

## Chapter 15

# MISSILE WARNING SYSTEMS

This chapter will address the missile warning systems which U.S. Space Command (USSPACECOM) controls in support of the North American Aerospace Defense Command (NORAD) agreement to protect the Continental U.S. and Canada from ballistic missile attack. Also covered are systems developed for theater-level missile defense developed in accordance with the Missile Defense Act of 1991, as amended by Congress in 1992, for the protection of forward deployed U.S. forces and it's allies.

### SPACE-BASED WARNING SENSORS

#### Defense Support Program (DSP)

The Defense Support Program (DSP), with a system of geosynchronous satellites, is a key part of North America's Early Warning System. In approximate 22,000 mile geosynchronous orbits, DSP satellites (**Fig. 15-1**) serve as the continent's first line of defense against ballistic missile attack and are normally the first system to detect missile launches. The system's effectiveness was proven during the Persian Gulf conflict, when DSP detected the launch of Iraqi Scud missiles and provided timely warning to civilian populations and coalition forces in Israel and Saudi Arabia. In addition to missile launches, the DSP system also has numerous sensors on board to detect nuclear detonations (NUDETs).

DSP ground stations feed processed missile warning data via communications links which include the Survivable Communications Integration System (SCIS) and MILSTAR satellites. These reports are sent to USSPACECOM and NORAD operations centers at Cheyenne Mountain Air Station (CMAS), Colorado, the Alternate Missile Warning Center (A/MWC) at Offutt AFB, Nebraska and other forward users.



**Fig. 13-1 DSP Satellite**

These centers immediately forward the data to various agencies and areas of operations around the world. The DSP program came to life with the first launch of a DSP satellite in the early 1970s. Since that time, DSP satellites have provided an uninterrupted early warning capability that has helped deter superpower conflict.

Over the years, the DSP system has seen many improvements in both the satellites as well as the ground stations. Initially, there were phase one and phase two, first and second generation, satellites weighing approximately 2,000 pounds with solar paddles generating about 400 watts of power. Then came the third generation satellite called Multiple Orbit Satellite/Program Improvement Module (MOS/PIM). Despite the multiple orbit option available on this generation of satellites, it was never exercised. This generation of satellite brought in, among other things, the anti-jam command capability known as CI-1. CI-1 was continued as part of the fourth

generation of satellites known as Sensor Evolutionary Development (SED). The major improvement in this generation was the increase in primary focal plane cells from 2,000 cells to 6,000 cells. Along with the increased cell count was the experimental Medium Wave Infrared (MWIR) package, also known as second color, which was placed on Satellite 6R/Flight 12. This package was a proof-of-concept for implementation on the fifth and final generation of DSP satellites, DSP-1. We refer to this fifth generation as the final generation of DSP satellites because of the development of the Space Based Infrared System (SBIRS), the DSP follow-on which will be discussed later.

The DSP-1 era started with Satellite 14 and will extend through Satellite 23 if all DSP-1 satellites currently in the hanger are launched. DSP-1 brought new innovations to the program: the AFSAT Modulation Compatibility Sub System (AMCSS), introduced to support data requirements of the Mobile Ground System (MGS) as well as local and global summary messages. The AMCSS also provided the replacement for the CI-1 anti-jam commanding system for use by the Large Processing Stations (LPS), such as the Continental U.S. (CONUS) Ground Station (CGS) and the Overseas Ground Station (OGS). The OGS was closed on 1 Oct 99 and the data is now relayed back to the CGS for processing. The satellite downlinks, Link-1 and 2, were changed significantly. Each was broken into two channels, I and Q. The format for Link-1/2 I and Q channels is Quadra Phase Shift-Keyed (QPSK). The purpose for the dual channel downlinks was to support the laser crosslink. The I channel was to support the local satellite and the Q channel was to carry the data from the remote satellite. The laser crosslink project never succeeded and was eventually canceled. The I and Q channels now carry local satellite data only. Another new innovation was the semi-

active cooling system. Previous generations of the satellite relied on an ice pack-type of device, which, via freezing and thawing, would maintain the focal plane temperature at  $-100^{\circ}\text{F}$ . Unfortunately, at the end of the satellite design life, the focal plane "ice pack" was at its end of life, leaving the focal plane temperature to rise. A rise in the focal plane temperature causes mission degradation.

