MAC COURSE 2500

Handout - H.O. 101

ORIENTATION/INTRODUCTION TO SESS

SOLAR OBSERVING OPTICAL NETWORK
(SOON) OPERATORS COURSE

MILITARY AIRLIFT COMMAND

AIR WEATHER SERVICE

DETACHMENT 4, 4TH WEATHER WING
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FOR TRAINING USE ONLY

AWS support could mean life or death in space

by
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and
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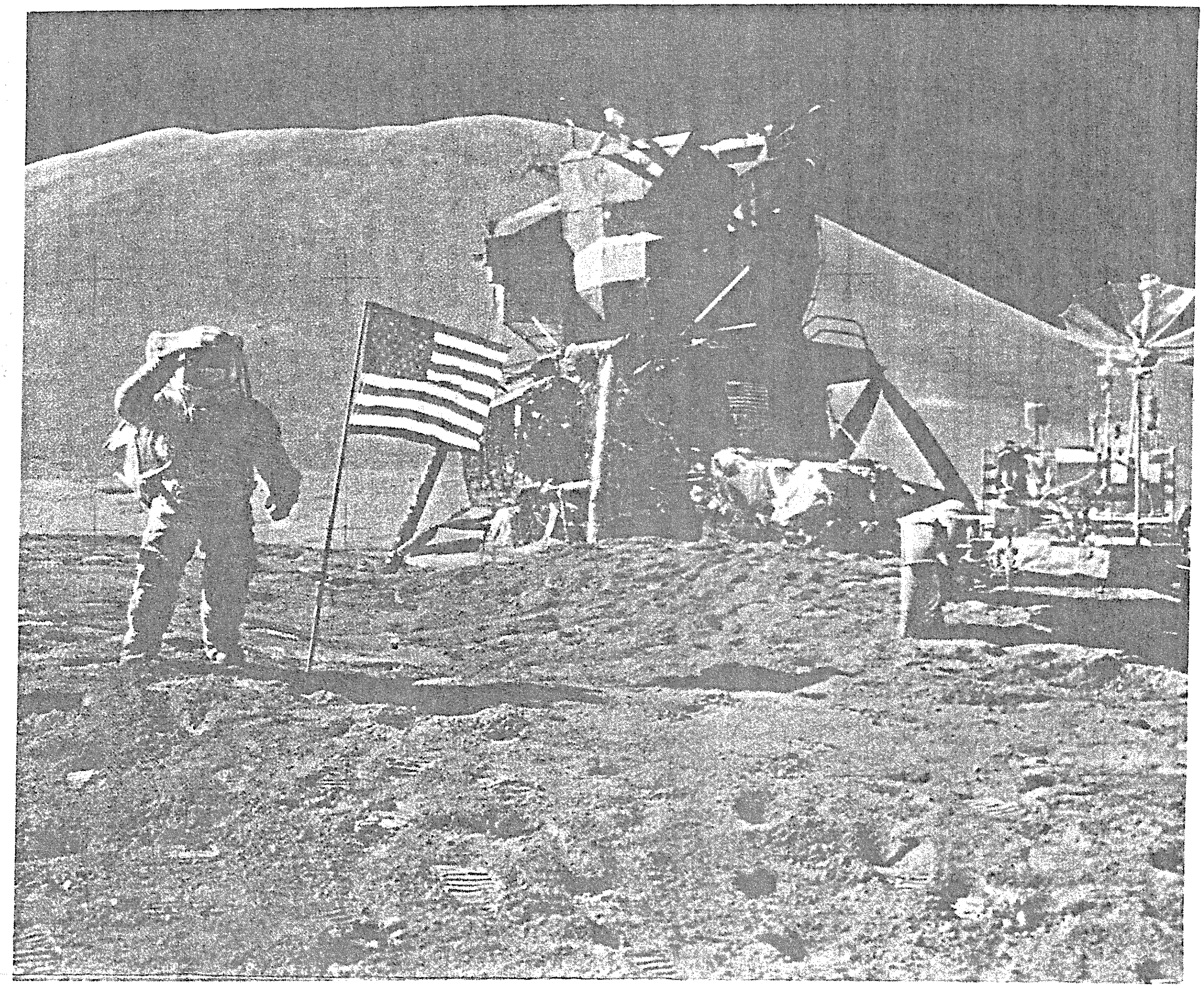

Astronaut Irwin salutes flag at Apollo 15 Hadley-Apennine landing site.

Space is a hazardous place for man and his fragile machines.

In space, as in the troposphere, Air Weather Service support is the leading edge of the warning network that protects people and resources. While the mission of Air Weather Service in space is the same as in the lower atmosphere, how we do it is very different.

