APPENDIX B

DEPARTMENT OF DEFENSE WEATHER PROGRAMS

The Department of Defense (DOD) operates a military environmental service system to provide specialized worldwide meteorological, space environmental and oceanographic analysis and prediction services in support of military forces. This system directly supports all phases of military operations, from strategic planning to tactical operations. While the Army and Marine Corps each have a small specialized weather support capability, the Naval Meteorology and Oceanography Command and Air Force Weather are the primary sources of military weather products. The military weather services contribute to the national and international weather observing capability by taking conventional observations on land and at sea where there are no other conventional weather observing capabilities and where the observations are most needed to meet military requirements. In addition, DOD maintains specialized observing capabilities, such as the Defense Meteorological Satellite and Global Weather Intercept Programs, to meet unique military requirements. Observational data are sent by military communications networks to military and civil facilities in the United States and overseas.

UNITED STATES AIR FORCE

METEOROLOGICAL SERVICES

The Air Force functional manager for meteorological and space environmental services is the Director of Weather (HQ USAF/XOW), within the HQ USAF, Deputy Chief of Staff for Plans and Operations. HQ USAF/XOW oversees the development and implementation of weather support concepts, doctrine, policies, plans, and programs to ensure effective weather support for the Air Force, Army, and other agencies as directed by the Chief of Staff, USAF. The Air Force also provides support to DOD Joint operations as directed by the Joint Chiefs of Staff under the Unified Action Armed Forces (JCS Publication 0-2) document. HQ USAF/XOW also interfaces with other military departments, federal agencies, and international organizations concerning coordination, cooperation, standardization, and interoperability of weather services.

Air Weather Service (AWS), a field operating agency (FOA) reporting to HQ USAF/XOW, provides centralized weather support to designated users through two centralized support organizations: Air Force Global Weather Center (AFGWC) and the Air Force Combat Climatology Center (AFCCC). Air Force Space Command provides space environmental support through the 50th Weather Squadron (50 WS), formerly the Air Force Space Forecast Center.

Observations. Meteorological observations are classified as surface, upper air, radar, or satellite observations. Observation and sensing of the space environment are discussed in the Space Environmental Services section.

Surface observations are taken by Air Force personnel to support military operations and for weather analysis and forecasting. Observations from both Air Force and Army locations (fixed and tactical) are made available to local users and are transmitted to AFGWC and to other military and civil locations throughout the world. There are 160 Air Force- operated surface observing locations or facilities in the continental United States (CONUS) and overseas.

Upper air observations provide a major input for numerical analysis and forecasting. Most of this information comes from U.S. and foreign rawinsonde sources and military and civilian satellite-derived data. Additional upper air information is obtained from military and civilian pilot reports.

Weather radar is a principal source of information for providing warnings of severe weather. By 1997, the Air Force will be operating 29 WSR-88Ds (Weather Surveillance Radar-1988 Doppler) and 148 off-site WSR-88D remote processors. The Air Force also operates approximately 7 conventional weather radars and 3 tactical weather radars. Many of the radars are part of the U.S. basic weather radar network or are used to support the National Hurricane Operations Plan. The tactical weather radars are used to support contingency operations. The Air Force is evaluating concepts for a tactical doppler weather radar which could operate in both mobile and fixed locations.

The Air Force manages the Defense Meteorological Satellite Program (DMSP), which provides a large volume of cloud, upper air, and space environmental data, and is the most important single source of global weather data used for combat support. On-board sensors provide AFGWC and the Navy's Fleet Numerical Meteorology and Oceanography Center (FNMOC) with visible, infrared, and microwave imagery of the entire globe, temperature and moisture sounding data, auroral electron counts, and other specialized space environment data. DMSP also supplies direct, real-time readout of regional image and mission-sensor data to selected land-based and shipborne terminals located worldwide.

The present DMSP satellite series (Block 5D-2) uses an operational linescan system (OLS). The visible detectors were selected to optimize distinction among clouds, ground, snow, and water. It uses both stellar and inertial references, together with on-board processors, to maintain stability and pointing accuracy. The DMSP also flies a microwave temperature and humidity sounder (SSM/T) which provides vertical temperature moisture and height profiles of the atmosphere. The microwave imager (SSM/I) observes rainfall, ocean surface wind speed, cloud and soil moisture, ice conditions, and other environmental data.

Communications. The utility of meteorological information depends on an effective communications network. The USAF global weather communications system provides for the collection of meteorological data from multiple, worldwide sources, delivers these data to weather centrals and forecast facilities, and distributes products to the field. The Air Force communications system consists of conventional alphanumeric networks, high-speed automated digital facilities, long-haul, point-to-point data circuits, facsimile networks, and high-frequency intercept facilities.

The Air Force-operated Automated Weather Network (AWN) is the backbone of military weather communications. Computers inter-connected with 2400 baud to 56 kilobaud circuitry deliver foreign and domestic weather data to designated users. Weather intercept sites in key overseas areas obtain World Meteorological Organization (WMO) weather broadcasts, as well as non-WMO broadcasts, for AWN delivery to AFGWC. The AWN also delivers these data to the Navy and to NOAA's National Centers for Environmental Prediction.

Overseas collection and dissemination networks deliver data to, and exchange data with, the AWN Automatic Digital Weather Switch (ADWS) at Hickam AFB, Hawaii, and RAF Croughton, UK. In the CONUS, the ADWS at Tinker AFB, Oklahoma, provides alpha numeric products to the Automated Weather Distribution System (AWDS), the CONUS Meteorological Data System (COMEDS), and other special teletype systems, and provides direct support to AWDS in the collection and dissemination of weather information. These circuits also collect and disseminate military Notice to Airman (NOTAM) message traffic to all DOD CONUS users.

The Communications Front-End Processor (CFEP) at Offutt AFB, Nebraska, is the hub of all communications at AFGWC. It drives dedicated circuits, the Interdepartmental Meteorological Data Exchange System (IMDES), and the weather chart facsimile system, which provides graphic data to worldwide military users. CFEP also interfaces with the AWN and drives separate graphics networks serving the CONUS, Alaska, Europe, Central America, and the Pacific.

Preparation of Analyses and Forecasts. The primary center for providing weather analyses and forecasts for Air Force and Army operations is AFGWC at Offutt AFB, Nebraska. AFGWC uses a networked computer system and an interactive graphics and imagery system to implement a "build-and-apply" concept. Worldwide weather data are relayed to AFGWC and blended with civil and military meteorological satellite data to construct a real-time, integrated environmental database. Computer programs further digest the data to construct models of the atmosphere and to forecast its future behavior. Manual tailoring of the data is critical for application to the specific needs of the warfighters. The interaction between forecaster and machine is accomplished with the Satellite Data Handling System (SDHS). SDHS consists of approximately 38 interactive workstations capable of high-speed interaction with satellite and conventional meteorological data to prepare forecasts and other environmental products. AFGWC also provides backup for the National Weather Service (NWS) facsimile network, the NWS Automation of Field Operations and Services (AFOS) products, and the National Severe Storms Forecast Center.

In support of DOD combat operations, Air Force Weather operates centralized units consisting of AFGWC, AFCCC, 50 WS, fixed theater Forecast Units (FU), fixed Weather Support Units (WSU), and provides personnel to deployed Joint Meteorological/Oceanographic (METOC) Operations Center (JMOC). Normally weather support is a mix of centrally and locally produced meteorological products. AFGWC is shifting to a regional emphasis with special cells designed for major world regions. These regional cells provide large scale analyses, forecasts and guidance for local meteorologists who apply the information to specific missions. Theater forecast units are specifically named units; e.g., the Korean Forecast Unit, designated to provide forecast services and products from a fixed location for a specific geographical area, tactical operation, or exercise. A JMOC provides the same services as a theater forecast unit; however, it is deployed to support a specific combat operation or exercise which is not or cannot be supported by theater forecast unit. AFGWC directly supports Air Force, Army, and Joint forces when the theater forecast unit lacks support capabilities and when a JMOC is not established.

Dissemination of Forecasts and Warnings. The Air Force and Army require worldwide meteorological services for specific operational and planning activities. Military users require meteorological information directed to the needs of weapon systems being developed or used, command and control systems, Army firing units, research, development and evaluation, testing, training and deployment of military forces, and contingency operations.

Air Force Weather enhances the unique global capability of military aviation while indirectly assisting civil aviation. Air Force personnel provide flight weather briefings, air/ground radio services, and tailored observations, forecasts, watches, and warnings for military operations.

A special aspect of the military weather mission is the need to provide decision assistance to commanders and resource managers. To fulfill this requirement, designated Air Force weather personnel serve as part of the working staff of operational Air Force, Army, and Joint force units. In this capacity, Air Force weather personnel identify all weather-sensitive areas of the operation, monitor the weather service provided in these areas, and provide expert advice to mitigate weather impacts on training or combat operations. This effort helps ensure that Air Force, Army, and Joint force units fulfill their missions regardless of the weather and results in efficient use of weather resources by gearing them to mission needs.

Deployed weather teams are the basic units providing weather support in a combat theater. These teams provide surface and upper air observations, staff weather officer services, and forecasts. The tactical forecast system, tactical weather radar, tactical meteorological satellite direct readout terminals, and tactical communications terminals provide the means to acquire vital meteorological data within a theater. A high frequency radio broadcast (HFRB) system is used to augment AFC4's transmission of alphanumeric and facsimile products to the theater weather force. The HFRB system consists of regional broadcast stations at Andersen AFB, Guam, Elmendorf AFB, Alaska, Elkhorn, Nebraska, and Croughton, England.