DSP satellites have routinely exceeded their design life by many years. Launched in December 1984, DSP Flight 12 for example, was on orbit and operational for well over twelve years and its original design life was three years. The design life on DSP-1 era birds is five years. There are currently three DSP-1 satellites that have surpassed their design life. DSP Satellite 14 for example is now going on its tenth year of operational service. As the capabilities of the DSP satellite have grown, so has their weight and power. Unlike the old lightweight, low power satellite, the new generation of DSP satellite weighs over 5,000 pounds and the solar arrays generate more than 1,400 watts of power.

On the ground station side of the DSP house, there have been many upgrades as well. In the early to late 1980s, two programs, the Large Processing Station Upgrade (LPSU) and the Peripheral Upgrade Program (PUP), were executed. These programs resulted in the total replacement of the OGS and CGS suite of mainframe computers and all peripheral devices. This was followed by the replacement of the Satellite Readout Station (SRS) hardware and software under the SRS Upgrade (SRSU) program. Also, the Data Distribution Center (DDC) received a makeover with replacement of all hardware and software under the Ground Communications Network Upgrade (GCNU) project (1990-1992). In the 1980s, the Simplified Processing Station (SPS) was replaced with the European Ground Station (EGS). The SPS, a fixed version of

the MGS, was housed in a shelter and used the MGS software suite. The upgrade replaced the shelters, hardware and software completely.

### *Mission of DSP*

The primary mission of DSP (Mission A) is to detect, characterize and report in real time, missile and space launches occurring in the satellite Field Of View (FOV). DSP satellites track missiles by observing infrared (IR) radiation emitted by the rocket's exhaust plume. IR is a small part of the large electromagnetic (EM) spectrum.

DSP also has an additional mission (Mission B) of detecting, characterizing and reporting nuclear detonations in support of Nuclear Test Ban monitoring.

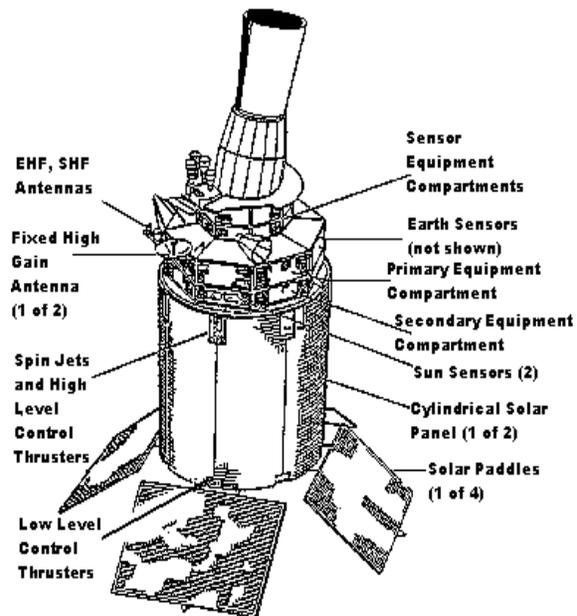
### *The DSP Satellite*

The DSP satellite is approximately 33 feet long, 22 feet in diameter, weighs over 5,000 pounds and is comprised of the satellite vehicle also referred to as the bus and the sensor (**Fig. 15-2**). The bus is made up of many subsystems that provide power, attitude control, thermal control and communications for the satellite and sensor.

The satellites are placed in a near circular, near equatorial, geosynchronous orbit. Global coverage can be efficiently achieved with three satellites. Additional satellites can provide dual coverage, providing for more accurate processing potential.

The Attitude Control Subsystem (ACS) maintains the spinning motion of the satellite about its earth-pointing axis. The satellite spins one revolution every ten seconds (6 rpm). The sensor bar, containing all the infrared (IR) detector cells, is fixed firmly to the satellite body. The spinning of the satellite then allows the slightly tilted boresight of the sensor bar to scan the entire hemisphere perimeter. The telescope is not aligned along the Z-axis (earth pointing axis) but

is tilted slightly off center. This tilt allows coverage by the sensor out past the lim (edge) of the earth. Cells in the center of the sensor bar are placed in such a way as to cover the NADIR (center of the FOV) area called NADIR fill.



