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THE NIMBUS II DATA CODE EXPERIMENT

LEON GOLDSHLAK
WILLIAM K. WIDGER, JR.

TECHNICAL NOTE NO. I
CONTRACT NO. NAS5-10114

JANUARY 1966

PREPARED FOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

ARACON GEOPHYSICS DIVISION
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FOREWORD

This report discusses the interpretation and use of the information provided by the Nimbus II Data Code experiment for acquiring and geographically locating APT and DRIR data. The work was performed by ARACON Geophysics, a Division of Allied Research Associates, Inc., Concord, Massachusetts, for the Goddard Space Flight Center, National Aeronautics and Space Administration. It was begun under Contract No. NAS 5-3253, and completed under Contract No. NAS 5-10114.

The authors wish to acknowledge the significant assistance of Mr. Bernard J. Trudell, Nimbus Project, GSFC, who provided necessary information, as well as helpful comments following a review of the initial draft of this report. Illustrative material was prepared by Messrs. William Harbour and Walter P. Smith.

ABSTRACT

The Nimbus II Data Code is an experimental communications system which is an integral part of the Automatic Picture Transmission (APT) system. It provides information as to the positions and times of both the ascending nodes and the perigees of current and near future Nimbus orbits, as well as the exact time of each APT picture on which it appears.

The information provided by Data Code is used to update an initial or subsequently provided ephemeris, which is mailed or transmitted over conventional weather or other communications at relatively infrequent intervals. These combined sources of data are designed to be used with standard APT plotting boards and geographical grids to provide all orbital information needed to acquire and geographically locate both APT and Direct Readout Infrared Radiometer (DRIR) data.

Detailed procedures for the interpretation of the Data Code, and its use for acquiring and locating the data, are provided.

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1. INTRODUCTION

The Nimbus II Data Code is basically an experimental communications subsystem developed to provide users of Automatic Picture Transmission (APT) and Direct Readout Infrared Radiometer (DRIR) data with updated ephemeris information required for the acquisition and geographical location of the APT and/or DRIR data. The Data Code information is provided as an integral part of the facsimile recorded APT display, and so is automatically received while acquiring the APT picture.

1.1 Objectives

The primary purposes of the Data Code experiment are to:

1. Automatically provide the precise times at which APT pictures are taken, thus eliminating the effort and inaccuracies inherent when each picture time must be manually determined at each ground station.

2. Provide, when combined with an initial or infrequently updated ephemeris message received through the mails or normal communications channels, sufficient current orbital information to APT ground stations to permit acquisition and geographical location of APT and/or DRIR data.

3. Eliminate the need for transmission of lengthy, daily ephemerides messages which overload already crowded conventional communications channels, and require APT stations to monitor such communications to insure receipt of the necessary orbital data. With the use of Data Code, all necessary updating information is provided automatically when an APT picture is received.

4. Provide local APT stations with an adequate basis for data acquisition and location, even if conventional communications are inadequate. Once having received an accurate ephemeris message for any satellite, the Data Code information permits updating of the required information for relatively extended periods of time.

1.2 Background

APT systems have already been flown experimentally on two satellites: TIROS VIII and Nimbus 1. The TIROS VIII APT camera operated from 21 December 1963, until May 1964; the Nimbus I from 28 August to 21 September 1964. Both flights demonstrated both the technical feasibility of the APT system and the great value of APT data to local meteorological stations.

Acquisition and location of the APT or DRIR data require that each station be equipped not only with the proper receiving and recording equipment, such as that discussed in Reference 1, but also:

1. Appropriate nomographs for plotting the subpoint path of the satellite and for determining its location relative to the receiving station (References 2 and 3).

2. Sets of appropriate geographical grids for use in locating the features in the data (References 2, 3, and 4).

3. Information as to the spatial location of the satellite as a function of time (i. e., ephemerides).

The plotting nomographs and the ephemerides are used by any local APT station, regardless of location, to develop tracking data by which the antenna can be kept aimed at the satellite (during the times it is within range of the station) and the APT or DRIR data acquired. These same nomographs and ephemerides, plus geographical grids, are then used to geographically locate and orient (i. e., grid) the features in the data; only then are the data ready for meteorological interpretation and use.

Since the plotting nomographs and grids are a permanent part of the necessary equipment of an APT station, the primary problem from an operational viewpoint is providing current ephemerides in a timely and efficient manner.

1.3 The Problem of Ephemerides Preparation and Communication

Although, in principle, a current ephemeris can be computed from a rather limited number of basic parameters, in practice it requires appropriate computer facilities, programs, and trained personnel. Accordingly, rather detailed ephemerides should continue, as at present, to be generated at central facilities and to be disseminated to local APT stations. It would be neither feasible nor desirable to place this burden on local meteorological personnel. In fact, any attempt to do so would almost certainly lead to essentially no operational use of the APT capability at most local weather stations.

Ideally, it would be desirable for central facilities to "custom tailor" the ephemerides data required by each local APT station, and so to disseminate individual messages to each station. Existing conventional communication links are, however, entirely incapable of adding such a message load to their present traffic, which already nearly saturates their capabilities. Even if it were presently possible, the problems would constantly increase as more APT stations are installed, more than one APT satellite (TOS in addition to Nimbus) is operating concurrently, and night side as well as day side pass data are made necessary by the inauguration of the DRIR capability.

In fact, even the present system (see below) will generate a message load taxing the capabilities of existing conventional weather communications systems when two APT satellites (TOS and Nimbus), plus the Nimbus DRIR subsystem, are concurrently in operation.

The present system for providing and using the required ephemerides data was developed (Reference 2) as a compromise between, on the one hand, overloading existing communications and, on the other, placing an excessive work load on the personnel of local APT stations. The information to be disseminated has been essentially limited to daily transmissions of incremental (two minute) values of the spatial positions of the satellite over that portion of a single orbit from which data can be obtained, and to the ascending nodes for the other orbital passes that will occur during a period of about twenty-four hours. Once the detailed spatial positions for the one orbit have been plotted on the standard APT plotting board, they change sufficiently slowly with time (over a day or so) to be used on other orbits merely by rotating them to different ascending nodes. Simple nomographs, tables, and geographical grids then permit the translated ephemerides to be used to easily compute tracking angles and geographical locations. The specific procedures have been described in some detail in References 2 and 3, and will not be recapitulated here.

The development of the Data Code capability now permits even a further reduction in the information to be disseminated, since it can be limited to an infrequent, rather than a daily, detailed ephemerides of a typical orbit. The detailed ephemerides will be provided in a format which will normally be valid for a week or more, and they can be computed sufficiently in advance of their valid period to permit their dissemination by mail, rather than requiring electrical transmission (with the exception, of course, of the initial message immediately following launch). All other information required by the user (that required for the day to day updating of the detailed ephemerides) will be provided by the Data Code and acquired concurrently with the APT picutres.

1.4 A Brief Summary of the Data Code Approach

At the orbit altitudes normally used for meteorological satellites, the shape of an orbit (i. e., its configuration relative only to the center of the earth) changes only very slowly with time (see Appendix A). Thus, when ephemeris data are provided in terms of an identifiable point on the orbit itself (rather than in terms relative to the earth's surface, such as the ascending node as used in the APT messages in References 2 and 3), the ephemeris remains valid for rather extended periods of time. By convention, the perigee of an orbit (the position along the orbit where its distance from the center of the earth is a minimum) is used as a unique and identifiable point in terms of which the ephemeris information for the remainder of the orbit is provided.

In using Data Code, the initial and subsequent ephemerides messages provide data on the spatial positions of the satellite relative to perigee. The Data Code information, transmitted with each APT picture, then provides the day to day locations of perigee relative to the surface of the earth, and the rate of change of the position of perigee. Thus, the Data Code information allows the semi-permanent, perigee-related ephemeris to be fixed in its proper position relative to the earth's surface at any given time, and its use to acquire and locate the APT or DRIR data.

Although the approach may sound rather vague and difficult when stated only in general terms, as those just above, in practice the necessary steps are simple and straight-forward. (The above, very brief summary was provided to aid the reader in subsequently visualizing the reason for the various steps, rather than having to accept them mechanically with no idea of subsequent steps and the ultimate goal.) The remainder of the report describes in some detail the format of the Data Code as recorded with the APT picture, the method of interpreting the Data Code information, and the procedures for using it and the perigee-related ephemerides to acquire and locate APT or DRIR data.

Many aspects of the procedures for the use of Data Code are identical or analogous to those discussed in References 2 and 3. Accordingly, only the modified procedures are discussed here, with the previously developed procedures incorporated by reference as appropriate.

2. DATA CODE FORMAT

The Nimbus II Data Code will appear adjacent to the left edge of the APT picture as the facsimile paper feeds through the recorder (Figure 1). The space occupied by the Data Code does not interfere with the square vidicon image (i. e., 8" x 8" for a Nimbus APT picture on a Fairchild facsimile recorder).*

The Data Code display consists of two rows, each of which is to be considered as divided into 50 equal parts. Row 1 (that nearest the edge of the paper) consists of 50 Character Blocks represented by alternating white and black squares (Figure 2a). Counting from left to right, as shown by the image as oriented in Figure 2a, the odd numbered character blocks are always white and the even numbered character blocks are always black. (As discussed later, character blocks 1, 11, 21, 31, and 41 are partially black in actual use.) The alternating white and black character blocks are used for visual reference and identification purposes only. They do not represent actual data content. Each character block represents four seconds of real time,** or 0. 16 inches on the 8" x 8" Fairchild facsimile display.

Row 2 is reserved for data content. The data are presented in the Binary Coded Decimal (BCD) notation. Four bit locations are available beneath each of the fifty character blocks (Figure 2b). (Although dividing lines are shown beneath each character block (Row 2) in Figures 2a and b, for clarity, they do not appear on the actual facsimile display.) The bit locations are identified from right to left (one to four) under each character block (see Figure 2b). Each bit location represents one second of real time, or 0.04 inches on the 8" x 8" Fairchild facsimile display.

A bit appears as a black rectangle totally occupying any of the four bit locations beneath the character blocks (Figure 3). The numerical value varies with each bit location, as shown in Table 1. If more than one bit appears under a single character block, the numerical values of each such bit are summed to obtain the digital value for the character block, as can be noted for character blocks 4, 6, 7, 8 and 10 in Figure 3.

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* If Data Code is later adopted for use on APT TOS, the exact image area may be slightly different since the two satellites presently use a somewhat different magnification factor (see Reference 3).

** As used here, real time refers to the actual time elapsed as the picture is scanned off the vidicon and recorded by the facsimile.

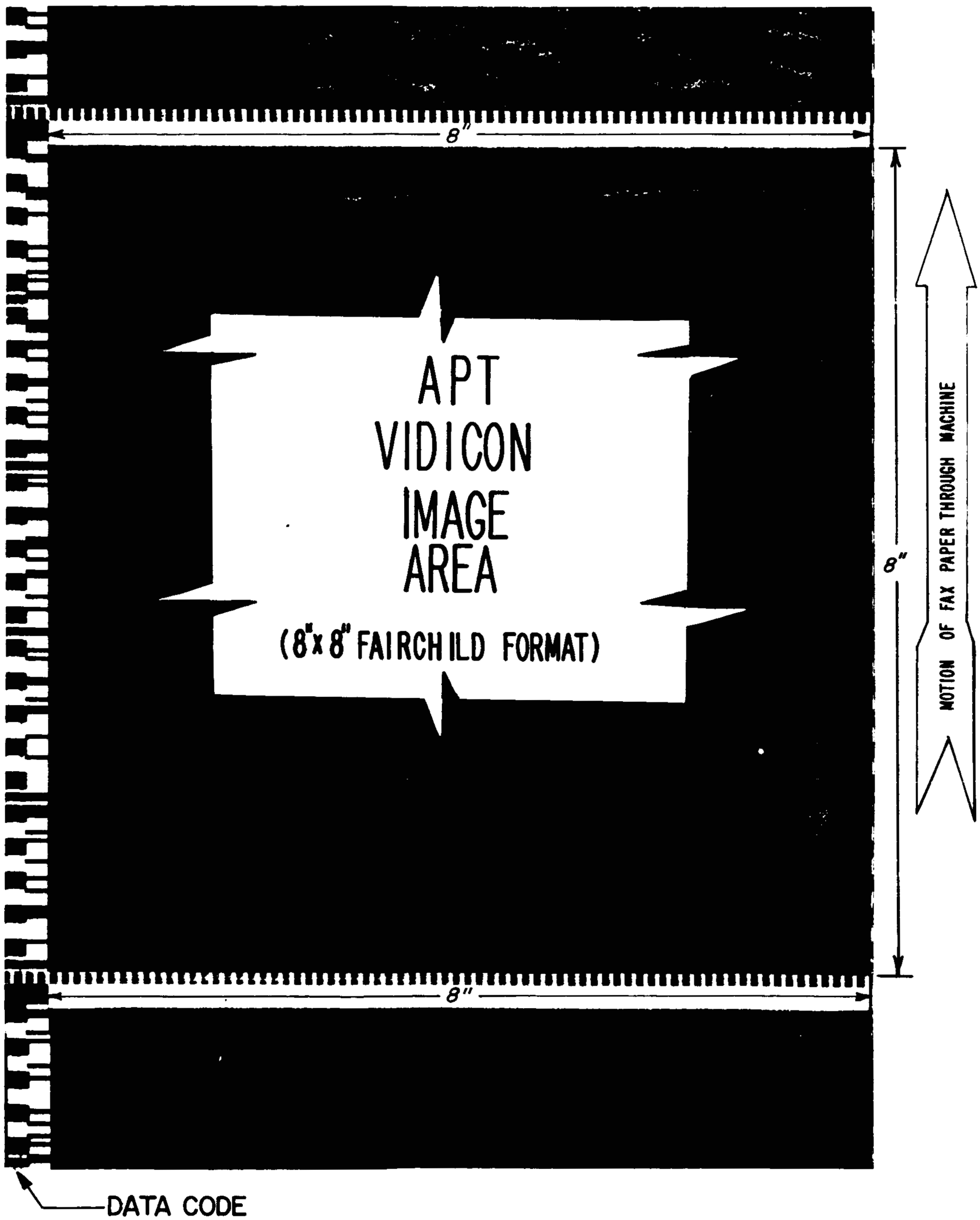

Figure 1. Data Code Location on APT Image

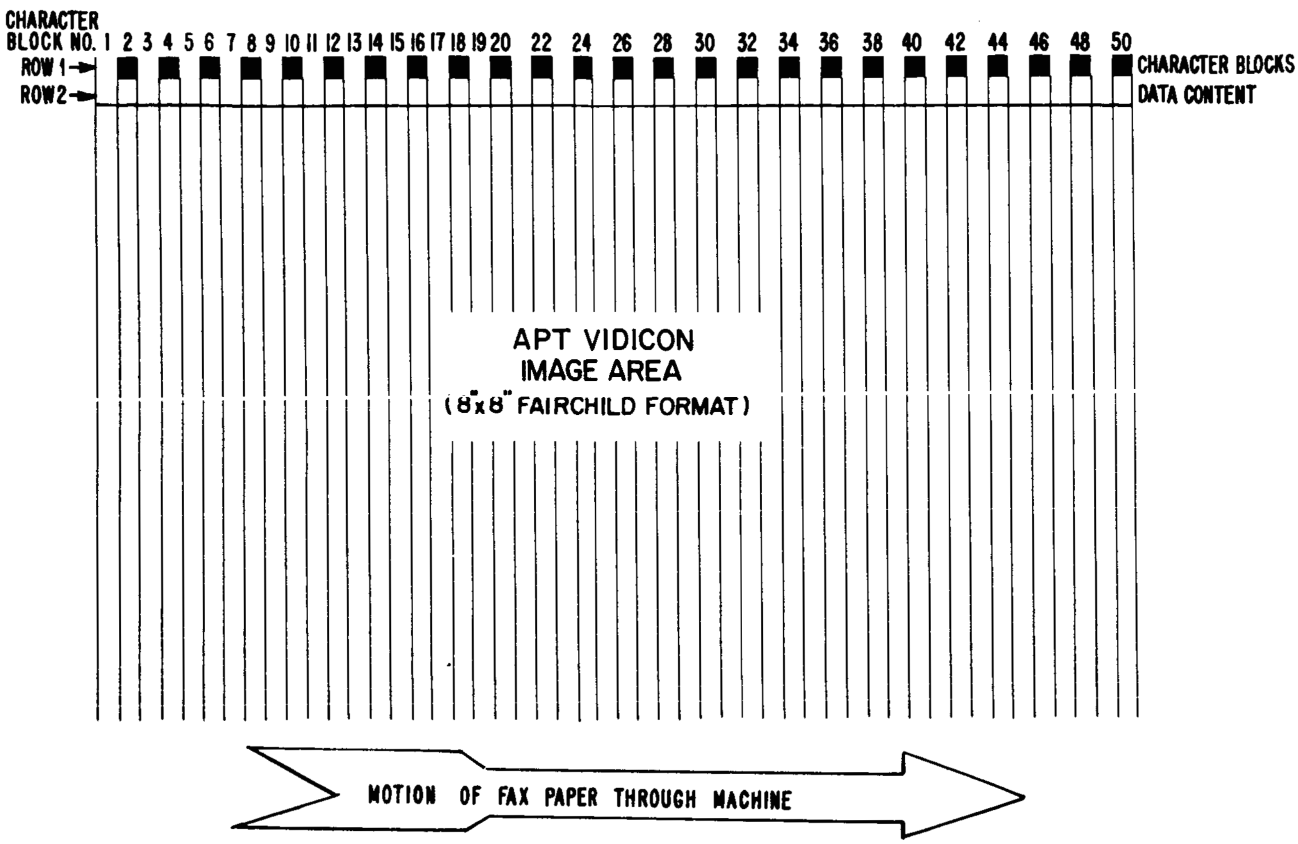

Figure 2a. Data Code Format

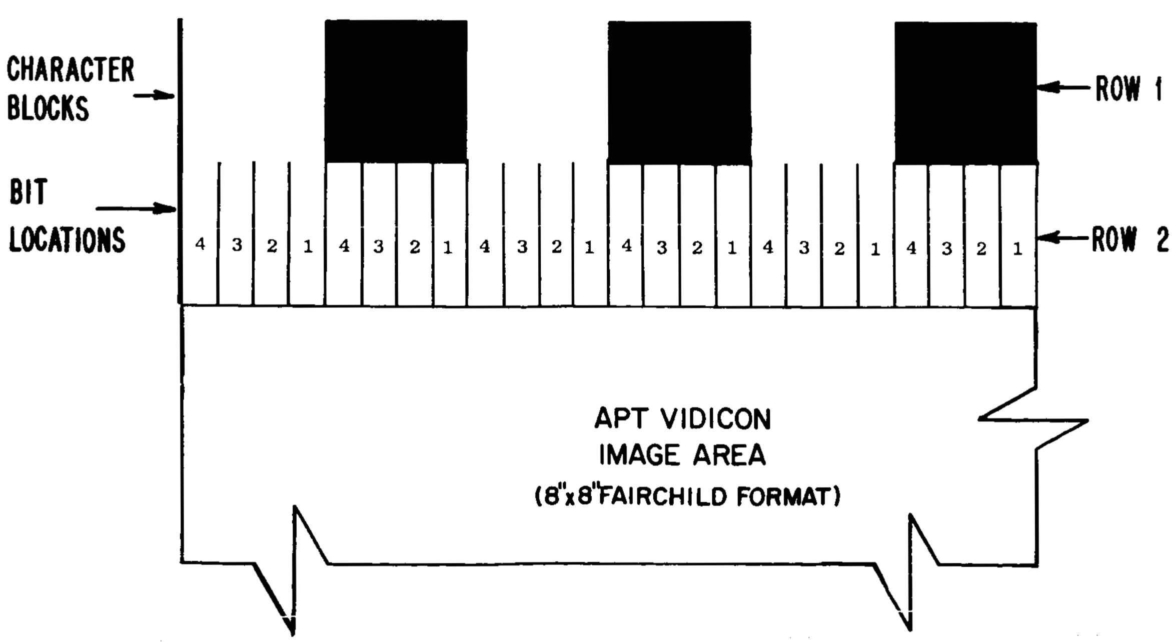

Figure 2b. Data Code Bit Locations (Enlarged)

TABLE 1

Numerical Values of Data Code Bits

Bit Location	Binary Code	Decimal Value
1	2^0	1
2	2^1	2
3	2^2	4
4	2^3	8

Figure 3 can be used to identify the digital value of any combination of bits. The value of a given combination of bits is the same, regardless of whether it is under a black or a white character block. For example, in Figure 5b, both character blocks 44 and 49 have a digital value of 5.

