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|                   |                                 |                     |
|-------------------|---------------------------------|---------------------|
| FACILITY FORM 808 | <b>N 69-19606</b>               |                     |
|                   | (ACCESSION NUMBER)<br><b>58</b> | (THRU)<br><b>1</b>  |
|                   | (PAGES)<br><b>NASA-A-99564</b>  | (CODE)<br><b>29</b> |
|                   | (NASA CR OR TMX OR AD NUMBER)   | (CATEGORY)          |

MAJOR SOLAR AND SOLAR  
INDUCED PHENOMENA DURING  
THE 20th SOLAR CYCLE  
I - THE FIRST SIX MONTHS OF 1967

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Report No. 00.1145

14 February 1969

Prepared under Contract NAS 9-7134  
with Missiles and Space Division  
ITV Aerospace Corporation

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## INTRODUCTION

This report is the first phase of the analysis of major solar activities during the increasing stage of the 20th solar cycle.

We will make a brief comparison of the first six months of 1967 with the corresponding period of the 19th solar cycle (July - December 1956). This period starts 27 months after the solar minimum during October 1964.

A realistic comparison of the two periods of the 19th and 20th solar cycle is not possible due to the great improvement in the observation and recording of solar and solar induced phenomena that are generally considered to be almost necessary conditions for the production of a solar proton event.

During and following the IGY several new techniques were developed that were sensitive to small increases in low energy protons in the neighborhood of the earth. In addition, satellites with orbits that extended beyond the earth's magnetosphere carried proton counters and detected events that could not have been observed by equipment in operation during the second half of 1956.

It is also well known that during 1956 the flare patrol averaged only about 72% of the time while the radio patrol at centimeter wavelengths covered only about 16 hours of the universal day.

1.0 STATISTICAL COMPARISON OF THE CORRESPONDING SIX MONTHS OF THE 19TH AND 20TH SOLAR CYCLE

The period from 1 January through 30 June 1967 has been chosen for a detailed study. This period was chosen for several reasons.

(a) Five confirmed solar proton events were reported, including one observed at ground level.

(b) Three of the confirmed proton events, including the one at ground level occurred during periods of very low solar activity.

(c) Two large  $\delta$  type sunspot groups crossed the solar disk. One produced two major events with associated phenomena and yellow coronal emissions at West Limb passage but no proton events were reported. The other produced four major events including two proton events.

(d) The general level of solar activity during the period was very low when compared with the corresponding period of the 19th solar cycle (1 July through 31 December 1956).

A very brief summary of activity from October 1964 through December 1966 will be included as an Appendix.

1.1 SUNSPOT ACTIVITY

1.1.1 Relative Sunspot Numbers

The daily relative sunspot numbers for the two periods are shown on Figure 1.1. We have also shown the smoothed monthly

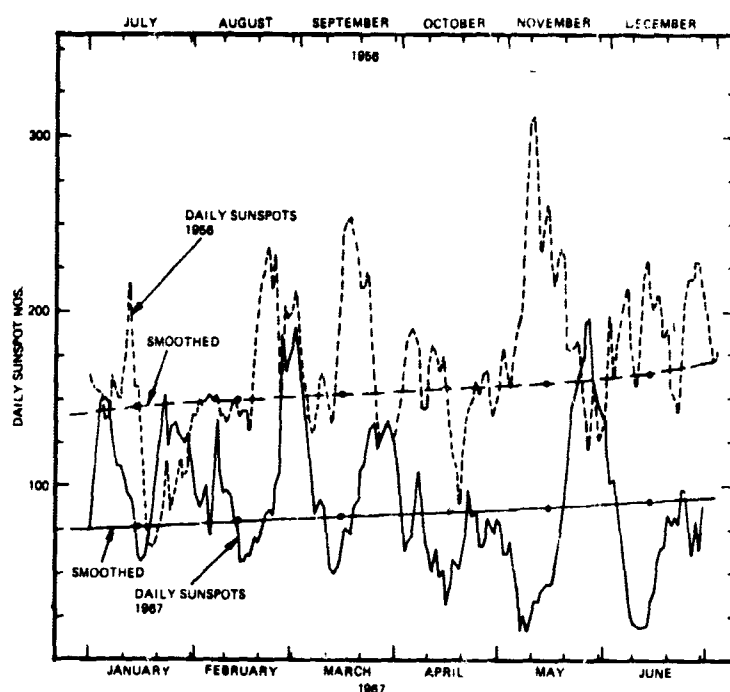


FIGURE 1.1 COMPARISON OF DAILY RELATIVE SUNSPOT NUMBERS JULY - DECEMBER 1966 AND JANUARY - JUNE 1967

sunspot numbers.\* It is seen that based on this parameter, the solar activity during this six month period of the 20th cycle is approximately 50% of the activity during the corresponding period of the 19th cycle. Further evidence of the lower level of activity is shown by the number of sunspot groups with maximum areas greater than 500 millionths of the solar hemisphere. There were 51 large sunspot groups during the second half of 1956 and only 10 during the comparable period of the 20th solar cycle.

#### 1.1.2 Sunspot Magnetic Class

There were seven sunspot groups with  $\beta\delta$  or  $\delta$ , magnetic classification during disk passage in the six months of 1956 and only three during the 1967 period. Two of these were reported with the new  $\delta$  type configuration by Mt. Wilson, the other was classified as  $\beta\delta$  or  $\delta$  on five days during disk passage. These data are summarized in Table 1.1.

The  $\delta$  type sunspot group (Mt. Wilson 16272) in February 1967 reached a maximum area of 1416 millionths on 28 February. It was an extremely active region during disk passage and met most of the conditions generally assumed to be necessary for a proton producing region. However, none has been reported.

\*See also Figures 1.1a, 1.1b, and 1.1c, page 50.

| 1956 |       |                 | 1967 |       |                 |
|------|-------|-----------------|------|-------|-----------------|
|      | Large | Complex<br>Mag. |      | Large | Complex<br>Mag. |
| July | 5     | 0               | Jan  | 3     | 0               |
| Aug  | 7     | 0               | Feb  | 1     | 1               |
| Sept | 11    | 2               | Mar  | 3     | 0               |
| Oct  | 6     | 1               | Apr  | 0     | 0               |
| Nov  | 12    | 2               | May  | 2     | 1               |
| Dec  | 10    | 2               | Jun  | 1     | 1               |
|      | 51    | 7               |      | 10    | 3               |

TABLE 1.1 COMPARISON OF THE NUMBER OF LARGE  
SUNSPOT GROUPS AND MAGNETICALLY  
COMPLEX GROUPS

On the other hand, the  $\delta$  type sunspot group (Mt. Wilson 16372) that crossed the solar disk between May 17 and May 30 met all of the conditions for a proton producing region. Two confirmed events have been reported.

#### 1.2 MAJOR FLARES

A comparison of the numbers of major flares with importance  $\geq 2+$  for the equivalent periods of the 19th and 20th solar cycles is shown in Table 1.2. These data are based on Volume I of the Solar Activity Catalogues (Reference 10) for the second six months of 1956, and the IAU Quarterly Bulletin (Reference 9) for the first six months of 1967.

| 1956  |    |    |    |                    | 1967 |          |         |          |
|-------|----|----|----|--------------------|------|----------|---------|----------|
|       |    |    |    | Hours<br>Obs.<br>% |      | 3B<br>3+ | 3N<br>3 | 2B<br>2+ |
|       | 3+ | 3  | 2+ |                    |      |          |         |          |
| Jul   | 0  | 0  | 0  | 82                 | Jan  | 1        | 0       | 1        |
| Aug   | 0  | 2  | 0  | 83                 | Feb  | 1        | 1       | 3        |
| Sep   | 0  | 2  | 1  | 81                 | Mar  | 1        | 1       | 1        |
| Oct   | 0  | 3  | 0  | 63                 | Apr  | 0        | 0       | 1        |
| Nov   | 1  | 2  | 3  | 59                 | May  | 2        | 2       | 6        |
| Dec   | 0  | 3  | 3  | 64                 | Jun  | 0        | 0       | 0        |
| Total | 1  | 12 | 7  |                    |      | 5        | 4       | 12       |

TABLE 1.2 COMPARISON OF THE NUMBER OF REPORTED  
MAJOR FLARES

The number of major flares listed for 1957 must be considered as a minimum since the flare patrol was operating only about 72% of the time during 1956 as shown in Column 4 of Table 1.2. While nearly a 100% patrol was maintained during 1967, the comparison of the number of major flares reported during the two periods may also be affected by the change in the method for classifying and reporting flare importance.

### 1.3 COMPARISON OF THE DAILY RF FLUX AT SELECTED CENTIMETER WAVELENGTHS

The daily solar flux values at 2800 Mc/s for the period July through December 1956 compared with flux values at 2695, 2800, and 3750 Mc/s for the period January through June 1967 is shown in Figure 1.2.

This plot shows an almost perfect agreement at 2695, 2800, and 3750 Mc/s. A similar agreement (Reference 11) between the flux values at 2800 and 3750 Mc/s was shown for the two periods, July through December 1957 and July through December 1960.

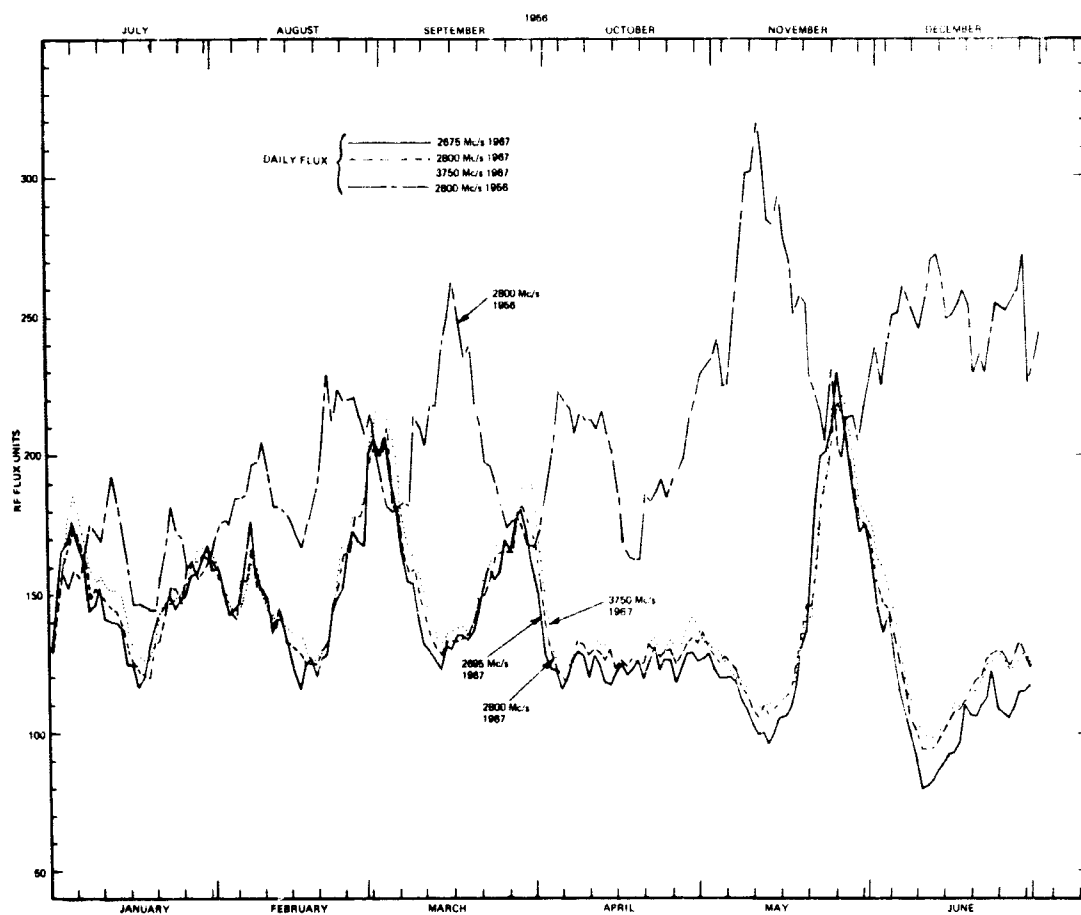


FIGURE 1.2 COMPARISON OF DAILY FLUX AT SELECTED CENTIMETER WAVE LENGTHS JULY - DECEMBER 1956 AND JANUARY - JUNE 1957

2.0 MAJOR SOLAR EVENTS DURING THE PERIOD JANUARY THROUGH  
JUNE 1967

2.1 GENERAL SUMMARY

For the purpose of this study we have defined a major solar, or solar induced event to be:

1. Flare with importance  $\geq 3B$  (4 cases).
2. RF emissions at centimeter wavelength (1695, 2700, 2800, 3000, or 3750 Mc/s) with peak flux  $\geq 500$  flux units - 7 cases.
3. A proton event observed by Riometers, Forward Scatter, Satellite or ground based Neutron Monitor - 5 cases.

