2.82E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:54:18" 5.925 0.025 "1 streetlight"
 "Orange (Na)" "20" "no" 4.25E-1 0.00 1.000 "Still Jersey shore of Hudson."
```

& "87-10-21, 21:56:02" 5.840 0.015 "1 streetlight"
"Orange (Na)" "20" "no" 13.25E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 21:57:02" 5.755 0.015 "1 streetlight"
"Orange (Na)" "20" "no" 8.87E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:00:30" 5.590 -0.005 "1 strtlt + another bright 1"
"Orange (Na)" "60" "no" 4.16E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:36:53" 5.515 0.035 "1 streetlight"
"Orange (Na)" "20" "no" 9.90E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:39:32" 5.420 0.035 "1 streetlight"
"Orange (Na)" "20" "no" 1.59E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:41:42" 5.235 0.040 "1 streetlight"
"Orange (Na)" "20" "no" 5.19E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:43:22" 5.145 0.040 "1 streetlight"
"Orange (Na)" "20" "no" 16.00E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:45:45" 5.050 0.040 "1 streetlight"
"Orange (Na)" "20" "no" 13.00E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:47:37" 4.965 0.040 "1 streetlight"
"Orange (Na)" "20" "no" 4.33E0 0.00 1.000
"Still Jersey shore of Hudson. Still clear out."
& "87-10-21, 22:49:43" 4.880 0.040 "2 streetlights as a pt"
"Orange (Na)" "60" "no" 8.50E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:51:36" 4.770 0.040 "2 streetlights as a pt"
"Orange (Na)" "60" "no" 11.65E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:53:29" 4.620 0.025 "2 streetlights as a pt"
"Orange (Na)" "60" "no" 13.60E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:55:07" 4.540 0.050 "1 streetlight"
"Orange (Na)" "20" "no" 11.24E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:57:21" 4.000 0.050 "1 streetlight"
"White (Hg)" "20" "no" 1.88E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 22:59:28" 3.845 0.040 "1 streetlight"
"White (Hg)" "20" "no" 3.82E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:01:18" 3.500 0.035 "1 streetlight"
"Orange (Na)" "20" "no" 9.25E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:07:20" 3.865 0.365 "2 streetlights"
"Orange + Greenis" "60" "no" 6.00E-1 0.00 1.000
"Still Jersey shore of Hudson."
& "87-10-21, 23:09:30" 3.985 0.340 "3 streetlights"
"Greenish (Hg)" "60" "no" 1.17E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:10:50" 4.195 0.345 "1 streetlight"
"Greenish (Hg)" "20" "no" 1.62E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:13:32" 4.400 0.360 "2 streetlights"
"Greenish (Hg)" "60" "no" 1.81E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:15:08" 4.495 0.360 "3 streetlights"
"Greenish (Hg)" "60" "no" 1.37E-1 0.00 1.000
"Still Jersey shore of Hudson. Still clear. Still pt src cal."
& "87-10-21, 23:17:29" 4.570 0.315 "3 streetlights"
"Greenish (Hg)" "60" "no" 1.51E-1 0.00 1.000
"Still Jersey shore of Hudson. Atmospheric fluctuations have dropped => steadier"
& "87-10-21, 23:19:49" 4.755 0.320 "1 streetlight"
"Greenish (Hg)" "20" "no" 2.61E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:22:38" 4.920 0.310 "cluster of streetlights"

```
 "White (Hg)" "60" "no" 5.21E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:27:58" 6.340 0.635 "marker lt atop bldg"
 "Red" "20" "no" 5.42E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:31:31" 6.380 0.635 "marker lt atop bldg"
 "Red" "20" "no" 5.59E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:33:06" 6.415 0.625 "marker lt atop bldg"
 "Red" "20" "no" 7.22E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:34:17" 6.445 0.625 "marker lt atop bldg"
 "Red" "20" "no" 7.22E-2 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:43:28" 1.860 0.045 "cluster of highway lights"
 "Orange (Na)" "60" "no" 2.99E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:47:26" 1.605 0.310 "cluster of highway lights"
 "Greenish (Hg)" "60" "no" 2.44E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:49:31" 1.450 0.260 "cluster 3 hway lts"
 "Greenish (Hg)" "60" "no" 2.69E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:50:55" 1.365 0.240 "cluster 3 hway lts"
 "Greenish (Hg)" "60" "no" 1.03E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:53:29" 1.365 0.115 "cluster 3 hway lts"
 "White (Hg)" "60" "no" 6.74E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:56:55" 1.165 0.195 "cluster 4-5 hway lts"
 "Orange (Na)" "60" "no" 13.82E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-21, 23:59:27" 1.025 0.035 "2 hway lts as pt"
 "Orange (Na)" "60" "no" 6.73E-1 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-22,  0:01:02" 0.875 0.045 "1 hway lt"
 "Orange (Na)" "20" "no" 2.22E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-22,  0:02:53" 0.710 0.065 "1 hway lt"
 "Orange (Na)" "20" "no" 1.44E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-22,  0:06:06" 0.375 0.065 "1 hway lt"
 "Orange (Na)" "20" "no" 1.36E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-22,  0:12:04" 0.400 0.375 "1 bright lt"
 "White (Na)" "60" "no" 3.52E0 0.00 1.000 "Still Jersey shore of Hudson."
& "87-10-22,  0:31:11" 0.190 0.385 "Neon sign etc. as pt"
 "Orangish Red" "60" "no" 3.18E-1 0.00 1.000
 "Eye does not resolve details well, though this looks slightly bigger than a pt."
& "87-10-22,  0:42:36" 359.615 0.185 "3 window lts, bldg"
 "Yellow" "60" "no" 12.38E-2 0.00 1.000 ""
& "87-10-22,  0:46:05" 359.265 0.235 "Lamp on bldg"
 "Greenish (Hg)" "20" "no" 2.24E0 0.00 1.000
 "Still Jersey, still clear, still pt src calibration."
& "87-10-22,  0:48:57" 358.735 0.450 "Lamp on bldg"
 "Greenish (Hg)" "20" "no" 6.93E-1 0.00 1.000 ""
& "87-10-22,  0:52:18" 358.370 0.460 "Lamp on bldg"
 "Greenish (Hg)" "20" "no" 5.13E-1 0.00 1.000 ""
& "87-10-22,  1:03:16" 358.370 0.460 "Lamp on bldg"
 "Greenish (Hg)" "20" "no" 5.75E-1 0.00 1.000 ""
& "87-10-22,  1:06:00" 358.455 0.180 "4 lights on bldg"
 "Orange (Na)" "60" "no" 6.68E-1 0.00 1.000 ""
& "87-10-22,  1:08:13" 358.280 0.170 "1 light on bldg"
 "Orange (Na)" "20" "no" 6.29E-1 0.00 1.000 ""
& "87-10-22,  1:09:47" 358.210 0.175 "1 light on bldg"
 "Orange (Na)" "20" "no" 16.56E-1 0.00 1.000 ""
& "87-10-22,  1:10:54" 358.155 0.185 "1 light on bldg"
```

```
"Orange (Na)" "20" "no" 14.80E-1 0.00 1.000 ""
& "87-10-22,  1:14:25" 357.980 -0.015 "1 light on post"
"Greenish (Hg)" "60" "no" 12.00E-1 0.00 1.000 "Compare to last night"
& "87-10-22,  1:23:17" 357.355 -0.025 "1 light on bldg"
"Greenish (Hg)" "20" "no" 15.68E-1 0.00 1.000
"Compare to last night?  1.568(clear) / .1796(rainy)"
& "87-10-22,  1:33:44" 349.895 -0.070 "Streetlight"
"Orange (Na)" "20" "no" 14.51E0 0.00 1.000
"Compare to last night:  14.51(clear) / 2.25(rainy)"
& "87-10-22,  1:51:23" 351.110 1.100 "Marker light on bldg"
"Red" "20" "no" 3.94E-1 0.00 1.000 "1 of 5"
& "87-10-22,  1:53:47" 350.870 1.100 "Marker light on bldg"
"Red" "20" "no" 4.08E-1 0.00 1.000 "1 of 5"
& "87-10-22,  1:54:55" 350.720 1.100 "Marker light on bldg"
"Red" "20" "no" 2.79E-1 0.00 1.000 "1 of 5"
& "87-10-22,  1:56:16" 350.540 1.085 "Marker light on bldg"
"Red" "20" "no" 3.10E-1 0.00 1.000 "1 of 5"
& "87-10-22,  1:57:08" 350.445 1.095 "Marker light on bldg"
"Red" "20" "no" 4.12E-1 0.00 1.000 "1 of 5"
& "87-10-22,  1:59:32" 351.180 0.775 "Marker light on bldg"
"Red" "20" "no" 1.57E-1 0.00 1.000 "1 of 4"
& "87-10-22,  2:01:05" 351.290 0.775 "Marker lights on bldg"
"Red" "20" "no" 3.42E-1 0.00 1.000
"2 of 4, only can be resolved through the telescope."
& "87-10-22,  2:03:13" 351.400 0.775 "Marker lights on bldg"
"Red" "20" "no" 2.14E-1 0.00 1.000 "1 of 4"
& "87-10-22,  2:27:28" 349.800 0.620 "Windows of bldg in Jersey"
"Yellowish" "180" "yes" 2.42E-1 0.00 1.000
"Now LUMINANCE calib.  Lum. = 10*(reading).  Mean over 5 stories of 16-storey bld"
& "87-10-22,  2:32:09" 350.445 0.465 "Windows of bldg in Jersey"
"Yellowish" "180" "yes" 1.96E-1 0.00 1.000
"Now LUMINANCE calib.  Lum. = 10*(reading).  Mean over 5 stories of different bld"
& "87-10-22,  2:40:47" 7.850 0.250 "Windows of bldg in Jersey"
"Yellowish" "60" "yes" 3.19E-1 0.00 1.000
"Now LUMINANCE calib.  Lum. = 10*(reading).  Mean over 22 stories."
& "87-10-22,  2:45:28" 8.435 0.260 "Windows of bldg in Jersey"
"Yellowish" "60" "yes" 7.02E-1 0.00 1.000
"Now LUMINANCE calib.  Lum. = 10*(reading).  Mean of 5 stories; new bldg."
& "87-10-22,  2:51:28" 15.165 2.670 "Windows in Manhattan"
"Yellowish" "180" "yes" 8.15E-2 0.00 1.000
"Now LUMINANCE calib.  A prominent bldg from here.  Avg over 3 stories."
& "87-10-22,  2:57:25" 4.880 1.225 "Sky in W over Jersey"
"Gray" "180" "yes" 1.00E-2 0.00 1.000 "Now LUMINANCE calib.  Just the sky."
```

2.2.7. File GOVISL.005 10-23-87 6:27a. *Now we move to a more south-looking apartment in High-rise #877. Height of eye at this location was taken to be 68 feet. Again, we don't have a documented aid to navigation to calibrate on. We calibrate for azimuth on the northwest tower of the Verrazano-Narrows Bridge, which is shown clearly on nautical charts, then calibrate for altitude on the* *roadway of the bridge, whose height can be estimated because the charts give the clearance __under__ the span.*

Later we calibrate on the Robbins Reef Light, a 30-watt bulb, 2.7 nautical miles toward Staten Island, that flashes one second in six. It took us over an hour of searching against the background of sodium vapor lights in New Jersey to spot this lighthouse so that we could calibrate on it. Of course, a mariner does not have so much time to spot each aid.

```
&"Calibration:"
"Here:  High rise #877-room 427        There:  NW light of VZ bridge          "
"Serial: 99997  Chr:  NA               Serial: 18     Chr:  Iso 2s            "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 36!255 N    74°  3!183 W    "
"Vector, Az:  194° 48!462 E of N, Alt:    0° 45!038, Dist: 5.1 naut. mi."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Cars below NW light VZ         "
"Serial: 99997  Chr:  NA               Serial: 19     Chr:  Going by          "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 36!255 N    74°  3!183 W    "
"Vector, Az:  194° 48!462 E of N, Alt:    0° 12!064, Dist: 5.1 naut. mi."
& "87-10-22, 21:48:21" 196.590 0.175 "Streetlight on VZ bridge"
 "Greenish (Hg?)" "20" "no" 6.66E-1 0.00 1.000
 "Pt src cal.; illum = 0.00023 * rdg * (20/6)^2 ; State Isl end of bridge"
& "87-10-22, 21:54:55" 196.290 0.235 "Light on cable of VZ"
 "Greenish (Hg?)" "20" "no" 14.40E-2 0.00 1.000
 "Just sample a few of these lights on the cable and then on the roadway."
& "87-10-22, 21:58:55" 195.945 0.405 "Light on cable of VZ"
 "Greenish (Hg?)" "20" "no" 7.00E-2 0.00 1.000 "Another sample."
& "87-10-22, 22:02:29" 196.040 0.210 "Light on rdway of VZ"
 "Greenish (Hg?)" "20" "no" 4.50E-1 0.00 1.000 "Another sample."
& "87-10-22, 22:05:15" 196.325 0.190 "Light on rdway of VZ"
 "Greenish (Hg?)" "20" "no" 4.94E-1 0.00 1.000 "Another sample."
& "87-10-22, 22:08:24" 197.820 0.110 "4 lts as pt, Stat Isl"
 "1 Or, 3 Greenish" "60" "no" 5.61E-2 0.00 1.000
 "Just something on Staten Island.  Pt src cal!"
& "87-10-22, 22:11:40" 198.400 0.005 "1 lt"
 "Orange (Na)" "20" "no" 18.00E-1 0.00 1.000
 "Just something on Staten Island.  Pt src cal!"
& "87-10-22, 22:14:51" 198.970 0.160 "14 lts as pt"
 "Orange (Na)" "180" "no" 4.21E0 0.00 1.000
 "Just something on Staten Island.  Pt src cal!"
& "87-10-22, 22:18:55" 199.215 0.165 "17 lts as pt"
 "Orange (Na)" "180" "no" 4.45E0 0.00 1.000 "All 17 sodium."
& "87-10-22, 22:23:12" 200.045 0.155 "15 lts as pt"
 "Orange (Na)" "180" "no" 3.77E0 0.00 1.000 "All 15 sodium."
& "87-10-22, 22:25:33" 200.645 0.155 "17 lts as pt"
 "Orange (Na)" "180" "no" 3.95E0 0.00 1.000 "All 17 sodium."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Cars below NW light VZ         "
"Serial: 99997  Chr:  NA               Serial: 19     Chr:  Going by          "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 36!255 N    74°  3!183 W    "
"Vector, Az:  194° 48!462 E of N, Alt:    0° 12!064, Dist: 5.1 naut. mi."
&"Calibration:"
```

```
"Here:  High rise #877-room 427        There:  Cars below NW light VZ          "
"Serial: 99997  Chr:  NA               Serial: 19      Chr:  Going by          "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 36!255 N    74°  3!183 W    "
"Vector, Az:  194° 48!462 E of N, Alt:    0° 12!064, Dist: 5.1 naut. mi."
& "87-10-22, 23:10:36" 198.145 -0.050 "Cluster of 12 as pt"
 "Org & greenish" "180" "no" 7.86E-2 0.00 1.000 "Pt src calib; Staten Island?"
& "87-10-22, 23:14:52" 198.065 -0.050 "Cluster of 3 as pt"
 "Greenish (Hg?)" "180" "no" 5.89E-2 0.00 1.000 "Pt src calib; Staten Island!"
& "87-10-22, 23:18:35" 198.350 -0.060 "Cluster of 6 as pt"
 "3 grnsh + 3 orng" "180" "no" 4.59E-2 0.00 1.000
 "Pt src calib; Staten Island!"
& "87-10-22, 23:20:43" 198.615 -0.265 "Cluster of 5 as pt"
 "orange" "180" "no" 5.83E-2 0.00 1.000 "Pt src calib; Staten Island!"
& "87-10-22, 23:24:32" 199.975 -0.075 "Cluster of 12 as pt"
 "2 Grnsh + 10 Org" "180" "no" 2.85E-1 0.00 1.000
 "Pt src calib; Staten Island!"
& "87-10-22, 23:28:42" 201.050 -0.010 "Cluster as pt"
 "1 red + Gr + Or" "180" "no" 1.44E-1 0.00 1.000 "Pt src calib; Staten Island!"
& "87-10-22, 23:34:15" 201.275 -0.020 "5 lights"
 "Greenish" "180" "no" 1.68E-1 0.00 1.000
 "Pt src calib; Staten Island.  Note that this stuff is some 5 miles away."
& "87-10-22, 23:38:37" 201.955 -0.030 "Cluster as pt"
 "White & Orange" "180" "no" 2.63E-1 0.00 1.000
 "Pt src calib; Staten Island.  Note that this stuff is some 5 miles away."
& "87-10-22, 23:42:44" 202.575 -0.055 "Cluster of 6 as pt"
 "Orange (Na)" "180" "no" 1.03E-1 0.00 1.000 "Pt src calib; Staten Island."
& "87-10-22, 23:47:11" 202.230 -0.215 "2 lamps"
 "1 Orang, 1 Grnsh" "60" "no" 1.66E-2 0.00 1.000 "Pt src calib; Staten Island."
& "87-10-22, 23:51:46" 202.695 -0.030 "2 lamps"
 "Orange (Na)" "60" "no" 3.12E0 0.00 1.000 "Pt src calib; Staten Island."
& "87-10-23,  0:07:14" 203.800 -0.030 "1 light"
 "Greenish (Hg)" "60" "no" 16.63E-1 0.00 1.000
 "Last of this series;  we're bumping the window frame."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Liberty's Torch                 "
"Serial: 99997  Chr:  NA               Serial: 2       Chr:  White?            "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 41!350 N    74°  2!700 W    "
"Vector, Az:  277° 57!988 E of N, Alt:    1° 17!807, Dist: 1.0 naut. mi."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light              "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s           "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W    "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light              "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s           "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W    "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
& "87-10-23,  2:53:40" 226.740 -0.080 "Robbins Reef Light"
 "White" "60" "no" 10.00E-1 6.00 0.083
 "Luminance is peak from oscilloscope.  Light is near a streetlight."
& "87-10-23,  3:11:53" 226.690 -0.015 "Streetlight"
```

```
 "Orange (Na)" "60" "no" 3.97E-1 0.00 1.000
 "Very near to Robbins Reef light;  makes it hard to see."
& "87-10-23,  3:18:38" 234.750 -0.185 "Cluster of 4"
 "Orange (Na)" "180" "no" 8.07E-1 0.00 1.000 "Pt src cal."
& "87-10-23,  3:20:59" 234.350 -0.185 "Cluster of 3"
 "Orange (Na)" "180" "no" 2.60E0 0.00 1.000 "Pt src cal.  Somewhere in Jersey."
& "87-10-23,  3:33:31" 231.755 -0.395 "Buoy"
 "Red" "60" "no" 14.00E-2 4.00 0.125
 "Luminance given is peak; it varies as buoy bobs."
& "87-10-23,  3:50:29" 230.980 -0.260 "Buoy"
 "Red" "60" "no" 4.00E-2 4.00 0.125
 "Luminance given is peak.  Apply pt src cal!"
& "87-10-23,  3:53:54" 230.260 -0.095 "2 streetlights"
 "Orange (Na)" "60" "no" 3.92E-1 0.00 1.000 ""
& "87-10-23,  3:56:39" 229.935 -0.070 "4 streetlights"
 "Orange (Na)" "180" "no" 9.50E-2 0.00 1.000 ""
& "87-10-23,  3:58:42" 229.050 -0.075 "3 streetlights as pt"
 "2 Or, 1 greenish" "180" "no" 5.78E-2 0.00 1.000 ""
& "87-10-23,  4:00:39" 228.065 -0.070 "4 streetlights as pt"
 "3 Or, 1 greenish" "180" "no" 3.13E-2 0.00 1.000 ""
& "87-10-23,  4:02:00" 227.335 -0.070 "4 streetlights as pt"
 "Orange (Na)" "180" "no" 10.02E-2 0.00 1.000 ""
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light             "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s           "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W    "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
& "87-10-23,  4:28:15" 226.990 -0.135 "1 streetlight"
 "Orange (Na)" "60" "no" 16.00E-1 0.00 1.000 ""
& "87-10-23,  4:30:48" 226.625 0.185 "7 streetlights as pt"
 "Greenish" "180" "no" 5.52E-2 0.00 1.000 ""
& "87-10-23,  4:32:37" 226.340 0.185 "Cluster of 10"
 "Greenish" "180" "no" 7.02E-2 0.00 1.000 ""
& "87-10-23,  4:35:03" 226.180 0.325 "Cluster of 3"
 "Orange" "180" "no" 2.43E-2 0.00 1.000 ""
& "87-10-23,  4:36:51" 225.935 -0.075 "Cluster of 3"
 "Orange" "180" "no" 8.53E-2 0.00 1.000 ""
& "87-10-23,  4:38:10" 225.890 0.115 "Cluster of 5"
 "Greenish" "180" "no" 4.73E-2 0.00 1.000 ""
& "87-10-23,  4:39:15" 225.690 -0.050 "2 lights"
 "Orange (Na)" "60" "no" 2.20E-1 0.00 1.000 ""
& "87-10-23,  4:40:27" 225.480 -0.005 "3 lights"
 "Orange (Na)" "60" "no" 7.18E-1 0.00 1.000 ""
& "87-10-23,  4:42:28" 225.540 0.125 "2 streetlights"
 "Greenish" "60" "no" 1.25E-1 0.00 1.000 ""
& "87-10-23,  4:44:38" 225.205 -0.060 "several lights"
 "Greenish + Orang" "180" "no" 7.02E-2 0.00 1.000 ""
& "87-10-23,  4:47:06" 224.855 -0.015 "6 lts on a pole"
 "Orange (Na)" "180" "no" 3.33E-1 0.00 1.000 ""
& "87-10-23,  4:51:40" 224.460 -0.030 "5 lts on a pole"
 "Orange (Na)" "180" "no" 7.40E-2 0.00 1.000 ""
& "87-10-23,  4:53:33" 224.300 0.245 "3 lights"
```

```
 "2 Or + 1 Gre" "180" "no" 2.67E-2 0.00 1.000 ""
& "87-10-23,  4:55:25" 224.150 -0.035 "1 light"
 "Orange" "60" "no" 5.04E-1 0.00 1.000 ""
& "87-10-23,  4:57:37" 223.910 0.185 "6 lts on bldg"
 "Orange" "180" "no" 2.13E-1 0.00 1.000 ""
& "87-10-23,  4:59:18" 223.800 -0.010 "2 lts"
 "Orange" "60" "no" 2.43E-1 0.00 1.000 ""
& "87-10-23,  5:02:29" 223.385 -0.035 "9 streetlights"
 "Orange" "180" "no" 15.63E-2 0.00 1.000 ""
& "87-10-23,  5:04:21" 223.075 -0.055 "5 streetlights"
 "Orange" "180" "no" 13.34E-2 0.00 1.000 ""
& "87-10-23,  5:07:08" 222.515 -0.020 "9 streetlights"
 "Orange" "180" "no" 2.18E-1 0.00 1.000 ""
& "87-10-23,  5:09:47" 222.285 -0.060 "8 streetlights"
 "4 Orang, 4 grnsh" "180" "no" 8.67E-2 0.00 1.000 ""
& "87-10-23,  5:11:40" 222.080 -0.060 "2 streetlights"
 "2 Greenish (Hg" "60" "no" 11.66E-1 0.00 1.000 ""
& "87-10-23,  5:16:28" 221.715 0.020 "7 streetlights"
 "4 Oran, 3 grnsh" "180" "no" 9.15E-2 0.00 1.000 ""
& "87-10-23,  5:18:23" 221.420 0.020 "12 streetlights"
 "Orange (Na)" "180" "no" 2.65E-1 0.00 1.000 ""
& "87-10-23,  5:20:41" 221.050 0.020 "11 lights"
 "10 Ora + 1 red" "180" "no" 1.26E-1 0.00 1.000 ""
& "87-10-23,  5:23:50" 220.970 0.300 "Sign clock, Chemica Bank"
 "White + red" "180" "no" 3.47E0 0.00 1.000 ""
& "87-10-23,  5:27:48" 220.795 -0.160 "6 lights"
 "yellowish (inc?)" "60" "no" 4.14E-1 0.00 1.000 ""
& "87-10-23,  5:30:17" 220.655 0.000 "7 lights"
 "orange (Na)" "180" "no" 10.30E-2 0.00 1.000 ""
& "87-10-23,  5:31:47" 220.100 0.000 "6 lights"
 "orange (Na)" "180" "no" 5.52E-2 0.00 1.000 ""
& "87-10-23,  5:33:59" 219.935 0.035 "6 lights"
 "orange (Na)" "180" "no" 5.50E-2 0.00 1.000 ""
& "87-10-23,  5:35:59" 219.315 -0.120 "1 light"
 "Greenish (Hg?)" "60" "no" 5.73E-1 0.00 1.000 ""
& "87-10-23,  5:40:02" 218.575 -0.050 "1 light"
 "Orange (Na)" "60" "no" 13.00E-1 0.00 1.000
 "This whole night has been clear."