To simplify location and identification of the various items of data provided by the Data Code format, the fifty character blocks have been divided into five words of ten character blocks each. Counting sequentially from left to right (Figure 4), character blocks 1, 11, 21, 31 and 41 are used as dividers between words. To distinguish these word dividers, the format of these five character blocks has been slightly modified. Instead of the white square that would normally appear in Row 1 in these locations, a rectangular bar is superposed through both rows in what would be bit locations two and three. Although the width and location of this bar corresponds (in Row 2) to a digital value of 6, this is merely a coincidence and the bars have no significance except as identifiers of the beginning of each of the five words.

A minor modification to this divider format occurs in character block 41. Here, although the format of Row 1 is the same as for the other divider blocks, in Row 2 the lower half of the rectangular bar is shifted one bit location to the right (i.e., to bit locations one and two -- see Figure 4). Again, the apparent digital value (3 in this case) has no significance to the user of Data Code.* This modification to the format identifies the difference in mode of operation between words one through four, and word five. The entries in words one through four are inserted on the basis of commands originated on the ground and transmitted from a Nimbus Data Acquisition Facility (DAF). Word five, on the other hand, is automatically generated by the spacecraft clock.

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* The difference in the format of the dividers is related to the electronics involved in the mode of generation of the data words, but need not concern us here.

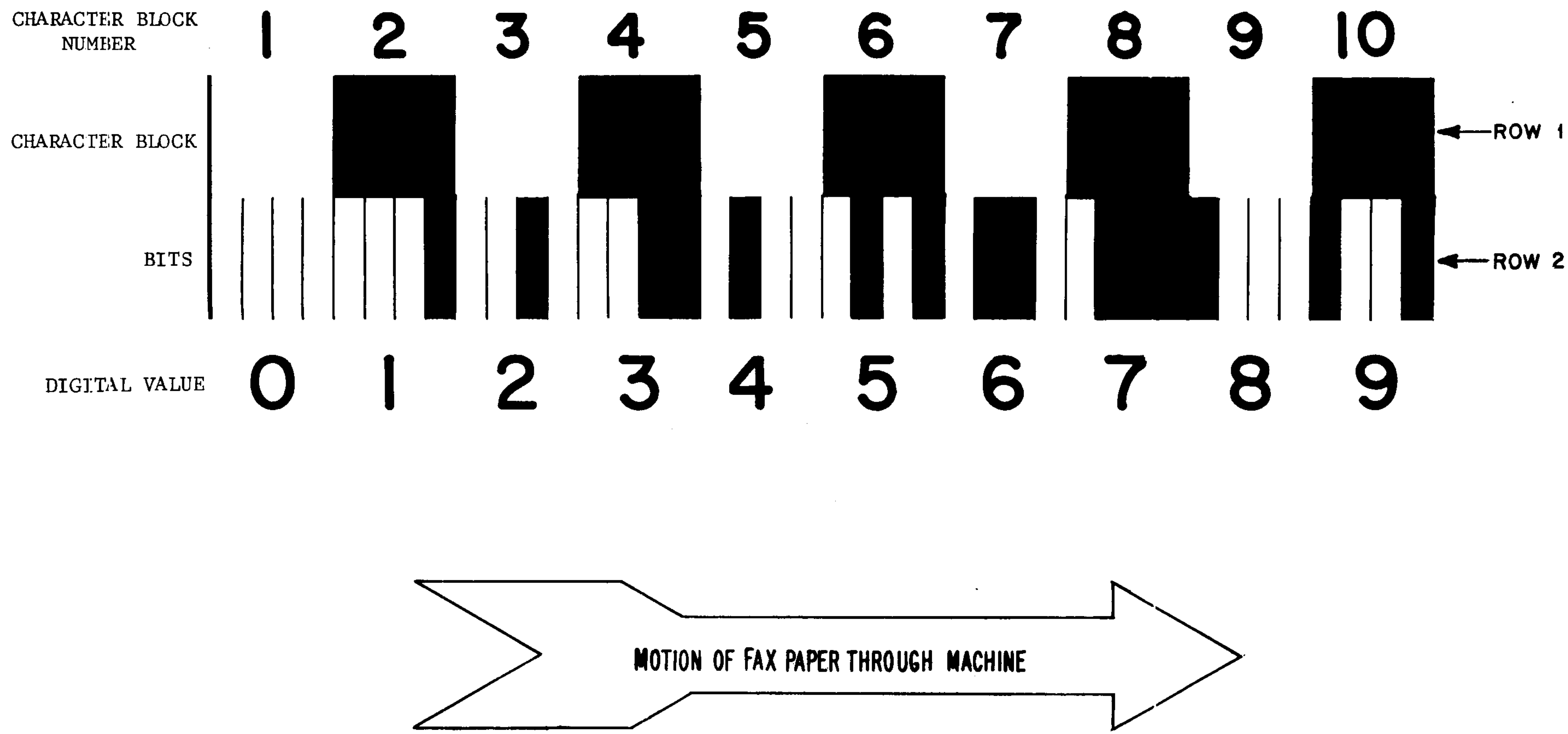

Figure 3. Sample Data Code Bits and Digital Values

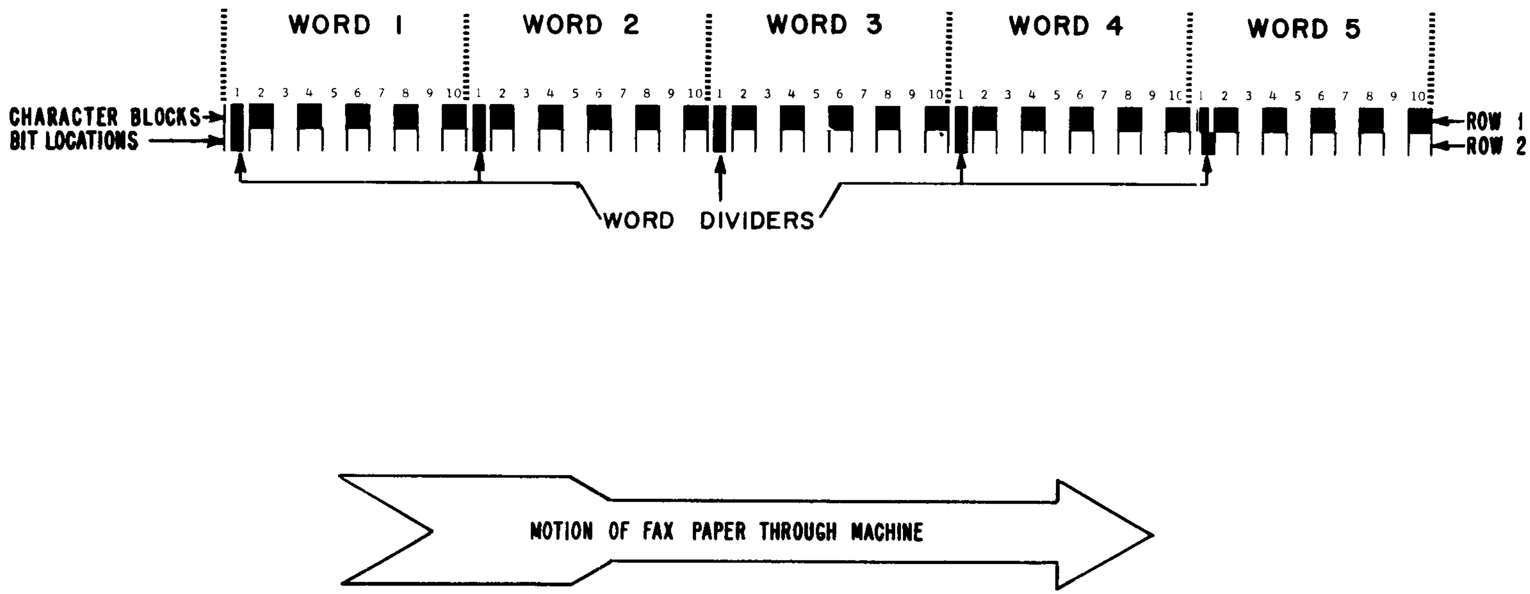

Figure 4. Identification of Data Code Locations and Format of Word Dividers

In subsequent discussions, the character blocks will be identified in terms of the word number (1 to 5) and of the character block within each word (1 to 10), as shown in Figure 4, rather than the 1 to 50 identification used in the previous description.

3. INTERPRETATION OF THE INFORMATION PROVIDED BY DATA CODE

The decision as to the information to be provided by Data Code was arrived at after considering: (1) presently established techniques for acquiring and locating APT data; (2) information required to acquire and locate DRIR data; and (3) the amount of space available in the Data Code format. A major consideration in the determination of the optimum information content for Data Code was to insure complete compatibility with the equipments previously developed and disseminated for acquiring and locating the APT and DRIR data; i.e., plotting boards, overlays, nomographs, tabulated information, geographical grids, etc. Use of the Data Code information does not require any new equipment and, furthermore, the procedures to be followed are, in so far as possible, analogous to those previously developed for acquiring and locating the APT data (References 2 and 3).

The types and formats of the Data Code information are summarized in Table 2 and Figure 5a, and are described in detail below. The procedures for the use of the several items of information are described in Section 4.

Since the detailed description of the information format is aided by an example, the sample Data Code shown in Figure 5b will be used. Before proceeding further, the reader is urged to become familiar with the binary coded decimal notation by decoding the series of digits represented by Figure 5b.

TABLE 2

FORMAT OF DATA CODE INFORMATION

WORD	CHARACTER BLOCK	ITEM OF INFORMATION	UNITS OR INTERPRETATION
1	1	Word Divider	
	2 - 5	Reference Orbit Number	
	6	Hemisphere of Ascending Node	0 = E; 7 = W
	7 - 10	Longitude of Ascending Node on Reference Orbit	Degrees and tenths
2	1	Word Divider	
	2 - 4	Longitude Increment between Successive Ascending Nodes	Degrees and hundredths (westward); initial 2 or 3 (20^{o} or 30^{o}) understood
	5 - 10	Ascending Node Time of Reference Orbit	Hours, Minutes, Seconds (UT)*
3	1	Word Divider	
	2 - 5	Time Increment between Successive Ascending Nodes = Nodal Period	(1 or 2 hours, understood), Minutes, Seconds
	6	Hemisphere of Perigee	0 = N; 7 = S
	7 - 10	Latitude of Perigee on Reference Orbit	Degrees and hundredths
4	1	Word Divider	
	2 - 7	Time of Perigee on Reference Orbit	Hours, Minutes, Seconds (UT)*
	8 - 10	Motion of Perigee, from one orbit to next	Thousandths of a degree of Great Circle Arc (i. e., in argument) per orbit
5	1	Word Divider (split)	
	2 - 4	Calendar Day of Picture	Day one to day 365 (366 for leap year); see Table 3
	5 - 10	Picture Time	Hours, Minutes, Seconds (UT)

* Note: If same day as that of picture (Word 5, CB 2-4), the first digit (Word 2, CB 5, or Word 4, CB 2) will be 0, 1, or 2. If following day, 4 is added to first digit: 4 = 0; 5 = 1; 6 = 2. If second day following that of picture, 7 is added to first digit: 7 = 0; 8 = 1; 9 = 2.

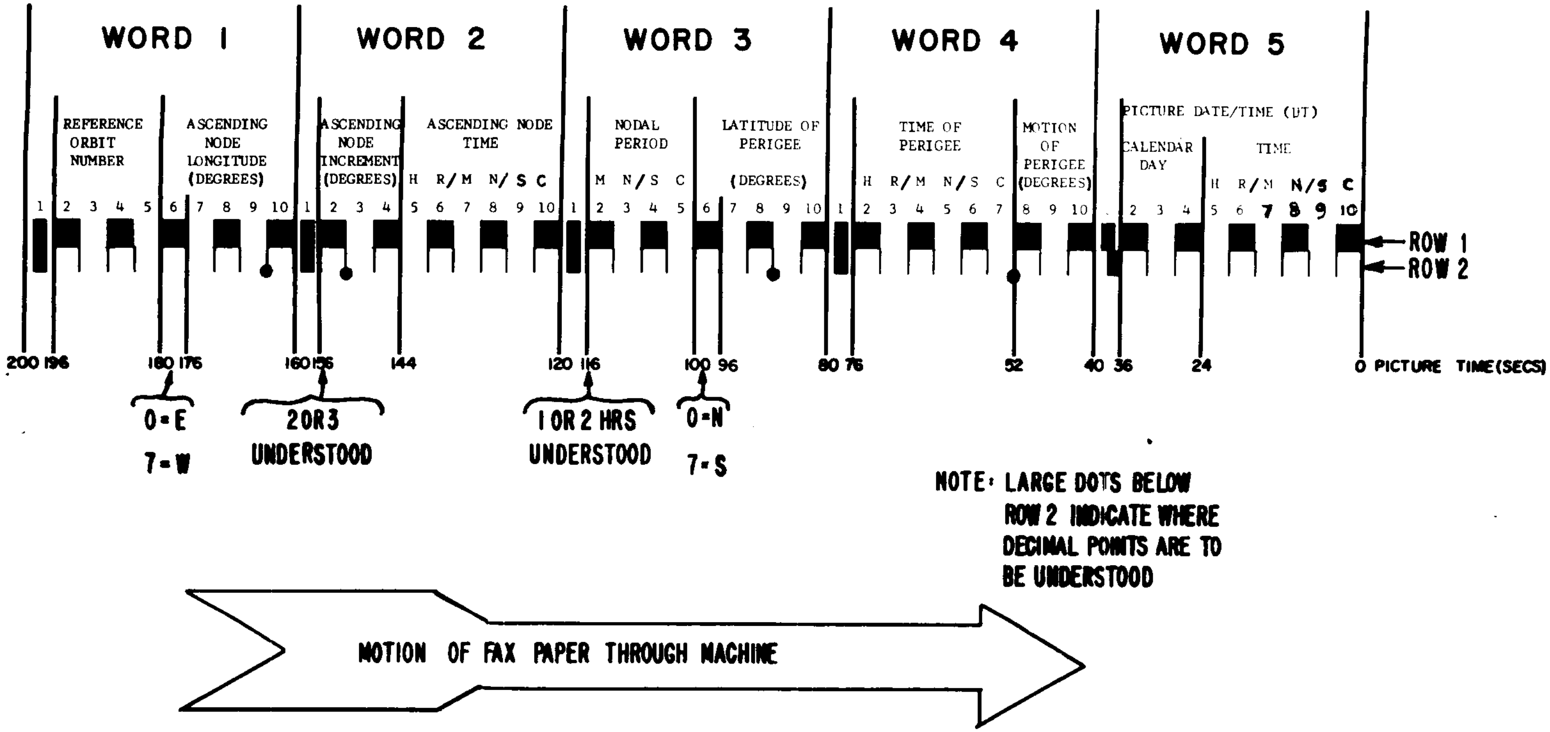

Figure 5a. Identification of Data Code Information

Figure 5b. Sample Data Code Message

Correct decoding of Figure 5b leads to the following series of digits (the word dividers are here represented by slashes):

/ 133871246 / 705121938 / 461401083 /122147107 / 095123156

3.1 Information Format

Proceeding now to the description of the information format, and using the example shown in Figure 5b and digitally decoded above:

Word 1, CB* 2-5	The number of a reference orbit, to which all other data in Words 1 through 4 correspond. The orbit number increases by one at each ascending node. The reference orbit will seldom be the one on which the Data Code information is acquired; usually it will refer to the 6th, 7th, 12th, or 13th orbit later. Example: 1338 Reference orbit number is 1338.
Word 1, CB 6	Hemisphere of ascending node of reference orbit; 0 indicates the eastern hemisphere; 7 indicates the western hemisphere.
Word 1, CB 7-10	Longitude of ascending node of the reference orbit in degrees and tenths. It is to be understood that a decimal point exists between CB 9 and 10. Example (for CB 6-10): 71246 Ascending node longitude of reference orbit is 124.6° W
Word 2, CB 2-4	The longitude increment, in degrees and hundredths, between successive ascending nodes. It is to be understood that a decimal point exists between CB 2 and 3. Because of the eastward direction of the rotation of the earth, the increment is always to the west for increasing orbit number. The value of the increment remains essentially constant over a period of days to weeks. For the altitudes of typical Nimbus, TIROS,

* CB = character blocks

and TOS orbits, the range of increments will be between 24 and 32 degrees. Accordingly, only the unit, tenths, and hundredths digits are given, with the tens digit (a 2 or 3, for 20 or 30) to be understood from the value of the unit digit. In any event, the full value of the increment is given in the mailed Ephemerides Message (see Section 4); this prevents any possible ambiguity, since the most current value (given by Data Code) will differ from that in the mailed message by at most a few hundredths of a degree. As described in References 2 and 3, the increment is used to determine the longitudes of ascending nodes for orbits other than the reference orbit.

Example: 705 Ascending node increment is 27.05^{o}.

Word 2, CB 5-10

Time (Universal) of ascending node of the reference orbit, in hours, minutes, and seconds. Since this reference orbit ascending node may occur on a different day than that of the orbit from which the Data Code is acquired (provided in Word 5, CB 2-4), and the first digit of the actual value of hours can not exceed 2, the first digit is also used to indicate the day, relative to that of the orbit from which the Data Code message is acquired. A 0, 1, or 2 for CB 5 is the actual tens digit for hours, on the same day as given in Word 5, CB 2-4. If the reference orbit ascending node occurs the next day (Universal time), 4 is added to the actual value (i.e., 4 = 0; 5 = 1; 6 = 2. If the reference orbit ascending node occurs on the second day following that of Data Code acquisition, 7 is added to the actual value (i.e., 7 = 0; 8 = 1; 9 = 2). On one orbit each day (that near 180^{o} for Nimbus), the day in Word 5, CB 2-4 will be changed automatically (by the spacecraft clock) part way along the orbit. Since the values in Words 1-4 can not be changed except while over a DAF*, the value here (Word 2, CB 5) refers in this case to the day carried in Word 2, CB 2-4 as the satellite

* Nimbus DAF's are located at Fairbanks, Alaska, and Rosman, North Carolina.

passes its ascending node.
Example: 121938 Ascending node on (reference) orbit 1338 is at 1219:38 U on day 95 (from Word 5, CB 2-4; see below), or April 5 (as it was not a leap year).

Additional Examples: If the digital value of CB 5-10 had been 521938, ascending node time would have been 1219:38 U on April 6; if 821938, 1219:38 U on April 7.

Word 3, CB 2-5

Time increment (nodal period) between successive ascending nodes in hours (understood), minutes, and seconds. Since nodal periods for the orbit altitudes anticipated for Nimbus, TIROS, and TOS range between 1 1/2 and slightly over two hours, the hours digit is omitted and only the values of minutes and seconds are given. Since nodal period changes only very slowly, any slight chance of ambiguity can be avoided by comparison with the complete value of nodal (ascending node) increment as given in the mailed Ephemerides Message. As described in References 2 and 3, the nodal period is used to determine the time of ascending node for orbits other than the reference orbit.
Example: 4614 Nodal period is 1 hour 46 minutes 14 seconds.

Word 3, CB 6

Hemisphere (north or south) in which perigee occurs. As discussed earlier, perigee (the point of lowest orbit altitude) is the point along the orbit to which, by convention, other points are referenced. As discussed in Appendix A, perigee rotates about the earth at a constant rate, and so its latitude is somewhat different from one orbit to another. CB 6 gives the hemisphere in which perigee is located on the reference orbit. 0 indicates the northern hemisphere; 7 indicates the southern hemisphere.

Word 3, CB 7-10

Latitude of perigee on the reference orbit, in degrees and hundredths. It is to be understood that a decimal point exists between CB 8 and 9.
Example (for CB 6-10): 01083 Latitude of perigee on (reference) orbit 1338 is 10.83° N.

