NASA Contractor Report 3076

Current Research on Aviation Weather (Bibliography)

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1. Introduction

It is the purpose of this study to provide a bibliography of current work being carried out in the various areas relative to aviation meteorology. Reports in the area of aviation meteorology from 1975 to the present were compiled and reviewed. These reports were then summarized to assist anyone desiring a quick review of current work in aviation meteorology.

With the advent of high speed jet aircraft, expanding business and pleasure flying, the jumbo jet carrying large numbers of passengers, and the expanding V/STOL aircraft field, particularly the increasing usage of helicopters, both civil and military, a wide spectrum of meteorological problems must be addressed by the many disciplines within the aviation community as well as the meteorologist if aviation's excellent safety record is to be maintained. The recent tragedy at Tenerife involving the collision of two 747 jumbo jets of Pan American Airways and KLM can be viewed as an indicator of future trends if the global expansion of aircraft operation continues without the same global expansion in aviation meteorological services. There must be an effective means of communication to apply, distribute, display, and present the operationally significant weather information on a timely basis for the controllers, pilots, and operational planners. Such a communication system does not presently exist. With the elimination of this problem, noticeable improvements in the orderly and safe flow of air traffic would be realized. The next decade should see a marked improvement in weather radar, weather satellites, and in the analysis and prediction of the state of the atmosphere up to 30 km, utilizing high speed computers. Weather radar will detect severe weather and produce air traffic conflict displays for air traffic controllers. Poor visibility as a result of fog will be improved by weather modification techniques so that adequate visibility for visual landings and take-offs can be maintained under most conditions.

Technical gaps must be eliminated for future improvements, especially in light of increased air traffic, particularly in the terminal area. This area is the most critical from the viewpoint of planning, dispatch, operations and air traffic control, with the elements of most serious concern being visibility, turbulence, low level wind shear, and icing. Accurate observations and forecasts of these elements are imperative in the years ahead. The inability of the weather system to provide this service by producing observations and forecasts with the accuracy and detail required in the future is a serious technical gap demanding prompt attention by the research community.

Much more theoretical and scientific knowledge of the atmosphere is required before any revolutionary breakthroughs can be expected in forecasting. The aviation weather service is on the brink of some very dramatic improvements. The role of automation in the future of aviation weather service must be accurately evaluated so that a viable man/machine mix will be achieved. The science of meteorology will continue to require the intervention of the meteorologist as the computer can only evaluate data based upon the information placed into it by the user.

The many different disciplines of the aviation community have been brought together recently by such meetings as the Meteorological and Environmental Inputs to Aviation Systems Workshops, held first in March 1977 and again in March 1978 at the University of Tennessee Space Institute, and the OAST Aviation Meteorology R and D Retreat presently being held each fall at Wallops Island. It is through the interaction of such groups that the many faceted problems of aviation meteorology will be solved.

To aid in the use of the review and accompanying bibliography, a listing of the subject headings is given below in the order in which they appear in the text.

Advanced Meteorological Instruments

Fog

Forecasting

Icing

Lightning

Visibilities

Low Level Wind Shear

Storm Hazards/Severe Storms

Turbulence

Training

Appendix A is a tabulation of the research work being carried out in these areas of aviation meteorology by the National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the Federal Aviation Administration.

2. Advanced Meteorological Instruments

Advancement in meteorological instruments in the past decade can be traced to several sources. One of the foremost would be the increased demand for more up-to-date and accurate weather forecasts within the aeronautical community as it has expanded into the age of the jumbo jet, supersonic transport, and concentration of operations in centralized hub areas. Another is from spinoff technology of the space program. Still another, though somewhat ambiguous in its nature of application, is military weapons systems and communication research. Research in automation of weather forecasting has linked the various meteorological measuring instruments and shown what systems need to be further refined.

Williams (1976) surveys uses of radar for measurement and study of meteorological conditions. The type of radar employed for a specific type of measurement will depend upon what is to be measured.

The use of pulse Doppler radar systems to identify and measure severe storm systems has been studied by Doviak et al (1978), Hendry and McCormick (1976), Burgess et al (1976), and Frisch and Strauch (1976). Bohne and Srivastava (1977), Freeman et al (1976), and Harris (1976) reported on the use of Doppler radar in the observation of precipitation. Atlas and Brown (1977) used an airborne synthetic aperture radar (SAR) for the detection and mapping of precipitation echoes.

Wang et al (1977) describe the use of lasers for analyzing rainfall. Toal and Davis (1976) described a multiple laser beam probe system for turbulence diagnostics.

The future use of satellites in meteorology is very great. Scofield and Oliver (1975) describe the synchronous meteorological satellite (SMS) and discuss its advantages and disadvantages.

Strauch and Chadwick (1977) demonstrated how the FM-CW Doppler radar can be used to measure the Doppler velocity spectrum of meteorological scatters with the same resolution and ambiguities as a pulse Doppler radar at the same transmitted signal bandwidth and repetition rate. Chadwick et al (1977) and Goss et al (1978) surveyed the FM-CW Doppler radar's potential for application as a device for measuring wind in the lower atmosphere in all weather conditions. Thus, it may be useful in revealing wind shear hazards at airports, predicting dispersal of air pollutants in valleys, near cities, and power plants, and for predicting the formation and dispersal of fog. The use of acoustic Doppler radar for real-time measurements of winds is reported by Davey (1977), Sirmans et al (1976), and Ray and Ziegler (1977). Campbell and Strauch (1977) report on a low power three cm pulse Doppler radar that has been constructed in hopes that it will alleviate some of the range and velocity aliasing that occurs with conventional pulse radars.

The use of lidar, light intensity detection and ranging, in atmospheric measurements has increased in this decade, and advances in its application to mesoscale remote sensing problems are reviewed by Reagan and Schotland (1975). Such applications of lidar as pollution, meteorology and cloud development are reviewed by Platt (1977) and Derr et al (1976). Kohl (1977) investigated the use of lidar to measure the slant range transmission along a landing approach path. Adrian and Orloff (1977) conducted investigations concerning the characteristics of the visibility function as determined by the parameters of laser anemometer systems and the electromagnetic scattering properties of the particles. Armstrong et al (1976) measured atmospheric aerosols using a transit-time lidar velocimeter. Fernald and Schuster (1977) also studied the use of lidar for aerosol measurement.

3. Fog

Current interest in the areas of fog and its effect on aviation appears to be primarily directed to efforts involving fog modification and dispersal. Intensive research and development over the past decade has led to operational implementation of several techniques for the dispersal of one type of fog and several promising concepts for the artificial dissipation of another. As Weinstein (1977) reports, the dispersal of supercooled fog and stratus, i.e., liquid water clouds at temperatures below 0°C, was the objective of the most publicized early weather modification experiments and is presently the only truly operational modification technology. Weinstein and Kunkel (1976) focus attention on such methods of supercooled fog dispersal as the airborne dropping of small pellets of dry ice and ground based chilling of the air, and to such methods of warm fog dispersal as helicopter downwash mixing, thermal fog dispersal and hygroscopic particle seeding.

In order to produce a clearing the helicopter downwash must reach the ground while the helicopter hovers at or above the top of the fog. Barker et al (1975) use a two-dimensional axially symmetric computer model to study downwash-induced fog clearing. The major factors affecting the size and penetration of the downwash are the strength of the helicopter downwash and the buoyancy of the downwash. The clearing can be enlarged beyond the size of the primary downwash by surface-induced divergence and by mixing of dry air into the fog.

Plank, Spatola, and Johnson (1977) determined values of diffusion coefficients from the observed closing times of nine conical shaped clearings in fog produced by hovering helicopters. The diffusion coefficients for the experiments ranged in value from 0.75×10^5 to 1.9×10^5 cm^2/sec. The values were consistent for experiments performed on the same day, but no other correlations with meteorological or geometric parameters of clearing were found.

Reinking et al (1977) describe the warm fog modification experiments conducted under Project Foggy Cloud VI. The aim was to develop an inexpensive, reliable, rapid method of dispersing warm fog and stratus. Several techniques were tested: (a) the dispensing of electrostatically charged droplets from aircraft to induce fog droplet coalescence and rainout, and the dispensing of electrostatically charged bubbles from the surface to collect and precipitate fog droplets, and (b) spreading and maintaining monomolecular films on the water surface to suppress evaporation and inhibit fog formation. Carroz and Keller (1976) conducted laboratory tests on charged drop sprays in support of the Project Foggy Cloud studies.

Also in the area of warm fog dispersal, Tag (1976) suggested that the use of charged particles or electric fields be considered as a technique for dissipating warm fogs. The study was done to determine the degree of improvement one could expect as the result of one aspect of electrically enhanced coalescence due to an externally applied electric field on neutral drops. Tag used a numerical simulation with a one-dimensional microphysical fog model which incorporates the process of collision-coalescence. He determined that a noticeable improvement in visibility can be achieved only under extremely large field strengths, and then only for certain fog spectra.

A numerical study of the use of highly charged water drops to clear warm fog has been conducted by Tag (1977). The mechanism studied is the polarization of neutral fog droplets and their capture by charged drops. A multi-level microphysical model is used to investigate the degree of visibility improvement resulting from variations in seeding drop size and charge, the concentration of seeding material, and the fog being seeded. It was determined that visibility improvement decreases with decreasing fog droplet size and increases with increasing seeding rate and seeding drop charge. Tag (1977) concluded that the charges and treatment concentrations simulated in the study would not be adequate for clearing fog. Consideration of the additional effects of electrostatic precipitation and increased field strengths could make charge drop seeding a viable method of fog dissipation.

A broad effort is being conducted to develop an operational warm fog dispersal system (WFDS) using ground based heat sources. Klein and Kundel (1975) described a method of calculating the ground jet case. The method can be used for jet velocities of 100 m/sec or less, wind velocities below or equal to the jet velocity, and jet temperatures to three times the ambient value. Kunkel (1975) reported on field tests which were conducted with a subscale momentum/heat system to determine the optimum heat and thrust requirements and combustor positions for a full-scale thermal fog dispersal system. The impact of the warm fog dispersal system on the air quality and noise level was also assessed by Weinstein (1976).

The FAA conducted a study in 1975 to determine the feasibility and cost effectiveness of a warm fog dispersal system at Los Angeles International (LAX). The Thermokinetic and Modified Passive Thermal methods were examined. The study concluded that for LAX, a Thermal fog dispersal system would be both feasible and cost effective.

It appears that supercooled fog dispersal will be much easier to achieve than that of warm fog due to its metastable condition. A series of controlled and free environment tests to determine the technical feasibility of using the cooling resulting from the adiabatic expansion of compressed air to initiate ice crystal production in supercooled fog has been done by Kunkel (1976) and Weinstein and Hicks (1975). It was found that approximately $10^3 cm^3$ of air, when compressed to 60 psig and released through a supersonic nozzle, will produce the same number of ice crystals as does the evaporation of 1 cm^3 of liquid propane. Hicks (1974) discusses the results of seeding and of an examination of the morphology of ice crystals produced by propane seeding. The ice crystal production efficiency of propane spray under various laboratory and field conditions is described. Beckwith (1975) outlines the different airport fog dispersal systems so far known and compares their capabilities. Facy (1974) summarizes fog dispersal techniques in terms of warm and cold fogs and discusses the effectiveness of the methods. Silverman and Weinstein (1974) describe the FIDO thermal fog dispersal system. The system cost and capabilities are examined.

The problem of fog forecasting is perhaps as important as dissipation. Gurka (1976) discusses the use of satellite imagery in the short range forecasting of fog and stratus formation during the night. Enhanced IR satellite pictures can provide the forecaster with a new tool for forecasting the extent of warm air advection fog and stratus formation. Frequently, areas in which fog and stratus are likely to form will appear as relatively dark areas on the satellite pictures taken a few hours after sunset. Ernst (1975) reports, however, that due to minimal temperature contrasts, non-detection of "invisible" fog and stratus in IR imagery may occur.

Numerical models have been used to investigate the development and formation of fog. Williams et al (1975) use a two-dimensional model for such an investigation. The model is designed to simulate the formation, development, or dissipation of advection fog in response to transfer of heat and moisture between the atmosphere and the surface as driven by advection over horizontal discontinuities in the surface temperature. Kessler and Baker (1976) developed a fog prediction model expressly for use of radiosonde data as initial input. While the model is not suitable in its existing form for general fog prediction, it is useful in probing mechanisms of fog formation.

Hung and Vaughan (1977) investigated the life cycles of advection warm fog using a numerical model. The formation, development, and dissipation were studied. The equation used for the model included the equations of continuity, momentum, and energy for the description of density, wind component, and potential temperature, together with two diffusion equations for the modification of water vapor mixing ratios and liquid water mixing ratios.

