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THE USE OF DMSP DIGITAL DATA FOR AURORAL MEASUREMENTS

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15 February 1981


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PREPARED FOR

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731
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**Title:**
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**Abstract:**
Using measurements of aurora made by ground and aircraft based photometers and correlated in space and time with DMSP observations, two DMSP night time sensors have been calibrated. A procedure has been developed for computer reduction and analysis of the calibrated DMSP digital tape data.
FOREWORD

The effort discussed in this report concerns measurements of auroral intensities and spatial variations using satellite, aircraft, and ground-based sensors. Primary emphasis has been on calibration of night time sensors on two DMSP satellites, and on development of computer techniques for handling the DMSP digital tape data.

The author wishes to thank R. Nadile (AFGL/OPR), technical monitor, for his encouragement and support. We also wish to thank J. Bass (Logicon) and H. Fish (RDP) for their efforts in development of the computer programs, and R. Sears, (Lockheed Missiles and Space Corp.) for providing ground station data.
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1. INTRODUCTION

The Defense Meteorological Satellite Program (DMSP) has been providing unclassified meteorological imagery to the scientific community since early 1973. The forerunner to DMSP was the classified Defense System Applications Program (DSAP) which provided so-called DAPP (Data Acquisition and Processing Program) data.

Our effort has concentrated upon development of a data analysis system which will allow optimal use of DMSP auroral and airglow imagery for a variety of applications. The current version of DMSP, known as Block 5D, became operational in late 1975 with the launch of the F1 satellite. Since that time, three additional satellites were launched successfully and one unsuccessfully, with approximately three more planned before a possible integration into the shuttle program.

Our program has included calibration of the night time visible sensors on the F1 and F2 satellites in the Block 5D series. By correlating auroral intensities measured by ground and airborne photometers with the DMSP observation simultaneous in space and time, the night sensors on these two satellites have been calibrated in terms of effective auroral intensity. The approach to this calibration is unique, to our knowledge, since earlier approaches have used DMSP auroral data taken from photographic transparencies. The current approach uses the digital telemetry information from which the transparencies are produced. This digital data has been supplied by AFGWC.

Access to digital data on magnetic tape has allowed straightforward development of computer approaches to data handling. The effort has been to develop a flexible system which allows manipulation of the data dependent upon the specific application and presentation in a variety of formats.

The program has also included correlation of auroral observations from the calibrated DMSP F2 satellite with data taken by an uncalibrated satellite.
2. CHARACTERISTICS OF THE DMSP BLOCK 5D SERIES

The primary sensor on the DMSP satellite provides visual and infrared imagery of the earth on a continual basis, with the primary mission to provide meteorological data. In addition to the primary sensor there are a variety of smaller sensor packages. These generally have included the SSJ electron spectrometer and the SSIE plasma monitor.

To date, our program has used only data from the primary visible sensor on the DMSP. Table 2-1 lists some of the characteristics of the night time visible sensor. The orbital characteristics of the satellite are also given.

In order to perform its primary mission of providing timely and accurate meteorological data for the U.S. military on a global basis, the DMSP has been placed in a polar orbit at an inclination of 98.7° with respect to the equator. The design orbital altitude is 450 nautical miles (833 km), yielding an orbit period of 101 minutes.

The total data system for the primary sensor on the Block 5D DMSP is called the OLS (Operational Linear System). The OLS contains a number of changes from the 5 B/C series which yield improved system performance in terms of spatial resolution and accuracy.

The requirement for global meteorological data requires that the OLS optical system performs a scan which will yield continuous data when outputs from successive orbits are placed side-by-side. To do this, the optics scan a full angle of 112.5° in a direction perpendicular to the subsatellite track. This scan corresponds to a geocentric scan angle of 27.5°, yielding a scan on the earth's surface of 1655 nautical miles (3065 km). The 101 minute orbital period corresponds to an earth rotation of 25.4° under the satellite during each orbit. Thus, successive orbits yield scans which overlap slightly the scans of the previous orbit.

