X-512-66-51

GSFC OPERATIONS CONTROL CENTER

SATELLITE SITUATION REPORT

VOL. 9, NO. 22

NOVEMBER 30, 1969

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

GEMINI NEWS CENTER

Release No. 17
June 4, 1965

HOUSTON, TEXAS -- Analysis by Norad Spadat computational facilities reveals the following earth satellites were within 1000 km (about 600 miles) of GT-4 Spacecraft at the time Astronaut James McDivitt reported the satellite sighting:

Object Identification	Spadats Number	Time (CST)	Distance in Kilometers from GT-4
*Fragment	975	2:56	439
*Tank	932	3:01	740
*Fragment	514	3:04	427
Omicron Transit 4A	646	3:06	905
Omicron Transit 4A	477	3:07	979
*Fragment	726	3:09	625
*Fragment	874	3:13	905
Omicron Transit 4A	124	3:13	722
10x20 Foot Debris of Pegasus -- Shroud (A or B) not a working part of Satellite 1385		3:16	757
Yo-Yo De-Spin Weight- 2' to 3'	167	3:18	684

Pegasus B at 3:06 (CST) was about 2000 km in the proper direction to be observed by the astronauts.

*4' to 6' in length down to 15" in length, 2' to 6" in width.

3 or 4 June 65

"UFOs" Watch GT-4 ?

On June 3, 1965, GT-4 Pilot Major James McDivitt and U.S. Major Space walker Edward White were launched into orbit from Cape Kennedy.

Edward White in the opening orbits got out of the GT-4 and walked through space for 20 minutes, twice as long as Alexei Leonov did for the USSR.

In a letter from Major McDivitt to Hayden Hewes, dated April 22, 1965, Major McDivitt relates that he has seen a great number of peculiar lights and objects in the skies at night and even in the day. However, in almost every instance he was able to identify these objects. As for sighting an object that he for certain identify the shape and size of and not be able to explain, "I'm afraid I just haven't seen this sort of thing," But he added "However, I know that there have been many reports of UFO's, and I just cannot speak for the other people."

Major McDivitt sighted three objects while in space during the four day space flight.

McDivitt said the first object was a cylindrical object sighted over Hawaii. He took five frames of movie film of it, but officials said all it shows is a unidentifiable white dot with a tail of light and a fanlike glow. (Cover photo)

The GT-4 went into its 21st orbit at 6:55 p.m.

MsDivitt spotted the second object during the 20th orbit, as the Spaceship was whirling across the United States

Gemini control asked McDivitt: "You still looking at that thing up there?"

McDivitt replied: "I've lost it. It had big arms sticking out of it, it looked like."

He said he had only seen it for about a minute, and had taken pictures with a movie camera although the position of the sun prevented any recognizable photographs.

There was some speculation it was the Pegasus 2 meteoroid detection satellite launched May 25, 1965.

Space agency officials ordered an immediate check by space tracking agencies to see what the objects were.

The Air Force tracking center at Colorado Springs, Colo., which keeps track of man-made objects in space is currently following 1,391 objects. Object No. 1,390 is GT-4 and object No. 1,391 is its burned out second stage rocket booster.

The Pegasus 2 was about 1,200 miles from the GT-4. Dr. Dwayne Catterson, flight medical expert, said he did not know if an object within 1,200 miles could be identified by the human eye. "But certainly if the contrast was great enough between sunlight on the object and background he could see an object there and he might well see reflection giving shape from the arm."

The third sighting came on the 38 orbit, officials said McDivitt described the object which was sighted over China as looking like "a bright star moving fast." He did not attempt to make pictures of it. The space flight took them 62 times around the globe,

Public Affairs Office
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, Alabama

Phone: 453-0034, 453-0035
(Curtis Hunt - residence - 852-1763)

August 4, 1969

IMMEDIATE RELEASE

Release No. 69-170

MARSHALL SPACE FLIGHT CENTER, Ala. -- Pegasus C, the third meteoroid technology satellite launched by a Saturn I rocket, has reentered the earth's atmosphere to end four years in orbit.

The North American Air Defense Command (NORAD) reported that the satellite reentered at 2:04 a.m. CDT over the Indian Ocean at 3.4 degrees north and 56.7 degrees east.

Pegasus A and Pegasus B are still in earth orbit. To free the radio frequencies, all three had been "turned off" last year after serving their purposes for more than double the design lifetime.

The three satellites, mounted on the forward end of S-IV stages, were launched by the last three Saturn I rockets. They sent data back to earth on meteoroids striking the detector panels of the 96-foot "wings."

Pegasus C was still operable at the time of reentry. A command was sent to the satellite a few hours before reentry which caused the beacon to begin operating. At that time the batteries were still working. The beacon was switched from batteries to solar power and allowed to operate until the vehicle was destroyed by reentry heat.

The Pegasus satellites were developed under direction of the NASA-Marshall Space Flight Center, the organization responsible also for development of the Saturn family of heavy launch vehicles.

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INTERNATIONAL
ASSOCIATION
OF GEODESY

CENTRAL BUREAU FOR SATELLITE GEODESY
SMITHSONIAN ASTROPHYSICAL OBSERVATORY
60 GARDEN STREET
CAMBRIDGE, MASS. 02138 U.S.A.

14 January 1966

Major Hector Quintanilla, Jr.
Wright-Patterson Air Force Base
Project Blue Book
FTD, TDEW/UFO
Dayton, Ohio

Dear Major Quintanilla:

In response to a request from Dr. J.Allen Hynek, of Dearborn Observatory, I am sending you a list of satellites (artificial) of visual magnitude 1.0 or brighter; the magnitudes are visual estimates by Moonwatch observers.

International designation	Name	SBADATS no.	Maximum m_V reported
60 Iota 1	Echo 1	49	+1
64 04 A	Echo 2	740	+0
65 09 A	Pegasus A	1085	+1
65 39 A	Pegasus B	1381	+1
65 60 A	Pegasus C	1467	-1
65 87 A	Proton II	1701	+1*

* = few observations

Sincerely yours,

Mrs.K.Haramundanis

KLH/bhs
cc:Mr.Martin
Mr.Hirst
Mr.Rolff
Dr.Hynek

Star Catalog
60 Garden Street
Cambridge
Massachusetts 02138

May 22, 1965

Dr.J.Allen Hynek
Dearborn Observatory
Evanston, Illinois

Dear Dr. Hynek:

The information which you requested regarding satellites with visual magnitudes of 3.0 or brighter is given below. All are orbiting as of this date. Many of the satellites launched in 1965, however, have magnitudes estimated from only a few observations, and thus for those objects, the magnitudes are to be considered less reliable.

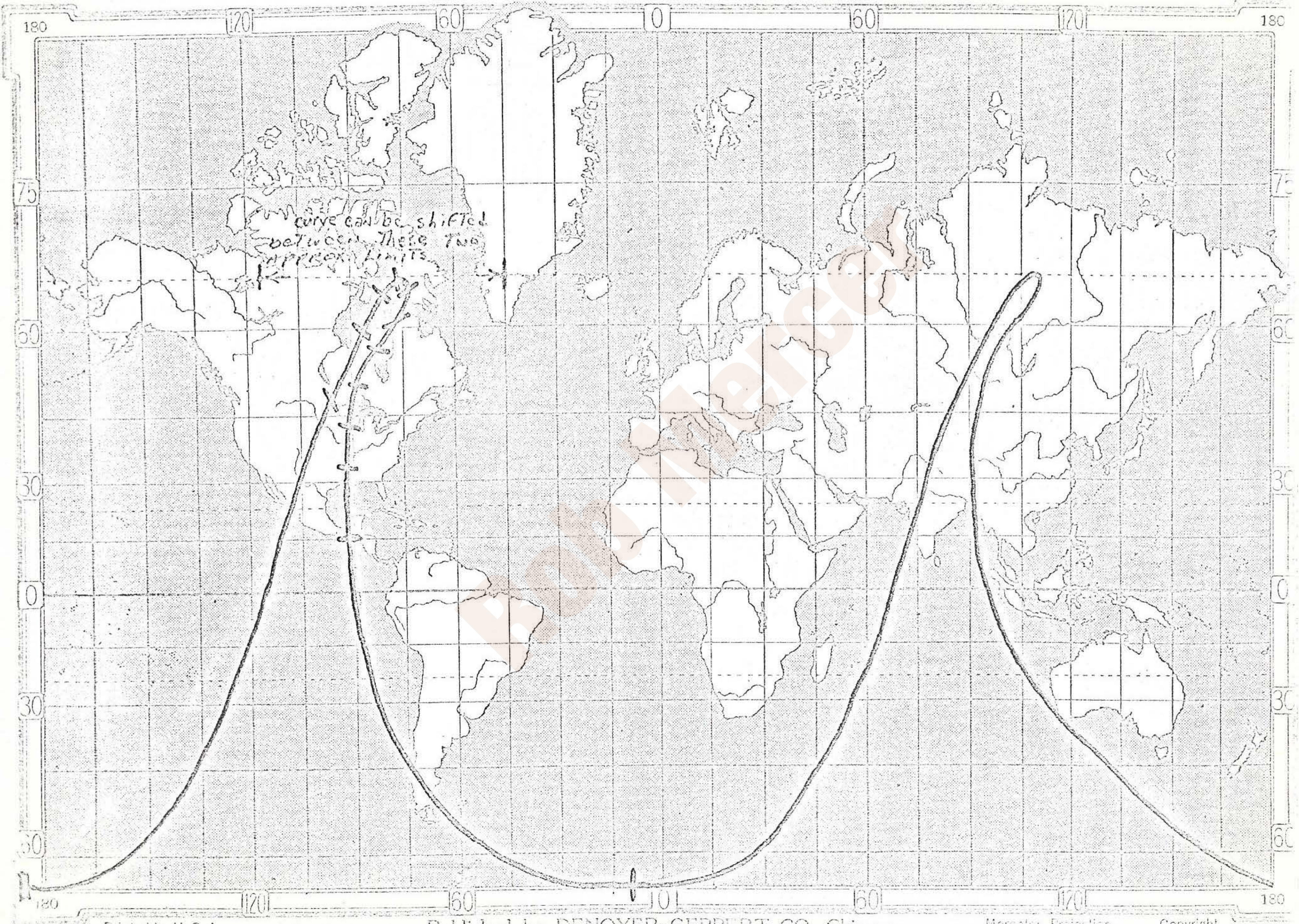
International designation	Name	Spadata No.	Maximum magnitude reported
60 Epsilon 3	Fragment Sputnik 4	36	+3
60 Zeta 1	Midas 2	43	+3
60 Iota 1	Echo 1	49	+0
60 Nu 2	Rocket Courier 1B	59	+3
61 Alpha 1	Samos 2	70	+3
62 Omicron 1	Ariel	285	+2
62 Beta-Alpha 2	Rocket Alouette	426	+3
62 Beta-Kappa	none	444	+1
62 Beta-Tau 6	Debris Injun 3	520	+3
63003A	None	527	+2
63027A	None	613	+2
63030A	Dual Tetrahedron	622	+3
63042B	None	682	+3
63047A	Centaur 2	694	+0
63049A	Rocket of an unnamed	703	+3
64004A	Echo 2	740	-2
64004B	Debris of Echo 2	741	+0
64005A	Saturn 5	744	-1
64030A	Starflash	811	+2
64050B	Rocket Cosmos 42	866	+1
64053A	Cosmos 44	876	+1
64074A	S55C	924	+2
64076A	AD-1B	931	+3
64080B	Rocket Cosmos 51	948	+2
64084A	San Marco	957	+2
65004A	Tiros 9	978	-1.5
65006B	Rocket Cosmos 53	984	+2
65009A	Pegasus A	1085	+0
65009B	Command Mod.	1088	+1
65011D	Debris Cosmos 56	1092	+3
65014A	Cosmos 58	1097	+2
65016C	Grav.Grad.3	1292	+3
65027A	Snapshot	1314	+3
65027C	Fragment EGRS 4	1316	+3

▭ HOUR MARKS

TYPICAL MOLNIYA ORBIT
12 HOUR PERIOD

Typical Molniya

Cartocraft Desk Outline Map, World. No. 7009



Printed in U.S.A.

Published by DENOYER-GEPPERT CO., Chicago

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DAYTON DAILY NEWS
24 Oct 66

Mysterious Ball 'Space Junk'

By **JACK JONES**, Daily News Staff Writer

A mysterious hard, metal sphere, found in a Wisconsin woods by a forest ranger Oct. 13 has been identified as space debris which re-entered the earth's atmosphere, Wright-Patterson Air Force base officials announced today.

Base officials would not elaborate on the identity of the object except to say that a detailed analysis is now under way to determine its metallic composition.

THEY declined to answer whether it was of Russian or American origin.

The charred spherical object, slightly over one foot in diameter and weighing 29 pounds, was found by Wisconsin State Forest Ranger James A. Pietila in a wooded area near Tomahawk, Wis.

He gave the object to the Artigo Air Force station at Antigo, Wis., which shipped it to WPAFB.

UNLESS designed to do so, it is unusual for pieces of space boosters or their payloads to re-enter the earth's atmosphere without burning up, the Air Force said.

A spokesman at the Tomahawk police station said the day after the discovery that the object "showed the effects of intense heat, as though it had come back through the earth's atmosphere."

He said hitting it with a hammer failed to dent it and scraping it with a file failed to scratch it.

"IT WAS very hard," he said, "it had to come through the air."

Maj. P. G. Scott of Antigo AFS was unable to identify the object.

He estimated the sphere had been in the woods about two weeks. He said it had printed numerals on the outside and was of a non-magnetic metal.

VOLUNTEER FLIGHT OFFICER NETWORK
SATELLITE RE-ENTRY NEWSLETTER

December 8, 1969

Smithsonian Astrophysical Observatory
60 Garden Street, Cambridge, Ma. 02140

The information contained in this newsletter is printed primarily for the Flight Operations Department and Flight Personnel of VFON member airlines. This newsletter is also sent to research agencies making beneficial use of its contents. Please advise this office of any needed further distribution of this newsletter to other agencies that might likewise find the information useful.