The only sources of timely data are six AWS Solar Observatories, some in very isolated locations; a few civilian observatories; and x-ray sensors on Geostationary Operational Enviromental Satellites (GOES).

The systems and astronauts affected are themselves isolated by the vast distance of space. Often, because of isolation or classification, the AWS forecaster who provided critical information may never realize the significance of his or her contribution. That's a far cry from the base weather station where the forecaster usually suffers the success or failure of a forecast right along with the rest of the base.

In James Michener's epic novel, *Space*, two Apollo astronauts, performing extra-vehicular activities on the surface of the moon, are killed by energetic protons resulting from an abnormally large solar flare. In this portion of the novel, one of the main characters is a young solar observer who is also a graduate student at the University of Colorado. The drama builds as he waits for the sun to rise at Boulder, Colorado so he can observe a sunspot region with the potential to produce a large event. Of course an event does occur.

The novel states the radiation measured by the astronauts is 5830 rems. (A rem is a unit derived from radiation and a quality factor determined by how well a particle of particular type and energy interacts with the human body.) Table 1 contains the Apollo limits.

Table 1. Established dose guideline in REM (Space Science Board, 1970).

Mission Operational Dose	Skin	Eye	Bonemarrow
30 Day Max	75	37	25
Quarterly Max	105	52	35
Yearly Max	225	112	75
Career Limit	1200	600	400

In addition, the Nuclear Effects Handbook predicts that exposure to 690-930 rems will cause immediate severe vomiting and nausea with up to 100 percent fatalities. Exposure to 6,200 rems would produce total incapacitation and be almost immediately fatal. Clothes, spacesuits, Lunar Module or Apollo Command Module all provide successively more protection. The astronauts in the novel had no warning to seek better protection.

Michener's novel, fortunately, is fiction. A real solar event of this size occurred in August 1982 (about a year before the fictional event of the novel). The following paragraphs detail the manner in which AWS handled it.

The technical analysis and verification of the record solar events of August 1972 extol the success of cooperation between the forecasters at solar observatories and the Air Force and civilian forecast centers. The first to note the significance of the sunspot region was the USAF/AWS Palehua Solar Observatory, Hawaii, four days before the first event. As the region moved toward the center of the sun and became easier to analyze, all our observatories commented on the active nature of the region.

At 010800Z August 72, Tehran (then an AWS observatory), reported "queer things are happening in Region 331, expect it to blow."

At 010915Z the first major event occurred. A number of other major flares followed. Despite the activity, the region did not subside. This led the civilian forecast agency at Boulder to label the region "very dangerous."

At 021957Z, one of the largest solar flares ever recorded occurred accompanied by emissions of large numbers of energetic protons. Smaller major events continued to occur until August 11 when the region rotated to the back side of the sun. When the AWS one-day forecast verifications were totaled for the event period, the average daily major solar flare forecast probability was 30 percent, three days out of 10 experienced major flares. The minor flare probability was 85 percent and seven of 10 days experienced minor flares.

Skin dose on the moon, from these events would have amounted to 4,000 rem in the space suit, 1,500 in a Lunar Module and 300 in a Command Module.

These events occurred between Apollo 16 and 17. Had an Apollo mission been on the moon, warnings provided by the AWS observatories would have assured the astronauts safe arrival home, although their radiation dose would have exceeded authorized career dosage levels thereby preventing them from flying in space again.

This sequence of events occurred 12 years ago. The experience level is much lower in today's solar observatories and forecast centers. Our lack of experience is partially offset by increased data. During a recent major flare, one of the biggest of this 11 year solar cycle, a solar forecaster at Palehua found that his communications had been knocked out by heavy rains and he raced to the bottom of the mountain to report a significant event by pay phone.

Current space shuttle astronauts fly only low altitude missions which don't travel further than 57 degrees north or south latitude. The magnetic field of the earth protects them from many of the problems associated with solar flares

Military shuttle flights from Vandenburg AFB will fly missions over both polar regions. There they will again be exposed to solar flare protons from major events and they will receive additional exposure from trapped radiation belt particles. Dr. Stuart Machtwey, a bio-medical expert at NASA's Johnson Space Center, calculated that the worst exposure which would be realized by shuttle astronauts in polar orbit during the 1972 event would be 280 rem on the skin inside the spacecraft. Conditions would be much worse in just a space suit.