Specialized Support. AFCCC, Scott AFB, Illinois, provides environmental data and specialized studies to support the Air Force, Army, and other government agencies. Typical support satisfies requirements for assessments of natural environmental effects on military plans, weapon systems, facilities, and intelligence activities. AFCCC collects environmental data from AFGWC and then sorts, checks, stores, and employs these data to produce tailored products. AFCCC also operates a facility, collocated with the National Climatic Data Center in Asheville, North Carolina, to facilitate cooperation and data exchange. AFCCC typically collects, quality assures, and applies worldwide surface and upper air observations, a three-dimensional (3-D) cloud analysis extracted from meteorological satellite imagery (Real-time Neph-analysis), a global analysis of snow cover, solar, geomagnetic, and space observations and indices, and many other specialized environmental data sets.

The Air Force also supports an array of Air Force and Army specialized requirements. Some of these are described below.

The Army weather support mission is completely integrated into the Air Force's overall mission concept. The Army trains and educates Air Force personnel about Army organizations, concepts of operations, and the weather sensitivities of Army operations and equipment. Air Force weather units are aligned and integrated with the Army intelligence organization. Weather products are tailored to be directly usable and understandable by Army personnel and are integrated into Army communications systems. Mobile and fixed meteorological equipment is programmed by the Air Force. In a tactical environment, weather personnel serve with echelon-above-corps, corps, divisions, separate brigades, regiments, aviation brigades, armored cavalry regiments, ranger regiments, and special forces groups (as well as subordinate battalions deployed at forward operating bases). The Air Force provides observer support to all command levels identified above. The Army Forward Area Limited Observing Program (FALOP) and the Army artillery meteorology (ARMYMET) program augment the Air Force observations in the tactical environment.

The Air Force provides meteorological products to the Nation's space and missile programs. This includes a wide range of weather observing services at the Air Force Eastern Range and the Kennedy Space Center. The Air Force also provides launch forecasting service for NASA's manned and unmanned launches and for commercial launches from the Kennedy Space Center. The Air Force also provides specialized meteorological services for the Air Force Western Range at Vandenberg AFB, California, and the Pacific Missile Range which includes Point Mugu and San Nicholas Island, California, and Barking Sands, Hawaii. In addition, the Air Force supports the White Sands Missile Range, New Mexico, the Kwajalein Missile Range, and other DOD research and test facilities.

The Air Force and Navy operate the Joint Typhoon Warning Center (JTWC) on Guam under the Naval Pacific Meteorology and Oceanography Center West, Guam. JTWC provides tropical cyclone warning services to DOD units and other U.S. subscribers in the area west of 180 degrees to the east coast of Africa in both hemispheres.

The Air Force directly supports DOD Special Strategic Programs, the National Command Authority, the

National Military Command System, and the National Security Agency. Tailored environmental support products are disseminated to these customers worldwide.

The Air Force and NOAA operate the Joint USAF/NOAA Space Environment Services Center at Boulder, Colorado. The center provides space environmental data, products, services, and solar forecasts to a wide variety of customers.

The Air Force also provides Agrometeorological output to the USDA's Foreign Agricultural Service and other national customers. The output provided includes diagnostic soil hydrology and other meteorological output pertinent to crop growth and yield estimation.

DOD Modeling and Simulation Executive Agent for the Air and Space Natural Environment. The Air Force was confirmed in 1995 by the Executive Council for Modeling and Simulation (EXCIMS), representing the Office of the Under Secretary of Defense for Acquisition and Technology as the Executive Agent. The Executive Agent is responsible for ensuring authoritative air and space environment models, algorithms, and data intended for cross-agency/cross-Service laboratories in air and space natural environmental boundaries. As of 1996, the Executive Agent will reside at AFCCC. It will be structured as a multi-service Modeling and Simulation division.

Air National Guard (ANG). There are two distinct functions within the ANG weather program. The traditional program consists of 33 weather flights, ranging in size from 13 to 25 personnel. The flights meet monthly to train for their wartime missions and support both Army National Guard (ARNG) and U.S. Army Reserve (USAR) units as well as ANG flying units. A Weather Readiness Center operates at Camp Blanding, Starke, Florida, to provide Army tactical skills training that is not available elsewhere in the Air Force. The ANG is also responsible for peacetime weather operations at locations where the ANG is responsible for airfield operations. Service employees of the ANG provide weather support at six locations, while contracted services are provided at six others.

Planned Enhancements. Air Force, Army, and joint force operational requirements for environmental support are the basis for all Air Force actions to improve existing or acquire new capabilities. The Air Force assesses these requirements and attempts to satisfy them through either hardware acquisitions or technique development. AWS and the Naval Meteorology and Oceanography Command are working on initiatives to improve environmental support to joint, interservice, and service operations. They focus on the strengths of each of the services and build on existing cooperative efforts.

The Air Force is modernizing and improving its base-level weather systems. This includes the Automated Weather Distribution System (AWDS) Pre-Planned Product Improvements (P3I) and Next Generation Weather Radar (NEXRAD--WSR-88D) programs. WSR-88D installations are in progress. AWDS installations were completed in Spring 1994.

To enhance AWDS in base weather stations and to expand forecasting capabilities, the AWDS P3I program consists of the following phases:

» Phase I. Interoperability with other command, control, communications, computer, and information (C4I) systems.

» Phase II. Improvement of processor speed of all workstations.

» Phase III. A remote briefing capability, an intra-AWDS product preparation capability, and improved meteorological satellite ingest capability.

The WSR-88D is being procured under the auspices of the NEXRAD Joint System Program Office. It is an automated, digitized, S-band Doppler system that was jointly developed and procured. It is operated and maintained by DOD, NOAA, and FAA within the CONUS and by the Air Force and Navy overseas. The system incorporates the latest technological advances in Doppler radar, data processing, communications, and display. The CONUS WSR-88D network will satisfy weather radar requirements in support of the general public, the military, and the aviation community. Installations of the WSR-88D are in progress and are expected to be completed by 1996.

The Centralized Data Management System (CDMS) transition is a related series of distinct acquisition, development, and integration efforts to transition AFGWC from a database-dependent applications environment to a centralized database management system. Under the CDMS transition, AFGWC centralized the management of a number of key databases on one computer for both unclassified and classified production. This acquisition will be integrated with improved AFGWC hardware/software systems and will transition to the centralized database management environment under planned programmed steps. CDMS transition reached initial operational capability in 1992 with operational support to the Global Applications Database. Full operational capability is currently scheduled for FY 2002 in conjunction with the AFGWC SDHS replacement.

The Cloud Depiction and Forecasting System (CDFS) II will make major software and hardware modifications at AFGWC to upgrade the weather satellite data processing, cloud depiction and forecasting, and classified weather support functions to meet customer-stated support requirements. CDFS II will also incorporate weather satellite data, cloud depiction and forecast data, and supporting databases into the AFGWC CDMS.

The MARK IVB Direct Readout program has procured new satellite receiver terminals to replace the aging MARK IIIs and some of the MARK IV terminals. In addition to providing high resolution satellite imagery from polar and geosynchronous weather satellites, the MARK IVB terminals accepts and uses data from the DMSP microwave imager and sounders and the TIROS microwave sounding units A and B. The MARK IVB produces both uniform gridded data fields and traditional meteorological products.

The Small Tactical Terminal (STT) program will procure small, lightweight, ruggedized, modularized, interoperable, first-in satellite receive terminals that will receive data transmitted by geostationary and polar orbiting (Automatic Picture Transmission) meteorological satellites. Full-scale production began in FY 1996.

SPACE ENVIRONMENTAL SERVICES

50th Weather Squadron (50 WS) is the Air Force focal point for operational space environmental support. 50 WS also participates with NOAA in the joint operation of the Space Environment Center (SEC) in Boulder, Colorado. Under existing agreements, SEC and 50 WS provide limited backup for each other during contingencies. Many DOD systems operate in, or are affected by, conditions above 50 kilometers. The space environment includes the thermosphere, ionosphere, and magnetosphere, as well as the regions that influence them, such as the sun and interplanetary space. 50 WS provides basic and specialized space environmental support to military electromagnetic communications, surveillance, and warning systems which operate in this environment. Space environment forecast products and/or specialized services are provided for the following:

» Ionospheric conditions.

» Energetic particle fluxes at satellite orbits.

» Solar flare, solar particle, and geomagnetic storm events.

» Upper-atmospheric density variations by providing geomagnetic and solar indices.

» High frequency (HF) radio wave propagation.

» Detailed post-analysis studies of operational system problems to determine if the space environment was a contributing factor.

The effects of the space environment on DOD systems are many and varied. The magnetosphere affects satellite operations through such phenomena as single event upsets (SEU) and spacecraft charging. Manned spaceflights are vulnerable to intense radiation from large solar flares and geomagnetic storms, particularly for high inclination orbits. Ionospheric conditions have a profound effect on the propagation of radio waves and radar signals, leading to communications blackouts and erroneous radar returns. Variations in the neutral atmosphere affect satellites orbiting at relatively low altitudes.

Sources of Space Environmental Data. To obtain solar data, the 50 WS operates a network of solar optical and radio telescopes. Solar Electro-Optical Network (SEON) observatories are located at Sagamore Hill, Massachusetts, Ramey, Puerto Rico, Holloman AFB, New Mexico, Palehua, Hawaii, San Vito, Italy, and Learmonth, Australia. The 50 WS also receives real-time solar X-ray and energetic particle data from the Geostationary Operational Environmental Satellites (GOES); DMSP, NOAA, and other DOD geostationary satellites provide additional energetic particle data in low-Earth and geosynchronous orbits.

A world-wide (primarily northern hemisphere) network of ionosondes and polarimeters provides ionospheric data. AWS is currently deploying the automated Digital Ionospheric Sounding System (DISS) to replace older instruments and provide improved ionospheric coverage. Of the 19 DISS sites programmed, 14 sites are operational, and the remaining 5 will be installed in the next few years.

The 50 WS monitors variations of the geomagnetic field using ground-based magnetometers through a cooperative agreement with the USGS, computes a real-time geomagnetic index, and transmits the derived index to users.

