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S. N. Landon

The Mount Performance of the Second GEODSS Telescope

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LEXINGTON, MASSACHUSETTS

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This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

THE MOUNT PERFORMANCE OF THE SECOND GEODSS TELESCOPE

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Group 94

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ABSTRACT

The second GEODSS telescope has an improved drive system consisting of a single DC drive motor on each axis. This arrangement should provide a stable and reliable drive system for the telescope, which is driven by incremental encoders. Measurements on the response of the telescope to computer commanded rates were therefore taken. These measurements were made via two computer programs; one sends rate commands to the telescope, and the other monitors the resulting positions of the telescope. The results of these measurements show that this telescope responds very accurately to rate commands over the range of most interest to us: $\pm$ 400 arc seconds per second. Data is also presented on the performance of the telescope with the Real-Time System. Specifically, the step and settle time of the telescope over a 3.7 degree field is examined. That field corresponds to the overlapped full field on the 14 inch telescope. A very satisfactory step and settle time of approximately 2 seconds has been achieved by the telescope for that case.

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INTRODUCTION

The reliable performance of the GEODSS telescope in response to computer generated rate commands is important. That is, the mount should travel at or near to the commanded rate and should not deviate significantly from it. Measurements of these responses were therefore made. The discussion of the method of measurement and of the data, which appears in Tables I and II, comprises the Sections I and II.

A further performance measure of the telescope mount is its ability to make a smooth transition between the rapid or 'slew' rate and the slower (0 - 200 arc seconds per second) rates of telescope travel. Such a test is readily available in the GEODSS Real-Time System software. The performance of the mount in this case is therefore discussed in Sections III and IV, and data on the Real-Time System performance of the telescope is presented in Table III.

I. THE METHOD OF TELESCOPE RATE MEASUREMENT

These measurements were taken at rates of 0 to 400 arc seconds per second by two concurrently running computer programs. One program sends out rates to the telescope, and the other monitors the position of the telescope 20 times a second. All data was taken with the programs running on a stand-alone basis in the MODCOMP IV computer so as to avoid the possibility of errors in the timing of the measurements. The data was taken in September 1977.

The binary command code for the null or stopped rate of the telescope and the rate maxima on both axes were dynamically determined by the program to insure the precision of the rate calculations. The rates are linearly spaced between the null rate and the rate maxima. The null rate code and the maximum rates can vary due to temperature, telescope balance and the current number of cameras and auxiliary telescopes that must be driven by the mount. Dynamic determination of these quantities controls for these factors. In any case, the null rate code and the rate maxima are reasonably stable for this telescope.

The telescope was then commanded to travel at rates from 0 to 400 arc seconds per second in steps of 25 arc seconds per second, beginning with 25 arc seconds per second. The telescope was commanded to remain at each rate for 10 seconds.

Initially, the telescope was positioned at the zenith. It next traveled in the north and east directions because the positive rates were tested first. When the signs of the rates were reversed, the telescope returned roughly to the zenith. Both axes were driven simultaneously during the entire experiment.

These measurements were therefore principally taken in the north and in the east. They cover elevations ranging from 20 to 90 degrees. As data on both directions on each axis shows the same behavior, the elevation angle is clearly not a significant factor in the mount performance of this telescope.

The telescope positions were then differenced at intervals of one second. The first second of data was discarded so as to exclude the effect of acceleration. Because the telescope accelerates at a rate in the vicinity of .5 degree per second^2, discarding one second of data should completely eliminate the effect of a rate increase of 25 arc seconds per second.

The remaining nine rates were then averaged so as to determine the effective telescope rate over the interval. The standard deviation of the rates was also computed to provide a measure of the typical error in the rates. This deviation is of interest because the computer must maintain as nearly constant a rate of the telescope as possible.

II. EXPLANATION OF THE TABLES OF RATE MEASUREMENTS

The rate measurement data is presented in two tables. The first table shows a summary of the results obtained. The 'mean rate' is the average of the 9 rates obtained at each commanded rate; the nine rates were in turn computed by the differencing of 9 seconds of data. The 'error' is the difference between the mean telescope rate and the commanded rate.