Based on reasonably complete data, 13 events satisfied one or more of the requirements during the first six months of 1967. These are summarized in Table 2.1.

It is seen that there is no reliable flare or solar region association with three of the proton events (events 3, 4, and 8) including the ground level event on 28 January recorded by several different neutron monitors.

These same 13 events are summarized in Table 2.2 where detailed data for the associated phenomena are given.

In the case of the three events with no reliable flare or region association we have given one or more possible (but not probable) flares or regions. The choice of possible associations are based on previous or future activity of the region or regions in question.

A detailed analysis of the phenomena associated with each of the major events has been carried out. If associated phenomena have not been reported or may have a questionable association with the chosen major event, we have examined other solar regions on the visible disk, and region on the far side of the sun, that crossed the West Limb one to three days before the event, and those that crossed the East Limb up to three days after the event.

In general, the attempt to find evidence of sufficient far side activity to cause the event in question, was unsuccessful. However, considerable insight was obtained about changes and growth of solar regions during the 14 days they were hidden from view.

TABLE 2.1  
STATISTICAL SUMMARY OF MAJOR SOLAR, OR SOLAR INDUCED EVENTS  
JANUARY THROUGH JUNE 1967

| Event No. | Date     | Flare Imp. (1)    | SWF  | II  | IV  | RF $\geq$ 500 (1) | Protons (1) | X-ray (2) | Area  | Flare Bright | Age | Spot Area $\geq$ 500 | Mag $\beta$ 5 | Type $\delta$ |
|-----------|----------|-------------------|------|-----|-----|-------------------|-------------|-----------|-------|--------------|-----|----------------------|---------------|---------------|
| 1         | 1-11     | 3B*               | No   | No  | No  | No                | No          | No        | 5100  | 3.5          | 2   | No                   | No            | No            |
| 2         | 1-12     | 1F                | SL/2 | Yes | No  | 550*              | No          | 6X        | 1500  | 3.0          | 6   | No                   | No            | No            |
| 3         | 1-28     | No <sup>(4)</sup> | No   | No  | No  | No                | GLE*        | 2.5X      | No    | No           | 7   | No                   | No            | No            |
| 4         | 2-2      | No <sup>(4)</sup> | No   | No  | No  | No                | PCA*        | No        | No    | No           | 1   | No                   | No            | No            |
| 5         | 2-13     | 3B*               | G/1+ | Yes | Yes | No                | No          | 12X       | 3700  | 2.5          | Rev | No                   | No            | No            |
| 6         | (5) 2-27 | 2B                | S/2+ | Yes | Yes | 560*              | No          | 31X       | 8300  | 3.5          | 2   | 1390                 | Yes           | Yes           |
| 7         | (5) 3-4  | 1B                | S/1+ | Yes | No  | 530*              | No          | No        | 6900  | 3.0          | 2   | W1(3)                | Yes           | Yes           |
| 8         | 3-11     | No <sup>(4)</sup> | No   | No  | No  | No                | PCA*        | No        | No    | No           | 1   | No                   | No            | Weak          |
| 9         | 3-22     | 3B*               | S/3  | No  | No  | 1650*             | No          | 13X       | 7500  | 4.0          | 3   | No                   | No            | No            |
| 10        | (6) 5-20 | 1B                | S/1  | Yes | Yes | 730*              | No          | 5X        | 6700  | 3.0          | 2   | No                   | No            | No            |
| 11        | (6) 5-21 | 2B                | S/2  | Yes | Yes | 1048*             | No          | 180 mm    | 7500  | 3.5          | 2   | No                   | No            | No            |
| 12        | (6) 5-23 | 2B                | SL/3 | Yes | Yes | 2500*             | PCA*        | 650 mm    | 8500  | 4.0          | 2   | 1293                 | Yes           | Yes           |
| 13        | (6) 5-28 | 3B*               | S/3  | Yes | No  | 1540*             | PCA*        | 320 mm    | 12000 | 3.5          | 2   | 716                  | Yes           | Yes           |

- (1) The \* indicates the major event.  
 (2) The peak X-ray flux is given X quiet sun background or in milli-ergs (me).  
 (3) The spot group near West Limb, large during disk passage.  
 (4) No reliable flare or region association.  
 (5) Associated with the same solar region.  
 (6) Associated with the same solar region.

TABLE 2.2 MAJOR SOLAR EVENTS JANUARY - JUNE 1967

| Event No. | Type of Major Activity                                                                                                                                                    | Date | FLARE DATA                                                                                     |                                                                                                                          |          |                                                              |          | RF SPECTRA                                  |                                   |                                | PROTON REPORTS                                                                                                                                                           |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|----------|--------------------------------------------------------------|----------|---------------------------------------------|-----------------------------------|--------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |                                                                                                                                                                           |      | Start                                                                                          | Max                                                                                                                      | Duration | Imp                                                          | Position | Start/Max Type/Imp/Dura.                    | Onset/Obs. Dura./Imp. Freq./Range | Onset/Obs. Dura./Imp. Range    |                                                                                                                                                                          |
| 1.        | 3B flare other phenomena very small or insignificant.                                                                                                                     | 1-11 | 0131                                                                                           | 0259                                                                                                                     | 106      | 3B                                                           | S26 W27  | None Rep.                                   | None Rep.                         | None Rep.                      | None Reported. Low energy protons OVO-3.                                                                                                                                 |
| 2.        | On RF $\geq 500$ flux units (3750 Mc/s).                                                                                                                                  | 1-12 | 0231                                                                                           |                                                                                                                          | 34       | 1F                                                           | N16 W90  | 0225/0236 5L/2/53                           | 0245/3 1.5/2 30-210               | None Rep.                      | None Reported                                                                                                                                                            |
| 3.1       | 16% increase in Neutron count at Deep River. Also PCA. No apparent solar region association. 3 possible regions.                                                          | 1-28 | 0456                                                                                           | 0458                                                                                                                     | 13       | 1-                                                           | N17 W32  | None Rep. between 2022 24th to 1618 on 29th | None Rep.                         | None Rep. 24th through 30th    | 16% increase Deep River Neutron monitor. Start 0819. Max 1115 UT. 134b Byrd Sta. PCA start 0600. 3db College 1800 UT. 4db Barter Island 1800 UT. 4db Barrow 1820 UT.     |
| 3.2       |                                                                                                                                                                           |      | 0514                                                                                           | -                                                                                                                        | 51       | 1                                                            | N17 E59  |                                             | None Rep.                         | None Rep.                      |                                                                                                                                                                          |
| 3.3       |                                                                                                                                                                           |      | 0743                                                                                           | 0751 0758                                                                                                                | 73       | 1-                                                           | S23 E19  |                                             | 0754.3/3 10.5/2 10-300            | None Rep.                      |                                                                                                                                                                          |
| 4.        | A small PCA. There is no reasonable solar region association.                                                                                                             | 2-02 | 0145                                                                                           | 0154                                                                                                                     | 43       | 1H                                                           | N29 E52  | 0144/0146 8/1/37                            | 0149.5/3 12.5/1 10-250            | None Rep.                      | < 2000 UT Peak 2.5 db between 0000 and 1000 on the 3rd. Lasting > 50 hrs.                                                                                                |
| 5.        | Importance 3B flare other phenomena small or insignificant. This flare and 2 subflares at 0810 and 1653 were the only ones reported in the region.                        | 2/13 | 1746                                                                                           | { 1815 LOCK<br>1816 SACP<br>1821 HOUH<br>1825 HALE<br>MCHA }                                                             | 297      | { 3B<br>4B<br>3B<br>2B }                                     | N21 W10  | 1804/1805 0/1-/66                           | 1803/H 17/3 20-300                | 1829/B 369/2 24-41             | None Reported                                                                                                                                                            |
| 6.        | Centimeter RF burst > 500 flux units (2695, 2700 and 2800 Mc/s). Large $\delta$ type sunspot group. Region flare productive.                                              | 2-27 | 1637                                                                                           | { 1644 LOCK<br>1714 SACP }                                                                                               | 113      | { 2B<br>2H }                                                 | N27 E02  | 1640/1655 5/2-/72                           | 1637/H 23/3 10-300                | 1640.6/B 106/3 17-41           | None Reported                                                                                                                                                            |
| 7.        | Centimeter RF burst > 500 flux units (2695 Mc/s).                                                                                                                         | 3-04 | 1715                                                                                           | { 1716 SACP<br>1718 HALE }                                                                                               | 19       | { 1B<br>1B }                                                 | N24 W68  | 1716/1718 3/1-/24                           | 1718/H 9/2 30-300                 | None Rep.                      | None Reported                                                                                                                                                            |
| 8.        | Small increase in near earth and space proton count.                                                                                                                      | 3-11 | Only minor flares observed during the 48 hours prior to the start of this small proton events. |                                                                                                                          |          |                                                              |          | None Rep. Mar. 10 or 11                     | 0134.5/3 5.5/1 30-210 Mar. 10     | < 1331/B > 660/3 22-41 Mar. 10 | VLF signals starting 2003. HF signals 9 and 12 Mc/s. Starting 2000 UT. Vela Satellite 2016. Mar at 0100 on 15th. Pioneer 7 at 11-0815. Absorption Shepherds Bay at 1800. |
| 9.        | Importance 3B flare and major RF events at Cm wave length.                                                                                                                | 3-22 | 0013                                                                                           | { 0033 CULO<br>LOCK<br>CHON<br>0034 SACP<br>MAHI }                                                                       | 92       | { 2B<br>3B<br>1B<br>2B }                                     | N24 E68  | 0028/0040 3/3/37                            | None Rep. B and H Observing       |                                | None Reported                                                                                                                                                            |
| 10.       | Major RF burst at Cm wave length moderate X-ray flux. This region is the source of the next 3 events.                                                                     | 5-20 | 1514                                                                                           | { 1520 SACP<br>1523 CAPS<br>1528 SACP }                                                                                  | 90       | { 1B<br>2B<br>1H }                                           | N25 E51  | 1532/1536 3/1/28                            | 1520/H 16/3 30-300                | 1513.5/B 46.5/3 9-41           | None Reported                                                                                                                                                            |
| 11.       | Very large X-ray burst recorded by Explorer 33. Major RF burst at Cm wave length.                                                                                         | 5-21 | 1918                                                                                           | { 1926 SACP<br>1926 LOCK<br>1926 HALE }                                                                                  | 72       | { 2B<br>2B<br>2B }                                           | N24 E39  | 1924/1932 3/2/46                            | 1923/H 22/3 10-300                | 1923/H 97/3 30-580             | None Reported                                                                                                                                                            |
| 12.       | Importance 2B flares and great RF bursts at all wave lengths. Large sunspot group with $\delta$ configuration. Flare at 1834 observed in white light by Sac. F. and ESSA. | 5-23 | 1802                                                                                           | { 1810 HOUH<br>1812 HALE<br>1814 LOCK<br>1817 SACP<br>HIAN }                                                             | 238      | { 2H<br>2B<br>2B<br>2B<br>2B }                               | N30 E25  | 1809/1815 8L/3/150                          | 1838/H 27/3 30-510                | 1839/H 281/3 30-580            | Increased proton count Vela Satellite 1925 UT. Ricometer by 2400 UT. 114b.                                                                                               |
|           |                                                                                                                                                                           |      | 1834                                                                                           | { 1843 HALE<br>1844 SACP }                                                                                               |          | { 2B<br>3B }                                                 | N27 E25  | 1834/- 3/3-/236                             | 1843.4/B 16.6/3 11-41             | 2052/B 188/3 24-41             | Lunar orbiting satellite reports 2.5 Rad/hr between 0500 and 0700 on May 25. Vela reports normal proton count at 0710 May 27.                                            |
|           |                                                                                                                                                                           |      | 1932                                                                                           | { 1944 HOUH<br>1947 SACP<br>1751 HOUH }                                                                                  |          | { 2B<br>2B<br>2B }                                           | N27 E28  |                                             |                                   |                                |                                                                                                                                                                          |
| 13.       | Importance 3B flare. Large X-ray emission. Great RF burst at Cm wave length. Followed by proton event. Observed by Ricometer, Satellite, and forward scatter.             | 5-28 | 0525                                                                                           | { 0539 CHON<br>0543 CATA<br>CAIS<br>VEND<br>0541 SINE<br>0545 PTEN<br>0552 TACH<br>0558 SINE<br>0558 CHON<br>0602 CULO } | 165      | { 2B<br>2B<br>3B<br>3B<br>2H<br>3B<br>4B<br>2H<br>3B<br>3B } | N28 W33  | 0530/0533 3/3/70                            | 0539/B 17/2 10-30                 | None Rep.                      | PCA onset by 0500 based on Ricometer and Vela Satellite. OGO satellite reported 3 times normal for protons > 20 Mev at 0700. Peak absorption 3.5 db.                     |

\*Associated with the same solar region.