CATALOG NUMBER	SATELLITE	SOURCE	NAME	ESTIMATED DECAYED DATES
4129	1969-88B	USSR	Intercosmos 1 Rocket Body	Dec. 16, 1969
1551	1965-20CX	USSR	Cosmos 61/62/63 Debris	Dec. 19, 1969
4060	1969-64H	US	Intelsat III F-5 Debris	Dec. 19, 1969
3924	1969-21U	USSR	Cosmos 269 Debris	Dec. 23, 1969
1376	1965-21E	US	OPS #7353 Debris	Dec. 27, 1969
1092	1965-11D	USSR	Cosmos 54/55/56 Rocket Body	Dec. 28, 1969
4059	1969-64G	US	Intelsat III F-5 Debris	Dec. 31, 1969
4128	1969-88A	USSR	Intercosmos 1 Payload	Dec. 31, 1969
4099	1969-64R	US	Intelsat III F-5 Debris	Jan. 01, 1970
3153	1968-20B	US	OPS #7076 Payload	Jan. 03, 1970
4219	1969-96A	USSR	Cosmos 308 Payload	Jan. 04, 1970
4087	1969-64L	US	Intelsat III F-5 Debris	Jan. 10, 1970
3868	1969-29T	USSR	"Meteor" Debris	Jan. 11, 1970
3297	1968-52B	US	OPS #5259 Payload	Jan. 12, 1970
4253	1969-102B	USSR	Cosmos 311 Rocket Body	Jan. 16, 1970
4000	1969-56A	US	Biosat-D Payload	Jan. 18, 1970
4136	1969-90A	USSR	Cosmos 303 Payload	Jan. 22, 1970
2519	1966-97B	US	OV3-2 Rocket Body	Jan. 23, 1970
4108	1969-64U	US	Intelsat III F-5 Debris	Jan. 29, 1970
3913	1969-29AE	USSR	"Meteor" Debris	Jan. 30, 1970
3404	1965-82NE	US	Titan 3C-4 Debris	Feb. 02, 1970
3774	1969-20B	USSR	Cosmos 268 Rocket Body	Feb. 03, 1970
3846	1969-31A	USSR	Cosmos 275 Payload	Feb. 07, 1970
3915	1969-41B	US	OPS #1721 Payload	Feb. 10, 1970
4198	1969-82BM	US	OPS #7613 Debris	Feb. 14, 1970
0004	1958-Alpha 1	US	Explorer 1 Payload	Feb. 18, 1970
1965	1965-82HA	US	Titan 3C-4 Debris	Feb. 20, 1970
2397	1966-74B	US	OPS #6810 Payload	Feb. 21, 1970
3114	1968-08B	US	OPS #6236 Payload	Feb. 22, 1970
3782	1969-21E	USSR	Cosmos 269 Debris	Feb. 23, 1970

As of this date, the box scores in space are as follows:

Total objects now in space: 1836

	US	USSR	UK	CANADA	FRANCE	ESRO	FED REP GERMANY
Earth orbiting payloads	291	74	3	3	5	3	1
Earth orbiting debris	1072	295	0	0	22	0	3
Space probes	18	14	0	0	0	0	0
Space debris	27	5	0	0	0	0	0
	1408	388	3	3	27	3	4

Possible satellite re-entry or bright fireball sightings are immediately sent to the Smithsonian Astrophysical Observatory for processing. These reports are considered helpful toward improving our knowledge of the middle and lower atmospheres, as well as other aspects of today's space development.

Steps should be taken to advise and assure all flight crew members that unidentified sightings, regardless of nature, the pilot reporting them, and the airline involved are all considered to be of the utmost confidence. They are also considered to be of extreme importance to scientists associated with this project.

Following are satellites that <u>have</u> re-entered the earth's atmosphere, a continuation from the last list you received.

CATALOG NUMBER	SATELLITE	SOURCE	NAME	DATE DECAYED	TIME (GMT)	LOCATION RE-ENTRY (DEGREES)		BALLISTIC CO-EFFICIENT
3254	1963-14BU	US	FTV Debris	11/02/69				
4117	1969-83B	US	ESRO 1-B Rocket Body	11/03/69	0714 ±08min	02°6S	121°8W	.03025
0922	1964-72A	US	OPS #3062 Payload	11/05/69	1452 ±09 min	54°2N	112°7W	.01976
4182	1969-93A	USSR	Cosmos 306 Payload	11/05/69				
4121	1969-25G	US	OUI - 18 Debris	11/06/69				
4091	1969-64Q	US	Intelsat III F-5 Debris	11/08/69				
4186	1969-95A	US	OPS #8455 Payload	11/08/69				
3725	1969-82RG	US	Titan 3C-4 Debris	11/11/69				
1344	1965-20P	USSR	Cosmos 61 Debris	11/14/69				
1659	1965-82W	US	Titan 3C-4 Debris	11/20/69				
4223	1969-98A	USSR	Cosmos 309 Payload	11/20/69				
4088	1969-64M	US	Intelsat III F-5 Debris	11/21/69				
4224	1969-98B	USSR	Cosmos 309 Rocket Body	11/22/69	1855 ±23 min	38°1S	159°2E	.006315
4114	1969-83A	ESRO	ESRO 1-B Payload	11/23/69	0952 ±03min	30°0N	342°0E	.01851
4232	1969-100A	USSR	Cosmos 310 Payload	11/23/69				
4233	1969-100B	USSR	Cosmos 310 Rocket Body	11/23/69	0633 ±06min	11°3N	24°5E	.01696
4225	1969-99A	US	Apollo 12 Payload	11/24/69	2058			
4235	1969-98D	USSR	Cosmos 309 Debris	11/25/69				
3799	1969-21G	USSR	Cosmos 269 Debris	11/26/69				
4234	1969-98C	USSR	Cosmos 309 Debris	11/26/69				
4089	1969-64N	US	Intelsat III F-5 Debris	11/27/69				
4236	1969-98E	USSR	Cosmos 309 Debris	11/30/69	1337 ±03min	43°6S	69°8E	.010524
4001	1969-56B	US	Biosat-D Rocket Body	12/01/69	2303 ±35min	9°2N	72°3E	.014052
4076	1969-73A	USSR	Cosmos 295 Payload	12/01/69	1759 ±12min	2°8N	107°5E	.01226

Following are statistics compiled from the "Volunteer Flight Officer Network" project as of this date:

Airlines participating	117
Countries cooperating	54
Total Flight crew members involved	45,961
Total unduplicated air route miles	2,809,046
Total reports received	2,035

Broken down as Follows:

1,597	Bright fireball sightings
103	Reports of 41 different satellite re-entries
54	Infrasonic sightings
46	Reports of cataloged and uncataloged debris re-entries
69	Unidentified sightings
32	Reports now being processed
40	Reports that were sent in as unknown and have since been identified as: bright naked eye visible satellites; weather ballons; satellite launches; ballistic missiles in flight; and upper atmosphere rockets probes (cloud type)

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          SMITHSONIAN ASTROPHYSICAL OBSERVATORY, CAMBRIDGE, MASSACHUSETTS 02138  -  EPHEMERIS VI

SATELLITE     6605601   1966 56 A   SDC NO. 2253   PAGEOS 1                     ABS.MAG. 0     EPOCH  40588.000000  MJD


S-N EQ.CROSSING     ORBIT   LATI-   CORRECTION TO   HT.IN
TIME UT  LONG.W     ANGLE    TUDE    TIME  LONG.W   MILES

                 1970  JANUARY  10

 0 35.9  341.32      0 SN    0.00      .0     .00   1949
 3 35.8   26.45     15 SN   15.00     6.0     .05   1811
 6 35.8   71.58     30 SN   29.97    11.8  359.81   1718
 9 35.7  116.72     45 SN   44.88    17.4  358.93   1673
12 35.7  161.85     60 SN   59.67    23.0  356.41   1676*
15 35.6  206.98     75 SN   74.13    28.6  347.64   1726*
18 35.5  252.11     90      84.57    34.3  278.61   1821*
21 35.5  297.24    105 NS   74.13    40.3  209.64   1960*
                   120 NS   59.66    46.7  201.05   2138*
                   135 NS   44.86    53.4  198.83   2349*
                   150 NS   29.95    60.7  198.36   2585*
                   165 NS   14.99    68.5  198.65   2832
                   180 NS    -.00    76.9  199.30   3071
                   195 NS  -14.98    85.9  200.09   3282
                   210 NS  -29.94    95.4  200.78   3440
                   225 NS  -44.84   105.2  200.94   3527
                   240 NS  -59.64   115.0  199.50   3530*
                   255 NS  -74.12   124.8  191.77   3450*
                   270     -84.57   134.3  123.67   3296*
                   285 SN  -74.12   143.2   55.46   3086*
                   300 SN  -59.65   151.7   47.39   2843*
                   315 SN  -44.86   159.5   45.44   2591*
SHADOW ENTRY  351  330 SN  -29.95   166.8   44.97   2348*
SHADOW EXIT    57  345 SN  -14.99   173.6   44.99   2131*


                 1970  JANUARY  11

 0 35.4  342.38      0 SN    0.00      .0     .00   1941
 3 35.4   27.51     15 SN   15.00     6.0     .04   1807
 6 35.3   72.64     30 SN   29.97    11.8  359.81   1718
 9 35.3  117.78     45 SN   44.88    17.4  358.93   1677
12 35.3  162.91     60 SN   59.67    23.0  356.41   1683*
15 35.2  208.05     75 SN   74.13    28.6  347.64   1737*
18 35.2  253.18     90      84.57    34.4  278.62   1835*
21 35.1  298.32    105 NS   74.13    40.4  209.66   1977*
                   120 NS   59.66    46.8  201.08   2157*
                   135 NS   44.86    53.6  198.87   2369*
                   150 NS   29.95    60.9  198.41   2605*
                   165 NS   14.99    68.8  198.71   2850
                   180 NS    -.00    77.2  199.37   3087
                   195 NS  -14.98    86.2  200.17   3292
                   210 NS  -29.94    95.7  200.87   3444
                   225 NS  -44.84   105.5  201.03   3524
                   240 NS  -59.64   115.3  199.58   3521*
                   255 NS  -74.12   125.1  191.84   3436*
                   270     -84.57   134.5  123.73   3278*
                   285 SN  -74.12   143.4   55.50   3066*
                   300 SN  -59.65   151.8   47.42   2824*
                   315 SN  -44.86   159.6   45.46   2573*
SHADOW ENTRY  351  330 SN  -29.96   166.8   44.99   2333*
SHADOW EXIT    59  345 SN  -14.99   173.6   44.99   2119*


                 1970  JANUARY  12

 0 35.1  343.45      0 SN    0.00      .0     .00   1934
 3 35.0   28.58     15 SN   15.00     6.0     .04   1804
 6 35.0   73.72     30 SN   29.97    11.7  359.80   1719
 9 35.0  118.86     45 SN   44.88    17.4  358.93   1681
12 34.9  163.99     60 SN   59.67    23.0  356.41   1691*
15 34.9  209.13     75 SN   74.13    28.6  347.65   1748*
18 34.8  254.26     90      84.57    34.4  278.63   1850*
21 34.8  299.40    105 NS   74.13    40.5  209.68   1993*
                   120 NS   59.66    46.9  201.11   2175*
                   135 NS   44.86    53.7  198.91   2389*
                   150 NS   29.95    61.1  198.46   2625*
                   165 NS   14.99    69.0  198.77   2868
                   180 NS    -.00    77.5  199.44   3101
                   195 NS  -14.98    86.6  200.25   3302
                   210 NS  -29.94    96.0  200.95   3448
                   225 NS  -44.84   105.8  201.11   3521
                   240 NS  -59.64   115.7  199.66   3512
                   255 NS  -74.12   125.4  191.91   3421*
                   270     -84.57   134.7  123.79   3260*
                   285 SN  -74.12   143.6   55.55   3047*
                   300 SN  -59.65   152.0   47.46   2805*
                   315 SN  -44.86   159.7   45.48   2556*
SHADOW ENTRY  349  330 SN  -29.96   166.9   45.00   2319*
SHADOW EXIT    59  345 SN  -14.99   173.6   45.00   2108*


                 1970  JANUARY  13

 0 34.8  344.54      0 SN    0.00      .0     .00   1927
 3 34.7   29.67     15 SN   15.00     6.0     .04   1801
 6 34.7   74.81     30 SN   29.97    11.7  359.80   1720
 9 34.7  119.95     45 SN   44.88    17.4  358.92   1686
12 34.6  165.08     60 SN   59.67    23.0  356.41   1700*
15 34.6  210.22     75 SN   74.13    28.6  347.65   1760*
18 34.6  255.36     90      84.57    34.5  278.64   1864*
21 34.5  300.50    105 NS   74.13    40.6  209.70   2011*
                   120 NS   59.66    47.0  201.14   2194*
                   135 NS   44.86    53.9  198.95   2409*
                   150 NS   29.95    61.3  198.51   2644*
                   165 NS   14.99    69.3  198.83   2886
                   180 NS    -.00    77.8  199.51   3115
                   195 NS  -14.98    86.9  200.33   3311
                   210 NS  -29.94    96.4  201.03   3451
                   225 NS  -44.84   106.1  201.19   3518
                   240 NS  -59.64   116.0  199.74   3503
                   255 NS  -74.12   125.6  191.98   3407*
                   270     -84.57   135.0  123.85   3242*
                   285 SN  -74.12   143.8   55.60   3028*
                   300 SN  -59.65   152.1   47.49   2786*
                   315 SN  -44.86   159.8   45.51   2539*
SHADOW ENTRY  349  330 SN  -29.96   167.0   45.01   2305*
SHADOW EXIT    59  345 SN  -14.99   173.6   45.01   2097*


S-N EQ.CROSSING     ORBIT   LATI-   CORRECTION TO   HT.IN
TIME UT  LONG.W     ANGLE    TUDE    TIME  LONG.W   MILES

                 1970  JANUARY  14

 0 34.5  345.64      0 SN    0.00      .0     .00   1921
 3 34.5   30.77     15 SN   15.00     6.0     .04   1798
 6 34.4   75.91     30 SN   29.97    11.7  359.80   1721
 9 34.4  121.05     45 SN   44.88    17.3  358.92   1691
12 34.4  166.19     60 SN   59.67    23.0  356.41   1708*
15 34.4  211.33     75 SN   74.13    28.7  347.66   1771*
18 34.3  256.47     90      84.57    34.5  278.66   1879*
21 34.3  301.61    105 NS   74.13    40.6  209.72   2028*
                   120 NS   59.66    47.1  201.17   2213*
                   135 NS   44.86    54.1  198.99   2428*
                   150 NS   29.95    61.5  198.56   2663*
                   165 NS   14.99    69.5  198.89   2903
                   180 NS    -.00    78.1  199.58   3129
                   195 NS  -14.98    87.2  200.41   3320
                   210 NS  -29.94    96.7  201.11   3453
                   225 NS  -44.84   106.5  201.27   3514
                   240 NS  -59.64   116.3  199.81   3493
                   255 NS  -74.12   125.9  192.05   3392*
                   270     -84.57   135.2  123.91   3224*
                   285 SN  -74.12   144.0   55.64   3009*
                   300 SN  -59.65   152.2   47.53   2768*
                   315 SN  -44.86   159.9   45.53   2522*
SHADOW ENTRY  347  330 SN  -29.96   167.0   45.03   2291*
SHADOW EXIT    59  345 SN  -14.99   173.7   45.01   2087*