Table II provides greater detail. The nine rates are tabulated, and the standard deviation, the mean rate and the rate deviation are also printed. The 'rate deviation' is the difference between the mean telescope rate and the commanded rate.

III. TELESCOPE STEP AND SETTLE TIMES

One important measure of the effectiveness of the telescope drive system for this application is the step and settle time of the telescope. The minimizing of that time allows for significantly improved scan coverage rates. Because the GEODSS project has as a major task the autonomous search for satellites, minimizing telescope travel times between fields of view of the telescope during such searches is important.

Equatorial scans are used to locate synchronous or near synchronous satellites. In order to effectively cover the entire equatorial belt, a wide field of view of the telescope coupled with minimum step and settle times of the mount is needed. Therefore, for equatorial searches, some sensitivity may be sacrificed for speed. That is, the 14 inch camera may be used in place of the 31 inch one. The 14 inch camera has a 7 degree diagonal field of view.

From the standpoint of the computer, use of the 14 inch telescope means that the telescope mount must be driven 3 to 4 degrees between fields of view instead of one degree as with the 31 inch telescope. The amount of overlap and the rectangular shape of the field of view are the reason that the range of 3 to 4 degrees is specified.

The use of a single DC motor to drive each axis of the mount allows for a smooth transition between rapid telescope travel - that is, rates of 4 degrees per second - and the slower rates. This smooth transition permits the use of rapid telescope travel between scan fields of view when the distance to be traveled exceeds one degree.

The 4 degree per second rate is consequently used to cover the majority of the distance between successive fields of view for the 14 inch telescope scans. Once the telescope is reasonably close to the target location, the slower rates are used so that the telescope will not overshoot. With this arrangement, a step and settle time of approximately 2 seconds is achieved by the telescope when traveling over a 3.7 degree distance; a 5-6 second travel time is obtained over a 15 degree distance. The 15 degree distance is the total distance in declination that the telescope must travel to cover the equatorial belt. There is no overshoot of the telescope in either case.

Table III contains data on the telescope performance of an equatorial scan pattern requiring the travel of the telescope over 3.7 and 15 degree fields.

IV. EXPLANATION OF SCAN PATTERN DATA

Table III contains the time and telescope position in right ascension and declination for two scan lines in an equatorial scan. Travel along the line consists of maintaining a fixed position in right ascension and stepping 3.7 degrees in declination between successive fields of view. The stare time is approximately 11-12 seconds for this case. In the table, redundant telescope positions are not entered separately when the telescope is stopped for the 11-12 seconds of stare time in which the operator and the MTI devices search for satellites.

The line length of the scan was specified as 15 degrees in declination. The program controlling the scan currently returns to the beginning of the line when one has finished. Thus, when the telescope moves to the next line, the step/settle time increases due to the greater distance the mount must travel.

It should be noted that the right ascension position changes slightly between steps along the declination axis. This motion is partly caused by the tolerance set for the purpose of minimizing telescope travel time; the telescope will attempt to complete its travel if it did not do so on the last cycle. Also, this scan was specified about a fixed azimuth and elevation rather than a right ascension and declination. Thus, as time progresses, the right ascension will change slowly. This change in right ascension is, however, not sufficient to interfere with the overlapping of successive fields of view.

One final phenomenon should be noted. In order to allow the same software to run on both telescopes, rapid travel on one axis disallows slow movement on the other axis. This arrangement reflects the multiple motors in the first telescope drive system. The effect of this restriction may be seen in the initially stationary right ascension position when the declination axis begins moving very rapidly. The right ascension axis then moves slowly once the declination axis reduces its speed. If this restriction were not in force, the right ascension axis would have begun moving at the same time as the declination one.

V. CONCLUSIONS

The telescope rate measurement data shows that the error in the mean rate seldom exceeds two arc seconds per second and frequently is zero. A very good response to rate commands is therefore produced by this telescope, especially considering that there is a 1.5 arc second per second granularity in the rates that the computer may send out to the telescope.