\*\*Events 10, 11, 12, 13 all from same solar region.

TABLE 2.2 (continued) SUNSPOT DATA

| Event No. | RF EMISSION ON WAVE LENGTH                                                                    |                          |                                    |                                    |                          |                              | X-RAY                                                                                                                                   | MONITOR PLAGE                                                        |                       | Remarks                                                                                                                                                                                                             |
|-----------|-----------------------------------------------------------------------------------------------|--------------------------|------------------------------------|------------------------------------|--------------------------|------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           | f                                                                                             | Obs                      | Start                              | Peak                               | Duration                 | Peak Flux                    |                                                                                                                                         | No.                                                                  | Event Day Area/Bright |                                                                                                                                                                                                                     |
| 1.        | 3750                                                                                          | Mag                      | 0137<br>0815                       | 0139.6<br>0310                     | 85<br>190                | 4<br>15                      | None Reported                                                                                                                           | 8632                                                                 | 5100/3.5              | Flare reported Helioshela only. Region no PCA characteristics. Forbush decrease 7% on 13th.                                                                                                                         |
| 2.        | 3750                                                                                          | Mag                      | 0827                               | 0836.1                             | 50                       | 550                          | 0826/0840/6/-<br>Slow Rise                                                                                                              | 8631                                                                 | 1300/3                | Flare reported Mitaka only.                                                                                                                                                                                         |
| 3.1       | Very weak emissions at Cn and a wave length 24th through 29th.                                |                          |                                    |                                    |                          |                              | 0857/0958/2.5/-<br>Slow Rise                                                                                                            | 8659                                                                 | 6100/3.5              | Other subflares at 0537 and 0645.                                                                                                                                                                                   |
| 3.2       |                                                                                               |                          |                                    |                                    |                          |                              | None Reported                                                                                                                           | 8670                                                                 | 3300/3.5              | Other subflares at 0804 and 0943.                                                                                                                                                                                   |
| 3.3       |                                                                                               |                          |                                    |                                    |                          |                              | 0737/0807/2.7/-<br>Slow Rise                                                                                                            | 8667                                                                 | 5400/3.5              |                                                                                                                                                                                                                     |
| 4.        | 3750                                                                                          | Mag                      | 0144                               | 0146.2                             | 13                       | 93                           | None Reported between<br>2358 UT Feb. 1 and<br>0858 UT Feb. 3                                                                           | 8680<br>Subflares reported from Flares<br>8673, 8681, 8682, and 8667 | 5800/3                |                                                                                                                                                                                                                     |
| 5.        | 8695<br>8800                                                                                  | Sgn<br>Oct               | 1753.2<br>1758.5                   | 1803.5<br>1803.5                   | 18.8<br>16               | 67<br>50                     | 1755/1804/12/-                                                                                                                          | 8687                                                                 | 3700/2.5              | While this was the largest flare of the new cycle to date, the region and associated phenomena did not exhibit the general characteristics of PCA events. A Forbush decrease of 7% occurred on the 15th at 2400 UT. |
| 6.        | 8800<br>8700<br>8695                                                                          | Oct<br>Pen<br>Sgn        | 1637<br>1636.2<br>1637             | 1650<br>1649.4<br>1649.2           | 83<br>18.7<br>64         | 560<br>536<br>990            | 1636/1658/31/-                                                                                                                          | 8704                                                                 | 8300/3.5              | This region was the source of 107 subflares and 56 flares with importance $\geq 1$ including 4 importance 2B flares on the 22nd and 23rd.                                                                           |
| 7.        | 8800<br>8695                                                                                  | Oct<br>Sgn               | 1715.8<br>1715.6                   | 1716.5<br>1716.2                   | 15<br>18.4               | 385<br>530                   | None Reported                                                                                                                           | 8704                                                                 | 6900/3.0              | The region was active at ELP with surges, loops, and yellow emissions. The return of 8670 (3.2 above) which produced strong yellow line emissions at WLP.                                                           |
| 8.        | Very weak RF emissions at Cn wave length during the 48 hours prior to the small proton event. |                          |                                    |                                    |                          |                              | None reported from<br>Explorer 33. McMath<br>reports a burst starting<br>at 0926, max 0931,<br>and 0940. 8-12A <sup>+</sup> 080<br>III. | 8715<br>8716                                                         | 3900/3<br>3900/35     | The sunspot, plage, X-ray, and spectral data listed for information only. None can be related to the small proton event.                                                                                            |
| 9.        | 3750<br>2800                                                                                  | Mag<br>Oct               | 0017<br>0102<br>0025.5<br>0058     | 0038.1<br>0128<br>0032<br>0130     | 43<br>147<br>33<br>47    | 2650<br>3400<br>1100<br>1500 | 0023/0038/13/-                                                                                                                          | 8740                                                                 | 7,000/4.0             | The region 8740 is a return of the region 8704 which crossed the solar disk (see Events 6 and 7) between 20 Feb. and 5 Mar. with the very large 8 type spot group which on the return has broken up into 3 groups.  |
| 10.       | 3000<br>2800<br>2700<br>2695                                                                  | Red<br>Oct<br>Pen<br>Sgn | 1513.5<br>1513<br>1513.7<br>1510.1 | 1520.6<br>1521<br>1520.9<br>1520.8 | 28<br>32<br>63.9<br>48.9 | 630<br>730<br>542<br>819     | 1510/1530/5/-                                                                                                                           | 8818                                                                 | 6700/3.0              | The plage contains 3 spot groups. This flare is from the leading group. Mt. Wilson, Sec. P., and Fraunhofer use different groupings of the individual spots. This region is the source of the next 3 events.        |
| 11.       | 2695<br>2700<br>2800                                                                          | Sgn<br>Pen<br>Oct        | 1922.5<br>1920.3<br>1922           | 1923.7<br>1923.3<br>1924.2         | 25.5<br>13.5<br>12       | 1048<br>724<br>830           | 1921/1927/45/180                                                                                                                        | 8818                                                                 | 7500/3.5              |                                                                                                                                                                                                                     |
| 12.       | 2695<br>2800                                                                                  | Sgn<br>Oct               | 1800<br>1808                       | 1807.7<br>1809.5                   | 35.5<br>3.0              | 33<br>27                     | 1758/1816/4/-                                                                                                                           | 8818                                                                 | 8500/4.0              |                                                                                                                                                                                                                     |
|           | 2695<br>2800                                                                                  | Sgn<br>Oct               | 1835.5<br>1835.5                   | 1839.1<br>1839                     | 34.5<br>34.5             | 2500<br>2300                 | 1834/1836/27/650                                                                                                                        |                                                                      |                       |                                                                                                                                                                                                                     |
|           | 2695<br>2800                                                                                  | Sgn<br>Oct               | 1910<br>1910                       | 1951.8<br>1952                     | 74.0<br>93               | 5400<br>8000                 | 1934/1952/4/280                                                                                                                         |                                                                      |                       |                                                                                                                                                                                                                     |
| 13.       | 3000<br>3750                                                                                  | Red<br>Mag               | 0528.5<br>0528                     | 0541.7<br>0541.6                   | 41.7<br>41.6             | 1100<br>1540                 | 0528/0551/94/320                                                                                                                        | 8818                                                                 | 12,000/3.5            |                                                                                                                                                                                                                     |

\*Events 6, 7 associated with the same solar region.

\*\*Events 10, 11, 12, 13 associated with same solar region.

TABLE 2.2 (continued) SUNSPOT DATA

| Event No. | Mt. W. Number | Mag. Type                         | Position | SUNSPOT DATA EVENT DAY |      |           | Type | Position | Longitude | Remarks                                                                                                                                                                                  |
|-----------|---------------|-----------------------------------|----------|------------------------|------|-----------|------|----------|-----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |               |                                   |          | Sac. F. No.            | Area | No. Spots |      |          |           |                                                                                                                                                                                          |
| 1.        | 16219         | $\alpha$ p                        | S26 W46  | 536                    | 11.2 | 2         | B    | S30 W44  | 244       | Spot seen on 11-13 only. Max. area 12. Plage return of 0609.                                                                                                                             |
| 2.        | 16204         | $\alpha$ p                        | N17 W87  | 518                    | 61   | 4         | C    | N18 W87  | 274       | Spot max. area 195 on 4 Jan. Plage area 8500. Brightness 3 on Jan. 5.                                                                                                                    |
| 3.1       | 16227         | $\beta$ s                         | N21 W35  | 548                    | 292  | 11        | D    | N21 W35  | 11        | Spot first seen Mt. W. 19th at E75. By Sac. F. on 22nd at E37. Max. area 319 at 2236 on 26th.                                                                                            |
| 3.2       | 16234         | $\beta$ p                         | N19 E52  | 556                    | 239  | 18        | D    | N19 E52  | 282       | Spot first seen Mt. W. and Sac. F. 26th at E72. Max area 241 at 2236 on 26th. Yellow line emissions at WLP.                                                                              |
| 3.3       | 16235         | $\alpha$ p                        | S23 E16  | 550                    | 333  | 11        | C    | S23 E16  | 319       | First seen Sac. F. 22nd at 1859. Max area 335 at 2207 on 26th.                                                                                                                           |
| 4.        | 16242         | $\beta$ p                         | N25 E54  | 565                    | 40   | 3         | D    | N26 E51  | 218       | The spot was last seen by Sac. F. at 2158 Feb. 8 at W40. Max area 102 Feb. 3.                                                                                                            |
| 5.        | 16260         | $\alpha$ p                        | N22 W14  | 588                    | 3    | 2         | A    | N22 W12  | 132       | This tiny $\alpha$ type spot was seen on the 12th and 13th only.                                                                                                                         |
| 6.        | 16272         | $\delta$                          | N24 W08  | 599                    | 1390 | 45        | F    | N24 W06  | 299       | This spot group reached a maximum area 1416 on Feb. 28. Mt. Wilson type $\delta$ , 23 Feb. through 3 Mar.                                                                                |
| 7.        | 16272         | $\delta$                          |          | 599                    | 292  | 12        | F    | N24 W74  | 297       | See 6 above.                                                                                                                                                                             |
| 8.        | 16290         | No Mt. W. Observation March 10-14 |          | 617                    | 115  | 16        | D    | N24 W22  | 170       | Sunspot data 10 Mar. No observations Mt. W. or Sac. F. on 11th. Both regions produced strong yellow line emissions at ELP. 16291 max area 772 on the 7th. 16290 max area 116 on the 6th. |
|           | 16291         | Possible Configuration            |          | 620                    | 440  | 52        | D    | S19 W14  | 162       |                                                                                                                                                                                          |
| 9.        | 16305         | $\alpha$ p                        | N23 E57  | 649                    | 443  | 1         | H    | N23 E58  | 302       | The plage contains 3 spot groups. In. F. associates the flare at N25 E70 with the spot 652 a very small $\beta$ type with a maximum area of 60 millionth on the 22nd.                    |
|           | 16308         | $\beta$ p                         | N25 E70  | 652                    | 60   | 5         | C    | N26 E72  | 286       |                                                                                                                                                                                          |
|           | 16307         | $\beta$ s                         | N20 E70  | 653                    | 104  | 3         | C    | N21 E71  | 288       |                                                                                                                                                                                          |
| 10.       | 16368         | $\alpha$ p                        | N23 E53  | 745                    | 144  | 8         | C    | N25 E50  | 243       | The spot group 745 maintains an almost constant area from the 21st through the 27th of 143-223 with a maximum of 186 on the 26th.                                                        |
|           | 16373         | $\beta$ p                         | N21 E55  | 754                    | 111  | 10        | D    | N24 E58  | 234       |                                                                                                                                                                                          |
|           | 16372         | $\beta$ s                         | N26 E63  | 746                    | 266  | 17        | E    | N27 E69  | 223       |                                                                                                                                                                                          |
| 11.       | 16368         | $\alpha$ p                        | N24 E33  | 745                    | 143  | 7         | C    | N25 E32  | 244       |                                                                                                                                                                                          |
| 12.       | 16372         | $\delta$                          | N24 E23  | 746                    | 1293 | 70        | F    | N27 E28  | 223       |                                                                                                                                                                                          |
| 13.       | 16372         | $\delta$                          | N26 W34  | 746                    | 710  | 71        | F    | N27 W31  | 223       |                                                                                                                                                                                          |

### 3.0 DETAILED ANALYSIS OF THE MAJOR SOLAR EVENTS

#### 3.1 IMPORTANCE 3B FLARE 11 JANUARY 1967

The first major solar event of 1967 occurred at 0130 UT on January 11 when an importance 3B flare was reported by Haleakala only. The flare occurred in McMath Plage 4632 at S24 W47. A very small RF burst was reported by Nagoya at 3750 Mc/s, no emissions were reported at other frequencies. No SWF or spectral emissions were reported at the time of the flare.