The orbital parameters of the satellite were configured to place it in a sun synchronous orbit, so that local time at the satellite is essentially constant for a given subsatellite latitude on each pass.
### Table 2-1. Characteristics of DMSP Block 5D Night Sensor

**DMSP BLOCK 5D (NIGHT)**

**ORBIT CHARACTERISTICS:**
- 450 NMI (833 km)
- 101 Minutes/Revolution
- 98.7° Inclination
- 81.3° North & South Max Lat. Subpoint

**SCAN CHARACTERISTICS:**
- 112.5° Full Angle
  - (27.5° Geocentric)
  - (1655 NMI)
- 1.5 NMI (2.8 km) Ground Resolution (nom.)
  - (Derived from 11.88 scan /sec rate and 5 Scan Average with 8 KHz onboard filter)
  - (Compensated FOV to yield nearly constant footprint)
- 1464 Resolution elements/scan

**ELECTRICAL CHARACTERISTICS:**
- Lin and Log Sensitivities
- Dynamic Range = 100 on Log
  - = 64 on Lin
- Ground Programmable Gain (Saturation Value)
  - In finer than 1db steps from 1 - 63.875 db
  - (DB = 20 Log V (Out)/V (In))
- S/N Better than 6 at $8E-09$ watts per cm sq per ster.
In the 5D series, F1 had equatorial crossings at approximately noon-midnight, providing excellent night-side auroral views. F2, F3, and F4 were morning-evening satellites with equatorial crossings in the 8 - 10 AM-PM time region.

A major change in the night time sensor for 5D compared to 5B/C was the shift to a photomultiplier as the detector from the silicon detector previously used. Silicon remains as the daytime sensor. Figure 2-1 shows the relative sensitivity curves for the photomultipliers used in F2 and F4. The response of the PMT's in F1 and F3 were quite similar to F2. The shift to red enhancement occurred in F4.

In addition to the day/night visual channel, the DMSP records simultaneous data in the infrared. In the F1 to F4 flights this channel was sensitive to thermal radiation in the 8 - 13 micron infrared band. The detector is HgCdTe cooled to approximately 108 K. To date, we have made only slight use of the infrared data. There is, as yet, no evidence of auroral effects being observable in this channel.

The design of the OLS improved considerably the uniformity of the system geometric resolution over the 5B/C series. The system is now required to have a resolution of 0.3 nautical miles for daytime viewing and 1.5 nmi for night imagery. The actual night resolution varies from approximately 1.2 nmi (2.2 km) at nadir to somewhat more than 1.5 nmi (2.8 km) at the ends of the scan.

The OLS uses an optical scanning technique combined with shaped detector surfaces to achieve its uniform spatial resolution, compared to the 5B/C series. The OLS rotates and switches the detector field of view to maintain image uniformity. This is combined with electrical gain switching along the scan to yield the desired scene sensitivity.

Overall sensitivity of the night time channel is controllable from the ground over a range of 63-7/8 db in 1/8 db steps. In addition, one may select either a logarithmic or linear response in the amplifier. (For our purposes, 20 db = factor of 10 in input signal level.)
Figure 2-1. Relative Response of DMSP Photomultipliers.
Data is processed and digitized on board the satellite. The basic scan rate of the sensor system was configured to give continuous earth coverage when combining the subsatellite track velocity with the field-of-view of the sensor system. Since the subsatellite track velocity for the orbital parameters given earlier is 3.55 nmi per second, the required scan rate corresponding to the daytime 0.3 nmi resolution is 11.88 scans per second for continuous coverage. The onboard processing averages over five successive scans to yield the so-called "smoothed" daytime resolution of 1.5 nmi and the fixed night time 1.5 nmi resolution.