&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light            "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s          "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W   "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
& "87-10-23,  6:12:28" 217.795 -0.160 "3 lts"
 "Orange (Na)" "180" "no" 5.13E-2 0.00 1.000 ""
& "87-10-23,  6:14:40" 216.635 -0.160 "5 lts"
 "Greenish (Hg)" "180" "no" 2.09E-1 0.00 1.000 ""
& "87-10-23,  6:17:50" 216.350 -0.170 "5 lts"
 "Greenish (Hg)" "180" "no" 6.82E-2 0.00 1.000 ""
& "87-10-23,  6:19:29" 215.990 -0.170 "5 lts"
 "Greenish (Hg)" "180" "no" 8.35E-2 0.00 1.000 ""
```

& "87-10-23, 6:21:26" 215.720 -0.155 "8 lts"
"4 Or, 4 Gr" "180" "no" 12.30E-2 0.00 1.000 ""
& "87-10-23, 6:23:19" 215.430 -0.130 "5 lts"
"4 Or, 1 Gr" "180" "no" 5.07E-2 0.00 1.000 ""
& "87-10-23, 6:25:14" 215.495 0.480 "1 lt"
"Greenish" "60" "no" 13.50E-2 0.00 1.000 "resume here; clear night."

2.2.8. File GOVISL.006 10-24-87 12:57a. *Just a short night of actual measurements, and then some calibrations related to picture taking. When you know exactly where to look, it's not so hard to spot the Robbins Reef Light.*

&"Calibration:"
"Here: High rise #877-room 427 There: Robbins Reef Light "
"Serial: 99997 Chr: NA Serial: 32275 Chr: Fl W 6s "
"Loc: 40° 41!218 N 74° 1!455 W Loc: 40° 39!400 N 74° 4!000 W "
"Vector, Az: 226° 43!766 E of N, Alt: - 0° 3!959, Dist: 2.7 naut. mi."
& "87-10-23, 20:11:02" 215.170 -0.080 "2 streetlights?"
"Orange (Na)" "180" "no" 1.38E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:17:34" 214.155 -0.080 "4 streetlights"
"Orange (Na)" "180" "no" 2.08E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:19:35" 213.645 -0.080 "10 streetlights"
"Orange (Na)" "180" "no" 8.42E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:23:56" 213.400 -0.050 "11 streetlights"
"Orange (Na)" "180" "no" 9.49E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:25:40" 212.980 -0.050 "4 streetlights"
"3 Orang, 1 Grnsh" "180" "no" 6.29E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:29:12" 212.655 -0.050 "4 streetlights"
"4 Orange (Na)" "60" "no" 17.42E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:31:32" 212.425 -0.100 "2 streetlights"
"Orange (Na)" "60" "no" 12.72E-2 0.00 1.000 "Pt src calib"
& "87-10-23, 20:39:35" 212.275 -0.210 "buoy 24 or 26"
"red" "60" "no" 4.00E-2 4.00 0.125
"Pt src calib; lum is peak from oscilloscope; there is a strip chart for this one"
& "87-10-23, 20:54:40" 212.060 -0.030 "9 streetlights"
"Orange (Na)" "180" "no" 1.69E-2 0.00 1.000 ""

& "87-10-23, 21:04:27" 211.705 -0.030 "3 lights on ship"
"Greenish (Hg)" "180" "no" 6.00E-2 0.00 1.000 "Ship was stopped."
& "87-10-23, 21:11:19" 211.210 0.300 "1 light on bldg"
"Greenish Wht" "60" "no" 18.00E-2 0.00 1.000 "Pt src cal."
& "87-10-23, 21:14:38" 210.410 -0.005 "3 streetlights"
"Orange (Na)" "180" "no" 3.37E-2 0.00 1.000 "Pt src cal."
& "87-10-23, 21:18:35" 209.865 -0.050 "4 streetlights"
"3 Orng, 1 Whitis" "180" "no" 5.73E-2 0.00 1.000 "Pt src cal."
& "87-10-23, 21:21:29" 209.005 -0.030 "14 streetlights"
"13 or, 1 wht" "180" "no" 6.60E-2 0.00 1.000 "Pt src cal."
& "87-10-23, 21:25:31" 208.715 -0.030 "22 lights"
"Orange (Na)" "180" "no" 14.99E-2 0.00 1.000
"Pt src cal; looks like these lights may be on a ship."
& "87-10-23, 21:31:01" 208.425 -0.040 "13 lights"
"Orange (Na)" "180" "no" 2.66E-1 0.00 1.000

```
 "Pt src cal; these seem to be on the same ship."
& "87-10-23, 21:34:50" 207.840 -0.010 "14 lights"
 "8 grnsh, 6 or" "180" "no" 15.77E-2 0.00 1.000
 "Pt src cal; can't tell if these are on land, or on another ship."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light          "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s        "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W  "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light          "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s        "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W  "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
& "87-10-23, 22:17:56" 202.850 -0.005 "1 light"
 "Greenish wht" "60" "no" 14.20E-1 0.00 1.000 "Pretty sure it's a mercury."
& "87-10-23, 22:21:09" 203.100 -0.020 "19 lights"
 "Orange (Na)" "180" "no" 12.00E-2 0.00 1.000
 "Pretty sure these are on a ship."
& "87-10-23, 22:23:31" 203.350 -0.035 "6 lights"
 "Orange (Na)" "180" "no" 7.44E-2 0.00 1.000
 "Pretty sure these are on the same ship."
& "87-10-23, 22:25:32" 203.230 0.055 "1 light"
 "Orange (Na)" "60" "no" 5.00E-1 0.00 1.000 "Still seems to be the same ship."
& "87-10-23, 22:33:11" 205.385 -0.030 "1 light"
 "Orange (Na)" "60" "no" 6.54E0 0.00 1.000 "On land."
& "87-10-23, 22:35:04" 206.045 -0.030 "4 streetlights"
 "Orange (Na)" "180" "no" 3.48E-1 0.00 1.000 "On land; pt src cal."
& "87-10-23, 22:37:00" 206.365 -0.030 "6 streetlights"
 "Orange (Na)" "180" "no" 1.36E-1 0.00 1.000 "On land; pt src cal."
& "87-10-23, 22:41:59" 206.610 0.105 "1 streetlight"
 "Greenish Wht" "60" "no" 7.39E-1 0.00 1.000 "Possibly on a ship."

