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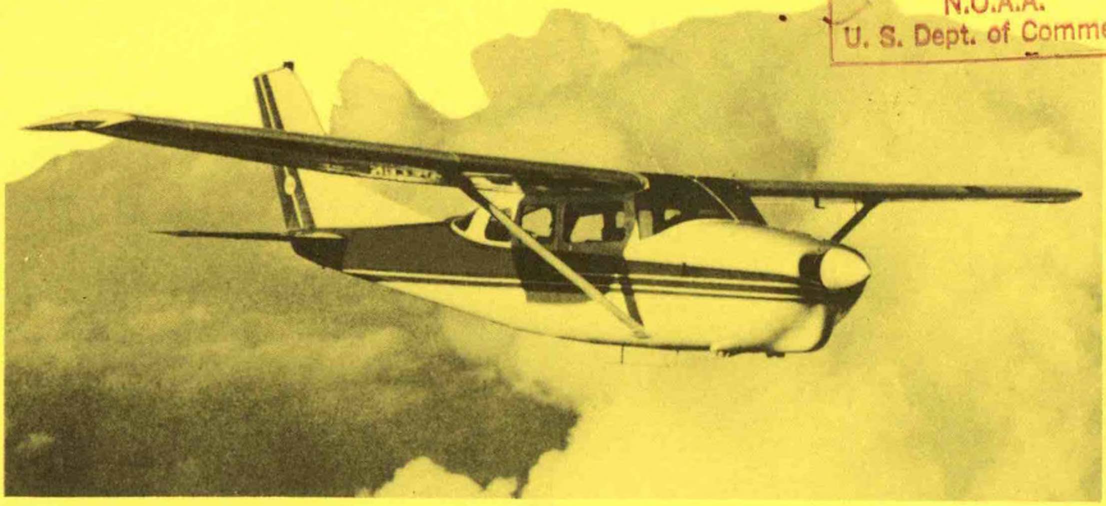
FEDERAL COORDINATOR FOR
METEOROLOGICAL SERVICES
AND SUPPORTING RESEARCH

National Aircraft Icing Technology Plan

FCM-P20-1986



Washington, D.C.
April 1986

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NATIONAL AIRCRAFT ICING TECHNOLOGY PLAN

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FOREWORD

This is the first National Aircraft Icing Technology Plan. It has been prepared because the Federal Government recognizes the need for a renewed focus on aircraft icing technology.

Icing is one of the major weather hazards to aviation. When ice accumulates in any form on airplanes and helicopters in flight or on the ground, it modifies its aerodynamic shape and weight and, therefore, cannot be tolerated because of its affect on safe flight. Aircraft systems, armaments, instruments, and communications are vulnerable areas which make icing encounters dangerous. Many aircraft are not equipped with aircraft icing protection systems and have to avoid areas where icing exists or is forecast. Since icing forecast areas can be large, civil and military operations may be disrupted even though the icing may not occur throughout the forecast area. It is difficult if not impossible to estimate the total economic impact. Icing caused and related accidents to military and civil aircraft result in fatalities every year. Some of these accidents and incidents involve aircraft equipped with ice protection devices, and some involve aircraft certificated for flight into known icing conditions, but most involve unprotected aircraft.

After an initial surge of icing-related research in the late 1940's, icing technology activities were deemphasized in the 1950's because many thought solutions to aircraft icing problems had been provided. Renewed interest in aircraft icing technology began in 1972 when the United States (U.S.) Army developed an in-flight Helicopter Icing Spray System (HISS) for the evaluation of U.S. Army helicopters for flight into known icing conditions.

In 1978, the Federal Aviation Administration (FAA) initiated a program in helicopter icing research. It was spurred by the helicopter industry requests to validate the existing atmospheric criteria for icing flight certification. Also in 1978, in recognition of the revitalized interest of FAA and Department of Defense (DOD) in aircraft icing, the National Aeronautics and Space Administration (NASA) organized an icing technology program. In 1979, the DOD established an operational requirement for accurate icing forecasts in support of aircraft that operate from the surface to 20,000 feet, and the U.S. Air Force (USAF) initiated a forecast technique development program.

FAA design standards for aircraft icing certification have been based upon icing parameters developed around 1950, and forecasting guidelines have been based on USAF studies with similar aircraft in the early 1950's. Therefore, there is difficulty in applying these standards and guidelines to newer generation aircraft with improved capabilities.