The solar and solar induced activity or lack of activity indicates that this event should not be classified as a major event.

The plage region which reached a maximum area of 5800 millionths on January 7 contained one sunspot group that was first seen by Mt. Wilson on January 1 at S20 E62, and Sacramento Peak on the 2nd at S19 E46, Heliographic Longitude 266. The spot increased in area as it crossed the solar disk to a maximum area of 418 millionth on January 6th. The decrease was gradual to an area of 288 millionths on the 9th. An area of only 92 millionths was reported by Sacramento Peak on the 10th at S19 W61. Mt. Wilson reported a  $\beta\gamma$  magnetic classification on the 5th and 6th with an average  $\beta_p$  magnetic classification during disk passage. In addition, a very small spot was reported by Sacramento Peak on the 7th at S28 W00 and again on the 11th, 12th and 13th at S30 Heliographic Longitude 244.

There were no X-ray observations by Explorer 33 at the time of the flare.

Based on the analysis of the region presented above, it is probable that the importance of the flare was overrated.

### 3.2 THE MAJOR CENTIMETER RF BURST ON 12 JANUARY

A major RF event was reported at 3750 Mc/s starting at 0227 UT lasting for 50 minutes with a peak flux of 550 flux units at 0236.2 UT. This RF emission has been associated with a West Limb flare with importance 1. The event is associated with a shortwave radio fade, a Type II slow drift burst at meter wavelength, and an X-ray burst with a maximum at 0240. No Type IV or proton event was reported.

The spectral plot of RF bursts associated with this event shown on Figure 3.1 does not display the "U" characteristic.

This was the only major event associated with the region (McMath 8631) that crossed the solar disk between 29 December and 12 January.

The sunspot group (Mt. Wilson 16204) had an  $\alpha_p$  magnetic classification, and a maximum area of 195 millionths on 4 January.

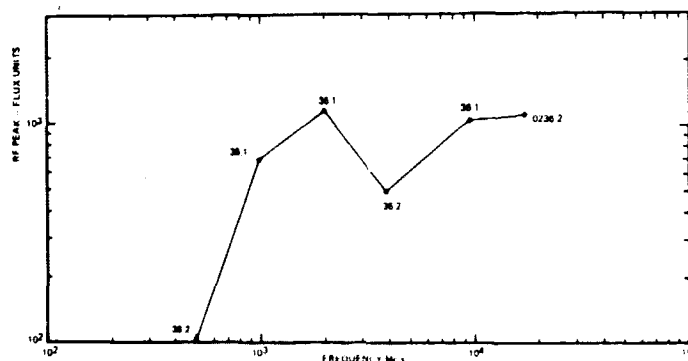


FIGURE 3.1 SPECTRA RF BURST ASSOCIATED WITH 1 F FLARE 12 JAN 1967 N18090

### 3.3 THE LARGE GROUND LEVEL EVENT ON 28 JANUARY 1967

A search of available plage, sunspot and flare data fails to reveal any region on the visible solar disk of sufficient importance to be associated with the ground level event with onset at 0825 UT. Minor X-ray events on 28 January have been reported by Van Allen at 0457, probably associated with subflares in McMath plage 8659, or 8670, in Mt. Wilson bipolar spot groups 16227 or 16234, with areas 292 and 239, respectively on flare day. A second minor X-ray burst reported with onset at 0737 is associated with another subflare at 0743 in a unipolar spot group 16235 at S23 E16 (McMath plage 8667). The spot had an area of 333 millionths on flare day. No shortwave radio fades were reported. Sydney reported a Type II slow drift burst with onset at 0754.5 UT, no Type IV was reported. Very small RF bursts were reported at centimeter wavelengths.

The phenomena associated with these regions are summarized in Tables 2.1 and 2.2 as events 3.1, 3.2, and 3.3.

Sacramento Peak observed 10 small sunspots on the visible disk on 28 January, they ranged in area 40 millionths of the solar disk, to 333 millionths. Six of the groups had crossed the Central Meridian. Three of the Eastern quadrant groups were within three days of CMP. Five of the groups had areas less than 10 millionths on the 28th.

Mt. Wilson reports 7 sunspot groups on the 28th, Sacramento Peak reports 8 groups and the ESSA maps show 7 groups on January 28, 1967.

The Neutron data for the January 28, 1967 event has been studied in detail by Baird, et al (Reference /1). The Neutron counting rate increase started at 0839 UT and reaching maximum of 16% at 1115, and was back to normal by 0700 on the 29th. In addition to the Neutron monitor increases reported by Baird, et al, with onset times ranging from  $0833 \pm 0002$  at Swathmore and the South Pole, to  $0842 \pm 0004$  at Thule, the event was observed on four VLF transmission circuits starting at 0200 on the Rugby to Boulder, and Aldra to Boulder transmission circuits, and at 0500 on the Rugby to Anchorage, and Annapolis to Anchorage circuits. Maximum absorptions occurred at 1600, 1200, 0600, and 0700 UT, respectively, with absorption still continuing on February 1. The forward scatter path Barrow to Anchorage showed absorption starting at 1800 with a maximum of approximately 10 db at 2100 UT.

The event was also observed by Riometers at College, and Barter Island, Alaska, with onset at 1800 with maximum of 3 db and 4 db, respectively, at 2200 UT. The starting time at Barrow, Alaska was 1820 UT with a maximum of 4 db at 2200. The Antarctica Stations at Byrd began to observe absorption as early as 0600 UT with a maximum of 13 db. The Riometer event lasted from three to four days.

During the 27 hours from 2300 UT on the 26th and 0200 on January 28, only three small flares were reported, one at N20 W59 from a small plage (8650) that produced only five minor flares during disk passage, the other two flares on the 27th were from a large plage (8659) at N16 W30 which covered three sunspot groups. The flares occurred in the neighborhood of the sunspot group 16229 a  $\beta_p$  spot which had been classified as  $\beta\gamma$  by Mt. Wilson on the 26th.

Several investigators (Lockwood; Baird, et al) have suggested that the event may have been caused by a flare from regions 39 to 70° beyond the West Limb.

With the onset of the ground level effect at 0825 and the polar cap absorption times ranging from 0600 at the Byrd Station to 1820 UT at Barrow, we have examined all regions that crossed the West Limb between January 23 and 28. None of the regions were of sufficient importance during disk passage to be probable sources of the ground level event and polar cap absorption. Plage region data are given in Table 3.1 showing the approximate distance behind the West Limb on the 28th.

Only four subflares were reported from plage 8648. While none were reported from plage 8660, the third region (8654) was slightly more active with 20 subflares reported between January 19 and January 26. Nine of the subflares were reported on the 23rd when the region was between 30 and 40 degrees west of the Central Meridian, while the last subflare was reported on the 26th at N13 W82.

| Date | Plage No. | Position Last Seen                    | Approximate Distance Behind the West Limb at 0800, January 28 | Sun Spot                                                                                                                  |
|------|-----------|---------------------------------------|---------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|
| 23   | 8648      | N24 W76                               | 51°                                                           | Small, Seen 21, 22 only                                                                                                   |
| 24   | 8660      | N23 W75                               | 37°                                                           | No Spots                                                                                                                  |
| 25   | None      |                                       |                                                               |                                                                                                                           |
| 26   | None      |                                       |                                                               |                                                                                                                           |
| 27   | 8654      | N13 W88<br>First seen<br>1/18, at E38 | 11°                                                           | Small Spot<br>first seen<br>1/19 at E18,<br>probably died<br>on disk. No<br>observation<br>Sac.P. 1/25,<br>Not seen 1/26. |

TABLE 3.1 REGIONS THAT CROSSED THE WEST LIMB  
BETWEEN JANUARY 23 AND 28, 1967

We have also examined all regions that were between one and three days behind the East Limb on January 28. These are shown in Table 3.2 on the following page.

| Date<br>ELP | Plage<br>No. | Latitude | Sunspot Activity During<br>Disk Passage                                                                                                         |
|-------------|--------------|----------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| 1-28        | 8673         | S24      | Contained small spots on 1-30 only at S27 E48. The plage is the return of part of 8632 which produced the importance 3B on 1-11.                |
|             | 8674         | N15      | Contained one small spot group seen on the 30th and 31st only.                                                                                  |
| 1-29        | 8675         | N02      | Plage lasted only 2 days, no sunspots.                                                                                                          |
|             | 8677         | N28      | No sunspots were seen during disk passage. Plage 8677 is part of region 8631 from the previous rotation, the source of a major RF burst at WLP. |
|             | 8676         | S37      | Plage lasted only two days. No sunspots observed.                                                                                               |
| 1-30        | 8678         | S27      | A return of plage 8632. No sunspots observed during disk passage.                                                                               |
|             | 8680         | N27      | Contained a $\beta_p$ spot group (16242) that was last seen on 2-9 at N29 W40.                                                                  |
|             | 8681         | S16      | Contained an $d_p$ spot (16241) last seen on 2-10 at W65, and a $\beta_p$ spot first seen on 2-2 at S15 E32, last seen on 2-4 at S15 E21.       |

TABLE 3.2 SOLAR REGIONS THAT WERE BETWEEN ONE AND THREE DAYS BEHIND THE EAST LIMB ON JANUARY 28

### 3.4 THE PCA EVENT ON 2 FEBRUARY 1967

A small PCA event is reported in Reference 16 in progress at 2000 UT on 2 February with a 2.5 db peak absorption between 0000 and 1000 UT on the 3rd with a duration  $> 50$  hours.

Seven sunspot groups were seen on the visible disk on 1 February at 2315 UT.

3 crossed the visible disk limb to limb.

2 crossed the East Limb and died on the disk.

2 were born and died on the disk.

None of the spots had an area greater than 150 millionths (Sacramento Peak data) at 2145 UT on February 1 while three had areas greater than 150 millionths at 1514 UT on the 3rd (no Sacramento Peak data on 2 February). The other spots on the 3rd had areas less than 100 millionths. Four of the spots reached maximum areas greater than 200 millionths during disk passage - the largest was 430 millionths at W01 on February 7.

None of the regions that were on the visible disk on 2 February were the source of important activity during disk passage, while a large number of minor flares were reported during the period from 22 January through 12 February when one or more of the February 2nd regions were on the visible disk. Only, two flares of importance  $\geq 1$  (one importance 2N and one with importance 2B) were reported prior to 2000 UT on February 2 and two with importance 2B after February 2.

No important radio emissions were reported at centimeter wavelengths ( $2680 \leq f \leq 3750$ , peak flux  $\geq 500$  flux units).

A minor (importance 1) shortwave radio fade was reported at 0144 UT lasting for 37 minutes is probably associated with an importance 1N flare in the neighborhood of a spot which at 2145 UT on the 1st had an area of only 40 millionths of the solar hemisphere.

The period from February 1 through February 4 was geomagnetically quiet.

The only indication of activity besides the PCA was an unusual fluctuation of the Deep River Neutron monitor which was probably still under the influence of the ground level event on 28 January. Between February the first and eighth the Neutron monitor data fluctuated by nearly 5% with a period of approximately 24 hours.

### 3.5 IMPORTANCE 3B FLARE ON 13 FEBRUARY 1967

This event has been discussed in considerable detail by Costelli.

The flare which started at 1746 UT was reported by four observatories with onset times ranging from 1746 to 1751, importances 4B and 3B. The plage region 8687 covered two very small spot groups. One was first seen on the 6th at E76 and died on the disk on the 14th at W22. The other was first seen on the 11th at E10 and died on the disk on the 13th at W13. The 3B flare under discussion occurred in the neighborhood of the three day spot.

The plage region was relatively flare productive during the first two days on the disk with seven subflares and six flares of importance  $\geq 1$ . Only eleven subflares were reported during the next five days prior to the major flare under discussion, which was the last flare reported from the region. Except for the small RF burst at the time of the 3B flare only one other flare (at 1833 UT February 6) was accompanied by RF bursts (also very small).