                 1970  JANUARY  15

 0 34.3  346.75      0 SN    0.00      .0     .00   1914
 3 34.3   31.89     15 SN   15.00     5.9     .03   1796
 6 34.3   77.03     30 SN   29.97    11.7  359.79   1722
 9 34.2  122.17     45 SN   44.88    17.3  358.92   1696
12 34.2  167.31     60 SN   59.67    23.0  356.41   1717*
15 34.2  212.45     75 SN   74.13    28.7  347.67   1783*
18 34.2  257.59     90      84.57    34.6  278.67   1894*
21 34.2  302.73    105 NS   74.13    40.7  209.74   2045*
                   120 NS   59.66    47.3  201.20   2232*
                   135 NS   44.86    54.2  199.03   2448*
                   150 NS   29.95    61.7  198.62   2682*
                   165 NS   14.99    69.8  198.95   2920
                   180 NS    -.00    78.4  199.66   3142
                   195 NS  -14.98    87.5  200.49   3328
                   210 NS  -29.94    97.0  201.19   3455
                   225 NS  -44.84   106.8  201.35   3509
                   240 NS  -59.64   116.6  199.89   3482
                   255 NS  -74.12   126.2  192.12   3377*
                   270     -84.57   135.4  123.96   3206*
                   285 SN  -74.12   144.2   55.68   2989*
                   300 SN  -59.65   152.3   47.56   2749*
                   315 SN  -44.86   160.0   45.55   2506*
SHADOW ENTRY  347  330 SN  -29.96   167.1   45.04   2277*
SHADOW EXIT    59  345 SN  -14.99   173.7   45.02   2077*


                 1970  JANUARY  16

 0 34.2  347.88      0 SN    0.00     0.0  360.00   1909
 3 34.1   33.02     15 SN   15.00     5.9     .03   1794
 6 34.1   78.16     30 SN   29.97    11.7  359.79   1724
 9 34.1  123.30     45 SN   44.88    17.3  358.92   1702
12 34.1  168.44     60 SN   59.67    23.0  356.42   1726*
15 34.1  213.59     75 SN   74.13    28.7  347.67   1796*
18 34.1  258.73     90      84.57    34.6  278.69   1909*
21 34.1  303.87    105 NS   74.13    40.8  209.77   2062*
                   120 NS   59.66    47.4  201.23   2251*
                   135 NS   44.86    54.4  199.07   2467*
                   150 NS   29.95    61.9  198.67   2701*
                   165 NS   14.99    70.0  199.02   2937
                   180 NS    -.00    78.7  199.73   3155
                   195 NS  -14.98    87.8  200.56   3335
                   210 NS  -29.94    97.3  201.28   3457
                   225 NS  -44.84   107.1  201.43   3504
                   240 NS  -59.64   116.9  199.96   3471
                   255 NS  -74.12   126.4  192.18   3361*
                   270     -84.57   135.6  124.02   3188*
                   285 SN  -74.12   144.3   55.73   2970*
                   300 SN  -59.65   152.5   47.59   2731*
                   315 SN  -44.86   160.1   45.57   2490*
SHADOW ENTRY  346  330 SN  -29.96   167.1   45.05   2264*
SHADOW EXIT    59  345 SN  -14.99   173.7   45.03   2067*


                 1970  JANUARY  17

 0 34.1  349.02      0 SN    0.00      .0     .00   1903
 3 34.1   34.16     15 SN   15.00     5.9     .03   1792
 6 34.0   79.30     30 SN   29.97    11.7  359.79   1726
 9 34.0  124.45     45 SN   44.88    17.3  358.92   1707
12 34.0  169.59     60 SN   59.67    23.0  356.42   1735
15 34.0  214.74     75 SN   74.13    28.7  347.68   1808*
18 34.0  259.88     90      84.57    34.7  278.70   1924*
21 34.0  305.03    105 NS   74.13    40.9  209.79   2079*
                   120 NS   59.66    47.5  201.26   2270*
                   135 NS   44.86    54.6  199.11   2487*
                   150 NS   29.95    62.1  198.73   2720*
                   165 NS   14.99    70.3  199.08   2953
                   180 NS    -.00    79.0  199.80   3168
                   195 NS  -14.98    88.1  200.64   3343
                   210 NS  -29.94    97.7  201.36   3458
                   225 NS  -44.84   107.4  201.51   3499
                   240 NS  -59.64   117.2  200.04   3460
                   255 NS  -74.12   126.7  192.25   3346*
                   270     -84.57   135.8  124.07   3170*
                   285 SN  -74.12   144.5   55.77   2951*
                   300 SN  -59.65   152.6   47.62   2713*
                   315 SN  -44.86   160.1   45.59   2474*
SHADOW ENTRY  344  330 SN  -29.96   167.2   45.07   2251*
SHADOW EXIT    61  345 SN  -14.99   173.7   45.03   2058
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SATELLITE     6605601   1966 56 A   SDC NO. 2253   PAGEOS 1                    ABS.MAG. 0     EPOCH  40588.000000  MJD
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S-N EQ.CROSSING     ORBIT   LATI-  CORRECTION TO  HT.IN
TIME UT  LONG.W     ANGLE    TUDE   TIME  LONG.W  MILES

                  1970  JANUARY  18

 0 34.0  350.17     0 SN    0.00     .0     .00  1898
 3 34.0   35.32    15 SN   15.00    5.9     .03  1791
 6 34.0   80.46    30 SN   29.97   11.7  359.79  1729
 9 34.0  125.61    45 SN   44.88   17.3  358.92  1713
12 34.0  170.75    60 SN   59.67   23.0  356.42  1745
15 34.0  215.90    75 SN   74.13   28.8  347.69  1821*
18 34.0  261.05    90      84.57   34.8  278.72  1939*
21 34.0  306.19   105 NS   74.13   41.0  209.82  2097*
                  120 NS   59.66   47.7  201.30  2288*
                  135 NS   44.86   54.7  199.16  2506*
                  150 NS   29.95   62.4  198.78  2738*
                  165 NS   14.99   70.5  199.15  2969
                  180 NS    -.00   79.2  199.88  3180
                  195 NS  -14.98   88.4  200.72  3349
                  210 NS  -29.94   98.0  201.44  3458
                  225 NS  -44.84  107.7  201.59  3493
                  240 NS  -59.64  117.5  200.11  3449
                  255 NS  -74.12  126.9  192.31  3330*
                  270     -84.57  136.1  124.12  3152*
                  285 SN  -74.12  144.7   55.81  2933*
                  300 SN  -59.65  152.7   47.65  2695*
                  315 SN  -44.86  160.2   45.61  2458*
SHADOW ENTRY  344 330 SN  -29.96  167.2   45.08  2239*
SHADOW EXIT    61 345 SN  -14.99  173.8   45.04  2049


                  1970  JANUARY  19

 0 34.0  351.34     0 SN    0.00     .0     .00  1893
 3 34.0   36.49    15 SN   15.00    5.9     .03  1790
 6 34.1   81.64    30 SN   29.97   11.7  359.79  1731
 9 34.1  126.78    45 SN   44.88   17.3  358.92  1720
12 34.1  171.93    60 SN   59.67   23.0  356.43  1754
15 34.1  217.08    75 SN   74.13   28.8  347.70  1833*
18 34.1  262.23    90      84.57   34.8  278.73  1955*
21 34.1  307.38   105 NS   74.13   41.1  209.84  2114*
                  120 NS   59.66   47.8  201.33  2307*
                  135 NS   44.86   54.9  199.20  2525*
                  150 NS   29.95   62.6  198.84  2756*
                  165 NS   14.99   70.8  199.21  2984
                  180 NS    -.00   79.5  199.95  3191
                  195 NS  -14.98   88.8  200.80  3355
                  210 NS  -29.94   98.3  201.52  3458
                  225 NS  -44.84  108.0  201.67  3487
                  240 NS  -59.64  117.7  200.18  3437
                  255 NS  -74.12  127.2  192.37  3314*
                  270     -84.57  136.3  124.17  3133*
                  285 SN  -74.12  144.8   55.85  2914*
                  300 SN  -59.65  152.8   47.68  2677*
                  315 SN  -44.86  160.3   45.63  2443*
SHADOW ENTRY  344 330 SN  -29.96  167.2   45.09  2227*
SHADOW EXIT    61 345 SN  -14.99  173.8   45.04  2041


                  1970  JANUARY  20

 0 34.1  352.52     0 SN    0.00    0.0  360.00  1889
 3 34.1   37.67    15 SN   15.00    5.9     .02  1789
 6 34.1   82.82    30 SN   29.97   11.7  359.78  1734
 9 34.2  127.97    45 SN   44.88   17.3  358.92  1726
12 34.2  173.12    60 SN   59.67   23.0  356.43  1764
15 34.2  218.27    75 SN   74.13   28.9  347.71  1846*
18 34.2  263.42    90      84.57   34.9  278.75  1970*
21 34.2  308.57   105 NS   74.13   41.2  209.87  2132*
                  120 NS   59.66   47.9  201.37  2326*
                  135 NS   44.86   55.1  199.25  2544*
                  150 NS   29.95   62.8  198.89  2774*
                  165 NS   14.99   71.1  199.28  2999
                  180 NS    -.00   79.8  200.02  3202
                  195 NS  -14.98   89.1  200.88  3361
                  210 NS  -29.94   98.6  201.60  3458
                  225 NS  -44.84  108.4  201.75  3480
                  240 NS  -59.64  118.0  200.25  3425
                  255 NS  -74.12  127.4  192.44  3298*
                  270     -84.57  136.5  124.23  3115*
                  285 SN  -74.12  145.0   55.89  2896*
                  300 SN  -59.65  152.9   47.71  2660*
                  315 SN  -44.86  160.4   45.65  2428*
SHADOW ENTRY  342 330 SN  -29.96  167.3   45.10  2215*
SHADOW EXIT    61 345 SN  -14.99  173.8   45.05  2032


                  1970  JANUARY  21

 0 34.2  353.72     0 SN    0.00     .0     .00  1884
 3 34.3   38.87    15 SN   15.00    5.9     .02  1789
 6 34.3   84.02    30 SN   29.97   11.7  359.78  1738
 9 34.3  129.17    45 SN   44.88   17.3  358.92  1733
12 34.3  174.32    60 SN   59.67   23.1  356.44  1774
15 34.4  219.48    75 SN   74.13   28.9  347.72  1859*
18 34.4  264.63    90      84.57   35.0  278.77  1986*
21 34.4  309.78   105 NS   74.13   41.3  209.89  2149*
                  120 NS   59.66   48.1  201.41  2345*
                  135 NS   44.86   55.3  199.30  2563*
                  150 NS   29.95   63.0  198.95  2791*
                  165 NS   14.99   71.3  199.35  3014
                  180 NS    -.00   80.1  200.10  3212
                  195 NS  -14.98   89.4  200.96  3366
                  210 NS  -29.94   99.0  201.68  3456
                  225 NS  -44.84  108.7  201.83  3473
                  240 NS  -59.64  118.3  200.32  3412
                  255 NS  -74.12  127.7  192.50  3282*
                  270     -84.57  136.7  124.28  3097*
                  285 SN  -74.12  145.1   55.93  2877*
                  300 SN  -59.66  153.0   47.73  2643*
                  315 SN  -44.86  160.4   45.67  2413*
SHADOW ENTRY  342 330 SN  -29.96  167.3   45.11  2203*
SHADOW EXIT    61 345 SN  -14.99  173.8   45.05  2024
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S-N EQ.CROSSING     ORBIT   LATI-  CORRECTION TO  HT.IN
TIME UT  LONG.W     ANGLE    TUDE   TIME  LONG.W  MILES

                  1970  JANUARY  22

 0 34.4  354.93     0 SN    0.00    0.0  360.00  1881
 3 34.5   40.08    15 SN   15.00    5.9     .02  1789
 6 34.5   85.24    30 SN   29.97   11.7  359.78  1741
 9 34.5  130.39    45 SN   44.88   17.4  358.92  1740
12 34.5  175.54    60 SN   59.67   23.1  356.45  1785
15 34.6  220.70    75 SN   74.13   29.0  347.74  1873*
18 34.6  265.85    90      84.57   35.0  278.79  2002*
21 34.6  311.00   105 NS   74.13   41.4  209.92  2167*
                  120 NS   59.66   48.2  201.44  2363*
                  135 NS   44.86   55.5  199.35  2581*
                  150 NS   29.95   63.3  199.01  2808*
                  165 NS   14.98   71.6  199.42  3028
                  180 NS    -.00   80.4  200.17  3222
                  195 NS  -14.98   89.7  201.04  3370
                  210 NS  -29.94   99.3  201.76  3455
                  225 NS  -44.84  109.0  201.90  3465
                  240 NS  -59.64  118.6  200.39  3400
                  255 NS  -74.12  127.9  192.56  3266*
                  270     -84.57  136.9  124.32  3079*
                  285 SN  -74.12  145.3   55.96  2859*
                  300 SN  -59.66  153.2   47.76  2626*
                  315 SN  -44.86  160.5   45.69  2399*
SHADOW ENTRY  342 330 SN  -29.96  167.4   45.12  2192*
SHADOW EXIT    61 345 SN  -14.99  173.8   45.06  2017


                  1970  JANUARY  23

 0 34.7  356.16     0 SN    0.00     .0     .00  1877
 3 34.7   41.31    15 SN   15.00    5.9     .02  1789
 6 34.7   86.46    30 SN   29.97   11.7  359.78  1745
 9 34.8  131.62    45 SN   44.88   17.4  358.93  1748
12 34.8  176.77    60 SN   59.67   23.1  356.45  1795
15 34.8  221.93    75 SN   74.13   29.0  347.75  1886*
18 34.9  267.08    90      84.57   35.1  278.81  2017*
21 34.9  312.24   105 NS   74.13   41.6  209.95  2185*
                  120 NS   59.66   48.4  201.48  2382*
                  135 NS   44.86   55.7  199.40  2599*
                  150 NS   29.95   63.5  199.07  2825*
                  165 NS   14.98   71.9  199.48  3042
                  180 NS    -.00   80.7  200.25  3232
                  195 NS  -14.98   90.0  201.12  3374
                  210 NS  -29.94   99.6  201.84  3453
                  225 NS  -44.84  109.3  201.98  3457
                  240 NS  -59.64  118.9  200.46  3387
                  255 NS  -74.12  128.2  192.62  3249*
                  270     -84.57  137.0  124.37  3061*
                  285 SN  -74.12  145.4   56.00  2841*
                  300 SN  -59.66  153.3   47.79  2610*
                  315 SN  -44.86  160.6   45.70  2385*
SHADOW ENTRY  340 330 SN  -29.96  167.4   45.13  2181*
SHADOW EXIT    61 345 SN  -14.99  173.9   45.06  2010


                  1970  JANUARY  24

 0 35.0  357.40     0 SN    0.00     .0     .00  1874
 3 35.0   42.55    15 SN   15.00    5.9     .02  1789
 6 35.0   87.71    30 SN   29.97   11.7  359.78  1749
 9 35.1  132.86    45 SN   44.88   17.4  358.93  1755
12 35.1  178.02    60 SN   59.67   23.2  356.46  1806
15 35.2  223.18    75 SN   74.13   29.1  347.76  1900*
18 35.2  268.33    90      84.57   35.2  278.83  2033*
21 35.3  313.49   105 NS   74.13   41.7  209.98  2202*
                  120 NS   59.66   48.5  201.52  2400*
                  135 NS   44.86   55.9  199.45  2618*
                  150 NS   29.95   63.7  199.13  2842*
                  165 NS   14.98   72.1  199.55  3056
                  180 NS    -.00   81.0  200.32  3241
                  195 NS  -14.98   90.3  201.20  3378
                  210 NS  -29.94   99.9  201.92  3450
                  225 NS  -44.84  109.6  202.05  3449
                  240 NS  -59.64  119.1  200.53  3373
                  255 NS  -74.12  128.4  192.67  3233*
                  270     -84.57  137.2  124.42  3043*
                  285 SN  -74.12  145.6   56.04  2823*
                  300 SN  -59.66  153.4   47.81  2593*
                  315 SN  -44.86  160.6   45.72  2371*
SHADOW ENTRY  340 330 SN  -29.96  167.5   45.14  2171*
SHADOW EXIT    61 345 SN  -14.99  173.9   45.07  2003


ELEMENTS OF  6605601    T = TIME IN DAYS U.T.