Word 4, CB 2-7

Time (Universal) of perigee, on the reference orbit, in hours, minutes, and seconds. The day, relative to that of Data Code acquisition, is given in CB 2 using the same convention as for ascending node time (Word 2, CB 5-10). A 0, 1, or 2 indicates the same day as that given in Word 5, CB 2-4. 4 is added to the actual value in CB 2 to indicate the following day (4 = 0; 5 = 1; 6 = 2); a 7 to indicate the second day following that of Data Code acquisition (7 = 0; 8 = 1; 9 = 2).
Example: 122147 Perigee on (reference) orbit 1338 is at 1221:47 U on April 5.

Additional Examples: If the digital values of CB 2-7 had been 522147, perigee would have been at 1221:47 U on April 6; if 822147, 1221:47 U on April 7.

Word 4, CB 8-10

The motion of perigee, stated in thousandths of a degree of great circle arc per orbit. It is to be understood that a decimal point exists just before CB 8. (The most current value, as given by Data Code, should not be drastically different from that in the latest mailed message.) The direction of the motion of perigee will always be opposite to that of the spacecraft for a near polar orbit; for Nimbus II, the motion of perigee will be south to north on the night side of the earth, and north to south on the day side (see Appendix A).
Example: 107 The motion of perigee is 0.107° per orbit.

Word 5, CB 2-4

As stated earlier, Word 5 is generated automatically by the spacecraft clock, rather than being inserted by a DAF. CB 2-4 give the date on which the APT picture was taken, expressed as the calendar day number (1 - 365, -366 for leap year). Table 3 correlates the calendar day number with the conventional notation for date. The day as given here is also used with Word 2, CB 5, to determine the day of ascending node for the reference orbit, and with Word 4, CB 2, to determine the day of perigee for the reference orbit, as described above.
Example: 095 The APT picture was taken on Day 95, or April 5 (April 4 if a leap year).

TABLE 3

TABULATION OF CALENDAR DAY NUMBER VERSUS DATE (FOR OTHER THAN LEAP YEARS)

DAY OF MONTH	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEPT	OCT	NOV	DEC	DAY OF MONTH
1	1	32	60	91	121	152	182	213	244	274	305	335	1
2	2	33	61	92	122	153	183	214	245	275	306	336	2
3	3	34	62	93	123	154	184	215	246	276	307	337	3
4	4	35	63	94	124	155	185	216	247	277	308	338	4
5	5	36	64	95	125	156	186	217	248	278	309	339	5
6	6	37	65	96	126	157	187	218	249	279	310	340	6
7	7	38	66	97	127	158	188	219	250	280	311	341	7
8	8	39	67	98	128	159	189	220	251	281	312	342	8
9	9	40	68	99	129	160	190	221	252	282	313	343	9
10	10	41	69	100	130	161	191	222	253	283	314	344	10
11	11	42	70	101	131	162	192	223	254	284	315	345	11
12	12	43	71	102	132	163	193	224	255	285	316	346	12
13	13	44	72	103	133	164	194	225	256	286	317	347	13
14	14	45	73	104	134	165	195	226	257	287	318	348	14
15	15	46	74	105	135	166	196	227	258	288	319	349	15
16	16	47	75	106	136	167	197	228	259	289	320	350	16
17	17	48	76	107	137	168	198	229	260	290	321	351	17
18	18	49	77	108	138	169	199	230	261	291	322	352	18
19	19	50	78	109	139	170	200	231	262	292	323	353	19
20	20	51	79	110	140	171	201	232	263	293	324	354	20
21	21	52	80	111	141	172	202	233	264	294	325	355	21
22	22	53	81	112	142	173	203	234	265	295	326	356	22
23	23	54	82	113	143	174	204	235	266	296	327	357	23
24	24	55	83	114	144	175	205	236	267	297	328	358	24
25	25	56	84	115	145	176	206	237	268	298	329	359	25
26	26	57	85	116	146	177	207	238	269	299	330	360	26
27	27	58	86	117	147	178	208	239	270	300	331	361	27
28	28	59	87	118	148	179	209	240	271	301	332	362	28
29	29	(60)	88	119	149	180	210	241	272	302	333	363	29
30	30		89	120	150	181	211	242	273	303	334	364	30
31	31		90		151		212	243		304		365	31

Note: This table is for years other than leap years. For leap years, add one to each calendar day number on and after that for March 1.

Word 5, CB 5-10 Time (Universal) at which the APT picture was taken, in hours, minutes, and seconds. This information is vital to geographical location, and avoids manual monitoring of the precise instant the picture is exposed.

Example: 123156 The picture was taken at 1231:56 U.

Summary of Example (Figure 5b): The information provided by the Data Code example in Figure 5b is as follows:

Reference orbit number	1338
Longitude of ascending node	124.6°W
Longitude increment of ascending node	27.05° per orbit
Time of ascending node	1219:38 U (on April 5)
Nodal period	1 hour, 46 min., 14 sec.
Latitude of perigee	10:83°N
Time of perigee	1221:47 U (on April 5)
Motion of perigee	0.107° per orbit
Day APT picture taken	April 5
Time APT picture taken	1231:56 U

It is suggested that the reader allow time (a few hours, or a day or so) for him to forget the specific values in the above summary and then, referring only to Figures 3, 5a, and 5b, and Tables 2 and 3, again decode the sample Data Code of Figure 5b to see if he obtains the proper interpretation, as summarized above. He should continue this practice until he is satisfied with his ability to locate, identify, and decode the information provided by Data Code.

Unfortunately, Figure 1 does not provide a logical Data Code message. It can, however, be used to practice decoding of the binary coded decimal notation. In this regard, it decodes as:

/ 107122147 / 010834614 / 121938705 / 712461338 / 292023818

As a second practice example with regard to interpreting the digital values, assume a Data Code message, after decoding from BCD to digital, was as follows:

/ 004300905 / 461594050 / 381971903 / 610237239 / 257182736

The reader should again practice interpreting these data with reference only to Figures 3 and 5a, and Tables 2 and 3. His proficiency can then be checked against the following tabulation:

Reference orbit number	43
Longitude of ascending node	90.5°E
Longitude increment of ascending node	24.61° per orbit
Time of ascending node	1940:50 U (on Sept. 15)
Nodal period	1 hour, 38 min., 19 sec.
Latitude of perigee	19.03°S
Time of perigee	2102:37 U (on Sept. 15)
Motion of perigee	0.239° per orbit
Day APT picture taken	September 14
Time APT picture taken	1827:36 U

3.2 Picture Time Determination When Word 5 is Missing

The format of the Data Code explicitly provides a method for determining the time an APT picture is taken, in the event that the information provided by Word 5 is missing. (This is most likely to occur when a satellite transmission is not acquired until sometime after the picture is exposed.)

The APT picture is exposed at exactly the time the extreme right scan line of Character Block 10 of Word 5 is generated. Each Character Block requires four seconds for its generation, and each bit location one second. Thus, if the precise time of generation of any point (bit location) along the Data Code is determined, and its location in terms of Word and Character Block identified, it is relatively simple to determine the total Character Blocks and any odd bit locations, and the equivalent time, between there and the right end of Word 5, CB 10. Subtraction then gives the time the picture was exposed.

A complication arises, however, from the fact that the facsimile stylus is covered to avoid the danger of electrical shock and the image is first accessible for marking about 6.35 cm (2.5 inches) after formation, which is over the heater bar in the Fairchild recorder. (The function of the heater bar is to dry the moist facsimile paper. The bar is approximately 1.5 cm (0.6 inches) wide and stretches across the width of the paper.) The paper can conveniently be marked here on the same side as the Data Code. Thus, in general the only time mark that can feasibly be applied will be offset from the point to which it applies. Hence, in determining picture time, this offset must be taken into consideration.

A suggested technique to handle this problem is as follows: With the facsimile shut off, uncover the stylus and carefully measure (say, for the Fairchild facsimile) 6.35 cm (2.5 inches) from the image forming line of the facsimile in the direction towards which the paper feeds. This is directly over the heater bar.* At this exact distance, scribe a mark on the case to each side of the paper. (For the convenience of later operators, it would also be well to place a notation stating that this mark is 6.35 cm from the stylus.) During an interrogation, at an integral minute (U), place a mark beside the Data Code exactly opposite these points and label this mark with the time at which it was made.

As soon as the paper is removed from the facsimile recorder, measure backwards (in the direction opposite to the feed of the paper) 6.35 cm (2.5 inches) from this mark, and place an "offset" mark. Connect the offset mark to its corresponding original mark by a lightly drawn arrow. If the time was carefully noted when the original mark was made, and if the measurements were made with precision, the offset mark is now beside the point along the Data Code generated at the time the original mark was made. The picture time can then be determined as discussed just above.

Of course, if Word 5 is fully acquired on a successive APT picture, the time of an earlier picture can very easily be calculated since, for Nimbus II, the interval between the times successive APT pictures are snapped is 208 seconds.

A full scale copy of Figure 5a can aid the APT user in locating, identifying, and reading off the Data Code entries. It can also be used for backup timing and for checking the size of the image as displayed on the facsimile paper. Accordingly, such a copy, along with a reproduction of the BCD interpretation, has been included as Figure 5c. It can be removed from this report, and could be used directly (after mounting and providing a protective transparent cover). Better still, it could be photographically copied, at exact scale, directly on an appropriate transparent base. (Note: It is anticipated that a transparent full-scale copy of Figure 5c--for the 8" X 8" Fairchild format--will be provided to the stations at a later date.)

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* Other situations, or most appropriate distances to be measured, may exist for different facsimile recorders.

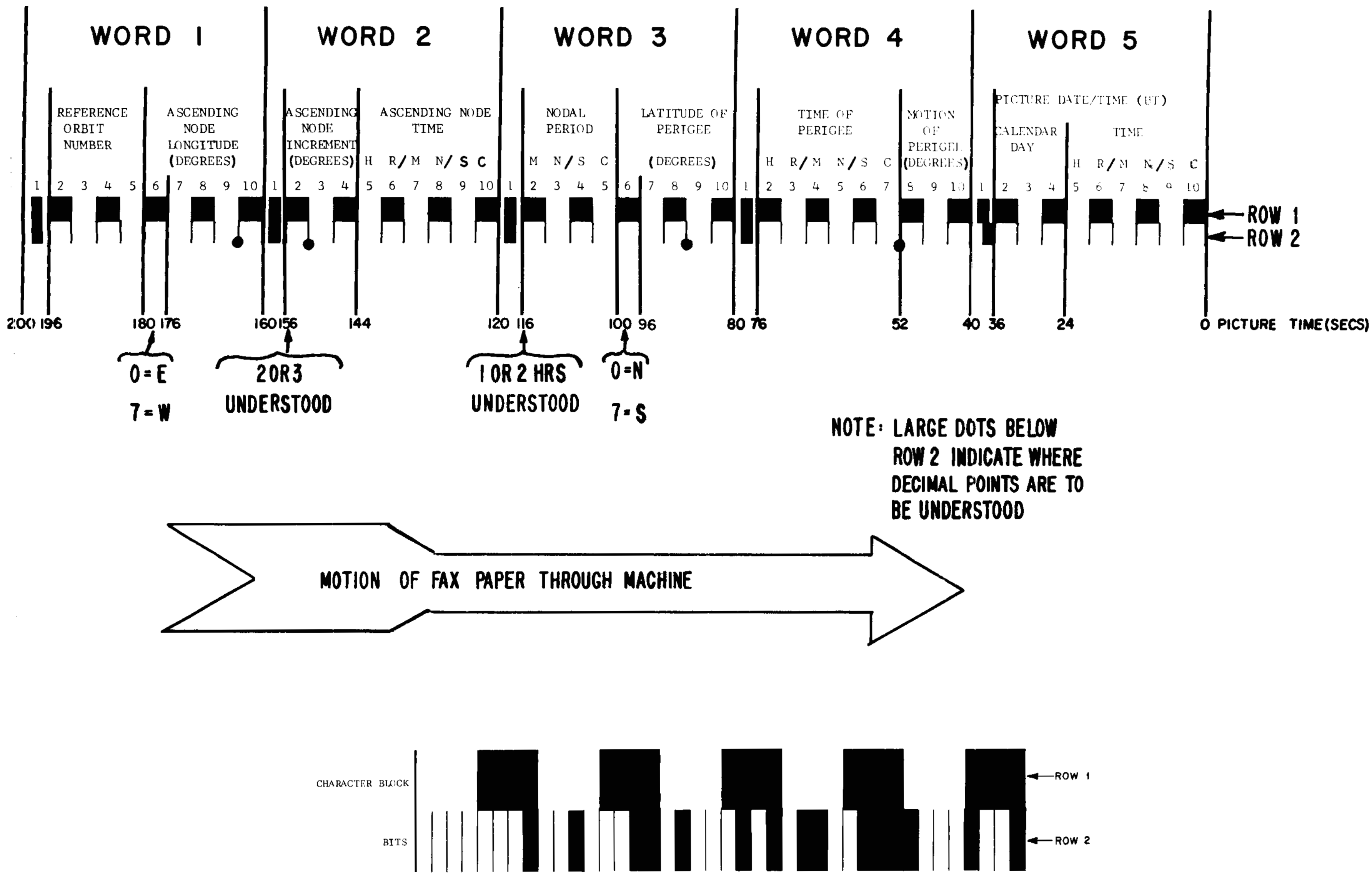

Figure 5c. Operational Data Code Template

4. USE OF DATA CODE FOR DATA ACQUISITION AND LOCATION

The following discussions are limited to those modifications to the APT and/or DRIR data acquisition and geographical location procedures that must be followed when using Data Code. The basic APT procedures are fully described in Reference 2, and particularly in the more recent Reference 3. Procedures applicable to the use of DRIR data are described in Reference 4. The following discussions assume the reader is already familiar with the material in either Reference 2 or 3; and, if using DRIR data, Reference 4.

The standard APT and/or DRIR procedures require that the user be provided a detailed ephemeris (a tabulation of satellite subpoint track and height as a function of time) for each day. When using Data Code, a detailed ephemeris is provided only initially, and at relatively infrequent intervals thereafter. The information provided by Data Code is then used to update the tabulated ephemeris to the degree necessary for daily operations.

4.1 Ephemerides Message

As soon as possible following the launch of Nimbus II, APT stations will be provided a Nimbus II Ephemerides Message. The message will be disseminated during "unscheduled" time on weather teletype circuits, and will simultaneously be mailed to participating APT stations.

In addition, subsequent centrally updated Nimbus II Ephemerides Messages will be disseminated by mail at periodic intervals. The frequency at which these subsequent messages are prepared will depend on the actual orbit of Nimbus II. It is anticipated that updated ephemerides messages will be prepared and mailed about weekly for highly elliptical orbits, but perhaps only once a month for nearly circular orbits. The frequency will be determined by the amount of error that would result from field use of the local updating procedures, using Data Code information, to be described below. The degree of accumulated errors, and the need for issuing an updated Ephemerides Message, will be monitored by personnel at the Nimbus Data Utilization Center of NASA's Goddard Space Flight Center. The updated ephemerides messages will be mailed to APT users in sufficient time to prepare completely updated subpoint tracks before large errors are accumulated from extrapolation. (Personnel at APT stations may care to compare the revised data provided by the updated ephemerides messages with those they obtain from the extrapolation techniques, described below, as a method of verifying the approach and their success in its execution.)

If a new station commences operation some time after satellite launch, it must arrange to obtain a copy of the most recent ephemerides message, and for the receipt of subsequent revisions.

Although the specific format for the initial and subsequent Ephemerides Messages is still under discussion at this writing, the content will include at least the types of information illustrated in Table 4. The message includes three classes of data:

1. A set of basic orbit parameters (the information grouped at the top of Table 4).

2. A subpoint track, referenced from perigee, with associated satellite heights. This subpoint track is expressed in terms of minutes from perigee, measured in the direction towards which the satellite travels (i.e., in the direction opposite to the motion of perigee).

3. Tabulation of argument of satellite versus latitude (see Section 4.3).

It is to be noted that the message includes all orbital information provided by Words 1-4 of the Data Code (see Sections 2 and 3). Accordingly, it can be used (in accordance with the procedures described below) to determine updated ephemerides for a few days before or after the date of the reference orbit whose parameters are provided in the Ephemerides Message. This permits acquiring an APT picture, which in turn provides current Data Code information.

The most currently available Ephemerides Message should always be used (this can be determined from the date of the reference orbit cited in the message).

4.2 Plotting of the Data in the Ephemerides Message

Place a blank transparent overlay on the APT plotting board. Using the data in the most current Ephemerides Message, plot the subpoint track on the basis of the given latitude-longitude coordinates. Mark each plotted point with a small hatch mark, and label it with the number of minutes from perigee and the satellite height at that point, as given in the Message.*

There are several points that will aid this plotting and the subsequent use of the information:

1. A small piece of masking tape can be used to avoid the danger of unintended rotations of the overlay during the plotting.

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* When updating from a subsequent Ephemerides Message, a check should first be made to see if the previously plotted track falls along the new points. If so, only the time from perigee points need be erased and replotted. As will be discussed in Section 4.3, the argument values always remain the same for any one satellite, since they are functions only of latitude and orbit inclination.

TABLE 4

NIMBUS II EPHEMERIDES MESSAGE

ORBIT 095; DATE (87) 28 Mar 1966

ASCENDING NODE: 08 51 16 UT; 151.23W Long.

INCREMENTS (PER ORBIT): 01Hr 38Min 19Sec; 24.23 Deg. Long.

DESCENDING NODE: 09 44 46 UT; 153.61W Long.

TIME OF PERIGEE: 09 42 15 UT

MOTION OF PERIGEE: 3.01 Deg/Day

MOTION OF PERIGEE: 0.201 Deg/Orbit

INCLINATION: 98.602 Degrees

PART I: EPHEMERIDES

MIN FROM PERIGEE	LATITUDE (DEG.)	LONGITUDE (DEG.)	HEIGHT (KM)	ARG. (DEG.)	MIN FROM PERIGEE	LATITUDE (DEG.)	LONGITUDE (DEG.)	HEIGHT (KM)	ARG. (DEG.)
0	N 18.1	W 149.2	428.7	161.9	56	N 4.4	E 13.3	914.1	4.4
2	N 10.3	W 150.9	431.3	169.7	58	N 11.3	E 11.7	898.8	11.3
4	N 2.5	W 152.6	438.9	177.5	60	N 18.1	E 10.1	880.6	
6	S 5.2	W 154.3	451.5	185.2	62	N 25.0	E 8.4	859.7	
8	S 13.0	W 156.0	468.8		64	N 31.9	E 6.5	836.5	
10	S 20.7	W 157.7	490.3		66	N 38.9	E 4.4	811.1	
12	S 28.3	W 159.7	515.6		68	N 45.8	E 2.0	783.9	
14	S 35.9	W 161.8	544.1		70	N 52.8	W 1.0	755.1	
16	S 43.3	W 164.2	575.1		72	N 59.7	W 5.0	725.1	
18	S 50.6	W 167.2	608.0		74	N 66.6	W 11.0	694.1	
20	S 57.8	W 171.0	642.1		76	N 73.2	W 21.0	662.6	
22	S 64.9	W 176.3	676.6		78	N 78.8	W 41.5	631.1	
24	S 71.5	E 175.0	711.0		80	N 81.4	W 84.4	600.0	90.0
26	S 77.4	E 158.7	744.5		82	N 78.4	W 125.0	569.9	
28	S 81.1	E 124.4	776.7	269.8	84	N 72.4	W 144.4	541.3	
30	S 80.0	E 80.0	807.0	272.3	86	N 65.5	W 154.1	514.8	
32	S 75.2	E 55.0	834.9		88	N 58.2	W 159.8	490.9	
34	S 69.2	E 42.9	860.1		90	N 50.7	W 163.8	470.3	
36	S 62.7	E 36.0	882.3		92	N 43.0	W 166.8	453.3	
38	S 56.1	E 31.5	901.2		94	N 35.3	W 169.3	440.5	
40	S 49.4	E 28.2	916.8		96	N 27.6	W 171.4	432.2	
42	S 42.7	E 25.5	928.8		98	N 19.8	W 173.4	428.8	
44	S 36.0	E 23.3	937.3		100	N 12.0	W 175.1	430.4	
46	S 29.3	E 21.3	942.2		102	N 4.1	W 176.8	437.1	175.9
48	S 22.6	E 19.6	943.5		104	S 3.6	W 178.5	448.7	183.6
50	S 15.8	E 17.9	941.2		106	S 11.3	W 179.7	465.1	191.3
52	S 9.0	E 16.3	935.5	351.0	108	S 19.0	E 178.0	485.9	199.0
54	S 2.3	E 14.8	926.4	357.7					

PART II: ARGUMENT OF SATELLITE VS LATITUDE

ARGUMENT (DEG.)	LATITUDE (DEG.)	ARGUMENT (DEG.)	LATITUDE (DEG.)	ARGUMENT (DEG.)	LATITUDE (DEG.)	ARGUMENT (DEG.)	LATITUDE (DEG.)
0.0	0.0 N	92.0	N	182	S	272.0	S
2.0		94.0	N			274.0	S
4.0							
6.0							
8.0							
10.0							
12.0							
90.0	81.0 N	180.0	0.0	270.0	81.0 S	360.0	0.0

2. If colored ink is available, it will help to distinguish this semi-permanent plot from the daily updating, to be described later. The use of a red acetate ink is suggested.

