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WINDOW: A COMPUTER PROGRAM FOR PLANNING ASTRONOMICAL OBSERVATIONS

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16. Abstract

A FORTRAN computer program called "WINDOW" has been written to simplify the planning of astronomical observations of a number of objects in a limited time. The program lists the azimuths at 15 minute intervals of up to 20 objects while they are in a given range of elevation angles — the window — and gives the elevation angle of each object at its time of transit. This work was motivated by the need to use observing time efficiently on flights of NASA-Ames' Lear Jet and C-141 observatories; WINDOW permits the investigator to prepare preliminary flight plans. However, the program is suited to planning ground-based observations as well. The program and a sample flight plan are described.

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WINDOW: A COMPUTER PROGRAM FOR PLANNING ASTRONOMICAL OBSERVATIONS

by

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Abstract

A FORTRAN computer program called "WINDOW" has been written to simplify the planning of astronomical observations of a number of objects in a limited time. The program lists the azimuths at 15 minute intervals of up to 20 objects while they are in a given range of elevation angles—the window—and gives the elevation angle of each object at its time of transit. This work was motivated by the need to use observing time efficiently on flights of NASA-Ames' Lear Jet and C-141 observatories; WINDOW permits the investigator to prepare preliminary flight plans. However, the program is suited to planning ground-based observations as well. The program and a sample flight plan are described.

Planning astronomical observations from the Lear Jet and C-141 observatories operated by NASA-Ames is complicated by the following considerations: (1) the telescopes operate in a restricted range of elevation angles or window: 14° - 28° for the Lear Jet, 35° - 75° for the C-141; (2) the flights are of limited duration: $2\frac{1}{2}$ hours for the Lear Jet, $7\frac{1}{2}$ hours for the C-141; (3) the telescopes can view only from the left sides of the aircraft, so that typically only half the flying time can be spent observing sources in a particular area of the sky; (4) the aircraft are moving about 500 miles per hour (air speed). To maximize observing time on a given flight, it is desirable to observe calibration objects and/or other objects when the aircraft is flying to or returning from the path required for observing the objects of primary interest. We developed program WINDOW to simplify (a) selection of feasible objects from a list of candidates, and (b) generation of a preliminary flight plan for use by the navigators.

The program computes and lists the azimuths at 15 minute intervals of up to 20 objects while they are in the window, and gives the elevation angle of each object at its time of transit. The entire calculation is done assuming fixed longitude and latitude for the observatory, so that no correction is made for motion of the aircraft. Since the aircraft heading for our airborne observations is approximately equal to the azimuth of the object plus ninety degrees, southerly objects (observed with the aircraft flying West) will require less heading change than indicated by the program, while northerly objects will require more heading change than indicated.

Typically the program is run for the list of candidate objects using longitude and latitude corresponding to the nominal position of the aircraft during the flight, which often is simply the position of the airfield where the plane is based (37.5° N. latitude 122° W. longitude for Moffett Field).