There has been interagency cooperation and support in some areas of icing technology; but in late 1983 a subgroup of the Federal Committee for Meteorological Services and Supporting Research and other high level officials in DOD, FAA, and NASA decided to promote greater coordination by forming a National Aircraft Icing Program Council. The Office of the Federal Coordinator for Meteorological Services and Supporting Research provides the infrastructure for the Council which was established in 1984. Membership on the council includes the Department of Commerce (DOC), DOD, Department of Transportation (DOT), NASA, and the National Science Foundation (NSF).

The Council has the responsibility for developing and maintaining a National Aircraft Icing Technology Plan and for providing policy guidance for its execution. Such a multiagency council approach offers opportunities for synergism that should result in efficiencies and cost-saving. The Council established the Working Group for Aircraft Icing, which has prepared this initial plan.

The planned program has dual objectives: improving aircraft icing technologies for the current generation of aircraft and promoting advances in aircraft icing technology that will be needed by 1995 to meet national aeronautical goals for new generations of aircraft. This plan presents a comprehensive list of aircraft icing needs and objectives, and describes the efforts now underway and proposed in these areas of need. It is recognized that the scope, definitions, and priorities may change as the National Aircraft Icing Technology Plan is implemented, and updating of the plan will be needed to reflect accomplishments and changes in agency missions and goals.

William S. Barney
Federal Coordinator for
Meteorological Services and
Supporting Research

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EXECUTIVE SUMMARY

The National Aircraft Icing Technology Plan encompasses research, education and guidance, and related elements that impact regulations, flight operations, and meteorological services. This plan will guide the development of the operational and technological support in aircraft icing needed by current aircraft and helicopters, and by new advanced technology aircraft and helicopters operating in a modernized National Airspace System. Specific goals of a balanced coordinated aircraft icing program that involves industry, universities and the Government are:

- capability for aircraft to fly in icing conditions with all systems operating to their mission requirements;
- capability to reduce cost and time for certification and qualification 30 percent by 1995;
- accurate monitoring and forecasting of aircraft icing;
- aviation community that understands aircraft icing.

By technologically superseding foreign competitive challenges, civil market opportunities can be captured. Technological and operational advances will enhance safety and productivity of the civilian fleet and improve military responsiveness and survivability. To support development of ice protected new generation aircraft requires technology advances by 1995 which will provide applications into the next century.

Needs and objectives are outlined in the plan in seven major areas:

- icing environment instrumentation;
- icing atmosphere characterization;
- icing atmosphere monitoring and forecasting;
- analytical simulation techniques;
- icing environment simulation facilities and research aircraft;
- ice protection systems;
- guidance.

The current status and capabilities in each of these areas are discussed and a program to meet the needs is described. In each program area, the plan addresses the basis for the activities, agency roles, estimated resources that are required, and benefits to be derived. Specific benefits of individual program areas contribute synergistically to improvements in safety and efficiency that are not necessarily an outcome of that program area itself. Therefore, all program areas are essential and need funding to assure a balanced program. The program plan makes the following key points:

o The Government will take the lead in support of instrumentation activities needed to sense the icing environment. A panel of experts will identify the priority needs in the icing instrumentation area and prepare a detailed plan for achieving cost effective improvements.

o The Government, with FAA leadership, is conducting a national effort to characterize all icing environments and provide valid aircraft design criteria in that area.

o The National Oceanographic and Atmospheric Administration (NOAA) will provide leadership for a coordinated program initiated to improve the understanding of the meteorological aspects of aircraft icing, and to improve the monitoring and forecasting of icing conditions. Opportunities for improvement are becoming available, with several large-scale Government programs in related meteorological areas and new remote sensing developments becoming available in the 1990's.

o Both Government and industry are in need of analytical simulation models to reduce cost and time at each stage of aircraft design, test, and certification. The National Aircraft Icing Technology Plan will direct advances to meet industry's design and certification requirements through an enhanced program for the development and validation of computer codes for aircraft icing conducted by NASA, FAA, industry, and universities. In particular, a concerted effort is needed to develop simulation tools for rotorcraft.

o NASA and DOD ground-test facilities and in-flight test facilities need enhanced capabilities to improve the certification/qualification process and to better study: how ice accumulates and sheds from aircraft; how aircraft performance and handling are affected by ice accumulations; and how well ice protection systems perform. These facilities can minimize the cost and time associated with natural icing tests. The Government is committed to a policy of providing industry access to its icing simulation facilities, subject to Government priorities.

o Improvements in ice protection technology are primarily an industry role, especially in the area of concept development and application of new technologies to the design of ice protection systems. The Federal role in ice protection systems may include NSF support in the concept development area through university grants. NASA will continue to support new ice protection concepts and, where appropriate, will demonstrate proof of principle and feasibility for various applications, and will develop and validate supporting analytical models.

o The Government, led by the FAA, will conduct efforts in the area of standards and guidance to: standardize the aeronautical and meteorological terms related to aircraft icing that are used in regulations, operations, and training; develop and adopt objective icing severity definitions, provide education and guidance to the aviation community that is consistent and reflects the current knowledge of aircraft icing; and to assure that regulations and guidance for certification for flight in known icing conditions will allow the introduction of new technology ice protection systems to meet safety standards.