Based on the extremely small spot group and lack of important flares or RF emissions at centimeter wavelength the probability that the 3B flare would be followed by a proton event would be very small.

We have shown (Reference 13) that only 27% of the 142 importance  $\geq 3$  flares confirmed during the 19th solar cycle were followed by an important PCA event. We have also found that of the 35 importance  $\geq 3$  PCA flares for which sunspot area data are available on flare day, the flare day area was greater than 500 millionths for 31 of the events. There were no cases where the flare day area was less than 225 millionths. Finally, we showed that 22 of the 31 importance  $\geq 3$  PCA flares occurred in either  $\beta\delta$  or  $\delta$  type spot groups.

### 3.6 THE LARGE $\delta$ TYPE SUNSPOT GROUP THAT CROSSED THE SOLAR DISK BETWEEN 21 FEBRUARY AND 6 MARCH 1967

This large  $\delta$  type spot, the source of the major events on 27 February and March 4 crossed the East Limb on 21 February. This was the return of the region which had crossed the West Limb on February 6 with yellow corona emissions reported. The ELP of the returning region was very active with surges, loops and yellow corona emissions.

During disk passage the sunspot group increased in area from 735 millionths on 23 February at N23 E47 to a maximum value of 1416 millionths on the 28th at W18, then decreased slowly to 987 millionths at W49 on March 2. The spot was the source of 182 subflares, while 56, 3, and 3 flares were confirmed with importance 1, 2, and 2B, respectively (IAU Bulletin 157) (Table 3.6.1).

The distribution of all flares reported and confirmed flares during disk passages is shown in Tables 3.6.1a and 3.6.1b.

Based on the yellow line coronal activity at the East Limb, the size and brightness of the plage region, the size, complexity, and the  $\delta$  configuration which persisted during most of the disk passage, the region would be considered a probable source for one or more proton streams during disk passages. The region was both flare productive and radio noisy from the time it crossed

|       | Region 8704, February, March 1967 |    |    |    |    |    |    |    |    |    |    |    |    |   |   |
|-------|-----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|---|---|
|       | 20                                | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 1  | 2  | 3  | 4  | 5 | 6 |
| Sub   | 4                                 | 9  | 11 | 16 | 28 | 15 | 14 | 15 | 10 | 10 | 16 | 13 | 11 | 6 | 4 |
| 1     | 2                                 | 6  | 6  | 6  | 2  | 8  | 1  | 1  | 1  | -  | 4  | 3  | 9  | 1 | 1 |
| 2     | -                                 | -  | 4  | -  | 2  | -  | -  | 1  | -  | -  | -  | -  | -  | - | - |
| 2B    | -                                 | -  | 2  | 2  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | - | - |
| Total | 6                                 | 15 | 23 | 24 | 32 | 23 | 23 | 15 | 18 | 10 | 20 | 16 | 20 | 7 | 5 |

TABLE 3.6.1a ALL FLARES REPORTED 20 FEBRUARY THROUGH  
6 MARCH FROM PLAGE 8704

|       | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 1 | 2 | 3 | 4  | 5 | 6 |
|-------|----|----|----|----|----|----|----|----|----|---|---|---|----|---|---|
| Sub   | -  | 2  | 3  | 2  | 3  | 1  | -  | 2  | -  | 6 | 5 | 5 | 3  | 1 | - |
| 1     | 1  | 6  | 9  | 3  | 6  | 7  | 2  | 2  | 1  | - | 3 | 4 | 9  | 2 | 1 |
| 2     | -  | -  | 1  | 1  | -  | -  | -  | 1  | -  | - | - | - | -  | - | - |
| 2B    | -  | -  | 2  | 1  | -  | -  | -  | -  | -  | - | - | - | -  | - | - |
| Total | 1  | 8  | 15 | 7  | 9  | 8  | 2  | 5  | 1  | 6 | 8 | 9 | 12 | 3 | 1 |

TABLE 3.6.1b CONFIRMED FLARES REPORTED IN THE IAU  
BULLETIN

the East Limb on 20 February. Approximately 97 subflares and 41 (unconfirmed) flares with importance  $\geq 1$  were reported by the time the region had reached the central meridian. A large number of the flares were accompanied by radio emissions at all wavelengths, with an occasional great burst at meterwave lengths. However, none of the bursts reached major intensity at centimeter wavelengths until the event on February 27. Several of the bursts covered a broad spectrum with strong indications of the "U" type spectra. This is shown on Figure 3.6.1. RF peak flux is shown for a wide range of frequencies for bursts associated with flares on February 23, 27, and March 4.

The reported start of the flare, importance and position are shown on Table 3.6.2, the reported times of peak flux at each frequency are shown on the figure.

|             | Flare<br>Start | Imp. | Position |
|-------------|----------------|------|----------|
| 23 February | 0830           | 2B   | N24 E44  |
|             | 2244           | 1-   | N23 E48  |
| 27 February | 1637           | 2B   | N27 E02  |
|             | 2335           | 1    | N28 W02  |
| 4 March     | 1715           | 1B   | N25 W69  |

TABLE 3.6.2 FLARE DATA FOR THE RF BURSTS  
SHOWN ON FIGURE 3.6.1

### 3.6.1 Major RF Burst at Centimeter Wavelength on 27 February

The activity on February 27 satisfied most of the almost necessary conditions for a proton event; a large spot group with a  $\delta$  configuration; RF bursts with peaks of 560, 536, and 590 flux units at 2800, 2700 and 2695 Mc/s, respectively; the RF peak followed the time of flare maximum by 6 minutes, the flare at N27 E02, with an importance 2B reported by Lockheed was accompanied by a shortwave radio fade; Type II slow draft burst at meter and dekameter wavelengths and Type IV at dekameter wavelength; a large X-ray event was observed by Explorer 33, with onset coinciding with the start of the flare and RF emission. The "U"-shaped spectral characteristic is shown on Figure 3.6.1. The data for this event are summarized in Tables 2.1 and 2.2.

### 3.6.2 Major RF Burst at Centimeter Wavelength on 4 March

This was the second major event associated with the active type sunspot group. Over half of the spot group had crossed the West Limb of the sun at the time of the flare. The region was still flare active and radio noisy. Mt. Wilson did not observe the sun on the 4th, but had classified the spot group as a  $\delta$  type on the 3rd at N24 W59.

The flare at 1715 on the 4th was classified with importance 1B by both Sacramento Peak and Haleakala with maximum at 1716 and 1718, respectively, indicating an extremely rapid increase in both flare brightness and area. The RF emission at centimeter also shows the impulsive characteristic with the increase to peak flux in less than one minute (Figure 3.6.2). The RF peak intensity followed the reported Sacramento Peak flare maximum by 1/2 minute and preceded the reported Haleakala flare maximum by 1 1/2 minute.

The "U" type spectral characteristic of this RF event is also shown on Figure 3.6.1.

No X-ray event was reported from Explorer 33 at the time of the flare.

Again we have strong evidence for a proton event, however, none was reported.

### 3.7 SMALL PCA EVENT ON 11 MARCH

A small proton event was reported by space vehicles and data from the polar cap. The event was in progress by 2000 UT on March 11 and continued for more than 60 hours with peak absorptions between 0100 and 0600 on the 12th.

The event was observed on VLF signals from Annapolis, Maryland to Anchorage, Alaska; Rugby, England to Anchorage, HF signals on 9 Mc/s and 12 Mc/s Thule to Anchorage. An increase

was also recorded in the neutron count by the Vela vehicles and Pioneer 7. No major flares or other outstanding solar events were reported during the 36 hours prior to the onset of the event at 2000 UT on the 11th.

Neither Mt. Wilson or Sacramento Peak recorded sunspot data on 11 March. Based on data for the 9th, 10th and 12th and the McMath-Hulbert Calcium plage data, it is evident that only two regions had the characteristics generally associated with proton events. Both regions crossed the East Limb with strong yellow coronal emissions. One sunspot group was first seen on 2 March at 2202 UT at N22 E76 reached a maximum area of 204 millionths at W08 on the 9th and was last seen on the 12th at N23 W49. No flares of importance  $\geq 1$  were reported from this region during the 36 hours prior to the start of the PCA, although 11 subflares were reported. The other sunspot group was first seen on 3 March at 1500 UT at S19 E77. This spot group reached an area of 772 millionth on 7 March (Mt. Wilson 16291) with a  $\beta\gamma$  magnetic classification. ESSA reports a weak  $\delta$  configuration. No flares with importance  $\geq 1$  and only 3 subflares were reported during the 36 hours prior to the start of the PCA event.

A third spot group, first seen on 27 February at 2158 UT at S21 E69 reached a maximum area of 598 millionths at 2346 UT at S21 E28. This group was given a  $\beta\gamma$  magnetic classification by Mt. Wilson (No. 16280) on 5 March and an average  $\beta_f$  during disk passage. The group had decreased to an area of 41 millionths on the 10th at S22 W74 and crossed the West Limb on the 11th. Only subflares were reported during the 36 hours in question. All of the other spot groups observed on the 9th, 10th and 12th were very small. No shortwave radio fades were reported and RF emissions at centimeter wavelengths were very weak.

Again, an examination of available data does not reveal any region on the far side of the sun within two or three days from the East or West Limbs as potential sources of the proton event.

The period from the first of March through the 17th was generally very quiet geomagnetically with only two 3-hour periods when the three-hour  $K_p$  exceeded 3+. In fact, the average three-hour  $K_p$  during the period was approximately 1.

3.8 IMPORTANCE 3B FLARE AND GREAT RF BURST AT cm  
WAVELENGTH ON 22 MARCH 1967

This event occurred near the East Limb in a large bright plage region. The plage (8740) is the return of a region that crossed the solar disk between 20 February and 5 March. It contained a very large  $\delta$  type sunspot group (see 3.6 above) which had broken up into three small spot groups during its passage of the far side of the sun.

Sacramento Peak data for the three spot groups at 2310 on the 21st, approximately one hour before the reported start of the flare, are given in Table 3.8.1. More detailed data are given in Table 3.8.2.

| Sac.P.<br>No. | Position | Heliog.<br>Long. | No.<br>Spots | Area | Mag        |
|---------------|----------|------------------|--------------|------|------------|
| 649           | N23 E59  | 301              | 1            | 213  | $\alpha_p$ |
| 652           | N26 E73  | 287              | 4            | 35   | $\beta_p$  |
| 653           | N21 E72  | 288              | 3            | 35   | $\beta_s$  |

TABLE 3.8.1 SACRAMENTO PEAK SUNSPOT DATA 2310  
UT, MARCH 21, 1967, PLAGE 8740

Sacramento Peak reported the flare beginning at 0022 UT, March 22, at N25 E70; associated with the spot group 652.

| Sac. P. No.  |                | 649                                                                                                 | 653       | 652       |
|--------------|----------------|-----------------------------------------------------------------------------------------------------|-----------|-----------|
| Mt. W. No    |                | 16305                                                                                               | 16307     | 15308     |
| First Seen   |                | 3/20                                                                                                | 3/21      | 3/21      |
| Position     |                | N26 E86                                                                                             | N26 E78   | N26 E78   |
| Heliog. Long | (average)      | 302                                                                                                 | 288       | 286       |
| Flare Day    | Area**         | 213-443                                                                                             | 35-104    | 35-60     |
|              | Position*      | N23 E59                                                                                             | N21 E71   | N26 E72   |
|              | Mag.           |                                                                                                     |           |           |
| Max. Area    | Date           | 3/26                                                                                                | 3/26      | 3/22      |
|              | Position       | N23 W04                                                                                             | N21 E10   | N26 E64   |
|              | Area           | 592                                                                                                 | 411       | 60        |
|              | Mag.           | $\beta_f$                                                                                           | $\beta_f$ | $\beta_f$ |
| Last Seen    | Date           | 4/01                                                                                                | 4/02      | 3/26      |
|              | Position       | N22 W79                                                                                             | 20 W78    | N26 E12   |
|              | Area           | 27                                                                                                  | 31        | 10        |
| Sac. P.      | Flare Position | N25 E70 Onset 0022                                                                                  |           |           |
|              |                | *Approximate position at start of the flare.                                                        |           |           |
|              |                | **Two values given, first is the area at 2310 UT March 21, second, is the area at 1557 UT March 22. |           |           |

TABLE 3.8.2 SUNSPOT BASIC DATA FOR EVENT ON  
MARCH 22

The flare was accompanied by a major shortwave radio fade and an X-ray burst of 13 times the quiet sun background.

Table 3.8.3a gives the distribution of all flares reported from plage 8740. Flares confirmed in the IAU bulletin are given in Table 3.8.3b.