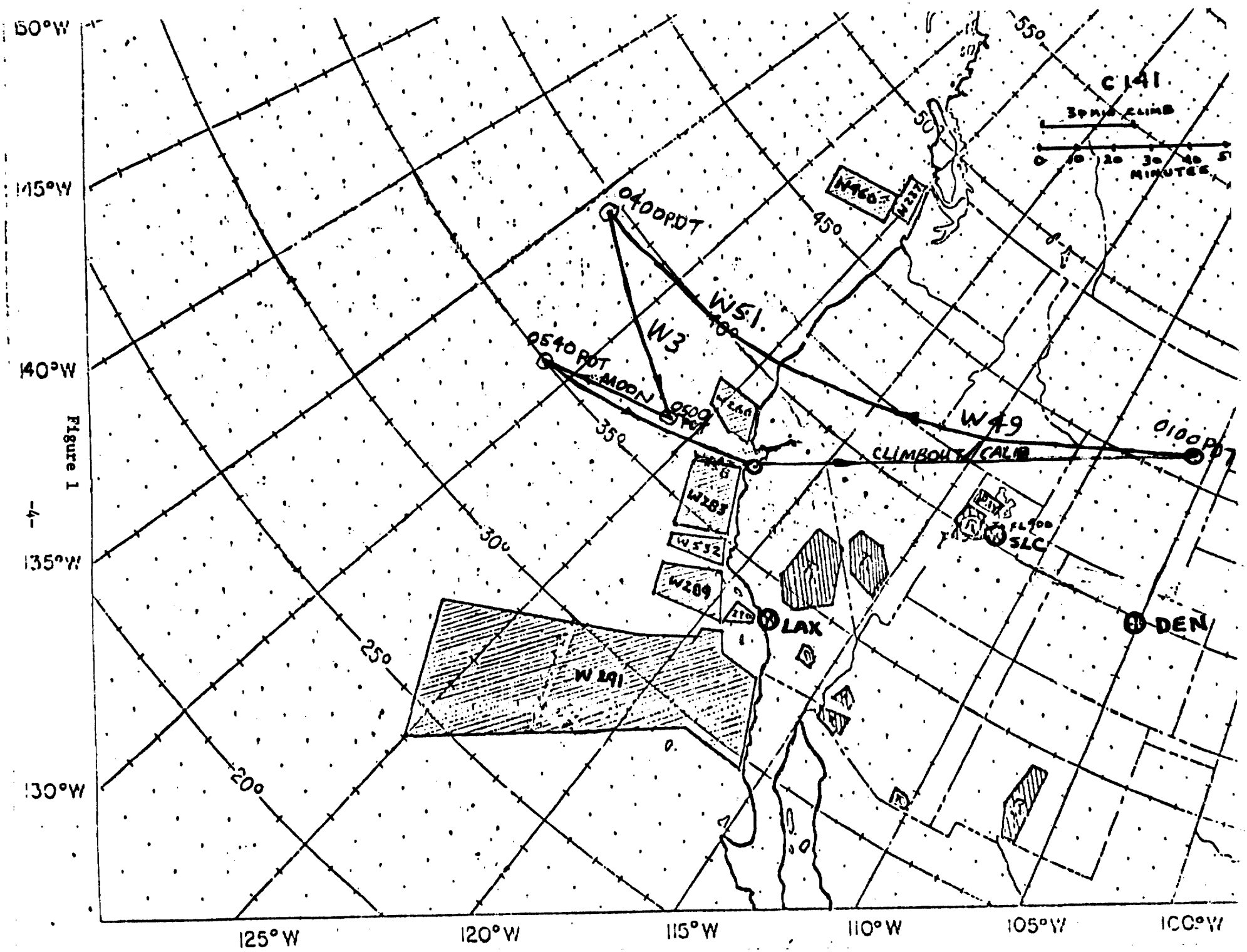
Trajectories of objects shown to be compatible for observation on a given flight are then used to generate a preliminary flight plan. This can be done by the navigators or the investigator. Aircraft trajectories corresponding to the suitable candidate objects are plotted on a map, as shown in Figure 1. Some trial and error is usually involved before the preliminary flight plan is satisfactory; care must be taken to avoid warning areas and international borders.

The detailed flight plan is made starting with the preliminary plan by the navigators. With little practice an investigator can use WINDOW to generate a preliminary plan which will be very close to the navigator's final plan. Successful flight plans with up to 12 observed objects in a 7½ hour flight have been made following this procedure. For ground-based work, the output of program WINDOW is suitable for planning multiple object observations with no further effort.

WINDOW is written in FORTRAN for use on the Ames CDC-7600; copies of the program are available on request from the authors. A version of the program used at NASA-Ames by the navigators runs on their HP 2100 computer.

The beginning of the FORTRAN program contains comment cards describing the use of the program, and a sample of input parameters. A copy of the beginning of the program, and its output corresponding to the flight plan of Figure 1 completes this report.

We are grateful to C. Swift for the coordinate transformation program and to J. Kroupa for the map showing the warning areas in the Western United States.