Warning and Forecast Services. In near-real-time, 50 WS provides operators advance warning of conditions that could degrade performance of their systems. Notifications include:

» Solar X-ray events which can disrupt HF communications on sunlit paths.

» Solar radio bursts which can disrupt communications systems and interfere with radar systems.

» Solar proton events which can produce radiation hazards to spacecraft and absorption of transpolar HF radio waves.

» Ionospheric disturbances which can degrade HF and satellite communications systems.

» Geomagnetic disturbances which can affect the orbital parameters of low altitude satellites, cause spacecraft charging and/or physical damage, disrupt HF radio wave propagation, or interfere with radar systems.

Future Improvements in 50 WS Support. 50 WS is enhancing its ability to observe the space

environment, analyze data, and model the near-Earth environment.

The **Ionospheric Measuring System (IMS)** is a planned replacement for the current polarimeter network. IMS, using signals from Global Positioning System (GPS) satellites, will measure total electron content. The initial purchase and deployment of five IMS units is in progress.

The **SEON Upgrade** will improve the capabilities of the SEON observatories. Efforts to upgrade obsolete and non-supportable equipment to maintain current capability continue.

A **Solar X-Ray Imager (SXI)** will be flown on the GOES-NEXT series of satellites. The SXI will monitor solar emissions in the extreme ultraviolet (EUV) and X-ray portions of the solar spectrum. These data will be downlinked to the SEC and transmitted to 50 WS in real-time.

The **Solar Wind Interplanetary Measurements (SWIM)** is an Air Force Phillips Laboratory investigation using data from NASA's WIND research satellite launched on 1 November 1994. SWIM provides two hours of real-time interplanetary solar wind data to 50 WS each day. Additionally, there will be two campaigns a year during which real-time data will be provided 8 hours a day. The expected life of SWIM/WIND is 5 to 7 years.

Solar Radio Burst Locator (SRBL). This new ground-based system is projected to be operational in 1999. SRBL radio mappings of active regions on the solar disk will augment the present optical observations of these phenomena which are limited by clouds and other atmospheric obscurants. Precise location of active regions on the solar disk is crucial to accurate forecasting of solar flare impacts on the near-earth environment.

The **Space Environmental Technology Transition (SETT)** program transitions state-of-the-art space environmental models to operational use at 50 WS. These models will specify and forecast the space environment from the Sun to the Earth's upper atmosphere. The output of these models will drive specific application programs tailored to customer needs. The transition of the SETT models to the 50 WS will be complete by 1999. Follow-on model development will focus on improving model accuracies and will replace surrogate parameters (as model inputs) with direct measurements wherever possible.

» Magnetospheric Models. The Magnetospheric Specification Model (MSM) provides specification of magnetospheric particle fluxes at geostationary altitudes and precipitating particle fluxes in the auroral zone. An upgrade to this model, the Magnetospheric Specification and Forecast Model, will provide forecast capability and increase the MSM coverage area. One application of MSM output will be as input for satellite anomaly programs. The MSM became operational at the 50 WS in FY 1995.

» Ionospheric Models. The Parameterized Real-Time Ionospheric Specification Model specifies global electron density using near-real-time satellite and ground-based data. It becomes operational in late FY 1996. A second ionospheric model, the Ionospheric Forecast Model (IFM) will be based on a model developed by Utah State University. When completed, IFM will provide an ionospheric forecasting capability; it is currently undergoing validation. Ionospheric model output will be used as input for space track radar correction and HF radio wave propagation programs. Another variant of ionospheric models, the Wide-Band Model, will provide estimates of ionospheric scintillation severity between two endpoints. The specification accuracy of this model has recently been improved by the inclusion of equatorial and high latitude climatological data.

» The Interplanetary Shock Propagation Model is designed to predict the time of arrival and the dynamic pressure pulse associated with solar flares. This will provide a 1-3 day warning of geomagnetic storms

resulting from solar activity.

» The Integrated Space Environmental Model is a coupling model and executive system being developed to integrate the SETT models into a single system sharing input and output data. It will provide a single framework to coordinate and facilitate the execution of all SETT models using scientific expertise and decision-making ability within the program, which will increase consistency of the outputs, optimize run times, and decrease forecaster workload.

SUPPORTING RESEARCH

The objective of the Air Force meteorological research program is to provide comprehensive knowledge of the atmosphere, how it works, how it limits system performance, and how it can be exploited to the advantage of the Air Force as a force multiplier. Improved measurement and prediction techniques, together with an early evaluation of weather effects on new systems, can make a significant difference and bring the Air Force, Army, and joint forces closer to their goal of conducting operations in all kinds of weather. Requirements for research and technology in meteorology are expressed in Mission Area Assessments and Mission Need Analyses. In addition, the AWS provides guidance in the form of documented Technology Needs.

Within the Air Force, the Phillips Laboratory, Geophysics Directorate (PL/GP) at Hanscom AFB, Massachusetts, is responsible for conducting both in-house and contractual basic research, exploratory development, and advanced technology development in the environmental sciences, including meteorology and space weather. Its exploratory development program in meteorology emphasizes moisture and cloud numerical weather prediction, satellite remote sensing, climatological studies, weather simulation, atmospheric density measurement and prediction, battlefield weather observing and forecasting, and tactical weather decision aids. Research and development (R&D) for DMSP, the Strategic Environmental Research and Development Program (SERDP), and the Defense Modeling and Simulation Office (DMSO) are also conducted. The entire Air Force atmospheric sciences R & D program is being carefully coordinated with similar efforts in the Army and Navy.

Weather Prediction. Research in weather prediction techniques and models is focused on mesoscale or battlefield domains. Particular emphasis is placed on cloud processes in the atmospheric boundary layer and studies of their formation, evolution, and dissipation. Procedures to better account in numerical models for surface exchange processes and for representing surface characteristics in model data bases will be stressed. These include: soil type, vegetation type and growth stage, soil moisture and temperature, and snow cover and depth. On-going studies of the sensitivity of boundary layer processes to the representation of surface characteristics will be translated into model algorithms for test and evaluation. Mesoscale model data impact studies will focus on both ground-based (profiler and surface sensors) and satellite (imagery and sounding) sources. Tactical wartime data denial experiments will also be conducted as part of these studies. Theater-scale analysis and forecasting models will be developed for use in a workstation environment.

Research to support the increasing needs for a global cloud prediction capability at AFGWC will take two approaches. Multivariate diagnostic algorithms from global and regional-scale numerical models will be evaluated to infer cloud characteristics (total cloud and layered amounts, bases, tops) for prediction intervals beyond 12 hours. Short-range cloud prediction (0-12 hr) techniques will seek to exploit new global cloud analysis capabilities to be available at AFGWC through the CDFS II hardware/software upgrade. Here imagery extrapolation methods will be augmented by simple physical models to account for short-term cloud growth and decay and by highly resolved (in space and time) cloud climatology statistics. In addition, diagnostic algorithms to provide surface and hazard predictions for Theater Battle Management are being sought.

Research to improve hazardous weather warning capabilities at air bases from WSR-88D Doppler weather radars will be focusing on better tornado, hail, and severe storm structure algorithms due to the use of a new mesocyclone detection model which was developed in FY 1994. The development of algorithms to define fine line features (such as gust fronts and synoptic-scale frontal boundaries) will be completed by FY 1996. Studies to identify lightning precursors in WSR-88D data for air mass thunderstorms will be initiated. Studies of the atmospheric electric field distribution aloft and its relationship to aerospace vehicle-triggered lightning will continue. These studies will focus on measurements taken with electric field sounding rockets in field programs to be conducted in FY 1996.

Satellite Remote Sensing. To enhance Air Force, Army, and joint force operations, a major effort is directed toward using satellites to determine temperature and water vapor vertical profiles and horizontal fields. Research efforts also include effectiveness studies for active satellite sensors, such as satellite-borne lidars and radars, for determining the profiles of wind and other weather variables with very high vertical resolution for initialization and assimilation into weather prediction models.

Techniques will be developed to incorporate microwave imagery and geosynchronous satellite data into the cloud analysis programs at AFGWC. The present level of support will continue for this research to develop new analytical methods in satellite meteorology. The ultimate goal is to more accurately specify cloud characteristics; e.g., cloud height, cloud physical thickness, optical depth, particle size, cloud phase, and rain areas. The design of satellite sensors in terms of wavelength, resolution, and bandwidth and the calibration of deployed satellite measurement systems, such as the DMSP SSM/T-2 water vapor sounder, will continue primarily in support of DMSP. Research on integration of the environmental information from a number of satellite measurement platforms and sensors is underway.

Characterization of cloudiness on the operational theater scale, based on direct readout of satellite weather data, is being implemented in support of tactical operations. A package of satellite cloud analysis algorithms, called TACNEPH, has been developed and will be implemented in the DMSP Small Tactical Terminal.

Climatology Studies. Support of Environmental Requirements Cloud Analysis and Archive (SERCAA) is the new global cloud analysis program for use in determining the radiative and hydrological effects of clouds on climate and global change. SERCAA is the prototype of the next-generation, real-time automated cloud analysis model. The first phase of SERCAA directly supports the CDFS II. An archive of these quality cloud products, which will be useful in environmental monitoring and climate change research, is planned.

In climatological technique development, weather simulation models are being developed to replicate numerically typical weather sequences for operational applications. Research in modeling clouds and visibility is being expanded to include additional atmospheric elements, specifically a mesoscale environmental simulation package to provide a realistic sequence of weather events at any given location. This model will allow environmental factors to be considered in the design stage of weapon systems and for application to war games.