& "87-10-23, 22:47:20" 207.850 -0.080 "12 lights"
 "5 Na + 7 Wht" "180" "no" 15.20E-2 0.00 1.000
 "Black background (a ship in the night?)"
& "87-10-23, 22:50:46" 208.625 -0.040 "24 lights"
 "Orange (Na)" "180" "no" 12.30E-2 0.00 1.000 "Probably on a ship."
& "87-10-23, 22:54:33" 209.905 -0.105 "4 lights"
 "3 Orange 1 whtsh" "180" "no" 4.44E-2 0.00 1.000
 "A dup with 87-10-23, 21:18:35; az was 209.865."
&"Calibration:"
"Here:  High rise #877-room 427        There:  NW light of VZ bridge       "
"Serial: 99997  Chr:  NA               Serial: 18     Chr:  Iso 2s         "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 36!255 N    74°  3!183 W  "
"Vector, Az:  194° 48!462 E of N, Alt:    0° 45!038, Dist: 5.1 naut. mi."
&"Calibration:"
"Here:  High rise #877-room 427        There:  Robbins Reef Light          "
"Serial: 99997  Chr:  NA               Serial: 32275  Chr:  Fl W 6s        "
"Loc:   40° 41!218 N    74°  1!455 W   Loc:   40° 39!400 N    74°  4!000 W  "
"Vector, Az:  226° 43!766 E of N, Alt: -  0°  3!959, Dist: 2.7 naut. mi."
&"Calibration:"
```

Chapter 3. Analysis of Data

3.1. Sandy Hook. 40° 28'.1 N, 73° 59'.9 W, height 12 ft. The observation point is on "North Beach" in the National Park area, along the path to the beach, next to the snow fence enclosing the bird sanctuary. All data were taken on the night of 1987 October 28. From this point, Romer Shoal light appears to bisect the span between the towers of the Verrazano bridge. The height of the sand at this point, and the latitude and longitude, were determined on an earlier date (1987 September 24) by observations with a rented surveyor's level and rod. Since the heights of the aids in the Light List[3] are given as height above mean high water, the height of this point was determined with the level and rod as height above the high water mark on the beach. Latitude and longitude were determined by sighting visible landmarks such as Romer Light, the Verrazano Bridge, and the standpipe on Sandy Hook, whose position can be found on the nautical chart. The latitude and longitude here may be less accurate than those for Governor's Island, while the height may be more accurate. Certainly latitude and longitude are within traditional navigational accuracy of 0'.1.

Various graphical analyses of the data were produced with a spreadsheet program. This program operates in such a way that the number associated with a histogram bin is the *upper* limit of the bin. The graphs appear in this chapter, some without comment in the text.

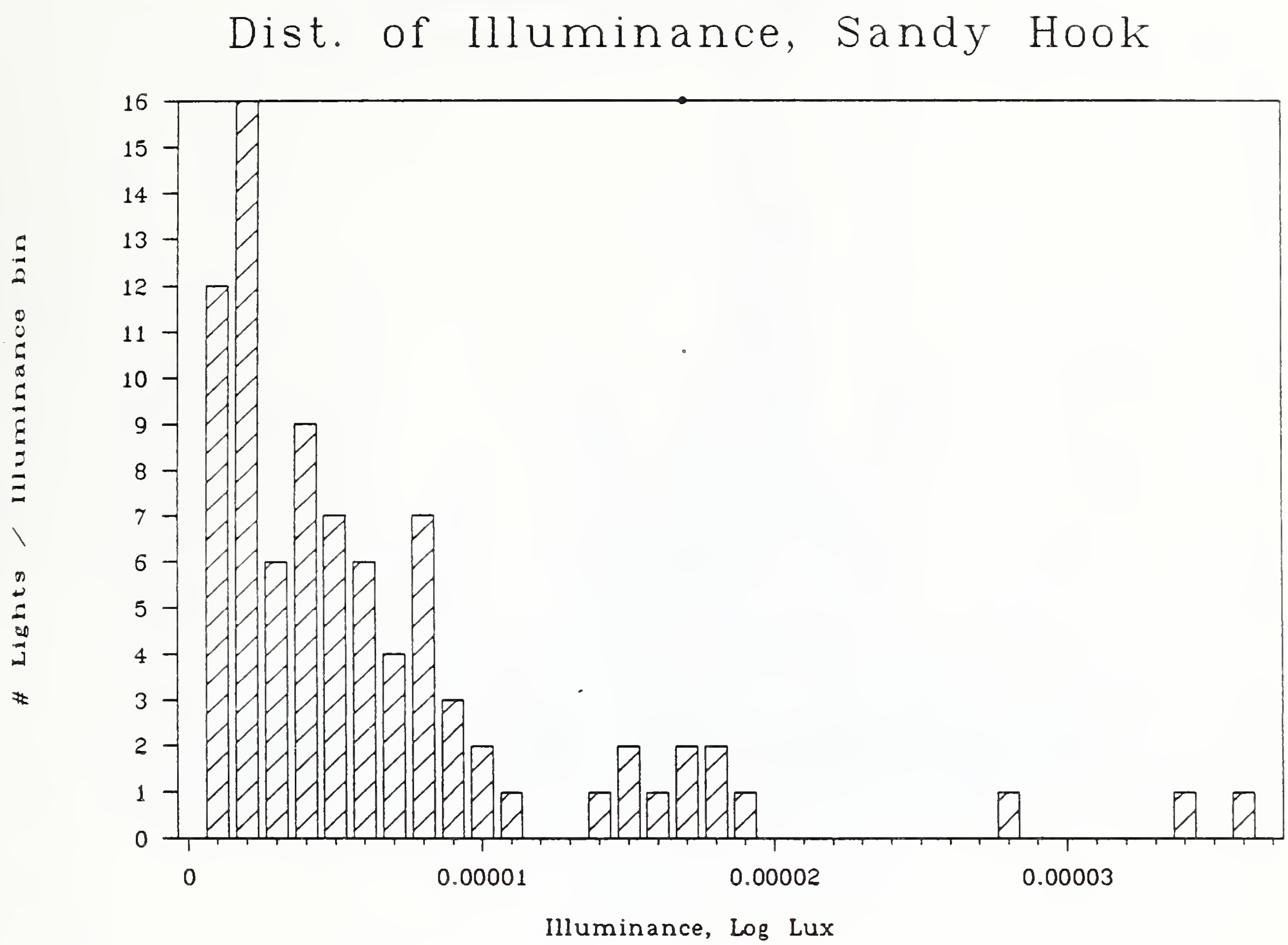

Figure 3.1. The distribution of illuminances at the observation point, due to lights seen across the water, Sandy Hook.

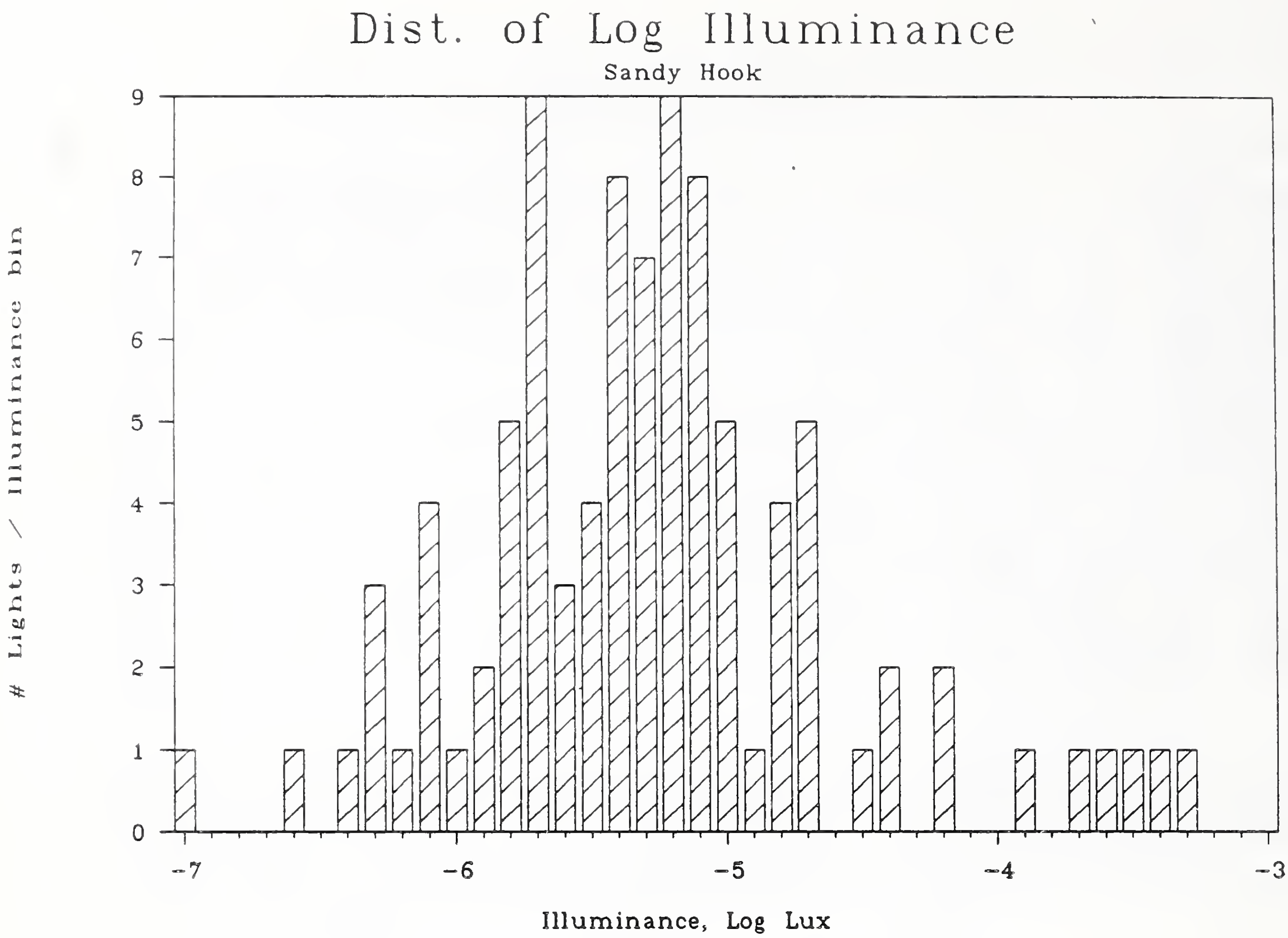

Figure 3.2. The distribution of $\log_{10}$(illuminance) at the observation point, Sandy Hook. This is a more revealing plot of about the same information as given in Fig. 3.1.

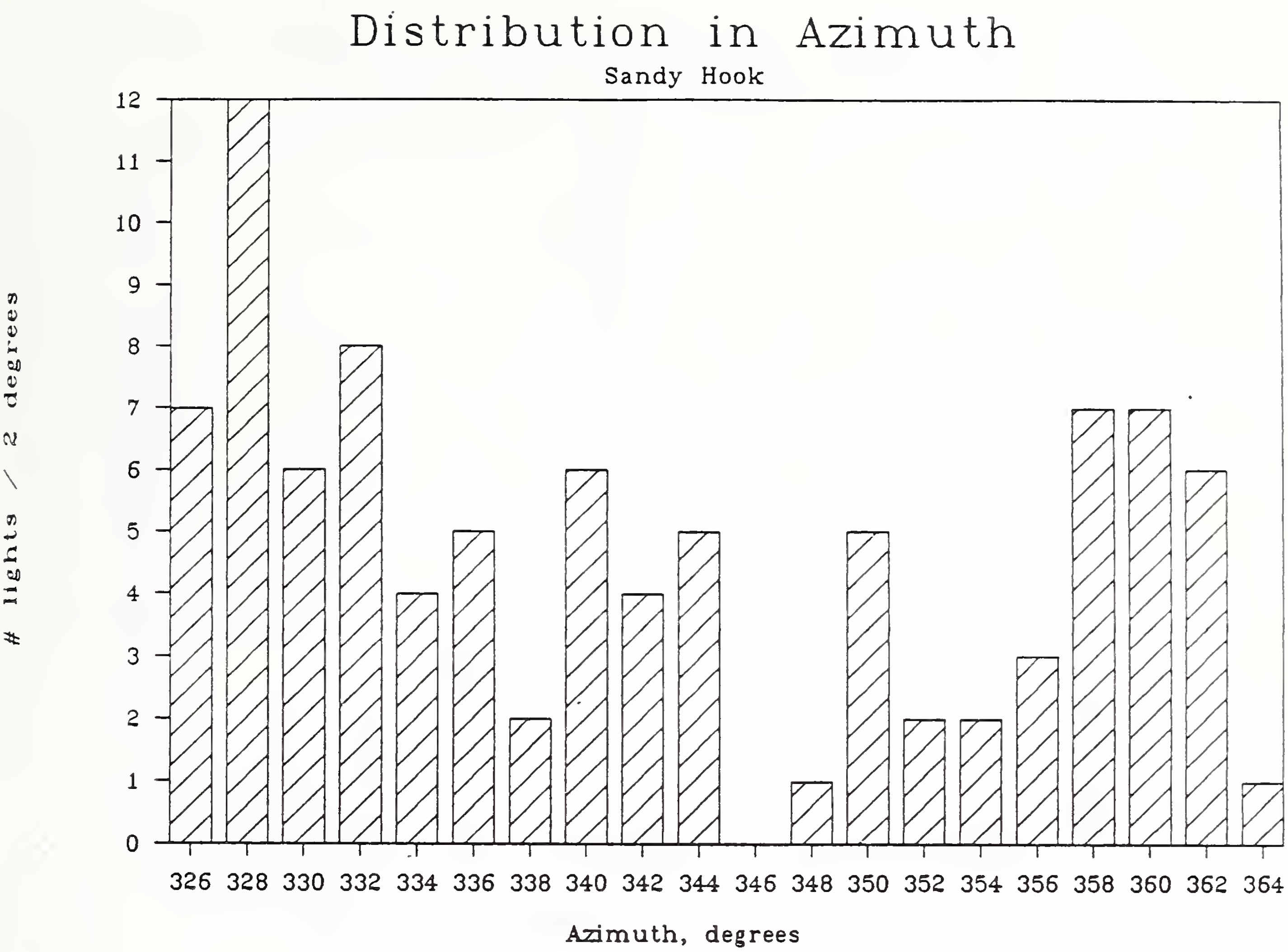

Figure 3.3. The distribution in azimuth of the lights seen from the Sandy Hook observation point. Note that the limits of azimuth shown here define the limits of the observations made.

Measurements were made over a limited range in azimuth, based on the plan negotiated with the Coast Guard contract monitor, Dr. Mandler. At Sandy Hook, the forty degree azimuth range is intended to span directions along the likely courses of ships coming in off the open Atlantic. Azimuths immediately to the east of north have been represented as angles greater than 360°, which is about the only way to handle this graph in the spreadsheet program.

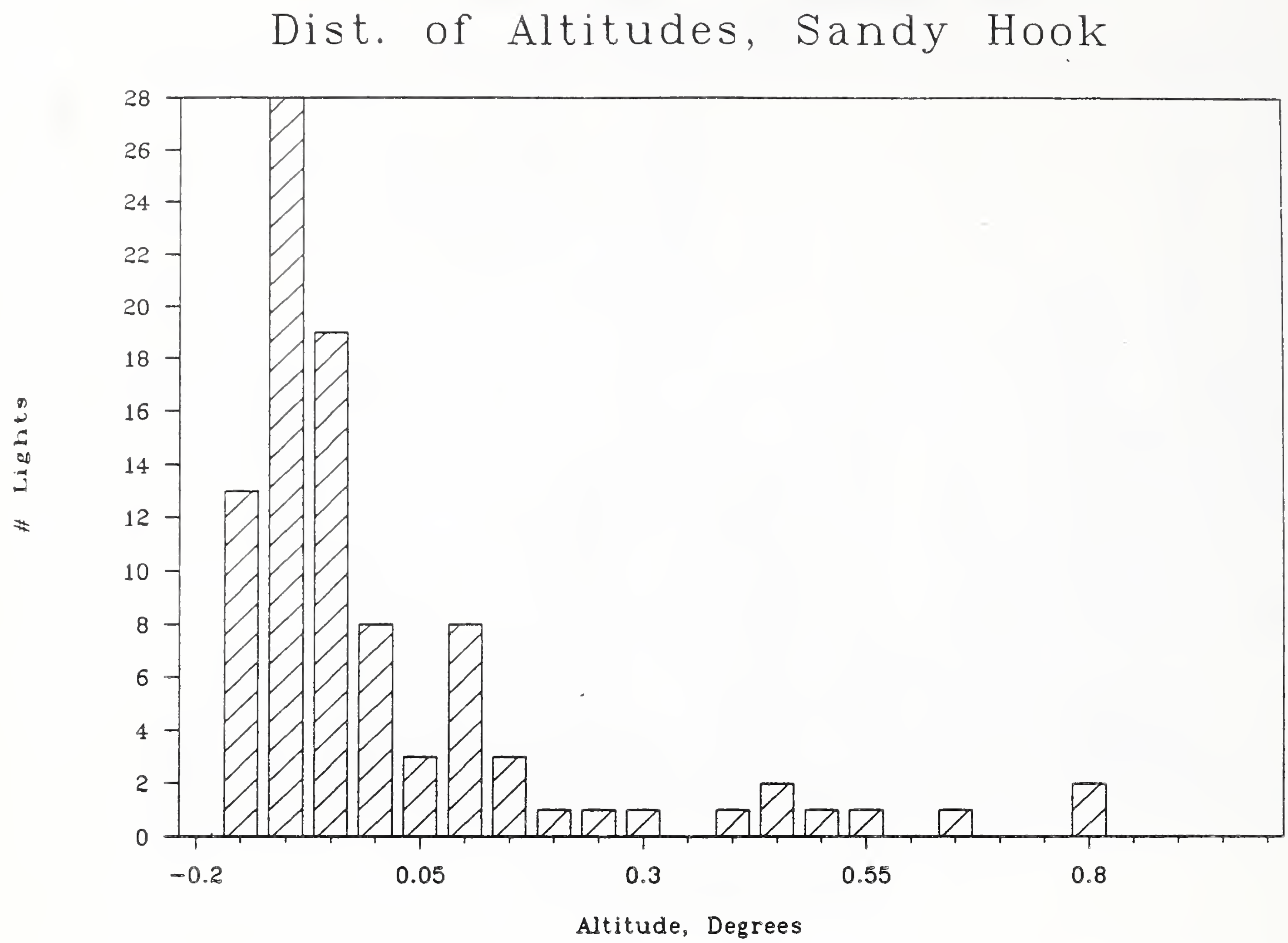

Figure 3.4. The distribution in altitude of the lights seen from Sandy Hook. This distribution is about what one would expect, with most lights near the horizontal.

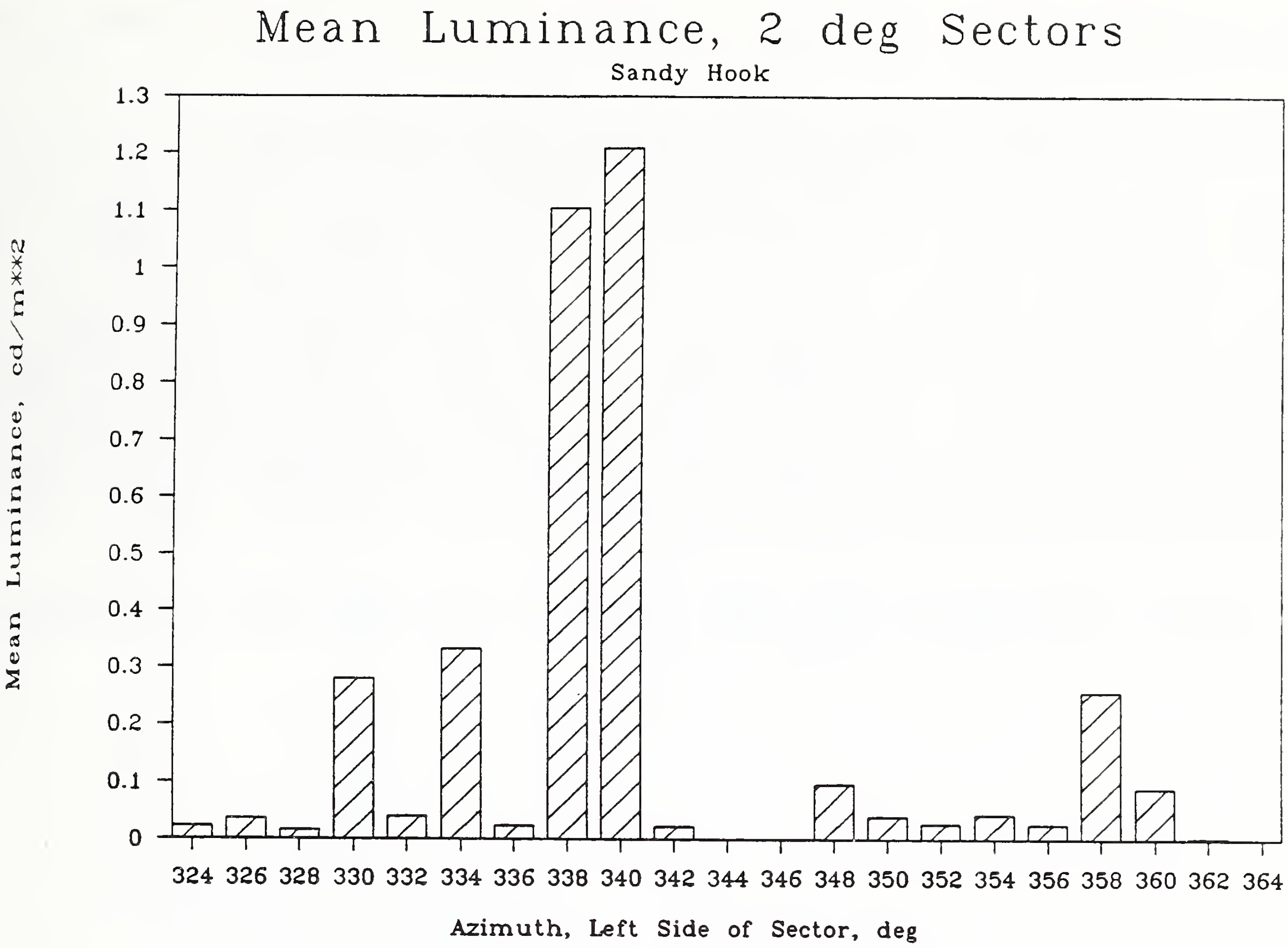

Figure 3.5. Mean luminance in rectangular areas near the horizon and 2° wide × 1° high, Sandy Hook. In this case, the rectangular areas extend in altitude from -0.2° to +0.8°. No lights were measured outside this range. When similar graphs are given below for the Governor's Island data, the vertical extent will be slightly different, and some lights will actually be excluded by the 1° vertical limitation. (Cf. Fig. 3.4.) For the method of calculation used to derive this figure, see section 4.5.

3.2. **Governor's Island, North Sector, 40° 41'.247 N 74° 1'.493 W,** height 77 ft. Governor's Island is entirely occupied by a Coast Guard base. After a few hours' search for a suitable observation point, on the afternoon of 1987 October 19, we settled on two temporarily vacant apartments in Building 877, a high-rise for family housing. Chart 12335** shows this structure as a rough T-shape, near the northwest-facing seawall, toward the southwest end of the island. Latitude and longitude of the two rooms were determined from the chart. One room was used to measure a "north sector," looking up the Hudson

---

**Nautical charts are available from Distribution Branch (N/CG33), National Ocean Service, Riverdale, Maryland 20737-1199; Ph: 301-436-6990.

River, while the other was used to measure a "south sector," looking down toward Staten Island.

Even the widest flat picture window would permit the photometer to scan only 180° of the horizon. Taking data from these apartments was made difficult by the fact that the sashes that could be opened were only two or three feet between aluminum posts; were bounded by the brick wall on one side or the other; and were near to a heater that interfered to some extent with positioning of the tripod. It was necessary to bring the tripod feet together, and to reposition the tripod repeatedly. Repositioning the tripod meant re-doing the calibration in altitude and azimuth, based on some landmark visible from the new position. This in turn meant identifying a suitable landmark. One finds, for instance, that the chart gives a latitude and longitude for the Statue of Liberty's torch, or for certain stacks in New Jersey, but no height. The compensating advantage of being indoors was that we could lock the doors and leave the equipment assembled during the day.

North sector measurements were taken primarily from High Rise 877, room 516, 40° 41!247 N, 74° 1!493 W, height 77 feet.

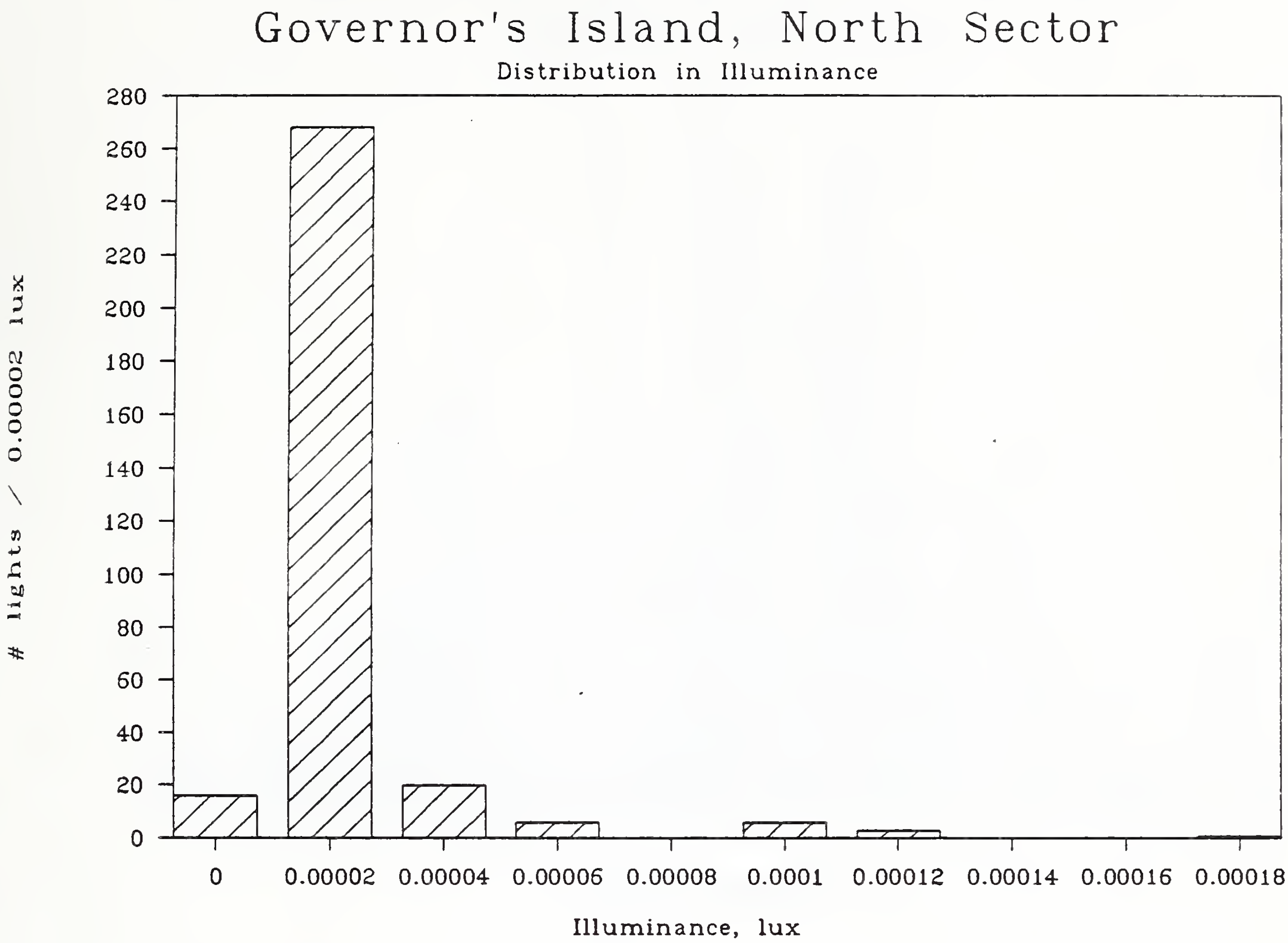

Figure 3.6. Distribution in illuminance of all lights in the Governor's Island "north sector."

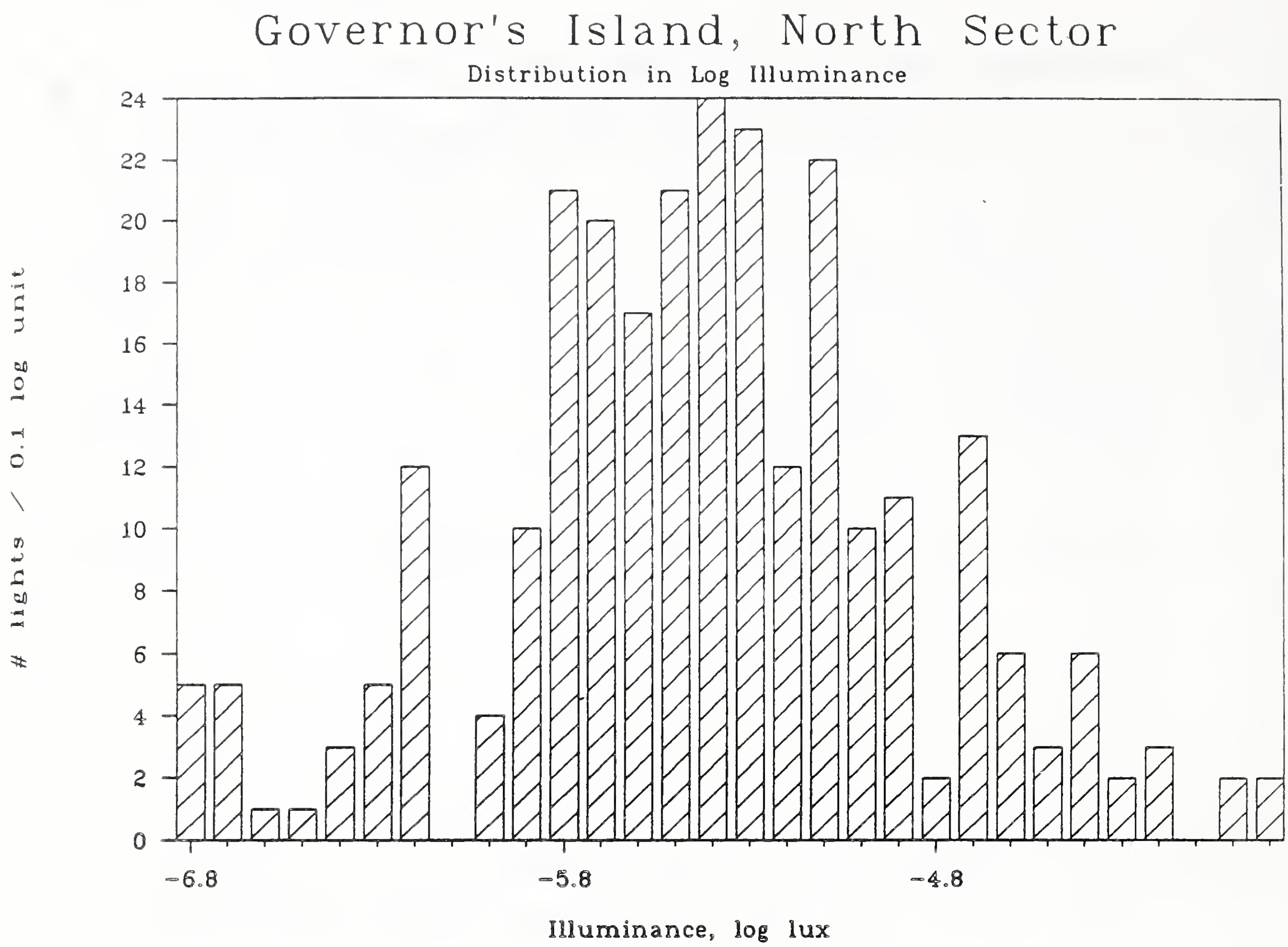

Figure 3.7. Distribution in log_{10}(illuminance) of all lights in the Governor's Island "north sector."

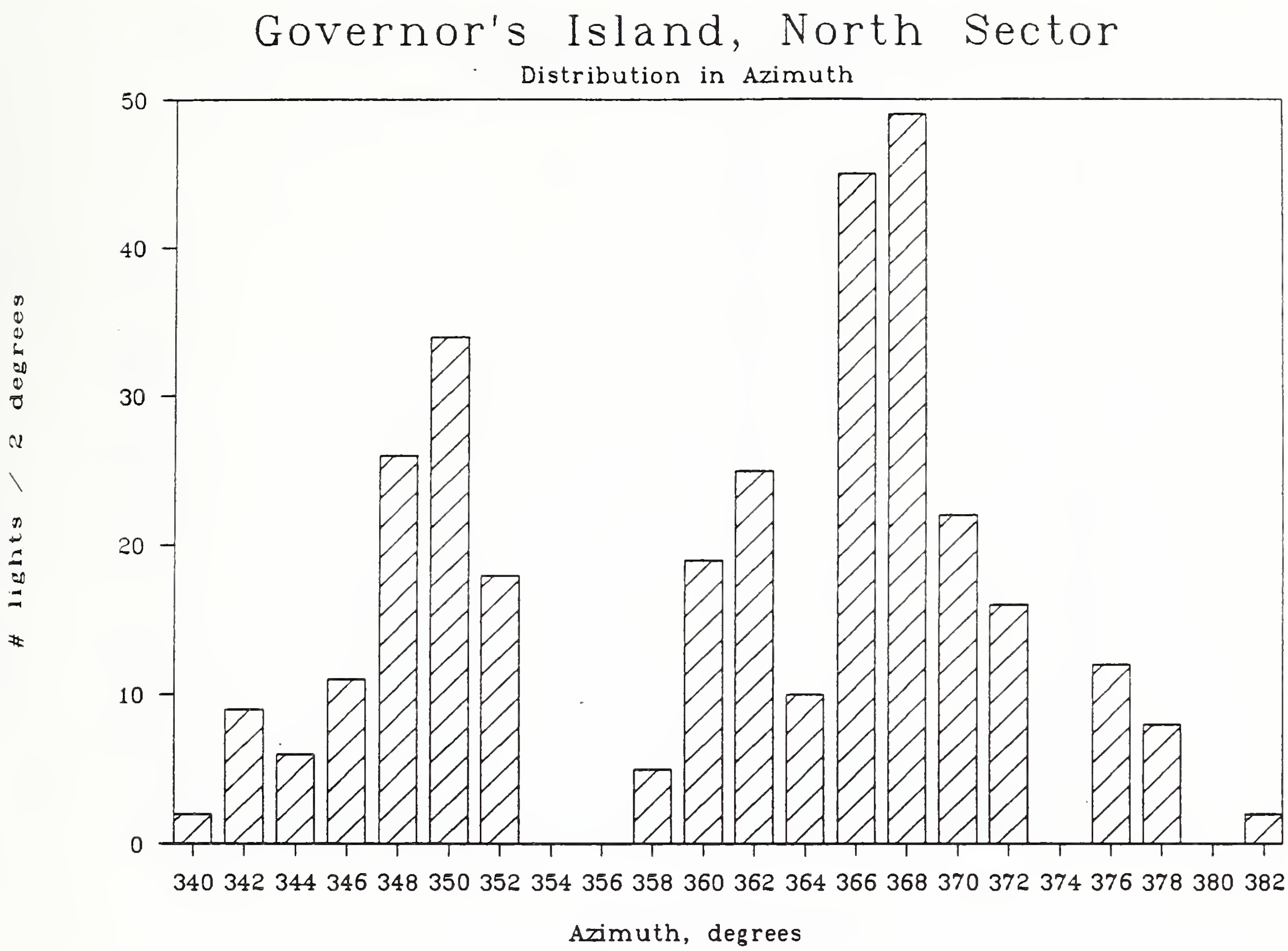

Figure 3.8. Distribution in azimuth of lights in the Governor's Island "north sector."

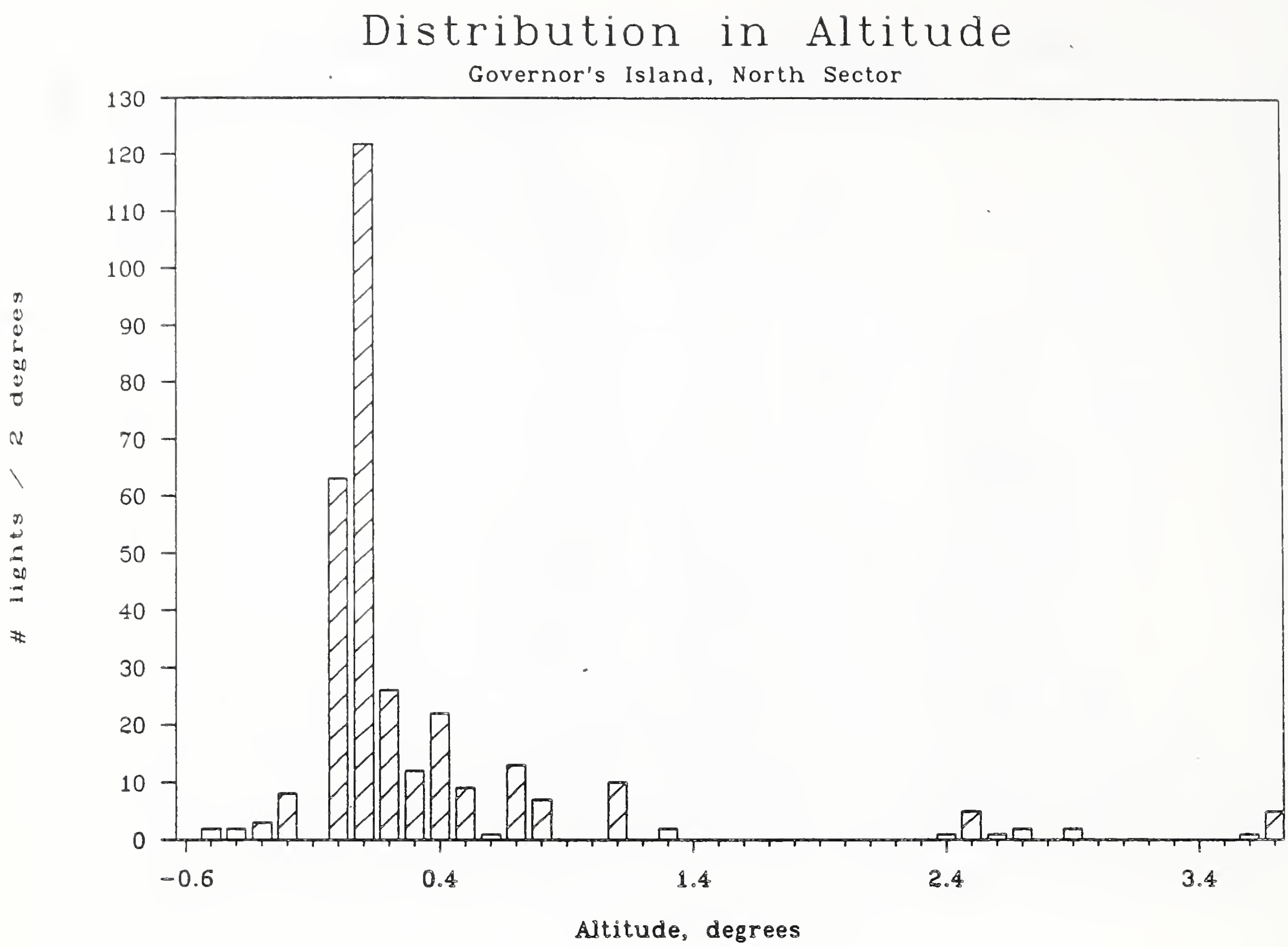

Figure 3.9. Distribution in altitude of all lights in the Governor's Island "north sector." The range is greater than at Sandy Hook because we are closer to some of the lights here.

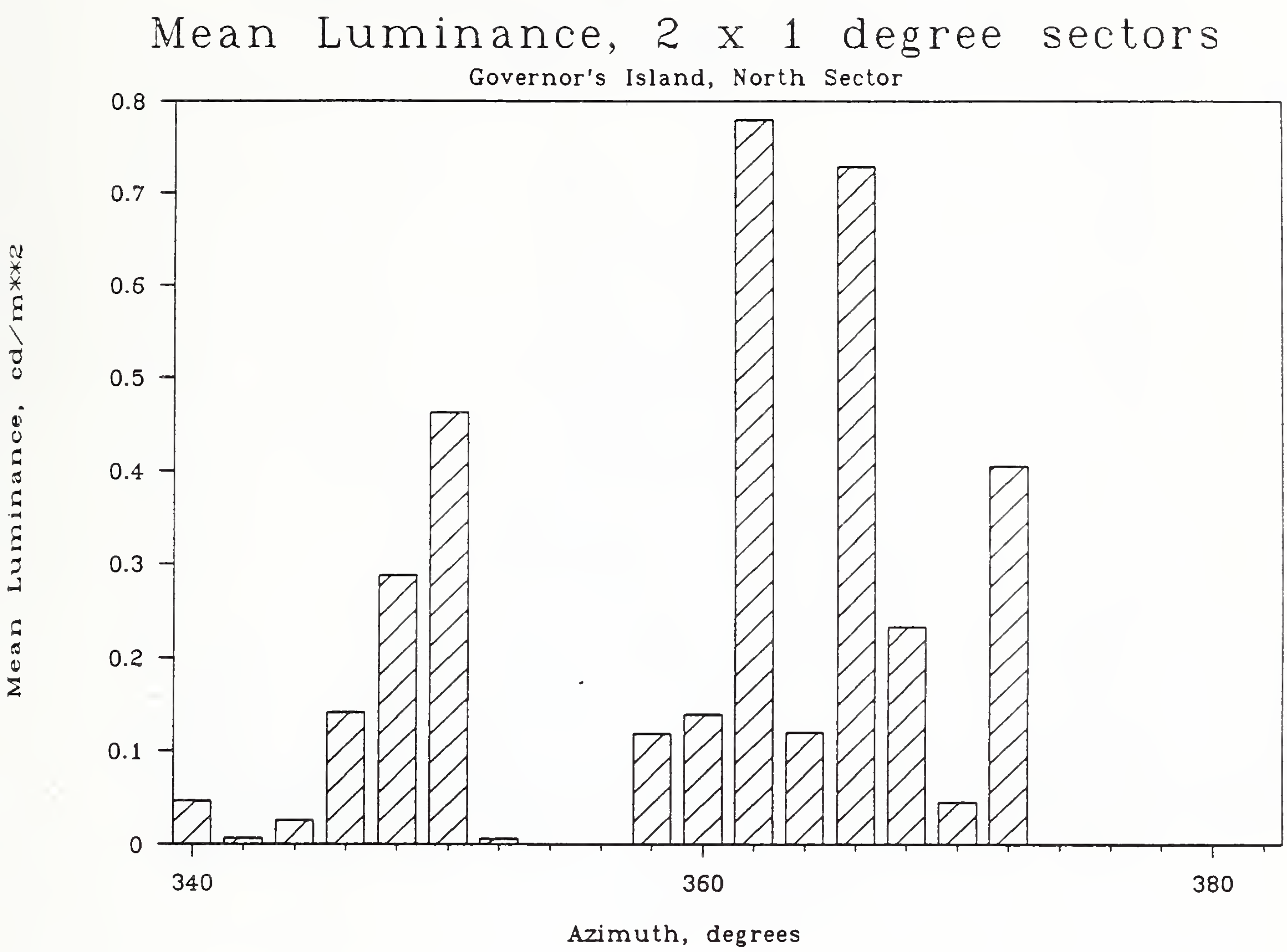

Figure 3.10. Mean luminance in 2° x 1° rectangles due to all point sources within the rectangle, Governor's Island "north sector." The rectangles extend in altitude from -0.1° to +0.9°.

3.3. Governor's Island, North Sector, Rainiest Points Excluded. As will be seen from the comments in the original data in Chapter 2, some of the Governor's Island data were taken during a rain. While the rain was perhaps just a drizzle to a man with an umbrella, it was a source of considerable attenuation and uncertainty to a man measuring lights in New Jersey through a telescope. Reference to the section 2.2.7 shows that three lights taken on the following clear night were believed to be duplicates of ones measured in the rain. The repeat measurements were those taken at 87-10-22, 1:14:25; 87-10-22, 1:23:17; and 87-10-22, 1:33:44. Based on these data, it can be estimated that the transmitted fraction from the New Jersey shore through the rain, was about 0.1, with fluctuation over time. The next five figures repeat the analyses in the preceding five, but now with 25 data points excluded---the 25 for which the comments clearly indicate heavy rain.

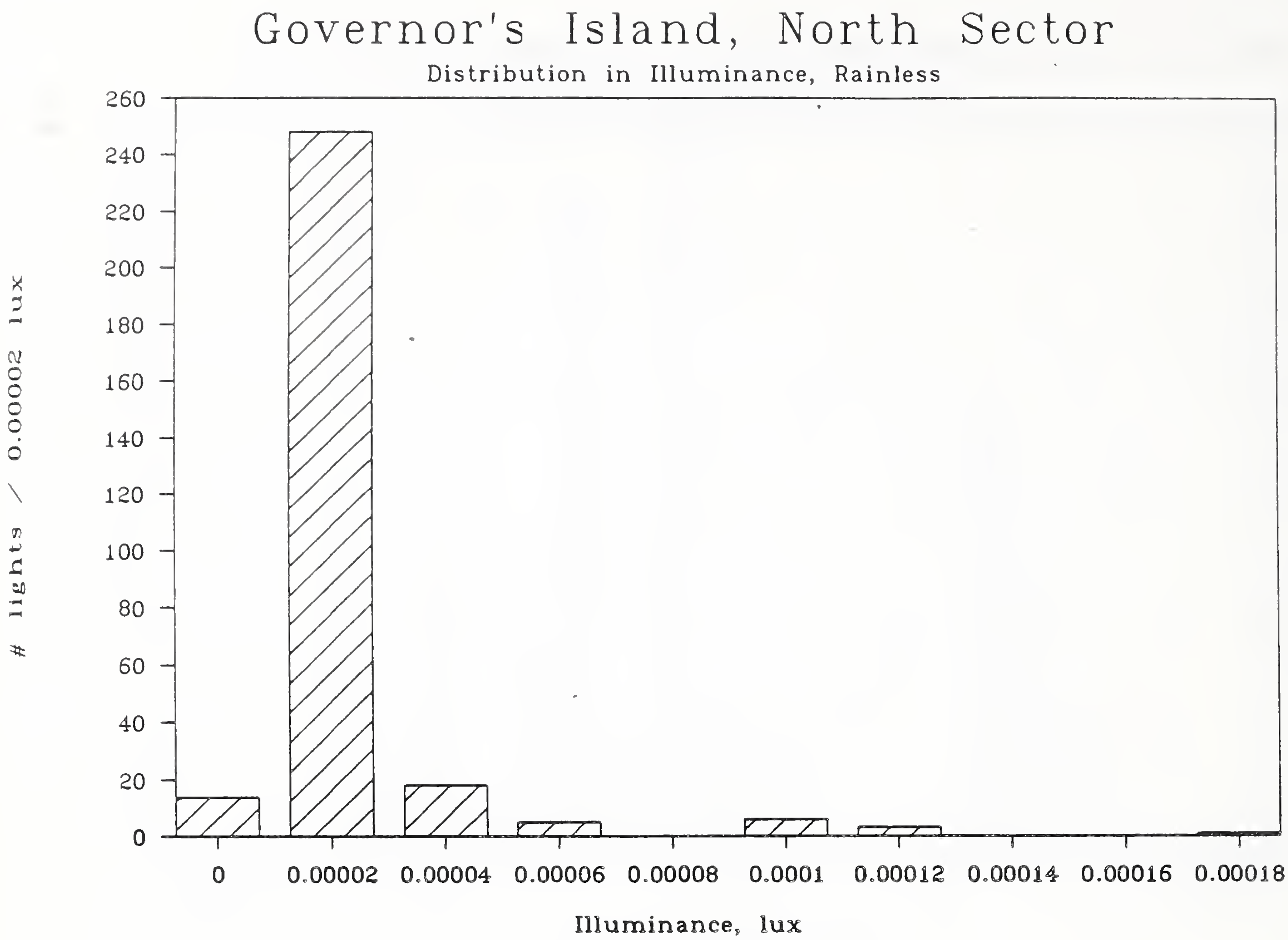

Figure 3.11. Distribution in illuminance, Governor's Island north sector, rainiest points excluded.

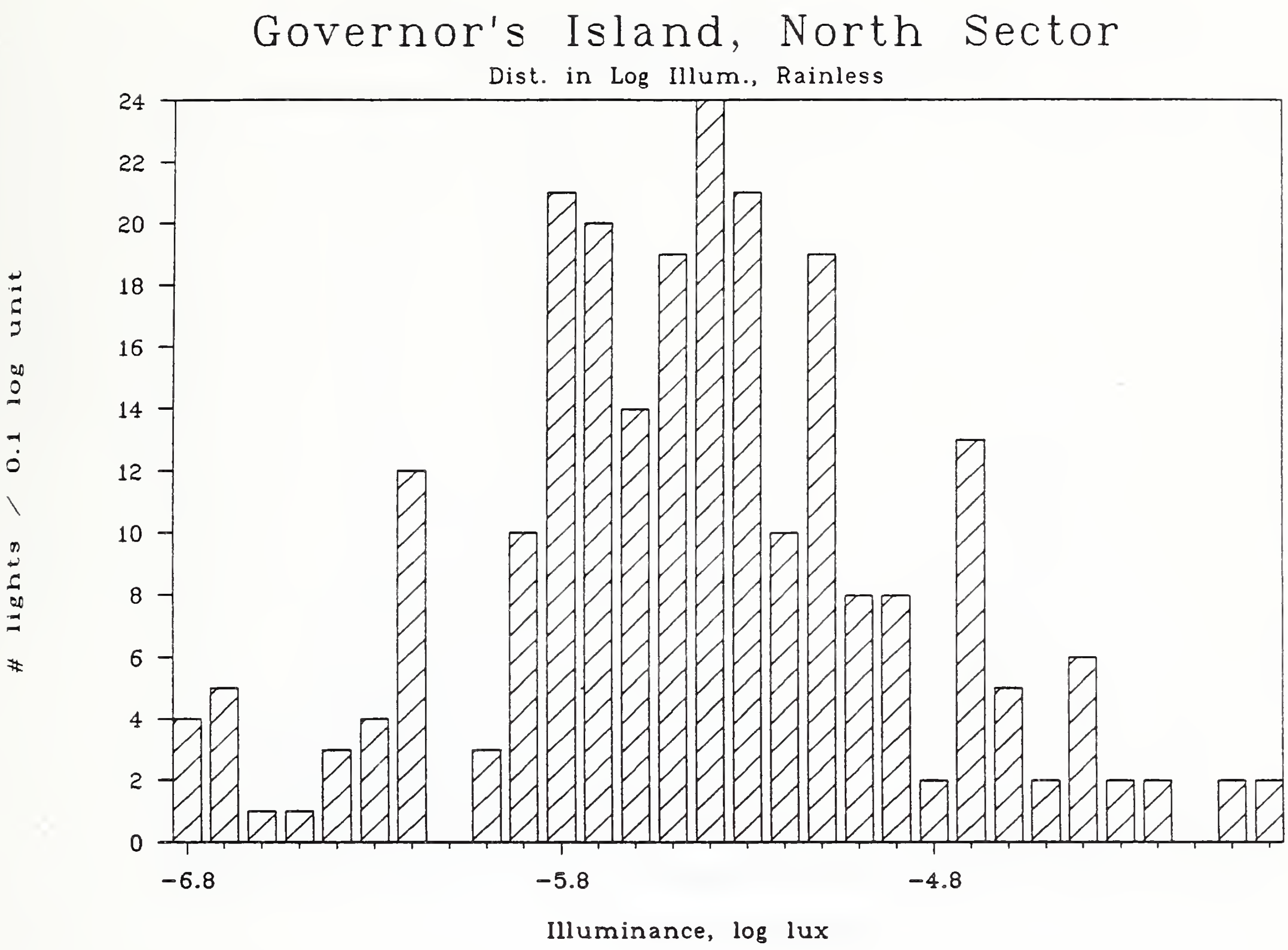

Figure 3.12. Distribution in $\log_{10}$(illuminance), Governor's Island north sector, rainiest points excluded.

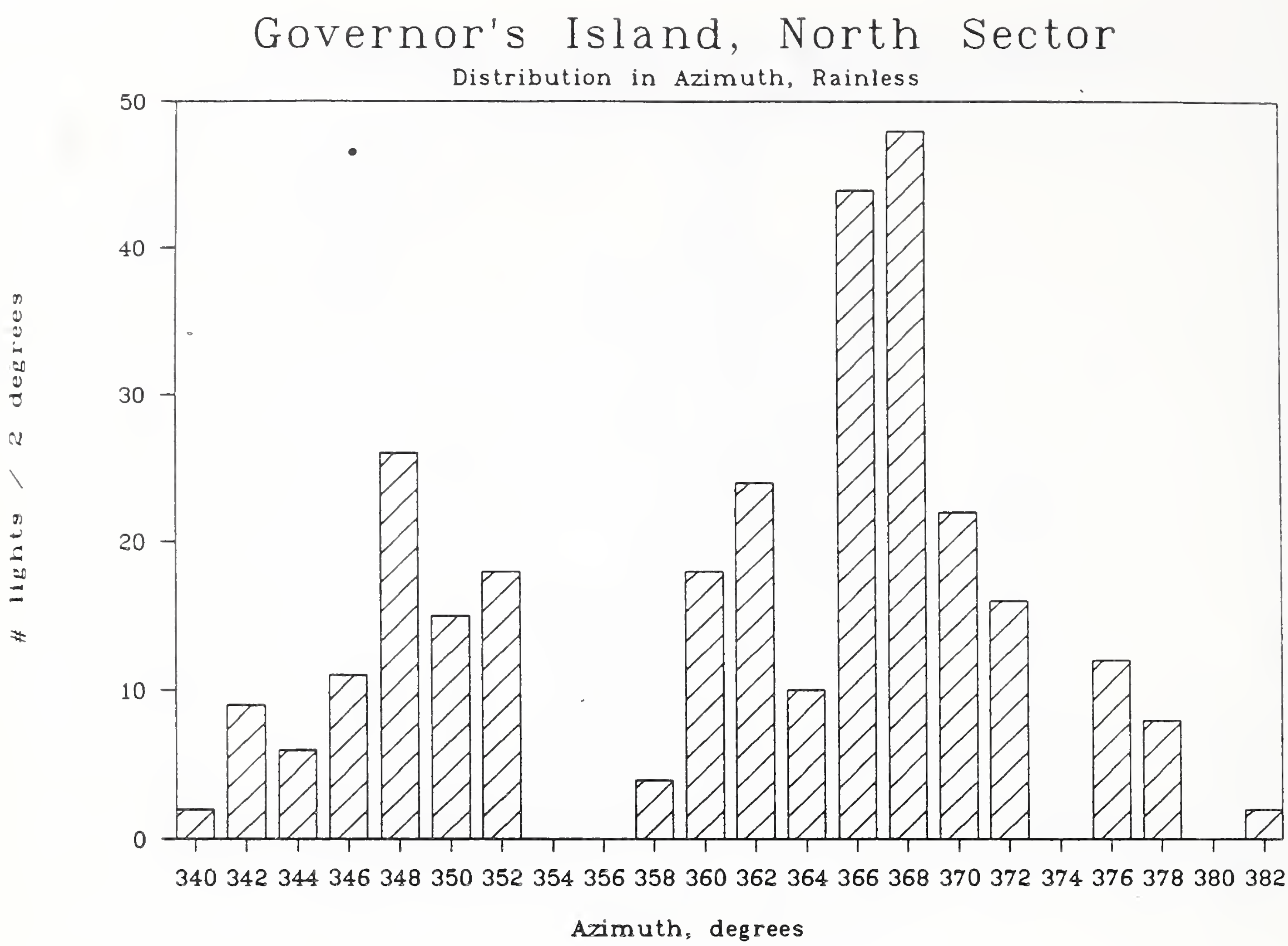

Figure 3.13. Distribution in azimuth, Governor's Island north sector, rainiest points excluded.

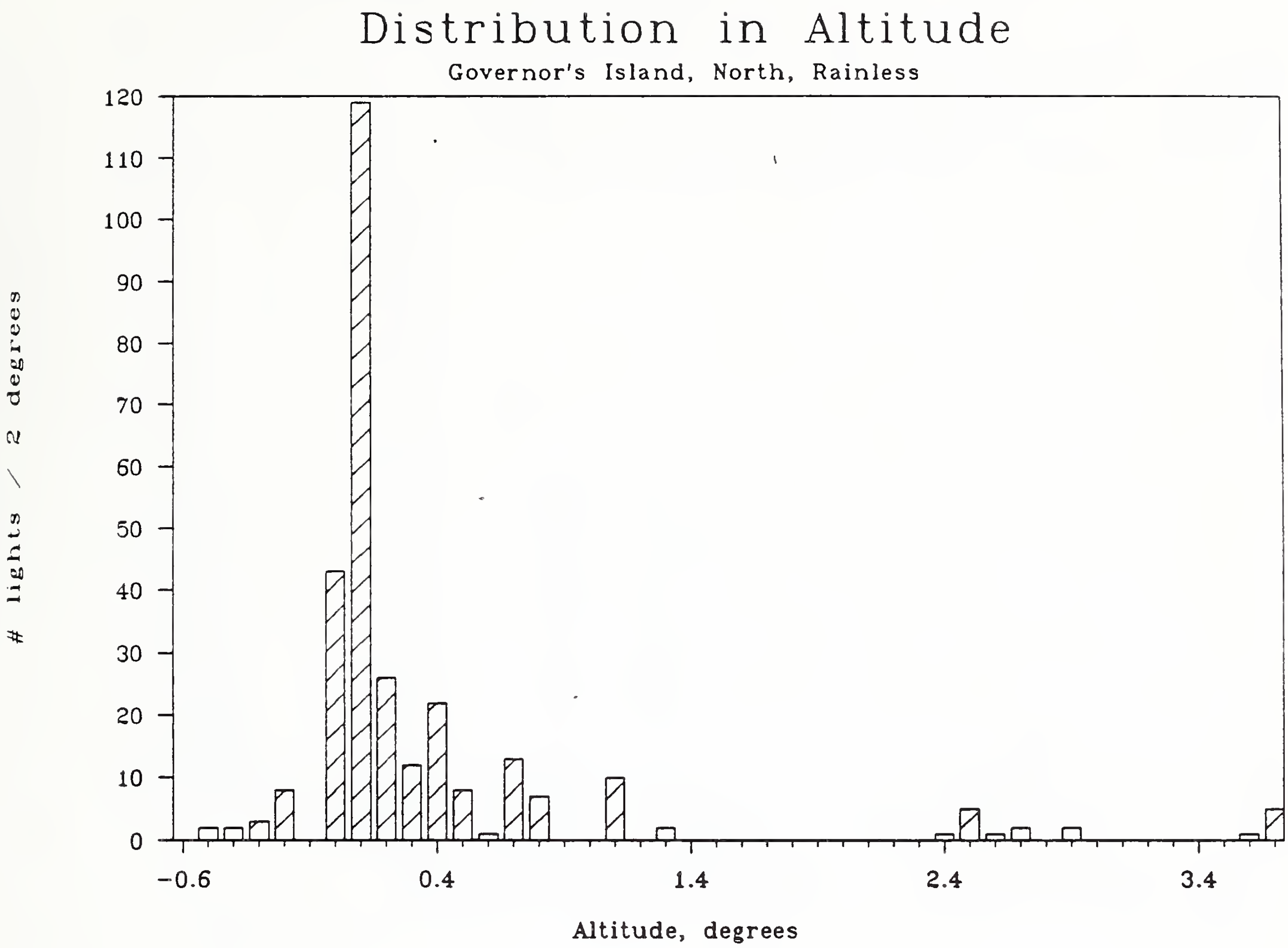

Figure 3.14. Distribution in altitude, Governor's Island north sector, rainiest points excluded.

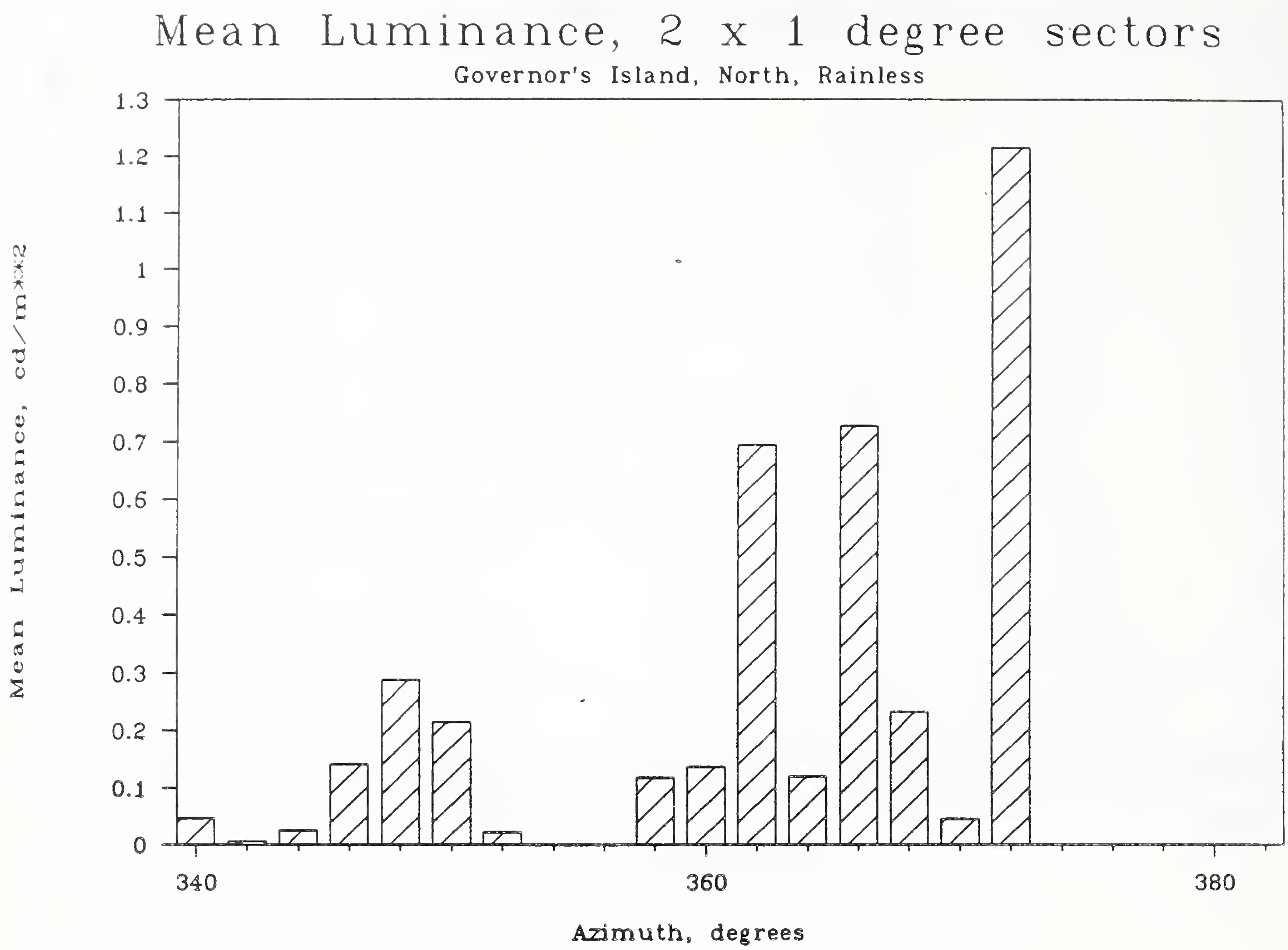

Figure 3.15. Mean Luminance in rectangles 2° wide × 1° high, Governor's Island north sector, rainiest points excluded. The vertical extent of the rectangles is -0.1° to +0.9°.

3.4. **Governor's Island, South Sector, 40° 41!218 N 74° 1!455 W,** height 68 ft. Viewing conditions were clear for all of these observations. As explained in Chapter 2, and particularly Section 2.2.7, some of these data depend on a less-than-ideal altitude calibration.

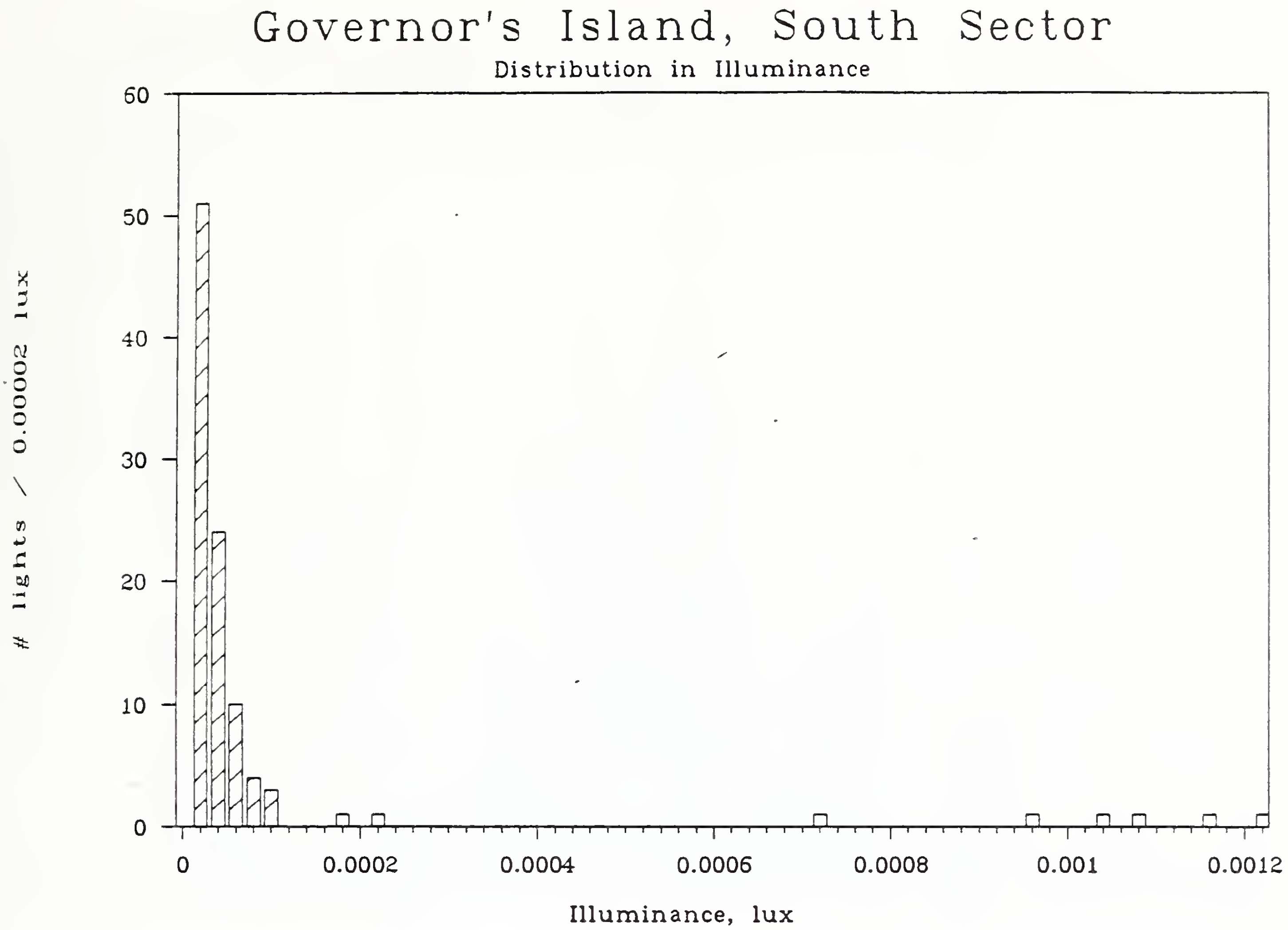

Figure 3.16. Distribution in illuminance, Governor's Island, south sector.

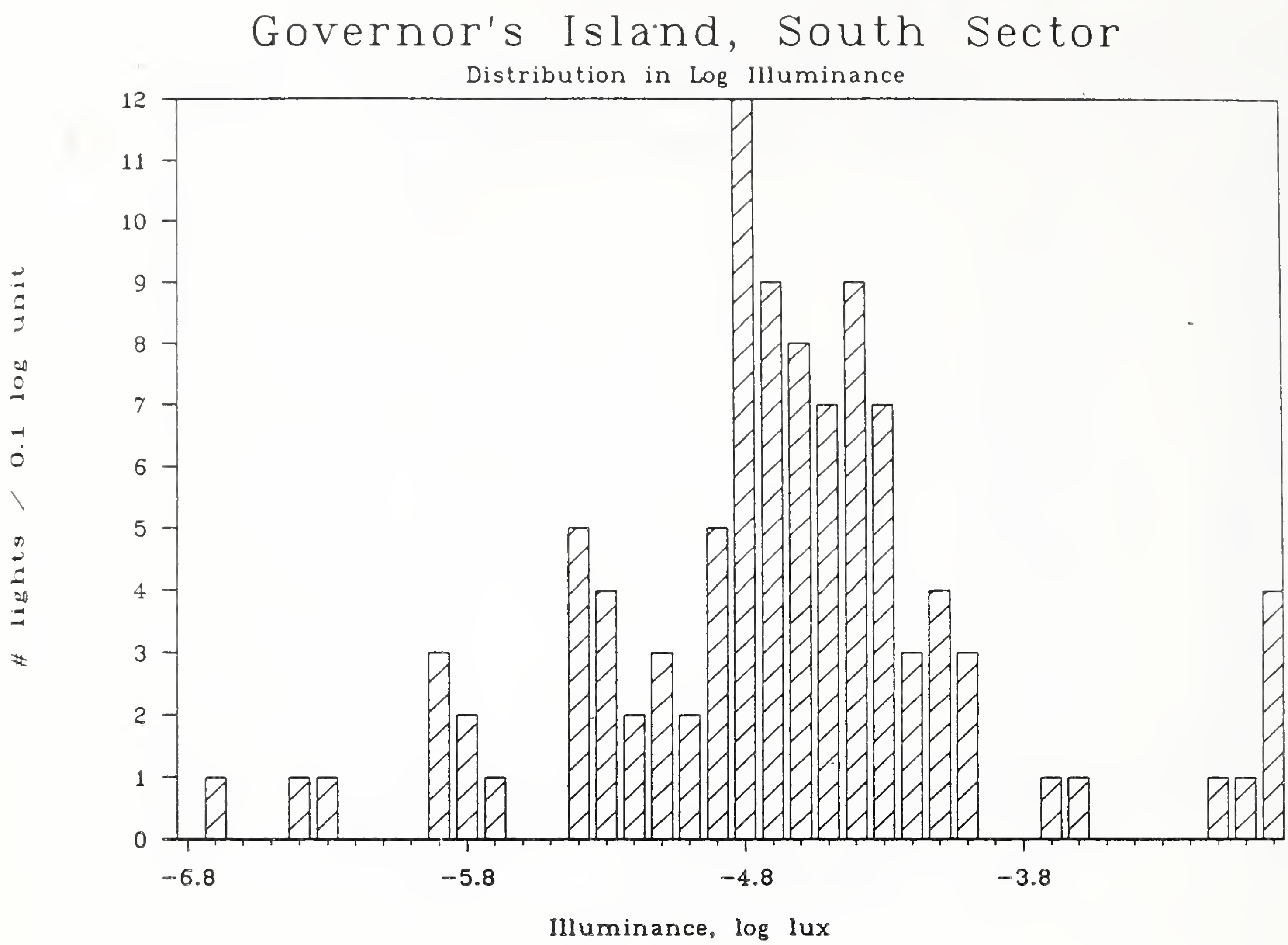

Figure 3.17. Distribution in $\log_{10}$(illuminance), Governor's Island, south sector.

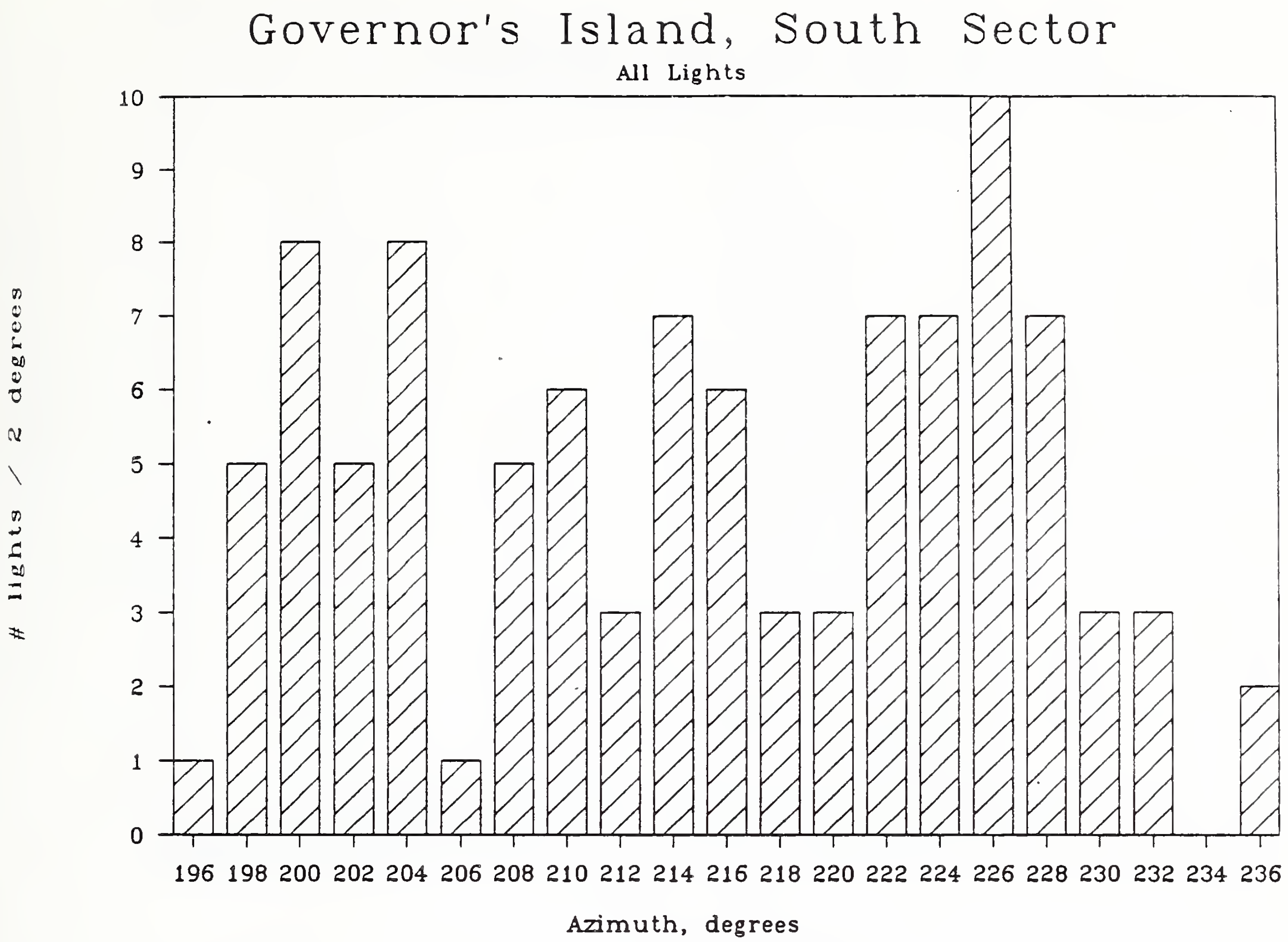

Figure 3.18. Distribution in azimuth, Governor's Island, south sector.

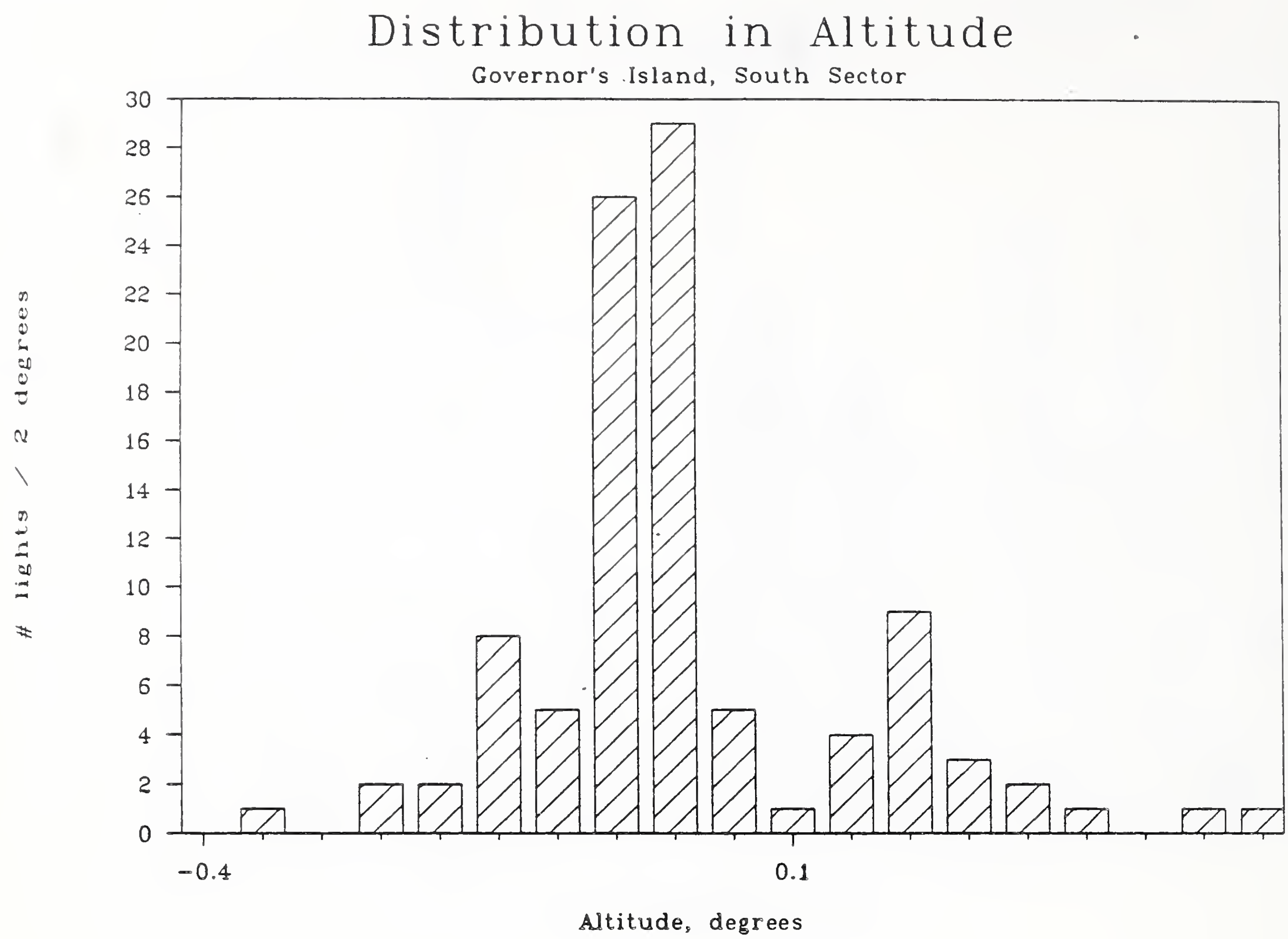

Figure 3.19. Distribution in altitude, Governor's Island, south sector.

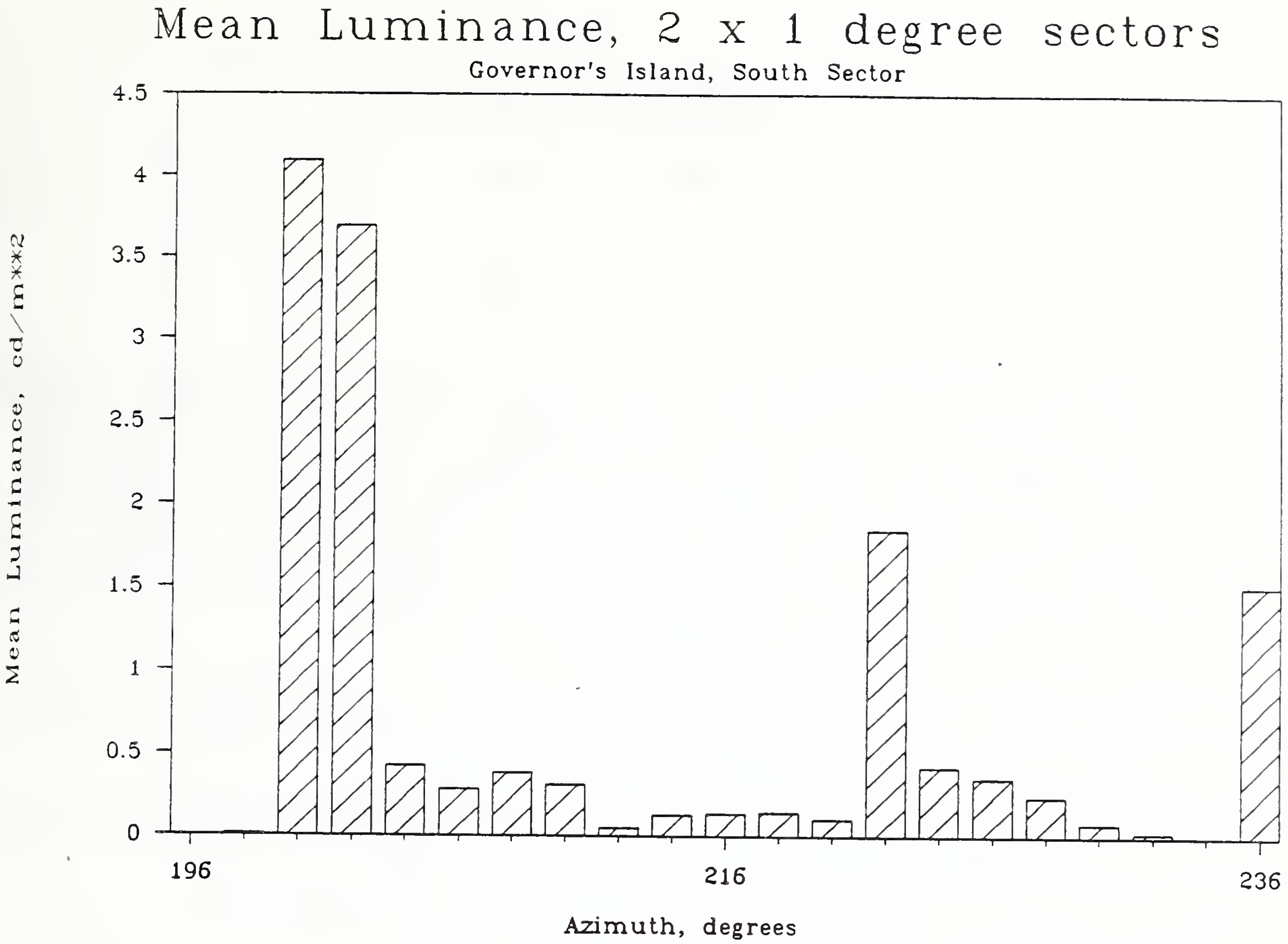

Figure 3.20. Mean luminance in rectangular areas 2° wide × 1° high, Governor's Island, South Sector. The 1° in altitude extends from -0.4° to +0.6°.