150°W
145°W
140°W
135°W
130°W
125°W
120°W
115°W
110°W
105°W
100°W
550
500
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400
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300
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C141
30 MIN CLIMB
0 10 20 30 40 5
MINUTES
0400 PDT
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W51
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CLIMBOUT
CALIF
W289
W532
W289
W291
LAX
SLC
DEN
FL 400

Figure 1

```
74/76  OPT=1                    FTN 4.5+413        07/08/76  16.1

      PROGRAM MOONS(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)
C
C  A PROGRAM TO FACILITATE PLANNING ASTRONOMICAL OBSERVATIONS OF UP TO 20 OBJECTS
C  *** INPUT *** FOR ALL CARDS COLUMNS 71 - 80 CAN BE USED FOR IDENTIFYING LABEL
C                SOUTH DECLINATIONS AND LATITUDES AND EAST LONGITUDES MUST BE
C                NEGATIVE ENTRIES THROUGHOUT
C                THE MAXIMUM DURATION FOR AN OBSERVATION IS 14 DAYS
C                   1.START OF OBSERVATION CARD (DAY,MONTH,YEAR,HOURS LOCAL TIME
C                   2. END  OF OBSERVATION CARD (DAY,MONTH,YEAR,HOUR) LOCAL TIME
C                    BY THE FOLLOWING FORMAT I2,A3,I2,3X,F10.2
C                   3.LATITUDE & LONGITUDE OF PLACE OF OBSERVATION (DEG,MIN,SEC)
C                    BY THE FOLLOWING FORMAT 6F10.2
C                   4.DIF IN HRS BETWEEN GREENWICH & OBSERVERS STANDARD MERIDIAN
C                    BY THE FOLLOWING FORMAT F10.2
C                   5.UPPER AND LOWER WINDOW ELEVATION ANGLES (DEGREES)
C                    BY THE FOLLOWING FORMAT 2F10.2
C                   6.NUMBER OF OBJECTS (N)
C                    BY THE FOLLOWING FORMAT F10.2
C                   7.OBJECT CARDS (UP TO 20 DIFFERENT OBJECTS)
C                    COLUMNS 1 - 10 AN ALPHAMERIC LABEL FOLLOWED BY THE RIGHT
C                    ASCENSION (HOURS,MINUTES,SECONDS) AND THE DECLINATION
C                    (DEGREES,MINUTES,SECONDS)
C                    BY THE FOLLOWING FORMAT A10,6F10.2
C     IF THE SUN IS DESIRED AS AN OBJECT SIMPLY LABEL A CARD AS "SUN       "
C      THE PROGRAM WILL THEN CALCULATE THE POSITION OF THE SUN (ACCURATE TO
C      WITHIN 10 SEC (150 ARCSEC) THROUGH 2000)
C     IF THE MOON IS DESIRED AS AN OBJECT, TWO OPTIONS ARE AVAILABLE
C      1.IF ONLY ONE CARD IS READ IN, THE MOON WILL BE TREATED AS A STATIONARY
C       OBJECT AND NO CORRECTION FOR POSITION ON THE EARTH WILL BE MADE
C      2.TO UPDATE THE MOONS POSITION AS A FUNCTION OF TIME AND CORRECT FOR THE
C       OBSERVATION POSITION ON THE EARTH, 3 OR MORE INPUT CARDS MUST BE USED,
C       THE FIRST CARD MUST GIVE THE POSITION OF THE MOON FOR 0 HR U.T. THE DATE
C       OF THE BEGINNING OF THE OBSERVATION, SUBSEQUENT CARDS MUST GIVE THE
C       POSITION OF THE MOON FOR 0 HR U.T. ON SUBSEQUENT DATES, THE LAST CARD
C       MUST GIVE THE POSITION OF THE MOON FOR 0 HR U.T. ON THE DAY FOLLOWING
C       THE DATE OF THE END OF THE OBSERVATION.  FOR THIS OPTION THE LABEL MUST
C       BE "MOON      "
C**** FOR CLARITY A SAMPLE SET OF INPUT CARDS IS GIVEN NEXT**********************
C15JUN76    18.                                                    START OBS
C18JUN76    10.                                                    END OBS
C37.        25.         0.          122.        3.          0.     NASA-AMES
C7.                                                                DIF IN HR
C35.        75.                                                    WINDOW

C9.                                                                # SOURCES
CSUN
CMOON       20.         7.          37.         -15.        -1.         -18.    15 JUN 76
CMOON       21.         0.          12.         -11.        -39.        -21.    16 JUN 76
CMOON       21.         49.         54.         -7.         -50.        -11.    17 JUN 76
CMOON       22.         37.         22.         -3.         -46.        -42.    18 JUN 76
CMOON       23.         23.         19.         0.          20.         33.     19 JUN 76
CJUPITER    3.          8.          18.         16.         36.         30.     16 JUN 76
C*51        19.         21.         22.         14.         25.         10.
C*49        19.         7.          50.         9.          1.          12.
CNGC7538    23.         11.         24.         61.         14.         0.
C*3         9.          21.         50.         61.         52.         54.
CDR21       20.         37.         14.         42.         9.          20.
C*17        18.         17.         33.         -16.        -12.        -15.
```