3. In more than half the cases, perigee will fall within that portion of the subpoint track that is within the limits of the edge of the plotting board. This leads to a discontinuity in the subpoint track of perigee (see Figure 6) which must be avoided. To prevent this, first plot only those points from perigee to the outermost latitude circle, plotting in the direction of increasing minutes from perigee. Then rotate the overlay westward exactly one orbit's increment of ascending node longitude, as given in the message (see Figure 6). This should result in the positions of the later subpoints of the message falling along, or in line with, the previously plotted track; if not, the amount of rotation was not correct. Then plot the remainder of the subpoint track lying within the limits of the plotting board.

When completed, the subpoint track should form a smooth, continuous curve. It should look like that in Figure 7. As can be seen, this subpoint track resembles the standard APT plot of a subpoint track (References 2 or 3), except that time at two minute intervals is now referenced from perigee rather than from ascending node.

4.3 Argument of Satellite Plot

To update this subpoint track for subsequent dates, it is necessary to work in terms of the argument of the satellite, for reasons discussed in some detail in Appendix A. The argument of a satellite is the angular distance, measured in degrees of great circle arc in the orbital plane and in the direction of satellite motion, from ascending node to the position of the satellite. By extension of the concept, the argument is the angular distance from ascending node to any given position along the orbit. Since the Nimbus orbit does not pass directly over the poles, the argument is not the same as the latitude of any given point along the orbit (see Section A.2). Equal distances in argument are, however, equivalent to equal angular distances along an orbit. If an orbit is rotated within its orbital plane (as occurs later, in the procedure for updating the ephemeris), all points along the orbit move an equal distance in argument.

Once the inclination of an orbit is given, the argument of any point can, however, be determined from the latitude of the point (see Section A.2). A tabulation of argument versus latitude, for the actual inclination of the Nimbus II orbit, will be

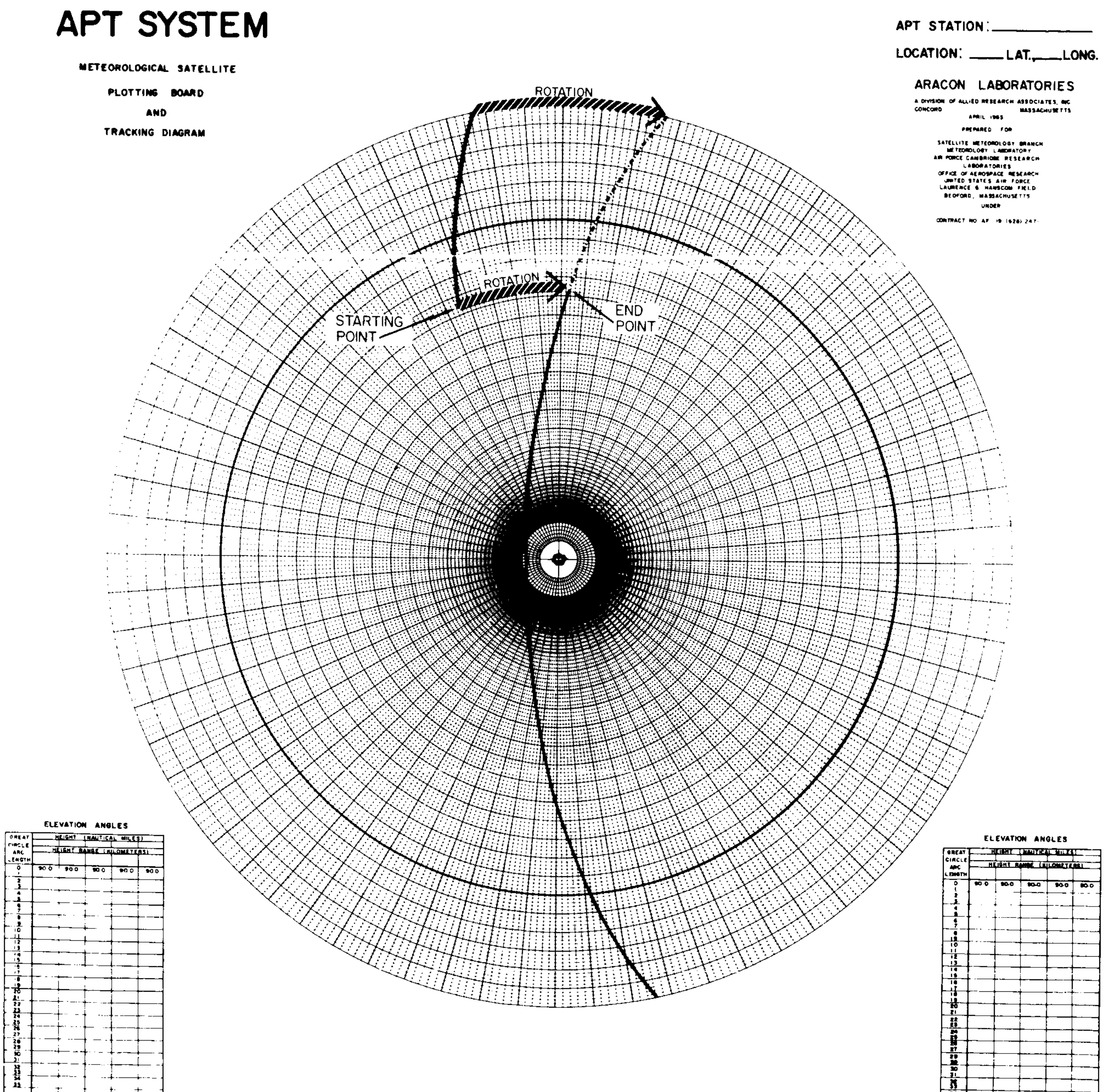

Figure 6. Method of Rotating Overlay to Obtain Continuous Subpoint Track

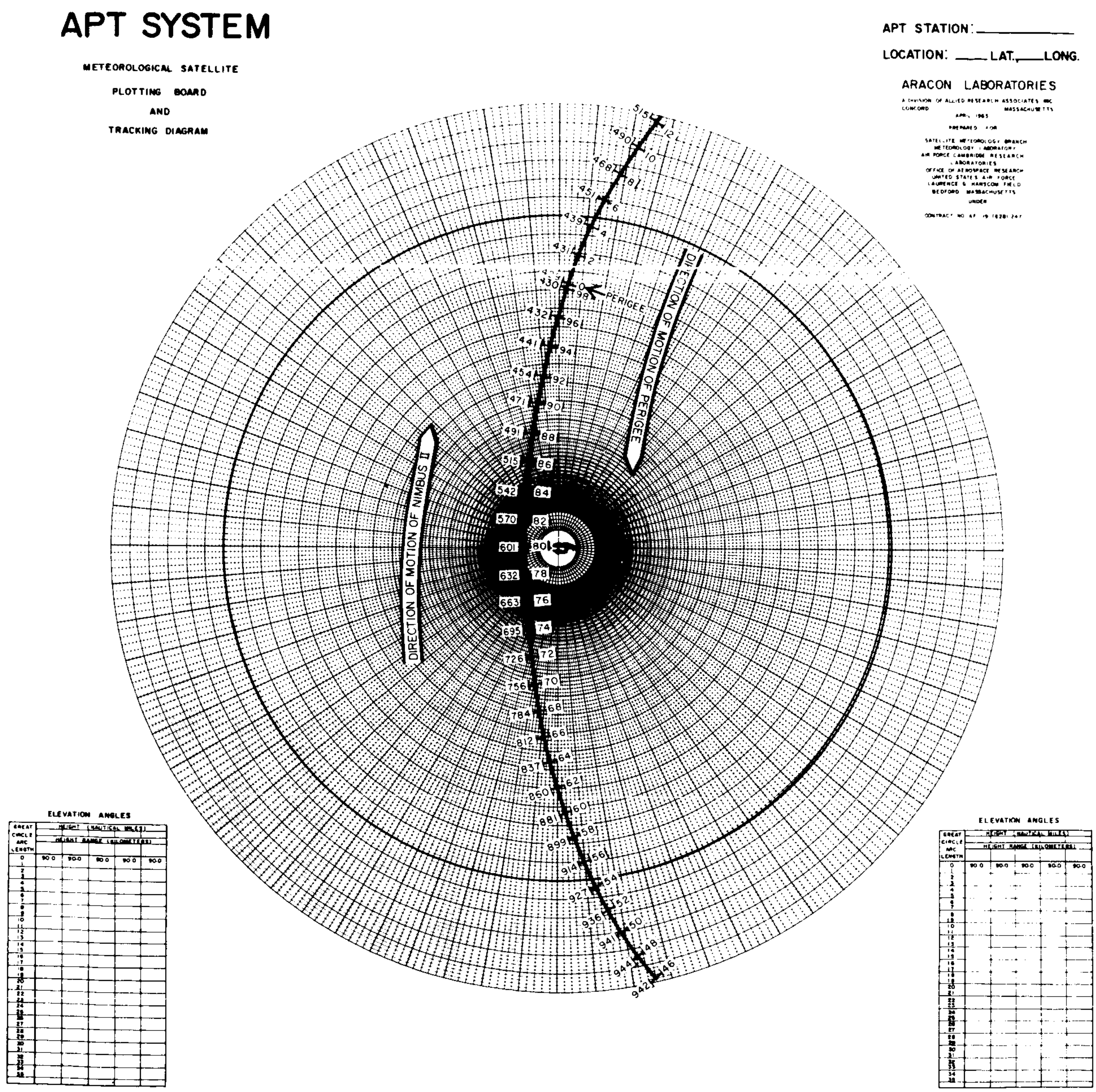

Figure 7. Plotted Subpoint Track, with Points Referenced from Perigee

included with the Ephemerides Message. In any event, Table 5, which is a tabulation of argument as a function of latitude and inclination, could be used. In Table 5, the orbital inclinations are given at one degree intervals. While interpolation between the given values is proper, this degree of accuracy is not normally required for APT purposes; and it is recommended that the latitude values tabulated for that inclination closest to the actual inclination be used. The actual inclination is stated in the Ephemerides Message. (Note, in Table 5, that a one degree inaccuracy in inclination leads at most to a one degree error in the latitude of a given value of argument, and even that much error occurs only at values of argument of 90° and 270°.)

Using the values from either the Ephemerides Message or Table 5, plot and label hatch marks representing argument, at 2° intervals, along the previously plotted subpoint track. (While this can be done in black ink, if necessary, a second color of ink - say green or blue - is preferable as it will make later steps easier.) The proper position of each hatch mark is determined from the latitude corresponding to the appropriate value of argument.

Figure 8 shows the values of argument properly plotted along the subpoint track. (For clarity, the time from perigee points have been omitted, and only 10° argument points are shown.) Note:

1. That the values of argument differ from those of latitude; for example, 60° of argument occurs at about 58 $1/2^{\circ}$ of latitude.

2. That 90° of argument always occurs at the point along the orbit nearest the north pole. 270° of argument always occurs at the orbital point nearest to the south pole.

This plot of the subpoint track, with labeled points of time from perigee, and of argument, is a semi-permanent plot that will be used repeatedly. It will need to be replotted only when a more current Ephemerides Message is received (see footnote in Section 4.2). It will be used as a basis for preparing updated subpoint tracks, with the additional information needed provided by Data Code.

4.4 Possible Initial Use of the Ephemerides Plot

For a day or so after the date of the reference orbit given in the Ephemerides Message, this semi-permanent subpoint track can be used directly for determining tracking data, and for locating APT and/or DRIR data. The procedures are identical with, or completely analogous to, those in References 2, 3, and 4. Note that the Ephemerides Message includes:

TABLE 5

ARGUMENT OF SATELLITE AS A FUNCTION OF LATITUDE AND ORBIT INCLINATION

Approximate Sun-Synchronous Orbit Altitude (n. mi.)	250	400	500	600	725
Inclination	i = 97.0 (83.0)	i = 98.0 (82.0)	i = 99.0 (81.0)	i = 100.0 (80.0)	i = 101.0 (79.0)
Argument of Satellite	Latitude	Latitude	Latitude	Latitude	Latitude
.00	.00	.00	.00	.00	.00
2.00	1.98	1.98	1.97	1.96	1.96
4.00	3.97	3.96	3.95	3.93	3.92
6.00	5.95	5.94	5.92	5.90	5.88
8.00	7.93	7.92	7.90	7.87	7.85
10.00	9.92	9.90	9.87	9.84	9.81
12.00	11.90	11.88	11.85	11.81	11.77
14.00	13.89	13.86	13.82	13.78	13.73
16.00	15.87	15.84	15.79	15.75	15.69
18.00	17.86	17.81	17.77	17.71	17.65
20.00	19.84	19.79	19.74	19.68	19.61
22.00	21.82	21.77	21.71	21.64	21.57
24.00	23.80	23.75	23.68	23.61	23.53
26.00	25.79	25.72	25.65	25.57	25.48
28.00	27.77	27.70	27.62	27.53	27.44
30.00	29.75	29.67	29.59	29.49	29.39
32.00	31.73	31.65	31.56	31.45	31.34
34.00	33.71	33.62	33.52	33.41	33.29
36.00	35.69	35.59	35.48	35.37	35.23
38.00	37.66	37.56	37.45	37.32	37.18
40.00	39.64	39.53	39.41	39.27	39.12
42.00	41.61	41.49	41.36	41.22	41.05
44.00	43.58	43.46	43.32	43.16	42.99
46.00	45.55	45.42	45.27	45.10	44.92
48.00	47.52	47.38	47.22	47.04	46.84
50.00	49.49	49.33	49.16	48.97	48.76
52.00	51.45	51.29	51.10	50.89	50.67
54.00	53.41	53.23	53.04	52.81	52.57
56.00	55.37	55.18	54.96	54.73	54.46
58.00	57.32	57.11	56.88	56.63	56.35
60.00	59.26	59.04	58.79	58.52	58.22
62.00	61.20	60.96	60.70	60.40	60.08
64.00	63.13	62.87	62.58	62.26	61.91
66.00	65.05	64.77	64.46	64.11	63.73
68.00	66.96	66.65	66.31	65.93	65.52
70.00	68.85	68.52	68.14	67.73	67.28
72.00	70.72	70.35	69.94	69.48	69.00
74.00	72.57	72.15	71.70	71.20	70.66
76.00	74.37	73.91	73.40	72.85	72.26
78.00	76.13	75.61	75.03	74.42	73.77
80.00	77.81	77.21	76.57	75.89	75.17
82.00	79.38	78.70	77.98	77.21	76.42
84.00	80.79	80.01	79.19	78.35	77.48
86.00	81.94	81.06	80.15	79.23	78.30
88.00	82.72	81.75	80.78	79.80	78.82
90.00	83.00	82.00	81.00	80.00	79.00

TABLE 5 (Cont.)

ARGUMENT OF SATELLITE AS A FUNCTION
OF LATITUDE AND ORBIT INCLINATION

Approximate Sun-Synchronous Orbit Altitude (n. mi.)	250	400	500	600	725
Inclination	i = 97.0 (83.0)	i = 98.0 (82.0)	i = 99.0 (81.0)	i = 100.0 (80.0)	i = 101.0 (79.0)
Argument of Satellite	Latitude	Latitude	Latitude	Latitude	Latitude
92.00	82.72	81.75	80.78	79.80	78.82
94.00	81.94	81.06	80.15	79.23	78.30
96.00	80.79	80.01	79.19	78.35	77.48
98.00	79.38	78.70	77.98	77.21	76.42
100.00	77.81	77.21	76.57	75.89	75.17
102.00	76.13	75.61	75.03	74.42	73.77
104.00	74.37	73.91	73.40	72.85	72.26
106.00	72.57	72.15	71.70	71.20	70.66
108.00	70.72	70.35	69.94	69.48	69.00
110.00	68.85	68.52	68.14	67.73	67.28
112.00	66.96	66.65	66.31	65.93	65.52
114.00	65.05	64.77	64.46	64.11	63.73
116.00	63.13	62.87	62.58	62.26	61.91
118.00	61.20	60.96	60.70	60.40	60.08
120.00	59.26	59.04	58.79	58.52	58.22
122.00	57.32	57.11	56.88	56.63	56.35
124.00	55.37	55.18	54.96	54.73	54.46
126.00	53.41	53.23	53.04	52.81	52.57
128.00	51.45	51.29	51.10	50.89	50.67
130.00	49.49	49.33	49.16	48.97	48.76
132.00	47.52	47.38	47.22	47.04	46.84
134.00	45.55	45.42	45.27	45.10	44.92
136.00	43.58	43.46	43.32	43.16	42.99
138.00	41.61	41.49	41.36	41.22	41.05
140.00	39.64	39.53	39.41	39.27	39.12
142.00	37.66	37.56	37.45	37.32	37.18
144.00	35.69	35.59	35.48	35.37	35.23
146.00	33.71	33.62	33.52	33.41	33.29
148.00	31.73	31.65	31.56	31.45	31.34
150.00	29.75	29.67	29.59	29.49	29.39
152.00	27.77	27.70	27.62	27.53	27.44
154.00	25.79	25.72	25.65	25.57	25.48
156.00	23.80	23.75	23.68	23.61	23.53
158.00	21.82	21.77	21.71	21.64	21.57
160.00	19.84	19.79	19.74	19.68	19.61
162.00	17.86	17.81	17.77	17.71	17.65
164.00	15.87	15.84	15.79	15.75	15.69
166.00	13.89	13.86	13.82	13.78	13.73
168.00	11.90	11.88	11.85	11.81	11.77
170.00	9.92	9.90	9.87	9.84	9.81
172.00	7.93	7.92	7.90	7.87	7.85
174.00	5.95	5.94	5.92	5.90	5.88
176.00	3.97	3.96	3.95	3.93	3.92
178.00	1.98	1.98	1.97	1.96	1.96
180.00	.00	.00	.00	.00	.00

TABLE 5 (Cont.)