3.5. **Nature of the Interfering Background Lights.** A bonus accrues from using the Cassegrain objective---a reflecting telescope---to make the measurements. The observer can resolve details through the instrument that would not be seen by the mariner's naked eye. In particular, this enabled us to include with nearly all the data a statement as to the nature of the light source. Table 3.1 gives a summary of the colors of individual lights seen through the telescope, based on a reasonable interpretation of the comments. In many cases the image of a group of lights was dropped into the Pritchard's aperture and measured as one point source; at the same time, some note was made of the type of lights in the group. Some of the notes are unambiguous, such as "6 orange, 1 wht," while others are more sketchy, because of the limitation on what could be seen through the telescope. In some cases, the lights measured as a group may have been resolvable by the naked eye, in other cases not. Therefore, the totals in Table 3.1 must be regarded as estimates of the relative numbers of lights in different categories, and not as exact counts of lights that would be seen from a particular observation point with the naked eye.

Table 3.1: Summary of Light Colors

Sector	Orange	White	Green	Yellow	Red
Sandy Hook	228	38	42	1	8
Governor's Island, North	218	101	82	21	29
Governor's Island, South	418	15	104	6	6

It can be said that most of the interfering lights were vapor discharge streetlights, or similar vapor discharge lights illuminating parking lots or piers. These were either high-pressure sodium vapor lights, recorded as "orange" or "orangish," and high-pressure mercury vapor lights, recorded as "white" or "green." Whitish lights may also have been metal halide, rather than mercury vapor, but metal halide usually has only specialized outdoor uses, such as sports arenas. Incandescent lights might have been recorded as whitish or yellowish, but again, they would be expected to be few.

One exceptional case was noted at 87-10-20, 23:52:42. A fluorescent light was seen through what must have been a tinted window. It looked green, and to the naked eye really looked like a green navigational aid.

The distribution of light colors in azimuth, based on the same counting process as Table 3.1, is given in Figures 3.21-3.23.

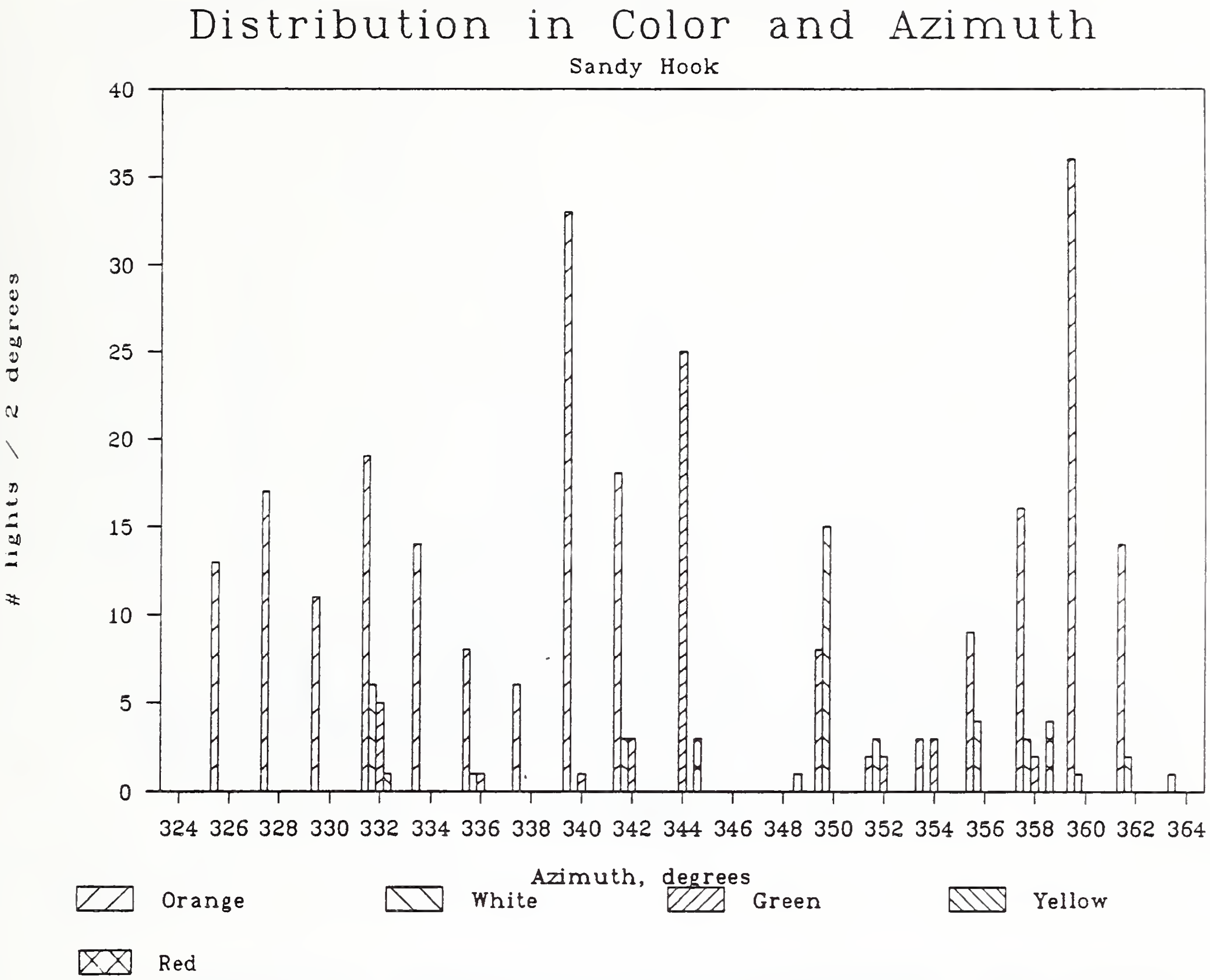

Figure 3.21. Distribution of colors in azimuth, Sandy Hook. In many cases, a group of lights was measured as a single point source. This figure and the next two are based on the colors of the lights within such groups, as recorded in the comments.

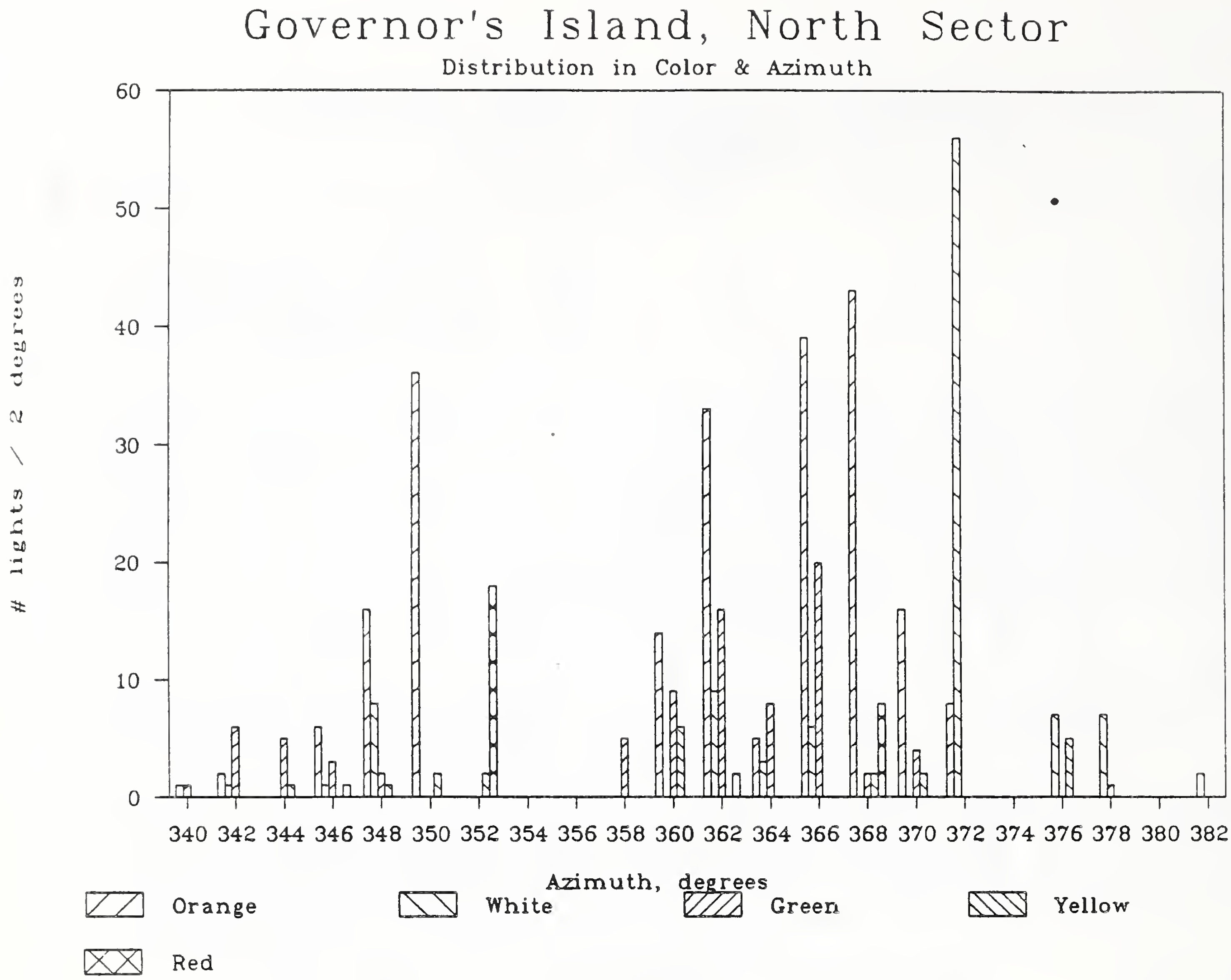

Figure 3.22. Distribution of colors in azimuth, Governor's Island, North Sector.

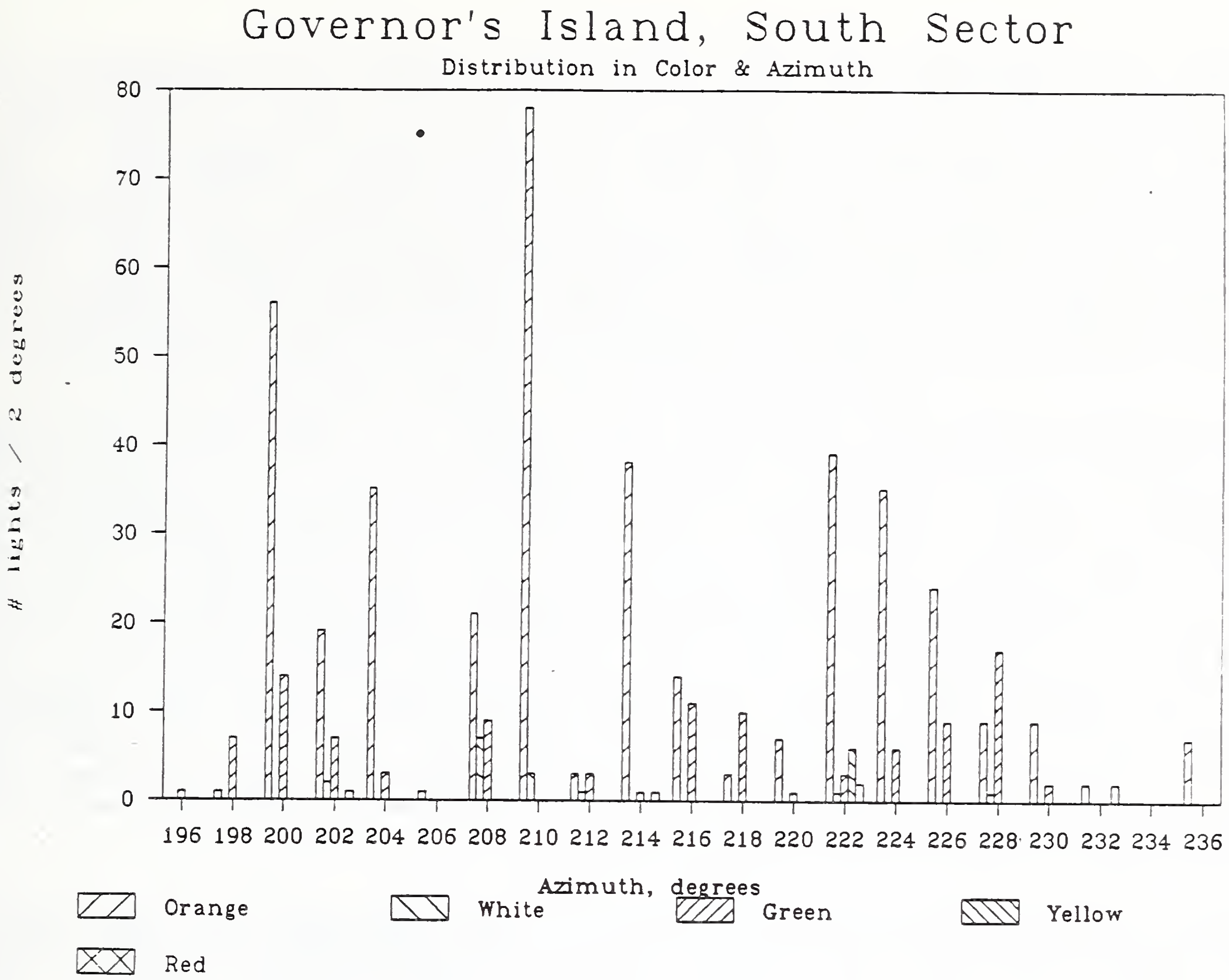

Figure 3.23. Distribution of colors in azimuth, Governor's Island, South Sector.

In any event, if navigational aids are to be made more conspicuous, an important step will be to make them look different from streetlights, in color or other properties. The chromaticities (x,y) of some representative streetlights are, high pressure sodium vapor: (0.512, 0.421); high-pressure mercury vapor deluxe: (0.385, 0.400); cool-white fluorescent: (0.365, 0.366)[4]; incandescent: (0.452, 0.409)[5].

3.6. Summary and conclusions. Most of the interfering lights on shore are streetlights, or similar lights on the docks. Although no instrument was available to us for colorimetry at a distance, we can reasonably infer that the chromaticities of the streetlights are those of standard sodium-vapor and mercury-vapor lights, for the most part.

Among the data taken for all locations, very few measurements were made on navigational aids themselves. Many of the aids are difficult to aim the instrument at, because they have a low duty cycle---they are off most of the time. For the same reason, they are harder to measure than steady lights. Most importantly, we took our assignment to be measurement of background lights, not measurement of aids. Having said all this, it is of interest to make some comparison of a measurement on an aid to those on other lights. Among the lights in the Governor's Island south sector is the Robbins Reef Light House, measured at 87-10-23, 02:53:40 (file GOVISL.005). The $\log_{10}$(illuminance) for this light is -4.58. Comparison with Figure 3.17 shows that from the observation point on Governor's Island, 68 feet up, Robbins Reef light sits squarely in the middle of the distribution of illuminances. This particular aid is known to be an unfiltered incandescent lamp, therefore not very different in color from the high-pressure sodium lights on the streets or docks of Staten Island that are behind it. It flashes one second in six.

Robbins Reef light is the same light that we used for aiming calibration, that we spent such a long time picking out on the horizon. It flashes once in six seconds for about a second. We were observing it from 2.7 nautical miles distance. Since it is offshore, and along the route from The Narrows up the Hudson, many vessels will pass nearer to it than 2.7 nautical miles, where they may see it as distinctly larger or brighter than lights on shore; also, they will see it moving relative to the shore lights. Certainly they should see it before they run aground on the reef. On the other hand, according to the standard calculations used by the Coast Guard, this light should be visible up to nine nautical miles away under clear conditions[3]. Thus, the background lights reduce the useful range of this light from nine miles to perhaps one mile or so, a considerable loss. Chart 12334 shows that there are other aids near to Robbins Reef, flashing yellow, red, and green, so this discussion has concerned only part of what a mariner sees.

Three red buoys were also measured in this sector, at 87-10-23, 3:33:31; 87-10-23, 3:50:29; and 87-10-23, 20:39:35. Log illuminances for these lights are -5.4, -6.0 and -6.0. These values put them near the bottom of the distribution in Figure 3.17, but this would be expected *a priori* for red lights, which are created by filtering out the green and yellow-green light to which light meters are most sensitive. It is well known, of course, that light meters underestimate the brightness that a human will perceive in a strongly colored light. The red aids may well be the most conspicuous because of chromatic brightness and the fact that few of the background lights are red. This raises visual science questions about chromatic brightness and conspicuity which are beyond the scope of this report[6,7].

For navigational aids to stand out from this background, they must be distinguishable from streetlights in some way. The traditional limitations on signal lights apply: shape cannot be manipulated, since the lights must be seen at distances up to 20 nautical miles, where any reasonable-sized light will be discerned only as a point (see Section 4.2). Only spectral composition, intensity, and flash characteristic can be manipulated, and these cannot be changed in ways that increase power consumption.

While this project was not intended to research novel aids, a few suggestions can be made. Sources such as lasers or LED's could give combinations of efficiency and saturated color that are not possible with filtered incandescent sources. In the bargain, the other properties of lasers could be exploited, such as polarization and coherence.

Suppose, for instance, that a red laser beam is split and emitted as two parallel beams from apertures 20 cm apart. At 0.5 kilometer, these two sources can be resolved and appear as twin red points. At greater distances, when the two lights are imaged as one on the retina, a Young's double-slit interference setup is created, and simple calculations indicate that at 10km, the interference fringes, spaced some 30mm apart, can be experienced as flashing that depends on side-to side movement of the head (or ship). Of course, to move the fringes farther apart, you would move the beams closer together. Exactly how this will work in practice with intervening atmospheric disturbance remains to see; and engineering problems arise in designing a buoy that splits a laser beam into numerous pairs of parallel beams.

Chapter 4. Photometric Theory

4.1. Introduction. The Pritchard photometer[1] is intended to measure luminance, so its use for this purpose alone would require little discussion. This chapter will explain the use of the Pritchard to measure illuminance due to point sources.

4.2. Extended vs. Point Sources. Imagine a tugboat with a large Lambertian (perfectly diffuse) source on the afterdeck, say a circular electroluminescent panel. Standing on the eastern shore of Governor's Island on a clear night, you watch the boat as it eases slowly away down the Buttermilk Channel. As the distance of the source increases, the solid angle subtended at the source by your eye's pupil diminishes. Hence, the light received by your eye decreases, as the square of the distance. *However*, the solid angle subtended by the source at your eye also decreases, meaning that the image area on your retina decreases, as the square of the distance. Hence, the luminous flux *per unit area* on your retina, within the image of the source, remains constant as the tugboat moves away. This suggests that an *intensive* light-radiating quality could be defined for such a surface, independent of its exact size and shape. That quantity, of course, is *luminance* [= luminous flux$\times$(area)$^{-1}\times$(steradian subtended at the source)$^{-1}$].