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WINDOW OUTPUT

```
START OBSERVATION  15 JUN 76  AT 1800 HOURS LOCAL TIME
 END  OBSERVATION  18 JUN 76  AT 1000 HOURS LOCAL TIME

OBSERVER LATITUDE =   37. DEGREES    25. MINUTES     0. SECONDS
OBSERVER LONGITUDE=  122. DEGREES     3. MINUTES     0. SECONDS

DIF IN HRS GREENWICH & OBSERVERS STANDARD MERIDIAN=  7.

WINDOW LOWER ANGLE=  35. DEGREES,  UPPER ANGLE=  75. DEGREES

GREENWICH SIDERIAL TIME & POSITION OF SUN FOR 0 HR U.T.  15 JUN 76
   GREENWICH SIDERIAL TIME=  17. HOURS   35. MINUTES   36. SECONDS
   POSITION OF SUN  R.A.=   5. HRS   33. MIN   58. SEC    DEC.=  23. DEG   18. MIN   19. SEC

NUMBER OF OBJECTS (MAX=20) =   9
```

OBJECT		R.A.(HRS	MIN	SEC)	DEC.(DEG	MIN	SEC)
1	SUN	5.	33.	58.	23.	18.	19.
2	MOON	20.	7.	37.	-15.	-1.	-18.
2	MOON	21.	0.	12.	-11.	-39.	-21.
2	MOON	21.	49.	54.	-7.	-50.	-11.
2	MOON	22.	37.	22.	-3.	-46.	-42.
2	MOON	23.	23.	19.	0.	20.	33.
3	JUPITER	3.	8.	18.	16.	36.	30.
4	M51	19.	21.	22.	14.	25.	10.
5	M49	19.	7.	50.	9.	1.	12.
6	NGC7538	23.	11.	24.	61.	14.	0.
7	W3	2.	21.	50.	61.	52.	54.
8	DR21	20.	37.	14.	42.	9.	20.
9	M17	18.	17.	35.	-16.	-12.	-15.

SIDERIAL	OBJECT 1	OBJECT 2	OBJECT 3	OBJECT 4	OBJECT 5	OBJECT 6	OBJECT 7	OBJECT 8	OBJECT 9	OBJECT 10	OBJECT 11	OBJECT 12	OBJECT 13	OBJECT 14	OBJECT 15	OBJECT 16	OBJECT 17	OBJECT 18	OBJECT 19	OBJECT 20	LOCAL