The smoothed data is filtered and digitized to yield 1464 pixels of data for each effective scan (average of five). The data is digitized with 5 bit resolution yielding a scene instantaneous dynamic range of 64 using the linear amplifier and a dynamic range of 100 using the log amplifier. The gain of the overall system can be changed over the 64 db range mentioned earlier to yield a total dynamic range of over $10^5$. 


3. EXPERIMENTAL PROGRAM

The calibration effort has involved a number of simultaneous or near simultaneous spatial-temporal correlations between various DMSP Block 5D satellites and aircraft and ground stations viewing auroral situations. This included the use of satellite ephemeris predictions generated by AFGL/SUA and projected flight plans of the AFGL/OP NKC-135 (SN 53120) Flying Laboratory. An example of printed ephemeris data is shown in Fig 3-1. In those missions that involved ground measurements, plans were coordinated with the Lockheed group (R. Sears).

DMSP data has been supplied by AFGWC in two different forms during the period of this program. Early in the program, digital data for the specified satellite, revolution and time period was supplied as an octal dump on paper of pixel information by scan line. Figure 3-2 is an example of few scan lines of information. Each line contains 1464 pairs of octal numbers which represent 8^2 levels of signal information for each pixel. In addition, there is time code, gain, and other housekeeping information in each scan line. The data format will be discussed in more detail in Section 4.

Later in the program (after February 1979), the data requested from AFGWC was supplied on digital magnetic tape in a format compatible with the AFGL CDC computer.

Table 3-1 is a tabulation of digital data supplied by AFGWC through February 1980. The table identifies the data, satellite, revolution number, and universal time for which data exists. It also lists whether the data exists on binary magnetic tape or as paper printout. The revolution number is considered redundant information. The date, time and satellite identification are the primary data identifiers.

3.1. Calibration of Fl

During the period January 1979 through early February 1979 the Lockheed optical research site at Chatanika, Alaska was in operation.
<table>
<thead>
<tr>
<th>STATION NO.</th>
<th>UNIV. TIME</th>
<th>ELEV (ft)</th>
<th>ZENITH (deg)</th>
<th>RANGE (km)</th>
<th>ALT (km)</th>
<th>RT (UTC)</th>
<th>DEC (UTC)</th>
<th>SUMMIT SITE</th>
<th>ALT (km)</th>
<th>SUN LIG. ALONG</th>
<th>LUX (UTC)</th>
<th>SET (UTC)</th>
</tr>
</thead>
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<td>1/18/78</td>
<td>18.45</td>
<td>63.97</td>
<td>153.58</td>
<td>17.27</td>
<td>65.46</td>
<td>22.74</td>
<td>115.10</td>
<td>15.90</td>
<td>27.90</td>
<td>173.95</td>
<td>15.90</td>
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</tr>
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<td>153.58</td>
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<td>27.90</td>
<td>173.95</td>
<td>15.90</td>
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<td>17.27</td>
<td>65.46</td>
<td>22.74</td>
<td>115.10</td>
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<td>27.90</td>
<td>173.95</td>
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<td>27.90</td>
<td>173.95</td>
<td>15.90</td>
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<tr>
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<td>1/18/78</td>
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<td>153.58</td>
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<td>65.46</td>
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<td>115.10</td>
<td>15.90</td>
<td>27.90</td>
<td>173.95</td>
<td>15.90</td>
</tr>
</tbody>
</table>

Figure 3-1. DMSP Ephemeris Data.
Figure 3-2. Dump of DMSP Digital Data (Octal)
Table 3-1. Digital Data Supplied by AFGWC