**Fig. 15-2. Defense Support Program Satellite**

### *DSP-1 Sensor Overview*

The sensor (**Fig. 15-3**) detects sources of IR radiation. A telescope/optical system and a Photoelectric Cell (PEC) detector array, comprised primarily of lead sulfide detectors and some Mercad-Telluride cells for the MWIR detection capability, are used to detect IR sources. IR energy enters the opening in the IR sunshade, passes through the corrector lens, travels past the PEC array, reflects off the mirror and is focused onto the PEC array.

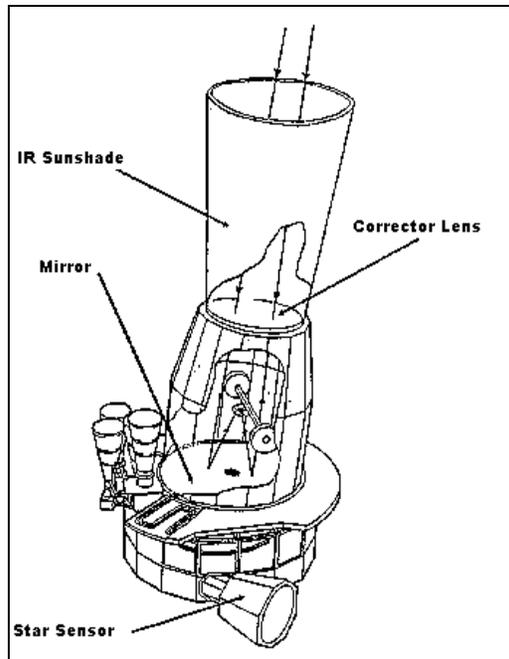


Fig. 15-3. DSP Sensor Schematic

A PEC array (Fig. 15-4) contains more than 6,000 detector cells. The cells are sensitive to energy in the infrared spectrum. As the satellite rotates, the earth's surface is scanned by this array. With the PEC array scanning the FOV, a cell passing across an IR source will develop a signal with an amplitude proportional to the source's intensity. The signal is then amplified, passed through an analog to digital converter and placed on the Link-1 downlink for transmission to the ground station.

The intensity of the IR energy is measured in kilowatts (kW). A standard unit of measure for the area of a sphere (IR energy radiated omni-directionally) is a steradian. Therefore, the intensity of the IR energy per unit area can be expressed in kilowatts per steradian (kW/s).

#### *Communications Subsystem Overview*

The satellite has transmitters, receivers and antennas for six encrypted communication links used to downlink satellite data and receive uplink command

instruction. The links perform as follows:

- Link 1 Downlink - transmits the following data: IR data (Mission A), NUDET sensor data (Mission B), star sensor data, jet firing and calibration alert data.
- Link 2 Downlink - transmits state of health (SOH) information obtained from voltage, current and temperature sensors and various other status monitors.

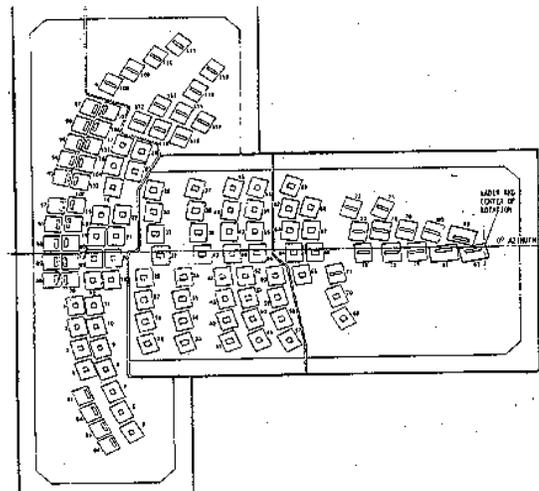


Fig. 15-4. PEC Array

- Link 3 Uplink - transmits satellite and sensor commanding data from the ground station to the satellite.
- Link 4 Downlink - satellite has two onboard impact sensors, which are basically accelerometers, to detect impacts on the satellite from space debris. Link 4 is the link on which this data is transmitted.
- Link 5/6 - link associated with the canceled laser crosslink system. Equipment removed and replaced with ballast.
- Link 7, 8 - serve as a backup or secondary set of communications links called the Mission Data Message (MDM) rebroadcast system.