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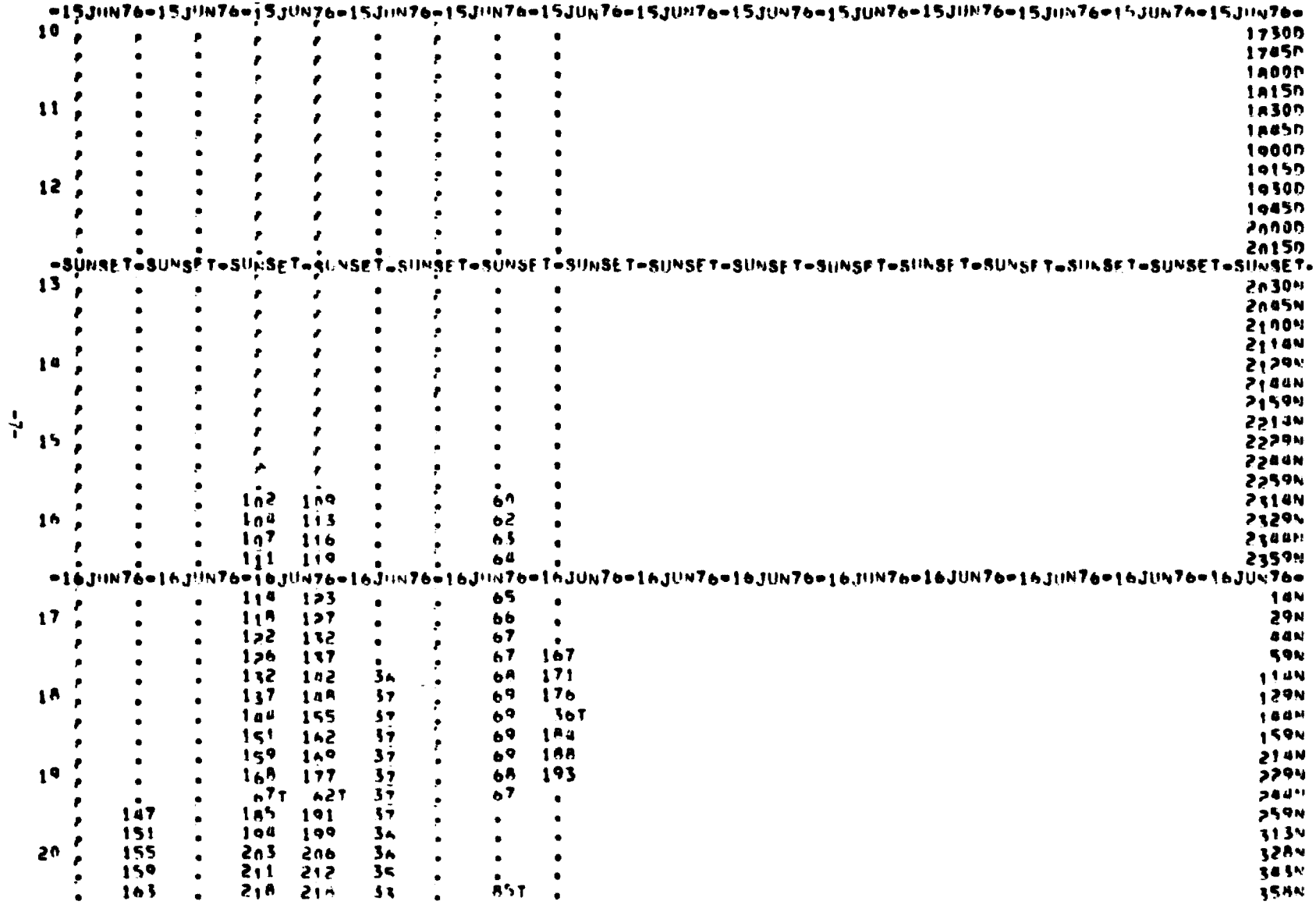
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122 132 67
126 137 67 167
132 142 34 68 171
137 148 37 69 176
144 155 39 69 36T
151 142 39 69 184
159 169 37 69 188
168 177 37 68 193
97T 42T 37 67
147 185 191 37
151 194 199 34
155 203 206 34
159 211 212 36
163 218 218 38 85T
14N
29N
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