A comparison of Tables 3.6.1b and 3.8.3b indicates that, although the total sunspot area in region 8740 is considerably smaller than the sunspot area during the previous rotation, the region is still considered to be flare productive.

No Type II or Type IV emissions were reported. The spectral plot of the RF emissions associated with flares from this region on the 22nd, 26th and 30th (Figure 3.8.1) do not show a region characteristic for the "U" type spectra. In addition, the period between 0000 UT on the 22nd and 2400 UT on the 26th was extremely quiet geomagnetically with no three-hour  $K_p$  index greater than 3- and no  $A_p$  greater than 4.

The RF profile for the burst at 2700 Mc/s starting at 0025.5 on the 22nd together with the times of associated phenomena, is shown on Figure 3.8.2. This is a class 3 profile very similar to the profiles shown as Figures 3.1 and 3.2 for 20 July 1961 and 7 July 1958, respectively in Reference 12, page 71.

| M A R C H |    |    |    |    |    |    |    |    |    |    |    |    |    |   |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
|           | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1  | 2 |
| Sub       | 3  | 11 | 4  | 14 | 10 | 13 | 15 | 14 | 19 | 22 | 20 | 17 | 9  | 7 |
| 1         | 1  | 4  | 2  | 2  | 1  | 3  | 3  | 5  | 3  | 3  | 5  | 4  | 11 | 2 |
| 2         | -  | -  | -  | -  | -  | -  | 2  | -  | -  | -  | 1  | 1  | -  | - |
| 2B        | -  | -  | -  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | -  | - |
| 3B        | -  | -  | 1* | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | - |
| Total     | 4  | 15 | 7  | 16 | 11 | 16 | 21 | 19 | 22 | 25 | 26 | 22 | 20 | 9 |

TABLE 3.8.3a ALL FLARES REPORTED 20 MARCH THROUGH  
2 APRIL FROM PIAGE 8740

| M A R C H |    |    |    |    |    |    |    |    |    |    |    |    |    |   |
|-----------|----|----|----|----|----|----|----|----|----|----|----|----|----|---|
|           | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 1  | 2 |
| Sub       | -  | -  | -  | 2  | 1  | 3  | 6  | 1  | 1  | -  | 3  | 2  | 2  | 1 |
| 1         | 1  | 4  | 1  | 3  | 1  | 3  | 2  | 4  | 4  | 3  | 3  | 8  | 9  | 2 |
| 2         | -  | -  | -  | -  | -  | -  | 1  | -  | -  | 1  | 1  | -  | -  | - |
| 2B        | -  | -  | 1* | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | - |
| 3         | -  | -  | -  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | -  | - |
| 3B        | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | - |
| Total     | 1  | 4  | 2  | 5  | 2  | 6  | 10 | 5  | 5  | 4  | 7  | 10 | 11 | 3 |

TABLE 3.8.3b CONFIRMED FLARES REPORTED IN THE  
IAU BULLETIN

\*This is the flare under study. It is classified 3B by both Sacramento Peak and Lockheed.

The event of 20 July 1961 was followed by a weak proton event while the 7 July 1958 event was followed by one of the largest PCA events of the 19th solar cycle.

This event has many of the characteristics generally associated with a proton event and an early alert might be considered. However, a continuous observation of the region would indicate a negative decision.

3.9 THE LARGE BRIGHT, ACTIVE REGION THAT CROSSED THE SOLAR DISK BETWEEN 18 MAY AND 1 JUNE 1967

The plage region (8818) crossed the solar disk between 18 May and 1 June. It was one of the largest of the present solar cycle. The plage contained three sunspot groups that reached maximum areas of 208, 538, and 1381 millionths on the 22nd, 27th, and the 24th, respectively (Table 3.9.1).

The region was flare productive during disk passage as shown in Table 3.9.2 below.

|                   | Sub-Flares | Minor Flares | Major Flares |    |    |
|-------------------|------------|--------------|--------------|----|----|
|                   |            |              | 2B           | 3N | 3B |
| East Quadrant     | 111        | 35           | 5            | 1  | 0  |
| West Quadrant     | 70         | 31           | 0            | 0  | 1  |
| Total Unconfirmed | 181        | 66           | 5            | 1  | 2  |
| Confirmed         | 32         | 32           | 4            | -  | 1  |

TABLE 3.9.1 SUBFLARES AND FLARES ASSOCIATED WITH SOLAR REGION 8818

| Sac. P. No.                                                                                    |          | 745             | 754       | 746      |
|------------------------------------------------------------------------------------------------|----------|-----------------|-----------|----------|
| Mt. W. No                                                                                      |          | 16368           | 16373     | 16372    |
| First Seen                                                                                     |          | 5/18            | 5/20      | 5/19     |
| Position                                                                                       |          | N25 E76         | N21 E54   | N26 E79  |
| Heliog. Long.                                                                                  |          | 243             | 236       | 223      |
| Flare Day                                                                                      | Date     | } See Table 2.2 |           |          |
|                                                                                                | Area     |                 |           |          |
|                                                                                                | Position |                 |           |          |
|                                                                                                | Mag      |                 |           |          |
| Max. Area                                                                                      | Date     | 5/22            | 5/27      | 5/24     |
|                                                                                                | Position | N25 E17         | N22 W37   | N27 E24  |
|                                                                                                | Area     | 20              | 53        | 13       |
|                                                                                                | Mag      | $\beta p$       | $\beta p$ | $\delta$ |
| Last Seen                                                                                      | Date     | 5/30*           | 5/30      | 5/30     |
|                                                                                                | Position | N25 W74         | N22 W67   | N27 W54  |
|                                                                                                | Area     | 34              | 221       | 369      |
| Confirmed                                                                                      | { Flares | 15              | 3         | 24       |
|                                                                                                | { Sub    | 12              | 3         | 17       |
| *Neither Sacramento Peak or Mt. Wilson observing on 5/31.<br>Mt. Wilson not observing on 5/30. |          |                 |           |          |

TABLE 3.9.2 SUNSPOT BASIC DATA REGION 8818

We have included all  $S_f$ ,  $S_n$ , and  $S_b$  flares under subflares, the minor flares include all flares reported as 1F, 1N, 1B, 2F and 2N. The 2B group includes those reported as 2B or 3F.

The number of flares reported in each grouping in the first three lines of the table is based on the individual reports published in Reference 15.

A large number of the subflares and many of the minor flares were reported by a single observatory, or were reported by two or more observatories with different importances. These and other problems have, in the past, introduced many uncertainties in the analysis of solar flares and their correlation with other phenomena. The first effort to eliminate this difficulty was carried out by Dodson and Hedeman at the McMath-Hulbert Observatory (Reference 6). The revised or "corrected" importance for all flares with importance  $\geq 2$  for the years 1954 through 1963 were given in the five volumes of the Solar Activity Catalogues by Jonah, Dodson, and Hememan. More recently, Dodson and Hedeman (Reference 7) published the re-evaluated catalogue of Solar Flares for 1964-1966. Based on methods developed at McMath-Hulbert Observatory, Meudon Observatory, and ESSA at Boulder. The flares published in the Quarterly bulletin (Reference 12) starting with 1967 and in Solar-Geophysical Data, starting with the final data for January 1968, will be "confirmed" solar flares.

Using the Quarterly Bulletin data for May 1967, the number of subflares, minor flares, and major flares from the region 8818 is given in the last line of Table 3.9.2.

The number of confirmed subflares and flares originating in or near the three sunspot groups is shown on the last two lines of Table 3.9.1

3.9.1     The Major RF Event at Centimeter Wavelength on 20 May

The first major solar event from region 8818 is associated with an importance 1B flare from the leading group in the plage. This is a small spot which at the time of the flare was located at N24 E50. The flare was accompanied by a minor shortwave radio fade, Type II, slow drift burst over the frequency may range from 10 to 300 Mc/s and a Type IV continuum from 9 to 41 Mc/s. A minor X-ray emission was reported by Explorer 33.

Major RF bursts covered the frequency range 2695 to 10700 Mc/s with minor bursts at 1415 and 960 Mc/s. The spectral plot is shown on Figure 3.9.1. The RF event shows an indication of a "U" type spectrum with decreasing flux with increasing wave for frequencies below 4995 Mc/s, however, the flux at 960 Mc/s is very weak and no emissions are reported at lower frequencies.

It is seen on Figure 3.9.1 that the spectra of the RF events, starting at 1254 UT, and 1524 UT on 19 May, exhibit a strong "U" type spectrum. On the other hand, the RF emission at 1504 UT on the 19th and at 1922 on the 21st have a fluctuating flux superimposed as indicated by the "U" shape

### 3.9.2 The RF Event Starting at 1920 UT on 21 May

This major RF event is associated with an importance 2B flare located east of the leading small sunspot group (area 153 millionths). Sacramento Peak Observatory reports that at the time of flare maximum (1926 UT) the flare emission was "apparent" on the white light photographic patrol. Other phenomena associated with this event include:

An importance 2 SWF that lasted for 46 minutes. Spectral emissions, Type II and Type IV, and one of the most intense X-ray flux observed by Explorer 33 to date. The X-ray increase started almost simultaneously with the RF onset and reached a maximum intensity of 180 milli-ergs (cm<sup>2</sup> sec)<sup>-1</sup>, approximately three minutes after the RF peak flux.

The RF spectral plot shown on Figure 3.9.1 has characteristics quite similar to those of the other RF events associated with this solar region. The RF time history at 2695 Mc/s and the X-ray emission 2-12A°, together with other associated phenomena

are shown on Figure 3.9.2. Overall activity of the region remained relatively low for the next 48 hours following the major event starting at 19<sup>00</sup> on the 21st.

In particular, activity associated with this small sunspot group was relatively low during the remainder of its passage of the solar disk with only five confirmed flares with importance 1N and two confirmed subflares.

### 3.9.3 The Large Proton Event on May 23, 1967

The largest of the three sunspot groups in the plage region 8818 rotated around the East Limb on 19 May at N26. The spot group was given a  $\beta\gamma$  magnetic classification on the 20th, and a  $\delta$  type the following day and the remaining days on the visible disk. The group (Sacramento Peak number 746, Mt. Wilson number 16372) increased in area to a maximum of 1381 millionths on the 24th at N27 E24 then decreased slowly and crossed the West Limb on 31 May.

Prior to the event on the 23rd, only 9 subflares, 6 minor flares, and 1 major flare (importance 2B at 2354 UT on the 21st) were confirmed. None of these flares were accompanied by important RF events.

Starting at 1802 three major flares were observed in rapid succession with maxima at 1814  $\pm$  3 minutes, 1843, and 1847  $\pm$  3 minutes. All of these flares were reported with importance 2B and

TABLE 3.9.3 SOLAR PROTON EVENTS (PROVISIONAL) MAY 1967  
(FROM IER-FB-274 JUNE 1967)

| Event No. | Date May | Time UT     | Detector                                                | Activity                                    |
|-----------|----------|-------------|---------------------------------------------------------|---------------------------------------------|
| 1         | 23       | 1925(1)     | Vela satellite system                                   | Increased neutron count                     |
|           |          | 24 0000     | Shepherds Bay riometer                                  | Absorption                                  |
|           | 24       | 0600        | Alaskan riometer network, VLF, HF, FWD-scatter circuits | Marked absorption, phase advances, fadeouts |
|           |          | 0930(2)     | Vela satellite system                                   | Maximum neutron count                       |
|           |          | 2100        | Lunar Orbiter satellite                                 | > 10 Mev proton flux still increasing       |
|           | 25       | 0100        | Ft. Churchill satellite experiment                      | Reading 1 RAD/hr and increasing             |
|           |          | 0300        | Alaskan riometer network                                | Absorption still increasing                 |
| 2         | 25       | 0715(1)     | OGO satellite                                           | 3x normal > 20 Mev proton flux              |
|           |          | ~ 0500-0700 | Lunar Orbiter satellite                                 | Reading approx. 2 1/2 RAD/hr                |
|           |          | 0800        | Shepherds Bay riometer                                  | Marked absorption                           |
|           |          | 1300        | Alaskan riometer network FWD-scatter circuits           | ≥ 20 db absorption on riometer              |
|           |          | 1353(2)     | Vela satellite system                                   | Maximum neutron count                       |
| 3         | 27       | 0710(3)     | Vela satellite system                                   | About normal proton levels                  |
|           | 28       | 0605(1)     | Shepherds Bay riometer                                  | Absorption begins                           |
|           |          | 0625        | Vela satellite system                                   | Increased neutron count                     |
|           |          | 0626        | Alaskan riometer network                                | Absorption                                  |
|           |          | 0626        | VLF, HF, FWD-scatter circuits                           | Phase advances, fadeouts                    |
|           |          | 0700        | OGO satellite                                           | 3x normal > 20 Mev proton flux              |
|           |          | 1200(2)     | Kiruna, Sweden riometer                                 | Absorption                                  |
|           | 31       | 0030(3)     | Alaskan riometer network                                | PCA ends                                    |

(1) Probable beginning time (2) Probable maximum time  
(3) Probable ending time

NOTE: Pioneer space probe system confirmed above events.

a total duration of 3 hours 58 minutes (see event 12, Table 2.2). Sacramento Peak Observatory reported that the third of these flares was observed in white light at 1845 UT and was apparent on the white light photographic patrol film at 1840 UT.