Dickson and Sagendorf (1977) conducted a series of SFL/oil fog diffusion tests. The tests were conducted over flat terrain in conditions of a stable lapse rate with wind less than two m/sec. The light winds appeared to enhance horizontal diffusion of the fog.

Several studies have been done in the area of fog formation or modeling of fog formation. A turbulent-radiative description of the low level atmosphere incorporating stratus cloud and fog was developed by Oliver et al (1978) based on methodology of second order closure. Illustrative application was made to the formation and structure of several fog and cloud episodes including advective-radiative fog and surface fog resulting from the nocturnal lowering of stratus. Ferri (1974) developed a model which considers the fog as a dynamical system whereby droplet depletion through fallout is balanced by a continuous process of evaporation and condensation. This model may be used to explain why fogs can be maintained for extended periods of time. Ferri presents equations and compares numerical examples with experimental data.

Several studies of radiation fog have been conducted. Roach (1976) estimated that radiative cooling is the principal agent of droplet growth in radiation fog. He showed gravitation settling to be the principal limiting factor on droplet growth in radiation fog.

An interpretation of field study observation in the evolution of radiation fog which led to a considerable clarification of the principal constraints in the development of radiation fog is described by Roach et al (1976). Radiation cooling promotes fog formation while turbulence inhibits it. Gravitational settling of fog droplets and soil heat flux emerge as decisive factors. Brown and Roach (1976) present a numerical model of fog and assess the effect of cloud cover and solar insulation on dispersing fog for which it is shown that: (1) a reduction in turbulent diffusion leads to earlier and thicker fog formation; (b) formation and growth of fog on a realistic time scale is simulated by the inclusion of radiative cooling due to water vapor and carbon dioxide and fog droplets; (c) inclusion of gravitational setting is necessary to simulate realistic liquid water contents; and (d) the nature of the underlying surface influences the time of onset of fog. During the field study, Roach (1976) examined some quasi-periodic oscillations of 10-15-min. periods in net flux of long wave radiation, surface temperature, and wind during the development of radiation fog.

Spencer et al (1976) studied the effects of coronal discharge on the growth of small droplets in a cloud chamber. It was found that the discharge produced a large number of nuclei for condensation. Chylek (1978) investigated the relationship between liquid water content and the extinction of fogs. Tampieri and Tomasi (1976) also investigated the relationship between fog droplets and their volume extinction coefficients. They also attempted to obtain information about the shape of droplet-size distributions from empirical data given by transmission measurements. Fitzgerald (1977) investigated errors in using nephelometers for determining fog droplet size. Several other studies have been done using a laser fog nephelometer to determine drop size and distribution by Dickson et al (1975).

4. Forecasting

In recent years the field of weather forecasting has made significant advances. This can be attributed to several factors. The automation of the weather services coupled with the use of high speed computers, better numerical modeling techniques, and the use of satellites and advanced radars have brought about these advances. A great deal of work is still being done to better refine the forecasts and provide a forecast as accurate and as up-to-date as possible.

Lindquist (1977) surveys some of the FAA programs to apply automation to aviation weather study. Ongoing programs include the Aviation-Automated Weather Observation System (AV-AWOS), the Aviation Weather and Notice to Airmen System (AWANS), and the Meteorological and Aeronautical Presentation System (MAPS). Planned programs include Voice Response System (VRS) and Pilot Self-Brief Terminal (PSBT). Lieurance (1977) surveyed the weather service requirements of the next decade. Rocke and Glassburn (1976) explain that the current FAA Flight Service System (FSS) is outmoded and obsolete. A new system design is currently being finalized by the FAA. Beran et al (1977) reviews the current state of aviation weather forecasting and its effect on weather-related accidents. The importance of mesoscale modeling and use of new remote sensing devices is discussed. An assessment of today's services and capabilities is given by Bromley (1977), and progress in meeting these challenges is outlined. A review of the effort to develop an AV-AWOS for unmanned locations is given by Mandel (1975).

The Automation of Field Operations and Services (AFOS) program of the National Weather Service (NWS) will provide a new dimension to local weather analysis and forecasting. By providing minicomputers, video displays and high speed communications to more than 200 weather stations around the country, AFOS will greatly increase the forecaster's ability to assess, process, display, and disseminate meteorological information. Detailed reviews of the AFOS are given by Klein (1976), Gross (1977), and Glakn (1976). In opposition to this effort at automation, Snellman (1977) argues for the retention of human guidance in operational short-range weather forecasting and against the trend in replacing the present man-machine mix of operational forecasting with purely machine products, except for the early hours of the forecast period.

Fawcett (1977) overviews the current prediction capabilities at the NWS's National Meteorological Center (NMC). The limits and prognosis for the future capabilities in weather forecasting are surveyed by Louise (1976), Pielke (1977), Treussart (1977), and Ramage (1976). Leith (1978) considers two methods of weather prediction which are being used and the future applicability of both.

The use of radars and radar data for use in forecasting and in real-time evaluation has become prominent in recent years. Bellon and Austin (1976) describe a system for preparing short-term weather forecasting maps through the automatic processing of radar data. Some of the operational and research uses of weather radar are reviewed by Smith (1975). Requirements for quantitative measurements of maximum echo height and echo intensity are emphasized. Some deficiencies of current weather radars are pointed out. Three models for forecasting radar echo displacements through the use of zero-tilt reflectives or vertically integrated liquid water content are analyzed by Elvander (1976). The use of radar in the prediction of local weather for use in real-time control operations has been studied by Trettel and Rai (1976) and Hill et al (1977). Payne (1977) presents a mathematical model for analysis of weather radar returns. Schaffner (1977) considers the characterization of weather radar returns, with the aim of providing guidelines for the simple display of storm watch data and short-term forecast reports. Atlas et al (1977) describe the use of an airborne synthetic aperture radar for the detection and mapping of precipitation. Riley and Johnson (1976) also report on the use of digital radar data for evaluating precipitation intensities. Haag (1976) reports a method for recording weather radar data. Thomson (1975) presents an overview of the development of acdar meteorology, i.e., acoustic detection and ranging systems.

The use of satellite data in weather forecasting has become commonplace, and with the new series of geostationary meteorology satellites, the linking of satellites with high speed computers and weather radars will give highly accurate real-time evaluation of meteorological conditions. Purdom (1976) discusses some of the uses of the Geostationary Operational Environmental Satellite (GOES) in forecasting. Miller and Hayden (1978) present results to determine the impact of satellite retrieval information on the spectral objective analyses and currently made six-layer numerical forecasts.

Billingsley and Hasler (1975) describe the Image Display and Manipulation System (IDAMS) for earth resources satellite data processing and the METPAK software package for performing meteorological operations on IDAMS. Tracton (1976) discusses preliminary sounding data from Nimbus-6. Satellite uses in forecasting is reportdd by Reynolds and Haar (1977) and Parikh (1978). Liou (1977), McCleese and Wilson (1976), Shull and Stephens (1977), Bunting and Conover (1976), and Weinreb (1977) consider the use of satellites for obtaining information about cloud thickness, elevations, and such properties as the water and ice content. Satellites, as reported by Randerson (1977), Weinmar and Guetter (1977), Gurka (1976) and Slodt and Grant (1976), are also being used to study and forecast cumulus activity and its related effect.

A bibliography of numerical forecasting techniques is given in Appendix B. While these models contribute in the total forecasting process, they are not considered to have a direct relation to aviation meteorology forecasting.

5. Icing

The basic problems and areas of necessary research in relation to aircraft icing have been known since the early days of flying. Perkins (1978) concluded that NACA research efforts within the 1940's and 1950's time frame had identified the range of icing parameters. He also concluded that the decline in NACA research in icing was due to the advent of the high altitude jet aircraft. This aircraft not only operated above the normal levels commonly associated with icing, but their high climb and descent speeds minimized the overall icing problem. Perkins also states that the problem areas that existed in the 1950's when NACA decreased their research efforts for the most part still exist today. The recent increase in demand for all weather operations, including operation in known or forecast icing conditions, for helicopters and general aviation has brought about a moderate resurgence in icing research and development efforts. Adams (1978) identified several areas in which this research should be directed.

The problem of protecting an aircraft so that safe operation within an icing environment can be conducted has been relegated primarily to the designer. The majority of recent icing research has been done in relation to testing and certification of helicopters. Adams (1977) gives a summary of the recent helicopter icing research that is being done by the Army Research and Technology Laboratories. Lake (1976) surveyed the status of research on helicopter icing and deicing and determined that the necessary data base and supporting theory were not acceptable. Hagen et al (1977) describes the tests conducted for icing approval of the YUH-16A helicopter. The results of the tests conducted using the Helicopter Icing Spray System are discussed. Kitchens and Adams (1977) describe the elements of a cyclic electrothermal ice protection system for a UH-1H helicopter, and summarize results of simulated and natural icing flight tests which have been conducted to date. Forward flight tests were made using the CH-47 Helicopter Icing Spray System and hovering tests using the Ottawa Spray Rig. A description of these simulation systems was given by Adams (1978). Shepherd (1976) reviews the operating principles of cyclic rotor ice protection systems, considering practical experience with tests of unprotected and protected under natural icing conditions. The problem of certifying helicopters for operation in icing conditions was considered by Lake and Bradley (1976). He considered such things as requirements for testing iced helicopters in forward and hovering flight, rotorcraft certification, techniques for observing and measuring ice accretion, performance of iced aircraft, and testing and certification of helicopters. He also outlines problems involved with conducting natural icing tests.

Another area in which icing research is continuing is in engine testing. Ice accumulation on engine inlets can cause a restriction in airflow to the engine, and if shedding occurs can lead to flameout or even compressor damage. Test techniques developed at the Arnold Engineering Development Center to evaluate the effects of environmental icing on the performance of aircraft turbine propulsion systems, propulsion system inlets, and aircraft system components are reported by Berg and Wolff (1976). A new system for preventing condensate and precipitate icing of gas turbine inlet systems was described by Gillingham (1976). The system used a combination heat exchanger/moisture operator called an Anti-Ice Moisture Separator (AIMS) to provide icing protection without the need to heat the inlet air to 0°C or above. It is estimated that AIMS systems will be able to prevent inlet icing at any ambient temperature that may be encountered.

Another problem is that of icing definitions. Current icing definitions are given in subjective terms and relate icing severity to the ability of the reporting aircraft to handle the specific icing encounter. Adams (1977) makes an assessment of icing definitions and recommends a method which would make icing forecast easier for the meteorologist to make and more generally applicable to all users. Newton (1977) also addresses the need for a definition of the intensity of icing conditions in terms of meteorological parameters which the forecaster can predict, the manufacturer can design to, and the pilot can identify.

6. Lightning

A great deal of concern has surfaced recently and a vast amount of research is being done dealing with lightning and electrostatic discharges and their effect on aircraft avionics, advanced composite materials, and the fuel systems and structures of the aircraft.

Robb et al (1975) presented a summary of electromagnetic shielding of aerospace vehicles. In this summary, electromagnetic shielding of aerospace vehicles may be arbitrarily divided into two basic aspects: shielding by counter currents induced in the shell by the incident currents or electromagnetic fields, and by symmetry of current flow. The differences are illustrated between the conclusions which might be drawn from the theoretical concepts only and what has been found to be of most importance in actual measurements in real operational aircraft tested with full-scale average lightning current magnitudes of 20,000 amperes and with the electrical systems and engines operating. Two computer programs, APERTURE and DIFFUSION, reported by Fisher et al (1975) and Maxwell (1975), have been developed which evaluate the internal magnetic fields produced by the two most important mechanisms by which external magnetic fields are coupled to the inside of the aircraft.

Another concern is with induced transient effects of atmospheric electricity on system avionics. Corbin (1977) presents a review work done by the Air Force Flight Dynamics Laboratory in this area. It includes: threat characterization and assessment; analytical modeling and software development; protection and hardening techniques;

and design guidelines, criteria, and handbooks. A major aspect of this work is the assessment of the hazard of static electricity to such aircraft systems as advanced composite structures, fuel systems, engines and their controls, external stores and electro-explosive devices, and structures such as radomes, canopies and windshields.