Research into specifying the probability of simultaneous cloud-free viewing from multiple sites under various cloud conditions is ongoing. Simulation of time evolution of 3-D scenes of weather elements will initially concentrate on cloud scenes. Whole-sky imagery data and concomitant satellite imagery will provide the basis for developing algorithms for ground-based and satellite (or aircraft)-based viewing scenarios. Weather simulation computer models for conceptual design and studies and analysis applications will continue.

The first of two DMSO projects focuses on developing techniques for simulating Environmental Effects for Distributed Interactive Simulation (E2DIS) and to conduct related requirements and capabilities surveys. The second is to implement into E2DIS format the 3-D cloud scene model developed in the first project.

Two programs are in progress to develop a more complete understanding of atmospheric effects on laser propagation. The first of these programs supports the Airborne Laser Program and is evaluating the effects of atmospheric phenomena near the tropopause on laser propagation. Modeling and measurements in support of a more complete understanding of turbulence, aerosols, and cirrus clouds on such propagation are the focus. In the second of these programs, investigations are underway to evaluate the ability to measure winds with a Doppler Lidar in support of weapons targeting (the so-called ballistic wind problem). Actual measurements are being conducted together with supporting meteorological observations and analyses.

The Climatological and Historical Analysis of Clouds for Environmental Simulations (CHANCES) program was initiated in 1994 and will continue into 1996 to expand the climatological analysis to include the tops and bottoms of layered clouds. The program is developing a very high resolution, global cloud climatology from conventional and meteorological satellite observations for planners of satellite and high-altitude aircraft surveillance operations.

Atmospheric Density. The objective of the atmospheric density work is to develop very accurate methods to measure and predict the density of the neutral atmosphere in the altitude range of 90 to 1500 kilometers. Current density models do not achieve the levels of accuracy required by the Air Force so new measurements of density will be made using recently developed, well-calibrated, and highly accurate instruments. These new measurements will be the basis for an upper atmospheric global circulation model that incorporates the current physical understanding of the processes that drive the upper atmosphere. Models will be used to calculate accurate trajectories of satellites, reentry vehicles, and space debris.

Battlefield Weather Observing and Forecasting. The battlefield weather program completed development of the electro-optical tactical decision aid (EOTDA) in FY 1994. This software is used on microcomputers in base weather stations and host command and control computer systems using an AFGWC-provided data base. This automated forecasting aid is used to predict acquisition and lock-on ranges for precision-guided weapons and target acquisition systems used by the Air Force, Navy, and Army.

The Air Combat Targeting/Electro-Optical Simulation effort in the Weather Impact Decision Aids (WIDA) program has developed a prototype scene simulation capability for mission planning systems used by tactical aircraft pilots. This prototype combines global terrain and features, target structure, meteorological and operational planning data, target infrared contrast and EO sensor performance models to provide commanders and aircrews complete in-theater environmental situational awareness. Another WIDA program is developing Night Vision Goggle (NVG) Operations Weather Software (NOWS) for predicting the impact of weather on operations which depend on NVGs for their success. The primary NOWS user is the Air Force Special Operations Command. Coordination to incorporate Navy requirements into NOWS is underway.

UNITED STATES NAVY

METEOROLOGICAL SERVICES

The U.S. Navy, operating in the atmosphere, oceans, and the interface between the two, has the unique requirement to integrate meteorological and oceanographic support globally. Sponsored by the Chief of Naval Operations, Office of the Oceanographer of the Navy, the Navy provides meteorological support for Navy and joint forces, meteorological products to the USMC, and oceanographic support to all elements of DOD. R&D is conducted under the sponsorship of the Chief of Naval Research and the Oceanographer of the Navy by warfare centers, laboratories, and systems commands, primarily the Naval Research Laboratory (NRL) and the Space and Naval Warfare Systems Command (SPAWARS), as well as various universities and organizations under Navy contract. Operational support to ships, units, and shore stations is provided by elements of the Naval Meteorology and Oceanography Command (NMOC). Direct support to staffs, ships, and units afloat and ashore is provided by officer and enlisted meteorology and oceanography (METOC) personnel assigned to these activities. Shore activities within the NMOC include the Fleet Numerical Meteorology and Oceanography Center, the U.S. Naval Oceanographic Office, the Naval Ice Center, four theater NMOC centers (Atlantic, European, Pacific, and Western Pacific), four NMOC Facilities, and 40 NMOC Detachments.

Fleet Numerical Meteorology and Oceanography Center (FNMOC) in Monterey, California is NMOC's processing center dedicated to running automated, state-of-the-art, operational global and high resolution regional/theater-scale atmospheric and oceanographic analysis and forecast models. The center acquires environmental data globally through links with DOD and NOAA satellite and data distribution systems. Numerically-generated products are distributed on Navy and Joint command and control, communications, computers, and intelligence (C4I) systems either directly or via the Navy theater METOC centers. These centers then develop value-added products and services tailored to specific operational requirements. In addition to its standard product suite, FNMOC is uniquely capable of providing high resolution meteorological and oceanographic products on short notice for any location in support of global contingency military and humanitarian operations. Other FNMOC products include atmospheric and oceanographic observations, data extracts, and input data for tactical decision aids. In addition to being the primary DOD global numerical weather prediction center, FNMOC is the designated national Center for Expertise for remotely-sensed microwave products by the Air Force/Navy/NOAA shared satellite processing agreement.

The Navy's program in meteorology is closely linked with oceanography, the focus of two other major Navy METOC centers. The Naval Oceanographic Office (NAVOCEANO), at Stennis Space Center, Mississippi, is responsible for collecting, processing, and distributing oceanographic, hydrographic, and other geophysical data and products. It is the Navy's primary processing facility for NOAA TIROS data and has been designated the national Center of Expertise for satellite-derived sea surface temperature measurements. NAVOCEANO's Warfighting Support Center (WSC) provides near real-time, tailored oceanographic products to support operational Navy and joint commands. Such products include global ocean front and eddy analyses, preprocessed multichannel sea-surface temperature (MCSST) analyses from polar-orbiting satellites, satellite altimetry and scatterometry data from ERS and TOPEX satellites, high-resolution ocean model output, and Special Operation Forces support. Furthermore, as NAVOCEANO is both an operational processing center and a DOD Major Shared Resource Center, R&D programs using NAVOCEANO's C-90 supercomputer can be easily transitioned to operational use in Navy METOC models.

Tailored ice forecasts and analyses are provided to DOD by the Naval Ice Center (NAVICECEN), located in Suitland, Maryland. The Navy, through NAVICECEN, NOAA and the U.S. Coast Guard, jointly operate the National Ice Center (NIC). The NIC provides sea and lake ice analyses and forecasts for the Arctic and Antarctic regions, coastal U.S. waters, and the Great Lakes to civil as well as military activities.

Four theater NMOC centers provide broad geographical METOC services within their areas of

responsibility. Aligned with specific Naval Component Commanders of the Unified Commanders-in-Chiefs (CINCs) and focused on operations within theater, these METOC centers manage and prioritize the dissemination of basic numerical METOC products from FNMOC and NAVOCEANO and add tailored services specifically to support theater requirements. They are hubs for data and product dissemination, providing full spectrum meteorological and oceanographic services to forces operating within their respective area of responsibility and a variety of special METOC products as needed to meet situational requirements of the Joint Force Commander. The Naval Pacific Meteorology and Oceanography Center (NPMOC), Pearl Harbor, Hawaii, assisted by NPMOC West, Guam, is responsible for the Pacific and Indian Oceans, Red Sea, and Arabian Gulf areas. Additionally, NPMOC West operates the Joint Typhoon Warning Center with the U.S. Air Force to provide tropical cyclone advisories to DOD and U.S. interests in the Western Pacific and Indian Oceans. NPMOC also issues tropical cyclone advisories, for the eastern and central South Pacific. The Naval Atlantic Meteorology and Oceanography Center (NLMOC), Norfolk, Virginia, is responsible for providing METOC services in the Atlantic Ocean and the Greenland, Norwegian, and Barents Seas. The Naval European Meteorology and Oceanography Center (NEMOC), Rota, Spain, provides METOC support to Joint and Naval forces operating in the Mediterranean, Black, and Baltic Seas. The Atlantic and Pacific NMOC centers share non-ice related METOC product and service support for the Arctic and Antarctic regions. Because of their in-theater presence and focus, NMOC centers are ideally suited to serve as Joint METOC Forecast Units (JMFU) or Coordinating METOC Forecast Centers (CMFC) in support of theater joint operations.

The four NMOC facilities at Jacksonville, Florida; San Diego, California; Pensacola, Florida; and Yokosuka, Japan; provide operations area, local and aviation forecast services, as well as services to aircraft, ship, and submarine staffs. Meteorological and oceanographic forecast guidance from the theater NMOC centers and FNMOC is used by all facilities.

There are 40 NMOC detachments worldwide. Primarily situated at Naval Air Stations, several are located at Naval Stations in support of sea-going units. They provide METOC forecasting and warning services to DOD and allied units within their local and functional areas of responsibility. Detachments within the continental U.S. use numerical products from both FNMOC and NOAA's National Centers for Environmental Prediction (NCEP). Overseas detachments use available USAF and foreign products in addition to core FNMOC numerical products. Two detachments provide specific technical services: one, at the National Climatic Data Center, Asheville, North Carolina, coordinates the Navy's climatological program as its part of the Federal Climate Complex; another, at Tinker AFB, Oklahoma, manages Naval data requirements for the USAF AWN.

On-Scene Support

The primary sources of on-scene Navy METOC support for forces afloat and those in-theater ashore are provided by permanently embarked Navy METOC personnel and deployable assets (Mobile Environmental Teams). METOC products and services provided to the operating forces are tailored to requirements of the Fleet and/or Joint Force Commanders and Fleet units. This support consists primarily of tactical METOC information and forecasts for operations, weapon and sensor system employment and tactical decision making, and climatological information for long-range planning. Products are made available to the operating forces via joint and Navy C4I systems, AUTODIN, the High Speed Fleet Broadcast, high frequency facsimile broadcasts, military networks, and center-maintained Bulletin Board Systems (BBSs).