<table>
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<tr>
<th>Date</th>
<th>Satellite</th>
<th>Rev. #</th>
<th>Time (U.T.)</th>
<th>Type of Data</th>
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<td>F1</td>
<td>10221</td>
<td>11:05-11:10</td>
<td>Paper</td>
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<td>10/25/78</td>
<td>F1</td>
<td>10972</td>
<td>10:30-10:56</td>
<td>Paper</td>
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<td>F1</td>
<td>11057</td>
<td>10:24-10:53</td>
<td>Paper</td>
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<tr>
<td>11/1/78</td>
<td>F1</td>
<td>11071</td>
<td>10:06-10:22</td>
<td>Paper</td>
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<td>11/2/78</td>
<td>F1</td>
<td>11085</td>
<td>9:45-10:09</td>
<td>Paper</td>
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<td>F2</td>
<td>8547</td>
<td>7:20-7:28</td>
<td>Paper</td>
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<td>2/2/79</td>
<td>F2</td>
<td>8604</td>
<td>7:52-7:57</td>
<td>Paper</td>
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<td>F2</td>
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<td>7:35-7:41</td>
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<td>8648</td>
<td>7:07-7:12</td>
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<td>2/5/79</td>
<td>F1</td>
<td>12432</td>
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<td>1594</td>
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<td>9/27/79</td>
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<td>11960</td>
<td>1:54-1:58</td>
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<td>13502</td>
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<td>1/14/80</td>
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<td>13516</td>
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<td>13530</td>
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<td>F2</td>
<td>13531</td>
<td>20:54-20:61</td>
<td>Mag</td>
</tr>
<tr>
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<td>F2</td>
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<td>Mag</td>
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<td>20:14-20:20</td>
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<td>F2</td>
<td>13857</td>
<td>20:37-20:43</td>
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<td>13871</td>
<td>20:32-20:39</td>
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This site includes a three channel meridian scanning photometer as one of its primary instruments. The photometer channels are designed to measure 427.8, 557.7, and 630 nm radiation with a field-of-view of 3°. The instrument scans 80° each side of zenith at a rate of two degrees/second. Data is taken in 4° increments.

Figure 3-3 shows the approximate subsatellite track for Revolution 12432 (5 February, 1979) projected onto the Alaska map. Shown is the approximate ground track of the Lockheed photometer intersection at auroral altitudes. Figure 3-4 is a reproduction of the DMSP transparency generated from night time sensor data for the portion of Rev 12432 over Alaska. The location of Fairbanks is circled and the intersection of the three-color meridian scanning photometer with a surface at approximately 100 km is shown. The square envelopes Anchorage.

The DMSP F1 sensor during the portion of the orbit over Alaska was operating in linear mode with gain equal to 25 db. Table 3-2 tabulates a portion of the meridian scanning photometer data and the DMSP output when viewing the same region. It can be seen that time coincidence of the spatial scans occurred at approximately 72 km south of Chetana during this scan (10 hr 58 min. UT). Averaging the two values nearest this coincidence yields an output of 58.13 for a 427.8 intensity of 1663 R. Since zero volts is an output of 63 and 5 volts is zero, this yields the following calibration (at 427.8; G = 25 Linear).

\[
\begin{align*}
1 \text{ volt} &= 4,300 \text{ R} \\
5 \text{ volts} &= 21,500 \text{ R}
\end{align*}
\]

Standardizing to a gain of 63 db yields, for F1, (427.8; G = 63, linear)

\[
\begin{align*}
1 \text{ volt} &= 54.1 \text{ R} \\
5 \text{ volts} &= 270 \text{ R}
\end{align*}
\]

3.2. Calibration of F2

A number of coordinated satellite and aircraft observations were made during the course of the program. For purposes of F2 calibration, the coordinated event of 27 September, 1979 is used. During this series of coordinated aircraft flights, the AFGL/OP NKC-135 (SN 53120)
Figure 3-3. Satellite and Ground Station Tracks for F1 (5 February 1979).
Table 3-2. GROUND SITE/DMSP F1 COINCIDENCE
(5 February 1979)