Now as the tugboat plows leisurely away, you walk on down to the southern end of Governor's Island, where you can watch it recede toward The Narrows and beyond. Assuming that the source diameter is one meter, you will see it get smaller and smaller until it is some 2 nautical miles away. Then it will subtend less than one minute of arc, and will appear only as a point of light. After that, the image of the light on your retina is limited by your eye's optics, and will get no smaller; but the luminous flux reaching your eye continues to decrease, so you will now see the point get dimmer and dimmer, rather than smaller and smaller. The light source is no more a geometrical point than it was in the Buttermilk Channel, but for practical purposes of you looking at it, it has become a point source. Luminance is no longer a helpful concept; instead you need a measure of the total light available to your eye from the source. That quantity is the *illuminance at the observation point due to the source* [= luminous flux (area)$^{-1}$].

4.3. Measuring Illuminance Due to a Point Source. The key to measuring illuminance due to a point source with the Pritchard telephotometer is to realize that "illuminance at the observation point due to the source" is also defined and meaningful when the source is an extended one rather than a point. Suppose we set up the Pritchard along the seawall on Governor's Island and adjust the aperture to have subtense θ. If necessary, θ includes any magnification correction because of a nonstandard lens on the instrument, and is the true angular subtense of a circular object that just fills the aperture. Now we get on the two-way radio with the master of the electroluminescent source, and keeping the Pritchard aimed at him while he moves slowly away, we ask him to stop when the source just fills the aperture. We now note in a handbook that the illuminance E due to a circular source of luminance L and subtense θ is given by[8]:

$$E = \pi L \sin^2(\theta/2) \quad . \qquad (4.1)$$

Now, the Pritchard will display the source luminance L, since the source fills the aperture. Hence, illuminance at the instrument due to the source is given by Eq. (4.1), where L and θ can be read from the meter. (If the source overfills the aperture---tugboat too near---Eq. (4.1) applies with the more abstract interpretation that E is the illuminance due to the *part* of the source covered by the aperture.)

Now suppose that a member of the tugboat crew turns off the electroluminescent source and turns on a much more compact incandescent bulb, which we see against a black background. We aim the Pritchard at this source, and then using the two-way radio again we get the crewman to adjust the point source intensity until the meter again reads L, as it did with the circular source.

We may now reason that if the meter reads the same, the same luminous flux is reaching the photomultiplier tube (with spectral correction filters), meaning that the flux per unit area at the entrance pupil of the objective lens is the same. This means in short, that E is still given by Eq. (4.1), with L now taken to mean the luminance *reading*. We can ignore the fact that L is no longer a meaningful luminance of an extended source.

Suppose that our helpful seaman now sets up his point source on a pier in Brooklyn where it will remain steady. We center a small aperture, say the 6′ one, over the source and note the reading. Now we adjust the aperture to the larger sizes, 20′, 60′, 180′. As we do this, the luminous flux reaching the photomultiplier tube from the one source remains constant, since its light always drops through the aperture. However, the reading on the instrument console will drop with each movement of the aperture wheel, and be diminished by a factor of approximately 900 when we reach the 180′ aperture. This occurs because presumably the instrument really responds to E, but incorporates in its circuits a compensation for Eq. (4.1). If we apply Eq. (4.1) each time as we change apertures, the computed values E can be expected to remain approximately constant.

4.4. Practical Calibration and Use of Eq. (4.1). To convert the raw data to measurements of illuminance at the observation point, we must apply Eq. (4.1) along with a number of corrections for other factors:

1.) With the Cassegrain objective in use for ordinary luminance measurements, the console does not read directly in luminance units. The reading must be multiplied by 10 to get luminance in $cd \times m^{-2}$.

2.) Most of the data were not taken with the photometer gain set to give 4.99 in the "CALIB" function, as called for in the case of luminance measurements. Instead, the gain was adjusted to a lower value, to give 3.13 in the "CALIB" step. The reason for this had to do with an alternate method of interpreting the data that was considered but rejected. Data taken with the lower gain setting must be multiplied by (4.99/3.13).

3.) The aperture settings as marked on the aperture wheel of the instrument and recorded in the data files apply when the 7-inch objective lens is in place. Thus, the 84-inch Cassegrain objective has a magnification of 12, which reduces the area in object space to which the aperture projects. The effective aperture is thus the size relative to the 7-inch lens, divided by 12. (There is a further problem that the diameters stated on the aperture wheel differ slightly from the true diameters. This can't be put in the formula, but must be dealt with through a table look-up. See the description of the apparatus.)

Applying Eq. (4.1) while correcting for these factors and applying the small-angle approximation, gives $E = \pi\times(\text{reading})\times 10\times(4.99/3.13)\times\sin^2((20'/12)/2)\times(\theta/20')^2$. That is $E = 2.94\times 10^{-6}(\theta'/20')^2$, where θ' is the aperture <u>in minutes</u>, before accounting for magnification. Equivalently, $E = 7.35\times 10^{-9}\ \theta'^2$. For the corresponding formula when the gain was set for "luminance calibration," it is only necessary to omit the factor (4.99/3.13), giving $E = 1.85\times 10^{-6}(\theta'/20')^2 = 4.625\times 10^{-9}\theta'^2$.

The most questionable assumption underlying the formulas just derived is that the sensitivity is uniform over the Pritchard's measuring aperture. In some applications, when the photometer is to be used for point-source measurements, a special calibration is done with a small source centered in the aperture. For our measurements, the objects actually measured were clusters of lights, not necessarily centered. No correction for non-uniform sensitivity over the aperture can really be made, and we must accept this non-uniformity as a source of random error.

Finally, it should be noted that the formula given as a comment in the data files, similar to those just derived, is not correct.

4.5. **Mean Luminance of a Sector with Point Sources.** Even though luminance is not a helpful concept for point sources, mean luminance can be computed for an area containing point sources. Luminance is defined as flux per unit area of the source and per unit solid angle subtended at the "source" (1) by the "receiver" (2)[9]:

$$L = \frac{d^2F}{dA_1 \cos\epsilon_1 \, d\omega_1} \tag{4.2}$$

where:

- dA_1 = area of surface element of source
- ϵ_1 = angle between given direction (1) - (2) and the normal n_1 to dA_1 .
- $d\omega_1$ = element of solid angle with apex (1) at the source.
- F = luminous flux.

Now we are interested in the case where the "source" (1) is a sector on the horizon, a few degrees wide by a few degrees high, as seen from the observation point; and the "receiver" (2) is the entrance pupil of the telephotometer.

Define

A_1 = source area, total

A_2 = receiver area, total

R = distance from source to receiver

ω_1 = total solid angle subtended by the receiver at the source

ω_2 = total solid angle subtended by the source at the receiver

Now the total flux is given by

$$F = \int_{A_1} dA_1 \int_{\omega_1} d\omega_1 \, L \cos\epsilon_1 \tag{4.3}$$

In general, the indicated integrals need to be broken into multiple integrals and L and ϵ_1 would be functions of the variables of integration, but here we take $\cos\epsilon_1 = 1$ and we want L to be an average, hence not dependent on the variables of integration. Thus,

$$F = A_1\omega_1 L \quad . \tag{4.4}$$

Now $\omega_1 = A_2R^{-2}$, by the definition of solid angle, and similarly, $A_1 = \omega_2R^2$. Thus

$$F = (\omega_2R^2)(A_2R^{-2})L = \omega_2A_2L \tag{4.5}$$

The (mean) illuminance at the receiver is thus

$$E = F/A_2 = \omega_2 L \quad , \tag{4.6}$$

or

$$L = E\omega_2^{-1} \quad . \tag{4.7}$$

If E, the illuminance at the observation point, was measured for N individual point sources in the sector ω_2,

$$L = \omega_2^{-1} \sum_{j=1}^{N} E_j \tag{4.8}$$

Now let

θ = angle of elevation

ϕ = azimuth angle.

Then if a sector extends from θ_0 to θ_1 and covers angle ϕ_0 in azimuth,

$$A_1 = R^2\phi_0(\sin\theta_1 - \sin\theta_0) \tag{4.9}$$

$$\omega_2 = A_1R^{-2} = \phi_0(\sin\theta_1 - \sin\theta_0) \tag{4.10}$$

For instance, in the analysis of the Sandy Hook data, it was convenient to use $\phi = 2° = 0.035$ radian, $\theta_1 = 0.8°$, $\theta_0 = -0.2°$. Then $\omega_2 = 6.092\times10^{-4}$ steradian or $\omega_2^{-1} = 1641$ sr^{-1}. (Note that because of the small-angle approximation, ω_2 would be virtually unchanged if a small constant were added to θ_1 and θ_0 to give, for instance, $\theta_1 = 1.0°$, $\theta_2 = 0.0°$.)

Chapter 5. Spherical Trigonometry

5.1. **Introduction.** The light intensity measurements are accompanied by true azimuth and altitude of the light, as seen from the actual observation point. The calibration for azimuth and altitude was done as a step in the data-taking process, by spotting landmarks of known position through the telephotometer.