The Navy's permanent afloat METOC organic assets are their OA Divisions, embarked aboard major aviation-capable combatants and command ships. Their primary objectives are safety, optimum tactical support to warfare commanders, and tailored on-scene products and services to the assigned task

force/group and allied units in joint, combined, or coalition military and humanitarian operations. The centerpiece of the OA Division's suite of METOC equipment is the Tactical Environmental Support System (TESS(3)), an interactive METOC data fusion system which receives, stores, processes, displays, and disseminates meteorological and oceanographic data. TESS(3) receives data from four major sources: global and theater METOC data fields from FNMOC and NAVOCEANO via the Navy's theater centers; remotely sensed satellite data and imagery from the onboard AN/SMQ-11 satellite data receiver/recorder; alphanumeric data via the High Speed Fleet Broadcast; and local observational data from the Shipboard Meteorological and Oceanographic Observing System (SMOOS). The TESS(3) data base and applications software is provided from the Oceanographic and Atmospheric Master Library (OAML) and the Geophysical Fleet Mission Program Library (GFMPL). The AN/SMQ-11 acquires geostationary satellite weather facsimile (WEFAX) broadcasts and DMSP and NOAA/TIROS satellite imagery. Local upper air sounding information is made available from the permanently installed AN/UMQ-12 Miniature Rawinsonde System (MRS). The division is also equipped with a PC-based high-frequency facsimile system (PCGRAFAX). Standard CD-ROM based climatology products, the Naval Oceanographic Data Distribution System (NODDS), and the PC Imaging Communications Systems (PICS) software programs are also part of the OA Division inventory.

The Mobile Environmental Teams (MET), based at the theater NMOC centers in Norfolk, Hawaii, and Rota, and at their facilities in Jacksonville, San Diego, and Yokosuka, are the Navy's deployable METOC assets. These teams provide short-term, on-scene services to units and activities without organic METOC personnel within the DOD, other government agencies, and elements of the armed forces of allied nations during combined exercises or operations. The MET have their own portable sensing and display equipment, the heart of which is the Mobile Oceanography Support System (MOSS). MOSS contains modules for tactical meteorological and oceanographic forecasting, polar-orbiting satellite ingest and processing, alphanumeric and facsimile data receipt and display, and *in situ* data collection via the MRS and expendable bathythermograph probes. METs may also deploy with a portable MRS and Alden Marine Facsimile Recorder. If required, they have the capability to install remote Navy Automated Meteorological Observing Systems (AMOS), to sense temperature, humidity, pressure, and winds and provide direct readout and/or telemetry of data via satellite.

U.S. Marine Corps (USMC)

Marine environmental forecasts are vital to the operation of the USMC. The Deputy Chief of Staff for Aviation, Headquarters, U.S. Marine Corps (Code ASL-44) is the cognizant office for Marine Corps Meteorological and Oceanographic Support and Requirements. The Marine Corps weather organization consists of two operational chains of command, one for garrison aviation weather units and the other for the Fleet Marine Force (FMF).

Garrison aviation weather units at Marine Corps Air Stations and facilities are manned by USMC METOC personnel and provide direct aviation weather support to host and tenant units. Integral to Marine Corps aviation activities, these weather units provide services to assigned activities and organizations, which include nine major air stations in the continental United States, one in Hawaii, and two in Japan.

Marine Corps METOC support activities are assigned to the FMF in the Aviation Combat Element (ACE) of the Marine Air Ground Task Force (MAGTF). ACE METOC support is derived from the Marine Wing Support Squadron (MWSS) within the parent Marine Aircraft Wing. The existing 10 MWSS METOC activities are equipped to provide support at a bare-based or expeditionary airfield by deploying the METMF. Additionally, Meteorological Support Teams from the ACE MWSSs can be assigned in direct support of the Command Element, Ground Combat Element, and Combat Service Support Element of the MAGTF.

Battlespace Management Systems

The Navy's METOC program remains focused on improving data collection, processing, and dissemination capabilities to support operations in the littoral and to ensure interoperability among the services. A key aspect of this design is a unifying fully-integrated C4I architecture allowing METOC activities to operate in unison with other service elements. Efforts in FY 1997 include:

Tactical Environmental Support System (TESS(3)). TESS(3) is a modular support system designed to provide Navy decision-makers on major combatant ships with METOC assessments and forecasts and to integrate this data with sensor and weapon platform parameters for system performance assessments. Data sources include *in situ* sensors, geostationary and polar-orbiting satellites, U.S. and foreign radio weather broadcasts, and data fields prepared ashore. The primary suppliers of these data are the theater METOC centers, which provide value-added products to fleet units in addition to the numerical prediction guidance generated by FNMOC, using a variant of TESS, the Naval Oceanographic Data Distribution and Expansion System (NODDES). NODDES expands previous METOC data distribution capabilities by increasing automation of routine operations and enhancing on-site interactive capabilities for finished product preparation and distribution. The planned TESS(3) and NODDES evolution includes expanded options for theater center modeling; complete integration with Navy and joint C4I systems; the development of small basin, mesoscale, coupled air/sea models; and the transition to Navy standard tactical computer (TAC-X) hardware.

Navy Integrated Tactical Environmental Sub-system (NITES). Through NITES, METOC data and products are made available to Navy and Marine Corps activities afloat and ashore via the Joint Maritime Command Information System (JMCIS) network. A modular data management and distribution subset of TESS(3) and a segment on the Navy C4I network, NITES uses TESS(3) data and products to feed real-time tactical decision aids resident with JMCIS. The open system design of NITES can provide interoperability with other DOD, Federal, and Allied command and control systems.

Mobile Oceanography Support System (MOSS) Upgrade. MOSS is presently undergoing a migration towards a modular, interoperable system -- a NITES variant. It has been upgraded to include a lightweight and portable IBM Thinkpad 755CD notebook computer with an IBM Dock II docking station. This migratory version, known as MOSS-2, operates at 100 MHz and has the additional capability to ingest real-time observational data collected by AMOS. The follow-on system, MOSS-3, will be a modular data management and distribution system operating in a portable UNIX environment and incorporating much of the NITES functionality.

Primary Oceanographic Prediction System (POPS). The POPS program was initiated to provide the computational capability necessary to run massive oceanographic and atmospheric models at both global and regional scales. New Cray C-90s at NAVOCEANO (POPS-I) and FNMOC (POPS-II) were installed as part of the Navy's and Federal Government's emphasis on high performance computing. POPS-I has been designated a DOD Major Shared Resource Center, with as much as 85 percent of the computer time on the C-90 devoted to supporting DOD R&D efforts which can then be transitioned to operational use. POPS-II is the numerical engine used by FNMOC in its role as the primary DOD Numerical Weather Prediction Center. Two subsidiary information systems support POPS at FNMOC -- the Oceanographic and Atmospheric Support and Information System (OASIS) and the Distributed Processing System (DPS). DPS receives incoming data and distributes final products to external users, while OASIS processes incoming data for POPS and packages POPS output for specific customers. Output from Navy's numerical models is made available to NOAA through a memoranda of agreement.

Operational Products and Services

The Optimum Track Ship Routing (OTSR) is a ship advisory service designed to minimize the risk of damage from extra-tropical and tropical storms, high seas, and sea ice. OTSR also assists port authorities and ships in port in the path of tropical cyclones by issuing recommendations for departure time and a sortie location to the Senior Officer Present Afloat. To maximize fuel economy, OTSR provides recommendations for ocean current assistance and avoidance routes in the vicinity of strong ocean currents. OTSR advise considers individual ship characteristics, cargo limitations, and planned operations.

Optimum Path Aircraft Routing System (OPARS) at FNMOC is a flight planning system to provide tailored routing information to meet individual mission requirements. Among its many options, OPARS can calculate the fuel load needed to arrive with a specific reserve, maximum cargo for a particular flight, in-flight refueling requirements, maximum time on-station, mandatory over water reporting positions, and fuel usage for specific routes and/or altitudes. In preparation for a flight brief, electronic route requests are sent to FNMOC by the servicing NMOC detachment. To determine optimal aircraft routing, four data bases are integrated in OPARS: environmental, air route structure, aircraft performance characteristics, and prohibited air space. A tailored flight plan is returned to the originator within minutes for briefing to the pilot.

Navy Oceanographic Data Distribution System (NODDS) is a PC-based software package originally developed in 1982 to make FNMOC numerical products available to front line DOD users. Products from FNMOC's global data bases can be selected for user-defined regions and, using an off-the-shelf licensed communications software package, are transmitted as a series of compacted ASCII files. All standard meteorological fields and synoptic observations available from FNMOC can be displayed along with a wide number of oceanographic and satellite products. NODDS can overlay up to three different fields, display individual sequence loops, zoom for more detail, display satellite imagery, and produce hard-copy output. NODDS is available to non-DOD Federal agencies and others in the civilian community through an agreement between Navy and NOAA. This version, referred to as NOAA-NODDS to distinguish it from the Navy version, makes available to NOAA unclassified real-time weather and ocean data and products from FNMOC for access by civilian users.

SUPPORTING RESEARCH

The Navy administers a diverse R&D program, ranging from software development to the engineering of sensors, interfaces, processing, display, and distribution devices. Application of R&D activities of the other services and Federal agencies is always considered, and use of existing government and commercial off-the-shelf items is made.

The Navy is a world leader in the field of numerical weather prediction for marine environmental services. Transitioning fundamental scientific research, through additional development, into the operational meteorological and oceanographic models is key to a successful numerical prediction program. This is an ongoing process at the Naval Research Laboratory's (NRL) Marine Meteorological Division, collocated with FNMOC, to keep the Navy Operational Global Atmospheric Prediction System (NOGAPS) and its companion Regional Atmospheric Prediction System (NORAPS) at the leading edge of technology. Continued upgrades to NOGAPS and NORAPS models are planned, incorporating asynoptic and remotely-sensed data in the model initialization process. The relocatable, high-resolution (15-45 km) nested NORAPS model is now used routinely for operational contingency support.