The activities in these program areas just described can improve the operational capability and efficiency of aircraft through improved aircraft design, and provide less costly and more timely product availability. The national interest in this icing program dictates continued and augmented Federal support, but both public and private sector efforts are vital for new technology advances to occur.

This plan is the first edition of the National Aircraft Icing Technology Plan. As the program is implemented, the plan will be reviewed and updated to assure that goals are realized, to improve operations in the National Airspace System, to strengthen our defense capabilities, and to improve our aeronautical product superiority in the international market place.

1. INTRODUCTION

A national aircraft icing technology program is vital to the maintenance of the nation's technological preeminence, economic health, and strategic well-being.

Icing disrupts civil and military aircraft operations and degrades aircraft performance and handling qualities, which affects flight safety and limits operational capability. Aircraft that are not properly protected avoid forecast and known icing conditions; their disrupted operational schedules cause incalculable economic losses. In addition, accidents and incidents attributed to icing result in fatalities every year in the United States, and a Navy study (reference 1) revealed a number of icing related mishaps among its unprotected trainers and helicopters and among some "all-weather" airplanes.

Essentially all civil transport category aircraft have been certificated by the Federal Aviation Administration (FAA) for flight in known icing conditions. In general, their ability to climb and descend fast and cruise at high altitudes minimizes exposure time to potential icing conditions. However, when large transport aircraft are forced to fly for extended periods in icing conditions, it may pose a hazard. Ice protection systems on these aircraft are sophisticated, expensive, require considerable power, and are heavy; but these penalties are small, relative to the cost and weight of current aircraft.

The most important icing-related concern for manufacturers of large civil aircraft, in addition to efficient design, is the time and cost to certificate the new ductless fan technology aircraft for flight in icing conditions. These new generation aircraft will require new concepts to provide power for ice protection.

Small fixed-wing airplanes and helicopters are more susceptible to icing problems due to their altitude limitations. Only a small percentage of the small fixed-wing airplanes have ice protection equipment. To avoid cost, power and weight penalties, systems for these aircraft that have ice protection equipment are generally less sophisticated than the systems used for transport aircraft. Therefore, few of these smaller airplanes are certificated for flight into known icing conditions or allowed to operate in areas of forecast icing.

General aviation is the fastest growing segment of the aviation industry, and the number of general aviation IFR operations are increasing rapidly. Current and projected trends all point to the needs for lightweight, low power-consuming, low-cost ice protection systems; for better knowledge of the icing environment and its impacts, and for improved design criteria and guidance for certification.

Similar needs apply to helicopters. The United States (U.S.) helicopter fleet is increasing and both civil and military operators need nearly all-weather capabilities for these aircraft which generally operate below 5,000 feet. The U.S. Army is now qualifying all new helicopters for flight into moderate icing conditions, whereas older military helicopters have been successfully qualified for flight into light icing conditions. The Army defines icing conditions in terms of outside air temperature (OAT) and liquid water content (LWC). The Army requires icing qualified helicopters to be instrumented for OAT and LWC, but present instrumentation does not operate properly throughout the entire range of temperature and

LWC conditions in which icing can occur. To date, no U.S. civil helicopter has been certified for flight in icing conditions, but the French have certificated a helicopter for flight in icing conditions. Foreign and U.S. manufacturers have expressed intent to obtain U.S. certification for several existing and new model helicopters.

In 1982, the Office of Science and Technology Policy (OSTP) established the following broad national aeronautic goals:

- Maintain a superior military aeronautical capability;

- Provide for the safe and efficient use of vehicles and facilities required for the National Airspace System;

- Maintain an environment in which civil aviation services and manufacturing can flourish;

- Ensure that the U.S. aeronautical industry has access to and can compete fairly in domestic and international markets consistent with U.S. export policy;

- Ensure the timely provision of a proven technology base to support future development of superior U.S. aircraft; and

- Ensure the timely provision of a proven technology base for a safe, efficient, and environmentally compatible air transportation system.