EPOCH = TO = 1970  JANUARY   2.000000 DT = T-TO DT2 = DT.DT
ARGUMENT OF PERIGEE (DEG.) =  62.3549 - 1.14182DT
R.A.(DATE) OF NODE (DEG.) = 138.2073 -  .17880DT
INCLINATION (DEG.) =  84.5466
ECCENTRICITY = .149975 -.0008660DT
SEMI-MAJOR AXIS (MEGAMETERS) =  10.553571
MEAN ANOMALY (REVS) =  .63597 + 8.007632DT -.0001566DT2


MODIFIED ORBITAL ELEMENTS

REFERENCE TIME  1970  JANUARY  10  0HOURS 56.30MINS. U.T.
INCLINATION  84.55 DEG.
ASCENDING NODE (LONG.) 346.44 DEG. WEST
PRIME SWEEP INTERVAL  ONE DAY  -4.64 MIN.
ARGUMENT OF PERIGEE  53.18 DEG.
     RATE OF CHANGE  -.14264 DEG. PER PERIOD
ANOMALISTIC PERIOD 179.885 MIN.
     RATE OF CHANGE   .00088 MIN. PER PERIOD
ECCENTRICITY  .143013
RADIUS OF PERIGEE  5621.0 MILES
RADIUS OF APOGEE   7497.1 MILES
     RATE OF CHANGE  -5.48 MILES PER DAY
ASCENDING NODE (R.A.DATE) 136.77 DEG.
     RATE OF CHANGE   -.17880 DEG. PER DAY
LATITUDE OF PERIGEE  52.83 DEG.

EXPECTED MAGNITUDE 2 TO 5
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Star Catalog
60 Garden Street
Cambridge
Massachusetts 02138

September 66

International designation	Name	SPADATS no.	m_V
60 00601	Midas 2	43	+3
60 00901	Echo 1	49	+0
60 01302	rocket, Courier 1B	59	+3
61 00101	Samos 2	70	+3
62 04902	rocket, Alouette	426	+2
63 003A	none	527	+2
63027A	none	613	+2
63 030A	Dual Tetrahedron	622	+3
63 047A	Centaur 2	694	+2
63 049A	rocket	703	+3
64 004A	Echo 2	740	-1
64 005A	Saturn 5	744	-1
64 011A	none	759	+2
64 047A	Syncom C	858	+3
64 053A	Cosmos 44	876	+3
64 072A	none	922	+3
64 074A	Explorer 23	924	+2
65 009A	Pegasus A	1085	+1
65 011B	Cosmos 55	1090	+2
65 014A	Cosmos 58	1097	+2
65 039A	Pegasus B	1381	+1
65 039B	rocket	1385	+2
65 052B	rocket, Cosmos 70	1432	+2
65 060A	Pegasus C	1467	-1
65 060B	debris, Pegasus C	1468	+2
65 087A	Proton 2	1701	+1

Katherine Haramundanis

SATELLITE PREDICTIONS BY THE USE OF EPHEMERIS VI

Introduction

In order to be able to observe a satellite, it must obviously be above the observer's horizon; it must be in sunlight, i.e., not in the earth's shadow; the time must be sufficiently long before sunrise and after sunset for the sky to be dark; and the observer must know just where in the sky to point his telescope at a given time in order to see it.

Positions in the sky can be indicated in several different ways. We shall do so by: (see Figure I)

Altitude, which is the angular elevation in degrees above the horizon, and

Azimuth, which is the "bearing" measured clockwise from North. It is similar to the compass bearing except that it is measured in degrees instead of compass points. For instance:

North-East = Azimuth 45°
West = Azimuth 270°, etc.

So much for the position of the satellite as seen by the observer. Now consider how to define its position in space.

Imagine a line drawn from the satellite to the center of the earth. Where this line cuts the earth's surface is called the Sub-Satellite Point. (As we shall make frequent use of this term, we shall abbreviate it to "Sub-Point.")

If we know the latitude and longitude of the Sub-Point and the height of the satellite above the surface of the earth, its position in space is determined. This information is obtainable from the Ephemeris and from it we can determine its position in the sky as seen from a known observing site.

We shall start by dealing with this problem and consider the question of illumination later.

Section (4) - Illumination

To the right of columns 7 and 11 there are asterisks on certain lines. These mean that at these latitudes (moving S-N when the asterisks follow col. 7 and N-S when they follow col. 11) the satellite is in sunlight and in a suitable position for observation. Note that the satellite can be sunlit but not in a suitable position for observation. If it is in a direct line between the earth and the sun, it will only be illuminated on the side away from the earth; moreover, there will be nowhere on earth in darkness from which it can be seen.

Example 4

In the section of the ephemeris for May 15, the satellite is in sunlight from near latitude -40° S-N to latitude 0° N-S. But between +20° S-N and +40° N-S, it is directly between the earth and the sun. Between -20° N-S and -45° S-N, it is in shadow.

How do we know it is in shadow here and not between +20° S-N and +40° N-S?

This information is given in the last line of the section, which also gives the latitudes of shadow entry and exit with more exactness than the asterisks.

Note: The figures given in the entry/exit line do not always agree exactly with the asterisks which can only be trusted for a rough indication.

Section (5) - Selection of Equator Crossing

To select an equator crossing that will bring the Sub-Point near your site, it is only necessary to apply the procedure of Example 3 in reverse. Instead of applying a correction from column 5 or 9 to a selected S-N equator crossing to get the longitude of the Sub-Point, at a given latitude, you apply the correction for your latitude with reversed sign to your longitude to find a suitable equator crossing.

As there are in general two longitude corrections for each latitude, there will be two S-N equator crossings that will bring the Sub-Point near your site.

Example 5

Suppose we require a crossing on May 15 to bring the Sub-Point near a site in position:

Longitude: 87°
Latitude : -30°

The longitude correction for -30° S-N is +28°.51. Applying this with reversed sign to your longitude gives, to the nearest degree, 58°. Looking in col. 2, we see that the nearest S-N equator crossing is 57°.35 at $11^{h}12^{m}.5$.

Similarly, using the correction for -30° N-S from col. 9, we get about 311°. The nearest tabular figure to this is 302°.44 at $3^{h}38^{m}.4$.

However, before deciding that an equator crossing will give a suitable satellite pass for observation, you must first see that the satellite is illuminated near one or both of the points at which it crosses your latitude. In the above example, it would be in shadow at the N-S crossing of latitude -30°, so the second equator crossing would be of no use.

It is also necessary to make sure that it will be dark enough when the satellite reaches your latitude.

Example 6

Take the first equator crossing found in Example 5. Applying the appropriate time correction, we find that it will be near the site at:

$$11^h12^m - 14^m = 10^h58^m \text{ U.T.}$$

to the nearest minute.

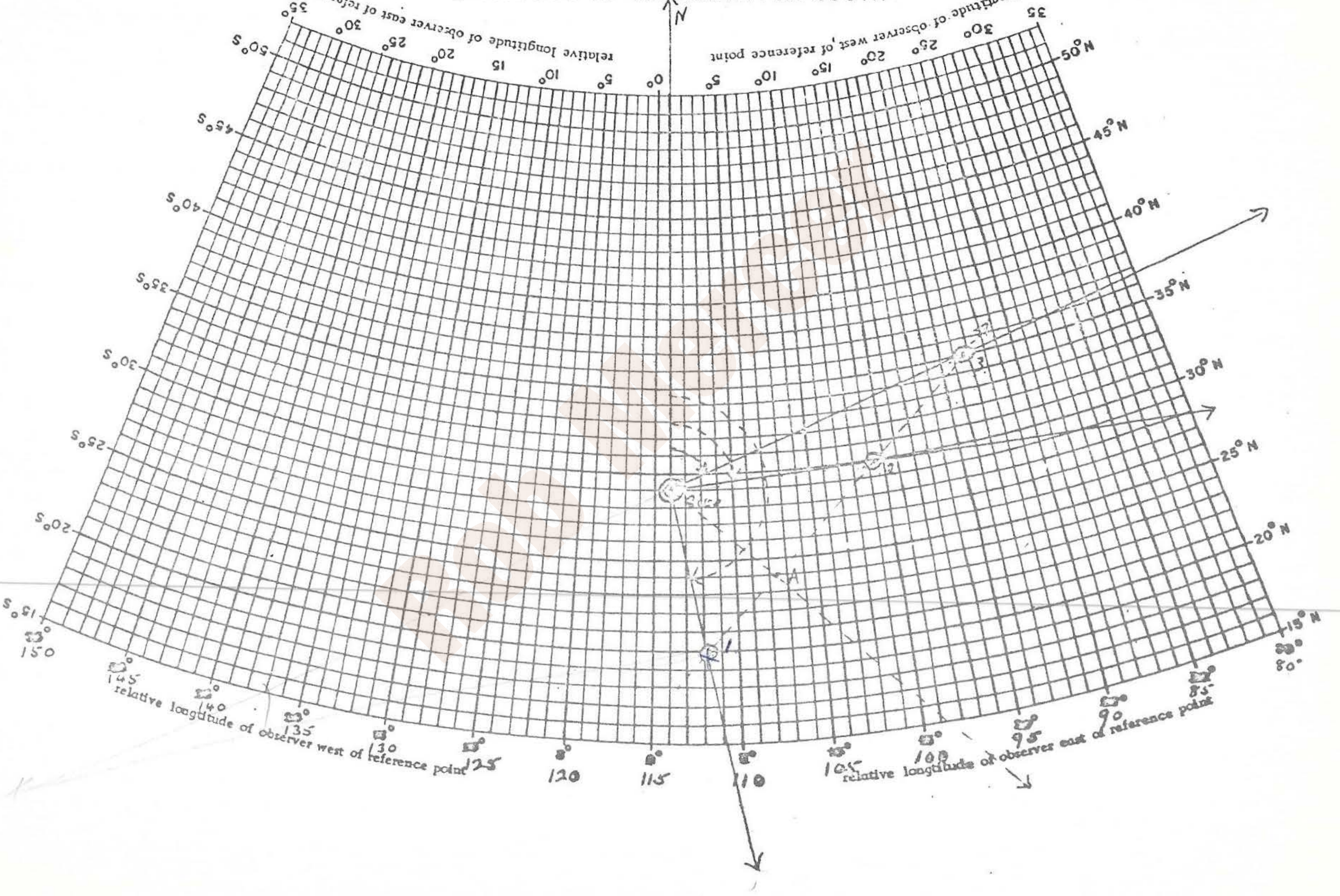
To correct U.T. to local time, we must subtract one hour for every 15° of west longitude, so the local time will be:

$$10^h58^m - 5^h48^m = 5^h10^m$$

It will certainly be dark enough at this time on May 15 in latitude -30°.

Chart No. 1a

SATELLITE ORBIT PLOTTING GRID
LATITUDES: 15°-52° NORTH AND SOUTH



Section (6) - Complete Prediction

We shall start by giving an example of a prediction using only the methods already described and then discuss the selection of the best point for observation and how to find it. The example will be given without the details of the calculation, merely referring for these to previous examples.

Example 7

Prediction required for May 29, 1965:

Site longitude : $114^\circ.0$
Site latitude : $+29^\circ.0$

(i) Finding suitable equator crossing (see Example 5)

Refer to last section of ephemeris. Nearest tabular latitude to site : $+30^\circ$
Only illuminated on S-N crossing.
Now: $114^\circ + 28^\circ = 142^\circ$
Nearest tabular S-N equator crossing:

Time (U.T.) : $11^h53^m.1$
Longitude : $129^\circ.07$

(ii) Check of local time (see Example 6)

Applying time correction from col. 4 and correction for longitude of site, local time is: $11^h53^m + 14^m - 7^h36^m = 4^h01^m$, at which time it will be dark.

(Note in passing that the next S-N equator crossing at $13^h46^m.5$ would not do, as the local time then comes out to be 5^h55^m, well after sunrise.)

(iii) Correcting to latitudes near site (see Example 3)

We shall make predictions for the three latitudes nearest the site: $+20^\circ$, $+30^\circ$ and $+35^\circ$ S-N.

Position No.	Latitude	Longitude	Time (U.T.)
1	$+20^\circ$(S-N)	$111^\circ.91$	$12^h02^m.4$
2	$+30^\circ$(S-N)	100.65	12 07.2
3	$+35^\circ$(S-N)	93.32	12 09.9

(iv) Azimuth, G.C.A. and height (see Examples 2 and 3)

Above positions are plotted on Chart No. 1a and measured. Heights are read from ephemeris.

Position No.	Azimuth	G.C.A.	Height
1	167°.5	9°.3	948 miles
2	80.5	11.9	873 miles
3	64.5	18.6	832 miles

(v) Altitude and summary (see Example 1)

Read from Chart No. 2.

Position No.	Time(U.T.)	Azimuth	Altitude	Slant Range
1	$12^h 02^m.4$	167°.5	48°.0	1170 miles
2	12 07.2	80.5	37.5	1250 miles
3	12 09.9	64.5	21.0	1620 miles

Note: Azimuth and altitude are given to the nearest half degree. Greater accuracy is hardly possible by this simple method and is seldom necessary in any case.

If the satellite passes near your site at the right time and in sunlight, the above method will nearly always find some point in the orbit at which the satellite can be observed, and many observers are content with this. It is, however, not necessarily the best point.

As a general rule, to which there are exceptions, the best time to observe the satellite is when it is nearest to you. If the height is changing appreciably, this point is not easy to find, but it is easy enough to find where the Sub-Point is nearest, which is good enough.

Look at Chart No. 1a. The line through the three positions plotted in Example 7 marks the path of the Sub-Point, moving in the direction of the arrow. It is slightly curved, but unless unusual accuracy is required, a straight line ruled between positions Nos. 1 and 2 is good enough. The nearest point to the site on this line is obviously the point A where the perpendicular from the site meets the line.