MDM consists of an uplink and downlink, which serve as a transponder to exchange information between various ground stations.

### *DSP Ground Stations*

DSP ground support now consists of one Large Processing Station (LPS) CGS, a simplified processing station known as EGS, and a Mobile Ground System (MGS). The CGS has responsibility for processing and reporting satellite mission data as well as commanding operational DSP satellites within its line of sight. The second processing station, EGS (location classified), has mission data responsibility, but does not have satellite commanding or the NUDET detection processing capability. The CGS has three main functional elements.

Satellite Readout Station (SRS). The purpose of the SRS is to perform the satellite communications and data conditioning function. Conditioned data is forwarded to the DRC for processing. The SRS at CGS has been upgraded as part of the SRS Upgrade (SRSU) program in the early to mid 1990s.

Data Reduction Center (DRC). The DRC operates as a vital part of DSP mission processing. The DRC accomplishes the following:

- Extracts significant data from the mission data stream regarding missile launches and nuclear detonations.
- Either automatically or via operator intervention, generates mission event and status messages for transmission to the users.
- Processes data to support satellite station-keeping and pointing functions.
- Processes data to support ground station equipment checkout and housekeeping.

Satellite Operations Center (SOC). The SOC houses the mission processing crew that evaluates and releases all DSP mission data. This center is the focal point for all ground station operations.

The MGS, located out of Greeley ANG, CO consists of six fully deployable units (tractor trailer rigs). The MGS is assigned to the 137<sup>th</sup> Space Warning Squadron. Once deployed, an MGS SOC can send its data back to the DDC or directly to the Missile Warning Center at Cheyenne Mountain Air Station (CMAS) via satellite broadcast methods.

### *Data Distribution Center (DDC)*

The DDC, collocated with CGS, functions as a communications center for all elements of the DSP system. The DDC routes mission data from the ground stations to the users. The DDC contains dual data processors that process both High Speed Data (HSD) and Low Speed Data (LSD), secure-voice terminals and a secure-teletype communications center. Dedicated and encrypted data, voice and teletype links from the ground stations are routed to the DDC. The DDC then retransmits these messages to the users.

### *Ground Communications Network (GCN)*

The GCN provides all required communications capability between the ground stations, DDC and the users. Primarily, the network consists of inter-site communication circuits (land lines and satellite links), modems, cryptographic equipment, data terminals and a Technical Control Facility (TCF). The hub of the GCN is the DDC. Data, secure voice, and secure teletype circuits from the ground stations to the DDC are routed over dual, diverse, dedicated and encrypted links.

Another portion of the GCN is the Survivable Communications Integration

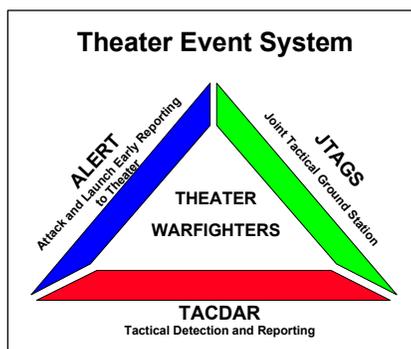
System (SCIS). CGS has a SCIS device to broadcast DSP message traffic to forward users. The GCN is the primary mode for transmission of DSP data. The backup for broadcast is the SCIS commercial high speed data circuits. From EGS there are still GCN HSD circuits in place to ship HSD directly to the DDC High Speed Message Processor (HSMP). This function of the GCN is still active because the only way to get DSP data to the Low Speed Message Processor (LSMP) and all the LSD users is through the HSMP at the DDC.

### Theater Missile Warning

Due to the growing need to get the smaller tactical threat of theater class ballistic missiles out to the warfighter, the Theater Event System was created.

#### *Theater Event System (TES)*

The TES (**Fig. 15-5**) provides highly accurate tactical threat data through the use of stereo processing of the Defense Support Program (DSP) satellite data. The TES is composed of three elements: Attack and Launch Early Reporting to Theater (ALERT), the Joint Tactical Ground Station (JTAGS), and the Tactical Detection and Reporting (TACDAR).



**Fig. 13-5. TES**

All three legs rely on IR detection for detection and profiling of theater ballistic missile launch.