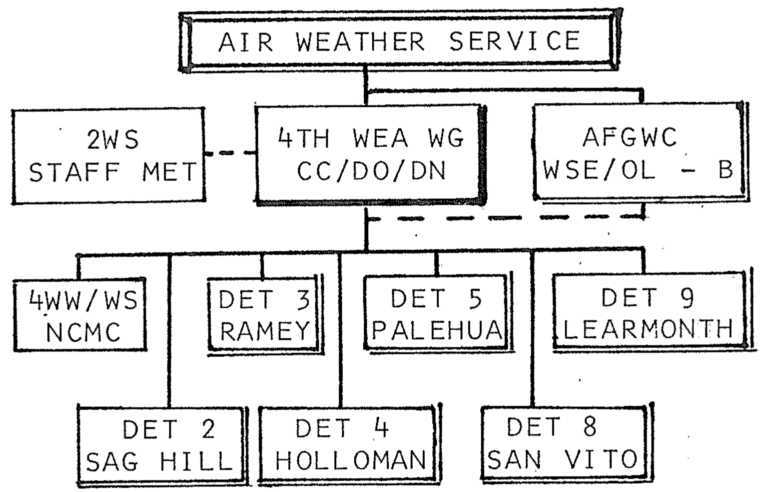
Machines are also vulnerable to space radiation. Problems are varied. Trapped or solar flare protons cause single computer elements to change value. If it is the wrong element, a satellite may be lost. Fortunately, most of the time, ground controllers are able to correct the problem. Protons also affect electro-optical devices. Heavier charged particles can damage computers causing long-term problems. Radiation belt energetic electrons can cause charging on space structures. The resulting arc discharges can cause serious damage. As computer elements become smaller, sensitivites to energetic particles become greater. The same can be said of larger space structures and space ship charging. Air Weather Service provides warnings and post analysis on all these effects. Requirements are increasing.

The sensitivites of military satellites to the space environment tend to be classified. Insight into the problem can be obtained by looking at equivalent civilian devices. The TRW Corporation's Tracking and Data Relay Satellite System, or TDRSS, contains one of the most sophisticated computers in space. Since launch the TDRSS has had one computer upset per day. Some of these affected the essential orientation of the spacecraft. If the most serious fault had gone uncorrected for one more minute, subsequent correction would have taken over 12 hours; during which the satellite would not have been usable.

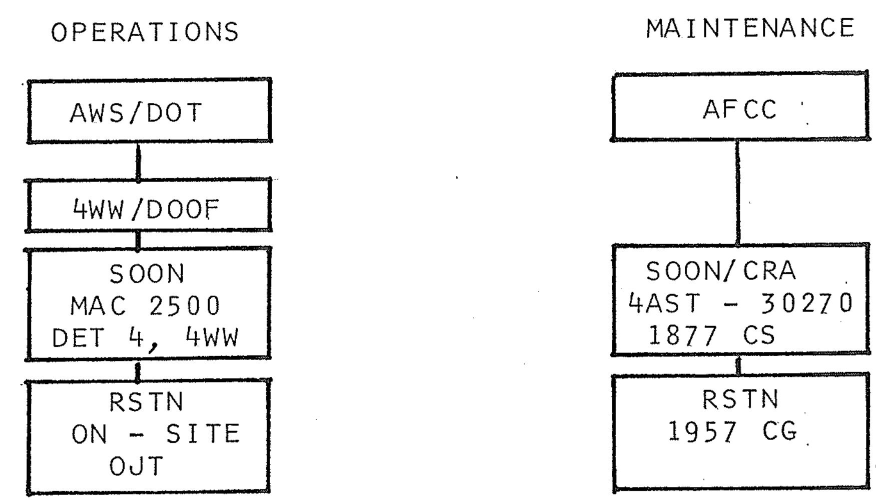
Not all faults are correctable. A moderate proton event in 1982 probably caused the demise of GOES-4 (Geostationary Operational Environmental Satellite number four). This points out a problem in our post analysis capabilities. Not all failures are as dramatic as GOES-4. Relating failures to solar events often cannot be reliably established since we cannot retrieve most satellites.

It's easy to reach the conclusion that the AWS Solar Observatories are vital to our space effort. As the Air Force presence in space increases, so will the AWS mission and the associated requirements for solar data.