<table>
<thead>
<tr>
<th>Distance South (km)</th>
<th>Photometer Time (U.T.)</th>
<th>F1 Time (U.T.)</th>
<th>F1 Output (63 to 0 = 0 to 5 volts)</th>
<th>Ground Site I (4278) (R)</th>
</tr>
</thead>
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<td>48</td>
<td>10:15:03</td>
<td>10:14:53</td>
<td>59.4</td>
<td>1115</td>
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<td>10:14:55</td>
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<tr>
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<td>10:14:57</td>
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<td>1569</td>
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<td>10:14:57</td>
<td>10:14:59</td>
<td>57.9</td>
<td>1756</td>
</tr>
<tr>
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<td>10:14:55</td>
<td>10:15:01</td>
<td>57.8</td>
<td>1937</td>
</tr>
<tr>
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<td>10:14:43</td>
<td>10:15:04</td>
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<td>10:14:49</td>
<td>10:15:09</td>
<td>56.8</td>
<td>2554</td>
</tr>
</tbody>
</table>
was operating from Pease AFB, New Hampshire, flying over Newfoundland and Quebec and returning to Pease. Two revolutions of F2 (Rev 11960 and Rev 11961) scanned regions of aurora which were viewed simultaneously by the AFGL twelve channel visible photometer (System E5 operated by PhotoMetrics). This photometer was near zenith (15° forward) pointing. Table 3-3 shows the aircraft coordinates (from the flight log) and the subsatellite location near the time of coincidence (1:56 U.T.). Fig 3-5 shows the approximate aircraft position on the Rev 11960 pictorial data.

Figure 3-6 shows the pixel values given from the computer reduction of the F2 Rev 11960 output supplied by AFGWC for the scan which included the photometer field-of-view (2° full angle). Averaging the six pixel values closest to the photometer field yields a pixel value of 26 (where zero to 63 is 5 volts to zero volts). During this portion of the orbit, F2 was operated at gain = 57 in Log mode.

The photometer output at the time of coincidence (1:55:17) yielded a value of 350 R at 427.8 nm.

The calculation of the F2 calibration is as follows. F2 during this time was in its logarithmic mode. The voltage telemetered is still 0 - 5 volts, yielding levels of 0 - 63 for pixel values. The equivalent linear voltage into the log amplifier is given by

$$V_{in} = 0.05 \log^{-1} \left[ \frac{5(1 - V_{pix})}{2.5} \right]$$

For our case, $V_{pix} = 26$, yielding

$$V_{in} = 0.05 \log^{-1} 1.75 = 0.747 \text{ volts}$$

0.75 volts in = 350 R (427.8)
1 volt in = 467 R
5 volts in = 2,333 R (G = 57)

For G = 63 we have:

Using $dB = 20 \log \frac{V_2}{V_1}$

1 volt = 234 R (427.8)    5 volts = 1170 R (427.8).
Table 3-3. AIRCRAFT DMSP F2 COINCIDENCE  
(27 September 1979)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<td>66°01'</td>
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<td>Left turn</td>
<td>56°04'</td>
<td>57°18'</td>
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<tr>
<td>01:54</td>
<td>52°06'</td>
<td>66°06'</td>
<td>325</td>
<td>End turn</td>
<td>49°18'</td>
<td>60°51'</td>
<td>11960</td>
</tr>
<tr>
<td>01:56</td>
<td>52°</td>
<td>66°19'</td>
<td>325°</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>02:03</td>
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<td>67°02'</td>
<td>327°</td>
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Figure 3-5. DMSP Photograph (F2, 27 September 1979).
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<th>LONG</th>
<th>ALT</th>
<th>ONGT</th>
<th>AZ</th>
<th>GAIN</th>
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<tr>
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<tr>
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<td>319.4</td>
<td>270 27 92.42</td>
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<tr>
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<td>166</td>
<td>57.17</td>
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<tr>
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<td>64.29</td>
<td>299.99</td>
<td>319.4</td>
<td>270 27 92.42</td>
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</tbody>
</table>

Figure 3-6. Pixel Values for F-2/Aircraft Coincidence.
3.3 Calibration Summary

As shown in Section 3.1 and 3.2, the calibration of F1, from a coincident measurement with the Chatanika Meridian Scanning Photometer and the calibration of F2 from a coincident measurement with the AFGL/OP NKC-135 are:

F1 (Linear Mode)

\[ 1 \text{ volt} = 54.1 \times \log^{-1} \left( \frac{63-G}{20} \right) \ R \ (427.8) \]

where

\[ G = \text{gain} \]
\[ \text{volts} = 5(1 - \frac{V_{\text{pix}}}{63}) \]
\[ V_{\text{pix}} = \text{telemetered pixel value (0 to 63)} \]
\[ I (427.8) = 270 (1 - \frac{V_{\text{pix}}}{63}) \log^{-1} \left( \frac{63-G}{20} \right) \ R \]

-----------------------------------------------------------------------------------------------

F2 (Linear Mode)

\[ I (427.8) = 1,170 (1 - \frac{V_{\text{pix}}}{63}) \log^{-1} \left( \frac{63-G}{20} \right) \ R \]

-----------------------------------------------------------------------------------------------

For the log mode we have

F1 (log)

\[ I (427.8) = 2.7 \log^{-1} \left[ 2 \left(1 - \frac{V_{\text{pix}}}{63} \right) \right] \log^{-1} \left( \frac{63-G}{20} \right) \ R \]

F2 (log)

\[ I (427.8) = 11.7 \log^{-1} \left[ 2 \left(1 - \frac{V_{\text{pix}}}{63} \right) \right] \log^{-1} \left( \frac{63-G}{20} \right) \ R \]
4. TREATMENT OF DATA

As mentioned earlier, the DMSP data of interest has been most recently supplied on magnetic tape by AFGWC. Figure 3-2 showed a dump of the tape data. Figure 4-1 gives the format of the data as supplied. The data for each scan line is composed of 250 36 bit words. Each 36 bit word, as seen in Figure 3-2, is composed of 12 octal digits (0 - 7). From the format of Fig 4-1, it can be seen that the first two words contain Line Count and Sync information. The pixel data is contained in the following 244 words as pairs of octal digits yielding levels of 0 - 63 for each pixel. Word 247 contains the time code as a 27 bit (9 octal digits) number representing U.T. in seconds times 1024. Word 248 contains a 9 bit (3 octal) number for the gain setting, with \( G_1 = \text{MSB} \) and \( G_9 = \text{LSB} \). \( G_1 - G_6 \) represent the whole number \( G = 0 \) to \( G = 63 \) values. Word 248 also contains a 4 bit number (M1 - M4). M1 gives information as to whether the amplifier is operating in linear or log mode. A zero in this position is used for linear and a 1 for log. M2 - M4, if all 1's, tell us that the amplifier was in preset gain mode. Other options are various AGC modes. The remaining bits in words 248 - 250 give calibration information for the various detectors and also vehicle identification.

Figure 4-2 illustrates the operations which are performed on the data. The digital data, as received from AFGWC on magnetic tape, is operated on by program PIXEL. This program unpacks data from the time interval of interest and merges this data with satellite ephemeris data for the time of interest for the particular satellite. This merged data, which now contains coordinate and time information for every pixel, is reformatted and output is made to permanent file for later use. PIXEL 2 is used only to provide a viewable output of this merged, reformatted data.

ARCLDB is a program used to produce a data base along an arc at an arbitrary angle to the satellite trajectory. This is necessary in order to compare the DMSP measurement with those of another instrument on the ground, on an aircraft, or on another satellite viewing a region.
Word #1

Frame/Line Count

<table>
<thead>
<tr>
<th>Frame Count</th>
<th>Line Count</th>
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</thead>
<tbody>
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</table>

1 = L
0 = T

Word #2

Computer Line Sync

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<td>111111</td>
<td>011111</td>
<td>000001</td>
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</table>
1 = L
0 = T