ARGUMENT OF SATELLITE AS A FUNCTION
OF LATITUDE AND ORBIT INCLINATION

Approximate Sun-Synchronous Orbit Altitude (n. mi.)	250	400	500	600	725
Inclination	i = 97.0 (83.0)	i = 98.0 (82.0)	i = 99.0 (81.0)	i = 100.0 (80.0)	i = 101.0 (79.0)
Argument of Satellite	Latitude	Latitude	Latitude	Latitude	Latitude
182.00	-1.98	-1.98	-1.97	-1.96	-1.96
184.00	-3.97	-3.96	-3.95	-3.93	-3.92
186.00	-5.95	-5.94	-5.92	-5.90	-5.88
188.00	-7.93	-7.92	-7.90	-7.87	-7.85
190.00	-9.92	-9.90	-9.87	-9.84	-9.81
192.00	-11.90	-11.88	-11.85	-11.81	-11.77
194.00	-13.89	-13.86	-13.82	-13.78	-13.73
196.00	-15.87	-15.84	-15.79	-15.75	-15.69
198.00	-17.86	-17.81	-17.77	-17.71	-17.65
200.00	-19.84	-19.79	-19.74	-19.68	-19.61
202.00	-21.82	-21.77	-21.71	-21.64	-21.57
204.00	-23.80	-23.75	-23.68	-23.61	-23.53
206.00	-25.79	-25.72	-25.65	-25.57	-25.48
208.00	-27.77	-27.70	-27.62	-27.53	-27.44
210.00	-29.75	-29.67	-29.59	-29.49	-29.39
212.00	-31.73	-31.65	-31.56	-31.45	-31.34
214.00	-33.71	-33.62	-33.52	-33.41	-33.29
216.00	-35.69	-35.59	-35.48	-35.37	-35.23
218.00	-37.66	-37.56	-37.45	-37.32	-37.18
220.00	-39.64	-39.53	-39.41	-39.27	-39.12
222.00	-41.61	-41.49	-41.36	-41.22	-41.05
224.00	-43.58	-43.46	-43.32	-43.16	-42.99
226.00	-45.55	-45.42	-45.27	-45.10	-44.92
228.00	-47.52	-47.38	-47.22	-47.04	-46.84
230.00	-49.49	-49.33	-49.16	-48.97	-48.76
232.00	-51.45	-51.29	-51.10	-50.89	-50.67
234.00	-53.41	-53.23	-53.04	-52.81	-52.57
236.00	-55.37	-55.18	-54.96	-54.73	-54.46
238.00	-57.32	-57.11	-56.88	-56.63	-56.35
240.00	-59.26	-59.04	-58.79	-58.52	-58.22
242.00	-61.20	-60.96	-60.70	-60.40	-60.08
244.00	-63.13	-62.87	-62.58	-62.26	-61.91
246.00	-65.05	-64.77	-64.46	-64.11	-63.73
248.00	-66.96	-66.65	-66.31	-65.93	-65.52
250.00	-68.85	-68.52	-68.14	-67.73	-67.28
252.00	-70.72	-70.35	-69.94	-69.48	-69.00
254.00	-72.57	-72.15	-71.70	-71.20	-70.66
256.00	-74.37	-73.91	-73.40	-72.85	-72.26
258.00	-76.13	-75.61	-75.03	-74.42	-73.77
260.00	-77.81	-77.21	-76.57	-75.89	-75.17
262.00	-79.38	-78.70	-77.98	-77.21	-76.42
264.00	-80.79	-80.01	-79.19	-78.35	-77.48
266.00	-81.94	-81.06	-80.15	-79.23	-78.30
268.00	-82.72	-81.75	-80.78	-79.80	-78.82
270.00	-83.00	-82.00	-81.00	-80.00	-79.00

TABLE 5 (Cont.)

ARGUMENT OF SATELLITE AS A FUNCTION
OF LATITUDE AND ORBIT INCLINATION

Approximate Sun-Synchronous Orbit Altitude (n. mi.)	250	400	500	600	725
Inclination	i = 97.0 (83.0)	i = 98.0 (82.0)	i = 99.0 (81.0)	i = 100.0 (80.0)	i = 101.0 (79.0)
Argument of Satellite	Latitude	Latitude	Latitude	Latitude	Latitude
272.00	-82.72	-81.75	-80.78	-79.80	-78.8[illegible]
274.00	-81.94	-81.06	-80.15	-79.23	-78.30
276.00	-80.79	-80.01	-79.19	-78.35	-77.48
278.00	-79.38	-78.70	-77.98	-77.21	-76.42
280.00	-77.81	-77.21	-76.57	-75.89	-75.17
282.00	-76.13	-75.61	-75.03	-74.42	-73.77
284.00	-74.37	-73.91	-73.40	-72.85	-72.26
286.00	-72.57	-72.15	-71.70	-71.20	-70.66
288.00	-70.72	-70.35	-69.94	-69.48	-69.0[illegible]
290.00	-68.85	-68.52	-68.14	-67.73	-67.28
292.00	-66.96	-66.65	-66.31	-65.93	-65.52
294.00	-65.05	-64.77	-64.46	-64.11	-63.73
296.00	-63.13	-62.87	-62.58	-62.26	-61.91
298.00	-61.20	-60.96	-60.70	-60.40	-60.08
300.00	-59.26	-59.04	-58.79	-58.52	-58.22
302.00	-57.32	-57.11	-56.88	-56.63	-56.35
304.00	-55.37	-55.18	-54.96	-54.73	-54.46
306.00	-53.41	-53.23	-53.04	-52.81	-52.57
308.00	-51.45	-51.29	-51.10	-50.89	-50.67
310.00	-49.49	-49.34	-49.16	-48.97	-48.75
312.00	-47.52	-47.38	-47.22	-47.04	-46.84
314.00	-45.55	-45.42	-45.27	-45.10	-44.92
316.00	-43.58	-43.46	-43.32	-43.16	-42.99
318.00	-41.61	-41.49	-41.36	-41.22	-41.05
320.00	-39.64	-39.53	-39.41	-39.27	-39.12
322.00	-37.66	-37.56	-37.45	-37.32	-37.18
324.00	-35.69	-35.59	-35.48	-35.37	-35.23
326.00	-33.71	-33.62	-33.52	-33.41	-33.29
328.00	-31.73	-31.65	-31.56	-31.45	-31.34
330.00	-29.75	-29.67	-29.59	-29.49	-29.39
332.00	-27.77	-27.70	-27.62	-27.53	-27.44
334.00	-25.79	-25.72	-25.65	-25.57	-25.48
336.00	-23.81	-23.75	-23.69	-23.61	-23.53
338.00	-21.82	-21.77	-21.71	-21.64	-21.57
340.00	-19.84	-19.79	-19.74	-19.68	-19.61
342.00	-17.86	-17.81	-17.77	-17.71	-17.65
344.00	-15.87	-15.84	-15.79	-15.75	-15.69
346.00	-13.89	-13.86	-13.82	-13.78	-13.73
348.00	-11.90	-11.88	-11.85	-11.81	-11.77
350.00	-9.92	-9.90	-9.87	-9.84	-9.81
352.00	-7.93	-7.92	-7.90	-7.87	-7.85
354.00	-5.95	-5.94	-5.92	-5.90	-5.88
356.00	-3.97	-3.96	-3.95	-3.93	-3.92
358.00	-1.98	-1.98	-1.97	-1.96	-1.96
360.00	-.00	-.00	-.00	-.00	-.00

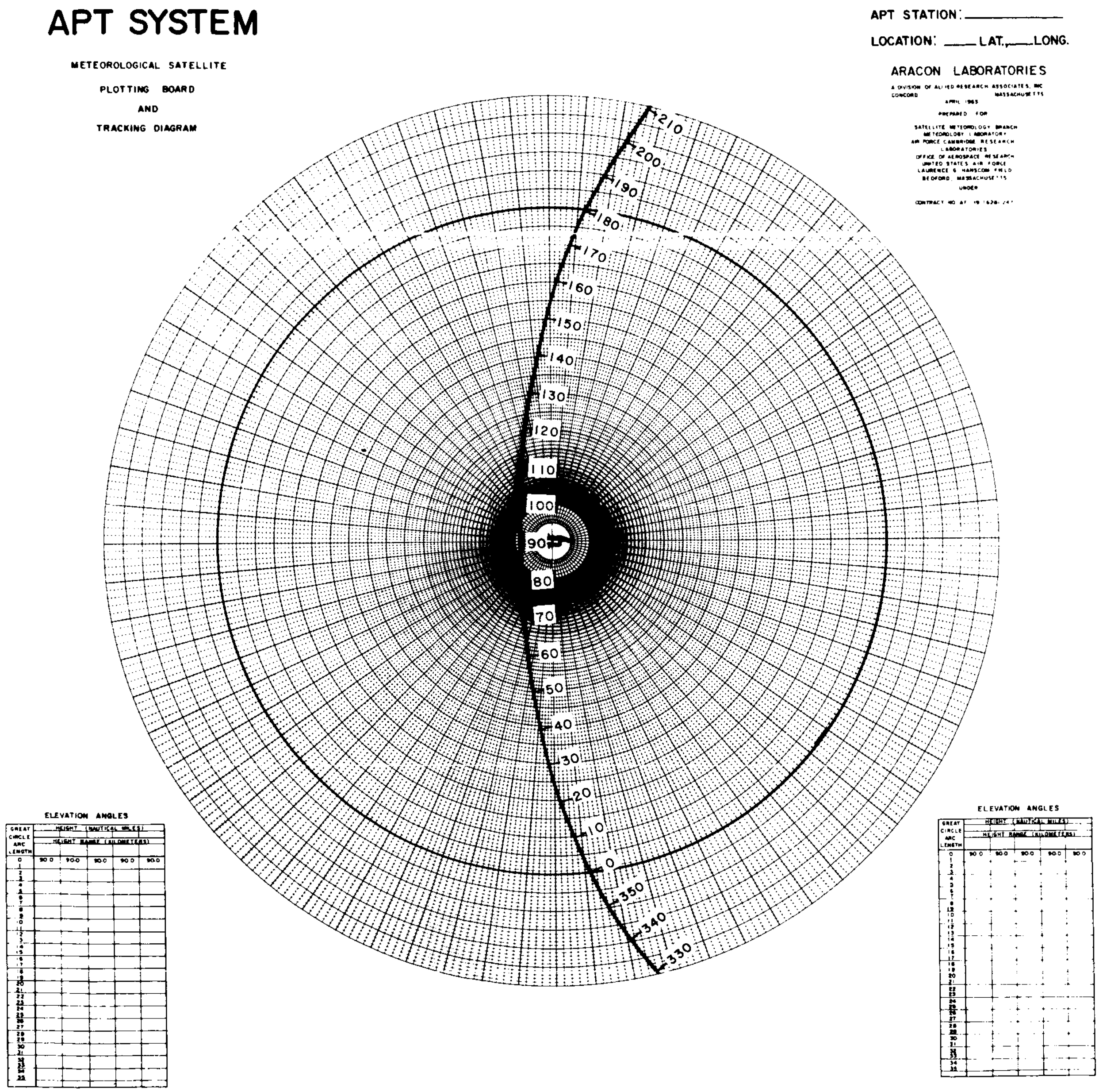

Figure 8. Plot of the Argument of the Satellite

1. Ascending Node Longitude, Time, and Increments

2. Perigee Latitude (the first entry in the ephemeris tabulation; that for minute zero) and Perigee Time.

The ascending node data are used, exactly as described in References 2 and 3, to rotate the subpoint track to the ascending node longitude of the orbit to be tracked.

When determining time (for computing antenna tracking data), or latitude relative to time (for determining geographic locations of the pictures or the DRIR data), it is recommended when using Data Code that it be done in terms of time relative to perigee (rather than time relative to ascending node, as in previous practice) since the subpoint track is now annotated in terms of time from perigee. For this purpose, use the latitude of perigee as given in the Ephemerides Message. For determining the time of perigee for orbits other than the reference orbit, it is necessary, when determining tracking data or picture locations, to assume that the time from the perigee of one orbit, to that of the next, is equivalent to the nodal period.* (See also Section 4.11.)

4.5 Updating of the Plotted Subpoint Track

After a day or so, depending on the actual orbit, it becomes necessary (as discussed in Appendix A) to determine an updated subpoint track if tracking and data location are to be performed with adequate accuracy. The necessary additional information for doing this is provided by Data Code. The following discussion will be constrained mainly to the mechanical procedures, with only a minimum of explanation. Appendix A describes the full rationale for these procedures in relatively non-technical terms.

Basically, the procedure required is a rotation (in argument) of the entire orbit by an amount equal to the motion (in argument) of perigee between (1) the position of perigee on the semi-permanent plot (that given in the most current Ephemerides Message) and (2) the position of perigee at about the time the satellite is to be tracked. As this rotation is made, the orbit altitude of each point along the orbit (when determined relative to perigee) retain its previous value.

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* Although this is a necessary and satisfactory approximation for this purpose, it is only an approximation. Because of the motion of perigee (see Appendix A), the Anomalistic Period (the time between successive perigees) is normally slightly different from the nodal period.

When making this rotation, it is best always to start, each time, from conditions at the time of the most current Ephemerides Message, and to rotate the orbit the total increment required since that time. This avoids the accumulation of errors that might result if the rotation was performed by adding another, most recent increment to one or more previous, short increments (see Section A.2).

4.6 Determining the Amount of Rotation from the Movement of Perigee

As stated earlier, the precise latitude and time of perigee, as used on the semi-permanent subpoint track plot, is given in the most current Ephemerides Message. A new latitude and time of perigee for a specified later (reference) orbit is given in the Data Code (the latitude in Word 3, CB 6-10; and the time in Word 4, CB 2-7).

In some cases, however, the desired orbit may not be the reference orbit used in the Data Code information received. In that case, the motion of perigee (per orbit, given in Word 4, CB 8-10) must also be used. The motion of perigee (in argument) is, for all practical purposes, a constant. The motion of perigee (given in thousandths of a degree per orbit) is multiplied by the number of orbits between the Data Code reference orbit and the desired orbit. The resulting value is the total displacement (in argument) of perigee over this number of orbits. The latitude of perigee as given for the Data Code reference orbit must be adjusted appropriately by moving the position of perigee this much <u>in argument</u> (not in latitude), along the subpoint track, to determine the position of perigee on the desired orbit.

For example, using the data in Table 4, perigee on orbit 095 was at 18.1°N, and the motion of perigee was 0.201 degrees per orbit. Assume a Data Code message with a Reference Orbit Number 131, a perigee at 25.3°N, and a motion of perigee of 0.202 degrees per orbit (in argument). Further assume the orbit of interest is 134. The motion of perigee between orbits 131 and 134 would be

$$3\ (0.202) = 0.606 = 0.6^{\circ} \text{ of argument.}$$

At low latitudes, this is also equal to approximately 0.6° of latitude, and the latitude of perigee on orbit 134 would be

$$25.3^{\circ} + 0.6^{\circ} = 25.9^{\circ}\ \text{N.}$$

(Note, from Figure 7, that perigee in this case was moving northward, and so the values are added. Remember that, for near-polar orbits, the motion of perigee is always in the direction <u>opposite</u> to that of the satellite.)

Furthermore, in this case, perigee had moved 25.9-18.1, or 7.8° of latitude, between perigee as given on the Ephemerides Message (and plotted on the semi-permanent subpoint track) and the position of perigee on orbit 134. In this case, again because it is near the equator (see Section A.2), the displacement of the argument of perigee would be essentially the same (i.e., 7.8° of argument); near the poles, however, this much displacement in latitude would lead to a far greater displacement in argument. For example, when near 80°, an 8° displacement in latitude may be approximately equal to a 12° displacement in argument.

4.7 Plotting of the Updated Subpoint Track

Once the movement of perigee has been determined (in terms of argument), the new subpoint track is determined by moving each two minute point plotted along the track (as referenced to perigee) a distance in argument, along the track, equal to, and in the same direction as, the movement of perigee. As each point is moved, it retains its previous value of time (relative to perigee) and of orbit altitude. In operational practice, only points within and immediately outside the station acquisition circle, and the point of perigee itself, need be updated.

If perigee happens to lie beyond the limits of the plotting board (e.g., near the south pole for a northern hemisphere station), the conversion between its movement in latitude and its movement in argument can be determined by using the equivalent latitudes, but in the hemisphere represented on the plotting board.

4.7.1 Specific Procedural Steps

The suggested procedure for actually accomplishing the above steps is as follows:

1. Place a second, blank overlay over the plotting board overlay containing the semi-permanent plot (that from the Ephemerides Message).

2. Now using black ink, trace on this new overlay the curve of the subpoint track.

3. Determine the point along the new subpoint track of the position (latitude) of perigee at the time of the desired orbit (Section 4.6). Label it with time relative to perigee (0), and the perigee orbit altitude. (If perigee is off the plotting board, temporarily plot it, and the perigee from the Ephemerides Message, at the corresponding latitudes within the limits of the plotting board.)

4. Determine the movement of perigee, in terms of argument, between the time of the semi-permanent plot and the newly plotted perigee point. This is done by reference to the 2° points of argument on the semi-permanent plot. (If it was necessary to temporarily plot perigee positions from outside the plotting board limits, they should now be erased.)

5. Displace each two minute point on the semi-permanent plot the same amount and direction, in argument, as the movement of perigee, and replot it on the new subpoint track. Label it with its same time (from perigee) and orbit altitude. (Note: for near polar orbits, the direction of the motion of perigee, and of all other points, is always opposite to the direction of the motion of the satellite, or towards smaller values of argument.)

This procedure should be applied to every point within or on the acquisition circle of the local APT station, and for at least the first point beyond the acquisition circle on each side.

Note the semi-permanent plot is never changed (until a new and more current Ephemerides Message is received), and that a second, blank overlay is used each time an updating is performed.

The frequency with which the subpoint plot needs to be updated, using the above procedures, depends on the degree of eccentricity of the orbit. If a nearly circular orbit is achieved, as planned, the variation of orbit altitude around the orbit will be rather small. (It is principally the variation of orbit altitude which creates the need for updating.) In general, an updating about once a day would seem to be in order, especially if perigee is used as the basis of time and latitude for tracking and data location computations (see Section 4.11). Advice as to the desirable frequency of local station updatings of the Ephemerides Message, using the Data Code, may be mailed to the stations. When an updating is performed on the plotting board, it should be prepared for a next day's orbit that will pass nearly overhead and for one from which data are to be acquired.

4.8 Use of the Updated Subpoint Track

Once the orbit is updated, its use for tracking is the same as for the initial semi-permanent plot, as described earlier (Section 4.4). Of course, the values used with regard to ascending node and perigee should now be those from a recent Data Code message, rather than from the older Ephemerides Message.

4.9 Examples of Updating the Subpoint Track

For a first example, we will use the data in the Sample Ephemerides Message (Table 4), and again the situation used as an example in Section 4.6. The data required here, as taken from Section 4.6, are as follows:

Ephemerides Message:

Orbit Number 095

Perigee 18.1° N

Orbit of Interest:

Number 134

Perigee (calculated in Section 4.6) 25.9° N

The left side of Figure 9 is a plot of a portion of Orbit Number 095 (taken from Table 4), showing the values of argument and the times from perigee. (For clarity, the satellite heights, which are uniquely tied to their respective values of time from perigee, are omitted.) As was stated in Section 4.6, and can be seen in Figure 9, the movement of perigee from 18.1° N to 25.9° N is equivalent to about a 7.8° change in argument.

The right side of Figure 9 shows the subpoint track updated to the conditions of orbit 134 by translating perigee and each 2 minute point by 7.8° in argument. For clarity, the two plots are shown side by side here, rather than one over the other as would be the actual case when executing the procedures on the plotting board. Again, for clarity, the data on satellite height are omitted, but the values of height versus time from perigee, in the plot on the right side of Figure 9, would still be the same as in Table 4 (i.e., 0 minutes = 428.7 km; 2 minutes = 431.3 km; 4 minutes = 438.9 km, etc.).

In this case, the amount of translation happened to be just about the same as the spacing of the 2 minute points, but this is merely a coincidence and would not normally be the case.

A second example is illustrated in Figure 10. An assumed Ephemerides Message Reference Orbit (orbit 243) is plotted in Figure 10b.

Assume perigee on orbit 243 was at 58.3° S. Assuming the station doing the updating is in the northern hemisphere, it will be necessary to temporarily plot perigee as if it were in the northern hemisphere. This is done in Figure 10a, where only the values of argument are shown along the subpoint track.