The G.C.A. and azimuth of A are measured in the usual way. We get the time and height by interpolating between the figures at positions Nos. 1 and 2 in proportion to the distance of A along the line between these points. The following example shows how it is done.

Example 8

Measuring along the line in the same way as when measuring for G.C.A., we get:

Position No. 1 to A : $5^\circ.5$
Position No. 1 to No. 2 : $14^\circ.3$
Ratio : 0.39

$$\text{Time at A (U.T.)} = 12^h02^m.4 + 0.39\,(12^h07^m.2 - 12^h02^m.4)$$
$$= 12\ 04.2$$

$$\text{Height of A} = 948 + 0.39\,(873 - 948)$$
$$= 948 - 0.39 \times 75 = 919 \text{ miles}$$

We also find for the point A:

Azimuth : $130^\circ.0$; G.C.A. : $7^\circ.8$
Hence: Altitude: $53^\circ.0$; Slant Range: 1090 miles

The complete prediction therefore is:

Time (U.T.): $12^h04^m.2$
Azimuth : $130^\circ.0$
Altitude : $53^\circ.0$
Slant Range: 1090 miles

A word of warning should be given here. The above method assumes that time and height change uniformly from position No. 1 to No. 2. This is always nearly enough true as regards time but not always with the height. The error caused by ignoring this is seldom likely to cause trouble, but there are a few cases in which it can.

We shall conclude with an example of a prediction for the Southern Hemisphere that will also illustrate a point concerning shadow entry.

SATELLITE ORBIT PLOTTING GRID
LATITUDES: 15°-52° NORTH AND SOUTH

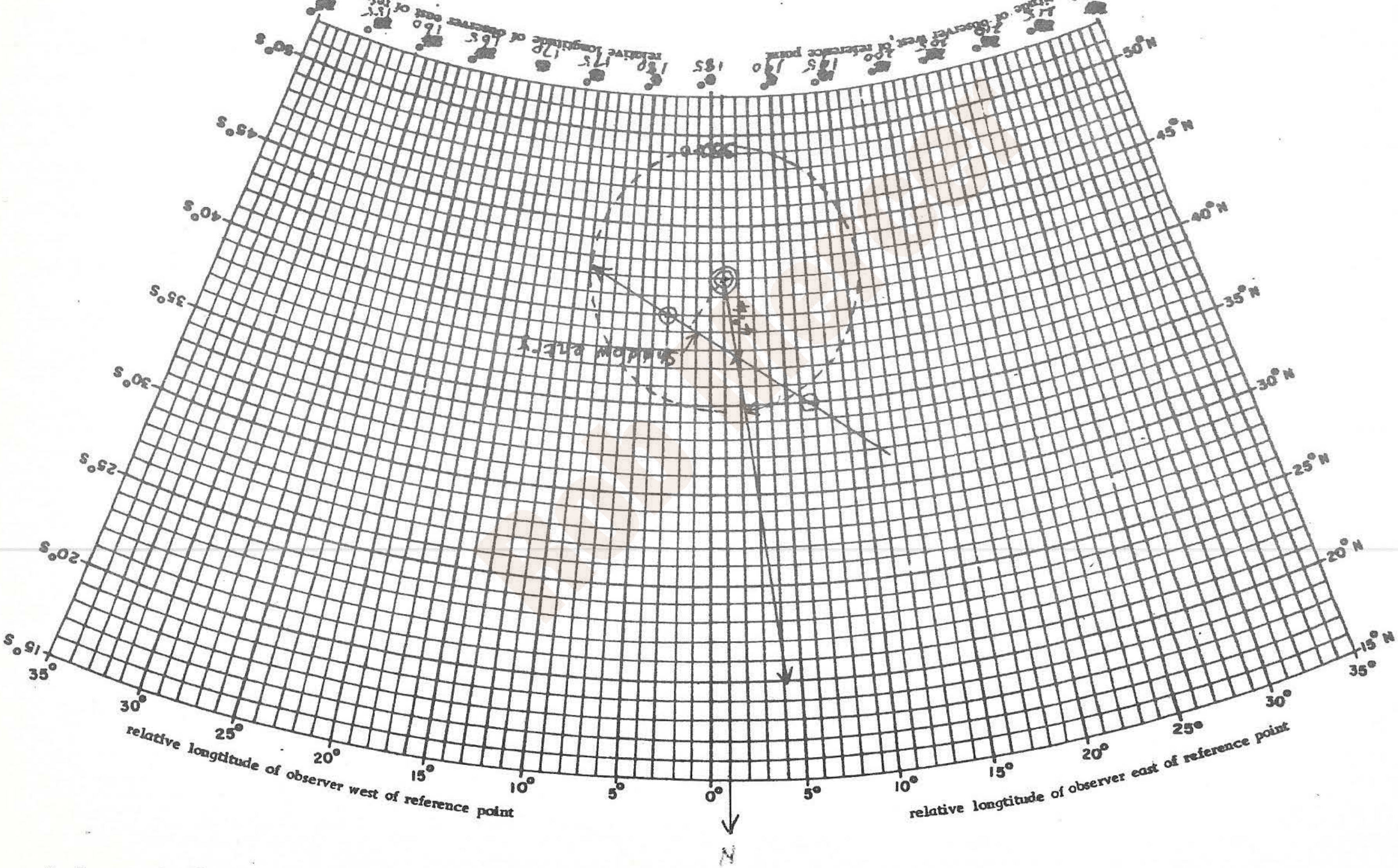


Chart No. 18

Example 9

Date prediction required: May 24, 1965

Site longitude: 186°.0
Site latitude : -42°.0

(i) Nearest tabular latitude in sunlight : -35° N-S
$186^\circ - 129^\circ = 57^\circ$
Nearest tabular S-N equator crossing:
Time (U.T.) : $8^h58^m.2$
Longitude : 62°.88

(ii) Approximate local time: $8^h58^m - 45^m - 12^h24^m = 19^h49^m$
At this latitude in May, the site will be in darkness.

(iii)

Position No.	Latitude	Longitude	Time (U.T.)
1	-35° (N-S)	191°.59	$8^h13^m.6$
2	-40° (N-S)	182.03	8 16.8

(iv) See Chart No. 1b. Note that for the Southern Hemisphere we use the chart inverted.

On plotting site and Sub-Point positions, we see that the perpendicular from the site meets the track at about latitude -39°.3. But shadow entry is at -39°.0, so, as the satellite is moving southward, it will be in shadow at -39°.3. We must therefore choose a point north of shadow entry - and not too close, in case the ephemeris is slightly in error.

To simplify the calculation, we select the point half-way between position No. 1 and No. 2. This gives:

Height: 990 miles
Time correction: $43^m.0$

We shall leave the reader to complete the working. The final prediction is:

Time (U.T.): $8^h15^m.2$
Azimuth : 352°.0
Altitude : 68°.5
Slant Range: 1050 miles

The above explanations and examples may appear rather long-winded. That is because we have tried to explain just what we were doing and why at each stage instead of laying down a series of arbitrary rules. In practice, a prediction is very easily made from Ephemeris VI and takes only a short time.

SMITHSONIAN ASTROPHYSICAL OBSERVATORY, CAMBRIDGE, MASSACHUSETTS

MAY 12, 1965

SATELLITE 1960 IOTA 1, ECHO I

These predictions are based on orbital elements revised on May 10, 1965
T_0 = May 11.0, times are in days, U.T.
Argument of perigee = 65°.969 + 3°.966 $(t-T_0)$
Right ascension of ascending node = 358°.757 - 3°.4037 $(t-T_0)$

Inclination = 47°.2618
Eccentricity = 0.056945 + 1.964 x 10^{-4} $(t-T_0)$
Semi-major axis = 7.771575 megameters
Mean anomaly (Rev.) = 0.18031 + 12.670540 $(t-T_0)$ + 2.9573 x 10^{-4} $(t-T_0)^2$

SATELLITE 6000901 1960 IOTA I

FOR OTHER LATITUDES

MAY 15, 1965

EQUATOR S-N			SOUTH-NORTH				NORTH-SOUTH			
TIME (UT) (1)	LONG. (W) (2)	LAT. (3)	TIME CORR. (4)	LONG. CORR. (5)	HT. (MI) (6)	BEAR. (N-E) (7)	TIME CORR. (8)	LONG. CORR. (9)	HT. (MI) (10)	BEAR. (N-E) (11)
1 44.9	273.71	47.5	26.1	-83.30	596	90.0	26.1	-83.42	596	90.0
3 30.4	302.44	45.0	21.5	-61.17	596	72.3	30.7	-105.63	615	107.7
5 31.9	331.17	40.0	17.8	-45.85	609	60.7	34.4	-120.93	643	119.3
7 26.4	359.89	35.0	15.1	-36.17	627	54.1	37.2	-130.60	670	126.0*
9 10.0	28.82	30.0	12.7	-28.78	647	49.5	39.6	-137.97	699	130.5*
11 12.5	57.35	20.0	8.3	-17.40	695	43.8	44.1	-149.32	758	136.3*
13 6.0	86.08	0.	0.	0.	811	39.9*	52.7	-166.67	887	140.1*
14 59.6	114.81	-20.0	-8.8	17.29	946	43.6*	-51.9	147.35	1018	136.4
16 53.1	143.54	-30.0	-13.8	28.51	1016	49.3*	-46.8	136.16	1077	130.7
18 46.6	172.26	-35.0	-16.6	35.79	1051	53.9*	-43.9	128.91	1104	126.1
20 40.1	200.99	-40.0	-19.9	45.33	1086	60.6*	-40.5	119.38	1128	119.4
22 33.7	229.72	-45.0	-24.4	60.43	1123	72.2	-35.9	104.30	1147	107.8
		-47.5	-30.2	82.35	1148	90.0	-30.2	82.39	1148	90.0

SHADOW ENTRY LAT. -12.5 EXIT LAT. -41.7

MAY 16, 1965

0 27.2	258.45	47.5	26.2	-83.35	593	90.0	26.2	-83.40	593	90.0
2 20.7	287.17	45.0	21.6	-61.14	598	72.3	30.8	-105.60	608	107.7
4 14.2	315.80	40.0	17.9	-45.83	615	60.7	34.5	-120.91	632	119.3
6 7.8	344.63	35.0	15.2	-36.14	635	54.1	37.2	-130.59	658	126.0*
8 1.3	13.36	30.0	12.8	-28.76	657	49.5	39.7	-137.96	684	130.5*
9 54.8	42.08	20.0	8.4	-17.39	708	43.7	44.1	-149.32	741	136.3*
11 48.3	70.81	0.	0.	0.	829	39.9*	52.6	-166.68	868	140.1*
13 41.9	99.54	-20.0	-8.9	17.27	964	43.6*	-52.0	147.32	1002	136.4
15 35.4	128.26	-30.0	-13.9	28.49	1032	49.3*	-46.9	136.13	1064	130.7
17 28.9	156.99	-35.0	-16.7	35.76	1065	53.9*	-44.0	128.87	1094	126.1
19 22.4	185.72	-40.0	-20.0	45.29	1098	60.6*	-40.7	119.34	1120	119.4
21 16.0	214.44	-45.0	-24.6	60.39	1131	72.2	-36.1	104.26	1144	107.8
23 9.5	243.17	-47.5	-30.3	82.31	1151	90.0	-30.3	82.35	1151	90.0

SHADOW ENTRY LAT. -16.3 EXIT LAT. -39.7

MAY 17, 1965

1 3.0	271.89	47.5	26.3	-83.32	592	90.0	26.3	-83.38	592	90.0
2 56.5	300.62	45.0	21.7	-61.11	601	72.3	30.9	-105.57	601	107.7
4 50.0	329.35	40.0	18.0	-45.80	622	60.7	34.6	-120.89	622	119.3
6 43.5	358.07	35.0	15.3	-36.12	645	54.0	37.3	-130.56	645	126.0
8 37.1	26.80	30.0	12.9	-28.74	670	49.5	39.8	-137.94	670	130.5*
10 30.6	55.52	20.0	8.5	-17.37	724	43.7	44.2	-149.30	724	136.3*
12 24.1	84.25	0.	0.	0.	848	39.9*	52.6	-166.69	848	140.1*
14 17.6	112.97	-20.0	-8.9	17.25	983	43.6*	-52.1	147.30	984	136.4
16 11.1	141.70	-30.0	-14.0	28.46	1049	49.3*	-47.0	136.10	1050	130.7
18 4.6	170.42	-35.0	-16.9	35.72	1080	53.9*	-44.2	128.83	1081	126.1
19 58.2	199.15	-40.0	-20.2	45.26	1110	60.6	-40.8	119.30	1111	119.4
21 51.7	227.87	-45.0	-24.7	60.35	1139	72.2	-36.3	104.21	1139	107.8
23 45.2	256.60	-47.5	-30.5	82.26	1152	90.0	-30.5	82.30	1152	90.0

SHADOW ENTRY LAT. -20.0 EXIT LAT. -37.6

MAY 18, 1965

1 38.7	285.92	47.5	26.4	-83.29	591	90.0	26.4	-83.33	591	90.0
3 32.2	314.04	45.0	21.8	-61.08	606	72.3	31.0	-105.54	596	107.7
5 25.7	342.77	40.0	18.2	-45.77	630	60.7	34.7	-120.86	613	119.3
7 19.2	11.49	35.0	15.4	-36.09	656	54.0	37.4	-130.54	633	125.9
9 12.8	40.22	30.0	13.0	-28.72	683	49.5	39.8	-137.92	656	130.5*
11 6.3	68.94	20.0	8.5	-17.36	740	43.7	44.2	-149.29	707	136.2*
12 59.8	97.66	0.	0.	0.	868	39.9*	52.6	-166.69	828	140.1*
14 53.3	126.39	-20.0	-9.0	17.23	1001	43.6*	-52.2	147.28	965	136.4*
16 46.8	155.11	-30.0	-14.1	28.43	1064	49.3*	-47.1	136.07	1034	130.7
18 40.3	183.83	-35.0	-17.0	35.69	1094	53.9*	-44.3	128.80	1067	126.1
20 33.8	212.56	-40.0	-20.3	45.22	1121	60.6	-41.0	119.27	1100	119.4
22 27.3	241.28	-45.0	-24.9	60.31	1145	72.2	-36.4	104.17	1133	107.8
		-47.5	-30.7	82.22	1153	90.0	-30.7	82.26	1153	90.0