The *Light List*[3] gives the latitude and longitude (to the nearest 0′.1) and the height above mean high water (to the foot) for many aids to navigation. The latitude and longitude of aids and of other landmarks such as the torch on the Statue of Liberty, the mast on the Empire State Building, and so forth, can be read to finer precision than 0′.1 from nautical charts, but the charts give the heights of only a few aids, and no heights for other landmarks.

Initially it was envisioned that many of the data would be taken from the outdoor observation decks of Robbins Reef Light (40° 39′.4 N, 74° 04′.0 W, height 56 ft) and Romer Shoal Light (40° 30′.8 N, 74° 00′.8 W, height 54 ft), so that the observing position would be known, and numerous other aids would be visible for the aiming calibration. In fact, the data were taken from positions that needed to be determined in an additional step. Also, the instrument could sometimes not be swung through wide angles from a calibration landmark to the observing direction, which complicated the calibration process. Nevertheless, the approach of calibrating by landmarks did prove workable. By one or another method, we did determine the latitude and longitude of the observation points, and find some distant landmarks to use, as detailed in Chapter 2.

5.2. **Derivation.** The mathematical task then is this: Given the latitude, longitude, and height above mean high water for two points *1* and *2*, find the vector from *1* to *2*, *expressed as azimuth, altitude and distance*. Refer first to Figure 5.1. Smart's[10] formula (A) applied to this triangle gives

$$\cos c = \cos a \cos b + \sin a \sin b \cos C \qquad (5.1)$$

$$c = \cos^{-1}(\cos a \cos b + \sin a \sin b \cos C) \quad . \qquad (5.2)$$

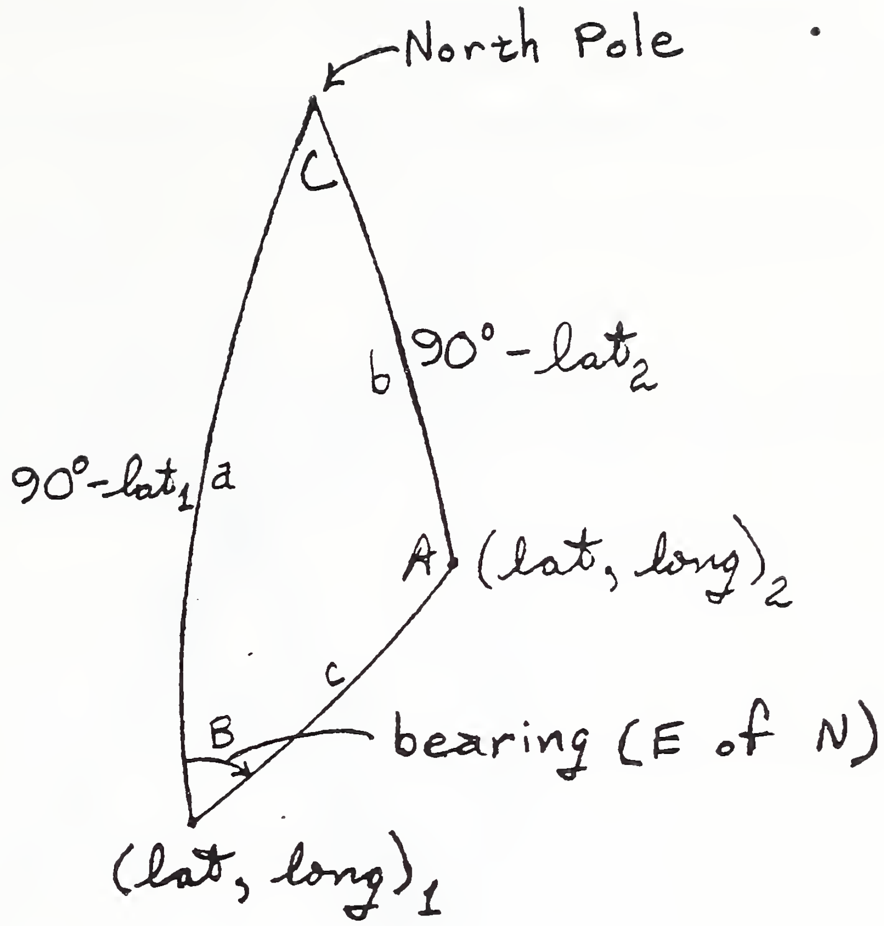

Figure 5.1. Diagram for derivation of the azimuth and great circle distance from one point to another near the surface of a spherical earth. Given are the latitude and longitude of points *1* and *2* (alias *B* and *A*). Both the sides and the angles of a spherical triangle may be expressed in angular units; the sides are great circles. The north pole is made one vertex of the triangle, so that sides *a* and *b* are the colatitudes of points *1* and *2*, and vertex angle *C* is the difference in the longitudes. We then seek *c*, which can be thought of as an angle subtended at the center of the earth, or as a great circle distance in nautical miles, equal to angle *c* in minutes; and we seek azimuth *B*, expressed as east of north.

If *c* is expressed in minutes, it is the great circle distance from *1* to *2* in nautical miles.

Now we know all three sides and we can use the same cosine formula in its alternate form

$$\cos b = \cos c \cos a + \sin c \sin a \cos B \qquad (5.3)$$

to derive

$$B = \cos^{-1}\left[\frac{\cos b - \cos c \cos a}{\sin c \sin a}\right] \qquad (5.4)$$

Angle B is the bearing of point 2 with respect to point 1, expressed as east of north. A problem of quadrant arises if *2* is west of *1*, but this is easily corrected in the computer program.

To derive the vector length and altitude, we refer to Figure 5.2.

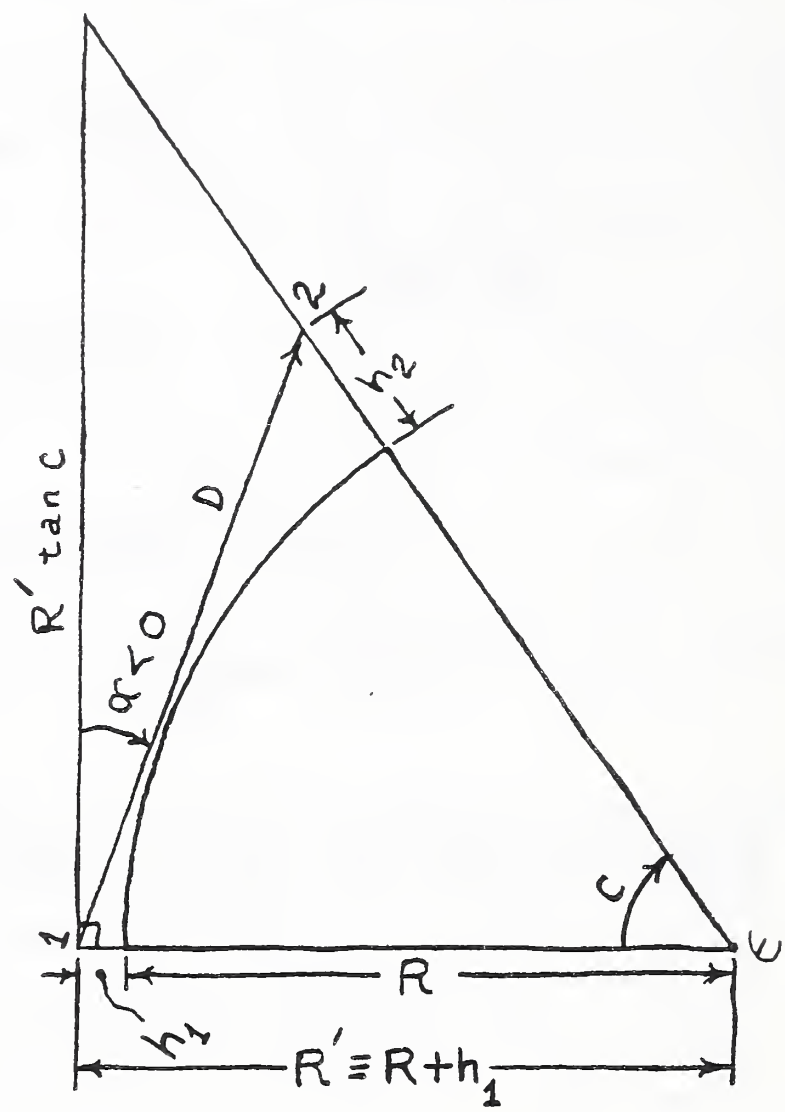

Figure 5.2 Diagram for the plane trigonometry problem of finding the angular altitude α and distance D, given the height of the observer, h_1, the height of the light, h_2, and the great-circle distance c. Point ϵ is the center of the earth; R is the earth radius, taken as $360*60*6080/(2\pi)$ = 20901500 feet.

We define

> R = radius of earth = 20901500 feet (based on a spherical earth of circumference 360*60 nautical miles).
>
> h_1 = height above mean high water at point *1*.
>
> h_2 = height at point *2*.

And we define the auxiliary variables:

$$R' = R + h_1$$

$$h' = h_2 - h_1 \quad .$$

We then write the law of cosines (plane trigonometry) as

$$D^2 = R'^2 + (R'+h')^2 - 2R'(R'+h')\cos c \quad . \tag{5.5}$$

Simplifying and applying $\cos c \approx 1 - (c^2/2)$ to avoid subtracting numbers that are nearly equal, we get

$$D^2 = (R'^2+R'h')c^2 + h'^2 \quad . \tag{5.6}$$

Altitude α is defined as positive above the horizontal, so that in Fig. 5.2, $\alpha<0$. Applying the (plane) law of sines to triangle ϵ-1-2 then we find

$$\alpha = \sin^{-1}[(R+h_2)\sin c/D] - \pi/2 \quad . \tag{5.7}$$

Chapter 6. Apparatus

6.1. Introduction. A major part of the effort on this project went into development of the apparatus, and the choice of apparatus had a large effect on where the uncertainties appear in the data.

Limited consideration was given to collecting the data with some sort of imaging device: film or a television camera, or some sort of electronic imaging device with greater sensitivity and flexibility than normal television. These are devices often used by astronomers for a similar task: making measurements through a telescope on distant point sources of light. Using an imaging device for the measurements would limit uncertainty in the relative positions of neighboring lights. With only a crude idea of the direction that the imaging device were pointed, one luminance-calibrated image might provide an interesting sample of, say, the New Jersey shoreline, with accurate relative positions of lights.

The drawback to imaging devices is that we did not know of a commercial device intended to be used for luminance measurements, and with a wide dynamic range. A decision to use an imaging device would have led to an open-ended task of device selection and calibration, with some risk that in the end, we still might not have detected the dimmest of the lights visible to mariners.

A sure way to get sensitivity, wide dynamic range, and luminance calibration was to measure individual lights with a Pritchard telephotometer[1], which is what we did. The Pritchard, with its normal 7-inch lens, can give a full-scale reading to a point source at the threshold of detection by a human. Its dynamic range in full-scale luminance reading, *at a fixed aperture setting*, is 10^8. This is also the approximate dynamic range for point source measurements, since the light collected from a point source is independent of aperture. (Dynamic range for actual luminance measurements is extended by the effect of the aperture to 10^{12} overall.) By contrast, an 8-bit image only has one full-scale setting; if the brightest light gives a reading of 2^8-1 = 255, the ideal case, all other lights give less-than-full scale; hence on the same basis used for the Pritchard, the digitized image has a dynamic range of $10^0 = 1$. Assuming no dark current or noise, we can consider that the dimmest light detected gives a reading of 1. By redefining dynamic range we can say that the dynamic range of the 8-bit image is 255 = $10^{2.4}$. Even by this dishonest comparison, the imaging device falls short of the Pritchard's range by $10^{8-2.4} = 10^{5.6}$.

In short then, it seemed safest to take data with the Pritchard telephotometer in this initial study. This determines what the actual dynamic range of illuminances is, and any future scheme to take the data a different way can be guided by this information. An added feature of the Pritchard was the option of using the 84-inch telescopic objective lens, which in the event we used for all data. Thus, we were able to use an instrument with both light sensitivity and angular resolution better than those of a human.

To aim the Pritchard at each light, with fine motion control and with calibration in azimuth and altitude, a special two-axis aiming device was constructed. Each axis was driven by a stepping motor, under computer control. This large motorized tripod head was also used to take still photographs, and could be used with other meters and cameras.

6.2. The Photometer. As previously mentioned, the light meter was a Pritchard photometer, model PR-1980A, made by Photo Research Division of Kollmorgen Corporation. Its detector is a photomultiplier tube.

In using the Pritchard, the operator looks into an eyepiece and sees an image of the object being measured and its surroundings, just as he might in aiming other telescopic instruments, such as a theodolite or camera[1]. The image is in fact brighter and sharper than one sees in a common 35 millimeter camera, because it is an aerial image with no ground glass in the path. A distinguishing feature of this image is that in its center a circular area is black. The black area is an image of an aperture in a mirror which is part of the optical path to the eyepiece. The mirror can be rotated, and any of six apertures brought into position, including five circular ones and a special rectangular one. Only the circular ones, with nominal measuring field diameters of 2′, 6′, 20′, 1°, and 3° were used in this study. The operator can clearly see the object being measured in its surroundings, but of course loses sight of a point source when he actually covers it with the aperture.

The instrument also has a spectral correction filter wheel, which was always set for photopic sensitivity V_λ, and a neutral density filter wheel, which was set to "open" (= 0 density), for nearly all measurements. The measurement electronics senses the settings of the aperture and neutral density wheels and ordinary luminance measurements are automatically corrected for their effects. Point source measurements must, in effect, have the aperture correction calculated back out; see Chapter 4. The reading on the Pritchard console comprises three or four significant figures and a power-of-ten multiplier. In the raw data of Chapter 2, the data are recorded in just this way with the power of ten and other digits as displayed. The computer program was written to record the data in this way, and indeed to constrain the power of ten to the instrument's actual range; unfortunately, the program restricted the range too much, so a few data are recorded with a factor of 0.1 absorbed into the significant digits, and a corresponding addition of 1 to the exponent.