In March 1985, the OSTP articulated specific goals to advance the aeronautical technologies that will be needed for new generation aircraft. These include subsonic transport aircraft and rotorcraft that incorporate active drag reduction systems, high-speed turboprop engines, all-composite primary structures, high-lift aerodynamic systems and new flight control and guidance improvements, improved supersonic aircraft, and hypersonic and transatmospheric vehicles which operate from conventional runways.

A program in aircraft icing technology must be reemphasized to support the accomplishment of these broad goals and to advance the technologies needed for new technology aircraft and components, both civil and military, as well as for military armament. The OSTP call for acceleration of the technology advances has a 1995 readiness target for application into the next century.

One of the driving forces for a national icing technology program is the growing competitive challenges of other nations in aeronautics, where the United States has traditionally provided the leadership. In recent years, other nations have conducted dedicated, subsidized research in the aircraft icing technology area, while, for a quarter century, beginning in the 1950's, the United States icing efforts were minimal. As a result, the French were the first to certify a helicopter for flight in known icing conditions.

To achieve the aeronautical goals requires a set of broad national goals to drive a coordinated aircraft icing technology program. These goals are:

- o Capability for aircraft to fly in icing conditions with all systems operating to their mission requirements;

- o Capability to reduce the cost and time for certification and qualification 30 percent by 1995;

- o Accurate monitoring and forecasting of aircraft icing environments;

- o Aviation community that understands aircraft icing.

Meeting these goals will require the participation of all segments of the research community: industry, universities, and the Government. The payoffs will include more capable civil and military aircraft, more efficient and reliable aircraft operations, and a stronger aviation economy. The challenges to be faced lie in many areas:

- o Knowledge of the icing atmosphere including its physical processes and properties;

- o Ability to accurately monitor and forecast icing environments;

- o Instrumentation to conduct research and certification, and to support operations in icing environments;

- o Research and test facilities which can simulate all icing conditions in the atmosphere;

- o Certification and qualification standards that address all atmospheric icing conditions;

- o Standardized language and units of measurement for aircraft and instrument designers, operators, and weather forecasters;

- o Computer models that simulate aircraft icing processes and the impact of icing on aircraft and their operations.

This plan sets forth a means for Federal Government involvement in advancing technology and provision of support facilities that U.S. aviation industry can use. In addition, it is recognized that the Federal Government must provide a regulatory environment that allows the introduction of new technology and products.

The Federal Government can only provide leadership, guidance, and part of the technology base and support needed to achieve the national goals. Our national interest dictates continued and augmented Federal support, but both public and private efforts are vital for new advances to occur. The private sector must share in the planning and development of new concepts and technology, and in the application of these new aeronautical products. University programs can contribute to the icing program through industry and Government support.

A successful National Aircraft Icing Technology Program will take more than augmented funding by Government and industry. It requires leadership, cohesive policies, and coordinated planning that will simultaneously strengthen our defense capabilities and improve our aeronautical products' superiority in the international market place.

2. PLANNING GUIDELINES

2.1 SCOPE

The National Aircraft Icing Technology Program encompasses research, education and guidance, and related elements that impact Federal Air Regulations (FARs), flight operations, and meteorological services. It is a balanced, coordinated, interdepartmental effort designed to meet the goals associated with icing technology in support of national aeronautical goals. The plan addresses needs and objectives in seven major areas: icing environment instrumentation, icing atmosphere characterization, icing atmosphere monitoring detecting and forecasting; analytical simulation techniques; icing environment simulation facilities and research aircraft; ice protection systems; and guidance. In each program area, this plan addresses the basis for the activities, agency roles, and funding.

The National Aircraft Icing Program Council recognizes that all program areas are essential and, regardless of priority, need adequate funding to assure a balanced program. Funding and manpower shown in this plan represent estimates of what is needed in each program area to perform the stated activities; and does not represent Federal committments to perform the work nor to fund at the stated levels. Regardless of the stated needs and objectives, individual agencies have to justify their own programs to obtain funding approval. In addition, it should be noted that funding costs shown in this plan do not include National Science Foundation grants, Departments of Commerce and Defense meteorological service programs, or Department of Transportation certification and regulatory programs.