In the future NORAPS will be replaced with the Coupled Oceanographic and Atmospheric Mesoscale Prediction System (COAMPS) model. The atmospheric component of COAMPS will feature triple-nested grids to resolutions of a few kilometers, non-hydrostatic physics, explicit moisture physics and

aerosols, and improved data assimilation. The underlying and fully coupled oceanographic component of COAMPS will combine the capabilities of the Optimum Thermal Interpolation System (OTIS), the Wave Model (WAM), and the Princeton Ocean Model (POM) to provide for fully interactive two-way coupling between ocean and atmosphere. With lateral boundary conditions provided by FNMOC global models, COAMPS will provide the high-resolution, relocatable, and fully-integrated meteorological and oceanographic prediction capability required to support joint littoral operations.

The principal focus of the Navy R&D program in remote sensing is the development of techniques to extract tactically significant information in the littoral regions of the world. Sensors aboard existing satellites are being exploited to the greatest extent possible, and plans are in place to incorporate new capabilities as they are introduced. Because many satellite processing algorithms are designed for use with tactical systems such as TESS(3), expert or rule-based scheme representations are employed wherever possible to reduce manpower-intensive interpretation procedures.

Development of upgraded data assimilation, quality control, and data management techniques in support of these models is also underway. A major thrust has been initiated in the area of numerical weather prediction to develop a shipboard tactical atmospheric forecast capability. This model, intended for use in TESS(3), will deliver high resolution (5 km), limited area (100's of km), short range (12-24 hour) atmospheric predictions and will assimilate locally acquired data in real-time.

ONR is exploring techniques to exploit the assimilation of environmental data through non-traditional sensors. One such effort in FY 1997 is to investigate the content and utility of a weather signal tap from the AEGIS AN/SPY-1 air search radar system, a potential candidate for a small-scale shipboard tactical weather radar.

SENSOR DEVELOPMENT

The Shipboard Meteorological and Oceanographic Observing System (SMOOS), currently being fielded, was developed as part of the Navy R&D program in sensor development. As a follow-on to SMOOS, advanced engineering and development of new sensors and related technologies is underway. Some of these include:

» Autonomous drifting buoys for surface and subsurface data.

» Autonomous sensor suites for all Navy ships.

» Aerosol measurement sensors.

» METOC data compression techniques to facilitate communications.

The AN/WSQ-6 series expendable drifting buoys will measure and report air and sea surface temperatures, barometric pressure, subsurface ocean temperature versus depth to 300 meters, omni-directional ambient noise, wind direction and speed, directional wave spectra, optical parameters, and other properties of the near-surface air/sea environment. The buoys sample and report hourly observations via Service ARGOS; as other communications networks such as Low-Earth Orbiting satellites become available, they will be utilized. Near-real-time data reception is available via Local User Terminals and TESS(3). As funding and testing permit new sensors will be added to the buoy platform. Multi-parameter, long-life, expendable instruments, such as the AN/WSQ-6 buoys, are vital to the success of the U.S. Navy's contribution to a global ocean observing capability.

The AN/UMQ-12 Mini-Rawinsonde (MRS) consists of a surface receiver, processor, and lightweight balloon-borne expendable sensor package to measure pressure, temperature, humidity, and wind direction and speed. The Navy will be transitioning to a GPS-based mini-rawinsonde system.

Development efforts undertaken by NOAA/NWS have been leveraged in Navy's selection of the NWS Automated Surface Observing System (ASOS) for Navy and Marine Corps use ashore. Acquisition and installation of ASOS systems continue at Navy and Marine Corps stations worldwide in support of aviation and local area forecasting requirements to replace equipment that has been operated beyond its maintenance life cycles. ASOS will assist aerographers in assimilating field meteorological parameters and improving efficient entry of surface aviation observations and synoptic weather reports into the AWN.

Principal User Processor Stations (PUPS) associated with WSR-88D are providing significant improvements in radar analysis of meteorological features and severe weather over the United States. The Navy and Marine Corps are participating in the WSR-88D program and will utilize these radars to satisfy their requirements for radar coverage, where possible. On-site WSR-88D PUPS will display imagery from NEXRAD systems covering areas of routine military operations and training.

The Navy is developing an Operational Requirements Document (ORD) for procurement of a Supplemental Weather Radar that will provide radar coverage at selected Navy and USMC sites, mostly overseas, not scheduled to receive a WSR-88D PUP. This system will replace the obsolete AN/FPS-106 weather radars now in use.

The Marine Corps Meteorological Mobile Facility Replacement (METMF(R)) is a transportable system for providing meteorological support to the Marine Air Ground Task Force (MAGTF). A cost and operational effectiveness analysis of a replacement METMF has been completed, and the system is nearing the demonstration and validation phases of the acquisition process. Housed in a 20 x 20 foot standard Marine Corps van and transportable by a C-130 aircraft, this system will provide a fully functioning weather office for Marine Corps expeditionary airfields for 30 days without resupply. It will include sub-systems for data collection (MRS for upper air and a variety of local and remote sensors), data processing (modified TESS(3)), satellite image ingest and display (via the USAF Small Tactical Terminal contract), Doppler radar display, communications, briefing support, and support for remote forces. The METMF(R) will be interoperable with the Marine Corps C4I systems and METOC systems of the other services via the Global Command and Control System (GCCS).

INTERAGENCY COOPERATION

To ensure maximum efficiency and benefit for Navy and NOAA cooperative activities, an Umbrella Memorandum of Agreement (MOA) was signed in 1993. Both agencies continue to review present agreements for conversion into annexes to this MOA and identifying new areas of cooperation. Specific areas include:

» Cooperative endeavors in operational numerical modeling between FNMOC and NCEP.

» Navy/NOAA/Coast Guard operation of the National Ice Center.

» AWS/Navy/NOAA agreement on shared processing of satellite data.

» Navy/NOAA agreement on ASOS procurement, installation, maintenance, and operation.

» Distribution of unclassified Navy METOC products to the civil sector via NOAA.

» Provision of meteorological services to Guam, the Commonwealth of the Northern Marianas Islands, and Micronesia.

» Satellite altimetry data processing.

MOAs also exist between the DOC, DOT, and DOD concerning the production and operation of the WSR-88D system. Additionally, Navy is a DOD participant in the development of the DOC/DOD/NASA converged National Polar-orbiting Operational Environmental Satellite System (NPOESS).

UNITED STATES ARMY

ARMY OPERATIONAL SUPPORT

Overview of Operational Equipment and Support Missions. U.S. Army weather support is a mix of Army and USAF personnel and equipment under law and according to Army-Air Force agreement. The U.S. Army provides direct weather support to two Army missions: upper air observations for artillery fire support, and limited surface weather observations to support Army weapon systems forward of Division tactical operations centers. The Air Force Major Commands (MAJCOMs) provide operational weather services to Major Army Commands (MACOMs) in combat, contingencies, and peacetime training. U.S. Army Forces Command (FORSCOM), U.S. Army Europe (USAREUR), U.S. Army Pacific (USARPAC), U.S. Army, South (USARSO), U.S. Army Special Operations Command (USASOC), Eighth U.S. Army (EUSA), and U.S. Army Training and Doctrine Command (TRADOC) have Air Force Weather personnel providing daily installation and tactical weather support. Army Artillery Meteorological (ARTYMET) crews provide direct support to artillery units in the same MACOMs. During peacetime training and activation, the Air National Guard (ANG) provides operational weather support to the Army Reserve and Army National Guard (ARNG), collectively designated the Reserve Component (RC). In addition, during exercises the ANG augments the active forces. The ANG acts like an Air Force MAJCOM in providing support to the Army RC.

Air Force-Provided Support. Under a joint service agreement, the Air Force is responsible for providing the Army with the necessary manpower and unique tactical and fixed weather equipment to meet tactical garrison active component (AC) and RC support requirements. Army support manpower requirements are provided from active, reserve, and guard weather units. While direct support of the artillery remains an Army responsibility and is supported by Army ARTYMET teams, Air Force weather teams provide supplemental information to artillery crews for areas beyond direct observation weather support to Combat, Combat Support, and Combat Service Support units throughout the peacetime/war continuum. Peacetime garrison activities include supporting flying operations at Army Airfields and severe weather watch, warning, and advisory services for post resource protection. With regards to equipment, the Air Force is responsible for installation, operation, and maintenance of standard Air Force meteorological and observing equipment at Army Air Field Weather Stations. Tactically, the Integrated Meteorological System (IMETS) is Army fielded and maintained, but uses Air Force meteorological software, Army vehicles, communications, and weather effects software. The Army provides all other tactical equipment to Air Force Teams through an Army Table of Organizations and Equipment.

The Army also provides the operational weather support to Army Research Development, Test and Evaluation (RDTE) ranges, centers, and other research facilities using the Test and Evaluation

Command (TECOM) Meteorological Teams (Met Teams) and U.S. Army Space and Strategic Defense Command (SSDC) contractors. TECOM operational support is described as part of the Army Materiel Command in the RDTE section. SSDC provides weather support to Kwajalein Missile Range (KMR) through a Meteorological Environmental Test Support contractor.

The Army provides the tactical field equipment and communications equipment to USAF weather teams (WETMs) for tactical operations. MACOMs have purchased off-the-shelf non-developmental items (NDI) to provide interim Army tactical equipment until the IMETS is fully fielded. IMETS is an automated mobile weather support and communications system. The Project Director (PD) for IMETS is under the direction of Program Manager, Intelligence Fusion. The Communications and Electronics Command (CECOM) and Army Research Laboratory (ARL) provide fielding and technical support to the PD, IMETS, and to artillery meteorological programs. IMETS will continue to be fielded in FY 1997.