Words #3 Thru #246

(#3 Thru #124 For Sample 2 Or Avg 2 x 2)
(#3 Thru #63 For Sample 4 Or Avg 4 x 4)

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<th>6 Bit Data</th>
<th>6 Bit Data</th>
<th>6 Bit Data</th>
<th>6 Bit Data</th>
<th>6 Bit Data</th>
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</tbody>
</table>

(#125 For Sample 7 Or #125 For Avg 2 x 2, Line 2)
(#127 For Avg 2 x 2, Line 1)
(#64 For Sample 4 Or #64 For Avg 4 x 4, Line 4)
#68 For Avg 4 x 4, Line 3
#72 For Avg 4 x 4, Line 2
#76 For Avg 4 x 4, Line 1

Word #247

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<th>000 E1-3</th>
<th>E4-9</th>
<th>E10-15</th>
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<th>E22-27</th>
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</table>

(#126 For Sample 7 Or #126 For Avg 2 x 2, Line 2)
(#130 For Avg 2 x 2, Line 1)
(#65 For Sample 4 Or #65 For Avg 4 x 4, Line 4)
#69 For Avg 4 x 4, Line 3
#73 For Avg 4 x 4, Line 2
#77 For Avg 4 x 4, Line 1

Word #248

<table>
<thead>
<tr>
<th>C1-6</th>
<th>G7-9 M2-3</th>
<th>M4 S P1-4</th>
<th>P5-8 E2-2</th>
<th>13-4 S H0-2</th>
<th>H2-8</th>
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</thead>
<tbody>
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<td></td>
</tr>
</tbody>
</table>

(#127 For Sample 7 Or #127 For Avg 2 x 2, Line 2)
(#133 For Avg 2 x 2, Line 1)
(#66 For Sample 4 Or #66 For Avg 4 x 4, Line 4)
#70 For Avg 4 x 4, Line 3
#74 For Avg 4 x 4, Line 2
#78 For Avg 4 x 4, Line 1

Word #249

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<th>C7-8 E1-4</th>
<th>25-10</th>
<th>E11-16</th>
<th>E17-22</th>
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<tbody>
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(#128 For Sample 7 Or #128 For Avg 2 x 2, Line 2)
(#132 For Avg 2 x 2, Line 1)
(#67 For Sample 4 Or #67 For Avg 4 x 4, Line 4)
#71 For Avg 4 x 4, Line 3
#75 For Avg 4 x 4, Line 2
#79 For Avg 4 x 4, Line 1

Word #250

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(#129 For Sample 7 Or #129 For Avg 2 x 2, Line 2)
(#133 For Avg 2 x 2, Line 1)
(#67 For Sample 4 Or #67 For Avg 4 x 4, Line 4)
#71 For Avg 4 x 4, Line 3
#75 For Avg 4 x 4, Line 2
#79 For Avg 4 x 4, Line 1

X May Be Either 1 Or 0

FORMATTED 6-BIT SMOOTH DATA OUTPUT

Figure 4-1. Format of Block 5D Tape Data.
DATA FLOW BLOCK DIAGRAM

Digital Data From AFGWC (Magnetic Tape)

→

PIXEL

→

PIXEL 2

Printed Output

→

ARCLDB

Intersecting Arc Data Cal Data

Ephemeris Data

→

ARCINT

Interpolation Size Step Size

Printed Output

Figure 4-2.
viewed by DMSP. The absolute calibration of the sensor is inserted in ARCLDB so that results are in kR.

The program ARCINT uses the data base produced by ARCLDB to compute, by interpolation, the intensity as measured by DMSP along an arc centered at an arbitrary point and at an arbitrary angle.

4.1 Event of 11 January, 1980

As an example of the output of the various data processing programs we use data taken by satellite F2 on 11 January, 1980. Fig 4-3 is a reproduction of the transparency as supplied by AFGWC for the time period near 20 hrs 27 min UT. The satellite was moving downward during this period. The pairs of squares in the left margin occur every 120 seconds. The upper pair are at a time of 20:25.7 UT. The large city in the lower right corner is Moscow, with Leningrad visible as the next largest city to the northwest.