2.2 COMPLEMENTARY PROGRAMS

The following, which are funded separately from the aircraft icing program, will be important elements of the program.

o The Next Generation Weather Radar (NEXRAD) system and Atmospheric Profilers are two of the major national programs that will provide a new generation of remote sensors that will be available in the 1990's. Atmospheric sounding systems on satellites (such as the Visible and Infrared Spin Scan Radiometer Atmospheric Sounder (VAS) and the 1836 H_z microwave sounder), digitized weather radars, and the radiometer portion of ground-based atmospheric profilers have the capacity to measure or infer liquid water content.

o The Program for Regional Observing and Forecasting Services (PROFS), a Department of Commerce/NOAA effort with interdepartmental support, has an overall objective to explore ways to improve the accuracy of mesoscale analysis and forecasting. Use of emerging technologies in data processing, data handling, and information dissemination are being coupled to advanced observational systems such as VAS, NEXRAD, and the ground-based profiler. PROFS can provide a test bed for aircraft icing forecast technique development and evaluation.

o Universities, the National Center for Atmospheric Research (NCAR), NOAA, DOD, NASA, and industry have aircraft that are instrumented for cloud seeding or cloud microphysics studies. These aircraft measure parameters such as liquid water content, droplet size distribution, ice accretion, outside air temperature, and dewpoint temperature. They will be collecting data during several multi-agency national observational field programs to be conducted during the next 10 years:

- The Genesis of Atlantic Lows Experiment (GALE), a cooperative program involving the National Science Foundation (NSF), universities, and Federal research laboratories, was conducted during the first 3 months of 1986. In addition to observations from research aircraft, data was gathered by surface and airborne Doppler radar, pilot reports, satellites, surface weather stations, augmented radiosondes (more stations, greater frequency), dropwindsondes, and digital recording of National Weather Service radars. One of the Doppler radars has dual polarization which gives the potential for providing information on dropsize distribution. These studies should improve prediction of the critical boundaries between rain, freezing rain, sleet, and snow.

- Microburst and Severe Thunderstorm (MIST), another special observational field program with potentially useful data for aircraft icing, will be conducted by NSF and the FAA during the spring and summer of 1986.

- Oklahoma-Kansas PRE-STORM conducted in 1985 and the National Stormscale Operational and Research Meteorology (STORM) Program, which is planned to begin in 1990, are other interdepartmental field programs which should provide an extensive source of data applicable to the aircraft icing program.

o The NSF sponsors basic research in science and engineering, primarily through grants to university researchers and its support of NCAR. Through its grants program, it will encourage aircraft icing-related basic research into:

- fundamental knowledge about ice formation on surfaces;

- materials to modify surface properties to inhibit ice formation;

- basic heat transfer mechanisms that govern the accretion of supercooled ice droplets on surfaces;

- instrumentation for liquid water content, drop-size distribution and ice accretion;

- the mechanical properties and bonding of ice accretion on aerodynamic surfaces and the conditions for fracture of accreted ice.

In addition, NSF's grants program will foster technology transfer from researchers in other fields to accelerate the development of nozzles that produce sprays having characteristics useful for aircraft icing simulation testing.

2.3 PLANNING PROCESS

Planning, to be continually effective, is an iterative process. As this plan is implemented and knowledge is gained, the elements in the plan will need to be updated by the National Aircraft Icing Program Council. This is the first edition of the National Aircraft Icing Technology Plan. Planning will continue with reviews annually and updates, as required.

3. PROGRAM ELEMENTS

This chapter sets forth seven major program elements of the National Aircraft Icing Technology Plan. These program elements are:

- o Icing environment instrumentation;
- o Icing atmosphere characterization;
- o Icing atmospheric monitoring and forecasting;
- o Analytical simulation techniques for aircraft icing;
- o Icing environment simulation facilities and research aircraft;
- o Ice protection systems;
- o Standards and guidance.

Each program element is discussed and presented in terms of needs, objectives, benefits to be gained, planned programs and schedules, and resources including estimated costs.

3.1 ICING ENVIRONMENT INSTRUMENTATION

3.1.1 Needs

o New and improved instrumentation for use in research, certification and operations;

3.1.2 Objectives

o Develop a detailed plan for improvement of current and development of new aircraft icing instrumentation.

o Establish performance and calibration criteria and operational limits for current and new instrumentation; and identify new requirements.

o Develop new instrument systems for sensing and analyzing the atmospheric icing environment.