**ALERT.** The ALERT facility is run by the Air Force's 11<sup>th</sup> Space Warning Squadron at Schriever AFB, CO and provides for a central CONUS processing element sending worldwide tactical missile threat data 24 hours a day.

**JTAGS.** JTAGS is the mobile, in-theater element of TES and provides the theater CINC a direct downlink of DSP data for in-theater processing. ARSPACE has operational control of the JTAGS (**Fig. 15-6**).



**Fig. 15-6. Joint Tactical Ground Station**

**TACDAR.** TACDAR is an additional sensor that can provide missile launch reports. The TACDAR sensor rides on a classified host satellite and therefore will not be discussed in this reference. Inquiries on TACDAR may be forwarded through USSPACECOM/J33.

#### *How do I get TES Data?*

The TES has the primary mission of reporting theater/tactical type threats. For theater warning, the TES system (ALERT, JTAGS, or TACDAR) reports the launch (voice and data) in theater over two types of satellite broadcast networks known as the Tactical Data Dissemination System (TDDS) and/or

the Tactical Information Broadcast Service (TIBS). Theoretically, one event could be reported by all three TES elements, but the “first detect--first report” procedures help control and deconflict multiple reports of the same event.

Warning data goes out over the theater satellite broadcast networks and can be incorporated in battle management systems such as Air Defense Systems Integrator (ADSI), the Constant Source Terminal, the Combat Intelligence Correlator (CIC), and the Airborne Warning and Control System (AWACS). The Air Force’s ALERT Facility (11<sup>th</sup> SWS) is under the 21<sup>st</sup> SW for TES reporting.

#### *TES Capabilities/Limitations*

**ALERT.** ALERT is dependent upon the DSP ground sites for receipt of DSP data. The DSP Ground Stations, TACDAR, and ALERT are all fixed ground sites. Critical spares, redundant power supplies, and logistics support infrastructures (including the use of the Mobile Ground Stations to reconstitute strategic warning) are in place for each of these sites. If a ground site outage occurs and it prevents getting a particular DSP satellite’s data, then ALERT could also use 1st Satellite Operations Squadron (1SOPS), 50 SW, and the Air Force’s Satellite Control Network (AFSCN) to receive the needed downlink. However, use of the AFSCN is based on a priority scheme, and there will be times when ALERT will not get a contested AFSCN antenna.

**JTAGS.** To get a JTAGS into theater, a warfighting CINC simply requests for the deployment. JTAGS is deployed on a C-141 or larger aircraft, and sets up to roughly the size of a small moving van. The JTAGS once in theater becomes the Joint Task Force’s Ground Component Commander’s asset. As such, the CINC is responsible for manning, power, and security requirements. JTAGS is dependent on a clear view to

the DSP satellites in their geosynchronous orbits. The direct downlink must have a clear path to the antenna, unblocked by hills, trees, or buildings. JTAGS allows the TES to be integrated (hard wired) into theater assets including those mentioned above. Hard-wiring allows the quickest dissemination of early warning data. Based on this warning data, a voice warning over in-theater communication networks could also be set up.

**TACDAR.** TACDAR information is limited in that it cannot be directly downlinked into theater. Processing must occur in the CONUS and then the information relayed across the satellite broadcast network following report processing.

Questions regarding TES data, the satellite broadcast network, and TES data receivers should be addressed to USSPACECOM (J3CP/J3M), HQ USSPACECOM, PETERSON AFB CO//J33OW//, DSN 692-6987, or COML 719-554-6987.

#### **Space-Based Infrared System (SBIRS)**

SBIRS will be the DSP follow-on system for the future. SBIRS is a consolidated, flexible system that will meet U.S. infrared space surveillance needs through the next several decades.