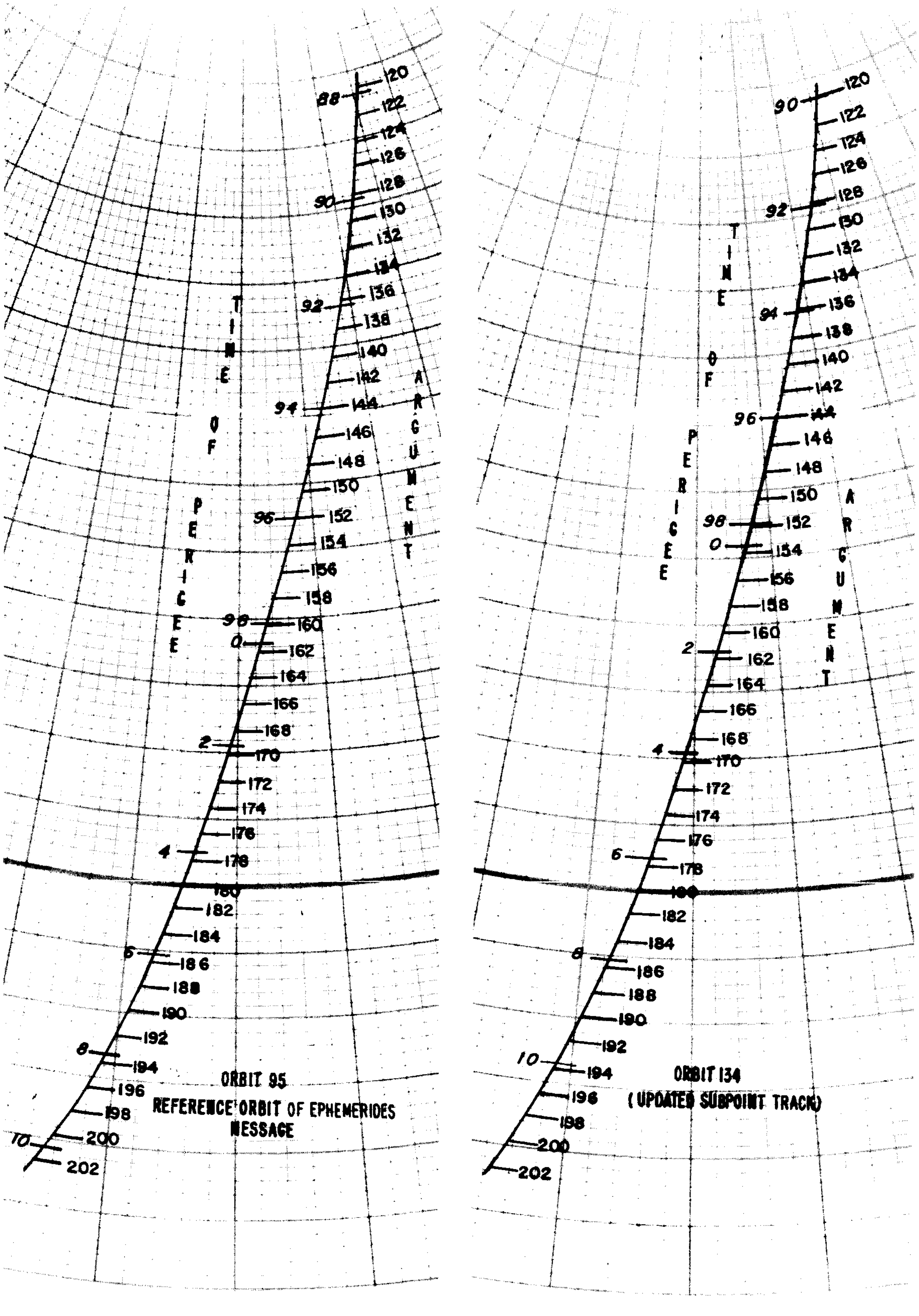

Figure 9. Example of Updating a Subpoint Track

Assume the Data Code message that was received used orbit 285 as its reference orbit, and indicated perigee as being at 66.9° S, with a motion of 0.245° per orbit. The orbit 285 value of perigee is also plotted on Figure 10a.

Further assume the orbit of actual interest is 291, or 6 orbits later. Over these six orbits, perigee will move 6 (0.245) = 1.47° in argument. This further movement is also plotted in Figure 10a, and it can be seen that the total movement of perigee from orbit 243 to orbit 291 is about 10.6° of argument (although only about 10.1° in latitude).

Figure 10c shows the subpoint track updated to the conditions of orbit 291, with perigee and the other 2 minute points translated 10.6° of argument in the direction opposite to the motion of the satellite (toward lower values of argument).

4.10 Determining the Subpoint Track on the Grids, for the Purpose of Determining the Picture Centers

The geographical positions of the centers of the APT pictures (or of the points where times have been determined along a DRIR strip; see Reference 4) can be determined only approximately by using the updated subpoint track on the plotting board, even when rotated to the appropriate ascending node. The most precise data locations, necessary for many meteorological applications (especially at the mesoscale), are obtained by also using an APT grid to extrapolate points (as established relative to perigee) to determine an updated subpoint track.

Although the projection-type APT grids developed by the National Environmental Satellite Center of ESSA (Reference 3) can be used for this purpose, it will be found easier to use the plastic grids (developed in association with Reference 2 and used with the TIROS VIII and Nimbus I APT experiments) for the updating, and then to use the projection grids for the actual geographic referencing of APT pictures. (If the plastic grids are not available, any map of about the same scale (1:1,000,000), and including the area covered by APT pictures acquired by the station, can also be used; and this will be found easier than the use of the projection grids. *)

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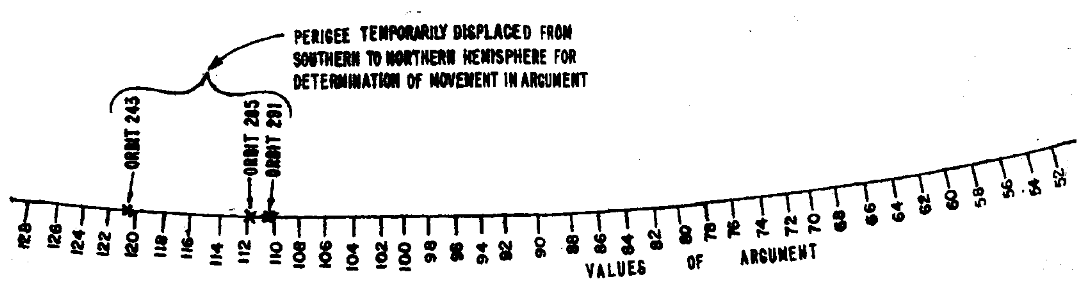
* The disadvantages of using the projection grids for the subpoint track updatings include:

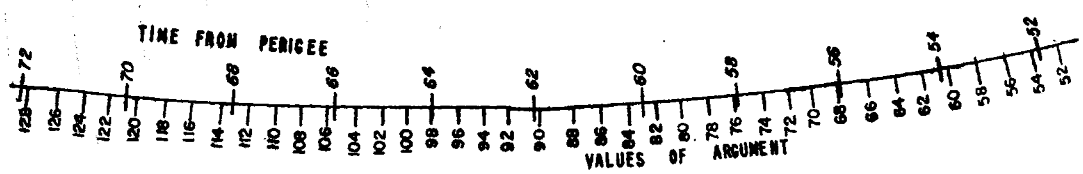
1. The need to repeat the plotting of argument along the heading line each time pictures are received. (This could be overcome if the NESC grids are later reissued with an actual heading line drawn, with argument plotted along it.)

2. The need to determine approximately the projection grid to be used (as regards central latitude), and the scale of projection (dependent on satellite height), before executing the remainder of the procedure to be followed.

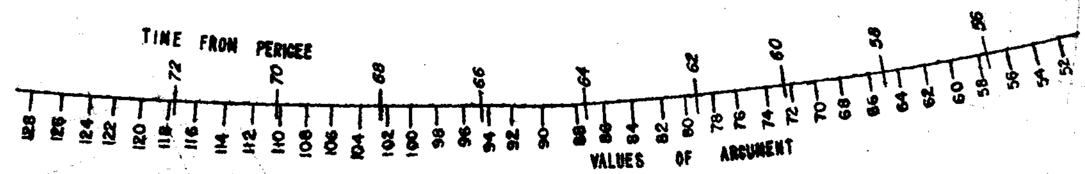
3. The possibility that it may be necessary to use more than one projection grid to update a sufficient length of subpoint track.



a. Use of Displaced Perigee



b. Orbit 243 (Reference Orbit of Ephemerides Message)



c. Orbit 291 (Updated Subpoint Track)

Figure 10. A Second Example of Updating a Subpoint Track

The procedure is as follows:

1. Select a grid or map with the APT station at about its central latitude, and with an area including the coverage of all APT pictures to be received by the station.

2. Draw the heading line (see Section A.2 for definition) across the center of the grid or map. This can be done using the procedures described in Reference 2, or by use of the projection grids (Reference 3), with the heading line transposed from the projection grid to the grid or map being used for the updating.

3. Using one of the sources of information discussed in Section 4.3, plot the argument of the satellite (at 2^{o} intervals) at the appropriate latitudes along the heading line.

4. Since this plot of the heading line and the values of argument is permanent (except when a new satellite with a greatly different orbit inclination is launched, see Section 4.3), it is now well to cover the above plots with a sheet of clear plastic so they will not be destroyed in subsequent, day to day use of the grid or map for subpoint track updatings.

5. Use (a) the difference between the ascending nodes of the reference orbit in the most current Ephemerides Message and the reference orbit of the latest Data Code, and (b) the ascending node longitude increment in the latest Data Code, to convert the subpoint longitudes used in the Ephemerides Message to the actual longitudes of the orbit on which the data are acquired.

6. Plot on the grid the subpoint track given in the most current Ephemerides Message, but using the longitudes computed just above. Label each point with its time (in minutes from perigee) and orbit altitude.

7. Determine the total movement of perigee, in terms of argument, from the time of the reference orbit in the Ephemerides Message to the time of the reference orbit on the most current Data Code. (Note: when updating the subpoint track on the grid, it should always be done by reference only to the most current Data Code reference orbit, which is not necessarily the orbit on which the picture or DRIR data are acquired.* This allows use of the latitude of perigee, and the time of perigee (plus the nodal period increments; see below) to determine a "false perigee" reference for picture center location. Otherwise, due to the motion of perigee, the anomalistic period (see end of Section 4.5), which is not given in the Data Code, would need to be used.)

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* Note, however, the longitudes used are those of the orbit on which the pictures or DRIR data are acquired; see steps 5 and 6 just above.

8. For each two minute point (relative to perigee), determine its value of argument by reading the argument (on the heading line) at the same latitude as that of the point (as plotted on the subpoint track).

9. Subtract the total movement of perigee in argument (as determined in step 7, just above) from this value of argument. Determine the latitude of this new value of argument from the plot of argument along the heading line.

10. Plot the updated subpoint position, on the subpoint track, at the new value of its latitude (that of the new value of its argument, as determined in step 9, just above). Label the updated point with its former value of time from perigee, and with its same orbit altitude.

Figure 11 illustrates the above procedure. It uses the sample subpoint track given in Table 4, but assumes that the orbit from which the picture data are acquired has an ascending node 72° east of that in the Ephemerides Message (as would be determined from the ascending node and the ascending node increment as given in the latest Data Code).

Assume the movement of perigee, between the reference orbit of the Ephermerides Message and the reference orbit of the Data Code (often not the orbit on which the pictures are acquired), was 5.1 degrees of argument. Consider the point 66 minutes from perigee. It is at a latitude of 38.8° N. Argument at this latitude is 39.5°. Subtracting 5.1° gives an updated argument of 34.4°, at a latitude of 34.2° N. This is then the latitude, along the updated subpoint track, of the point 66 minutes from perigee. Figure 12 shows the subpoint track updated for all points within the area of the grid.

4.11 Determining the Geographical Location of the Picture Center (or of a Point on the DRIR Data)

To locate a picture center:

1. Determine the (Universal) time of a "false perigee", for the orbit on which the data are acquired, from the time of perigee of the Data Code reference orbit and the nodal period given in the Data Code (i.e., by assuming the time from the perigee of one orbit to the "false perigee" of a later one is the nodal period times the difference in orbit number).

2. Determine, from this "false perigee" time and the (Universal) time of the picture, the minutes from perigee of the time of the picture.

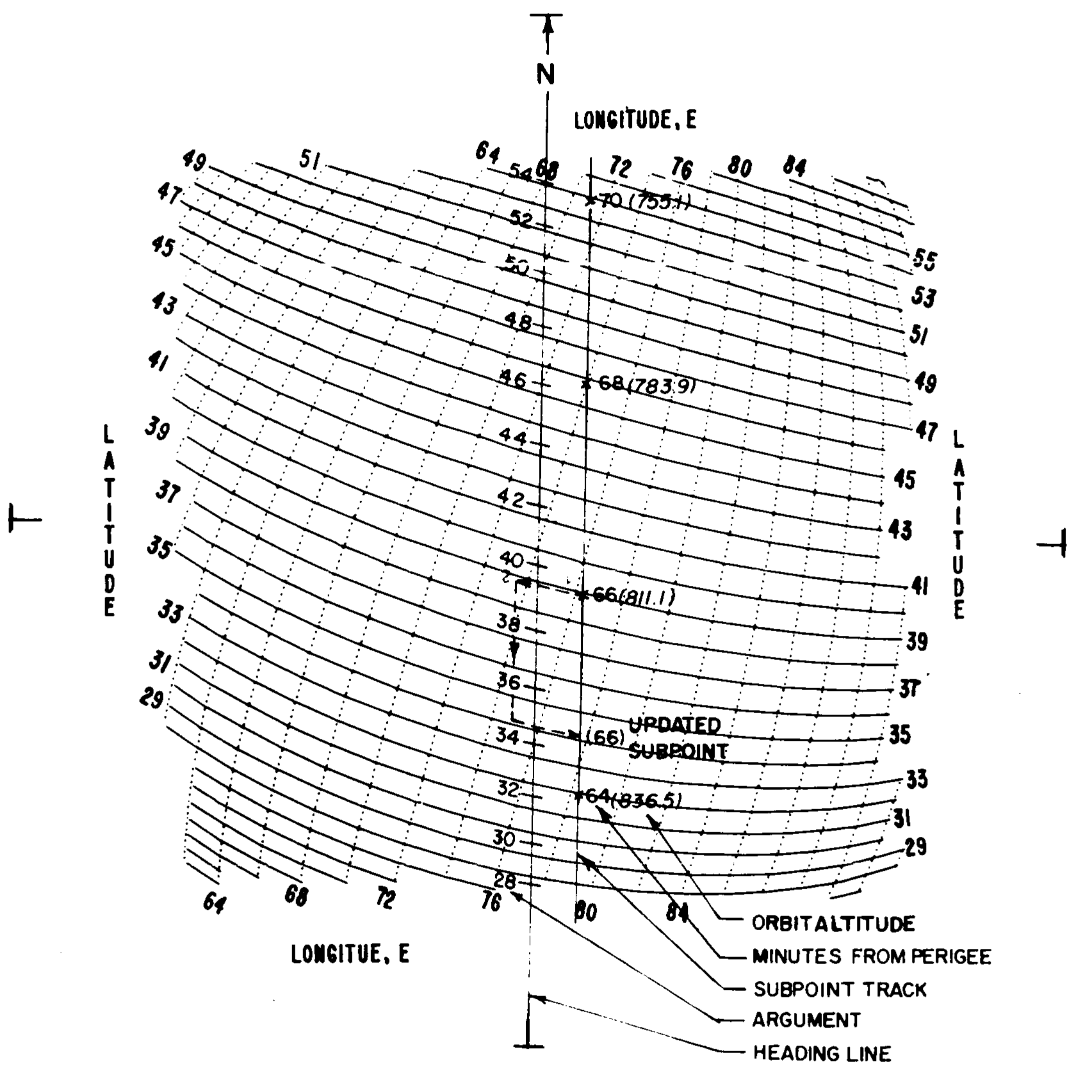

Figure 11. Procedure for Updating a Subpoint Track on a Grid

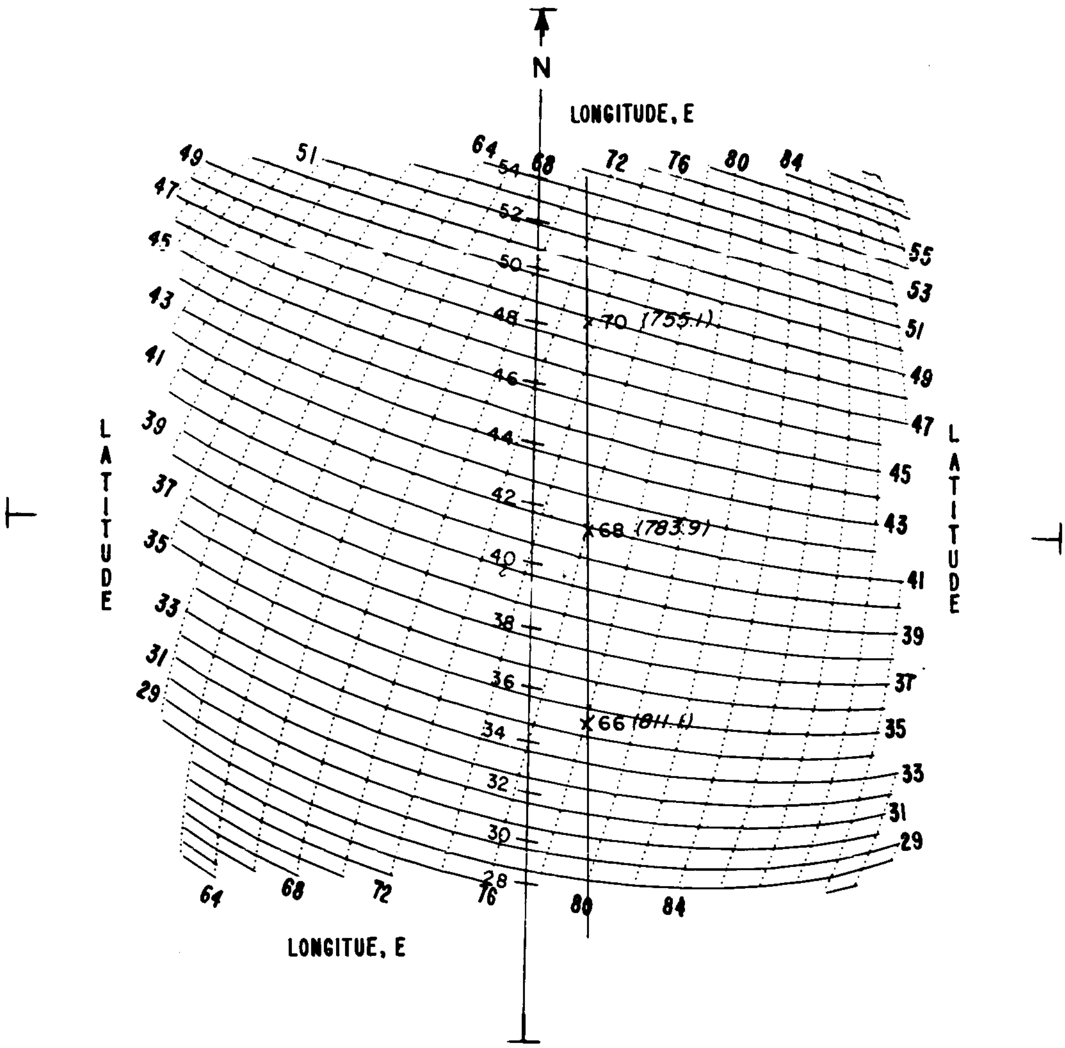

Figure 12. Updated Subpoint Track

3. The picture center will be located along the updated subpoint track at this time from perigee, and is located by interpolation between the two minute points plotted along the subpoint track.

4. Use this picture center point and the (interpolated) orbit altitude to select (a) the appropriate (projection) grid, (b) the scale at which to project it, and (c) the latitude and longitude at which to place the picture center on the (projected) grid.

Otherwise, the procedures are the same as given in References 2 and 3. For the DRIR data, use the procedures given in Reference 4, and the above techniques to determine the locations, along the DRIR centerline, for which times of observation were determined.

As an example of the above procedures, assume a picture was taken on Orbit 154, at 2143:54 U, and that the updated subpoint track shown in Figure 12 is the one to be used to determine the location of the picture center (i.e., it is plotted at the longitudes of Orbit 154). Further assume the Data Code reference orbit (that shown in Figure 12 as regards updated times from perigee) is Orbit 150, that its perigee was at 1506:09 U, and that the nodal period was 1 hour 50 min. 30 sec.

Since it is obvious that the last perigee before the picture time occurred before the ascending node on Orbit 154, we use the "false perigee" for Orbit 153, the third orbit after the Data Code reference orbit. Adding 3 nodal periods (3 X 1 hr. 50 min. 30 sec., or 5 hr. 31 min. 30 sec.) to the perigee of Orbit 150 gives a "false perigee" for Orbit 153 of 2037:39 U. Thus, the picture was taken 66 min. 15 sec. after the "false perigee" on Orbit 153, or at the 66 min. 15 sec. after perigee point along the updated subpoint track shown in Figure 12. Accordingly, the picture center is located at 36.7°N 77.2°E.