SHADOW ENTRY LAT. -23.1 EXIT LAT. -35.2

SATELLITE 6000901 1960 IOTA 1

FOR OTHER LATITUDES

MAY 19, 1965

EQUATER S-N			SOUTH-NORTH				NORTH-SOUTH			
TIME (UT)	LONG. (W)	LAT.	TIME CORR.	LONG. CORR.	HT. (MI)	BEAR. (N-E)	TIME CORR.	LONG. CORR.	HT. (MI)	BEAR. (N-E)
0 20.8	270.00	47.5	26.6	-83.26	592	90.0	26.6	-83.30	592	90.0
2 14.3	298.73	45.0	22.0	-61.05	611	72.3	31.2	-105.51	592	107.7
4 7.8	327.45	40.0	18.3	-45.74	639	60.7	34.8	-120.83	605	119.3
6 1.4	356.17	35.0	15.5	-36.06	667	54.0	37.5	-130.51	623	125.9
7 54.9	24.89	30.0	13.1	-28.69	696	49.5	39.9	-137.89	644	130.5
9 48.4	53.62	20.0	8.6	-17.34	756	43.7*	44.3	-149.27	692	136.2*
11 41.9	82.34	0.	0.	0.	886	39.9*	52.6	-166.69	810	140.1*
13 35.4	111.06	-20.0	-9.1	17.22	1018	43.6*	-52.2	147.27	948	136.4*
15 28.9	139.78	-30.0	-14.2	28.41	1078	49.3*	-47.2	136.05	1018	130.7
17 22.4	168.60	-35.0	-17.1	35.66	1105	53.9*	-44.4	128.78	1054	126.1
19 15.9	197.23	-40.0	-20.5	45.19	1130	60.6	-41.1	119.24	1089	119.4
21 9.4	225.95	-45.0	-25.0	60.27	1150	72.2	-36.6	104.14	1126	107.8
23 2.9	254.67	-47.5	-30.8	82.18	1151	90.0	-30.8	82.23	1151	90.0

SHADOW ENTRY LAT. -26.3 EXIT LAT. -32.4

MAY 20, 1965

0 56.4	283.39	47.5	26.7	-83.22	594	90.0	26.7	-83.26	594	90.0
2 49.9	312.11	45.0	22.1	-61.01	618	72.3	31.3	-105.47	588	107.7
4 43.4	340.83	40.0	18.4	-45.71	650	60.7	35.0	-120.79	598	119.3
6 36.9	9.55	35.0	15.6	-36.04	680	54.0	37.7	-130.48	613	125.9
8 30.4	38.27	30.0	13.2	-28.67	711	49.4	40.1	-137.86	632	130.5
10 23.9	67.00	20.0	8.7	-17.32	774	43.7*	44.4	-149.25	676	136.2*
12 17.4	95.72	0.	0.	0.	906	39.9*	52.7	-166.68	790	140.1*
14 10.9	124.44	-20.0	-9.1	17.20	1035	43.6*	-52.3	147.26	928	136.4*
16 4.4	153.16	-30.0	-14.3	28.38	1092	49.3*	-47.3	136.03	1001	130.7
17 57.9	181.88	-35.0	-17.2	35.63	1117	53.9	-44.5	128.75	1038	126.1
19 51.4	210.60	-40.0	-20.6	45.16	1138	60.6	-41.2	119.21	1076	119.4
21 44.9	239.32	-45.0	-25.2	60.24	1153	72.2	-36.7	104.11	1117	107.8
23 38.4	268.04	-47.5	-30.9	82.15	1148	90.0	-31.0	82.19	1148	90.0

SHADOW ENTRY LAT. -29.5 EXIT LAT. -29.5

MAY 21, 1965

1 31.9	296.76	47.5	26.9	-83.17	597	90.0	26.9	-83.22	597	90.0
3 25.4	325.48	45.0	22.3	-60.97	626	72.3	31.5	-105.43	587	107.7
5 18.9	354.20	40.0	18.6	-45.67	662	60.7	35.1	-120.75	592	119.3
7 12.3	22.92	35.0	15.7	-36.00	694	54.0	37.8	-130.44	604	125.9
9 5.8	51.04	30.0	13.3	-28.64	727	49.4	40.2	-137.83	621	130.5
10 59.3	80.35	20.0	8.7	-17.31	792	43.7*	44.5	-149.22	661	136.2*
12 52.8	109.07	0.	0.	0.	926	39.9*	52.7	-166.66	770	140.1*
14 46.3	137.79	-20.0	-9.2	17.18	1052	43.6*	-52.3	147.26	908	136.4*
16 39.8	166.51	-30.0	-14.4	28.35	1105	49.3	-47.4	136.02	982	130.7*
18 33.3	195.23	-35.0	-17.3	35.61	1127	53.9	-44.6	128.74	1021	126.1
20 26.8	223.95	-40.0	-20.7	45.12	1145	60.6	-41.3	119.19	1062	119.4
22 20.3	252.67	-45.0	-25.3	60.20	1155	72.2	-36.8	104.08	1107	107.8
		-47.5	-31.1	82.12	1144	90.0	-31.1	82.16	1144	90.0

SHADOW ENTRY LAT. -32.4 EXIT LAT. -26.4

MAY 22, 1965

0 13.8	281.99	47.5	27.0	-83.13	601	90.0	27.1	-83.18	601	90.0
2 7.3	310.10	45.0	22.4	-60.93	635	72.3	31.6	-105.39	586	107.7
4 0.7	338.82	40.0	18.7	-45.64	673	60.7	35.3	-120.71	588	119.3
5 54.2	7.54	35.0	15.9	-35.98	708	54.0	38.0	-130.40	597	125.9
7 47.7	36.26	30.0	13.4	-28.62	742	49.4*	40.4	-137.79	611	130.5
9 41.2	64.97	20.0	8.8	-17.29	810	43.7*	44.7	-149.19	649	136.2
11 34.7	93.69	0.	0.	0.	945	39.8*	52.8	-166.64	751	140.0*
13 28.2	122.41	-20.0	-9.3	17.17	1067	43.6*	-52.3	147.26	889	136.3*
15 21.7	151.13	-30.0	-14.5	28.33	1116	49.3	-47.4	136.01	945	130.7*
17 15.2	179.04	-35.0	-17.4	35.58	1135	53.9	-44.6	128.72	1005	126.1
19 8.6	208.56	-40.0	-20.8	45.10	1150	60.6	-41.4	119.17	1047	119.4
21 2.1	237.28	-45.0	-25.4	60.18	1155	72.2	-36.9	104.06	1096	107.8
22 55.6	266.00	-47.5	-31.2	82.09	1138	90.0	-31.2	82.13	1138	90.0

SHADOW ENTRY LAT. -34.7 EXIT LAT. -23.2

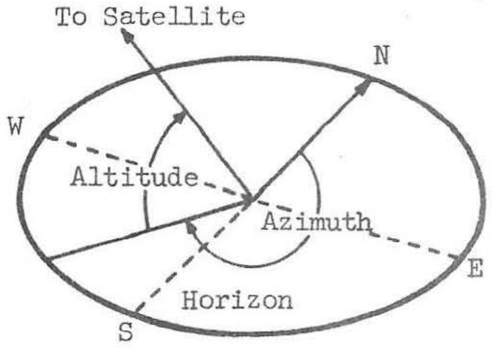


Figure 1.

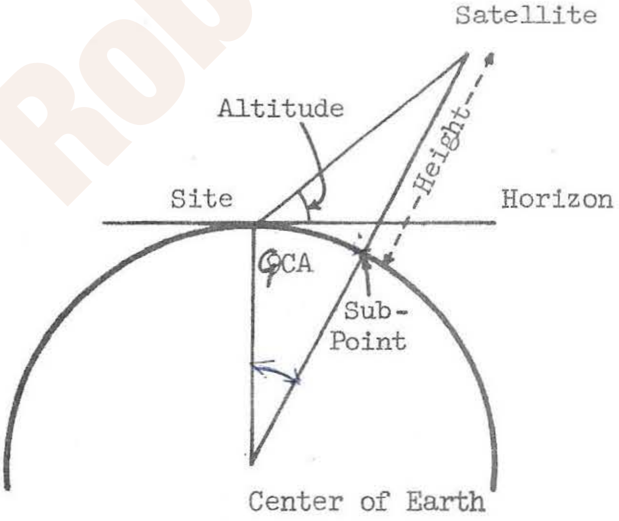


Figure 2.

```
                         SATELLITE      6000901         1960          IOTA      1
  EQUATOR                                          FOR OTHER LATITUDES
    S-N                                     SOUTH-NORTH                          NORTH-SOUTH
 TIME      LONG.       LAT.    TIME     LONG.    HT.   BEAR.        TIME     LONG.    HT.   BEAR.
 (UT)       (W)                CORR.    CORR.   (MI)   (N-E)        CORR.    CORR.   (MI)   (N-E)
                                          MAY 23, 1965

  0 49.1   294.71      47.5    27.2   -83.09    607   90.0         27.2   -83.13    607    90.0
  2 42.6   323.43      45.0    22.6   -60.89    645   72.3         31.8  -105.34    587   107.7
  4 36.1   352.15      40.0    18.8   -45.60    687   60.7         35.5  -120.66    584   119.3
  6 29.5    20.86      35.0    16.0   -35.94    724   54.0         38.2  -130.35    591   125.9
  8 23.0    49.58      30.0    13.5   -28.59    760   49.4*        40.5  -137.75    602   130.5
 10 16.5    78.29      20.0     8.9   -17.27    829   43.7*        44.8  -149.15    636   136.2
 12 10.0   107.01       0.      0.      0.      964   39.8*        52.9  -166.62    734   140.0*
 14  3.5   135.73     -20.0    -9.3    17.15   1082   43.5*       -52.2   147.27    869   136.3*
 15 56.9   164.44     -30.0   -14.6    28.31   1126   49.3        -47.4   136.01    945   130.7*
 17 50.4   193.16     -35.0   -17.5    35.55   1143   53.9        -44.6   128.72    986   126.1*
 19 43.9   221.87     -40.0   -20.9    45.07   1154   60.6        -41.4   119.10   1031   119.4
 21 37.4   250.59     -45.0   -25.5    60.15   1154   72.2        -37.0   104.04   1083   107.8
 23 30.9   279.30     -47.5   -31.3    82.06   1130   90.0        -31.3    82.10   1130    90.0
                      SHADOW    ENTRY LAT.  -37.0        EXIT LAT.  -19.7

                                          MAY 24, 1965

  1 24.3   308.02      47.5    27.4   -83.04    614   90.0         27.4   -83.08    614    90.0
  3 17.8   336.73      45.0    22.8   -60.85    657   72.3         32.0  -105.29    588   107.7
  5 11.3     5.45      40.0    19.0   -45.56    702   60.7         35.7  -120.61    582   119.3
  7  4.8    34.16      35.0    16.1   -35.91    741   54.0*        38.4  -130.30    586   125.9
  8 58.2    62.88      30.0    13.6   -28.56    778   49.4*        40.7  -137.70    595   130.5
 10 51.7    91.59      20.0     8.9   -17.25    849   43.7*        45.0  -149.10    624   136.2
 12 45.2   120.31       0.      0.      0.      984   39.8*        53.0  -166.59    716   140.0*
 14 38.7   149.02     -20.0    -9.4    17.13   1095   43.5        -52.2   147.28    848   136.3*
 16 32.1   177.74     -30.0   -14.7    28.29   1135   49.3        -47.4   136.01    925   130.6*
 18 25.6   206.45     -35.0   -17.6    35.53   1149   53.9        -44.6   128.71    967   126.1*
 20 19.1   235.16     -40.0   -21.0    45.04   1156   60.6        -41.4   119.15   1013   119.4
 22 12.5   263.88     -45.0   -25.6    60.12   1151   72.2        -37.0   104.02   1068   107.8
                      -47.5   -31.4    82.04   1121   90.0        -31.4    82.08   1121    90.0
                      SHADOW    ENTRY LAT.  -39.0        EXIT LAT.  -16.2

                                          MAY 25, 1965

  0  6.0   292.59      47.5    27.6   -82.99    621   90.0         27.6   -83.04    621    90.0
  1 59.5   321.30      45.0    22.9   -60.81    668   72.3         32.2  -105.24    591   107.7
  3 53.0   350.02      40.0    19.1   -45.53    716   60.7         35.9  -120.56    581   119.2
  5 46.4    18.73      35.0    16.2   -35.88    757   54.0*        38.5  -130.26    582   125.9
  7 39.9    47.44      30.0    13.7   -28.53    795   49.4*        40.9  -137.65    589   130.5
  9 33.4    76.16      20.0     9.0   -17.24    868   43.7*        45.1  -149.06    614   136.2
 11 26.8   104.87       0.      0.      0.     1001   39.8*        53.1  -166.56    700   140.0*
 13 20.3   133.58     -20.0    -9.5    17.12   1107   43.5        -52.1   147.30    829   136.3*
 15 13.8   162.30     -30.0   -14.7    28.27   1142   49.2        -47.4   136.02    906   130.6*
 17  7.2   191.01     -35.0   -17.7    35.51   1153   53.8        -44.6   128.72    949   126.1*
 19  0.7   219.72     -40.0   -21.1    45.02   1157   60.6        -41.5   119.14    996   119.4*
 20 54.2   248.43     -45.0   -25.7    60.10   1147   72.2        -37.1   104.01   1054   107.8
 22 47.6   277.15     -47.5   -31.4    82.02   1112   90.0        -31.5    82.06   1112    90.0
                      SHADOW    ENTRY LAT.  -40.7        EXIT LAT.  -13.0

                                          MAY 26, 1965

  0 41.1   305.86      47.5    27.8   -82.94    630   90.0         27.8   -82.99    630    90.0
  2 34.6   334.57      45.0    23.1   -60.76    682   72.3         32.4  -105.19    596   107.7
  4 28.0     3.28      40.0    19.3   -45.49    733   60.7         36.1  -120.51    582   119.2
  6 21.5    31.99      35.0    16.4   -35.85    775   54.0*        38.8  -130.20    579   125.9
  8 15.0    60.70      30.0    13.8   -28.50    815   49.4*        41.1  -137.60    583   130.5
 10  8.4    89.42      20.0     9.1   -17.22    888   43.7*        45.3  -149.01    604   136.2
 12  1.9   118.13       0.      0.      0.     1020   39.8*        53.3  -166.52    684   140.0*
 13 55.3   146.84     -20.0    -9.5    17.10   1119   43.5        -52.0   147.32    809   136.3*
 15 48.8   175.55     -30.0   -14.8    28.25   1149   49.2        -47.3   136.03    886   130.6*
 17 42.3   204.26     -35.0   -17.8    35.49   1156   53.8        -44.6   128.72    929   126.1*
 19 35.7   232.97     -40.0   -21.2    45.00   1156   60.6        -41.5   119.15    977   119.4*
 21 29.2   261.68     -45.0   -25.8    60.08   1141   72.2        -37.1   104.00   1038   107.8
 23 22.6   290.39     -47.5   -31.5    82.01   1100   90.0        -31.5    82.05   1100    90.0
                      SHADOW    ENTRY LAT.  -42.3        EXIT LAT.   -9.5
```

```
                         SATELLITE      6000901         1960          IOTA      1
  EQUATOR                                          FOR OTHER LATITUDES
    S-N                                     SOUTH-NORTH                          NORTH-SOUTH
 TIME      LONG.       LAT.    TIME     LONG.    HT.   BEAR.        TIME     LONG.    HT.   BEAR.
 (UT)       (W)                CORR.    CORR.   (MI)   (N-E)        CORR.    CORR.   (MI)   (N-E)

                                          MAY 27, 1965

  1 16.1   319.10      47.5    28.0   -82.89    641   90.0         28.0   -82.93    641    90.0
  3  9.6   347.81      45.0    23.3   -60.72    697   72.3         32.7  -105.13    601   107.7
  5  3.0    16.52      40.0    19.4   -45.45    750   60.7*        36.3  -120.46    583   119.3
  6 56.5    45.23      35.0    16.5   -35.81    794   54.0*        39.0  -130.14    578   125.9
  8 49.9    73.94      30.0    13.9   -28.48    834   49.4*        41.3  -137.54    579   130.5
 10 43.4   102.66      20.0     9.2   -17.20    909   43.6*        45.6  -148.98    595   136.2
 12 36.8   131.36       0.      0.      0.     1037   39.8*        53.4  -166.48    668   140.0*
 14 30.3   160.07     -20.0    -9.6    17.09   1129   43.5        -51.9   147.35    789   136.3*
 16 23.8   188.78     -30.0   -14.9    28.23   1153   49.2        -47.2   136.05    865   130.6*
 18 17.2   217.49     -35.0   -17.9    35.47   1157   53.8        -44.6   128.74    909   126.1*
 20 10.7   246.20     -40.0   -21.3    44.98   1153   60.6        -41.4   119.15    958   119.4*
 22  4.1   274.91     -45.0   -25.9    60.06   1133   72.2        -37.1   104.00   1020   107.8
 23 57.6   303.62     -47.5   -31.5    82.00   1087   90.0        -31.6    82.04   1087    90.0
                      SHADOW    ENTRY LAT.  -43.7        EXIT LAT.   -6.2

                                          MAY 28, 1965

  1 51.0   332.33      47.5    28.2   -82.84    652   90.0         28.2   -82.88    652    90.0
  3 44.5     1.04      45.0    23.5   -60.67    712   72.3         32.9  -105.07    608   107.7
  5 37.9    29.75      40.0    19.6   -45.41    768   60.7*        36.5  -120.39    586   119.3
  7 31.4    58.46      35.0    16.6   -35.78    814   54.0*        39.2  -130.08    578   125.9
  9 24.8    87.16      30.0    14.0   -28.45    854   49.4*        41.6  -137.48    576   130.5
 11 18.3   115.87      20.0     9.2   -17.18    929   43.6*        45.8  -148.90    587   136.2
 13 11.7   144.58       0.      0.      0.     1054   39.8*        53.6  -166.43    653   140.0
 15  5.2   173.29     -20.0    -9.6    17.08   1138   43.5        -51.8   147.38    769   136.3*
 16 58.6   202.00     -30.0   -15.0    28.21   1157   49.2        -47.1   136.07    844   130.6*
 18 52.1   230.71     -35.0   -17.9    35.45   1157   53.8        -44.5   128.75    888   126.0*
 20 45.5   259.41     -40.0   -21.3    44.96   1149   60.6        -41.4   119.16    938   119.4*
 22 39.0   288.12     -45.0   -25.9    60.05   1124   72.2        -37.1   104.00   1002   107.8
                      -47.5   -31.6    81.99   1072   90.0        -31.6    82.03   1072    90.0
                      SHADOW    ENTRY LAT.  -44.7        EXIT LAT.   -2.8

                                          MAY 29, 1965

  0 32.4   316.83      47.5    28.4   -82.79    664   90.0         28.4   -82.83    664    90.0
  2 25.9   345.54      45.0    23.6   -60.63    727   72.3         33.1  -105.01    616   107.7
  4 19.3    14.24      40.0    19.7   -45.37    786   60.7*        36.8  -120.33    590   119.3
  6 12.8    42.95      35.0    16.8   -35.75    832   54.0*        39.5  -130.02    579   125.9
  8  6.2    71.66      30.0    14.1   -28.42    873   49.4*        41.8  -137.42    575   130.5
  9 59.6   100.36      20.0     9.3   -17.16    948   43.6*        46.0  -148.84    581   136.2
 11 53.1   129.07       0.      0.      0.     1069   39.8*        53.8  -166.38    640   140.0
 13 46.5   157.78     -20.0    -9.7    17.07   1145   43.5        -51.6   147.42    751   136.3*
 15 40.0   186.48     -30.0   -15.0    28.20   1158   49.2        -47.0   136.10    825   130.6*
 17 33.4   215.19     -35.0   -18.0    35.44   1156   53.8        -44.4   128.78    869   126.0*
 19 26.9   243.90     -40.0   -21.4    44.95   1144   60.6        -41.3   119.18    919   119.3*
 21 20.3   272.60     -45.0   -25.9    60.04   1115   72.2        -37.1   104.01    984   107.8*
 23 13.7   301.31     -47.5   -31.6    81.99   1058   90.0        -31.6    82.03   1058    90.0
                      SHADOW    ENTRY LAT.  -45.6        EXIT LAT.    0.4


MODIFIED ORBITAL ELEMENTS FOR EARTH SATELLITE      6000901

REFERENCE TIME 1965 Y  5 M 15 D  2 H  8.72 M UT
INCLINATION  47.26 DEG.
ASCENDING NODE (LONG.) 279.75 DEG. WEST
PRIME SWEEP INTERVAL  ONE DAY -17.35 MIN.
ARGUMENT OF PERIGEE  82.19 DEG.
     RATE OF CHANGE  0.31295 DEG. PER PERIOD
ANOMALISTIC PERIOD 113.628 MIN.
     RATE OF CHANGE -0.00042 MIN. PER PERIOD
ECCENTRICITY 0.05770
RADIUS OF PERIGEE  4549.7 MILES
RADIUS OF APOGEE   5107.0 MILES
     RATE OF CHANGE -0.30 MILES PER DAY
ASCENDING NODE (R.A.) 344.84 DEG.
     RATE OF CHANGE -3.40370 DEG. PER DAY
LATITUDE OF PERIGEE 46.69 DEG.
READ IN EXPECTED MAGNITUDE IS +1
```