The standard lens of the Pritchard has a focal length of 7 inches. The fields measured have approximately the subtenses marked on the aperture wheel when the 7-inch lens is focused at infinity. An optional accessory is an 84-inch Cassegrain objective; this is a reflecting telescope with a folded optical path that is fortunately much less than 84 inches in external length. Obviously, substituting this objective lens introduces a relative magnification of 12, reducing the field diameter of each aperture by this factor.

Even with the 7-inch lens in place, the aperture diameters are not all exactly equal to the nominal values. Table 6.1, taken from the instruction manual[11] gives the true and nominal diameters. The true diameters as given in this table were used in computing the graphs in Chapter 3.

Table 6.1: True Diameters of Apertures

Label on "MEASURING FIELD" Selector (Nominal Value)	Actual Value of Measuring Field Angle (7-inch Standard Objective Lens, focussed at Infinity)
2′	1.9′
6′	6.0′
20′	19′
1°	1.0°
3°	3.2°

6.3. **The Aiming Device.** When the Cassegrain objective is mounted to the photometer head, the combined mass is some 13 kg, and the overall length is some 87 cm. With the twelve × magnification of the Cassegrain, the smallest measurable field subtends 2′/12 = 0.17′. While this represents a level of resolution beyond the real needs of the project, it does mean that an aiming precision of a fraction of a minute of arc is desirable. The aiming device that was built has the strength, rigidity, and fine motion to swing the instrument as required, with four limitations:

1. The setup must be protected from any wind in excess of a few knots. (On the beach at Sandy Hook, for instance, shelter was provided by a tent.)

2. The instrument must be mounted with its center of gravity as near as possible to the center of motion.

3. For greatest accuracy, backlash in the gears would have to be taken into account, with all points approached from the same direction.

4. For improved repeatability, the stepper motors and the driver assembly (but not the control electronics or software) would have to be replaced, to increase the motor torque. As it is, the stepper motors operate very near to slipping, and indeed seem to slip in the course of a series of measurements.

Rotation at fine resolution is provided in two axes by identical rotary tables, model 20801-P, made by Daedal Corporation of Harrison City, Pennsylvania. The device cradles the Pritchard photometer in such a way that the center of gravity of the photometer-telescope combination is close to both axes of rotation. The rotary tables accept small stepper motors of NEMA frame size 23.

Two stepper motors and attendant electronics were purchased from Rogers Labs Inc., of Santa Ana, California. Five hardware items are necessary to run the stepper motors:

1. The stepper motors themselves.

2. The driver module, a small circuit card that actually switches the power to the motor windings.

3. A power supply to supply 12-14 volts DC to the driver board (item 2).

4. A stepper controller, in the form of a card that resides in an IBM PC-compatible computer.

5. The PC-compatible computer itself.

Subject to various compatibility constraints, any one of these units can be replaced by an alternate model with some effect on overall performance. In the system we assembled, we used a top-quality controller card (item 4), but bottom-quality stepper motors and driver module (items 1 and 2). The problem of the slipping stepper motors, previously mentioned, could probably be solved by substituting larger stepper motors and a more sophisticated driver module. The larger motors, which would be longer but present the same mechanical interface, would provide higher maximum torque. The better driver would prevent the rapid decline of torque with speed.

Each rotary table is geared to turn once for 180 revolutions of its stepper motor. If the motors are run in half-step mode, they make one revolution per 400 half-steps. Thus, the nominal precision of aiming is 1/200 degree, or 0.3′. This precision represents a true ability to adjust aiming in small steps, but accuracy cannot be this good because of unavoidable backlash. Depending on the direction of movement, backlash can be several half-steps. A microstepping drive could improve nominal precision, but not reduce backlash.

6.4. Computer and Joystick. The stepper motor controller card is plugged into the bus of a Compaq portable computer, an early model based on the 8088 chip. This computer incorporates a carrying handle and a monochrome monitor, and is distinguished by its sturdy chassis and housing. Although it is an older model, it was upgraded to a recent version of the ROM BIOS, 640K of RAM, an 8087 math chip, and an internal 20 megabyte hard disk.

Also added to this computer were a joystick interface (gameport) and a joystick with two buttons. A joystick driver subroutine was written in the C language, and then software was provided by which the operator, while sighting through the Pritchard, could control its movement by the joystick. The driver reads out joystick position by means of a timing loop, which may not run quite as fast as it would if coded in assembly language. This means that only about 15 discrete positions can be read out for each axis. Because of this crudeness, and other reasons having to do with unavoidable computing delays and the need to ramp motor speed up and down, joystick control of the motors does not give the smooth, quick response that one might hope for; however, a software linkage was developed between the joystick and the motors which did give the operator useful control.

The operator is able to calibrate azimuth and altitude against a visible landmark, and then aim the photometer either by keyboard commands or by the joystick. The computer program maintains the calibrated values for azimuth and altitude through all movements and automatically stores them with the other data. This makes the data files humanly readable (Chapter 2) and simplifies later analysis. The only limitations to calibration are mechanical ones such as backlash in the gears, slippage of the stepper motors, and slippage of the tripod on its footing. Where the tripod sat on an interior floor, on Governor's Island, a bag of chains and a bag of sand were used to immobilize two of the legs. At Sandy Hook, only a thin cloth tent floor separated the tripod from the beach, so its feet were effectively dug into the sand; this was assumed to give a non-slippery footing.

Chapter 7. Software

7.1. Overview. All functions of calibration, aiming, and recording of data are integrated into a single interactive program, for which the executable code is called tj.exe. Code from various sources was integrated into the one large program:

1. The main application-specific code, written in C by James A. Worthey.

2. A purchased library of utilities called *Vitamin C*, which provides screen windows and other user-interaction facilities.

3. Assembly and object code provided by Rogers Labs to permit control of the stepper-motor interface from a C program.

In addition, one feature available to the user was to branch temporarily to a file editor, which was PCWrite, a commercial program. So, in a sense, PCWrite became a part of the software. Furthermore, PCWrite includes an "exit" function, so that it was possible to branch to PCWrite and thence to DOS, <u>without stopping the program and losing calibration.</u>

Consideration was given to including the novel source code, item 1, in this chapter. Unfortunately, all this wonderful code would have doubled the length of the report. Therefore, only two short files and part of a third are presented which may be particularly revealing of how the task was approached. Other files are described briefly. A draft of the chapter with the code included may be available to interested readers. (Please contact the author.)

In addition to the main program, a final section of this chapter gives the filter program needed to make the data files compatible with the spreadsheet program Lotus 1-2-3.

7.2. Technical Tidbits. The Aztec C compiler (from Manx Software) was used, along with the Aztec assembler, and an Aztec utility to put object files into the proper format for the Microsoft linker. Then the Microsoft linker was used to create the final file tj.exe. This somewhat roundabout approach was used because one of the modules from Rogers Labs was supplied only as an object file suitable for the Microsoft linker. In principle, this method should work efficiently; the extra conversion step takes only a few seconds and can be invoked automatically by the MAKE utility. However, consistency problems arose related to the assembler pseudo-ops that pass commands to the linker, the result being that the executable code would crash. This bug took some serious effort to eliminate. Anyone starting on a similar project might be well advised to buy the C compiler assumed by the stepper motor vendor. At a minimum, that would make the bugs easier to trace, since a symbolic debugger could be used.

The code grew so large that it had to be compiled with the compiler's "large code" option. This is simple in principle, but forced substitution of libraries and some rewriting of the vendor-supplied assembly code.

It was discovered in the field at Sandy Hook that simply flushing the output buffer with the fflush() call does not protect a file if power is lost before closing it. Manual backups were done at Sandy Hook, but some more automatic backup procedure could be added to these programs.

7.3. File NAVIG.H, the Application-Specific Header File. Most of the new code makes use of these declarations and definitions.