The FORSCOM GOLDWING System is an NDI system, providing operational support until IMETS is fielded and other modern tactical communications systems become available in the MACOMs. GOLDWING will be used in conjunction with IMETS for AC or RC forces, which are not scheduled to get IMETS because of funding constraints. IMETS communicates with GOLDWING over HF radio.

Artillery meteorological crews are assigned to artillery units at division level, to Field Artillery Brigades, and to Separate Brigades with a direct support Artillery Battalion. Army soldiers regularly take tactical upper air observations to support artillery units during tactical training exercises, at permanent Army Artillery Ranges, or during the full range of combat missions. Artillery meteorological crews also take limited surface observations at tactical locations on an "as needed" basis to support artillery operational requirements.

Artillery meteorological crews currently use the Meteorological Data System (MDS), AN/TMQ-31, to take upper air observations during tactical operations. It is a mobile upper air sounding system on a 5-ton truck and trailer. The MDS provides upper air data to the Field Artillery Tactical Data System for use in adjusting artillery fire, to USAF WETMs, and to the Chemical Officer for use in smoke, and in Nuclear, Biological, and Chemical (NBC) defense operations. The MDS will continue in the active forces until replaced by the Meteorological Measuring System (MMS), AN/TMQ-41, and will be the main system in the RC for the next several years. The MMS is scheduled for fielding in FY 1996 and 1997. The MMS will be deployable on a small vehicle and reduce the size of the Artillery Meteorological Crews. MDS will be refurbished and issued to the RC as it is replaced by the MMS. The U.S. Army Field Artillery School (USAFAS), Fort Sill, Oklahoma, develops the requirements documents and is the combat developer for artillery meteorological equipment.

The Army provides supplemental, limited surface observations when required in tactical situations to support Army operations. These observations are taken by Intelligence personnel in the forward combat areas when directed by the Intelligence Officer (S2).

Headquarters, Department of the Army, Office of the Deputy Chief of Staff for Intelligence (ODCSINT) is responsible for Army weather support policy. Office of the Deputy Chief of Staff for Operations (ODCSOPS) is responsible for validating and prioritizing weather support requirements and programs to meet Army requirements. The Army Staff also has a full-time active duty User Liaison assigned to the NPOESS Integrated Program Office.

U.S. Army Space and Strategic Defense Command (USASSDC). Army Space Command (ARSPACE), a subcommand of USASSDC, assumed a new role in FY 1995, and is expected to

continue in FY 1997, to provide Army Space Support Teams to deploying Army units. One element of this support is a high resolution weather satellite receiver, which can be readily transported, and which directly acquires and processes the full telemetry stream of civilian and military weather satellites. Imagery and data are used by the staff weather officer in preparation of tailored products and forecasts for use on the battlefield. This equipment is used in contingencies and training exercises, and provides an interim capability pending delivery of IMETS, Block II and III in the FY 1997-99 time frame. Beginning in FY 1996 and continuing in FY 1997, ARSPACE is participating in Task Force XXI through its submission of the Tactical Weather (TacWx) initiative. TacWx represents a teaming with the Army Research Laboratory's Battlefield Environment Directorate to provide the Task Force XXI commander with near-real-time state-of-the-art weather information and products. The system consists of ARSPACE Deployable Weather Satellite Workstation, ARL Battlescale Forecast Model, and the AF Tactical Forecast System. Lessons learned will be forwarded to the IMETS program as IMETS moves into similar capabilities for its Block II system development.

U.S. Army Kwajalein Atoll (USAKA) is a subcommand of USASSDC, which provides operational support to the test facilities KMR. KMR meteorological services support contractor performs meteorological functions in support of missile operations and for synoptic purposes, including surface, upper air, and meteorological satellite observations, and the preparation of daily aviation, marine, and special weather forecasts for the range.

Army Corps of Engineers Civil Operational Activities. The Corps of Engineers (COE) operates a network of about 8,000 gauges of which 2,200 are land-based limited meteorological observing sites. The remainder are hydrologic in-nature. The meteorolo-gical portion measures precipitation and other data in the United States to provide information for regulating COE dams and other water projects used for flood control, navigation, hydroelectric power, irrigation, water supply, water quality, and recreation. The COE transfers funds to NOAA/NWS to collect and maintain precipitation information from 423 of these sites.

The remainder are maintained by the COE. Data from many of these sites are automatically telemetered using satellite, microwave, landlines, radio, etc. to provide for real-time use of the data. Although the COE finances the network, data are made available to all other federal agencies.

Training and Doctrine Command Programs. TRADOC manages and develops training programs, writes Army and Joint weather support doctrine (concepts and field manuals), and establishes the weather requirements documents for Army tactical weather support equipment. The U.S. Army Intelligence Center and Fort Huachuca (USAIC&FH), Fort Huachuca, Arizona, is the proponent and user representative for the tactical support in wartime, contingencies, and peacetime tactical training. The USAFAS, Fort Sill, Oklahoma, is the proponent for upper air meteorological support. The Engineer School, Fort Leonard Wood, Missouri, coordinates weather support requirements in Terrain Analysis and Topographic Engineering. TRADOC schools submit requirements for weather support to HQ TRADOC for approval. HQ TRADOC normally submits requirements filled by USAF support to Air Combat Command for implementation. Requirements for Army provided communications or tactical equipment is submitted to ODCSOPS to prioritize and program resources.

USAIC&FH is the functional proponent for tactical Army weather support. The Center's Weather Support Team writes tactical weather support concepts and doctrine; identifies deficiencies and baseline requirements; provides weather support training to Intelligence and USAF personnel supporting the Army; and establishes requirements documents for weather support equipment, except in the artillery support area. USAIC&FH sponsors the Joint Army/Air Force tactical weather concept, which embraces the "Owning the Weather" initiatives of the Army Research Laboratory's Battlefield Environment Directorate. These TRADOC concepts describe how weather support to the future Army will be

provided. They also describe the employment of IMETS with its capability to integrate information from national and indigenous sources to provide a 3-D of weather and environmental effects on and above the battlefield.

IMETS is a mobile, automated system that receives, integrates, models, and processes weather data from multiple sources. It provides near-real-time weather observations and tailored forecasts using digital displays to other Army tactical users. It provides tactical decision aids and weather effects information to help Army warfighters become more effective. IMETS integrates Air Force weather processing capabilities with Army Battle Command System hardware and software in a vehicle-mounted standard shelter able to move with the supported ground force. IMETS will provide tailored weather data fields to the All Source Analysis System, Digital Topographic Support System, and other Army Battlefield Operating Systems to support Army operations.

Automated Meteorological Sensor System (AMSS), a future battlefield weather data collection system, was originally planned for procurement in FY 1996 but is currently unfunded because of budget constraints. It is planned to be a source of tactical surface observations in forward areas and to send data to IMETS to support forecasting processes. Alternate sources of funding will be sought for future years.

USAFAS trains all field artillery meteorological crew members with a staff of 30 military and civilian instructors. USAFAS also has the role of developing requirements documents for new upper air observing systems and writing operational support concepts, doctrine, and procedures to be taught in the classroom and executed in the field.

The Aviation Center, Chemical School, and Engineer School incorporate weather instruction and procedures into training programs in their mission areas. The Engineer School develops methods of measuring and forecasting state of the ground parameters for terrain analysis and trafficability assessments. This includes identifying, justifying, and documenting requirements to interface meteorological and engineer battlefield systems. It also monitors R&D advances to incorporate these in combat development initiatives. Weather is taught in the Engineer Officer Advance Course. The Aviation Center has unique operational requirements for weather observations and USAF forecast support at remote training locations. Fort Rucker operates additional observing and communications equipment to relay all types of USAF-provided weather information to these Army sites.

Headquarters, TRADOC is the TRADOC approval authority for joint weather doctrine, weather hardware requirements, and weather support policy for TRADOC.

WEATHER SUPPORT RESEARCH, DEVELOPMENT, TEST, AND EVALUATION

Army Meteorological Research, Development, Test and Evaluation. Under Army-Air Force agreement, the Army has responsibility for weather support for RDTE to support Army ground combat missions. The Corps of Engineers and the Army Materiel Command (AMC) are the major contributors to weather research. The Medical Research and Development Command does research related to soldiers performance in the range of weather conditions expected to be encountered in all theaters of operations.

Corps of Engineers (COE). The COE is responsible for reviewing all emerging Army systems for environmental effects, as stated in Army Regulation 70-1. The COE also manages the Technology Demonstration (DT-08) program. Tactical Decision Aids (TDAs) are developed for this program by three COE laboratories: Topographic Engineering Center (TEC), Cold Regions Research and Engineering Laboratory (CRREL), and the Waterways Experiment Station (WES). WES develops

TDAs supporting terrain analysis. TDAs interpret the impact of weather and terrain conditions on Army systems and operations. They are based on weather and terrain limitations, known as critical values. Critical threshold values are determined from design criteria, operational testing, or other evaluations of Army capabilities in adverse weather. Critical values define system limitations and are used by decision makers to take advantage over opposing forces. Technology demonstrations are currently being transitioned to terrain and weather systems such as IMETS, the Digital Topographic Support System (DTSS), the Army Tactical Command and Control System (ATCCS), and Battle Command Decision Support System.