CHART FOR DETERMINING ELEVATION & SLANT RANGE OF SATELLITE

ALL DISTANCES ARE IN STATUTE MILES - 5 STATUTE MILES EQUAL APPROXIMATELY 8 KILOMETERS.

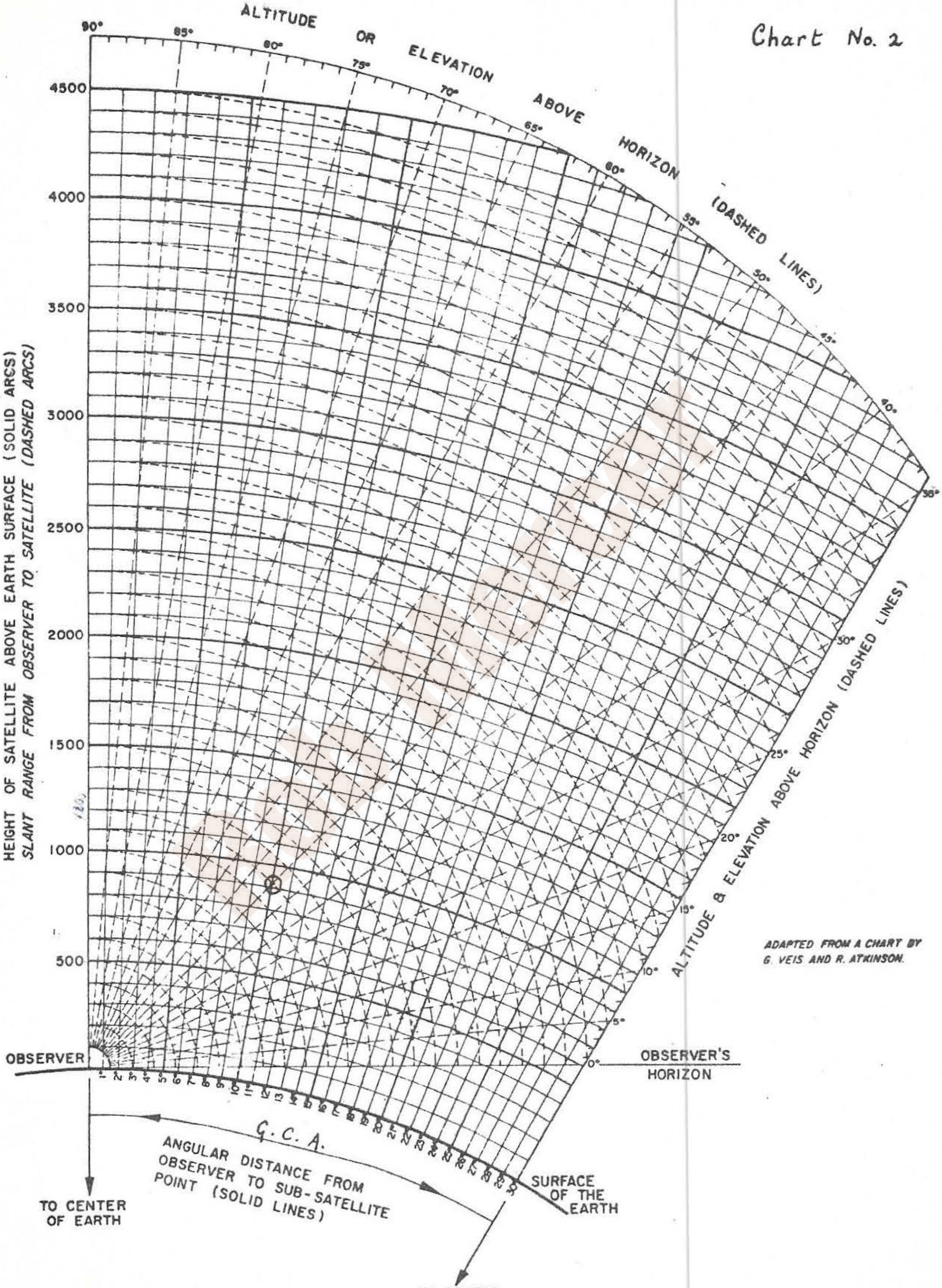
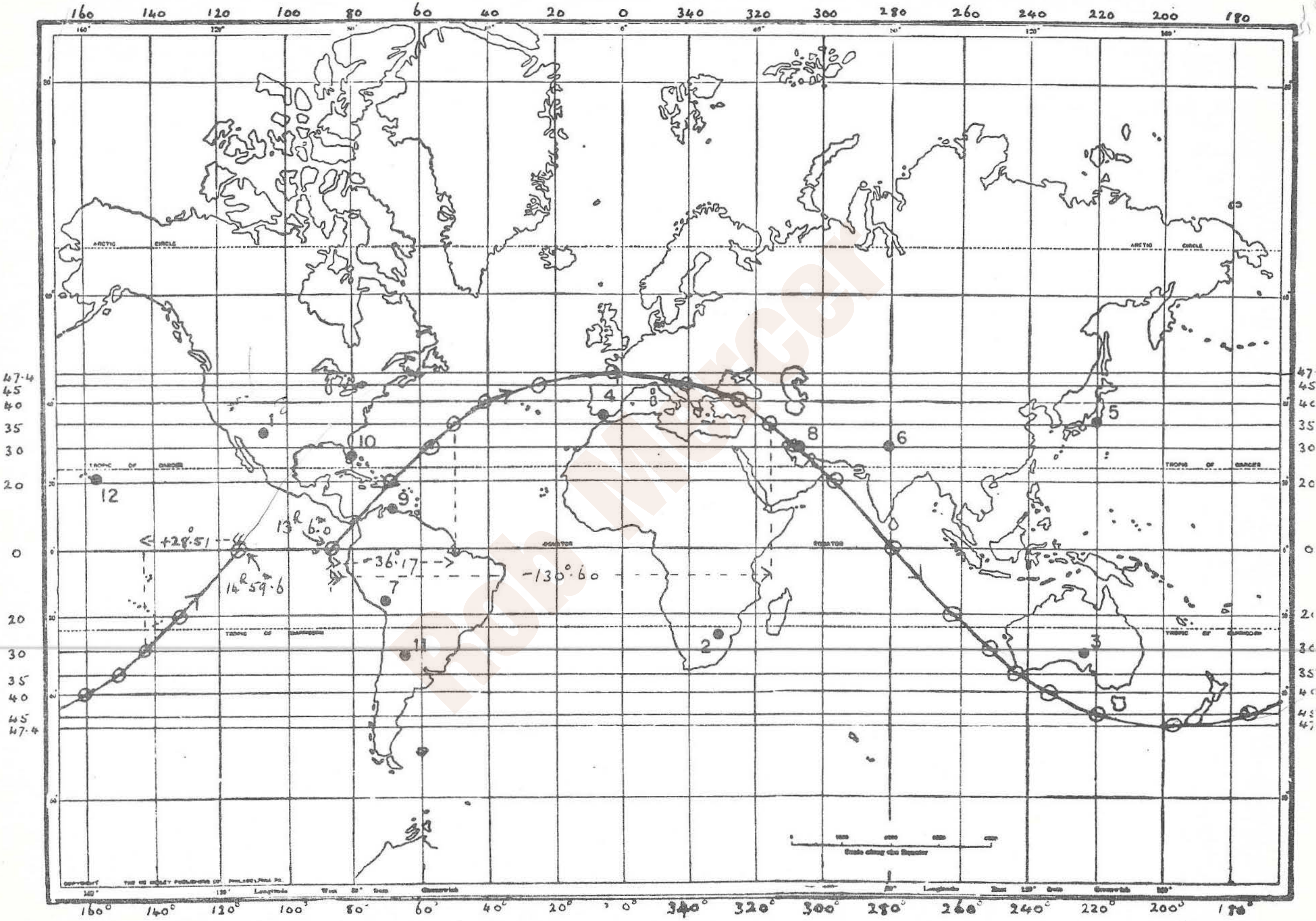


Chart No. 2

ADAPTED FROM A CHART BY G. VEIS AND R. ATKINSON.

Chart No. 3


160
140
120
100
80
60
40
20
0
340
320
300
280
260
240
220
200
180
47.4
45
40
35
30
20
0
20
30
35
40
45
47.4
1
2
3
4
5
6
7
8
9
10
11
12
ARCTIC CIRCLE
TROPIC OF CANCER
EQUATOR
TROPIC OF CAPRICORN
+28°.51
$14^h 59^m.6$
$13^h 6^m.0$
-36°.17
-130°.60

Section (1) - Altitude

See Figure 2. This is a cross section through the center of the earth taken so as to include the satellite and the observing site.

The altitude is the angle between the tangent at the site, representing the observer's horizon, and the line from the site to the satellite.

We can determine the magnitude of this angle if we know the height of the satellite and the distance along the earth's surface from the site to the Sub-Point. As this distance is measured on the spherical surface of the earth, it is, of course, an arc of a great circle.* We shall refer to it as the G.C.A. Note that it is measured, not in miles, but in degrees, just as latitude and longitude are.