3.1.3 Discussion

A required tool in every area of aircraft icing technology is instrumentation, and it pervades all areas of this plan as an element which needs resurgence for developing new technologies. Icing environment instrumentation includes sensors to measure liquid water content, drop size, temperature and ice accretion rate. Such instrumentation is needed to describe the icing environment, both natural and simulated. In operational flights, these instruments can alert pilots to icing conditions and control ice protection systems. Analytical model development requires validation which would benefit from more reliable and efficient instrumentation. Icing atmosphere forecast technique development and evaluation will be greatly impacted by instrumentation because it is a primary tool in the monitoring process.

Many instruments in use today for obtaining icing environment information are not sufficiently accurate, reliable, or consistent. For example, one important measurement needed is liquid water content (LWC), but LWC measurements are beset with calibration and repeatability problems. The current LWC sensors available for operational use do not measure LWC directly but only the rate of ice accretion; time-averaged or instantaneous values of LWC are then deduced from calibrations which contain uncertainties.

In addition to calibration uncertainties, there is also an inherent error at temperatures greater than -5°C where run-off can cause underestimations of LWC. Further instrument development is needed to more accurately measure LWC in the presence of large drops and in clouds with mixed ice and water. Research grade "hotwire" LWC sensors are calibrated directly in LWC which can operate at all ambient temperatures but are subject to drift and need frequent attention to rezero in cloud-free air during flight.

Accurate droplet size distribution is needed for designing and validating analytical simulation models of droplet trajectories, impingement and ice accumulation. Recent tests have called into question the reliability, accuracy and correlation of current modern laser spectrometers used for these measurements. These instruments also calculate LWC, but experience shows them to be unreliable for this purpose. A need exists, therefore, to develop and validate calibration methods and systems for field calibration use for all current and future instruments.

Some airborne monitoring instruments available now are either not rugged enough to withstand the operating environments or are unsuitable for use in all classes of aircraft because of weight, power, size, and vibration restrictions. Accurate, rugged, reliable, and easily used instruments are needed for airborne use both in research and future operational use.

A current problem is that there are no existing standards for calibrating icing environment instrumentation. The FAA and NASA have several independent and joint efforts underway in specific areas of icing instrumentation testing and calibration, but little work is proceeding in areas of new instrument technology. In addition, NSF has been conducting research into an ultralightweight airborne sensor for measuring LWC and other related parameters with potential to be mounted on aircraft or radiosondes. Because such instrumentation may have limited commercial uses, it is important that the Government take the initiative to lead and support new instrumentation development. A program outline to satisfy this need is shown in Figure 1.

Figure 1 indicates that a detailed plan for icing instrumentation will be prepared in 1987. Such a plan will identify the priority needs, estimate the costs and benefits associated with improvements in icing instrumention, and propose a detailed plan for achieving established goals. This plan will consider whether the schedule shown in Figure 1 can be accelerated. As a first step towards developing the plan, NASA hosted a droplet trajectory workshop in May 1986 that addressed many instrumentation issues. A panel of experts will consider the results of that workshop as well as related activities by the Society of Automotive Engineers and the American Society for Testing and Materials.

3.1.4 Benefits

- o Provide standardization of measured parameter values that will result in reduced cost of testing and analysis.

- o Provide more reliable and accurate instruments with more extensive operating ranges, requiring fewer instruments.