The standard deviation of the rates obtained varies between 0 and 7 arc seconds per second. These deviations indicate the need for the software to monitor the telescope frequently so as to reduce their size. This is, however, an expected phenomenon, and the variations are within a reasonable range.

The measurements on the second telescope rates therefore indicate that the mount is responding accurately to rate commands in the region of prime interest to us: $\pm$ 400 arc seconds per second.

Further, the achievement of a two second telescope step and settle time over a 3.7 degree field of view indicates that the single motor drive system provides effective performance of the mount at a combination of fast and slow rates.

TABLE I

TELESCOPE RESPONSE TO RIGHT ASCENSION RATE COMMANDS

COMMANDED VS ACTUAL RATES

UNITS ARE ARC SECONDS/SECOND

RATE	DATA	ERROR
-400	-398.3	1.7
-375	-373.3	1.7
-350	-348.3	1.7
-325	-323.3	1.7
-300	-298.3	1.7
-275	-273.3	1.7
-250	-248.3	1.7
-225	-223.4	1.6
-200	-198.3	1.7
-175	-173.3	1.7
-150	-150.0	0.0
-125	-125.0	-0.0
-100	-100.0	0.0
-75	-75.0	-0.0
-50	-50.0	0.0
-25	-25.0	-0.0
25	25.0	0.0
50	50.0	0.0
75	76.6	1.6
100	101.7	1.7
125	125.0	0.0
150	150.0	-0.0
175	175.0	0.0
200	200.0	-0.0
225	225.0	-0.0
250	248.3	-1.7
275	275.0	0.0
300	300.0	-0.0
325	323.3	-1.7
350	350.0	0.0
375	373.3	-1.7
400	400.0	-0.0

TABLE I (Continued)

RATE	DATA	ERROR
-400	-397.3	2.7
-375	-372.0	3.0
-350	-348.0	2.0
-325	-323.3	1.7
-300	-298.7	1.3
-275	-272.7	2.3
-250	-247.3	2.7
-225	-224.0	1.0
-200	-198.7	1.3
-175	-173.3	1.7
-150	-148.0	2.0
-125	-122.7	2.3
-100	-99.3	0.7
-75	-74.0	1.0
-50	-48.7	1.3
-25	-23.3	1.7
25	24.7	-0.3
50	49.3	-0.7
75	74.7	-0.3
100	100.0	-0.0
125	125.3	0.3
150	150.7	0.7
175	176.0	1.0
200	199.3	-0.7
225	225.3	0.3
250	250.0	-0.0
275	275.3	0.3
300	300.7	0.7
325	326.0	1.0
350	350.7	0.7
375	374.7	-0.3
400	400.0	-0.0

TABLE II

.TELESCOPE RESPONSE TO RATE COMMANDS

COMMANDED RATE= -400 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-398.3	MEAN RATE=-397.3
RATE DEVIATION= 1.7	RATE DEVIATION= 2.7
STD DEV= 7.5	STD DEV= 3.8
RIGHT ASCENSION RATES	DECLINATION RATES
-404.9	-396.0
-389.9	-402.0
-390.0	-390.0
-405.0	-402.0
-405.3	-396.0
-389.7	-402.0
-405.0	-396.0
-390.0	-396.0
-404.9	-396.0

COMMANDED RATE= -375 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-373.3	MEAN RATE=-372.0
RATE DEVIATION= 1.7	RATE DEVIATION= 3.0
STD DEV= 4.7	STD DEV= 4.0
RIGHT ASCENSION RATES	DECLINATION RATES
-375.1	-366.0
-375.0	-372.0
-374.9	-372.0
-375.1	-378.0
-374.9	-372.0
-360.2	-366.0
-374.9	-378.0
-375.1	-372.0
-374.9	-372.0

COMMANDED RATE= -350 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-348.3	MEAN RATE=-348.0
RATE DEVIATION= 1.7	RATE DEVIATION= 2.0
STD DEV= 6.2	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
-345.1	-342.0
-360.1	-354.0
-344.7	-348.0
-345.2	-348.0
-345.1	-348.1
-345.1	-347.9
-359.9	-348.0
-344.9	-348.0
-344.9	-348.0