It is to be noted that, in the Data Code procedures, the Ephemerides Message provides data for the entire subpoint track (not just its daylight portion) and therefore it provides a basis for location of the night side DRIR data to be transmitted by Nimbus II. In fact, it is expected to provide the only basis for acquiring and locating DRIR data, since there is not time on available weather communications to send the night side ephemeris data in the format of the standard APT message used for TIROS VIII, Nimbus I, TOS, and the Nimbus II APT data.

5. SUGGESTED PROCEDURES DURING THE NIMBUS II DATA CODE EXPERIMENT

The following procedures are suggested for those APT stations desiring to participate in the Nimbus II Data Code Experiment.

It should be understood at the outset that, at least for a reasonable period of time following the launch of Nimbus II, both the standard daily APT message (Reference 3) and the Ephemerides Message discussed in this report will be transmitted to participating APT stations. Thus, the standard APT procedures, as discussed in Reference 3, will be available if required.

On the other hand, stations whose APT sets have been modified for, and which desire to acquire and use, DRIR data (Reference 4) will have to depend on the Data Code procedures, since the types of message described in Reference 3 will not be disseminated for the night side portion of the Nimbus II orbit.

During the period immediately prior to the Nimbus II launch, stations desiring to participate in the Data Code Experiment should prepare their APT nomographs and train their personnel in both the standard APT procedures (Reference 3) and the Data Code procedures discussed in this report.

For at least a few days after the launch of Nimbus II, it is suggested stations use the standard (Reference 3) techniques as the primary basis for acquisition and location of APT data. During this same period, however, the Data Code procedures should also be tried in parallel, and the merits and results of the two procedures compared. If, after a reasonable trial period (3 to 5 days), the Data Code procedures seem to provide results as good as the standard techniques, the Data Code should then be tried as the primary method, with the standard procedures used as a confirming backup. If this continues to provide satisfactory results, the standard procedures could be dropped except for emergencies.

It is requested that participating stations provide information, analogous to that in Figure 13, by mail to:

Nimbus Data Utilization Center
Attn: APT Coordinator
Nimbus Project, Code 450
Goddard Space Flight Center
Greenbelt, Maryland 20771

FIGURE 13

NIMBUS II APT, DRIR, AND DATA CODE
DAILY SUMMARY AND EVALUATION REPORT

Mail to:
Nimbus Data Utilization Center
Attn: APT Coordinator
Nimbus Project, Code 450
Goddard Space Flight Center
Greenbelt, Maryland 20771

APT Station: ______________________ Mail Address: ______________________

Location: ________° Lat.; ________° Long. ______________________

Telephone No.: ______________________

Station Chief (or Person Primarily Responsible for APT at Station): ______________________

Date: ______________________

(Signature not required)

APT PICTURE CENTER LOCATION

Orbit	Picture Time (U)	Standard APT Procedures (Daily Message) Lat	Standard APT Procedures (Daily Message) Long	Data Code Lat	Data Code Long	As Deduced From Landmarks Lat	As Deduced From Landmarks Long	Picture Quality*
____	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____
	____	____	____	____	____	____	____	____

DRIR DATA LOCATION

Orbit	Time (U) of Point Marked & Used	Data Code Lat	Data Code Long	As Deduced From Landmarks Lat	As Deduced From Landmarks Long	Data Quality*
____	____	____	____	____	____	____
	____	____	____	____	____	____
____	____	____	____	____	____	____
	____	____	____	____	____	____
____	____	____	____	____	____	____
	____	____	____	____	____	____
____	____	____	____	____	____	____
	____	____	____	____	____	____

* E = Excellent; G = Good; F = Fair; P = Poor; U = Unusable (Please comment on reverse for F, P or U data)

(SEE REVERSE)

COMMENTS ON PICTURE DEGRADATION (I. E., NOISE, INTERFERENCE, CONTRAST, ETC.)

APT: ____________________

____

____

____

DRIR: ____________________

____

____

____

Is Data Code Legible? ____________________

DAILY SUMMARY OF PICTURE UTILIZATION

APT: ____________________

____

____

____

DRIR: ____________________

____

____

____

SUGGESTIONS FOR IMPROVING DATA CODE INFORMATION OR PROCEDURES

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OTHER REMARKS

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Daily mailings would be appreciated during the first 15 days following the launch of Nimbus II. Thereafter, the daily information sheets can be mailed weekly unless special circumstances suggest a more urgent transmittal of information might be desirable. Such special circumstances would include:

1. A drastic change (improvement or degradation) in the accuracy of the Data Code method.

2. Suggestions as to ways to significantly improve the Data Code information or procedures, within the constraints that this report should make obvious.

APPENDIX A

SIMPLIFIED THEORETICAL BASIS OF THE DATA CODE PROCEDURE FOR EPHEMERIS EXTRAPOLATION

A detailed and rigorous discussion of the factors influencing the orbit of a satellite would not be in order in a primarily procedural report such as this one. Such information is available in Reference 5, and in various full and often highly theoretical treatments of orbital mechanics (some of which are cited in Reference 5). It is very much in order, however, to demonstrate that the procedures adopted for Data Code are proper, and adequately accurate.

A. 1 Properties of an Elliptic Orbit

Once a satellite has been injected into orbit, the shape of the orbit, relative only to the center of the earth, is essentially constant at the altitudes normal to meteorological satellites (i. e., about a few hundred miles).

Figure A-1 illustrates an elliptical orbit about the earth. (Some aspects have been deliberately exaggerated for clarity of illustration.) We will first consider only one of the two orbit orientations shown, that where perigee (the point of lowest orbit altitude) is near the south pole.

First, however, to insure Figure A-1 is understood:

1. The large, outer circle is merely a means of depicting the argument of the satellite. The argument of a satellite is the angular distance, measured in degrees of great circle arc in the orbital plane (the plane of Figure A-1) and in the direction of satellite motion, from ascending node (northbound equator crossing) to the position of the satellite. The satellite is moving counter-clockwise in Figure A-1. Argument is zero at the right of Figure A-1 (the northbound crossing of the equatorial plane) and increases counter-clockwise.

2. We have arbitrarily used an orbit with a 100 minute period in Figure A-1. The times in minutes from perigee that it requires the satellite to reach various points on its orbit are indicated just outside each of the two orbits.

3. Orbit altitudes in kilometers (arbitrarily chosen to illustrate pertinent points) are indicated at various points just inside each orbit.

Returning now to the orbit with perigee near the south pole, we note that the times, to cover equal portions of the orbit as expressed in argument, vary widely.

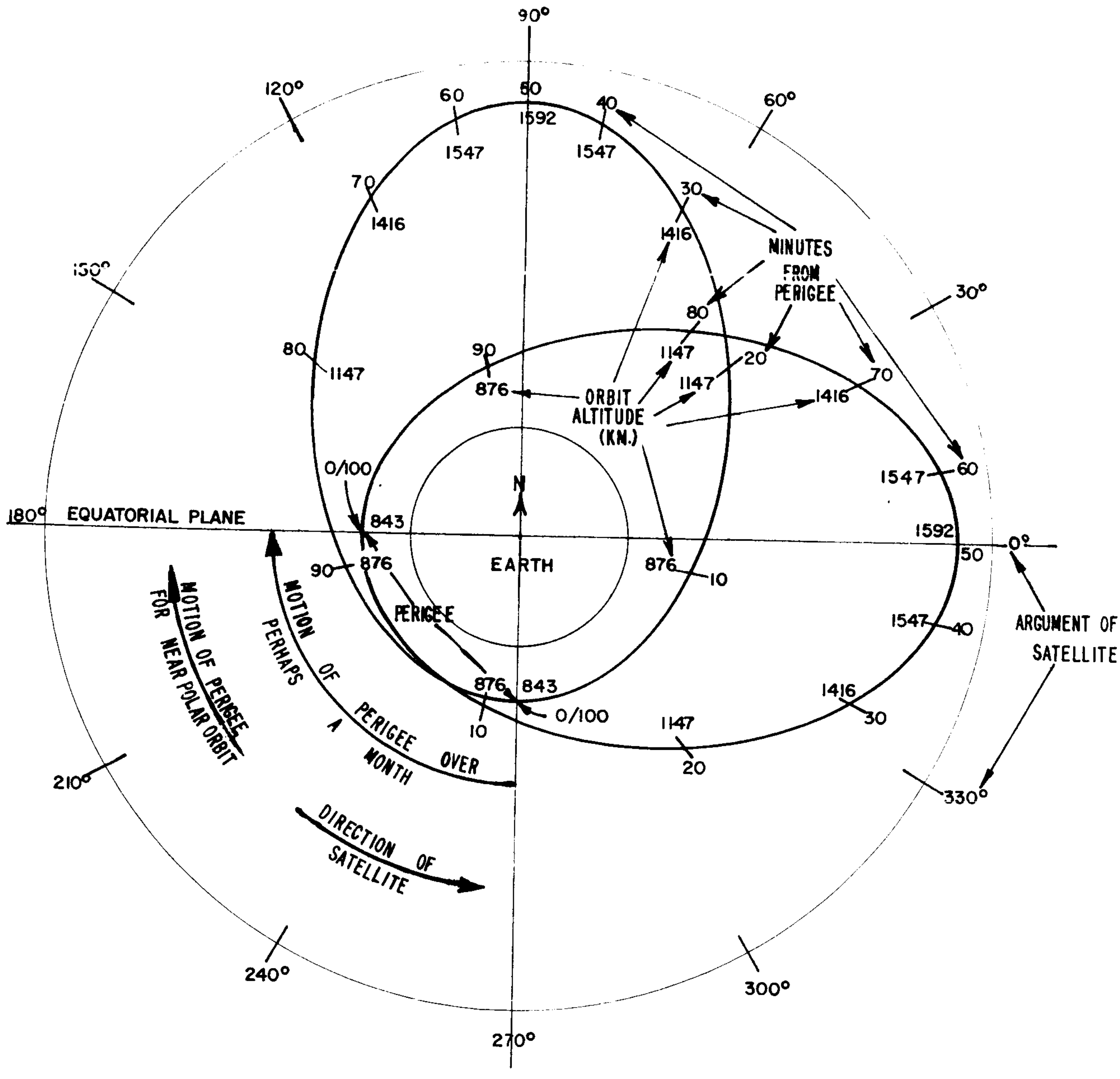

Figure A-1. Relationships between Perigee, Time from Perigee, and Argument, for an Elliptical Orbit

Near perigee, where the satellite is moving most rapidly, it covers a large distance in argument in a short period of time (i. e., about 80° of argument in 10 minutes in Figure A-1). Near apogee (point of highest orbit altitude), the satellite moves more slowly and covers only about 10° in argument in a similar 10 minute interval.

It should be obvious from Figure A-1 that equal distances in argument represent also essentially equal distances over the earth's surface. Accordingly, the distance the satellite moves across the earth during a given time interval also varies from one part of the orbit to another.

Although the shape of an orbit will remain essentially constant for long periods of time, its orientation in space will not normally do so. The changes in the orientation of the orbit in space are primarily due to the nonspherical shape of the earth (the equatorial bulge and the concurrent flattening of the poles).

One of these changes in orientation, the precession of the plane of the orbit (a rotation of the orbit plane in absolute space about the earth's axis; see References 5 and 6) need not concern us here. It does, however, influence the positions of the ascending nodes (which are directly used in the APT procedures), and it directly determined the choice of the (near 80°, retrograde) inclination of Nimbus orbits (Reference 7).

The second change in orientation is a slow and constant rotation of an elliptical orbit in its own plane. (This is illustrated in Figure A-1 by the rotation of the orbit from an initial perigee near the south pole to a perigee near the equatorial plane on the left side of the diagram.) The direction and rate of this rotation are functions of (1) the orbital inclination, (2) the average altitude over the entire orbit, and (3) the direction of satellite motion.

For altitudes near those planned for Nimbus, the rate of rotation is about 2 - 3° per day (in argument; Reference 5). The direction of rotation depends solely on inclination (Reference 5). For orbital inclinations greater than 63.4° (as in the case for Nimbus, whose orbital inclination is near 80°, retrograde), the direction of orbital rotation is opposite to the direction of motion of the spacecraft (i. e., towards smaller values of argument). (For inclinations less than 63.4°, the rotation of the orbit and the motion of the satellite are in the same direction.)

In Figure A-1, the two orbits shown are intended to illustrate the rotation of the Nimbus orbit that might occur over an interval of about a month.

For the immediately following discussion, it will be convenient to temporarily consider the earth as non-rotating, since we will need to consider points on the earth itself only in terms of their latitude. For any given value of orbit inclination, each value of argument always has a corresponding value of latitude (see Table 5 and Section A.2). (Factors related to the rotation of the earth are taken into consideration by (a) the change in longitude, from one orbit to another, of ascending node (see References 2 and 3), (b) the plotting of the data, in actual practice, along a subpoint track, and (c) the difference between the subpoint track and the heading line - see Section A.2).

From Figure A-1, it is obvious that any point that can be identified along the orbit ellipse rotates (in argument and about the earth) at the same (essentially constant) rate as the entire ellipse. For example, in Figure A-1, while the ellipse and its perigee rotate 90°, the point 70 minutes from perigee rotates from about 115° (in argument) to about 25°, or also 90°. Furthermore, since there is no significant change in the shape of the orbit, each point retains its orbit altitude as it rotates (1416 km in the case of the above discussed 70 minute point), neglecting the rather small effects of the non-spherical shape of the earth (which introduces an error, at most, of about 6 nautical miles, or 10 km.) Accordingly, if we know the rate of rotation of any one point of the orbit and the shape of the orbit, we can predict the future position and altitude of any point on the orbit at any given time.

By a convention long established in astronomy, perigee (the point of lowest orbit altitude) is chosen as the unique point on the orbit whose motion is determined, and as the point to which we reference all other points (in terms of time from perigee as the satellite moves around its orbit). When an orbit ephemeris is calculated (as by the computer facilities at NASA's Goddard Space Flight Center, the time (Universal) and the argument (angular distance from ascending node) of perigee are determined for a specified orbital revolution (or numbered orbit). By the fixed relationships between argument and latitude, for a known inclination (Table 5, or Section A.2), the latitude of perigee on that orbit can then easily be determined, thus relating the position of perigee to the earth's surface. The computations also provide the rate of motion of perigee (in argument), thus allowing the prediction of the position of perigee (in either argument or latitude) at any future time. (Note - see Section A.2 or Table 5 - that a given change in argument does not lead to an equal change in latitude, and that this is especially true at high latitudes.)

By accepted practice, the longitude of perigee is usually not given directly, but is established by implication when the longitude of ascending node (northbound equator crossing) is computed. (Of course, the longitude of perigee and that of ascending node will only very rarely be the same.)

To provide the information needed for the Data Code technique, we then have the orbit computations provide us with the latitude, longitude, and height of perigee, and of each point at successive two minute intervals from perigee,* for a single orbit. As perigee, and the orbit as a whole, rotate, the heights of each two minute point, and the distances (in argument) between any given pair of points, remain essentially constant. Since the motion of perigee can be predicted, so can the future positions of the two minute points. The relationships between argument and latitude (Section A.2 and Table 5) allow us to relate the change in argument, during such a rotation, to changes in latitude. Thus, a simple rotation of the orbital path within the orbital plane conserves those properties (altitude and distance) of the two minute data points along the orbit that are pertinent to our purposes, and so is a valid procedure for updating ephemerides for acquiring and locating APT and DRIR data.

Figure A-1 also can be used to illustrate the troubles that would arise if we did not take this rotation of a non-circular orbit into account in the Data Code procedures. On the initial orbit (that with its perigee near the south pole), the times (relative to perigee) from 60 to 89 minutes (about 29 minutes along the orbit) cover some 80° in argument (from 100° to 180°), which, for a near-polar Nimbus orbit, is also equal to nearly 80° in latitude. Yet, only 30 days later (the second orbit), the times from 90 to 100 minutes (only 10 minutes along the orbit) cover nearly the same distance and the same band of latitudes along the earth. Obviously, this makes a great difference when relating time, relative to an equator crossing, to distance from the equator, as the APT procedures require. Furthermore, on the initial orbit, the orbit altitude at an argument of 100° (about a latitude of 80°) is over 1500 km, while 30 days later it is less than 900 km; this difference in altitude leads to a significant difference in the scale of the APT pictures (or the DRIR data) and the proper location of points other than near the picture center. While the degree of eccentricity of an orbit is not related to the rate of rotation of perigee and the orbit as a whole, it does effect the need for taking the rotation into account and the frequency with which the orbit needs to be updated.

A.2 Effect of Earth Rotation on the Validity of the Procedures

We now need to consider the effects of the rotation of the earth within the orbit. Because of this earth rotation, the subpoint path (the track of the satellite over the earth) and the heading line (the instantaneous direction of the motion of the satellite projected on the earth's surface, or the instantaneous intersection of the earth's surface and the orbital plane) are not quite the same. Looking along the orbit in the

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* For clarity, only 10 minute points are shown in Figure A-1.

direction of satellite motion, the heading line is directed slightly ($0 - 4^{o}$) to the east of the subpoint track (except at the northernmost and southernmost limits of the orbit.)

The rotation of the orbital path in its own plane is equivalent to translating points along, or parallel to, the heading line. In updating the subpoint path on the grids (Section 4. 10), this is exactly what was done and there is accordingly no question as to the validity of that procedure.

On the APT plotting board, however, only a subpoint track is plotted, and the rotation of the orbit plane is approximated by the translation of the points along the subpoint track to provide a rotated and updated orbit. It remains to be shown that, if any error is introduced, it is so small as to be acceptable, and that we were proper in omitting the extra labor that would be involved in using translation along the heading line (analogous to that on the grids, Section 4. 10, where the few points to be updated and the additional accuracy thus incorporated in the meteorological data locations made it both tolerable and advisable).

For this purpose, let us first investigate more precisely the relationship between latitude and the argument of the satellite. We can do this by reference to Figure A-2, where

O = center of earth

P = arbitrary point along an orbit (it could be perigee)

EBAQ = the equator

PB = meridian of longitude through P

PA = intersection with earth's surface of orbit plane through P, or heading line at point P

i = orbit inclination

ϕ = latitude

ω = angular distance along orbit, or argument

Since PBA forms a right angle, from the trigonometry of right spherical triangles,

$$\sin \phi = \cos (90 - \omega) \cos (90 - i), \text{ or} \tag{1}$$

$$\sin \phi = \sin \omega \sin i . \tag{2}$$

Once injection into orbit is completed, i is a constant; so let us represent sin i as I = a constant ≤ 1

$$\text{Thus, } \sin \phi = I \sin \omega . \tag{3}$$

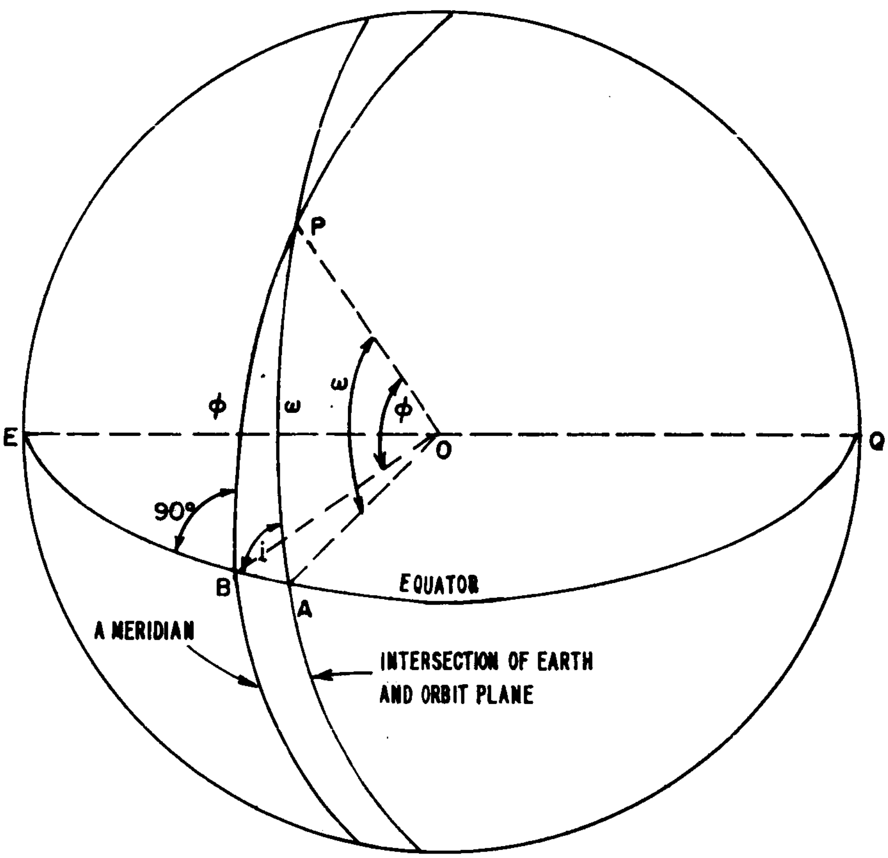

Figure A-2. Perigee as a Function of Latitude

This is the expression relating latitude and argument, which was tabulated in Table 5. Although ϕ in Equation (3) would go from 0 to 360°, in Table 5 we have expressed ϕ in the more conventional $-90^\circ \leq \phi \leq 90^\circ$ format normal to latitude.