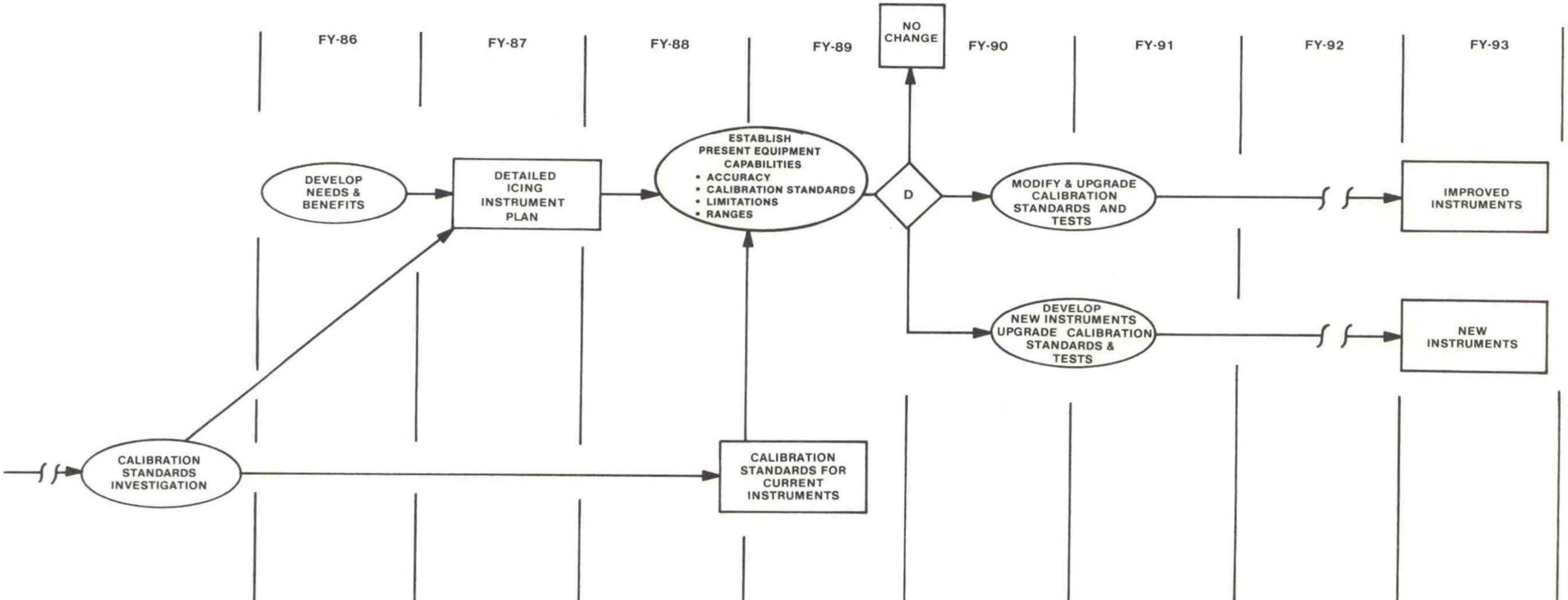
- o Advancement of ice protection system state-of-the-art and capability by providing better inputs to control systems.

- o Provide capability to validate analytical and scaling techniques.

- o Provide greater meterological analysis capability through instruments that are low cost, lightweight, rugged, small, reliable, and easy to calibrate.

3.1.5 Resources

The current projected federal funding needs for planning, testing, evaluation, and calibration of instrumentation specifically for the icing environment (not including meteorological systems like NEXRAD, Profiler or Satellites) is about $300K to $500K per year during FY-1986 through FY-1993. Development and procurement costs of new instruments are not included in this edition of the plan. The instrumentation plan scheduled for completion in FY-1987 will provide estimated development costs to be included in updates to this plan.



LEAD ORGANIZATION - NASA

FY	86	87	88	89	90	91	92	93
REQUIRED FUNDS ($Thousands)	350	300	300	300	500	500	400	200
MY'S (IN-HOUSE)	4	3	3	3	5	5	4	2

FIGURE 1. ICING INSTRUMENTATION

3.2 ICING ATMOSPHERE CHARACTERIZATION

3.2.1 Need

o Valid characterization of atmospheric icing environments for aircraft design criteria.

3.2.2 Objective

o Complete the characterization of all icing environments for aircraft design purposes and refining Federal Air Regulations (FARs).

3.2.3 Discussion

With regard to standards for aircraft safety and operations, the FAA and DOD have different regulations, regulatory responsibilities, and mission requirements. Therefore, each uses different approaches to "approval" of aircraft for operation in known icing environments. The FAA certification is based upon compliance with regulatory requirements whereas the DOD uses a qualification process based upon compliance with military standards and specifications that are heavily influenced by mission requirements.

FAA certification is intended to provide safe aircraft operations under known icing conditions and culminates in the issuance of documentation to the manufacturer which certifies that an aircraft is safe for operation under the specified conditions. The FAA's certification process requires a demonstration by the manufacturer that the aircraft and its critical components are in compliance with requirements for operating in known icing conditions as defined in FARs and appropriate guidance materials. This guidance, which addresses large and small airplanes, rotorcraft, and aircraft engines is in the form of policy letters, letters of instruction, or advisory circulars (AC).

FAA's certification of an aircraft for flight in known icing conditions can be a long and expensive process which typically takes several years for a new aircraft type and involves extensive cooperation between the FAA and the manufacturer. The process is normally initiated at the manufacturer's request for certification which must identify the aircraft type, applicable rules, types of ice protection systems, and any special considerations that may require new policy or guidance. This is followed by the manufacturer's certification plan which is a document that details the procedures proposed for showing compliance with the requirements and other considerations. It addresses design of ice protection system(s); test instrumentation; test procedures and methodologies; data interpretation and analysis methods; required results; and acceptance criteria. Upon FAA approval, the plan becomes the basic document that governs all compliance activities directed toward that particular certification effort.