Solid state components in control, communication and avionics equipment are highly susceptible to lightning surges or other forms of electromagnetic disturbances. To protect these components transient protectors with low breakdown voltages and short response times are needed. Chen (1975) examined the operation and the characteristics of gas discharge transient protectors (glow lamps and gas-filled spark gaps), semiconductor breakdown diode transient protectors and metal oxide varistor protectors. It is found that of all types of transient protectors, the gas-filled spark gaps, semiconductor breakdown diodes and zinc oxide-bismuth oxide varistors are the most effective. Conti and Cary (1975 and 1976) survey radome protection techniques which generally involve enclosing the radome and/or the radar system with suitably distributed metallic elements. Another source of electrostatic build-up and discharge is the windscreens and canopies. Sharp (1975) investigates the effects of results of such an accumulation. He found that the windscreen or canopy may hold a charge of several thousand volts relative to its mounting structure. Antennas are also good sources of electrostatic build-up and lightning stroke attachment. Lee et al (1978) analyzed responses of aircraft antennas to a broadband electromagnetic wave such as the nuclear electromagnetic pulse. They divided antennas into five classes: blades, loops, slots, bowls, and long wires. For each class of antenna a detailed equivalent circuit, input impedence, and effective height at the antenna's conductor are given.

Kung and Amason (1976) considered the vulnerability of graphite and boron epoxy to lightning strike damage when proper design cautions are not taken. They introduced two new design concepts. The isolation concept--the complete isolation of the advanced composite structure from lightning current paths. The conductive concept--the use of graphite composite structure to safely conduct lightning currents. Laboratory simulated lightning test data supporting these two design concepts are presented. For accurate simulation tests of the effects of natural lightning on aircraft components and systems, certain significant parameters of the natural environment must be controlled. Clifford (1976) shows that improper test conditions or controls in the testing of composites for lightning damage can cause unrealistic damage. Attention is given to high peak current simulation and the swept-stroke lightning simulation. Robb et al (1975) conducted swept-stroke studies involving protected non-metallic structures, and damage and protection in the case of composite helicopter blades. Additives for paints over thin metal skins covering fuel tanks are considered, taking into account strength tests which showed that a very significant reduction in the puncture voltage could be obtained with the aid of aluminum powder. Philips et al (1975) concluded that a lightning strike on components made from carbon fiber reinforced plastics is unlikely to bring about serious and incapacitory structural damage. The experiments considered showed that the damage caused by simulated lightning strikes on carbon fiber composites involves a characteristic burn which volatizes the resin from the fibers. Perry (1975) conducted further studies on boron-containing composites.

A major problem in the area of lightning safety hazards to aircraft is the effect of lightning on fuel and the fuel systems. After the Elkton accident, as reported by Auburn (1975), in which a lightning-induced ignition of the fuel/air mixture in a reserve fuel tank led to loss of the aircraft, investigations were conducted to find methods to prevent similar accidents. He reports on the technology which is evolving that would enable a designer to provide protection that would eliminate the risk of accidental ignition of fuel vapors within tanks and vent systems and also on the development of federal regulations based on this technology. Inspection of current practices in the aircraft industry by Shaw (1976) revealed that in many cases the lightning safety problem is considered to be solved by installing a lightning-proof aircraft filler cap. Plumer (1977) considers other factors influencing lightning effects on fuel systems as well as total aircraft lightning interactions. Lippert (1976) reports on the AFFDL's Advanced Fuel Vulnerability program aimed at assessing relative vulnerability and identifying hazards associated with advanced (all but natural petroleum) fuels to determine their feasibility for use in military aircraft. The initial considered fuel for testing was liquid hydrogen (LH_2). The Air Force is also developing for basic computer analysis to apply as a vulnerability assessment the Intrasystem Electromagnetic Compatibility Analysis Program (IAP) as described by Hubert (1975).

Studies to determine the lightning strike point locations on aircraft have been done. The location of the lightning strike attachment may present a serious problem especially for military aircraft and commercial SST. Knuller and Plumer (1975) report on the lightning protection program of the S-3A anti-submarine warfare aircraft which is expected to operate under all weather conditions with a high lightning strike probability. NASA's study of lightning effects on the F-8 digital fly-by-wire flight control system is reported by Plumer (1975). The military is also concerned with atmospheric electric discharges on advanced radar, ECM, and target detection systems as summarized by Ormsby (1975). Nanevicz (1975) and Reynolds (1975) have studied the special problems associated with supersonic aircraft, taking into account such factors as precipitation charging, engine charging, engine discharging and tailcap antenna method of lightning protection using a strip consisting of metal segments connected by means of an appropriate resistance material.

The modeling of lightning hazard has increased due to the cost associated with full-scale simulation and the associated effect of trying to collect lightning strike data from natural sources. McKague (1977) presents a probabilistic model for analyzing and predicting aircraft lightning hazards. The model takes into account three basic factors in calculating the frequency with which a given type of aircraft will be struck by lightning: a geometric factor, which may be considered a measure of lightning flash density; and a service-related factor, which defines the probability of encountering lightning under a specified set of operating conditions. Clifford (1975) and Phillpott et al (1975) discuss the value of determining the location of probable lightning attachment points and swept-strike lightning zones on new aircraft designs through the use of lightning attachment points tests.

Plumer and Perry (1975) collected data which makes it possible to predict with reasonable accuracy the rate of incidence and the location of lightning strikes in the case of conventionally shaped aircraft. It is pointed out that altitude limitations or unusual thunderstorm activity can appreciably increase the incidence of strikes for a given aircraft. Pierce (1975) considered questions related to the lightning strike incidence.

While a great deal of research is being done in the area of aircraft/lightning interaction and in the protection of aircraft and sensitive systems to the effects of lightning, continuing research on the physics of lightning formation and the stroke discharge is also critical. The mechanism of the basic lightning discharge is described by Anderson (1975). This mechanism is explained in its three stages: (1) the leader deposits negative charge during about 10 to 20 microseconds; (2) on contact with the opposing charge center, the return stroke takes place and overdischarges the lightning channel within 100 microseconds, leaving the channel positive; and (3) slow discharge takes place for some milliseconds, during which negative charge again moves into the channel from the cloud charge to neutralize the positive charge. Golde (1977) presents discussions of several of the mechanisms of lightning formation, while Smyth and Smyth (1976) describe many of the observed characteristics of the lightning discharge.

The electric fields produced by stepped and dart-stepped leaders which immediately precede the return strokes in lightning discharges have been studied extensively. Krider et al (1977), Livingston and Krider (1978), and Jacobson and Krider (1976) studied in detail the stepped leaders and associated electric field. Hill (1977), building upon the work of Krider et al, suggests that the energy dissipation of the field takes place primarily ahead of the advancing secondary streamer. Orville (1975) used a high speed slitless spectrograph to study dart leader spectral emissions. Le Vine (1977) also offered a method for assessing spectral radiation of lightning. The results indicate that the magnitude of the spectrum of the received signal can be related to the spectrum of the source current, possibly providing a means for the study of lightning current wave forms.

The lightning return stroke with its high peak currents and transient voltages has been studied very extensively. Boyle and Orville (1976) describe a data analysis method by which the electric current can be remotely determined. Le Vine et al (1977) measured the HF and VHF radiations produced during a return stroke. Tiller et al (1976) studied the properties of the electric field intensity from first and subsequent lightning return strokes. Properties considered included electric field wave shape versus distance, initial peak rise time versus distance, rise time histograms, initial peak magnitude versus distance normalized initial peak magnitude histograms, normalized initial peak magnitude versus rise time, ramp starting time versus distance, and field at 170 microseconds versus distance. Other studies to measure the field strength and flash properties have been conducted by Uman et al (1976) and Herman et al (1976). Also, studies to statistically determine cloud-to-cloud and cloud-to-ground strike probabilities have been conducted by Buset and Price (1975) and Prentice and MacKerras (1977).

The intensity of precipitation can be used as an indicator of lightning. Marshall and Radhakant (1978) found high intensity level regions on radar precipitation maps to be the sources of lightning observed by a radio detection finder. Carte and Kidder (1977) studied the position of lightning flashes in relation to rain and hail. Gaskell et al (1977) used airborne studies to characterize atmospheric currents associated with precipitation and the precipitation element parameters of charge, diameter, and field. Satellite observation of lightning parameters has been studied by Turman (1977).

Research in efforts to artificially initiate lightning has increased. Chaff seeding used to alter lightning production and intense electric field in isolated thunderstorms is reported by Priest (1977). Griffiths (1977) discusses a hypothetical cloud seeding method for facilitating lightning. Baughman et al (1976) present results of statistical analyses of data from an investigation of lightning modification by randomized cloud seeding with silver iodide. Another method for triggering lightning where rockets with steel wire attached are fired into thunderclouds is reported by Gary (1975).

7. Visibility

The determination of visibility has concerned aviation since the early days of flight. Douglas (1978) reviewed recent work in visibility and determined that the greatest advances were in instrumentation techniques used to measure visibility.

Rowe (1978) considered the problems of low ceiling and visibility, from the viewpoint of both the meteorologist and flight scheduler, as the problem of accurately forecasting the onset, duration, and extent of low ceilings and visibilities. The need for prevailing visibility and how instruments would determine it were considered. The use of and forecasting of prevailing visibility is particularly important to the general aviation community.

Kreid (1977) conducted an analysis of a modulated CW lidar system for remote sensing of the atmospheric visibility. A technique for the measurement of phase shift with a modulated CW lidar system was evaluated by Bufton and Iyer (1978). The single-scatter, single-wavelength, scalar-backscatter lidar equation was investigated by Kohl (1977) to determine the transmission along a line from a point on the ground to the decision height on the three-degree aircraft glide slope. The Monte Carlo method was used by Kunkel and Weinman (1976) to calculate monostatic lidar returns from such atmospheric visibility hazards as thick haze, fog, rain, and stratus clouds. Parameters which relate to visibility measurement for two visibility measurement systems, a pulsed array of laser diodes and a modulated CW He·Cd laser, have been analyzed by Ganiaris (1976). Weinman (1976) derived multiple scattering contributions to lidar returns from turbid atmospheres by means of analytical theory.

Shumabukuro et al (1976) determined the atmospheric transmissivity by measuring the intensity of an extraterrestrial radiation source at various zenith angles. Investigations have also been done by Adrian and Orloff (1977) to determine the use of laser anemometers to measure visibility characteristics and particle size. The monitoring and determination of slant visual range has been investigated using various visibility measuring devices as reported by Douglas and Booker (1977). Efforts have been made to predict sensor equivalent visibility.

8. Low Level Wind Shear

The severe problem of low level wind shear (LLWS), like so many other problems in aviation meteorology, has begun to attract serious concern only after several accidents have been attributed to it. Coons and Mandel (1977) give a status report of the FAA's Wind Shear Research and Development Program. The report overviews the research being done into the meteorological conditions giving rise to hazardous LLWS. Two ground-based wind shear detection systems are described. Langweil (1976) describes the FAA wind shear program, which is designed to alleviate the hazards of wind shear in the terminal area. In response to a number of aircraft accidents which were attributed to wind shear, the FAA has designed a Low Level Wind Shear Alert System. This was prompted by analysis of the accidents which revealed that substantial differences existed between the reported surface winds measured at centerfield and the surface winds existing in the approach and departure corridor.

Fujita (1977) examined three separate aircraft accidents related to wind shear to determine what meteorological similarities existed. All accidents occurred as the aircraft, either descending or climbing, lost altitude while experiencing strong wind shear inside a downburst cell. Similar spearhead radar echoes were observed to the north of each accident site. Fredrickson (1977) also reviews accident patterns in the take-off and approach and examines flight recorder accident dates in wind shear accidents in an effort to determine what might be done to alleviate the severity of the problem.

Frost and Camp (1977) surveyed the various types of wind shear which cause problems to aircraft operations. The study was limited to low level wind shears such as might be encountered in the take-off and landing phases of the flight. The types of shears discussed were limited primarily to frontal, thunderstorm, and shears associated with stable and neutral boundary layers. Frost, Camp and Wang (1978) continued the studies of Frost and Camp (1977) and developed mathematical models of wind profiles for use in fast-time and manned flight simulation studies aimed at defining and eliminating these wind shear hazards. Frost, Crosby, and Camp (1978) developed a computer model to simulate aircraft landing through thunderstorm gust fronts. Flight paths, as well as control inputs necessary to maintain specified trajectories, are presented and discussed for aircraft having characteristics of a DC-8, B-747, augmentor-wing STOL, and a DHC-6.

Sources and causes of LLWS around airports has been investigated to identify what might be hazardous situations. Fichtl et al (1977) analyzed some potential sources of LLWS in and around airports. The area covered included: wind shear over flat terrain with near-homogeneous surface properties, the turning layer, shear flow over inhomogeneous terrain (airport and urban areas), thunderstorms, turbulent flow fields over bluff bodies (individual buildings), and recirculating wake flow downstream of three-dimensional block bodies. Sowa (1977) considered how unique terrain near an airport can cause significant LLWS to exist under certain meteorological conditions. The terrain near two airports, Anchorage, Alaska and Portland, Oregon, is considered and specific procedures that enable the pilot to identify the wind shear are given.