The first two flares caused great shortwave radio fades, and importance 3 spectral emissions of Type II and Type IV extending from the dekameter through the meter wavelength.

The RF time history at 2695 and 2800 Mc/s, the X-ray burst recorded from Explorer 33 together with indicated times of associated phenomena are shown on Figure 3.9.3.

Relatively weak RF emissions and X-ray flux accompanied the first flare, starting two and four minutes, respectively, before the reported start of the flare. The RF peak at 1810 occurred (see insert Figure 3.9.3) at the same time as the earliest reported time of flare maximum which the peak X-ray flux at 1816 UT occurred one minute before the fourth and latest reported time of flare maximum.

In the case of the second flare (or second phase) the flare, SWF, and X-ray all start approximately one minute before the onset of the RF burst at 2695 and 2800 Mc/s.

Except for the fact that flare maxima occur after the RF peak, this phase of the events meets all of the almost necessary conditions for a proton event to follow and an alert would be in order. In fact, the Vela satellite system recorded an increase in neutron count at 1925 UT, approximately 10 minutes before the start of the third (phase) flare in the sequence. Lindgren (Reference 14) states that the increase is very slow at the start making it difficult to determine the onset time. Lindgren estimates the start at about 2000 UT, and takes about 36 hours for the flux to build up to its maximum value. A summary of the preliminary data is given in Table 3.9.3. This indicates the Vela satellite's maximum at 0930 while the Alaskan riometer network and forward scatter circuits establish the maximum  $\geq 20$  db at 1300 UT on May 25. The Explorer 33 open counter and ion chamber show a maximum at 1200 UT on May 25.

This sequence of events with two major RF bursts separated by about 75 minutes, with the second RF peak greater than the first by a factor of about 4 and the PCA onset sometime between the two peaks, is similar in many respects to the great RF bursts on 21 September 1963 (Reference 12).

The X-ray burst associated with the flare at 1832 is the most intense observed by Explorer 33.

The spectral plots of the three phases of the RF bursts are shown on Figure 3.9.4. The first two phases show a decreasing flux with increasing wavelength, while the great burst starting at 1935 has the "U" type spectrum.

#### 3.9.4 The PCA Event on May 28, 1967

The final event associated with plage region 8818 and the large  $\delta$  type sunspot group 16372 occurred when the sunspot was at N26 W32. The  $\delta$  configuration was still observed while the area had decreased to a value between 939 (at 1517 UT on the 27th) and 710 (at 1415 UT on the 28th) millionths while the plage had reached an area of approximately 12,200 millionths with a brightness of 3.5.

An importance 3B flare started at 0525 UT with maximum values reported by 8 of the 10 observatories that reported the flare. The times of flare maximum ranged from 0539 to 0602 UT (Table 2.2) while importances ranged from 2N to 4B. The flare was classified as 2B in the Quarterly Bulletin, but since 6 of the reporting observatories reported the flare as  $\geq 3B$ , a classification of 3B is generally accepted.

The flare was associated with a strong shortwave fade with a maximum intensity 8 minutes after the reported start of the flare. No Type IV emission was reported, but an importance 2 slow drift burst (Type II) of short duration (2 minutes) was recorded at meter and dekameter wavelengths (Figure 3.9.5). Major RF bursts were recorded at frequencies from 17,000 to 100 Mc/s. The RF emission show a strong "U"-shaped spectrum, with the times of peak flux varying from 0540.4 at 200 Mc/s to 0542 UT at 10,700 Mc/s (Figure 3.9.6).

The X-ray burst showed an increase at 0528, coincident with the onset of the centimeter RF emission, and three minutes after the reported start of the flare and two minutes before the start of the shortwave radio fade as shown on Figure 3.9.5

On the basis of the RF data presently available, the time of the RF peak flux at both 3000 Mc/s and 3750 Mc/s follows the time of flare maximum reported by Ondrejov by nearly 3 minutes, but coincides ( $\pm$  a few tenths of a minute) with the mean time of flare maxima as reported by Ondrejov, Catania, Siberie, and Athens, with the X-ray peak occurring nearly 10 minutes later. In other words, there does not appear to be an indication of an impulsive onset of these phenomena.

The PCA onset time, as shown on Table 3.9.3, occurs about 45 minutes after the start of the flare with maximum absorption of 3.5 db at about 1200 UT.

The distribution of flares and subflares for each day during the transit of Region 8818 across the visible disk, Table 3.9.4a is based on the individual reported in Reference 16. Table 3.9.4b is based on the confirmed flares reported in the IAU Quarterly Bulletin.

|       | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Sub   | 2  | 6  | 9  | 16 | 23 | 24 | 20 | 11 | 13 | 9  | 15 | 8  | 9  | 14 | 2  |
| 1     | 2  | 4  | 4  | 5  | 8  | 2  | 3  | 5  | 6  | 10 | 3  | 6  | 4  | 2  | -  |
| 2     | -  | -  | 1  | -  | 1  | -  | -  | -  | 1  | -  | 1  | 1  | -  | -  | -  |
| 2B    | -  | 1  | -  | -  | -  | -  | 4  | -  | -  | -  | -  | -  | -  | -  | -  |
| 3     | -  | -  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 3B    | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 2  | -  | -  | -  |
| Total | 4  | 11 | 15 | 21 | 32 | 26 | 27 | 16 | 20 | 19 | 19 | 17 | 13 | 16 | 2  |

TABLE 3.9.4a ALL FIARES REPORTED 17 MAY THROUGH 31 MAY  
1967 FROM PLAGE REGION 8818

|       | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
|-------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Sub   | 1  | 2  | 4  | 3  | 8  | 1  | 3  | 4  | -  | -  | 2  | -  | 1  | 2  | 1  |
| 1     | -  | 5  | 3  | 3  | 4  | 1  | -  | 1  | 4  | 5  | 3  | 3  | 2  | 1  | -  |
| 2     | -  | -  | -  | -  | 1  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 2B    | -  | -  | -  | -  | 1  | -  | 3  | -  | -  | -  | -  | -  | -  | -  | -  |
| 3B    | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | 1* | -  | -  | -  |
| Total | 1  | 7  | 7  | 6  | 14 | 2  | 6  | 5  | 4  | 5  | 5  | 4  | 3  | 3  | 1  |

TABLE 3.9.4b CONFIRMED FIARES REPORTED IN IAU BULLETIN

\*See comments on following page.

\*The flare at 0529 May 28 at N28 W32 was classified 2B in the IAU Bulletin. However, a 3B importance seems to be in order. Ten observatories reported start times between 0527 and 0552 UT and times of flare maximum between 0539 and 0602 UT. Six observatories assigned an importance 3B or greater, two classified the flare with importance 2B and two with importance 2N (see event 13, Table 2.1).

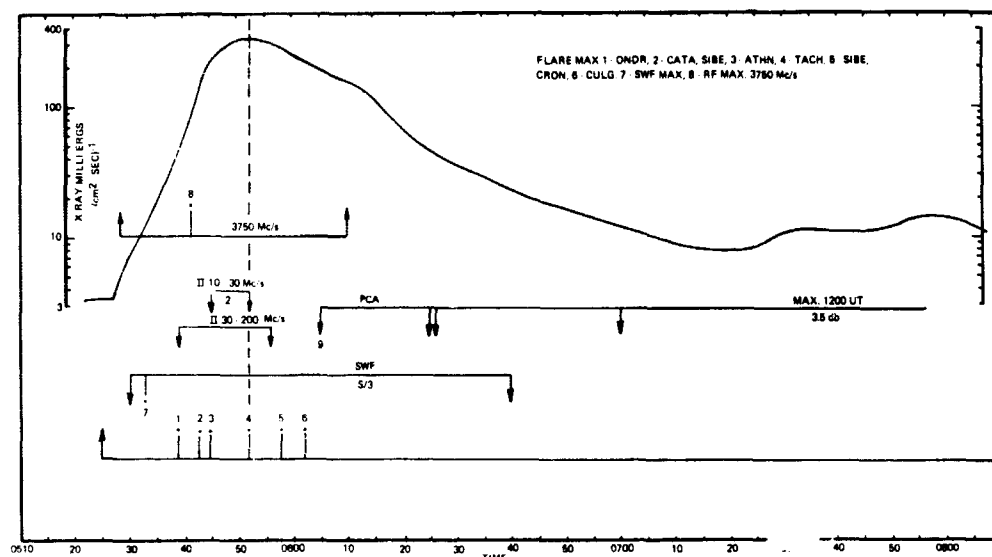
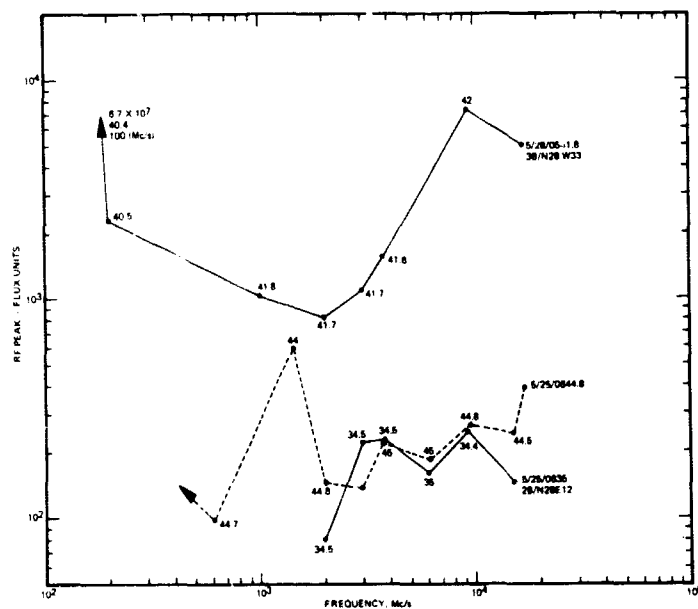