TABLE II (Continued)

COMMANDED RATE= -325 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-323.3	MEAN RATE=-323.3
RATE DEVIATION= 1.7	RATE DEVIATION= 1.7
STD DEV= 7.5	STD DEV= 3.4
RIGHT ASCENSION RATES	DECLINATION RATES
-330.0	-330.1
-314.9	-324.0
-330.1	-317.9
-315.0	-324.0
-329.8	-324.0
-330.0	-324.1
-315.0	-324.0
-330.1	-323.9
-315.0	-318.0

COMMANDED RATE= -300 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-298.3	MEAN RATE=-298.7
RATE DEVIATION= 1.7	RATE DEVIATION= 1.3
STD DEV= 4.7	STD DEV= 2.5
RIGHT ASCENSION RATES	DECLINATION RATES
-299.9	-300.0
-299.9	-300.0
-284.9	-294.0
-300.0	-300.0
-299.9	-300.0
-300.1	-300.0
-300.0	-294.0
-300.2	-300.0
-299.8	-300.0

COMMANDED RATE= -275 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-273.3	MEAN RATE=-272.7
RATE DEVIATION= 1.7	RATE DEVIATION= 2.3
STD DEV= 6.3	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
-285.0	-276.0
-270.1	-270.0
-269.9	-270.0
-269.9	-276.0
-285.2	-270.0
-269.9	-270.0
-269.9	-276.0
-270.1	-270.0
-270.1	-276.1

TABLE II (Continued)

COMMANDED RATE= -250 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-248.3	MEAN RATE=-247.3
RATE DEVIATION= 1.7	RATE DEVIATION= 2.7
STD DEV= 7.4	STD DEV= 2.5
RIGHT ASCENSION RATES	DECLINATION RATES
-255.0	-246.0
-240.1	-252.0
-254.9	-246.1
-240.2	-246.0
-255.0	-246.0
-239.9	-246.0
-255.2	-252.0
-254.9	-246.0
-239.9	-246.0

COMMANDED RATE= -225 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-223.4	MEAN RATE=-224.0
RATE DEVIATION= 1.6	RATE DEVIATION= 1.0
STD DEV= 4.7	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
-225.2	-222.0
-225.0	-228.0
-225.0	-222.0
-210.2	-222.0
-225.0	-227.9
-224.9	-222.1
-225.0	-222.0
-225.1	-228.0
-225.0	-222.0

COMMANDED RATE= -200 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-198.3	MEAN RATE=-198.7
RATE DEVIATION= 1.7	RATE DEVIATION= 1.3
STD DEV= 6.3	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
-195.1	-198.1
-194.7	-197.9
-210.2	-198.0
-194.8	-198.0
-195.1	-198.0
-209.8	-204.0
-195.1	-198.0
-195.1	-198.0
-194.8	-198.0

TABLE II (Continued)

COMMANDED RATE= -175 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-173.3	MEAN RATE=-173.3
RATE DEVIATION= 1.7	RATE DEVIATION= 1.7
STD DEV= 7.4	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
-165.0	-173.9
-180.0	-174.0
-165.1	-174.0
-179.9	-174.0
-179.8	-168.0
-165.2	-174.0
-180.0	-174.0
-164.9	-174.0
-180.2	-174.1

COMMANDED RATE= -150 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-150.0	MEAN RATE=-148.0
RATE DEVIATION= 0.0	RATE DEVIATION= 2.0
STD DEV= 0.1	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
-150.0	-150.0
-150.0	-144.0
-150.0	-150.0
-149.8	-150.0
-150.2	-150.0
-150.0	-144.0
-150.0	-150.0
-150.0	-150.0
-150.0	-144.0

COMMANDED RATE= -125 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-125.0	MEAN RATE=-122.7
RATE DEVIATION= -0.0	RATE DEVIATION= 2.3
STD DEV= 7.0	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
-135.2	-120.0
-119.9	-126.0
-120.1	-120.0
-134.8	-126.0
-120.2	-120.0
-119.8	-126.0
-120.2	-120.0
-134.8	-120.0
-120.2	-126.0