Cox (1976 and 1977) reviewed the multi-dimensional nature of wind shear investigations. Hardy (1976) investigated the nature of waves' instabilities, weather conditions leading to strong wind shear and some of the features of vertical wind shear. Three major regions were considered: near the surface, in the free atmosphere, and in the vicinity of a thunderstorm. Melvin (1977) presents a general description of wind shear and how it might effect pilots.

Moorehouse (1977 and 1978) investigates the effect of wind shear on airspeed indication in the landing approach which sometimes has the appearance to the pilot of less airspeed stability, and thus causes a potential overcontrol problem. Terry (1976) also compared airspeed fluctuations with reported windspeeds. Heffley (1977) performed a simulator experiment to classify important features of random turbulence for the landing approach flight phase.

The effect of LLWS on STOL, V/STOL, and powered lift STOL is particularly pronounced. Frost et al (1977) extended the work of Kaynyzky (1971) to investigate the performance of a helicopter landing in the steady state mean flow field behind a tall building. The performance of the helicopter in an unsteady wind field about a building is computed for a helicopter landing or taking off on a six-degree glide slope over the building. A review of the influence of wind gradients on the longitudinal and lateral motion of V/STOL aircraft was done by Nelson and Curtin (1977). An experimental technique is presented for studying the effect of wind shear on the aerodynamic characteristics of V/STOL aircraft. Hoh (1977) investigated, by analysis and through the use of piloted moving-base simulators, the effect of wind shear on powered lift STOL airplanes in the landing configuration. Powered lift airplanes were found to be more vulnerable to horizontal wind shear than conventional STOL. Reid (1976) applied a fixed probe theory to wind tunnel data to produce estimates of STOL aircraft response to turbulence during the landing approach. Reid et al (1977) describe four techniques which can be applied to predict the response of an aircraft to wind shear and turbulence during the landing approach.

Frost et al (1975) modeled flow over surface obstruction using the boundary layer Boussinesq approximation to simulate large wind shears such that adverse flying conditions could be approximated for helicopters, STOL vehicles, etc.

Several attempts have been made to monitor and detect wind shear using radar. Browning et al (1978) use a pulsed Doppler microwave radar technique for obtaining high resolution measurements of wind shear. Chadwick et al (1976) investigated the use of FM-CW radar techniques to monitor and process wind data such that real-time analysis can be done. Chadwick et al (1976) showed that an FM-CW radar can be used as a Doppler radar to measure winds. Mandics and Beran (1976) developed an acoustic wind profiling system, designed to detect hazardous wind shear conditions at an airport. Preliminary results from the system which was tested at Dulles International Airport are presented. Gaylor et al (1977) demonstrated an acoustic echo sounder array to measure instability within the atmospheric boundary layer. Frost et al (1977) use a series of instrumented wind towers to measure the effects of buildings on surface winds.

Hill (1976) investigated wind shear associated with airflow over mountains and its effect on aircraft during flight. Mitchell and Hovermale (1977) investigated wind shear associated with a thunderstorm gust front. Using meteorological tower data, Hall and Neff (1976) present new observations of the internal structure and wind shear in thunderstorm gust fronts. They found that even at distances as great as 16 km from thunderstorms, the wind shear in density currents from such storms can be a hazard to aircraft landing and taking off. Goff (1976) also used meteorological tower data to study cold air outflow from a thunderstorm containing shear and turbulent zones which may adversely affect an aircraft. Orville (1977) studied the wind profile in the sub-cloud layer of a thunderstorm to determine a more complete picture of the wind structure during pre-thunderstorm conditions.

9. Storm Hazards

In recent years a great deal of research has been directed at the problem of severe storms and severe weather hazards, hail, lightning, rain, tornadoes, and wind shear. The objective of the research into severe storms is to acquire data whose analysis will lead to a better understanding, early detection, and prediction of severe storms and other significant mesoscale events. There is a need for more accurate measurements of verticle temperature and moisture profiles as well as detailed internal airflow patterns to promote better understanding of the structure of convective storms. Lilly (1975) described the structure and dynamics of severe convective storms based on current literature.

Miller (1975) used the dual Doppler radar coplane method of scanning and data reduction to determine the internal airflow and radar reflectivity structure of a convective storm. McFarland and Sasaki (1977) analyzed, from synoptic upper air observations, horizontal wind components, potential temperature, and mixing ratio fields associated with a severe storm environment in the south central United States. Eagleman and Lin (1977) used dual Doppler radar data to analyze three different times during the life cycle of a severe thunderstorm. The horizontal perturbation and relative winds, vertical winds, horizontal divergence and vorticity are compared for the three different times of measurement. Wulk and Brown (1975) describe the application of single Doppler radar analysis in the study of mesoscale cyclonic circulation and flow around an obstacle, and various techniques of dual Doppler analysis. Ray and Wagner (1976) used radar to infer a dynamical structure from storms by employing two or more coherent radars positioned to allow construction of the three-dimensional wind field.

Wang and Burns (1975 and 1976) considered forecasting and warning of severe storms from the vantage point of pattern recognition by machine. A severe storm pattern recognition machine is described. Muench (1976) and Georges and Greene (1975) considered the usefulness of radar data from the point of the short duration of the storm and the economic feasibility of an operational system. Lemon et al (1977) survey the potential of single Doppler radar to provide an improvement in severe thunderstorm warning. Burgess et al (1976) describe a single Doppler data display which allows simultaneous presentation of the principal moments of the Doppler spectrum while retaining ease of viewing and interpretation. Smith and Hung (1975) used a three-dimensional, nine-element, high frequency CW Doppler sounds array to detect ionosphere disturbances during periods of severe weather, particularly during periods with severe thunderstorms and tornadoes. Hung et al (1978) and Hung and Smith (1978) used a ground-based ionospheric sounding array to detect atmospheric acoustic-gravity waves associated with severe storms. The possibility of developing the system as a remote sensor for the detection and prediction of severe storms is discussed.

Burgess (1977) and Brown and Lemon (1977) report on the use of single Doppler radar as a method of warning for tornadoes.

Jeffreys et al (1977) report on the use of a scanning laser Doppler velocimeter system for measuring naturally occurring tornado-like phenomena. Hart et al (1977) analyzed the effects of tornadoes on certain frequencies of radio noise. Umenhofer (1975) discussed the behavior of overshooting tops in tornado-producing thunderstorms.

The use of Doppler radar to measure and analyze various properties of convective storms has been made by Hall et al (1976), Carbone et al (1976), Vaughan and Vonnegut (1976), A.J. Heymsfield (1976), Elvander (1975), Frisch and Stauch (1976), G.M. Heymsfield (1976), Zrnic et al (1976), and Brandes (1977).

The turbulence associated with severe storms, either within the storm or in the surrounding area, is a significant danger to aircraft. MacPherson and Isaac (1977) used a specially instrumented T-33 aircraft to study turbulence characteristics of cumulus clouds. Lee and Kraus (1975) describe a plane shear indicator and instrument which will graphically depict turbulent wind shear. Mitchell and Hovermale (1977) numerically investigated thunderstorm gust fronts. McCarthy and Blick (1976) analyzed the closed loop longitudinal control to predict the effects of both turbulence and wind shear on aircraft dynamics and the resulting time history of aircraft motion during simulated landings. Newton and Frank Lauser (1975) summarized the migration velocities of convective storms for six situations with different environmental wind fields. Lin and Chang (1977) studied the effects of shearing and veering environmental wind fields on thunderstorms. Orville (1977) studied wind profiles in the sub-cloud layer of thunderstorms.

The use of satellites in the observation and analysis of severe storms is increasing. Shenk et al (1975) describe the Severe Storms Observation Satellite (SOSS). Fujita (1975) presents a method of severe storm identification based on satellite data. Dove (1975) considers some of the limitations in the use of SMS-1 satellite imagery in thunderstorm detection. Bunting and Conover (1976) presented a method to use satellite data to determine a variety of cloud conditions including cumulus.

Studies of severe convective storms, including tornadoes, indicate that hail is almost always associated with them. Danielsen (1975) reviewed the growth of hail in a convective storm and concluded that hail, rather than rain, is responsible for the large radar reflectivities, and primarily responsible for the mass loading of the updrafts. Orville and Kopp (1977) used a two-dimensional lime dependent cloud model to simulate the evolution of hail cells and hailstorms. Changron (1977) surveyed the climatology of hail in North America. Gertzman and Atlas (1977) considered some sampling errors in the measurement of rain and hail parameters.

Various studies have been conducted in the area of hail suppression. Browning and Atlas (1977) suggested that progress in hail suppression research requires simultaneous improvements in methods of evaluating seeding effects and in monitoring the physical structure of the hailstorm and the hail. Linkletter and Warburton (1977) analyzed the effectiveness of AgI in suppressing hail formation. Sartor and Cannon (1977) considered the knowledge necessary for modification of thunderstorms to suppress hail from the point of when, where, and how much to seed. Changnon (1977) described a method to evaluate the potential value of hail suppression.

The detection of hail by the use of dual wavelength radar has been studied by Eccles (1975 and 1976), Jameson and Mueller (1975), and Marker (1976). Observations of the radar reflectivity of hail have been made by Jameson (1977), Naldvagel and Federer (1976), and Orville et al (1977). Ulbrich (1977) and Rinehart et al (1975) studied hail with Doppler radar.

Ulbrich (1978) presented a rain parameter diagram which displays the relationship between all rainfall parameters defined in terms of an exponential drop size distribution. Katz (1977) proposed a probabilistic model for the sequence of daily amounts of precipitation. Studied of rainbands in frontal systems have been done by Houze et al (1976), Scott and Hobbs (1977), and Herzegh and Hobbs (1977). Johnson (1976) used a diagnostic model to estimate the role of convective scale precipitation downdraft in cumulus clouds. Wang et al (1977), Atlas and Ulbrich (1977), and Crane (1976) used radar to track and measure rainfall paths and rates.

10. Turbulence

Turbulence in the atmosphere is one of the greatest hazards to flight, whether encountered near the ground during transitional flight or at cruising altitudes. Burnstein (1978) reports that NTSB air carrier records from 1964 to 1975 show 68 accidents involving clear air turbulence (CAT). Kuhn et al (1977) considered a method of detecting CAT by infrared observations of water vapor. Cadet (1977) measured energy dissipation within intermittent clear air turbulence patches. Chadwick et al (1976) used FM-CW radar to detect wind variation in clear air. Bender et al (1976) concluded that CAT probabilities are significantly higher over mountains than flat terrain. Waco (1976) determined the ratio of turbulent to total flight miles with respect to altitude.

Taylor (1977) discussed problems encountered by aircraft operating under conditions of turbulence with respect to: determination of gust structure, aircraft reaction to gusts of known structure, and the determination of operating statistics. Terry (1976) compared airspeed fluctuation and wind speed during landing to evaluate effects of turbulence on normal landing approaches. Reid (1978) investigated the adverse effects of turbulence on an aircraft during landing. Jacobson and Jashi (1977 and 1978) evaluated handling qualities of aircraft in the presence of turbulence. Yazawa (1977) developed a method for identifying aircraft stability and control derivatives in the presence of turbulence. Heffley (1977) performed an analysis and brief simulator experiment to identify and classify important features of random turbulence for the landing approach flight phase.

Turbulence in the atmospheric boundary layer has been investigated extensively in recent years. Wyngaard (1977) discusses the use of contemporary modeling techniques for investigating turbulence in the atmospheric boundary layer. Bitte and Frost (1976) use a mathematical model to describe ground-wind induced flow fields around surface obstructions such as buildings, bridges, or other man-made structures. Frost et al (1977) used instrumented wind towers to measure the three components of wind about a simulated block building. Fichtl and Perlmutter (1976) developed a linear stochastic model to simulate vertically nonhomogeneous gusts. Perlmutter et al (1976) considered the effects of nonhomogeneous gusts on aircraft during take-off and landing.

Angular spectrum measurements of atmospheric turbulence have been made by Lewis and Ramsey (1977) using a helium-neon milliwatt laser. Gage and Jasperson (1977) use a Metrac positioning system to determine diffusion coefficients from turbulence data. Nakatani et al (1977) used a nitrogen pulse laser to measure turbulence. Zeman and Lumley (1977) developed a second order model for a buoyancy-driven layer. Nappo (1977) simulated atmospheric turbulence using observed and estimated winds. Karmal and Caughey (1977) investigated the structure of turbulence in the atmospheric boundary layer. Lilly (1978) presents observational analysis of the turbulent scale features of a mountain wave. Zeman and Tennekes (1977) reported on the growth of the planetary boundary layer due to turbulent entrainment.