Fig. 4-4 shows the output of program PIXEL 2 for a 10 second time portion roughly midway between the upper two pairs of time squares. This is an example of short-form printout for the merged pixel-geographic information. A minimal amount of data is shown for each scan line. This includes the time of the scan, subsatellite coordinates, altitude of the satellite, the altitude assumed for the aurora (100 km), the octal digits which give the gain (in this case 310 octal or 011001000 binary, yielding \( G = 25 \)) and state of the amplifier (74 octal or 111100 binary, yielding \( \log \text{preset gain} \)). The final set of columns give the minimum and maximum decimal values for pixels on that scan line and the location pixel number of these values. Pixel number runs from -732 to 732. It should be remembered that minimum decimal value represents maximum signal. Negative pixel location numbers are on the right half of the picture. Figure 4-5 is the long-form output of PIXEL 2, showing coordinates and values for every pixel in a particular scan.

Figure 4-6 shows the output of program ARCLDB for points near a portion of the line drawn on the photo in Figure 4-3 representing the intersection of an arbitrary scan by another instrument with the
Figure 4-4. Short-Form Output of Program PIXEL 2.
Figure 4-5. Long-Form Output of PIXEL 2.
spherical shell containing the aurora at 100 km. In the photo (Fig 4-3), the right hand portion has been cropped, so that the center of the DMSP scans (the subsatellite track) is actually moved to the right and very nearly passes through the circle representing the center of the arbitrary scan. The arbitrary scan is centered at a latitude of 70° North and longitude of 320.5° West. It is taken at an azimuth of 325° east of north.

Fig 4-6 displays a small portion of the data base of pixels selected for each scan line near the intersection with the arbitrary scan. The calibration data was included as an input to this program, so that pixel values are given in equivalent kR of 4278 Å intensity.

Fig 4-7 shows the output of program ARCINT for the 800 km arbitrary scan intersection, using the data base created by ARCLDB for interpolation of pixel values near the intersection with each scan line. By comparing Fig 4-7 with the photo in Fig 4-3, one can readily see the intercept with the auroral arc. The intensity maximizes at approximately 6.4 kR at -58.5 km.
**Figure 4-7. Output of Program ARCINT.**

**Table**: Output of Program ARCINT.

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<th>S/N</th>
<th>INT(R)</th>
<th>S/N</th>
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<td>.99</td>
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<td>.96</td>
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<td>235.40</td>
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**SATELLITE DROPZ**: FWS 3474

**DATE**: 01/10/00

**ARC PARAMETERS**

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<tr>
<th>LATITUDE</th>
<th>74.000 DEG N</th>
<th>LONGITUDE</th>
<th>275.566 DEG W</th>
<th>AZIMUTH</th>
<th>221.400 DEG E FROM N</th>
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<td>-318.000 NM</td>
<td>HALF WIDTH</td>
<td>9.600 NM</td>
<td>DELS</td>
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**GAIN**: 10.000

**SKIM**: 4 PLOT: 0 DELT: 2.000
5. CONCLUSIONS

Auroral data taken by night time sensors on DMSP has been used in the past to provide information on structure and global motion. Most of this data was extracted from photographic transparencies which had been synthesized by AFGWC from digital information. In this effort we have developed techniques for using digital data directly, thus maintaining the full system capability of the DMSP. In addition, by correlation with calibrated aircraft and ground photometers, we have calibrated the night time sensors on DMSP F1 and F2. This, then, yields calibrated downward looking auroral and airglow sensors with global coverage.

The computer techniques which have been developed should allow prediction of intensity levels seen by other satellites viewing portions of the regions covered by DMSP. As future DMSP satellites are launched, the technique will allow study of spatial frequencies in aurora and airglow and should add considerably to the data base on global aurora and airglow intensity variations.