TABLE II (Continued)

COMMANDED RATE= -100 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE=-100.0	MEAN RATE= -99.3
RATE DEVIATION= 0.0	RATE DEVIATION= 0.7
STD DEV= 7.1	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
-105.2	-102.1
-104.8	-96.0
-90.1	-102.0
-105.0	-96.0
-105.0	-102.0
-89.7	-102.0
-105.2	-96.0
-105.0	-102.0
-90.0	-96.0

COMMANDED RATE= -75 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= -75.0	MEAN RATE= -74.0
RATE DEVIATION= -0.0	RATE DEVIATION= 1.0
STD DEV= 0.1	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
-74.9	-78.0
-75.1	-72.0
-75.1	-71.9
-75.0	-78.0
-75.0	-72.0
-75.0	-72.0
-75.0	-78.0
-75.0	-72.0
-75.0	-72.0

COMMANDED RATE= -50 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= -50.0	MEAN RATE= -48.7
RATE DEVIATION= 0.0	RATE DEVIATION= 1.3
STD DEV= 7.0	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
-44.9	-48.0
-59.9	-48.0
-45.2	-48.0
-44.9	-48.0
-45.1	-48.0
-60.0	-54.0
-44.8	-48.0
-45.2	-47.9
-59.9	-48.0

TABLE II (Continued)

COMMANDED RATE= -25 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= -25.0	MEAN RATE= -23.3
RATE DEVIATION= -0.0	RATE DEVIATION= 1.7
STD DEV= 7.2	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
-14.8	-24.0
-30.2	-23.9
-30.2	-24.0
-14.9	-24.0
-29.8	-24.0
-30.2	-24.0
-14.9	-18.0
-30.0	-24.0
-30.0	-24.0

COMMANDED RATE= 25 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 25.0	MEAN RATE= 24.7
RATE DEVIATION= 0.0	RATE DEVIATION= -0.3
STD DEV= 7.1	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
14.9	24.0
30.2	24.0
30.0	24.0
29.8	24.0
15.1	30.0
30.0	24.0
29.9	24.0
15.0	24.0
30.2	24.0

COMMANDED RATE= 50 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 50.0	MEAN RATE= 49.3
RATE DEVIATION= 0.0	RATE DEVIATION= -0.7
STD DEV= 7.0	STD DEV= 2.5
RIGHT ASCENSION RATES	DECLINATION RATES
45.1	48.0
45.1	47.9
59.8	54.1
45.2	47.9
60.0	48.0
44.8	48.0
45.2	54.0
60.0	48.0
44.9	48.0

TABLE II (Continued)

COMMANDED RATE= 75 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 76.6	MEAN RATE= 74.7
RATE DEVIATION= 1.6	RATE DEVIATION= -0.3
STD DEV= 4.8	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
75.0	72.0
90.1	78.0
75.0	72.0
75.0	78.0
74.8	72.0
75.1	78.0
75.0	72.0
75.0	78.0
74.8	72.0

COMMANDED RATE= 100 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 101.7	MEAN RATE= 100.0
RATE DEVIATION= 1.7	RATE DEVIATION= -0.0
STD DEV= 6.3	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
105.0	96.0
104.8	102.0
90.1	102.1
105.0	102.0
105.2	95.9
105.1	102.1
89.7	102.0
105.2	96.0
105.0	102.0

COMMANDED RATE= 125 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 125.0	MEAN RATE= 125.3
RATE DEVIATION= 0.0	RATE DEVIATION= 0.3
STD DEV= 7.1	STD DEV= 3.4
RIGHT ASCENSION RATES	DECLINATION RATES
120.1	126.0
119.9	126.0
135.2	126.0
119.9	126.0
120.0	125.9
134.9	126.0
120.1	120.0
119.9	132.0
135.1	120.0