Hildebrand (1977) investigated a new technique for the investigation of atmospheric turbulent diffusion using Doppler radar and radar reflecting choff. Lessen et al (1977) studied the growth of an unbounded, density-stratified, turbulent shearing layer in the presence of a gravity field using the postulate of marginal instability. Lee and Su (1977) used a numerical method to determine the stratified shear flows over a long obstacle. Yu (1977) studied the atmospheric boundary layer with a turbulent energy closure scheme. Other investigations using a turbulent closure scheme have been done by Burk (1977), Blackadar (1977), and Berman and Stearns (1977).

11. Training

Training in the area of aviation meteorology, with emphasis on safety, is generally considered to be a process of pilot education. While this may be true, since most accidents occur during flight under instrument flight rules, particularly landing under instrument conditions, the advice of the controller cannot in all cases be ruled out as having some effect upon the situation in which the pilot finds himself. Twenty-five accident reports involving civil aviation aircraft were summarized by the Van Nostrand Reinhold Company (1977), with emphasis on pilot error. Causes of the accidents included icing, failure to take into account destination weather conditions, incorrect assumptions about position, premature descent, and pilot panic.

Roscoe (1978) considers the overall workload on the pilot as a major contributing factor in accidents which occur during take-off and approach for both visual and instrument conditions. Jennings and Chiles (1977) conducted a study for the FAA testing time-sharing ability as a factor in complex performance. Another factor involving pilot performance is the effect of disturbances which can cause distortion in the pilot perception of the instruments, studied by Ephrath and Curry (1977).

The use of simulation in pilot training has increased in recent years. Spady (1977) conducted a series of tests using an FAA qualified simulator to measure pilot scanning behavior. Belson (1976) reports on the Compu-Scene, a computer-generated-image visual display system which has been fitted to provide an infinity view through the windscreen and side windows on the flight deck. The military uses motion simulators which can simulate pitch, roll, and yaw. Hawkins (1977) reports on simulator tests which have been done to determine cockpit visibility with respect to pilot seating. Waller (1977) conducted studies to evaluate pilot scanning behavior. Studies of varying levels of motion parallax from both radial and vertical motion on perception of the orientation of a runway relative to the ground have been done by Mertens (1978).

Training cannot solve all the problems associated with safety in aviation meteorology; if proper or additional training is given some accidents can be prevented. Cooper et al (1978) reviewed the problem of training with respect to the areas of turbulence, visibility, severe storms, lightning and icing. Recommendations were made as to the future needs in these areas.

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APPENDIXES

APPENDIX A

TABULATION OF NASA, NOAA, AND FAA RESEARCH — PAGE

ADVANCED METEOROLOGICAL INSTRUMENTS

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
JDOP	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Ken Wilk Don Burgess	The objectives are to evaluate the potential of Doppler radar for improving severe storm warnings and for use in detection of weather hazards to aviation; develop suitable displays; and develop common requirements for next generation weather radar for public warning and aviation services. Doppler radar will be evaluated in NWS, AWS, and FAA operations. Suitable data displays will be developed and common Doppler radar requirements will be established.
Weather Radar Display	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Kenneth Welk Dave Zittel	Development of a remote weather display for use in aviation weather briefing and in aircraft traffic control. Development in cooperation with FAA the application of commercially available systems to provide real-time radar data to Flight Service Stations (FSS).
RADAR Vincent S. Murino (301)427-7768 Project No.: 8AA830	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	Kenneth H. Shreeve James O. Abernathy	A cooperative effort to study new techniques and equipment to improve the NWS weather radar facility and its usefulness. EDL, in cooperation with the National Severe Storms Laboratory (NSSL), SDO's, Techniques Development Laboratory (TDL), OTW, OMSO, and others will work to improve hydrologic and meteorologic output products, communications, and to establish new equipment and technique requirements and specifications.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Remote Sensor Applications Donald H. Beran	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Donald W. Beran Robert M. Hardesty Robert M. Huffaker Jeffrey R. Keeler T. Rhidian Lawrence Peter A. Mandics J. Frank Pratte	The objective is to identify applications of remote sensing concepts and create optimum remote sensing systems for these uses. The group conducts system analysis, integration, and field tests, as well as cost effectiveness studies, to guide selection and development of sensors or sensor systems for specific applications. A concept and program for using coherent lidar to measure winds from the ground, aircraft, and satellites was developed and evaluated in a preliminary feasibility study. Lidar scanning techniques for use on aircraft and satellite platforms were developed. An acoustic radar system was turned over to the FAA for testing in an operational environment. A complete set of operational manuals and system specifications was prepared for the FAA wind shear sensor. A Program Developement Plan was prepared for a Prototype Regional Observing and Forecasting Service (PROFS). This plan would use systems methodology to design the service and guide future technology transfer. In the future the group will: complete a feasibility and preliminary design study for a satellite mounted global wind monitoring system based on a coherent lidar technology; start the airborne phase of Doppler lidar program; start the design of the PROFS system by organizing an interdisciplinary team made up of individuals representing each NOAA MLC with back-

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				grounds and expertise in observations, forecasting, and information dissemination; and survey all mesoscale weather research and development activities which will impact the PROFS effort. Creation of a :t prototype PROFS facility to serve nd as the proving ground for new observation forecasting, and dissemination of techniques is planned. This facility would produce systems for use by the NWS and other government agencies who have the requirement for providing regional meteorological support.
Environmental Radiometry David C. Hogg	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	David C. Hogg Martin T. Decker Fred O. Guiraud William L. Taylor Ed R. Westwater	The objective is the realization of microwave systems, primarily radiometric, for continuous, remote measurement of atmospheric temperature, water vapor and liquid water, for use in atmospheric research, and by the weather services. Interaction with NWS on the installation of a dual-channel water vapor radiometry system at Denver has been initiated. They hope to test for transfer to the NWS at Denver, a complete new all-weather antenna facility.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Meteorological Radar Earl E. Gossard	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Earl E. Gossard W. Carroll Campbell Russell B. Chadwick Harold W. Frank Nathan M. Kohn Robert A. Kropfli L. Jay Miller William R. Moninger Kenneth P. Moran Gordon E. Morrison Richard G. Strauch	The overall objective is to increase understanding of the dynamical processes controlling local weather by creating and using a multi-station, transportable Doppler radar facility capable of measuring three-dimensional wind fields, and an FM-CW radar facility capable of sensing the structure of the atmosphere under clear, cloudy, or precipitation conditions. A computerized FM-CW radar system for control of antenna, control of data recording and processing and for velocity has been developed. The FM-CW system has been successfully integrated and operated over phone lines. A plane shear indicator has been incorporated into FM-CW radar. They supervised the modification of an air traffic control radar for clear air wind measurement for the FAA.
Atmospheric Studies William H. Hooke	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	William H. Hooke Alfred J. Bedard George Chimonas Franco Einaudi Jeannette Garing Gary E. Greene Duane A. Haugen Michael R. Jones J. Chandran Kaimal O. Neall Strand John C. Wyngaard Jessie M. Young	The overall objective is to increase the national understanding of the atmosphere by working with the WPL program areas and outside groups to apply remote sensors to atmospheric research. Development and installation has been made of two systems for detection of thunderstorm gust fronts at O'Hare and Dulles International Airports as well as development of an omnidirectional wind threshold sensor. They have begun to instruct the FAA and NWS how to operate the gust front detection system.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Atmospheric Spectroscopy Vernon E. Derr	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Vernon E. Derr Norman L. Abshire Robert F. Calfee Richard E. Cupp Hans L. Ericson Gordon M. Lerfald Garner T. McNice Madison J. Post Ronald L. Schwiesow	The overall objective is to develop laser and other optical techniques for remote geophysical sensing. Apply these techniques and others to atmospheric science programs relevant to NOAA's monitoring, forecasting, and warning services and to weather modification studies. A system-free comparison is made of effectiveness of radar and lidar for sensing clouds as a function of droplet size distribution. Theory of scattering from disk-shaped ice particles is used to explain variations in cloud albedo, and relations between backscatter and extinction coefficients obtained.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Digital Operations for General Aviation Loyd C. Parker (804)824-3411 RTOP #505-07-18	NASA	Wallops Station Wallops Island, VA		FOR OBJECTIVES SEE FORECASTING
Atmospheric Acoustics Freeman F. Hall	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Freeman F. Hall, Jr. Edmund H. Brown John E. Gaynor William D. Neff Edward J. Owens	FOR OBJECTIVES SEE FORECASTING
Digital Operations Technology H.J.E. Reid, Jr. (804)827-3551 (512-52-03) RTOP #505-07-13	NASA	Langley Research Center Langley Station, VA		FOR OBJECTIVES SEE FORECASTING

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Surface Observing Systems Exploratory Instrumentation Vincent S. Kurino (301)427-7768 Project No.: 8AA8103	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	Melvin Sanders, Jr.	FOR OBJECTIVES SEE FORECASTING
Wind Shear	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Judith Stokes Jean T. Lee Ed. Brandes	FOR OBJECTIVES SEE LOW LEVEL WIND SHEAR
Aviation Safety Technology (HUD, CAT Radiometer Detector, Fire-Resistant Materials, NTSB Assistance) Leonard Roberts/ Dean Chapman (415)965-5567/965-5225 RTOP #505-08-21	NASA	Ames Research Center Moffett Field, CA 94035		FOR OBJECTIVES SEE TURBULENCE
Clear Air Turbulence P.M. Kuhn (303)499-1000 x6208	Dept. of Commerce/NOAA	Atmospheric Physics and Chemistry Laboratory Boulder, CO 80302	Dr. I. Nolt Dr. F. Caracena L.P. Stearns F.J. Holitza F.M. Gould	FOR OBJECTIVES SEE TURBULENCE

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Knowledge of Atmospheric Processes D.H. Camp (205)453-2087 RTOP #505-08-19	NASA	Space Sciences Laboratory Fluid Dynamics Branch Marshall Space Flight Center, AL 35812	Fluid Dynamics Branch, Electro-Optical Branch, Environmental Applications Branch/MSFC University of Tennessee Space Institute, Tullahoma, TN 37388 University of Dayton Research Institute Dayton, OH University of Oklahoma Norman, OK University of Alabama, Huntsville Huntsville, AL FWG Associates Tullahoma, TN 37388 PBR Electronics Athens, AL Aeronautical Research Associates Princeton, NJ Computer Science Corp. Huntsville, AL Science Applications Huntsville, AL Penn State University Arizona State University	FOR OBJECTIVES SEE TURBULENCE

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Aviation Weather Sustaining Engineering Raymond Colao (202)426-8427 Project No.: 151-451	Dept. of Commerce/NOAA	National Weather Service Systems Development Office, Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	Bob Strickler Doug Downen	Technical data package recommendation to Operating Services resulting in improved availability and more cost effective operations and maintenance for such systems as: transmissometers, RVR signal data converters, wind measurement devices, ceilometers, ASI, temperature equipment.
Development of Ground Doppler Weather Radar J. Muncy (202)426-8427 Project No.: 152-462-06	Dept. of Transportatior FAA	NOAA, NSSL	E. Kessler and Staff	Develop and demonstrate operational utility of ground Doppler weather radar.
Interpretation of Weather Echoes on ATC Radars J. Muncy (202)426-8427 Project No.: 152-462-06	Dept. of Transportatior FAA	NOAA, NSSL	K. Wilk D. Zittel J. Dooley	Prepare rules for interpretation of weather echoes on en route and terminal radars.
Radar Echoes by Size and Intensity J. Muncy (202)426-8427 Project No.: 152-462	Dept. of Transportation FAA	NOAA. National Climatic Center Asheville, NC	R. Baldwin	Look at films of five radar echoes and obtain quantitative data on reflectivity, intensity, and geographic extent of these echoes. Applies to airborne or ground weather radar at any frequency one chooses.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Airborne Doppler Weather Radar James Muncy (202)426-8427 Project No.: 152-462-08	Dept. of Transportation FAA	NOAA ERL	Bobbie Trotter R. Strauch	Prove operational utility of Doppler weather radar for airborne commercial aviation.
Evaluation of Ryan Stormscope J. Muncy (202)426-8427 Project No.: 152-462-03	Dept. of Transportation FAA	USAF AFDL, Wright-Patterson AFB, OH	I. Mangold	Compare airborne weather radar with Ryan Stormscope.
Automated Weather Observation Systems Eric Mandel (202)426-8427 Project No.: III 153-451	Dept. of Transportation FAA	National Weather Service Systems Development Office, Equipment Development Laboratory	James A. Cunningham	Develop a series of automated weather observation systems ranging from systems which provide only wind and altimeter setting to systems which provide a complete aviation surface weather observation, including cloud cover, ceiling and visibility.