```
struct ptsph
  {
   double wlong, nlat, height ; /* W longitude, N latitude, elev mn hi wtr  */
   char *name ;   /* e. g., "Empire State"  */
  } ;
typedef struct ptsph ptsph_t ;

struct vcsph
  {
   double dist, bearing, alt ;  /*  naut mi, deg E of N, deg above level  */
   char *nm_tail, *nm_head ;
  }  ;
typedef  struct vcsph vcsph_t  ;

struct stick{int x,y ;
             int btn1, btn2 ;
            } ;
typedef struct stick stick_t;
stick_t *joy(), *ctr0() ;

typedef struct sp{int xcen, ycen ;
                  int xfac, yfac ;
                 } stkpm_t ;

typedef struct
  {long int serial ;
   char name[51];
   ptsph_t loc ;  /* location in 3-D on sphere  */
   char flash[21] ;  /* (flash) characteristic */
   int range ;  /* range in nautical miles  */
  } light_t ;

typedef struct
  {COUNT movit ;  /*  window number for movit window  */
   COUNT calib ;  /*  window for calib procedure  */
   COUNT count ;  /*  x & y counts  */
   COUNT check ;  /*  window to check calibration  */
   COUNT dir ;  /*  current aim direction, az & alt  */
   COUNT general ;  /*  general menu  */
   COUNT indat ;  /*  input the actual data  */
   COUNT ll ;  /*  light list window  */
   COUNT revdat ;  /*  data review window  */
   COUNT stick ;  /*  window for joystick setup only  */
   COUNT drive ;  /*  drive to direction  */
```

```
   COUNT status ;  /*  you guessed it  */
  } vc_window_number_t ;

#ifndef WDO_SETUP
extern vc_window_number_t wno ;
#else
vc_window_number_t wno ;
#endif

char *dmstr() ;
double degmin_in() ;
int stk_actv(), upd_count(), upd_dir() ;
long int az2ct(), alt2ct(), ang2ct() ;

#define PI (double)3.14159265358979
#define FT7 (double)57.29577951308232  /*  180/π  */
#define R (double)20901500.0   /*  radius of Earth in feet  */
#define GAMEPORT  0x201
#define DM2DD(deg,min) (deg>=0.0 ? (deg)+(min)/60.0 : (deg)-(min)/60.0)
```

7.4. File TRYJOY.C, the Main Program. As the name implies, this started out with a routine to test the joystick routines, which became the main routine. This is in the spirit of a one-time project.

7.5. File JOYSTK.C, Containing Routines Pertaining to Joystick. The user must be allowed to adjust the potentiometers on the joystick, for hardware centering. Then software centering must be done so that the joystick output can be converted to an interval centered on (0,0). Finally, the actual joystick readings must be taken, and optionally converted to zero-centered form. These chores are handled by the routines in this file.

7.6. File TRIG.C, Mainly Routines that Deal with Trigonometry. Some of the shorter and more interesting routines in this file are reproduced here, including the one that does the spherical trigonometry, getvec().

```
/**********************************/
/*  file trig.c                   */
/*  catch-all for routines that   */
/*  deal with deg, min, spherical */
/*  trig, etc.                    */
/*                                */
/*  Jim Worthey, 1987 August 14   */
/**********************************/

#include <math.h>
#include <vcstdio.h>
#include <time.h>
#include "navig.h"
#define ABS(X) (X>=0?X:-(X))
/*************************************************************************/
```

```
/*  function dmstr(), returns a pointer to a string in which a degree value */
/*    is expressed as degrees, minutes, and decimal fractions of a minute.  */
/*  Jim Worthey, 1987 June   */
/****************************/

char *dmstr(degree)
   double degree;

{
   int wholdeg ;
   int jj, c ;
   double minute ;
   static char buff[33], sign ;
      /* >= seems to fail w/ double:  */
   if(ABS(degree) > (double)999.0) return(NULL) ;
   sign = ((float)degree >= 0.0) ? ' ' : '-' ;
   wholdeg = (degree = fabs(degree)) + 0.5/60000.0 ; /* round up within 0!0005
*/
   minute = 60.0*(degree-wholdeg) ;
   if((float)minute < 0.0) minute = 0.0 ;
   sprintf(buff,"%c%3d  %6.3f",sign,wholdeg,minute) ;
   buff[4] = 248 ;
   for(jj=0 ; c = buff[jj] ; jj++)
     { if(c == '.') buff[jj] = '!'; }
   return(buff) ;
}
```

```
/***********************************/
/*  getvec()                       */
/*  finds vector between 2 points  */
/*  on a sphere, working structure */
/*  to structure.                  */
/*                                 */
/*  Jim Worthey, 1987 June         */
/***********************************/

getvec(tail, head, vector)
ptsph_t *tail, *head  ;
vcsph_t *vector  ;

{
   double A, B, C, a, b, c ;  /*  cf. diagram 87 May 14  */
   double rprime, hprime, D, alfa  ;

   a = (90.0 - tail->nlat) / FT7  ;
   b = (90.0 - head->nlat) / FT7  ;
   C = (tail->wlong - head->wlong) / FT7  ;
   c = acos(cos(a)*cos(b) + sin(a)*sin(b)*cos(C))  ;
   B = acos((cos(b) - cos(a)*cos(c))/(sin(a)*sin(c)))  ;
   if(C<0.0) B = 2.0*PI - B  ;
   vector->dist = FT7*60.0*c  ;  /*  result in nautical miles  */
   vector->bearing = FT7*B  ;
/*  Now do a round-earth determination of altitude in degrees:  */
   rprime = R + tail->height ;
   hprime = head->height - tail->height ;
   D = sqrt( (rprime*rprime + rprime*hprime)*c*c + hprime*hprime) ;
   alfa = (-PI/2.0) + asin( (R+head->height)*sin(c)/D );
   alfa = ((R+head->height) > (rprime/cos(c)) ) ? fabs(alfa) : -fabs(alfa) ;
   vector->alt = FT7*alfa  ;
   vector->nm_tail = tail->name ;
   vector->nm_head = head->name ;
}

/****************************************************************/
/*  dmnum(),  convert (double)degrees to (double)whole_degrees */
/*  and (double)decimal_minutes.                                */
/*                                                            */
/*  Note that the reverse function is a macro in navig.h,  */
/*  DM2DD(deg,min).             */
/*                            */
/*  Jim Worthey, 87 Aug 28    */
/******************************/

void
dmnum(deg,wholdeg,decmin)
 double deg, *wholdeg, *decmin ;
{
 double ad, wd, dm ;
```

```
#define ZERO (double)0.0
 ad = fabs(deg) ;
 wd = deg >= ZERO ? floor(ad) : -floor(ad) ;
 dm = (ad - fabs(wd))*60 ;
 *wholdeg = wd ;
 *decmin = dm ;
}

/*************************/
/* char *Casio()          */
/* returns date and time   */
/* as a string in Japanese  */
/* watch format .          */
/*                        */
/* Jim Worthey           */
/* 87-09-20, 22:11:04    */
/**********************/

/*  #include <time.h>   {this is @ top}  */

char *
Casio()
{struct tm tim ;
 static char buf[19] ;
 dostime(&tim) ;
 sprintf(buf,"%2d-%02d-%02d, %2d:%02d:%02d",
 tim.tm_year,tim.tm_mon+1,tim.tm_mday,tim.tm_hour,tim.tm_min,tim.tm_sec ) ;
 return buf ;
}
```

7.7. File LITES.C, Just Routines Pertaining to Reading in the Light List. Since the calibration depends on knowing the latitude and longitude of distant landmarks (say 1-10 nautical miles away), data on some aids to navigation and other landmarks are read from a file named LIGHT.LST, by a routine in this file.

7.8. File MOTOR.C, Motor Control Routines and Much of the Window Code. The original rationale of this file was to collect the routines that directly control the stepper motors, but it grew far beyond that. All stepper control is done through movit(). This lets the other routines use signed long integers (32 bits) to represent movements, while the actual motor control subroutines (in assembly language) demand unsigned integers (16 bits) plus a separate direction control parameter. Long integers xcount and ycount are the integer versions of true azimuth and altitude, with 72000 counts to a full circle. Several of the routines to display the windows need access to xcount, ycount, so the windowing code is included here. This is by far the longest file.

7.9. Data File LIGHT.LST. This is typical of the files from which light list information was read. Different versions were used at different times in the field. Lines beginning with asterisks are comment lines that are ignored when the information is read in. The second comment is the key to the data lines.

```
*  NEW YORK HARBOR (Chart 12327)
* No., Name & location, N/W, Characteristic, Ht, Range
*
* Ambrose Channel
32095, Lighted Whistle Buoy A, 40 28.8  73 53.7, Mo (A) W, 0, 6
32100, West Bank (Range Front) Light, 40 32.3 74 02.6, See LL, 69, 16
32105, Staten Island (Range Rear) Light, 40 34.5 74 08.6, F W direc, 231, 18
32275, Robbins Reef Light, 40 39.4  74 04.0, Fl W 6s, 56, 9
32340, Sandy Hook Light, 40 27.7 74 00.1, F W, 88, 19
32370, Romer Shoal Light, 40 30.8  74 00.8, Fl (2) W 15s, 54, 13
32385, Scotland Lighted Horn Buoy S, 40 26.5  73 55.0, Mo (A) W, 0, 0
32480, Sandy Hook Point Light, 40 28.3  74 01.2, Iso W 6s, 38, 15
23, Bug Light, 40 28.59  74 1.07, Fl 2.5s, 25, 6
* Chapel Hill South Channel
32485, Range Front Light, 40 25.3  74 03.4, Iso G 6s, 45, 0
* Old Orchard Shoal
32700, Old Orchard Shoal Light, 40 30.7  74 06.0, See LL, 51, 8
32710, Great Kills Light, 40 31.3  74 07.9, Fl W 4s, 35, 6
32850, Atlantic H'lnds Brkwtr Light, 40 25.1  74 01.2, Fl W 4s, 29, 7
16, Coney Island Light, 40 34.59  74 00.73, Fl R 5s, 75, 16
* Our Viewing Points
99999, Beach I - along path, 40 28.1  73 59.9, NA, 12, 0
99998, High rise #877-room 516, 40 41.247 74 1.493, NA, 77, 0
* Landmarks not on the Light List (some heights are guesses):
15, Sandy Hook Standpipe, 40 28.1  74 00.5, Dark, 100, 0
18, NW light of VZ bridge, 40 36.255  74 3.183, Iso 2s, 500, 0
19, Cars below NW light VZ, 40 36.255  74 3.183, Going by, 200, 0
21, SE light of VZ bridge, 40 36.493  74 2.32, Iso 2s, 500, 0
22, Cars below SE light VZ, 40 36.493  74 2.32, Going by, 200, 0
20, Parachute Tower, 40 34.372  73 59.0883, 303, 0
1, Empire State Bldg, 40 44.9 73 59.17, Red??, 1054, 0
2, Liberty's Torch, 40 41.35 74 02.7, White?, 200, 0
4, Brooklyn Pier 2, 40 41.967 74 0.02, F G, 43, 0, 0
5, Brooklyn Pier 2, 40 41.978 73 59.922, F R, 54, 0, 0
6, Brooklyn Red Hook, 40 40.853 74 1.045, Quick G, 0, 0
7, Brooklyn Red Hook, 40 40.9 74 0.883, Iso G 6s, 0, 0
8, World Trade South Bldg, 40 42.65  74 0.817, Red??, 1200, 0
9, World Trade North Bldg, 40 42.717  74 0.82, Red??, 1200, 0
10, Chrysler Bldg, 40 45.088 73 58.545, Red??, 1000, 0
11, Ritz Bldg, 40 45.69  73 58.233, Red??, 800, 0
13, Bkln Br NW Tower, 40 42.428  73 59.687, ??, 400, 0
14, Bkln Br SE Tower, 40 42.237  73 59.687, ??, 400, 0
-1
```

7.10. **Program FILTER.C, Self-Contained Program to Translate Ampersands.** The data files were recorded just the way they appear in Chapter 2, with the ampersands (&'s) and newline characters. To make the data readable by Lotus 1-2-3, it is necessary to eliminate all comments and calibration notes, then to eliminate some of the newlines, so that each data set appears on one long line. The comments and calibration notes are easily deleted with a line editor; the following filter program eliminates all newlines except those followed by an ampersand.

The "file import" function in 1-2-3 has the limitation that it can only accept files up to 8192 characters long. To help cope with this, FILTER puts an extra blank line after about 7900 characters. With the blank line as a marker, it is easy to break up the longer data files with the help of a line editor.

```
  /*  This program is adapted from cat.c on p. 154 of the
      Kernighan and Ritchie text
  */
#include <stdio.h>

main(argc, argv)    /* filter: revise data files */
int argc;
char *argv[];
{
    FILE *fp, *fopen();

    if (argc == 1) /* no args; copy standard input */
      filecopy(stdin);
    else
      while (--argc > 0)
         if ((fp = fopen(*++argv, "r")) == NULL) {
      fprintf(stderr,
          "filter: can't open %s\n", *argv);
      exit(1);
         } else {
      filecopy(fp);
      fclose(fp);
         }
    exit(0);
}

filecopy(fp)   /* copy file fp to standard output */
FILE *fp;
{int c,d,nchars,bigenuf,notyet=1;
#define RETURN 13
#define LINEFEED 10
 if( (d = getc(fp)) == EOF)
   return 0 ;
 nchars = 1 ;
 while ((c = getc(fp)) != EOF)
  {bigenuf = (nchars++ > 7900) ;
   switch(d)
```

```
    {
    case RETURN:
       break;
    case LINEFEED:
       if(c == '&')
         {putc(RETURN, stdout);
          putc(LINEFEED, stdout);
          if(bigenuf && notyet)
            {putc(RETURN, stdout) ;
             putc(LINEFEED, stdout) ;
             putc(RETURN, stdout) ;
             putc(LINEFEED, stdout) ;
             notyet = 0 ;
            }
         }
       break;
    default:
       putc(d, stdout);
    }
   d = c ;
  }
}
```

Chapter 8. Recommendations for Future Work.

8.1. Apparatus Improvements. As mentioned previously, a shortcoming of the apparatus was that the stepper motors barely had the torque to move the Pritchard plus its objective lens without slipping (losing the count). Some of the data may be contaminated by slippage on the order of tens of pulses. Remembering that there are 72000 pulses per revolution in either axis, this slippage does not destroy the significance of the data.

Except for this slippage, the apparatus must be considered a successful design. The aiming device as built seems to represent a fair compromise between rigidity and light weight. (It is now about at the limit of tolerable weight and unwieldiness for field equipment.) The software permits the data to be taken quickly, and gives some flexibility to correct errors and otherwise deal with the unexpected.

Therefore, if further data on distant lights are sought in the future, it would make sense to use the same apparatus, but to deal with the problem of slippage. The best way to do this is to replace the stepper motors and the driver module. A constant-current driver could be used, along with motors that have about twice the stall torque and are matched to the electrical characteristics of the new driver. These parts can be substituted while leaving the other hardware and the software unchanged. The constant-current driver is distinguished by its ability to maintain full torque at high speed; therefore, the speed settings could be increased, giving a quicker response to aiming commands, while still reducing slippage.

An additional improvement to the aiming device would be to use stepper motors with shaft encoders and provide position feedback to the software. This would be much more complicated to implement, involving extensive hardware and software problems, and is *not* recommended.

With the aiming device improved in reliability, further data-taking should be approached a little differently. Measurements should be scheduled in seasons when the air is clear, either spring or fall, but when it is not too cold to work out of doors. Data can be taken most quickly at an unobstructed out-of-doors location, such as a roof or a beach. In spite of any speed-up, much more time should be budgeted for the actual data-taking, to permit a more painstaking approach and to allow for bad weather.

A totally optional apparatus improvement would be to let the computer get the luminance reading directly from the Pritchard. A binary-coded-decimal signal is available as parallel TTL voltages on the particular instrument used. The hardware cost would be small. New software would be needed, not only to decode the signal, but also to compute a time-average at the proper moment. This would be justified if much larger sets of data were to be collected. It would not have been justified for the present project.

Any future scheme to collect data with an imaging device such as a sensitive video camera should still use the aiming device and its software because of the overriding benefits of true calibration of azimuth and altitude. With true aiming calibration, you can kick the tripod or take a three-day break for bad weather, or anything, then recalibrate and have data that will make sense with a minimum of questions on how to splice the data sets together.

8.2. Further Data Analysis. An obvious conclusion from the data is that most of the background lights which interfere with vision of navigational aids are streetlights. Streetlights will of course differ with respect to lamp wattage and type, lens design, and orientation. In spite of these complications, it might be interesting to see how well the data can be explained by assuming that all streetlights are alike and that all illuminance differences are due to the inverse square law and atmospheric attenuation. The distances to the streetlights measured could be estimated using maps and the azimuths at which they were seen. Such an explanation of the data could lead a rule-of-thumb formula for interfering illuminances, involving just the distance to lit streets on shore.

8.3. Summary and Conclusions. The summary and conclusions are not in this chapter, they are in Section 3.6.

REFERENCES

1. Richard A. Walker, "Optical systems for defining the viewing and measuring fields in luminance/radiance meters," *Applied Optics* **9**, 2060-2068, 1972.

2. Günter Wyszecki and W. S. Stiles, *Color Science*, first ed. (John Wiley, New York, 1967), p. 569.

3. Department of Transportation, United States Coast Guard, *Light List, Volume 1: Atlantic Coast*, COMDTINST M16502.1 (U. S. Government Printing Office, Washington, 1987).

4. James A. Worthey, *Global Features of Color Rendering and Vision Difficulties under Fluorescent Lights*, Doctoral Dissertation, Indiana University (Bloomington), 1981.

5. Günter Wyszecki and W. S. Stiles, *Color Science*, first ed. (John Wiley, New York, 1967), p. 47.

6. Gerald L. Howett, *Emergency vehicle warning lights*, National Bureau of Standards Special Publication 480-16, 1978.

7. Gerald L. Howett, "The coming redefinition of photometry," *Journal of the Illuminating Engineering Society* **15**, 5-18.

8. Günter Wyszecki and W. S. Stiles, *Color Science*, first ed. (John Wiley, New York, 1967), p. 390.

9. Günter Wyszecki and W. S. Stiles, *Color Science*, first ed. (John Wiley, New York, 1967), p. 373.

10. William Marshall Smart, *Textbook on Spherical Astronomy*, Sixth Edition revised by Robin Michael Green (Cambridge University Press, Cambridge, 1977).

11. Photo Research Division, *Instruction and Maintenance Manual for the Spectra Pritchard Photometer* (Photo Research, Burbank, 1973).

NBS-114A (REV. 2-80)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET** *(See instructions)*	1. PUBLICATION OR REPORT NO. NBSIR 88-3807	2. Performing Organ. Report No.	3. Publication Date JUNE 1988

4. TITLE AND SUBTITLE

Lights of New York Harbor

5. AUTHOR(S)

James A. Worthey

6. PERFORMING ORGANIZATION *(If joint or other than NBS, see instructions)*

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS *(Street, City, State, ZIP)*

Coast Guard Research and Development Center
U.S. Department of Transportation
Avery Point
Groton, Connecticut 06340-6096

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

This report presents measurements on shore lights of the New York harbor area, taken from three observation points. In particular, measurements were made of the illuminance at the observation point due to distant lights, considered to be point sources. This is a measure of point source intensity appropriate to this situation, and quantifies what a mariner will see sailing into or out of New York harbor at night. The measurments are of interest because lights on shore make it hard to see the lights maintained by the U. S. Coast Guard as aids to navigation. One conclusion is that most of the interfering lights are high-pressure sodium vapor lamps used to light the streets, roads, and docks. The distributions of the lights in intensity, position, and color are presented graphically.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

Aids to naviagtion; Aiming device; Buoy; Lighthouse; Photometry; Signal lights.

13. AVAILABILITY

☒ Unlimited
☐ For Official Distribution. Do Not Release to NTIS
☐ Order From Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.
☒ Order From National Technical Information Service (NTIS), Springfield, VA. 22161

14. NO. OF PRINTED PAGES

91

15. Price

$13.95

USCOMM-DC 6043-P80