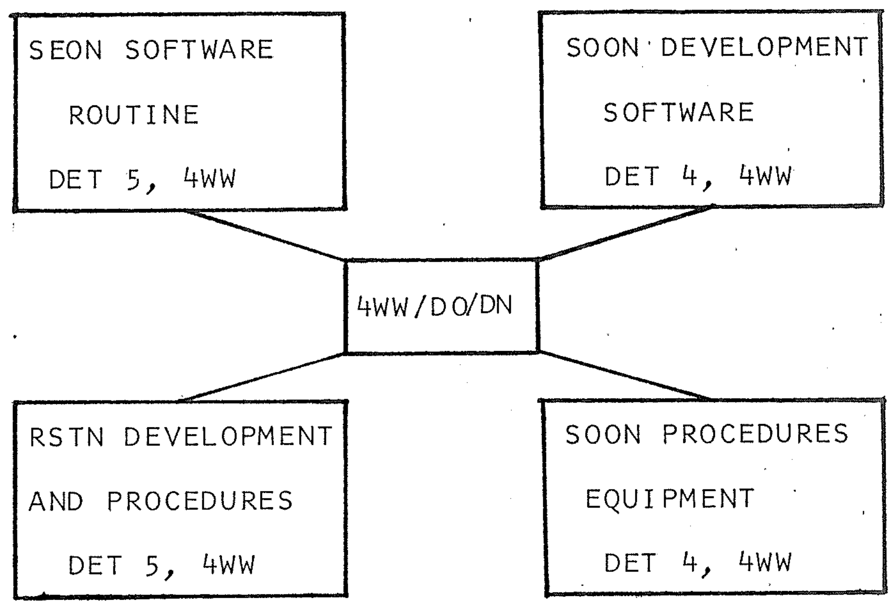
SESS ORGANIZATION



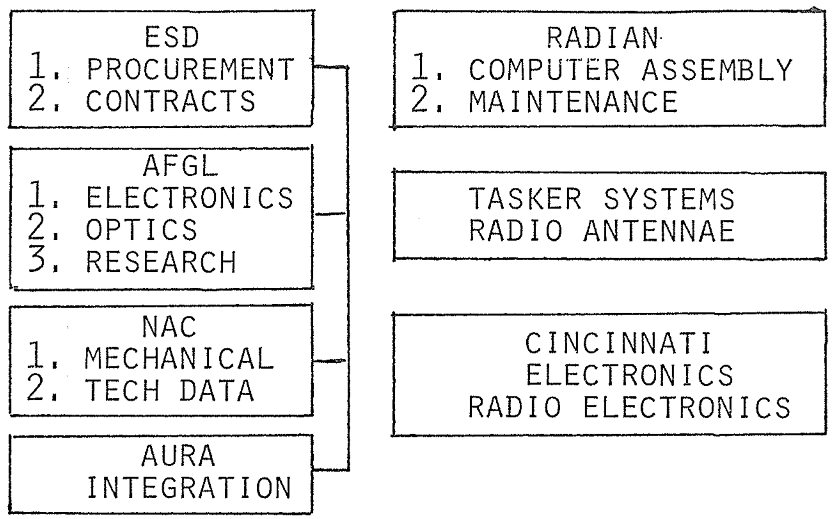
SESS TRAINING



PROGRAM AND PROCEDURE CONTROL



RELATED ORGANIZATIONS



AFGWC CUSTOMERS

1. SECRETARY OF THE AIR FORCE SPECIAL STRATEGIC SYSTEMS (SAFSS)
2. COBRA DANE RADAR
3. FPS-8 PHASED ARRAY RADAR
4. SLBM DETECTION RADAR
5. EARLY WARNING SYSTEM (BMEWS)
6. AWACS (SENTRY)
7. USAF SATELLITE CONTROL FACILITY
8. AEROSPACE DEFENSE COMMAND (ADCOM)
9. SAC HF COMMUNICATIONS
10. STRATEGIC COMMUNICATIONS (STRATCOM)
11. USN, USCG VLF/HF NAVIGATION SYSTEMS (NAVCOM)
12. AIR FORCE COMMUNICATIONS COMMAND (AFCC)
13. TACTICAL EXERCISES, ARMY COMMUNICATIONS
14. GEOPHYSICAL EXPERIMENTS, NATURAL RESOURCE SURVEYS