FORECASTING

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Aviation Safety Technology --Applied Laser Technology E.A. Weaver (205)872-1597(FTS) RTOP #505-08-29	NASA	Optics Branch Electronics and Control Laboratory Marshall Space Flight Center, AL 35812	Optics Branch, Environmental Branch, Communications and Tracking Branch/MSFC Raytheon Co. Sudbury, MA M and S Computing, Inc. Huntsville, AL Lockheed Misseles and Space Co. Huntsville, AL Computer Science Corp. Huntsville, AL University on Tennessee Space Institute Tullahoma, TN 37388 Alabama A and M University Huntsville, AL	The objective of this RTOP is to develop electro-optic remote atmospheric flow sensors using the laser Doppler technique. These sensors will be used to measure both natural and induced atmospheric flow phenomena emphasizing those that are hazardous to aircraft operations both in the terminal area and those encountered along an airlane. The primary objective for FY 78 will be the flight test of the Clear Air Turbulence (CAT) Detection System and Wind Shear System development. System feasibility studies, theoretical analyses, and design studies required to advance the system technology will be performed. In addition, breadboard hardware will be used to determine feasibility, capability, operational requirements, and system hardware and software specifications required for special applications. There are four major tasks: Task 1: Pulsed CO_2 Laser Doppler Clear Air Turbulence Detection System Development. Task 2: CW Laser Doppler System Development. Task 3: Advancement of CO_2 Laser Doppler Technology for Remote Atmospheric Velocity Measurements. Task 4: Wind Shear System Study and Development.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Digital Operations for General Aviation Loyd C. Parker (804)824-3411 RTCP #505-07-18	NASA	Wallops Station Wallops Island, VA		The objective is to demonstrate systems feasibility of utilizing advanced low cost digital systems technology to provide: (1) automatic voice airport advisory information at uncontrolled airports of weather conditions, active runway and existing hazardous conditions for VFR & IFR traffic; (2) automatic voice air traffic and mid-air collision advisories to traffic at uncontrolled airports using standard NAV-COM frequencies without transponder requirement; (3) a solid state general aviation crash recorder having critical accident investigation parameters retained in non-volatile storage; (4) an advanced general aviation pilot training system for single and twin engine aircraft which provides in-flight simulation and evaluation of piloting procedures for private; commercial, multiengine and instrument training. Approach includes studies of systems concepts, systems definition, engineering model development, evaluation and demonstration of technology improvements achieved.
Atmospheric Acoustics Freeman F. Hall	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Freeman F. Hall, Jr. Edmund H. Brown John E. Gaynor William D. Neff Edward J. Owens	The objective is to improve NOAA and other government agency abilities in atmospheric monitoring, forecasting, warning, and research through the development of acoustic sounding techniques. A NOAA Mark VII sounder combined with a Data General minicomputer and various other instruments were incorporated into a meteorological observing system for the Air Force and installed at Cloudcroft, NM. A NOAA Mark VII sounder was installed at Wright-Patterson AFB.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Digital Operations Technology H.J.E. Reid, Jr. (804)827-3551 (512-52-03) RTOP #505-07-13	NASA	Langley Research Center Langley Station, VA		Development of advanced systems such as NAVSTAR/GPS coupled with the rapid advances in electronics and RF technology can have tremendous impact on future aircraft and ATC operations. Work done under this RTOP will, in conjunction with FAA and DOD, identify potential candidate concepts for such future systems, develop the technology required for, and perform, proof-of-concept experiments to develop the data base required for future aircraft and ATC system planning. The technology will also be developed for special applications such as multi-purpose radars for weather and turbulence detection and weather penetrating mapping functions. Studies will be performed to define user-class requirements for GPS equipment, and to develop low-cost technology for implementation of L-band spread-spectrum user equipment. Experiments will be performed to validate user-class capabilities, and to develop dual-fail-operational redundancy techniques which will be required in future systems. Digital data link technology will be extended to use with the GPS system, and combined experiments run in conjunction with FAA.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Systems Engineering Analysis and Data/Information Technology for OA Disciplines John J. Quann (301)982-4834 RTOP #656-44-02	NASA	Goddard Space Flight Center Greenbelt, MD		The objectives of this RTOP are: (1) the definition, evaluation, and analysis of the long term data management requirements associated with the Weather & Climate Program and the determination of development activity necessary to meet these requirements; (2) the survey, analysis and assessment of data compression and image coding schemes; and (3) the survey, analysis and assessment of data base management systems and applications software. Future data and information management requirements will be defined, analyzed and validated with respect to Severe Storm and Local Weather research involving localized areas and ranging in duration from a few minutes to a few days. Global Weather research involving large scale phenomena having a period from several days to weeks, and Climate research incorporating long term characteristics of the atmosphere, ocean, and land. All work performed will be directly related to the needs of the Weather & Climate program and will be coordinated with the Discipline Center for Data Management at MSFC in support of their function for the Office of Applications. Active participation will be established and maintained on the NASA Image Coding Panel and on the Data Base Management Systems (DBMS) Technology and Applications Software Panel. The expected results will include an assessment of the data management and data technology related aspects of the long range objectives of the Weather & Climate program.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Surface Observing Systems Exploratory Instrumentation Vincent S. Murino (301)427-7768 **Project No.: 8AA8103**	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	Melvin Sanders, Jr.	To develop, test, and evaluate new instrumentation which uses advances in sensor and processor technology. Primary emphasis in the development of next generation sensors has been on sensor systems geared toward automating manual observations. Infrared (IR) Stereo Radiometer System and Laser Present Weather Identifier are examples of this emphasis. Efforts are also to develop a no-moving parts anemometer and a Radio-Acoustic Sounding System (RASS) for radiosonde applications. Determine the feasibility of using the stereo radiometric measurement technique for the passive determination of cloud light and amount. For the laser present weather identifier, expand data base of laser generated signatures for the evaluation of various processors, develop recommendations and a specification for the gross states of rain, snow, fog, hail, and clear, and develop recommendations for additional experimentation to improve and refine its capabilities. Using the RAMOS specification parameters, evaluate other pressure sensors than SAW. Develop a prototype laser precipitation yes/no sensor model.
Aviation Automatic Weather Observing Station System (AV-AWOS) Vincent S. Murino (301)427-7768 **Project No.: RD5907**	Dept. of Transportation Federal Aviation Administration (FAA)	National Weather Service Systems Development Off. Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	James A. Cunningham	To design, develop, and evaluate an automatic weather station capable of providing aviation weather observations of the same quality as now provided by human observers. Also development of procurement specifications.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Local Forecast Applications Vincent S. Murino (301)427-7768 Project No.: 8C2702	Dept. of Commerce/NOAA	National Weather Service Systems Development Off Techniques Development Laboratory 8060 13th Street Silver Spring, MD 20910	Dale A. Lowry David J. Vercelli Harry R. Glahn David B. Gilhausen	To monitor NWS predictions and warnings and to update guidance; supply guidance to the forecasters in the same form as the final product; and to introduce worthwhile new products into the NWS expanded services program. Programming for the Automation of Field Operations and Services (AFOS) minicomputers will be under direction of this office. 1) Aviation Monitoring and Updating: The software has been developed for a system which will automatically monitor aviation terminal forecasts within each WSFO's are of responsibility to insure their validity and representativeness. A prototype system has been designed to simulate the Washington, D.C. WSFO which monitors 12 terminals. 2) Computer-Worded Forecast: The computer program that produces the CWF also prints out the matrix of digital forecasts upon which the CWF is based. The matrices and CWF's for 42 stations can be called up on the IBM360/40KCRT system. This pair of products will be implemented along with AFOS. 3) PoP Updating: During 1977 TOL developed and started testing two schemes to update PoP forecasts for the 12-24-hr. period. The first scheme is based on MDA data in the area of interest. The other scheme is based on surface observations at points surrounding the area of interest. Tests show only marginal improvements over current MOS PoP prediction by either system.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				4) Flash Flood Alerting: Derivations have been made for the necessary relationships for the small MDR boxes of the future. 5) Interactive Forecasting: ADL started this AFOS task to create a forecasting system more powerful than either man or machine working alone.
Systems Development and Experimentation Forecaster Aids and Applications Vincent S. Murino (301)427-7768 Project No.: 8C27037	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Integrated Systems Laboratory 8060 13th Street Silver Spring, MD 20910	Hugh M. O'Neil	Integration of the forecasters aid and application programs into the AFOS software at WSFO's, WSO's, and RFC's. Translate results of techniques development into AFOS compatible software programs. Analyze man-machine interaction and optimize software through experimentation. Develop a multi-position operating system.
Automated Aviation Weather Forecast Project, Aviation Weather Design Study Task Vincent S. Murino (301)427-1768 Project No.: AD5902	Dept. of Defense U.S. Air Force	National Weather Service Systems Development Off. Techniques Development Laboratories 8060 13th Street Silver Spring, MD 20910	Dr. Robert G. Miller	To examine methods to generalize the Model Output Statistics (MOS) approach by removing known limitations and constraints. To select the most promising of these methods and propose a program for developing and testing in automated aviation forecasting applications. To determine the feasibility of a software system which both develops and applies MOS equations in a real-time operation.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
JDOP	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Ken Wilk Don Burgess	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Weather Radar Display	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Kenneth Welk Dave Zittel	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Remote Sensor Applications Donald H. Beran	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Donald W. Beran Robert M. Hardesty Robert M. Huffaker Jeffrey R. Keeler T. Rhidian Lawrence Peter A. Mandics J. Frank Pratte	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Environmental Radiometry David C. Hogg	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	David C. Hogg Martin T. Decker Fred O. Guiraud William L. Taylor Ed R. Westwater	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Atmospheric Spectroscopy Vernon E. Derr	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Vernon E. Derr Norman L. Abshire Robert F. Calfee Richard E. Cupp Hans L. Ericson Gordon M. Lerfald Garner T. McNice Madison J. Post Ronald L. Schwiesow	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Meteorological Radar Earl E. Gossard	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Earl E. Gossard W. Carroll Campbell Russell B. Chadwick Harold W. Frank Nathan M. Kohn Robert A. Kropfli L. Jay Miller William R. Moninger Kenneth P. Moran Gordon E. Morrison Richard G. Strauch	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Severe Local Storms Prediction Vincent S. Murino (301)427-7768 Project No.: 8C3781	Dept. of Commerce/NOAA	National Weather Service Systems Development Off Techniques Development Laboratory 8060 13th Street Silver Spring, MD 20910	Mikhail A. Alaka Ronald M. Reap Jess P. Charba Wilson A. Shaffer Robert C. Elvander Paul E. Long, Jr.	FOR OBJECTIVES SEE STORM HAZARDS

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PEPFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Clear Air Turbulence P.M. Kuhn (303)499-1000 x6208	Dept. of Commerce/NOAA	Atmospheric Physics and Chemistry Laboratory Boulder, CO 80302	Dr. I. Nolt Dr. F. Caracena L.P. Stearns F.J. Holitza F.M. Gould	FOR OBJECTIVES SEE TURBULENCE
Aviation Safety Technology --Applied Laser Technology E.A. Weaver (205)872-1597(FTS) RTOP #505-08-29	NASA	Optics Branch Electronics and Control Laboratory Marshall Space Flight Center, AL 35812		FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Interpretation of Weather Echoes on ATC Radars J. Muncy (202)426-8427 Project No.: 152-462-06	Dept. of Transportation FAA	NOAA, NSSL	K. Wilk D. Zittel J. Dooley	SEE OBJECTIVES FOR ADVANCED METEOROLOGICAL INSTRUMENTS
Severe Weather Tracking and Prediction John W. Hinkleman (202)426-8427 Project No.: 152-462-02	Dept. of Transportation FAA	Environmental Research and Technology (ERT)	Robert Crane	Computer techniques for presenting current radar severe weather data and forecast position information for en route and terminal ATC operations.
Integrated Aviation Weather System for the National Airspace System John W. Hinkleman (202)426-8427 Project No.: 152-462-01	Dept. of Transportation FAA	Several contractors Transportation System Center Minority Services Inc. Mitre	Various investigators Ed Spitzer, TSC R. Johnson, MSI R. Thompson, Mitre	A system engineering effort to provide a comprehensive integrated aviation weather system tying all weather program segments together.
Improved Aviation Weather Forecasting Arthur Hilsenrod (202)426-8427 Project No.: 152-461-01	Dept. of Transportation FAA	National Weather Service Techniques Development Laboratory 8060 13th Street Silver Spring, MD 20910	Dr. M. Alaka	Improve the accuracy, timeliness and location of thunderstorm forecasts and associated hazards in the 0-2 hour time range including 0-10, 0-20 and 0-30 minute forecasts.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Automated Weather Observation Systems Eric Mandel (202)426-8427 Project No.: III 153-451	Dept. of Transportation FAA	National Weather Service Systems Development Office Equipment Development Laboratory	James A. Cunningham	SEE OBJECTIVES FOR ADVANCED METEOROLOGICAL INSTRUMENTS