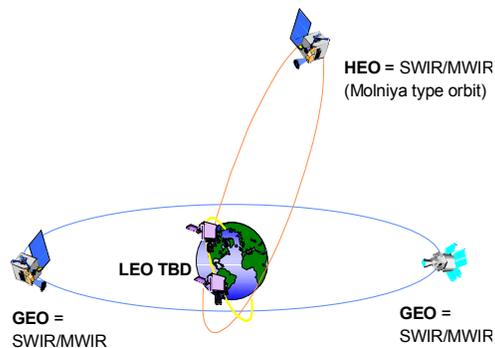
#### *SBIRS Mission*

The SBIRS mission is to develop, deploy, and sustain space-based surveillance systems for missile warning, missile defense, battlespace characterization, and technical intelligence. The SBIR High Engineering and Manufacturing Development (EMD) contract, awarded in November 1996, will be a 10-year effort. SBIRS is intended to be an integrated “system of systems” including multiple space constellations and an evolving ground element. The integrated SBIRS architecture will pro-

vide Theater Missile Defense (TMD) track data after target acquisition to the interceptor systems and Defense Battle Manager, cueing interceptors to commit and launch earlier than autonomous radars alone. This cueing effectively extends an interceptor's range and increases its effectiveness.

### *SBIRS Architecture*

The baseline SBIRS architecture (**Fig. 15-7**) includes four satellites in Geosynchronous Earth Orbit (GEO), a yet to be determined number of Low Earth Orbit



**Fig. 13-7. Space Based Infra-Red System**

(LEO) satellites, a set of infrared sensors hosted on two satellites in Highly Elliptical Orbit (HEO) and ground assets.

The ground assets include:

- CONUS-based Mission Control Station (MCS), a backup and survivable control station
- Overseas Relay Ground Stations (RGS)
- Relocatable terminals
- Associated communications links

The SBIRS High Component element, featuring a mix of geosynchronous Earth Orbit (GEO) satellites, Highly Elliptical Earth Orbit (HEO) satellites, and a new consolidated Ground Process-

ing station, will incrementally replace the existing DSP infrastructure over the FY99 - FY04 time frame. The first SBIRS GEO launch is scheduled for 2004. This element is the first of two planned elements that will provide an enhanced follow-on capability to the current DSP system.

The SBIRS low component is envisioned to provide a unique, precision midcourse tracking capability critical for effective ballistic missile defense as well as providing enhanced capability to support missile warning, technical intelligence and battlespace characterization.

The Common Ground Segment will be delivered incrementally. The first increment consolidates DSP and Attack and Launch Early Reporting to Theater (ALERT) mission functions at one CONUS ground station, the MCS, and is scheduled to become operational in Nov 2001. A second increment will be accepted for operation by the government around the 2004 timeframe and provides all ground segment functions necessary for high altitude space-based IR early warning elements. The ground segment has the ability to incorporate functions and equipment in a third increment necessary for the Low space element when it is deployed.

### **GROUND BASED WARNING SENSORS**

#### *Ballistic Missile Early Warning Systems (BMEWS)*

Independent studies conducted by both the U.S. and the U.K. in the 1950s indicated the need for ballistic missile early warning facilities. The U.S. study concluded that a three radar system should be built across the northern tier. The U.K. study indicated the need for a single facility located in England. After subsequent negotiations between the two governments, the BMEWS network was born.

BMEWS Site I is located at Thule AB, Greenland (**Fig. 15-8**). Site II is at Clear AFB, Alaska and Site III is at RAF Fylingdales in the U.K. These sites originally used separate detection and tracking radars but were both upgraded to phased array technology in the late 1980s to early 1990s.



**Fig. 15-8. BMEWS, Thule AB, Greenland**

The 12th Space Warning Squadron (12SWS) at Thule now operates a dual face, solid state, phased-array radar (AN/FPS-123). The 13SWS at Clear operates three detection radars (AN/FPS-50s), each 400 ft long and 165 ft high. Clear also operates a tracking radar (AN/FPS-92) that is 84 ft in diameter and weighs 100 tons. Under the Clear Upgrade Program, Clear will upgrade to a dual-faced phased array radar. The project, started in FY98, will use existing equipment from El Dorado Air Station's PAVE PAWS radar (PAVE PAWS South West) since it was deactivated and has transitioned into cold storage. The new dual faced phased array radar in Alaska is scheduled to be completed by Jan 2001. Royal Air Force (RAF), Fylingdales is the site of the world's first three-faced phased array radar (AN/FPS-126). The Initial Operating Capability (IOC) was carried out in July 1992 and Joint (U.S./U.K.) Operational Capability (JSOC) in November 1992.