CUSTOMERS USING

SPACE ENVIRONMENTAL SUPPORT SYSTEM (SESS) DATA

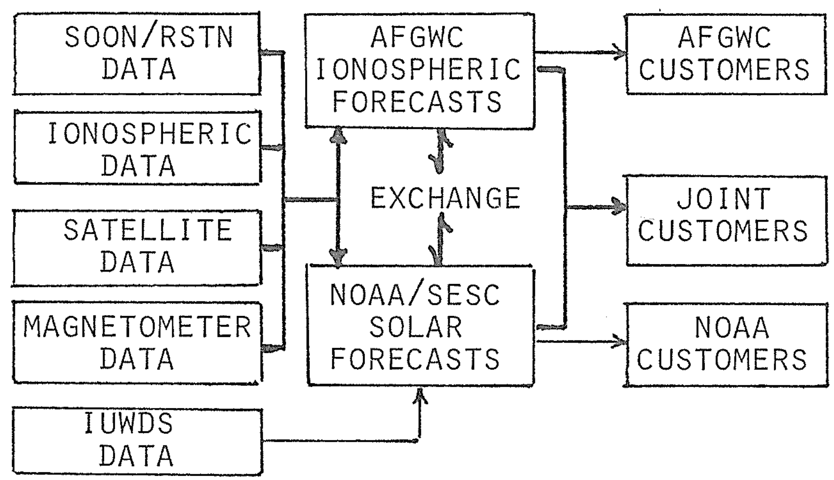
PRODUCT	DATA SOURCE	PRIMARY CUSTOMER
1. TOTAL ELECTRON CONTENT FORECAST	SHEMYA TEC	16 SURS/DO/RAYTHEON MANAGER, SHEMYA AFB
2. EXTENDED PERIOD REPORT	SESS SITES	AFCC PLUS 12 OTHERS
3. OBSERVED AND 3-DAY FORECASTS OF 2800 MHz SOLAR RADIO FLUX AND GEOMAGNETIC INDICES	ALGONQUIN RADIO OBSERVATORY (CANADA) AND SESS SITES	NORAD PLUS 9 OTHERS
4. SOLAR RADIO BURST ADVISORY	SESS SITES	NORAD PLUS 5 OTHERS
5. PROTON EVENT ALERT AND FORECAST	GOES, DSP, SESS SITES	NORAD PLUS 12 OTHERS
6. GEOMAGNETIC DISTURBANCE ADVISORY	SESS SITES	NORAD PLUS 16 OTHERS
7. SOLAR EVENT ADVISORY (X-RAY)	X-RAY FLUX FROM GOES	NORAD PLUS 12 OTHERS
8. SOLAR EVENT ADVISORY (FLARE)	SESS SITES	AFSC PLUS 7 OTHERS
9. POLAR CAP ABSORPTION EVENT ADVISORY	THULE RIOMETER	AFSC PLUS 15 OTHERS
10. HF PROPAGATION FORECASTS	SESS SITES PLUS OTHERS	SAC PLUS 4 OTHERS

PRODUCT	DATA SOURCE	PRIMARY CUSTOMER
11. PRIMARY HF RADIO PROPAGATION REPORT	SESS SITES, NAVY, COAST GUARD	AFSC PLUS 77 OTHERS
12. SECONDARY HF RADIO PROPAGATION REPORT	SESS SITES, NAVY, COAST GUARD	AFSC PLUS 59 OTHERS
13. EVENT WARNING MESSAGE	SESS SITES	NORAD PLUS 28 OTHERS
14. JOINT USAF/NOAA REPORT OF SOLAR AND GEOPHYSICAL ACTIVITY	SESS SITES AND OTHERS	AFSC PLUS 53 OTHERS
15. PLANETARY GEOMAGNETIC INDEX 7-DAY FORECAST	SESS SITES AND OTHERS	AFSC PLUS 16 OTHERS
16. SHORT-RANGE PLANETARY GEOMAGNETIC INDEX AND 10.7CM FLUX FORECAST	SESS SITES AND OTHERS	AFSCF, SUNNYVALE AFS
17. MEDIUM-RANGE PLANETARY GEOMAGNETIC INDEX FORECAST	SESS SITES AND OTHERS	AFSCF, SUNNYVALE AFS
18. LONG-RANGE PLANETARY GEOMAGNETIC INDEX AND 10.7CM FLUX FORECAST	SESS SITES, NASA, AND OTHERS	AFSCF, SUNNYVALE AFS
19. SOLAR RADIO FLUX PREDICTION AID	ALGONQUIN RADIO OBSERVATORY	NORAD PLUS 13 OTHERS
20. MAGNETOMETER ANALYSIS	SESS SITES	NORAD PLUS 15 OTHERS

PRODUCT	DATA SOURCE	PRIMARY CUSTOMER
21. SOLAR AND GEOPHYSICAL ACTIVITY SUMMARY	SESS SITES AND OTHERS	US ARMY PLUS 14 OTHERS
22. SOLAR REGION SUMMARY	SESS SITES	NORAD PLUS 13 OTHERS
23. SOLAR FLARE SUMMARY	SESS SITES	NORAD PLUS 9 OTHERS
24. SOLAR RADIO FLUX SUMMARY	SESS SITES	AFSCF & VANDENBERG AFB
25. FIXED FREQUENCY SOLAR RADIO BURST SUMMARY	SESS SITES	AFSCF, VAFB, NORAD
26. SWEEP-FREQUENCY SOLAR RADIO BURST SUMMARY	SESS SITES	VANDENBERG
27. SOLAR PROTON OBSERVATORIES	GOES	AFSCF
28. SATELLITE SOLAR PARTICLE BULLETIN	VARIOUS SATELLITES	AFSC PLUS 5 OTHERS
29. AURORAL OVAL ANALYSIS	DMSP	NORAD
30. SHORT-TERM HF ADVISORY	GOES	MAC PLUS 22 OTHERS