VISIBILITY

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Remote Sensor Applications Donald H. Beran	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Donald W. Beran Robert M. Hardesty Robert M. Huffaker Jeffrey R. Keeler (PTP) T. Rhidian Lawrence Peter A. Mandics J. Frank Pratte	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Surface Observing Systems Exploratory Instrumentation Vincent S. Murino (301)427-7768 Project No.: 8AA8103	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Equipment Development Laboratory 8060 13th Street Silver Spring, MD 20910	Melvin Sanders, Jr.	FOR OBJECTIVES SEE FORECASTING
Knowledge of Atmospheric Processes D.H. Camp (205)453-2027 RTOP #505-08-19	NASA	Space Sciences Laboratory Fluid Dynamics Branch Marshall Space Flight Center, AL 35812		FOR OBJECTIVES SEE TURBULENCE

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Evaluation of Visibility Systems for CAT III B Operations John Simeroth, ARD-432 (202)426-8454 Project No.: 151-462-03	Dept. of Transportation FAA	Humbolt County Arcata, CA	Jim Wilkerson	Test existing visibility systems, and make necessary modifications, to provide reliable RVR observations down to 300 feet RVR to support CAT III B operations.
Automated Weather Observation Systems Eric Mande (202)426-8427 Project No.: III 153-451	Dept. of Transportation FAA	National Weather Service Systems Development Office Equipment Development Laboratory	James A. Cunningham	SEE OBJECTIVES FOR ADVANCED METEOROLOGICAL INSTRUMENTS

LOW LEVEL WIND SHEAR

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Wind Shear	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Judith Stokes Jean T. Lee Ed. Brandes	To examine the hazards associated with wind shear in the terminal area and structure a program designed to characterize the wind shear problem and establish required work needed to arrive at solutions. Collections of wind and temperature data in the echoing subcloud layer using aircraft and Doppler radar will be made. Wind and temperature data will be collected in the precipitation-free region associated with thunderstrom outflow using aircraft, tower, surface station, radiosonde or tethered balloon data. Investigations will be made of the turbulent structure of the subcloud layer and the outflow gust front. Correlation of high level tower wind gust data with surface gust data. The effects of environmental wind flow and stability or turbulenc structure in the subcloud region will be determined. Aircraft response to GCA approaches in a thunderstorm gust front will be made. Gust front data will be provided for laboratory simulation of gust fronts. Determinations of steady state characteristics of outflow and gust front feature will be done. Value of surveillance and Doppler radar in detecting and scaling frontal convection will be assessed.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Glide Path Shear Dr. P.M. Kuhn and Dr. F. Caracena (303)499-1000 x6208	Dept. of Commerce/NOAA	Atmospheric Physics and Chemistry Laboratory Boulder, CO 80302	Dr. I. Nolt L.P. Stearns F.J. Holitza F. Gould	The objective is to develop and test an airborne infrared radiometer which will remote sense low level wind shear and its intensity on take-offs and landings and sound a 2-3-minute cockpit alert.

STORM HAZARDS

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Thunderstorm Turbulence	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Jean T. Lee	Identification of wind features in thunderstorms related to turbulent areas and other hazards such as wind shear. Determination of correlations between the thunderstorm hazards and Doppler radar wind spectrum observations. Development of methods for real-time display of Doppler radar wind data and other parameters in a manner easily interpreted.
Severe Local Storms Prediction Vincent S. Murino (301)427-7768 Project No.: 8C3781	Dept. of Commerce/NOAA	National Weather Service Systems Development Off. Techniques Development Laboratory 8060 13th Street Silver Spring, MD 20910	Mikhail A. Alaka Ronald M. Reap Jess P. Charba Wilson A. Shaffer Robert C. Elvander Paul E. Long, Jr.	Develop automated techniques for predicting thunderstorms and severe local weather (hail, tornadoes, damaging wind) for periods of 24 hrs. Products will be adapted to the NWS operational environment and will provide guidance to the NSSFC and local public weather and aviation forecasters. Apply MOS techniques to generate objective 12-48-hour probability forecast of thunderstorms and severe local weather from the output of current and future operational NMC and TOL models. Apply a combination of MOS and classical statistics to generate 2-6-hour forecasts of the same phenomena. Make use of radar observations, alone or in conjunction with other meteorological information, to develop corresponding forecasts in the 0-2-hour range. Develop a boundary layer model for more accurate prediction of parameters germane to severe local weather.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Digital Operations Technology H.J.E. Reid, Jr. (804)327-3551 (512-52-03) RTCP #505-07-13	NASA	Langley Research Center Langley Station, VA		FOR OBJECTIVES SEE FORECASTING
Clear Air	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Dr. K. Doviak Dr. R. Ernic Jean T. Lee	FOR OBJECTIVES SEE TURBULENCE
Knowledge of Atmosphere-Advanced Measurement Techniques R.E. Carr (804)824-3411 RTOP #505-08-13	NASA	Wallops Station Wallops Island, VA 23337		FOR OBJECTIVES SEE TURBULENCE
Knowledge of Atmospheric Processes D.W. Camp (205)453-2087 RTOP #505-08-19	NASA	Space Sciences Laboratory Fluid Dynamics Branch Marshall Space Flight Center, AL 35812		FOR OBJECTIVES SEE TURBULENCE

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Aviation Safety Technology --Applied Laser Technology E.A. Weaver (205)872-1597(FTS) RTOP #505-08-29	NASA	Optics Branch Electronics and Control Laboratory Marshall Space Flight Center, AL 35812		FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Severe Weather Tracking and Prediction John W. Hinkelman (202)426-8427 Project No.: 152-462-02	Dept. of Transportation FAA	Environmental Research and Technology (ERT)	Robert Crane	SEE OBJECTIVES FOR FORECASTING
Helicopter Icing Environment for Airworthiness Standards Certification Arthur Hilsenrod (202)426-8287 Project No.: 152-463-01	Dept. of Transportation FAA	To be determined	To be determined	To obtain on icing conditions below 5000 feet, especially off the north-east coast of the U.S. where icing data below 5000 feet is lacking. The data obtained will be in the form of liquid water content, drop size distribution and outside air temperature.

TURBULENCE

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Aviation Safety Technology (HUD, CAT Radiometer Detector, Fire-Resistant Materials, NTSB Assistance) Leonard Roberts/ Dean Chapman (415)965-5567/965-5225 RTOP #505-08-21	NASA	Ames Research Center Moffett Field, CA 94035		The objective of this RTOP is to improve aviation safety by increasing the understanding of the causes of accidents, by developing materials and piloting techniques for avoiding accidents, and by increasing the probability of survival of accidents when they occur. The approach to operations studies will include developing new techniques for sensing and displaying wind shear. Additionally, as part of a joint NASA/FAA program, simulator investigations will be conducted on the effectiveness of integrated head-up displays (HUD) on reducing hazards associated with wind shear and low visibility in the landing approach. The fire hazards program pertains to the exploration of fire-hardened concepts for civil aircraft cabin materials systems such as lavatories, galleys, cargo compartments and aircraft interior passenger compartments in order to enhance human survivability in aircraft in-flight, ramp, and post-crash fires. The technology base for fire safe aircraft systems will be developed utilizing the outputs of the R&T programs on fire-resistant materials and fire control systems. Laboratory and sub-scale tests will be conducted to assess the flammability, smoke and other properties of state-of-the-art and advanced cabin materials which have a potential for increasing the fire-hardening of aircraft. Post-accident analysis is a cooperative program with the National Transportation Safety Board, Bureau of

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				Aviation Safety (NTSB-BAS). The general objectives are to develop improved data processing techniques for analyzing aircraft accident recordings.
Knowledge of Atmospheric Processes D.H. Camp (205)453-2087 RTOP #505-08-19	NASA	Space Sciences Laboratory Fluid Dynamics Branch Marshall Space Flight Center, AL 35812	Fluid Dynamics Branch, Electro-Optical Branch, Environmental Applications Branch/MSFC University of Tennessee Space Institute, Tullahoma, TN 37388 University of Dayton Research Institute Dayton, OH University of Oklahoma Norman, OK University of Alabama, Huntsville Huntsville, AL FWG Associates Tullahoma, TN 37388 PBR Electronics Athens, AL Aeronautical Research Associates Princeton, NJ Computer Science Corp. Huntsville, AL Science Applications Huntsville, AL Penn State University Arizona State University	The objectives are: (1) to define, model, and simulate the wind and turbulence environments for aircraft accident investigation; (2) the definition and investigation of severe environments relative to the identification of aircraft operating hazards; (3) the development of techniques and procedures whereby the knowledge of the natural environment can be better utilized for the safe operation of aeronautical systems; and (4) research relative to the need for new and/or improved meteorological instrumentation for use in enhancing the safe operation of aeronautical systems. To accomplish the objectives the following four-prong approach is to be used: (1) the development of models of atmospheric boundary layer flow properties; (2) the development of probabilistic models of turbulence and the conditions which lead to turbulence; (3) performing analytical and laboratory tasks relative to the life cycle of fog; and (4) the development and/or modification of meteorological instruments as needed to meet the requirements of the first three parts of the approach. To accomplish the above objectives, the following tasks are to be performed: (1) induced wind environments and the correlation of lateral and longitudinal qusts and their effect

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				on aeronautical systems; (2) natural environment reconstruction for accident and operating hazard investigation; (3) definition of free atmosphere perturbation, turbulence studies, and thunderstorm investigation; (4) fog modification model development; (5) development of new (or modification of) meteorological instrumentation needed for use relative to the safe operation of aeronautical systems; and (6) hypersonic vehicle design criteria.
Wake Vortex Minimization M.R. Barber (305)258-3311 RTOP #514-52-04	NASA	Hugh L. Dryden Flight Research Center Edwards AFB, Calif. 93523		This RTOP covers continuing DFRC activities related to full-scale, flight test evaluations of various aerodynamic wake vortex alleviation devices. These devices have been and/or are being developed in ground facility tests at ARC and LaRC. The approach taken is that of flying the devices on actual transport aircraft (e.g., 747's, DC-10's, L-1011's, etc.). Comparisons of the vortex characteristics with and without the devices are made by probing the aircraft's wake with specially instrumented probe aircraft (e.g., DFRC's T-37, ARC's Lear Jet, and the FAA's DC-9). To facilitate wake probing, specialized vortex visualization systems are being used and developed.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Wake Vortex Minimization C.T. Snyder (415)965-5567 RTOP #514-52-01	NASA	Ames Research Center Moffett Field, CA 94035		The objective of this program is to reduce the wake vortex behind aircraft in order to reduce the landing separation distance imposed on transport aircraft by lift-generated wake vortices from the present 3 to 6 miles to 2 miles without significant detriment to aircraft performance. Experiments will be conducted in flight and in ground-based facilities and theoretical studies will be made on innovative techniques to reduce the wake vortex behind transport aircraft.
Wake Vortex Minimization A.W. Hall (804)827-3274 RTOP #514-52-03	NASA	Langley Research Center Langley Station, VA 23665		The objective of this effort is to reduce the hazard potential of wake vortices shed by transport aircraft through aerodynamic means without significant detrimental effects on ai-craft performance. This objective will be met by developing experimental techniques and theoretical numerical methods to enhance the understanding of the fundamental flow mechanisms associated with the generation of multiple vortex wakes, their interaction, and turbulent decay. A detailed understanding of the relationship of aircraft span-load distribution and turbulence effects will be obtained.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Clear Air	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Dr. K. Doviak Dr. R. Ernic Jean T. Lee	To investigate the use of 10 cm Doppler radar in the detection and description of wind shear in the clear air. With suitable configuration resulting in increased sensitivity, the 10 cm Doppler radar can be used to measure wind speeds in the clear air. It appears that sufficient radar returns may be obtained in clear air during synoptic situations which produce critical wind shear. Concurrent Doppler radar data will be obtained while instrumented aircraft transverses the shear zone.
Knowledge of Atmosphere-Advanced Measurement Techniques R.E. Carr (804)824-3411 RTOP #505-08-13	NASA	Wallops Station Wallops Island, VA 23337		The objective is to develop advanced measuring techniques, to measure and mathematically model varying atmospheric wind conditions associated with the air-sea interface, various surface roughness and low level atmospheric turbulence. Data for model development are being collected from 0-250 feet at 50-foot intervals using 3-dimensional anemometers having wind response frequencies to 100 Hz. Empirical statistics derived under various atmospheric conditions are being analyzed for correlation with existing theory and development of new theory and modeling parameters.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Clear Air Turbulence P.M. Kuhn (303)499-1000 x6208	Dept. of Commerce/NOAA	Atmospheric Physics and Chemistry Laboratory Boulder, CO 80302	Dr. I. Nolt Dr. F. Caracena L.P. Stearns F.J. Holitza F.M. Gould	The objective is to develop and test for FAA approval an airborne clear air turbulence (CAT) infrared radiometer detector to provide 2-6-minute cockpit alerts to subsequent CAT encounters. A computer model for horizontal transfer of radiation in the water vapor bands (270-520 cm^{-1}) to enable determination of proper pass band for radiometer optics has been developed.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Atmospheric Spectroscopy Vernon E. Derr	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	Vernon E. Derr Norman L. Abshire Robert F. Calfee Richard E. Cupp Hans L. Ericson Gordon M. Lerfald Garner T. McNice Madison J. Post Ronald L. Schwiesow	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Digital Operations Technology H.J.E. Reid, Jr. (804)827-3551 (512-52-03) RTOP #505-07-13	NASA	Langley Research Center Langley Station, VA		FOR OBJECTIVES SEE FORECASTING
Wind Shear	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Judith Stokes Jean T. Lee Ed. Brandes	FOR OBJECTIVES SEE LOW LEVEL WIND SHEAR
Knowledge of Atmospheric Processes E.E. Kordes (805)258-3311 x501 RTOP #505-08-14	NASA	Hugh L. Dryden Flight Research Center P.O. Box 273 Edwards, CA 93523		FOR OBJECTIVES SEE TRAINING