FIGURE 3.8.5 THE X-RAY BURST STARTING 0529 UT ON MAY 28, 1967 WITH TIME OF RELATED PHENOMENA

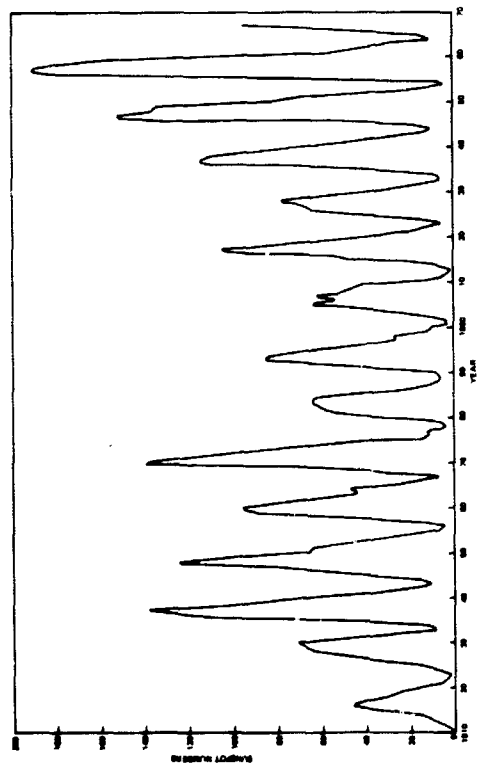


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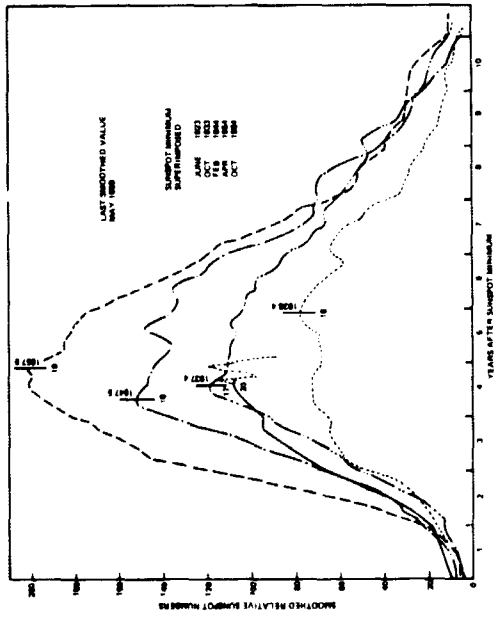
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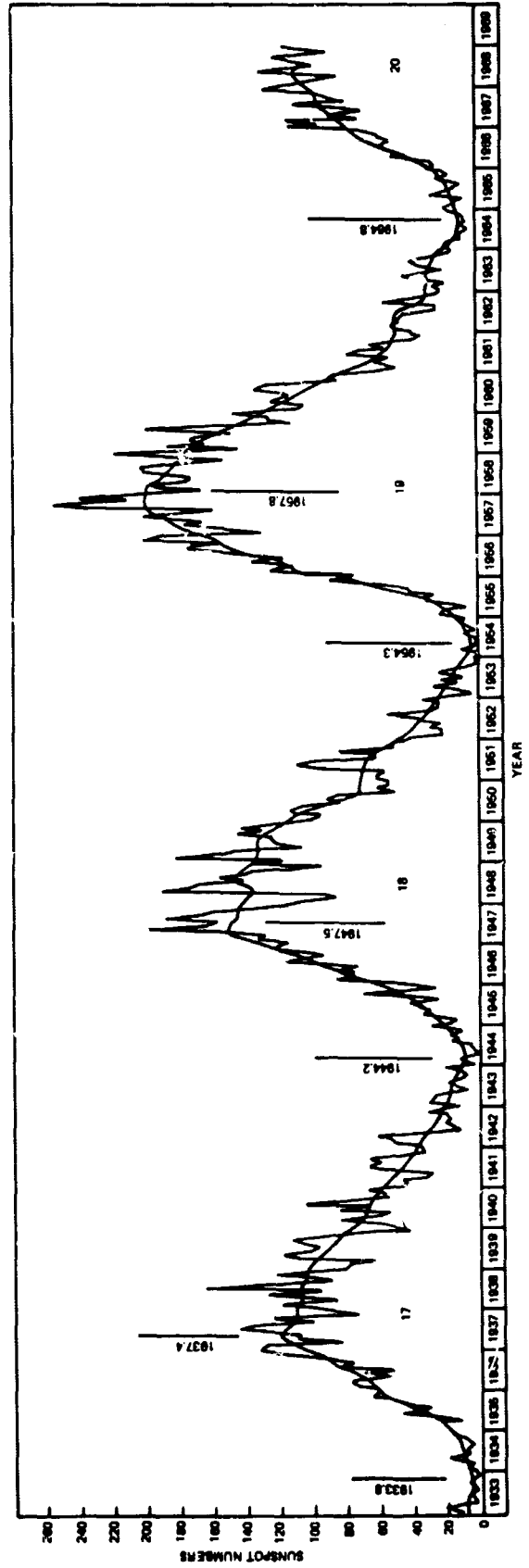
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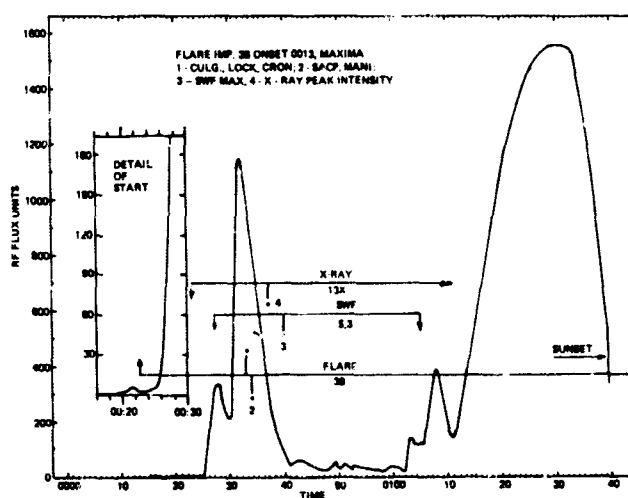
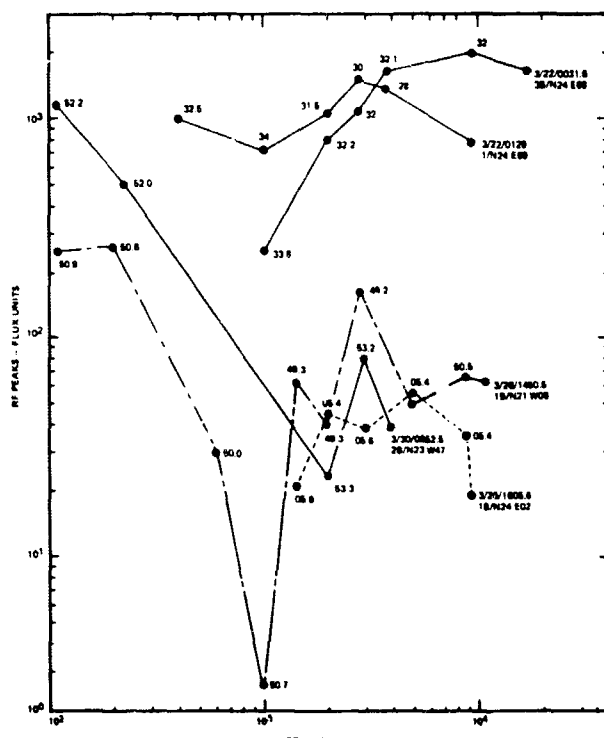
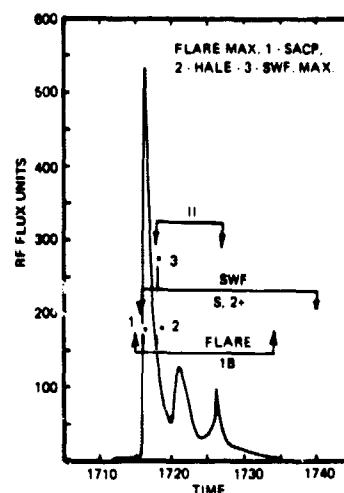
ANNUAL SMOOTHED MEAN SUNSPOT NUMBERS 1810 - 1968  
FIGURE 1.1a



COMPARISON OF SMOOTHED MONTHLY SUNSPOT  
NUMBERS FOR SOLAR CYCLES 16 - 20 WITH SOLAR  
MINIMUM AS COMMON POINT  
FIGURE 1.1b



1.1c MONTHLY MEANS AND SMOOTHED RELATIVE SUNSPOT NUMBERS CYCLES 17 - 20  
FIGURE 1.1c



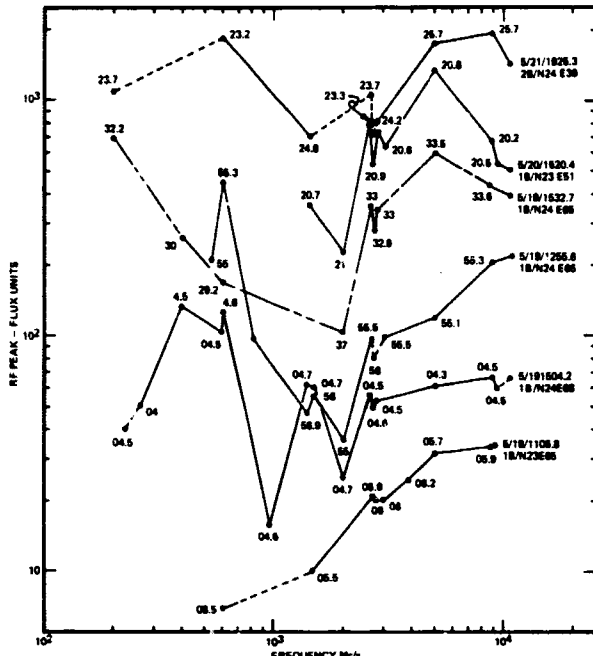


FIGURE 3.3.1 SPECTRUM OF SOLAR RADIO EMISSIONS ON MAY 19, 20, AND 21, 1967 SOLAR REGION 6516

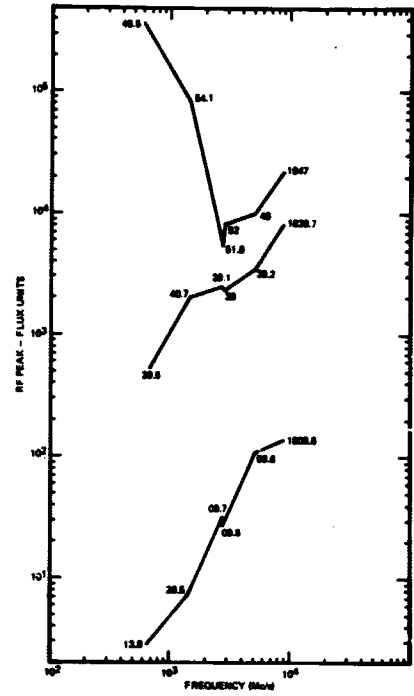


FIGURE 3.3.2 SPECTRUM OF RF BURSTS (2 PHASES) ASSOCIATED WITH THE IMPORTANCE 20 FLARE MAY 23 FROM SOLAR REGION 6516

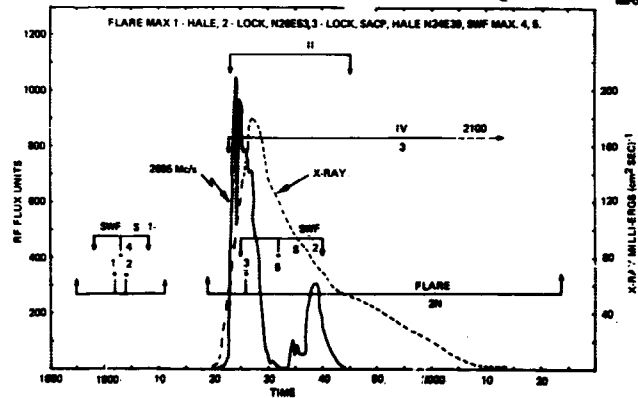


FIGURE 3.3.3 RF BURST AT 2000 MHz AND X-RAY BURST 2-12 Å ASSOCIATED WITH THE 20 FLARE ON MAY 21, 1967

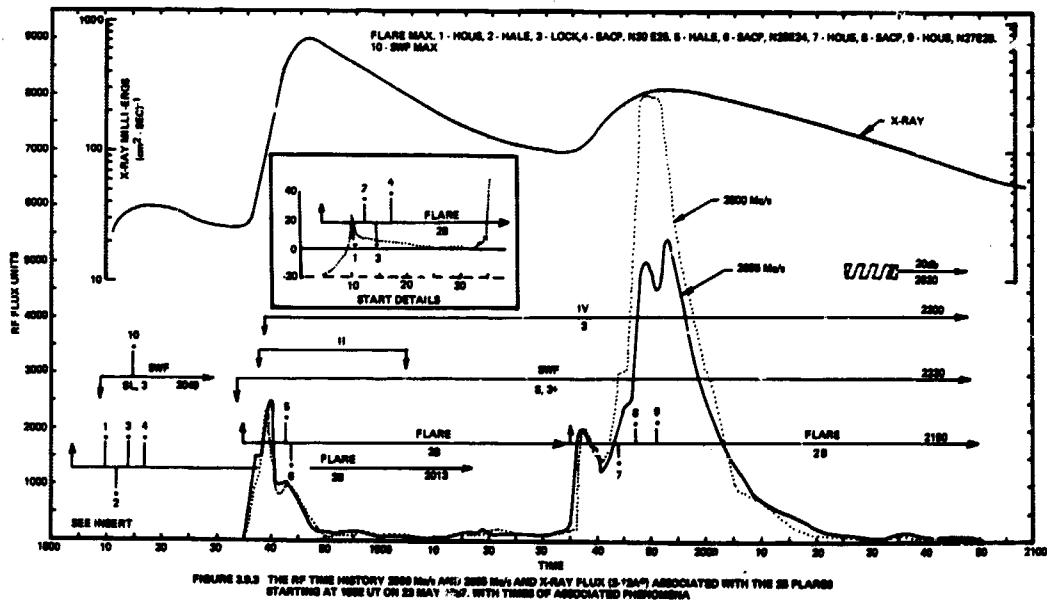


FIGURE 3.3.4 THE RF TIME HISTORY 2000 MHz AND 2000 MHz AND X-RAY FLUX (2-12 Å) ASSOCIATED WITH THE 20 FLARE STARTING AT 1900 UT ON MAY 21, 1967, WITH TIMES OF ASSOCIATED PHENOMENA