» Topographic Engineering Center (TEC). The TEC, Fort Belvoir, Virginia, provides basic and applied environmental support to Army R&D programs and coordinates the development of TDAs relating to environmental effects on combat systems, operations, and personnel. This includes the development and integration of environmental effects data bases and models that are relevant to military plans, operations, and the acquisition communities. TEC also develops models and techniques to assist in the generation of proxy environmental information (climate and terrain) for data sparse areas and the integration of models to enable the spreading of this information spatially over map backgrounds. TEC is also responsible for developing integrated software modules that are designed to be exploited in the synthetic environment areas and for developing techniques to portray natural and induced battlefield environments, thus enhancing computerized battle simulations. TEC also contributes to the development of policies and procedures for the consideration of realistic natural environmental conditions for application in the materiel acquisition process. As preparer and custodian of AR 70-38, TEC provides special climatological studies and guidance to materiel acquisition activities. TEC also reviews all emerging materiel systems for environmental effects.

» Cold Regions Research and Engineering Laboratory (CRREL). Under the military portion of its civil and military support mission, CRREL in Hanover, New Hampshire, provides weather support to Army weapons systems RDTE, combat, and combat support mission areas, and develops climatological studies on the effects of winter environment on Army operations. CRREL is responsible for modeling in the areas of Cold Regions Surface-Air Boundary Process, Winter Scene Dynamics, and Spatially Distributed Prediction Over Winter Terrain. CRREL develops data bases and models predicting Infrared and millimeter wave (MMW) weapon system performance, and the capability of technology to enhance military operations in cold environments. Under a Memorandum of Understanding (MOU), the U.S. Army Test and Evaluation Command (TECOM) provides operational observing, weather instrumentation, and forecasting services for CRREL's RDTE efforts through a Met Team located at CRREL.

Army Materiel Command (AMC). The Army Materiel Command (AMC) is responsible for the design, development, test, and evaluation of equipment to satisfy requirements for meteorological support equipment. AMC provides climatological and meteorological support to RDTE projects involving electro-optics and obscurants. It is also responsible for determining weather effects critical threshold values and environmental sensitivities of battlefield systems. AMC has several subcommands and elements carrying out weather R&D responsibilities.

Test and Evaluation Command (TECOM). TECOM is a subcommand of AMC providing operational support to 11 ranges and test sites with collocated Meteorological (MET) Teams. Under responsibilities established in Army Regulation 115-10

/Air Force Joint Instruction 15-157, the TECOM MET Teams provide weather support and atmospheric characterization to Army RDTE. MET Teams provide atmospheric data collection, analysis, consultation, warning, and forecast services for Army and other DOD RDTE.

MET Team FY 1997 funding has leveled off in FY 1997 following several years of decline, using a combination of both programmed funds and users funding. This will enable TECOM to continue basic meteorological support at Army RDTE ranges and sites, but meteorological instrumentation will be acquired through Army technical development resources or through direct funding from RDTE projects for test specific or unique requirements. Personnel and funding reductions in this program have limited the development of new technology, limited the development of new technology, limited training, and limited the capability of the MET teams. Program Element 06650601 funding of $0.342M represents a 5 percent reduction in funding, but will still enable full support to the modeling and simulation, test support, and chemical/biological requirements of Dugway Proving Grounds.

Army Research Laboratory (ARL). The ARL Battlefield Environment Directorate (BE) is the lead DOD agency for R&D in the portion of the atmosphere unique to the Army warfighter's battlespace--the planetary boundary layer. BE's mission is to "Own the Weather" by providing atmospheric effects information to decision makers on the battlefield in planning and executing operations. The joint Army/Air Force OTW initiative will provide knowledge of current and forecast battlefield environment conditions, along with their effects on systems, soldiers, operations, and tactics, to provide a decisive advantage over opponents.

Under the DOD Project Reliance taxonomy, BE is the lead agency for multi-service programs in transport and diffusion modeling and mobile atmospheric profiling, with the latter technology transferring out of BE to engineering development in FY 1997. In addition, BE contributes to tri-service goals in the areas of theater data fusion and predictions, boundary layer processes, and atmospheric effects.

The BE program is driven by the Army's need for meteorological information at smaller scales than used by either the Air Force, Navy, or civilian community, and over data sparse geographic regions. The Atmospheric Modeling & Simulation Division will have been moved to Adelphi, Maryland, along with the BE management during 4th quarter-FY 1996. The Battle Weather Division is scheduled to remain at White Sands Missile Range, New Mexico, until FY 1999, when it is also planned to be moved to Adelphi, Maryland.

The Atmospheric Modeling & Simulation efforts address: (1) models and simulations of environmental effects on electro-optical systems under realistic battlefield conditions; (2) acoustic propagation and background models for predicting environmental effects on acoustic signatures and sources; (3) micrometeorology, optics and beam propagation in the boundary layer; (4) transport and diffusion of chemical/biological agents and other aerosols released into the atmosphere; and (5) in-situ and remote detection of chemical/biological agents and pollution aerosols.

As a result of the transition to Maryland, the Atmospheric Profiling Research Facility will be split, with TECOM assuming the 50 MHz profiler, which will remain at White Sands Missile Range, along with the NOAA 404 MHz radar. ARL BE will continue to perform boundary layer profiling research with the FM-CW radar and Sodars at an eastern location. BE's acoustic field work will also be moved east, including the 56 foot long Mobile Acoustic Source.

The Battle Weather efforts include: (1) methods to provide accurate and timely artillery meteorology information for precision strike applications; (2) tactical weather data assimilation and distribution in conjunction with battlescale forecast modeling and tactical decision aids; and (3) transitioning advanced weather technology to Battlefield Automated Systems and Battle Laboratories, to allow the warfighter to exploit weather as a combat multiplier and gain tactical advantage over the enemy.

BE is working closely with Army users and other DOD organizations to ensure the highest possible payoff for its R&D dollars.

Army Research Office (ARO). The Army Research Office (ARO), Research Triangle Park, North Carolina, manages the Army's extramural basic research program in the atmospheric sciences. These programs are concerned with atmospheric dynamics at small scales, propagation of electromagnetic radiation through natural and induced obscurants, and the physics of the atmospheric boundary layers.

The basic research program is conducted through the individual investigator program and several special initiatives. The focus of the research is on the atmospheric processes and effects of the atmospheric boundary layer where the Army operates. Objectives of the research are to develop, from first principles, the physical basis for understanding the boundary layer processes, thereby, leading to a better understanding of atmospheric effects on soldiers, materials, and weapon systems. The research examines dispersion of battlefield materials, the effects of heterogeneous terrain features on air flow, and the development of natural obscurations. An essential element of the research is the development of instrumentation to measure the volumetric fields of wind velocity, temperature, and moisture of the boundary layer at turbulence time scales.

Two areas of special funding are also managed. The Augmentation Awards for Science and Engineering Research and Training program provides funding for additional graduate and undergraduate students working under existing sponsored research programs. The other area is in Congressionally mandated funding to academic institutions. This office manages one such program.

Communications and Electronics Command (CECOM). The CECOM Intelligence and Electronic Warfare (IEW) Directorate, Fort Monmouth, New Jersey, assists CECOM Systems Management Directorate and other internal organizations in developing and fielding weather support systems; and helps the Program Executive Officer for Command and Control Systems with technical management of weather programs. Current programs supported are the MMS, IMETS, and the Meteorological Profiler System (MPS).

The MMS is a light version of the Meteorological Data System (MDS). MMS is now being fielded to the active Army. MMS is an upper air meteorological data collection, processing, and dissemination system that provides data to field artillery and target acquisition users. The system meets Army requirements of "roll-on, roll-off" capability during assault. The system is NDI and the contractor, ETG, is building 40 systems for the Army.

The MPS will provide the current meteorological system with new and enhanced capabilities. It will provide a suite of sensors which will reduce the time staleness of atmospheric data. These sensors are capable of sensing the atmosphere on an almost continual basis. It also provides a four dimensional (time and space) model of local terrain to further improve the accuracy of data.

The IMETS is a tactical meteorological collection, analysis, forecasting, display, and dissemination system, operated by USAF weather teams in support of Army tactical operations. Data is collected from sources, such as military and civilian forecast agencies, satellite imagery, upper air Army artillery teams, USAF weather teams, etc. The IMETS is capable of merging two or more tactical data displays to form composite displays over various map and digital terrain backgrounds; combining satellite imagery with surface observations; and displaying forecast rain and cloud imagery movement. Data and tactical decision aids are disseminated to tactical users over landlines, area communications, and HF radio.

Medical Research and Development Command. The U.S. Army Research Institute of Environmental

Medicine, Natick, Massachusetts, conducts research on the effects of temperature, altitude, work, and nutrition on the health and performance of individual soldiers or combat crews operating Army systems.

Applied research efforts in thermal physiology and biophysical modeling are directed toward improving soldier performance and minimizing health risks in climatic extremes. The sensitivity of the soldier to weather parameters (primarily ambient air temperature, dew point temperature, wind speed, and solar radiation) defines an operational envelope for unimpaired human performance. The goals of applied research efforts are to develop methods to assess and extend the boundaries of the envelope in both training and operational settings.

In support of the Army Ranger training facility at Eglin AFB, Florida, Medical Research and Materiel Command and USARIEM are participating in the development of an automated thermal injury risk assessment system. The MERCURY-Ranger test bed system is being developed in partnership with the Army Research Laboratory's Battlefield Environment Directorate (ARL/BED), the Canadian Defence and Civil Institute of Environmental Medicine, and the USAF's 46th Weather Flight at Eglin AFB. Contractor technical support for MERCURY is provided by Science Applications International Corporation and, through the Advnaced Research Project Agency, Bolt Beranack and Newman Corporation. The MERCURY program ingests data from several local surface weather stations and automatically spreads the data across a region of interest using objective and heuristic interpolation methods. The resulting high resolution (1 km) gridded weather data fields are then used as inputs to the thermal strain prediction models for heat stress, cold air exposure, or cold water immersion. Results are displayed as color coded map overlays of thermal injury risk categories or tolerance times. This highly automated test bed system is intended to provide a platform for evaluating methods needed to translate real-time weather information into robust assessments of soldier system health risks and performance limitations.

Appendix A
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