TABLE II. (Continued)

```
          COMMANDED RATE=  150 ARC SECONDS/SECOND
RIGHT ASCENSION DATA                      DECLINATION DATA
   MEAN RATE= 150.0                       MEAN RATE= 150.7
  RATE DEVIATION= -0.0                   RATE DEVIATION=  0.7
    STD DEV=  0.1                           STD DEV=  1.9
RIGHT ASCENSION RATES                     DECLINATION RATES
          149.9                                150.0
          150.0                                150.0
          150.0                                150.0
          150.0                                150.0
          149.9                                150.0
          150.2                                150.0
          149.9                                150.0
          150.0                                150.0
          150.0                                156.0


          COMMANDED RATE=  175 ARC SECONDS/SECOND
RIGHT ASCENSION DATA                      DECLINATION DATA
   MEAN RATE= 175.0                       MEAN RATE= 176.0
  RATE DEVIATION=  0.0                   RATE DEVIATION=  1.0
    STD DEV=  7.1                           STD DEV=  2.8
RIGHT ASCENSION RATES                     DECLINATION RATES
          165.1                                174.0
          180.0                                180.0
          180.0                                174.0
          164.9                                174.0
          180.0                                180.0
          180.2                                174.0
          164.8                                174.1
          180.1                                173.9
          180.2                                180.0


          COMMANDED RATE=  200 ARC SECONDS/SECOND
RIGHT ASCENSION DATA                      DECLINATION DATA
   MEAN RATE= 200.0                       MEAN RATE= 199.3
  RATE DEVIATION= -0.0                   RATE DEVIATION= -0.7
    STD DEV=  7.1                           STD DEV=  2.5
RIGHT ASCENSION RATES                     DECLINATION RATES
          195.1                                198.0
          195.0                                198.0
          210.2                                204.0
          194.7                                198.0
          195.2                                198.0
          209.8                                198.0
          195.0                                204.0
          210.0                                198.0
          194.9                                198.0
```

TABLE II (Continued)

COMMANDED RATE= 225 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 225.0	MEAN RATE= 225.3
RATE DEVIATION= -0.0	RATE DEVIATION= 0.3
STD DEV= 0.1	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
224.9	222.0
225.2	228.0
225.0	228.0
224.9	222.0
224.9	222.0
225.2	228.0
225.0	222.0
224.9	228.0
224.9	228.0

COMMANDED RATE= 250 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 248.3	MEAN RATE= 250.0
RATE DEVIATION= -1.7	RATE DEVIATION= -0.0
STD DEV= 7.5	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
240.0	252.0
255.1	246.0
240.0	252.0
255.0	252.1
254.9	252.0
240.1	245.9
255.0	252.0
255.0	246.0
239.9	252.0

COMMANDED RATE= 275 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 275.0	MEAN RATE= 275.3
RATE DEVIATION= 0.0	RATE DEVIATION= 0.3
STD DEV= 7.0	STD DEV= 1.9
RIGHT ASCENSION RATES	DECLINATION RATES
270.1	276.0
269.8	276.0
285.1	276.0
270.1	270.0
284.8	275.9
270.1	276.1
270.1	276.0
284.8	275.9
270.2	276.1

TABLE II (Continued)

COMMANDED RATE= 300 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 300.0	MEAN RATE= 300.7
RATE DEVIATION= -0.0	RATE DEVIATION= 0.7
STD DEV= 10.1	STD DEV= 3.4
RIGHT ASCENSION RATES	DECLINATION RATES
299.9	300.0
300.2	300.0
315.1	306.1
284.8	294.0
315.2	306.0
284.9	300.0
299.9	300.0
300.2	300.0
299.9	300.0

COMMANDED RATE= 325 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 323.3	MEAN RATE= 326.0
RATE DEVIATION= -1.7	RATE DEVIATION= 1.0
STD DEV= 7.4	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
315.1	324.0
330.1	324.0
329.9	324.0
315.0	330.0
330.0	324.0
315.0	324.0
330.0	330.1
330.0	324.0
314.9	330.0

COMMANDED RATE= 350 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 350.0	MEAN RATE= 350.7
RATE DEVIATION= 0.0	RATE DEVIATION= 0.7
STD DEV= 7.1	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
360.2	348.0
345.1	348.0
344.9	354.0
359.9	354.0
345.2	348.0
344.9	354.0
360.2	348.0
344.7	354.0
345.1	348.0