PRODUCT	DATA SOURCE	PRIMARY CUSTOMER
31. ELECTRON DENSITY PROFILE FORECASTS	SESS SITES AND OTHERS	SPACE COMMAND
32. SATELLITE EMPHEMERIS DATA	NASA, NOAA, EUROPEAN SPACE AGENCY	KENNEDY SPACE FLIGHT
33. MAJOR GEOMAGNETIC STORM	SESS SITES	SAC
34. POLAR CAP ABSORPTION EVENT	THULE, GOES	SAC
35. PROTON EVENT	SESS SITES AND OTHERS	SAC
36. SEVEN-DAY OUTLOOK	SESS SITES AND OTHERS	AFCC PLUS 12 OTHERS
37. SUNSPOT NUMBER PREDICTION BULLETIN	SESS SITES AND OTHERS	AFCC PLUS 19 OTHERS
38. MAJOR CHANGE IN TOTAL ELECTRON CONTENT	SESS SITES AND OTHERS	NORAD
39. IONOSPHERIC DATA (f_oF_2 AND M-FACTOR)	SESS SITES AND OTHERS	SHEMYA, PATRICK, VANDENBERG
40. SCINTILLATION FORECAST	SESS SITES AND OTHERS	SAC, AFSCF

FORECAST CENTER PRODUCTION



SOLAR OBSERVING OPTICAL NETWORK

SOON BACKGROUND & PURPOSE

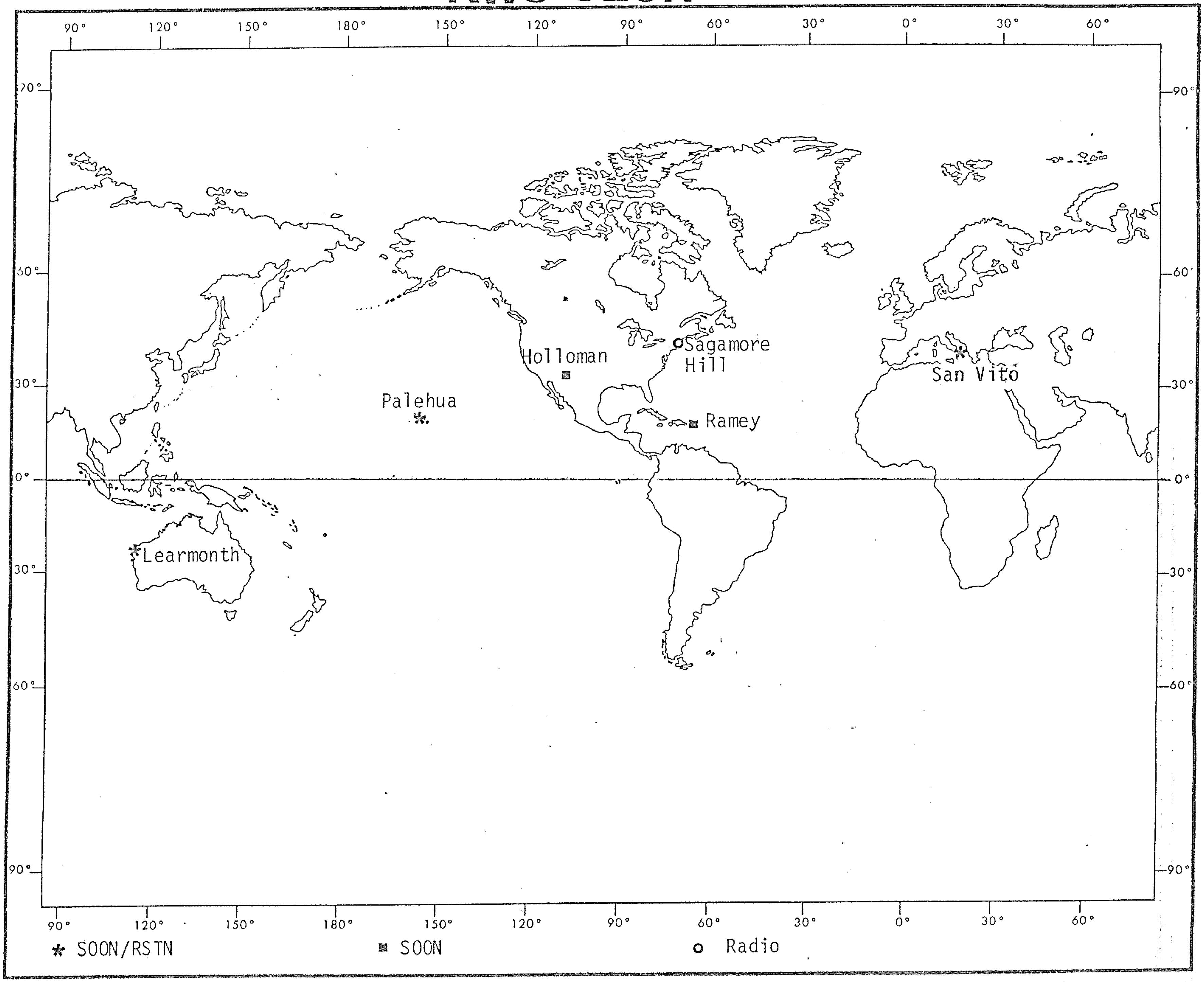
BACKGROUND

1. SOLAR VARIATIONS AFFECT MILITARY OPERATIONS
2. NEED FOR RAPID NOTIFICATION
3. SYSTEMATIC OBSERVATIONS FOR FORECASTING
4. LIMITED OPTICAL CAPABILITY

PURPOSE

1. REPORT SOLAR DATA CONTINUOUSLY, SYNOPTICALLY, AND AUTOMATICALLY
2. STANDARDIZED EQUIPMENT AND PROCEDURES
3. MAINTAINED, SUPPORTED BY U.S.A.F. LOGISTICS

AWS SEON


Learmonth
Palehua
Holloman
Sagamore Hill
Ramey
San Vito
* SOON/RSTN
SOON
Radio

AN/FRR-95 (RSTN) DATA

EQUIPMENT:	FREQUENCIES:
28 FT ANTENNA	245 MHZ
	410 MHZ
	610 MHZ
8 FT ANTENNA	1415 MHZ
	2695 MHZ
	4995 MHZ
	8800 MHZ
3 FT ANTENNA	15400 MHZ
SWEEP FREQUENCY INTERFEROMETER	25-75 MHZ

NON-SOON/RSTN NETWORKS

IONOSPHERIC

VI SOUNDERS, RIOMETERS, POLARIMETERS

SATELLITES

X-RAYS, SOLAR WIND, ENERGETIC PARTICLES,
MAGNETIC FIELDS, COMMUNICATIONS

MAGNETOMETERS

EARTH'S MAGNETIC FIELD VARIATIONS

MISC: RADAR, HF RADIO, "HAMS."

SESS COMMUNICATIONS

1. TELETYPE

   DEDICATED CIRCUIT SITES TO ADWS, THEN AWN TO AFGWC. DIRECT COMPUTER/CIRCUIT INTERFACE PLUS BACK-UP EQUIP. NOAA/AFGWC SELDADS II CIRCUIT.