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
JDOP	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Ken Wilk Don Burgess	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Wind Shear	Dept. of Commerce/NOAA	National Severe Storms Laboratory Norman, OK 73069	Judith Stokes Jean T. Lee Ed. Brandes	FOR OBJECTIVES SEE LOW LEVEL WIND SHEAR
Aviation Safety Technology --Applied Laser Technology E.A. Weaver (205)872-1597(FTS) RTOP #505-08-29	NASA	Optics Branch Electronics and Control Laboratory Marshall Space Flight Center, AL 35812		FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Correlation of Reflectivity and Gusts Measured by Probing Aircraft J. Muncy (202)426-8427 Project No.: 152-462-06	Dept. of Transportation	NOAA, NSSL	J. Lee	Establish relationship between radar reflectivity and aircraft measured turbulence.

TRAINING

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Knowledge of Atmospheric Processes E.E. Kordes (805)258-3311 x501 RTOP #505-08-14	NASA	Hugh L. Dryden Flight Research Center P.O. Box 273 Edwards, CA 93523		The objective of this work is to measure and mathematically model environmental and behavioral characteristics of the atmosphere required for improved understanding of superior aircraft design and more efficient operations. Data from instrumented aircraft flight tests will be used to update models of turbulence and provide basis for definition of atmospheric conditions in which turbulence, temperature transients, pressure altimetry problems and excessive wind shear occur. Development and acquisition of sensors needed to measure atmospheric phenomena are also included in this effort. The math modeling and analysis of associated meteorological condition will be studied both in-house and on contracts or grants. Results of this work will be applicable to aircraft system design and flight test activities and to flight operations, routing and scheduling.
Aviation Safety Technology -- Flight Safety A.W. Hall (804)827-3274 RTOP #505-08-23	NASA	Langley Research Center Langley Station, VA 23665		A technology base will be developed which can be used to reduce the number of aviation accident opportunities and to minimize the fatalities and damage resulting from accidents. This will be accomplished by programs aimed at providing a data base for continued knowledge of the usage of various types of general aviation and transport aircraft relative to their original design criteria. Research on equipment and systems will be undertaken to improve the accuracy and reliability of

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				operational information relative to visibility and meteorological phenomena. Research will also be conducted to provide improved protection of the aircraft and its systems from hazards such as lightning, turbulence and wind shear.
Aircraft Propulsion Systems Safety Technology J.W. Gregory (216)433-4000 RTOP #505-08-22	NASA	Lewis Research Center Cleveland, OH		The purpose of this research is to provide a broad base of safety oriented technology for identifying, defining and dealing with hazards associated with aeronautical propulsion systems; establish criteria for systems design and operating techniques leading to reduction in accidents, loss of life and injuries, and loss of equipment; support and perform research and technology activities that lead to solutions of problems impacting on aviation safety with particular emphasis on propulsion systems; and coordinate activity results with the FAA, NTSB, DOD, other interested government agencies and the aviation community. Specific areas of current activities include: rotor burst protection, general aviation engine tolerance to substitute fuels, aircraft fire technology, and measurement of ozone concentrations in aircraft interiors.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Aviation Safety Operating Problems and Survivability Materials, NTSB Assistance Leonard Roberts (415)965-5567 RTOP #505-08-21	NASA	Ames Research Center Moffett Field, Calif. 94035		The objective of this RTOP is to improve aviation safety by increasing the understanding of the causes of accidents, by developing materials and piloting techniques for avoiding accidents, and by increasing the probability of survival of accidents when they occur. The approach to operations studies will include developing new techniques for sensing and displaying wind shear. Additionally, as part of a joint NASA/FAA program, simulator investigations will be conducted on the effectiveness of integrated head-up displays (HUD) on reducing hazards associated with wind shear and low visibility in the landing approach. The fire hazards program pertains to the exploration of fire-hardened concepts for civil aircraft cabin materials systems such as lavatories, galleys, cargo compartments, and aircraft interior passenger compartments in order to enhance human survivability in aircraft in-flight, ramp, and post-crash fires. The technology base for fire safe aircraft systems will be developed utilizing the outputs of the R&T programs on fire-resistant materials and fire control systems. Laboratory and sub-scale tests will be conducted to assess the flammability, smoke and other properties of state-of-the-art and advanced cabin materials which have a potential for increasing the fire-hardening of aircraft. Post-accident analysis is a cooperative program with the National Transportation Safety Board, Bureau of Aviation

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				Safety (NTSB-BAS). The general objectives are to develop improved data processing techniques for analyzing aircraft accident recordings. In addition, the effects of solid fire extinguishments on engine nacelle fires will be assessed and the flammability characteristics of hydraulic fluids will be evaluated.
Helicopter Aeroelasticity, Acoustics and Flight Dynamics R.J. Tapscott (804)827-3149 RTOP #505-10-23	NASA	Langley Research Center Langley Station, VA 23665		University grants and contracted studies will be continued to define wake geometry and analytical procedures which include unsteady aerodynamic effects and wake characteristics in predicting airloads, structural response, vehicle dynamics, and performance. In-house experimental studies will be continued to better define local flow parameters for improved prediction of rotor blade airfoil performance. Analytical, wind tunnel, whirl tower, and flight investigations will be made to define configuration improvements for better performance and operational suitability. In-house analytical and experimental studies will be made to evaluate potential of higher harmonic control inputs for vibration reduction and to evaluate the effects of higher frequency fluctuating blade loads and airfoil thickness distribution on radiated noise. Both ground-based simulation and flight vehicles will be used to conduct experimental studies exploring advanced control and display concepts based on computer-centered flight control

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				technology, computer-generated symbology for enhancing real-world scene displays, and synthesized integrated control/display formats. A specially equipped CH-53 helicopter will be used to conduct real-world instrument flight operations studies in congested, remote, and offshore areas to establish the technology base for design of IFR suitable vehicles, guidance systems, and navigation and air traffic control procedures.
General Aviation Air Traffic Flow Dynamics Loyd C. Parker (804)324-3411 RTOP #505-10-18	NASA	Wallops Flight Center Wallops Island, VA 23337		The objective is to collect and analyze general aviation piloting procedures and aircraft flight dynamics data to define significant performance and operational parameters during landing approach and departure from airports. A data base has been collected which is comprised of over 3000 three-dimensional radar tracks of arrival and departure flight profiles and the corresponding environmental conditions which existed for each flight. Math models for the analysis and quantitative definition of pilot and aircraft performance and piloting procedures have been developed. Math models for analysis of the mid-air collision hazard in uncontrolled airspace, simulation of existing air traffic and for assessment of new air traffic pattern concepts have also been defined and prototype models demonstrated. Utilizing these models, pilot procedures will be characterized for various aircraft type and environments and simulations of vari-

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
				ous uncontrolled traffic pattern concepts conducted to minimize the mid-air collision hazard and improve community noise exposure created by present patterns.
Human Factors in Aviation Safety H.P. Klein (415)965-5094 (505-09-31; 505-08-21) RTOP #515-51-11	NASA	Ames Research Center Moffett Field, CA 94035		This research is designed to obtain information regarding factors in the national aviation system that cause or contribute to the occurrence of human errors in aviation operations, to evaluate the risks attributable to those factors, and to examine ways of eliminating them from the aviation system, or of ameliorating their potentially harmful effects. Descriptive and analytic studies of occurrences, incidents and accidents are used to determine system and other factors associated with human errors in aviation operations. Full mission simulation studies are performed to evaluate the ways in which these factors influence human performance. These studies are supplemented where required by laboratory studies of human behavior in complex systems. Candidate solutions and intervention strategies are examined in full mission simulations or in flight. The program is carried out in close collaboration with other government and industry groups which must implement promising solutions designed to reduce the number of seriousness of human errors in the aviation system.

PROJECT TITLE AND MANAGER	SUPPORTING ORGANIZATION	PERFORMING ORGANIZATION	INVESTIGATOR(S)	OBJECTIVES
Environmental Radiometry David C. Hogg	Dept. of Commerce/NOAA	Wave Propagation Laboratory NOAA	David C. Hogg Martin T. Decker Fred O. Guiraud William L. Taylor Ed R. Westwater	FOR OBJECTIVES SEE ADVANCED METEOROLOGICAL INSTRUMENTS
Digital Operations for General Aviation Loyd C. Parker (804)824-3411 RTCP #505-07-18	NASA	Wallops Station Wallops Island, VA		FOR OBJECTIVES SEE FORECASTING
Digital Operations Technology H.J.E. Reid, Jr. (804)827-3551 (512-52-03) RTCP #505-07-13	NASA	Langley Research Center Langley Station, VA		FOR OBJECTIVES SEE FORECASTING

APPENDIX B

NUMERICAL WEATHER PREDICTION

APPENDIX B

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APPENDIX C

ACRONYMS

Appendix C

Acronyms

AEHP	Atmospheric Electricity Hazards
AFGWC	Air Force Global Weather Center
AFOS	Automation of Field Operations and Services
AIM	Airmans Information Manual
AIRMET	Airman Meteorological Advisory
AMOSV	Automated Meteorological Observation Station-Mark V
ATC	Air Traffic Control
AV-AWOS	Aviation-Automatic Weather Observation System
AWS	Air Weather Service
CAA	Civil Aviation Administration
CAT	Clear Air Turbulence
CTOL	Conventional Take-Off and Landing Aircraft
DH	Decision Height
DOD	Department of Defense
DOT	Department of Transportation
ECM	Electronic Counter Measure
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulation
FSS	Flight Service Stations
GA	General Aviation
GFWS	Gust Front Warning System
HISS	Helicopter Icing Spray System
IAP	Intrasystem Analysis Program

IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IRU	Integrating Rate Unit
JDOP	Joint Doppler Operations Program
LAES	Landing Aid Experiment Station
LLWAS	Low-Level Wind Shear Alert System
LSI	Large Scale Integrated Circuits
LWC	Liquid Water Content
MDA	Minimum Descent Altitude
MOS	Model Output Statistics
MSFC	Marshall Space Flight Center
NAFEC	National Aviation Facility Experimental Center
NASA	National Aeronautics and Space Administration
NEMP	Nuclear Electromagnetic Pulse
NHC	National Hurricane Center
NMC	National Meteorological Center
NOAA	National Oceanic and Atmospheric Administration
NSSFC	National Severe Storms Forecast Center
NSSL	National Severe Storms Laboratory
NTSB	National Transportation Safety Board
NWS	National Weather Service
OAST	Office of Aviation Safety Technology
RVR	Runway Visual Range
SELS	Severe Local Storms

STOL	Short Take-Off and Landing Aircraft
SVR	Slant Visual Range
UTSI	University of Tennessee Space Institute
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
V/STOL	Vertical and Short Take-Off and Landing Aircraft
WPL	Wave Propagation Laboratory
WSFO	Weather Service Forecast Office

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16. ABSTRACT

The purpose of this study was to assemble a readily usable reference of basic and applied research programs related to the various areas of aviation meteorology. To accomplish this a literature search was conducted which surveyed the major abstract publications such as the International Aerospace Abstracts, the Meteorological and Geoastrophysical Abstracts, and the Scientific and Technical Aerospace Reports. In addition, NASA and DOT computer literature searches were run; and NASA, NOAA, and FAA research project managers were requested to provide writeups on their ongoing research.

The acquired information was reviewed and assembled into a bibliography that will be readily available to anyone desiring information in the area of aviation meteorology.

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