TABLE II (Continued)

COMMANDED RATE= 375 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 373.3	MEAN RATE= 374.7
RATE DEVIATION= -1.7	RATE DEVIATION= -0.3
STD DEV= 4.7	STD DEV= 3.0
RIGHT ASCENSION RATES	DECLINATION RATES
359.9	372.0
375.0	378.0
375.0	372.0
375.1	372.0
374.9	378.0
375.0	378.0
375.0	372.0
375.1	372.0
375.0	378.1

COMMANDED RATE= 400 ARC SECONDS/SECOND

RIGHT ASCENSION DATA	DECLINATION DATA
MEAN RATE= 400.0	MEAN RATE= 400.0
RATE DEVIATION= -0.0	RATE DEVIATION= -0.0
STD DEV= 7.0	STD DEV= 2.8
RIGHT ASCENSION RATES	DECLINATION RATES
404.9	402.0
404.9	402.0
390.1	402.0
404.9	396.0
390.1	402.0
404.9	396.0
404.9	402.0
390.2	396.0
405.0	402.0

TABLE III

TELESCOPE SCAN PATTERN PERFORMANCE

OBSERVATION TIME	RIGHT ASCENSION	DECLINATION
259:03:07:01-14	22:18:22.99	-04:26.40
259:03:07:15	22:18:39.01	-02:14.10
259:03:07:16	22:18:40.99	-01:22.50
259:03:07:17-28	22:19:42.99	-01:20.40
259:03:07:29	22:19:42.99	01:00.30
259:03:07:30	22:20:09.98	02:21.30
259:03:07:31-42	22:20:11.02	02:23.60
259:03:07:43	22:20:11.02	04:45.60
259:03:07:44	22:20:29.01	06:05.99
259:03:07:45-56	22:20:29.01	06:08.10
259:03:07:57	22:20:29.01	08:29.10
259:03:07:58	22:20:45.00	09:50.70
259:03:07:59-08:10	22:20:45.00	09:52.90
(proceeding to new scan line)		
259:03:08:11	22:14:09.99	07:32.10
259:03:08:12	22:08:52.99	03:34.10
259:03:08:13	22:08:52.99	-00:23.60
259:03:08:14	22:07:46.97	-03:39.10
259:03:08:15	22:04:39.02	-04:21.40
259:03:08:16-28	22:04:06.00	-04:26.90
259:03:08:29	22:03:55.00	-02:14.20
259:03:08:30	22:03:04.02	-01:23.20
259:03:08:31-42	22:03:02.99	-01:20.90
259:03:08:43	22:03:02.99	01:00.30
259:03:08:44	22:02:54.99	02:21.00
259:03:08:45-56	22:02:54.02	02:23.40
259:03:08:57	22:02:54.02	04:46.20
259:03:08:58	22:02:59.98	06:05.90
259:03:08:59-09:10	22:03:01.03	06:08.00
259:03:09:11	22:03:01.03	08:30.49
259:03:09:12	22:03:11.02	09:50.70
259:03:09:13-24	22:03:12.00	09:52.80

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GEODSS telescope — incremental encoders — Real-Time System

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

The second GEODSS telescope has an improved drive system consisting of a single DC drive motor on each axis. This arrangement should provide a stable and reliable drive system for the telescope, which is driven by incremental encoders. Measurements on the response of the telescope to computer commanded rates were therefore taken. These measurements were made via two computer programs; one sends rate commands to the telescope, and the other monitors the resulting positions of the telescope. The results of these measurements show that this telescope responds very accurately to rate commands over the range of most interest to us: ±400 arc seconds per second. Data is also presented on the performance of the telescope with the Real-Time System. Specifically, the step and settle time of the telescope over a 3.7 degree field is examined. That field corresponds to the overlapped full field on the 14 inch telescope. A very satisfactory step and settle time of approximately 2 seconds has been achieved by the telescope for that case.