There is a formula for calculating altitude from height and G.C.A. but it is easier to read it from a chart such as Chart No. 2, which is nothing more than an enlarged version of Figure 2, with the angles and distances marked off, the latter in statute miles. In addition to the altitude, the chart enables the distance from the observer to the satellite (the "Slant Range") to be read off. It is useful to know this as a guide to how bright the satellite is likely to appear.

Example (1)

Take: G.C.A. = 10°
Height = 910 miles

The chart shows:

Altitude = 45°; Slant Range = 1200 miles.

Chart No. 2 illustrated here is on too small a scale to give very accurate results, particularly when the slant range is small, but larger scale copies of the chart are available. For very close satellites other charts of a different type can be used.

---

*A "great circle" on the earth's surface is one that divides it into halves, such as the equator or a meridian. Others, such as the parallels of latitude (except the equator) are called "small circles."

Section (2) - G.C.A. and Azimuth

So far, we have assumed that height and G.C.A. are known. As will be seen shortly, the ephemeris gives the height and (among other things) the latitude and longitude of the Sub-Point. Using these and the position of your site, the G.C.A. and also the azimuth can be worked out from a formula but are more easily if less accurately obtained by direct measurement on a map.

A map to be used for this purpose should meet the following requirements as closely as possible:

(i) It should be at least 30° square with the position of the site near the middle.

(ii) The scale should be uniform; that is, distances on the map should be in the same proportion to distances on the ground in all parts of the map.

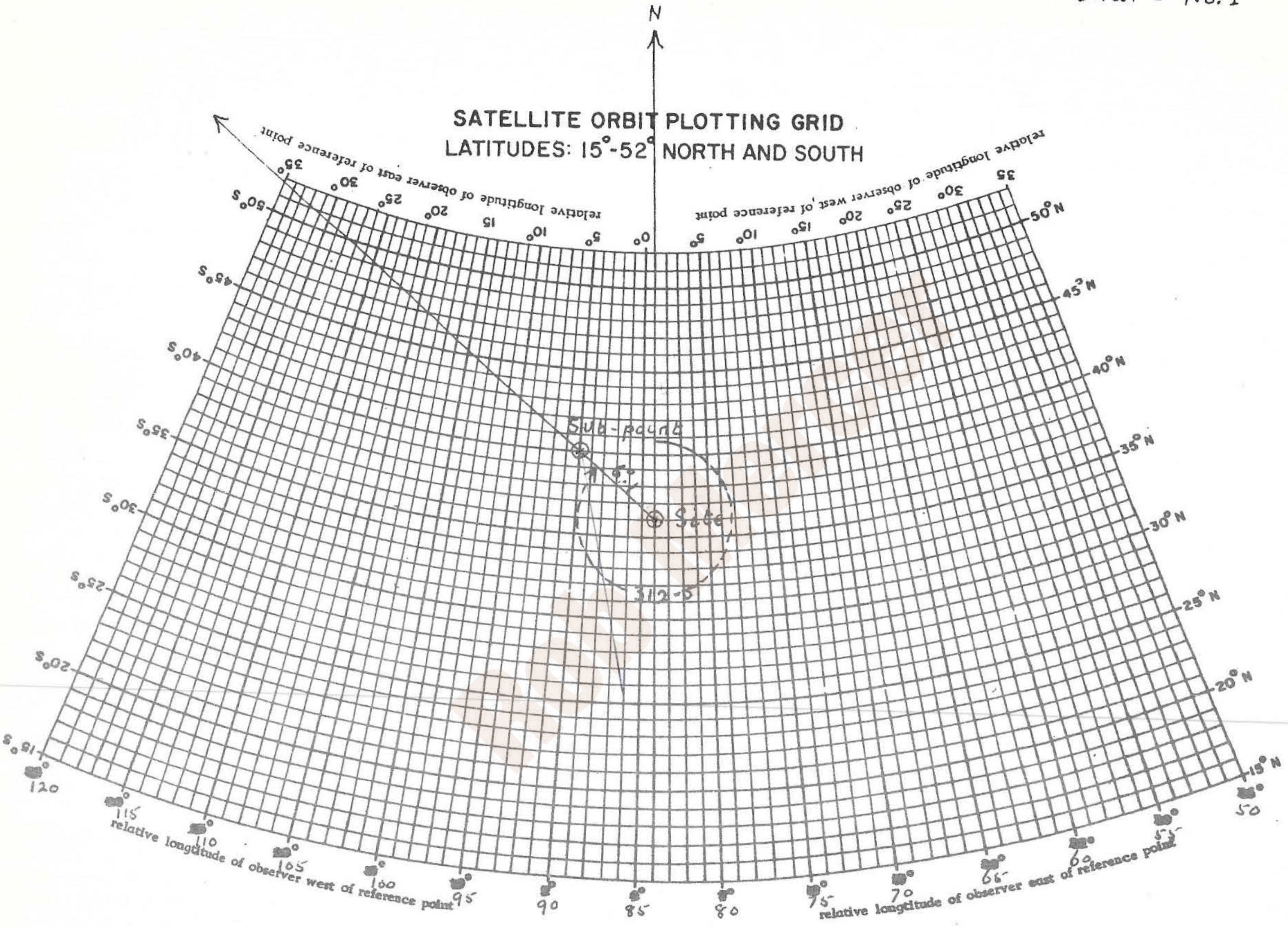
(iii) Directions from the site to other points should be the same as the corresponding directions on the ground.

The map we shall use (Chart No. 1), while not of the best type for the job, is good enough for our purpose and has the advantage of being adaptable to any site within a fairly wide range of latitude. It shows nothing but lines of latitude and longitude. Other details, such as coast lines, are not required and would merely complicate the map to no purpose.

Start by marking in the longitudes in steps of 5° on the heavy lines so that your site is near the middle of the map. Mark the position of your site and that of the Sub-Point and measure the distance between them. This is best done with dividers, measuring against the vertical (latitude) scale of the map. Since the scale of the map is not quite uniform, varying a little at different latitudes, it is best to measure near the latitude of the site.

To obtain the azimuth of the Sub-Point (which is, of course, also that of the satellite), simply draw a line due North from the site and another from site to Sub-Point and measure the angle between them with a protractor. Take care to measure clockwise from North.

Chart No. 1


N
SATELLITE ORBIT PLOTTING GRID
LATITUDES: 15°-52° NORTH AND SOUTH
relative longitude of observer east of reference point
relative longitude of observer west of reference point
0°
5°
10°
15
20°
25°
30°
35
50° S
45° S
40° S
35° S
30° S
25° S
20° S
15° S
50° N
45° N
40° N
35° N
30° N
25° N
20° N
15° N
Sub-point
Satel
312-5
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
relative longitude of observer west of reference point
relative longitude of observer east of reference point

Example (2)

Refer to Chart No. 1. We have taken the positions to be:

	Site	Sub-Point
Latitude :	+36°	+40°
Longitude:	− 84°	90°

We find: G.C.A. : 6°.1

Azimuth : 312°.5

(The computed figures are : G.C.A. : 6°.20; Azimuth : 312°.05.)

Section (3) - Latitude, Longitude and Time from Ephemeris VI

Refer to the specimen copy of Ephemeris VI for Echo I.

It will be seen to be divided into sections, one for each day, and each section is divided into eleven columns which have been numbered for reference. Each sheet of the ephemeris covers a period of 15 days.

In order to appreciate the meaning of the ephemeris more clearly, first look at Figures 3 and 4 which illustrate the relative motions of the satellite, the orbit and the earth; and then at Chart No. 3 which shows the track of the Sub-Point for one particular revolution.

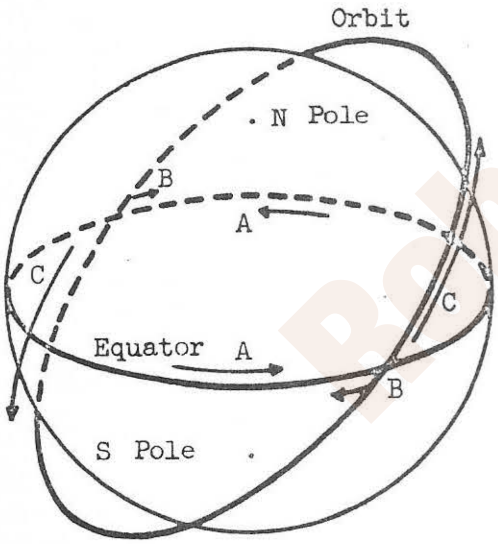


Figure3.

Motion of Earth (A), Orbit (B), and Satellite (C)

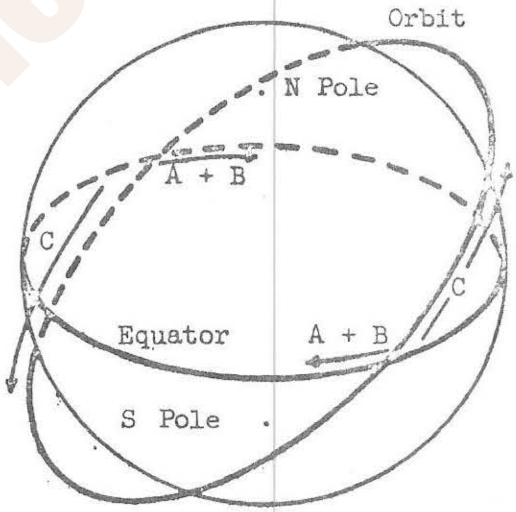


Figure 4.

Relative motion of Orbit and Earth (A+B); and motion of Satellite (C).

Let us start at the point where the Sub-Point crosses the equator from South to North.

Since this particular satellite moves eastward in its orbit faster than the earth rotates eastward under it (most of them do), the Sub-Point crosses each successive parallel of latitude at a point farther East than the last. When it has reached a latitude roughly equal to the angle of inclination of the orbit plane to the equator, it turns southward, crossing the equator again, this time from North to South, on the opposite side of the earth. The path is then traced out in reverse in the Southern Hemisphere and the Sub-Point finally crosses the equator again from South to North. As the earth has been rotating eastward under the orbit, it will do so at a longitude farther West than that at which it started.

Observe that, except at the extreme North and South points, the Sub-Point crosses each parallel of latitude twice.

Now return to the ephemeris.

Columns 1 and 2 give the time and the longitude at which the Sub-Point crosses the equator from South to North on each successive revolution. Times are given in hours, minutes and one decimal and longitudes in degrees and two decimals. Longitudes are measured West.

Column 3 gives a series of selected latitudes to which the remaining columns refer.

Columns 4, 5, 6 and 7 refer to the latitude crossings at which the Sub-Point is moving from South to North; and the remaining columns to those at which it is moving from North to South.

Columns 4 and 8 give the corrections to be applied to the times in column 1, and columns 5 and 9 give the corresponding corrections to the longitudes in column 2.

Columns 6 and 10 give the height of the satellite in miles. Ignore columns 7 and 11. They give the direction of motion of the Sub-Point, but we shall not use this information.

The use of the ephemeris will be best explained by means of an example.

<u>Example (3)</u>

Look at the section headed May 15, 1965. About halfway down cols. 1 and 2, we find a South to North equator crossing at:

Time (U.T.) : $13^{h}\,6^{m}.0$
Longitude : $86^{\circ}.08$

Looking in col. 6 opposite latitude 0°, we find that the height is 811 miles.

Now follow the satellite round, following the arrows (corresponding to the line on Chart No. 3).

At latitude +35° S-N, we have, using columns 4, 5 and 6:

Time (U.T.) : $13^{h}\,6^{m}.0 + 15^{m}.1 = 13^{h}21^{m}.1$
Longitude : $86^{\circ}.08 - 36^{\circ}.17 = 49^{\circ}.91$
Height : 627 miles

At latitude +35° N-S, now using columns 8, 9 and 10:

Time (U.T.) : $13^{h}\,6^{m}.0 + 37^{m}.2 = 13^{h}43^{m}.3$
Longitude : $86^{\circ}.08 - 130^{\circ}.60 = -44^{\circ}.52 = 315^{\circ}.48$
Height : 670 miles

Still following the arrows, we note that after passing latitude 0° North to South, the corrections change sign. This simply means that they are now to be applied to the S-N equator crossing <u>toward</u> which the satellite is moving, not <u>from</u> which it is moving, as we have been doing so far.

Thus, if we want to follow the same revolution, we must now apply the corrections to the crossing at:

Time (U.T.) : $14^{h}59^{m}.6$
Longitude : $114^{\circ}.81$

At latitude -30° S-N (cols. 4, 5 and 6) we have:

Time (U.T.) : $14^{h}59^{m}.6 - 13^{m}.8 = 14^{h}45^{m}.8$
Longitude : $114^{\circ}.81 + 28^{\circ}.51 = 143^{\circ}.32$
Height : 1016 miles

The Sub-Point track on Chart No. 3 was drawn for this revolution, and we have indicated the three points worked out in the above Example.

NEWS RELEASE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WALLOPS STATION, WALLOPS ISLAND, VIRGINIA 23337
TELEPHONE: VALLEY 4-3411 - EXTS. 584 and 579

FOR RELEASE: Thursday, February 22, 1968

Release No. 68-3

WALLOPS LAUNCHES SIX EXPERIMENTS OVERNIGHT

The National Aeronautics and Space Administration conducted six chemical cloud experiments between sunset last night and dawn today from its Wallops Island, Va., Station.

Liftoff times were 6:17 p.m., 12:09 a.m., 1:30 a.m., 3:00 a.m., 4:30 a.m., and 6:02 a.m. EST. There were seven launches scheduled in this series. The second launch planned for 10:30 p.m. was cancelled because of payload problems.

Three different chemicals--triethylborane (TEB), trimethylaluminum (TMA), and sodium--were used in this series, to continue the study of short term and seasonal variations in wind structure in the upper atmosphere. Similar tests were conducted at Wallops in January and July 1966, and August 1967.

The dawn firing was a sodium vapor experiment which generated a reddish-orange cloud visible for hundreds of miles

-more-

along the East Coast. The other five payloads consisted of TEB (first one) and TMA (the next four) vapor trails which formed pale green and blue clouds, less visible than the sodium.

The payloads were flown on Nike-Apache research rockets and the vapor trails were ejected at altitude ranges of about 50 to 90 miles. Data on wind conditions were obtained by photographing the motion of the trails from five camera sites within a 100-mile radius of Wallops Island.

The first rocket was equipped with a photometer for observing airglow in sunlight above the dark earth to get a vertical profile (or chart) of atomic oxygen. The five other payloads carried Langmuir probes for measuring electron energy distribution.

The launchings were conducted in cooperation with the GCA Corporation, Bedford, Mass., under contract to NASA's Goddard Space Flight Center, Greenbelt, Md. William T. Burns was the Wallops Station Project Engineer, responsible for coordinating pre-launch, launch, and tracking operations.

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