BMEWS provides warning of an Intercontinental Ballistic Missile (ICBM) attack on the CONUS and Southern Canada. BMEWS also provides warning of a Sea-Launched Ballistic Missile

(SLBM)/ICBM attack against the U.K. and Europe. BMEWS' tertiary mission is to conduct satellite tracking as collateral sensors in the Space Surveillance Network (SSN).

### *PAVE PAWS*

Increasing technology provided the Former Soviet Union (FSU) with the capability to launch ballistic missiles from an underwater Sea-Launched Ballistic Missile (SLBM) platform. Studies indicated the need for dedicated early warning facilities to detect such an attack. The first two sensors, Otis and Beale, came on line in 1980 with an additional two, PAVE PAWS South East (PPSE) and PAVE PAWS South West (PPSW) following seven years later. PPSE and PPSW have since been deactivated and closed (1995).

PAVE PAWS NE (**Fig. 15-9**) is located at Cape Cod AS, Massachusetts and is operated by the 6SWS. PAVE PAWS NW is at Beale AFB, California and is run by the 7SWS. Both sites operate a dual-face, phased-array radar (AN/FPS-123).



**Fig. 15-9. PAVE PAWS, Cape Cod AS**

The 6SWS is atop Cape Cod's Flitcraft Hill. The 6SWS occupies 120-plus acres of what was once Otis Air Force Base, and is now the Massachusetts Military Reservation. The squadron receives host-tenant support from Hanscom Air Force Base, Otis Air National Guard Base and from the U.S. Coast Guard Station on Cape Cod.

PAVE is an Air Force program name while PAWS is an acronym for Phased Array Warning System.

The primary purpose of PAVE PAWS is to detect an SLBM attack, determine the potential numbers and probable destination of the missiles, then report this information to NORAD, U.S. Strategic Command (USSTRATCOM) and the National Command Authority (NCA). Additionally, PAVE PAWS provides information on the location and velocity of earth-orbiting satellites to USSPACECOM and the Space Control Center (SCC) at Cheyenne Mountain AS, Colorado.

The main difference between phased array and conventional radar is that phased array systems like PAVE PAWS are steered electronically. The phased array radar incorporates nearly 3,600 small, active antenna elements coordinated by two computers. One computer is on-line at all times and the second computer will automatically take control if the first fails. The computers feed energy to the antenna units in precise, controlled patterns, allowing the radar to detect objects at very high speeds since there are no mechanical parts to limit the speed of the radar sweep. The PAVE PAWS radar can electronically change its point of focus in milliseconds, while conventional dish-shaped radar may take up to a minute to mechanically swing from one area to another.

The PAVE PAWS main building is shaped roughly like a pyramid with a triangular base 105 feet on each side. The two radiating faces, each containing approximately 1,800 active antenna elements, are tilted back  $20^{\circ}$  from the vertical. PAVE PAWS radar beams reach outward for approximately 3,000 nautical miles in a  $240^{\circ}$  sweep. At this extreme range, it can detect an object the size of a small automobile. Smaller objects can be detected at closer range.

*Perimeter Acquisition Radar Attack Characterization System (PARCS)*

PARCS is located just 20 miles south of the Canadian border at Cavalier AS, North Dakota. PARCS (**Fig. 15-10**) was originally built as part of the Army's Safeguard Anti-Ballistic Missile (ABM) system. In 1976, the ABM system was deactivated and the sensor became available for Air Force use in December 1977. PARCS' primary mission is to provide warning and attack characterization of an SLBM/ICBM attack against the U.S. and southern Canada. Its secondary mission is to track earth orbiting objects for the Space Surveillance Network (SSN).

PARCS is a single-faced, phased array radar. The radar, communications equipment, computer and operations room are housed in a reinforced concrete building. The single-faced radar is northern looking over the Hudson Bay,



**Fig. 15-10. PARCS Radar Site**

and is sloped at a  $25^{\circ}$  angle. Due to its initial design as part of the ABM system, it can rapidly characterize the type of missile attack for use by NORAD and the National Command Authorities. Also, due to its greater power and rapid scan rate, PARCS is one of the most valuable sensors in the SSN.

## Summary

The DSP strategic ICBM processing sites, the TES tactical ballistic missile processing sites, and the host of missile warning radar sites around the globe provides the world's most sophisticated

missile warning system for the National Command Authorities, Unified Commanders and the entire joint military community.

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