2. TELEPHONE

   PRIMARILY AUTOVON. AFGWC, 4WW/WS, AND PALEHUA WORLD-WIDE. CONUS LIMITED HOLLOMAN AND RAMEY. LEARMONTH SATELLITE.

3. NOAA HOTLINE

   SIX CONUS DROPS. CAN BE USED FOR PHOTOFAX OR TELE-COPIER TO NOAA AND AFGWC.

4. SELSIS

   DIGITAL IMAGE STORAGE AND TRANSMISSION. HOLLOMAN, LEARMONTH, AND KITT PEAK TO NOAA.

SESS/SOON-RSTN History

1948 - Dr. Menzel (Harvard U.) proposed that the AF build a solar observatory. AWS helped with the briefings and later in the site surveys for the solar observatory at Sacramento Peak NM.

1958 - Just after the first Sputnik launch, AF asked AWS to consider extending its mission. AWS made a comprehensive proposal, but the only part approved was to begin training AWS officers in geophysics and astrophysics.

1960 - The AWS mission statement (AFR 23-1) was changed to include "Special support to the Air Force in closely related scientific fields, including geophysics and astrophysics, as directed by Chief of Staff USAF". The Space Physics Branch was established at HQ AWS, a one man unit.

1962 - The first Solar Forecast was Issued (1 Oct 62) (as a test). Addressees: Det 1, 4WW, Ent AFB, Det 11, 4W Group, Patrick AFB; Space Systems Division (SSD), LA California; 6549 Aerospace Test WG, Sunnyvale CA; in November, they decided to continue the test indefinitely.

1963-64 - There was an increase in interest in Solar data. SSD wanted Ap and F10 observations. Sunnyvale complained that solar flare reporting was much too slow because they needed reports within one hour. Several customers were added to the daily forecasts. Solar forecasting effort moved to 4WW at Ent AFB and consisted of two people.

1965 - First SESS training courses were held. AWS people were sent to augment existing observatories. Solar Forecast Facility was organized (four people).