From Equation (3), we note that:

1. When ϕ ranges from 0 to 360°, there is a unique value of argument for each value of latitude (for a given orbit inclination).*

2. Since $I \leq 1$, $\sin \phi \leq \sin \omega$, or $\phi \leq \omega$. We can see this in Table 5, where, as ω goes from 0 to 90°, ϕ goes only from 0 to a maximum value equal to i; or, in other words, when $\omega = 90^\circ$, $\sin \omega = 1$, $\sin \phi = \sin i$, and $\phi = i$.

Now, differentiating Equation (3), we obtain:

$$\cos \phi \, d\phi = I \cos \omega \, d\omega, \text{ or} \tag{4}$$

$$\frac{d\omega}{d\phi} = \frac{\cos \phi}{I \cos \omega} \tag{5}$$

Since $\cos \omega = \sqrt{1 - \sin^2 \omega}$ (6)

substitution of (3) and (6) in (5) gives:

$$\frac{d\omega}{d\phi} = \frac{\cos \phi}{I \sqrt{1 - \frac{\sin^2 \phi}{I^2}}} = \frac{\cos \phi}{\sqrt{I^2 - \sin^2 \phi}} \tag{7}$$

This demonstrates that the relationship between ϕ and ω is not one of direct proportionality. (If it were, $\frac{d\omega}{d\phi}$ would equal a constant.) When $\phi = 0$ (at the equator):

$$\left(\frac{d\omega}{d\phi}\right)_{\phi=0} = \frac{1}{I} = \frac{1}{\sin i} \tag{8}$$

For $i \approx 90^\circ$, $\left(\frac{d\omega}{d\phi}\right)_{\phi=0} \approx 1$, as we noted in the example in Section 4.6.

When $\phi = i$ (its maximum value, where $\omega = 90^\circ$, or $90^\circ \pm 90^\circ$), (7) becomes,

$$\left(\frac{d\omega}{d\phi}\right)_{\phi=i} = \frac{\cos i}{\sqrt{I^2 - \sin^2 i}} = \infty, \tag{9}$$

since $I = \sin i$. Thus, the rate of change of argument increases from approximately one (for near polar orbits, like Nimbus) near the equator, to very large (and rapidly increasing) values near the poles.

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* This is, for practical purposes, also true when $-90^\circ \leq \phi \leq 90^\circ$; but now there are two values of ω for each value of ϕ; one for the northbound and the other for the southbound portion of the orbit.

We can now relate the above discussion to the procedures we used on the plotting board to update the subpoint track. You will recall we plotted the two degree values of the argument along the subpoint track, by virtue of the relationships between latitude and argument given in Table 5. In so doing, we were implicitly using Equation (3) -- -- $\sin \phi = I \sin \omega$.

Accordingly, if our updating procedures could have been restricted to advancing from precisely some plotted two degree point of argument to precisely any other plotted point of argument, there would be no source of error in the procedure (other than very small ones due to inaccuracies in plotting, use of inclination to only the nearest degree, etc.). In fact, we would implicitly be doing just what we did on the grids (Section 4.10), which we have already seen was a rigorous procedure.

In practice, however, a two minute point from perigee will usually lie somewhere between two 2° points of argument, both on the Ephemerides Message reference orbit and on the updated subpoint track. Here, the nonlinear relationships between ϕ and ω (Equations 3 and 7) may lead to minor errors in interpolation, especially near the poles where the relationships are particularly nonlinear. It was to minimize the number of these errors in interpolation that we recommended always starting from the Ephemerides Message reference orbit when performing a subpoint track updating (see Section 4.5).

These errors are particularly likely to occur when updating to an orbit other than the Data Code reference orbit (as described in Section 4.6). There, we must make an additional movement of perigee, from its precise latitude as given in the Data Code reference orbit, by an amount of argument determined by the motion of perigee per orbit, (in argument) times the number of orbits since the Data Code reference orbit. The above discussion shows why, in Section 4.6, we had to be so careful in distinguishing the movement of perigee in latitude from that in argument, and to use the appropriate motion in the proper way.

As a conclusion to the above discussion, we can state that the procedures developed and described in the main part of the report provide an accurate method for acquiring and locating APT and DRIR data. The only sources of error are minor ones such as:

1. Inaccuracies in plotting.
2. Use of unit values of orbit inclination, if Table 5 is used.
3. Interpolation between 2° values of argument.

REFERENCES

1. Stampfl, R.A., and W. G. Stroud, 1963: The Automatic Picture Transmission (APT) TV Camera System for Meteorological Satellites, NASA, TN D-1915.

2. Goldshlak, L., 1963: APT Users' Guide, Scientific Report No. 1, Contract No. AF 19(628)-2471, Allied Research Associates, Inc.

3. National Weather Satellite Center, 1965: APT Users Guide, Environmental Science Services Administration, Washington, D. C.

4. Smith, R. B., 1965: Manual Gridding of DRIR Facsimile Pictures, Technical Note No. 7, Contract No. NAS 5-3253, ARACON Geophysics Division, Allied Research Associates, Inc.

5. King-Hele, D., 1965: Satellites and Scientific Research, Routledge and Kegan Paul, London, or Dover Publications, New York, 180 pp. (see espec. pp. 2-6, and 16-23).

6. Widger, W.K., Jr., 1966: Meteorological Satellites, Holt, Rinehart and Winston, New York, 280 pp. (see espec. Chapter 12).

7. Bandeen, W.R., 1961: Earth Oblateness and Relative Sun Motion Considerations in the Determination of an Ideal Orbit for the Nimbus Meteorological Satellite, NASA Technical Note D-1045.

25 March 1966

The Addendum, Errata and Operational Modification for the NIMBUS II DATA CODE EXPERIMENT (attached) dated March 1966 is designed to simplify operational procedures. It incorporates errata previously issued and dated February 1966.

The enclosed Addendum, Errata and Operational Modification (March 1966) provides techniques to make both the operational tracking and gridding procedures, as described in the manual, similar by using the satellite nodal period and "false perigee" concept in both procedures. These modified techniques do not require updating the locations of perigee and the time/height data points from the reference orbit to the tracking orbit. Instead, the data point locations along the latest available reference orbit are assumed to be identical with the data point locations along the desired tracking orbit. This data point positional approximation is valid for time periods of the order of one day for nominal meteorological satellite orbits.

The authors acknowledge the suggestions and contributions made to the Addendum by personnel from the U.S. Navy and ESSA.

ARACON Geophysics Division
Allied Research Associates, Inc.

ADDENDUM, ERRATA and OPERATIONAL MODIFICATION for the NIMBUS II DATA CODE EXPERIMENT (Technical Note No. 1)

Contract No. NAS 5-10114

Page 3, Lines 1 and 6

Add * to "TOS"

Page 3, Last Paragraph, Line 3

Change "ephemerides" to "ephemeris"

Page 3, Last Paragraph, Line 10

Change "picutres" to "pictures"

Page 3, Bottom of Page

Add footnote: "*An acronym for TIROS Operational System. The spacecrafts used in this system are named ESSA, which is an acronym for Environmental Survey SAtellite.

Page 4, Last Line

Add "It is recommended that Reference 3 be read prior to this report and that this report be read prior to Reference 4."

Page 5, Paragraph 1, Line 1

Change "adjacent to the left edge of" to "in place of the usual white phasing bar on"

Page 5, Paragraph 2, Line 2

Change "(that nearest the edge of the paper)" to "(the left column of the Data Code)"

Page 5, Paragraph 2, Line 9

Change "block represents" to "block is generated by 16 vidicon raster lines and represents"

Page 5, Paragraph 3, Line 6

Change "bit location represents" to "bit is generated by 4 vidicon raster lines and represents"

Page 5, Footnote (*)

Delete footnote

Page 8, Table 1, Column 3

Change "Decimal" to "Digital"

Page 12, Paragraph 1, Line 9

Add * to "equipment"

Page 12, Bottom of Page

Add footnote: "*A map (1:1,000,000 scale) may be necessary; refer to second paragraph of Section 4.10, Page 41."

Page 13, Table 2, Column 3, Last Line

Change "Picture Time" to "Picture Time to the nearest second after shutter operation"

Page 13, Table 2, Footnote (*), Lines 1 and 2

Add ** to "CB"

Page 13, Below Footnote (*)

Add footnote: "**CB is an abbreviation for Character Block(s)."

Page 14, Figure 5a and Page 22a, Figure 5c

Change "0 Picture Time (Secs)" to "0 ELAPSED TIME (SECS)"

Add: "The numbers in the ELAPSED TIME (SECS) row indicate the elapsed times in seconds from the beginning of the scan of the first raster line of video to the Character Blocks illustrated."

Page 16, Discussion of Word 2, CB 5-10, Last Line

Change "Word 2" to "Word 5**"

Page 16, Bottom of Page

Add footnote: "**Caution: Stations in the vicinity of 180° should be alert for a possible discrepancy in the indicated day of the next reference orbit. Check of prior and/or following acquired orbits should resolve this ambiguity."

Page 20, Discussion of Word 5, CB 5-10, Line 1

Add * to "taken"

Page 20, Bottom of Page

Add footnote: "*Accurate to the nearest second following the operation of the shutter, may be up to 0.99 second after the precise picture time."

Page 21, Section 3.2, Paragraph 2

Delete. Insert following: "The APT picture is exposed at 2.5 seconds before the beginning of the video transmission. Each Character Block requires 4 seconds for its generation, and each bit 1 second. Thus, if the precise time of generation of any point (bit) along the Data Code is determined, and its location in terms of Word, Character Block and bit identified, it is relatively simple to determine the elapsed time.* Subtraction then gives the time the vidicon scan was started, and if a further subtraction of 2.5 seconds is made, the picture time is determined."

Page 21, Bottom of Page

Add footnote: "*Elapsed time is illustrated in Figure 5a, Page 14, and Figure 5c, Page 22a, of the ELAPSED TIME (SECS) row of numbers."

Page 22, Last Paragraph

Add new paragraph: "Picture time may also be determined as indicated on Pages 22 and 23 of Reference 3."

Page 23, Paragraph 1, Line 4

Change "use" to "geographic referencing"

Page 24, Footnote (*), Line 2

Change "time" to "time/height"

Page 26, Line 6

Change "track of perigee" to "track at perigee"

Page 26, Line 15

Add * to "Figure 7."

Page 26, Bottom of Page

Add footnote: "*It is recommended that the time and height values be placed on the same side of the subpoint track and the values of argument, to be plotted next, be placed on the opposite side."

Page 29, Lines 17 and 24

Change "time from" to "time/height from"

Pages 30 through 33, Table 5, Column 1

Below "Inclination" add "(Retrograde)"

Page 35, Line 11

Delete.

Page 35, Line 15

Change "Section 4.11" to "Sections 4.8 and 4.11"

Page 35, Section 4.5, Paragraph 2, Line 4

Change "at about the time the satellite is to be tracked." to "given in the Data Code for the next reference orbit."

Page 35, Section 4.5, Paragraph 2, Line 6

Change "retain" to "retains"

Page 36, Section 4.6

Delete all after first paragraph.

Insert following paragraphs below first paragraph:

"Determine the total movement of perigee, in terms of argument, from its position on the reference orbit in the Ephemerides Message to its position on the reference orbit of the most current Data Code. When updating the semi-permanent subpoint track, it should always be done by reference only to the most current Data Code reference orbit, which is not necessarily the orbit on which the picture or DRIR data are acquired. This allows use of the latitude of perigee to determine a "false perigee" reference for tracking. If perigee were updated to its actual position for the orbit on which data are received, the anomalistic period, which is not given in the Data Code, would be required.

"For example, using the data in the Ephemerides Message (Table 4), perigee on orbit 095 was at 18.1°N. Assume a Data Code Reference Orbit number of 131, with a perigee at 25.3°N. Further assume the orbit of interest is 134.

Orbit	Lat. of Perigee	Argument of Perigee	Obtained from
095	18.1°N	161.9°	Current Ephemerides Message
131	25.3°N		Latest Data Code
131		154.7°	Calculation* or Plotting Board
134	25.3°N	154.7°	False Perigee

"Total movement of perigee is 161.9° minus 154.7°, which is 7.2 degrees of argument. Remember, for near-polar orbits, the motion of perigee is always in the direction opposite to that of the satellite. The argument of 154.7° is used as the argument of a "false perigee" for the orbit of interest, orbit 134. This is the concept used in the daily APT Predict Messages.

*Interpolation of the latitude versus argument values given in the Ephemerides Message.

Page 37, Paragraph 1

Delete. Insert following: "In this case, because it is near the equator (see Section A.2), the displacement in actual latitude (south to north) of perigee would be essentially the same (i.e., 7.2°); near the poles, however, this much displacement in argument would lead to a far smaller displacement in actual latitude. For example, when near 80°, a 12° displacement in argument may be approximately an 8° displacement in actual latitude. Since, one degree of latitude equals one degree of Great Circle Arc, latitude can be used to measure angular movements on Great Circles in the same manner as latitude is used to measure distances. Therefore, latitude could be used to measure the angular displacement in argument if the subpoint track were a Great Circle.

Page 37, Section 4.7.1, Line 7

Change "at the time of the desired" to "as given in the Data Code for the reference"

Page 38, Lines 2 and 3

Change "done by" to "done by interpolation or by"

Page 38, Line 6

Change "minute point" to "minute time/height point"

Page 38, Line 12

Change "every point" to "every time/height point"

Page 38, Section 4.7.1, Last Sentence

Delete

Page 38, Section 4.8, Line 1

Change "tracking is" to "tracking is the same as described in Reference 3 and is"

Page 38, Section 4.8, Line 4

Add: "To determine the time (Universal) of the time/height points for the tracking log, do the following:

1. Determine the time (Universal) of the "false perigee" for each pass on which the data are to be acquired. This is accomplished by adding a time increment to the Data Code time (Universal) of perigee on the reference orbit (Word 4, CB 2-7). The time increment is the nodal period (Word 3, CB 2-5) multiplied by the difference in orbit numbers between the reference orbit and the orbit of the "false perigee". Caution: Remember the orbit number increases by one at the ascending node (Page 98, Reference 3).

2. Add the time-from-perigee values of the points to the time of the "false perigee".

Page 39, Section 4.9, Line 9

Change to "'False Perigee' (determined in Section 4.6) 25.3°N."

Page 39, Section 4.9, Line 14

Change "25.9" to "25.3"

Page 39, Section 4.9, Lines 15 and 17

Change "7.8" to "7.2"

Page 39, Last Paragraph, Line 3

Add * to "perigee"

Page 39, Bottom of Page

Add footnote: "*This method should be used if an interpolation of the latitude versus argument values of the Ephemerides Message is not used."

Page 40, Figure 9, Right-hand Diagram

This diagram should be adjusted to show the errata values inserted on Page 39.

Page 41, Paragraph 1, Lines 2 and 3

Delete all after "66.9°S"

Page 41, Paragraph 2, Sentence 2

Delete

Page 41, Paragraph 2, Lines 2 and 3

Delete all before "it can"

Page 41, Paragraph 2, Lines 4 and 5

Change "291" to "285", "10.6°" to "9.1°" and "10.1°" to "8.6°"

Page 41, Paragraph 3, Line 2

Change "10.6°" to "9.1°"

Page 42, Figure 10a

Delete "ORBIT 291 and its perigee point"

Page 42, Figure 10c

This Figure should be adjusted to show the errata values inserted on Page 41.

Page 43, Line 2

Add ** to "grid"

Page 43, Procedure 7., Line 1

Change "determine the" to "determine by interpolation the"

Page 43, Procedure 7., Lines 1 and 2

Change "the time of" to "its position on" (2 places)

Page 43, Procedure 7., Sentence 3

Delete. Insert following sentence: "This allows use of the latitude of perigee to determine a 'false perigee' reference for picture center location, and the Data Code time of perigee and nodal period to determine a time of 'false perigee' (Sections 4.8 and 4.11)."

Page 43, Procedure 7., Line 9

Change "Section 4.5)" to "Section 4.4)"

Page 43, Bottom of Page

Add footnote: "**Caution: If an NESC position grid is used, be sure to select a grid from the "South to North" set of grids."

Page 44, Section 4.11, Steps 1. and 2. Delete. Insert the following:

1. Determine the time (Universal) of the "false perigee" for each pass on which the data are to be acquired. This is accomplished by adding a time increment to the Data Code time (Universal) of perigee on the reference orbit (Word 4, CB 2-7). The time increment is the nodal period (Word 3, CB 2-5) multiplied by the difference in orbit numbers between the reference orbit and the orbit of the "false perigee". Caution: Remember the orbit number increases by one at the ascending node (Page 98, Reference 3).

2. Convert the time (Universal) of the picture to minutes from perigee, in this case the "false perigee," by subtracting the perigee time from the picture time.

Page 45, Figure 11 and Page 46, Figure 12

Change "longitue, E" to "longitude, E" in the lower left of the grids

Page 47, Paragraph 5, Last 3 Sentences

Delete. Insert following sentences: "Adding 3 nodal periods (3 x 1 hr. 50 min. 30 sec., or 5 hr. 31 min. 30 sec.) to the perigee time, Orbit 150 gives a "false perigee" time of 2037:39U for Orbit 153. Thus, the picture was taken 66 min. 15 sec. after the time of the "false perigee" on Orbit 153, or at the 66 min. 15 sec. after perigee point along the updated subpoint track shown in Figure 12. Accordingly, the picture center is located about 35.4°N 77.8°E.

Page 54, Line 22

Insert ")" after "Center"

Page 56, Line 24

Add "(retrograde)" after "orbit inclination"

Page 58, Line above Equation (9)

Change "or $90^{\circ} \pm 90^{\circ}$)" to "or $90^{\circ} \pm n\ 90^{\circ}$)"

Page 59, Paragraph 4, Line 5

Delete the comma following the word "orbit"

Page 59a

Insert APPENDIX B between pages 59 and 60. The user is requested to read APPENDIX B after reading Section 4.6 of the original document.

Page 60, Reference 2

Add: (Out of print; may be available through the Defense Documentation Center or the Federal Clearing House for Scientific and Technical Information.)

APPENDIX B

A NOTE ON THE USE OF THE ANOMALISTIC PERIOD FOR TRACKING PROCEDURES

The following information pertaining to the Anomalistic Period is provided as a refinement to the tracking procedures as outlined in The Nimbus II Data Code Experiment, Section 4.6–4.8. Its use (providing additional tracking accuracy) is not necessary in the day to day operations but would be necessary if the Data Code and Daily Message were not received for several days. In this case, to relocate the satellite signal, the following procedure would be used in conjunction with the original updating procedure described in Section 4.6.

The Anomalistic Period is defined as the time between successive perigees. This time interval is a necessary piece of information to obtain a correct time of perigee when the satellite subpoint track is updated beyond the reference orbit given in the Data Code.

The Anomalistic Period is not provided explicitly in the Data Code* but can be derived by one of the following methods:

(1) Obtain the time of perigee (Word 4, CB 2–7) from two successive reference orbits and subtract the earlier perigee time from the latter.

(2) If the time of perigee for two successive orbits is not available, subtract the times of any two perigees and divide this time difference by the number of orbits between the two perigees.

As a further step, to obtain the perigee time (Universal) of a desired tracking orbit the derived or given (in the Ephemerides Message) Anomalistic Period must be multiplied by the difference in orbits between the reference orbit and a desired tracking orbit.

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*It may be included in the Remarks section of the Ephemerides Message.