1966 - More training courses were conducted and more people were sent to augment observatories. Solar Forecast Facility moved to Cheyenne Mt.; Det 7, 4WW and OLs were established:

OL 10 - Cheyenne Mt, Colorado
OL 1 SAC Peak, New Mexico
2 Sagamore Hill, Massachusetts
3 Maui, Hawaii
4 Athens, Greece
5 Manila, Phillippines
6 El Segundo, California
7 Ramey, Puerto Rico
8 Ft Davis, Texas - never manned
9 Tehran, Iran

24 hours-a-day operation began for the forecast facility at Cheyenne Mt.

1968 - Ionospheric work began with the 440L forecast (Ionospheric MUF/LUF Forecast). There were 46 officers and enlisted at 11 different locations, worldwide.

1969 - Administrative control of overseas sites was given to 1st and 2nd Weather Wings. More emphasis was placed on ionosphere, now a 24 hrs/day operation. MAC/ROC authorizes SOON development.

1970 - The first 24 hour High Frequency radiowave propagation forecast for public release was made. Det 7 deactivated and 4WW became SESS manager.

1971 - SOON cost estimated at $461,700 per system.

1972 - NOAA and AWS agreed to cooperative SESS forecasting. Boulder (NOAA) got the Solar Forecast mission, while AWS kept the ionospheric mission. 4WW is disbanded and 12th WS became SESS manager.

1973 - Forecast Center moved to AFGWC, to use the greatly increased computer power available there. Unitech, Inc. of Austin TX awarded contract to supply SOON computer system.

1974 - Many new customers. Data Monitors were added to handle increased data as we approach solar maximum. There now are about 85 AWS and 15 AFCS people working full time in SESS activities as well as several STAFF METS who require SESS training and experience. NOAA had originally planned to fund for two of the telescopes, but dropped out in February 1974. During this time period, it was also decided to locate the CONUS site at Holloman rather than La Posta. Completion date slippage began to become a problem in 1974, but the prototype design test and evaluation was finally conducted at Sacramento Peak at the end of the year.

1975 - Events moved a little faster. In February, the SOON and RSTN systems were combined into one network. An abbreviated operators training course was also conducted at Sacramento Peak in February. The Initial Operational Test & Evaluation (IOT&E) Plan was approved and the SOON building at Palehua was finished in April. ESD, ATC, AFGL, and AFLC participated in the AWS IOT&E in May and June. The Palehua telescope became operational in July, and AWS bought their first AN/FMQ-7 in October.

1976 - The production approval for four additional telescopes was given in February. In view of the decreasing USAF role at Sacramento Peak and the need for an affiliation closer to the standard logistics system, the Naval Avionics Facility, Indianapolis (NAFI - now NAC, for Naval Avionics Center) was contracted to provide the mechanical assemblies and technical data. The first SOON maintenance and operator training courses were conducted at Palehua by ATC in October and November 1976.

1977 - Det 7, 12WS was activated on 1 April. The telescope acceptance testing was completed and declared operational in October. Hectic was the word for October, November, and December with the testing, maintenance, operations, and concurrent Ramey maintenance and operator training in progress. The agreement to establish the Learmonth, Australia site was signed in October.

1978 - The third AN/FMQ-7 became operational at Ramey PR in January. Dr. Dunn (AURA) began the magnetograph installation on the Holloman telescope in August. Operator training for the first contingent of personnel for the Learmonth site was conducted in September - October. A demonstration of the "Mapping" project was held on 12 October. The second group of Learmonth operator and maintenance personnel were trained in October - November - December.

1979 - The Learmonth RSTN began limited operations in August. The AN/FMQ-7 was shipped in late September, with an operational target date of November. Training for the last group of operators was conducted in July and August. The Holloman magnetograph became fully operational in July.

1980 - The Holloman and Ramey observatories were shifted to 3rd Weather Wing in April, and the Ramey magnetograph becomes operational. Learmonth finally gets their SOON telescope "on-line" in August, 1980. No Mid East site yet.

1981 - Palehua's magnetograph is installed in early 1981, but they lose their electric power smoother when it rolls off a truck taking it in for repairs. A requirement is submitted to upgrade Holloman and Ramey to the HP21MX computer systems. The fifth SOON telescope is basically ready for installation but there still is no place to put it.

1982 - Radio interference tests published in early 1982 rule out Holloman as a practical RSTN site. Site surveys for a Mid East location continue.

1983 - San Vito, Italy selected as Mid East SOON/RSTN site, with an expected operational date in 1986. 4th Weather Wing reactivated with the intent of becoming single SESS manager. CONUS sites and Ramey come under 4WW effective 1 October.

1984 - Remaining SESS sites under 4WW effective 1 April.

1985 - Computer upgrade to HP21MX started at Holloman 1 July. San Vito site construction with November completion target.

1986 - Det 8 (San Vito) activated 1 Jan. IOT & E conducted in June; fifth site becomes operational, and the SOON/RSTN is <u>finally completed!</u>