The DOD approach to qualifying aircraft for flight intc icing conditions is driven by clearly defined contractual requirements. Within the DOD, the respective services adopt somewhat differing approaches to meet their individual requirements. Each service seeks primarily to ensure compliance with overall military specifications and standards. In addition, the Army's icing-related qualification process also requires extensive icing environment testing of the aircraft in natural as well as simulated icing conditions. In contrast, the Navy and the Air Force place far less emphasis upon natural icing tests of the entire aircraft. They rely largely on component testing in artificial icing environments.

Army helicopters are qualified for flight into icing conditions in a two-stage testing process. Initial qualification is conducted by flying helicopters in an artificial icing cloud behind the Army JCH-47C Helicopter Icing Spray System (HISS). Final qualification is conducted under natural icing conditions to verify the artificial icing test results and to obtain operational experience under natural icing conditions.

Aircraft for the Navy are, in general, manufactured to specifications and are then evaluated for conformance with those specifications. The specifications include a "continuous maximum" type of exposure icing criterion for the aircraft, but preproduction negotiations between the manufacturer and the Navy often result in less stringent icing criteria on the grounds that the original standard is unnecessary or too expensive. After delivery of the first models, both technical and operational evaluations are performed on all components and systems. Low temperature tests performed on the aircraft's environmental control systems are typically under controlled artificial icing conditions such as those created in the Eglin AFB Climatic Chamber. The engines are tested separately at the Naval Air Propulsion Center. Newer, high-performance fixed-wing aircraft are tested by flights in artificial icing conditions. No blanket approval for unrestricted flight into icing conditions results from these tests.

Air Force approval for aircraft flight in icing environments is based on military standards and specifications. Some USAF aircraft must be capable of flying into forecast or known icing conditions. The manufacturer builds the aircraft to contract specifications which generally contain all or portions of the standards. The aircraft capabilities are then demonstrated in artificial icing conditions in the Eglin AFB Climatic Chamber and behind the NKC-135 spray tanker. If an aircraft does not meet icing specifications, operational limits are included in the Technical Orders for the particular aircraft.

The icing environment is one of the major barriers to full utilization of aircraft with safety. To overcome this barrier, knowledge of the different atmospheric icing environments need to be made useful to aircraft designers, test engineers and certification authorities. To adequately design aircraft for the hazards of the icing environments, accurate information is needed about atmospheric icing conditions including the key variables: liquid water content, temperature, dewpoint, dropletsize distribution, and horizontal and vertical extent of clouds.

The designer specifies the time in which the aircraft can be flown in icing conditions of a given type and intensity when the aircraft is designed. Aircraft certification and approval authorities define the icing environment in which aircraft must demonstrate safe operations and develop data for certification. For research and testing of aircraft and ice protection systems under natural or artificial conditions, engineers specify the conditions under which the tests are to be conducted.

The aviation community needs a valid characterization of all atmospheric icing environments for aircraft design criteria. Currently, only one element of the atmospheric icing environment, the supercooled cloud, has been characterized for aircraft design and certification. The other icing environments not now characterized are: snow, freezing precipitation, mixed conditions, ice crystals, and supercooled ground fog. The supercooled cloud characterization now used was established in 1951 by the Civil Aeronautics Authority and the National Advisory Committee for Aeronautics for use in certifying aircraft in flight in known icing conditions. It is included in FAR Part 25 and Part 29, Appendix C. DOD uses the same data and includes it in MIL-E-38423. During the late 1970's, the helicopter industry challenged this characterization as too severe for altitudes below 10,000 feet and requested its validation. Subsequent studies have resulted in a new characterization of the supercooled cloud environment for altitudes below 10,000 feet above ground (reference 2). This new characterization can now be used by normal and transport category helicopters seeking altitude limited certification (reference 3).

The FAA, with support of DOD and NASA, is leading a national effort to characterize all icing environments. Current efforts are directed to retrieving all available worldwide data which have been gathered on properly equipped research aircraft in all the atmospheric icing environments. These data will be compiled in standard formats and stored in computerized data banks available to the entire U.S. aviation community. These data will be analyzed and additional research efforts conducted, if needed, to assure completeness of each data base. Analysis of completed data bases will be conducted to establish characterization of each icing environmental condition. If additional research data retrieval means are not required, all characterization should be completed in 1989. If further data retrieval is required, it is estimated a minimum of two additional years to 1991 will be required (see Figure 2).

3.2.4 Benefits

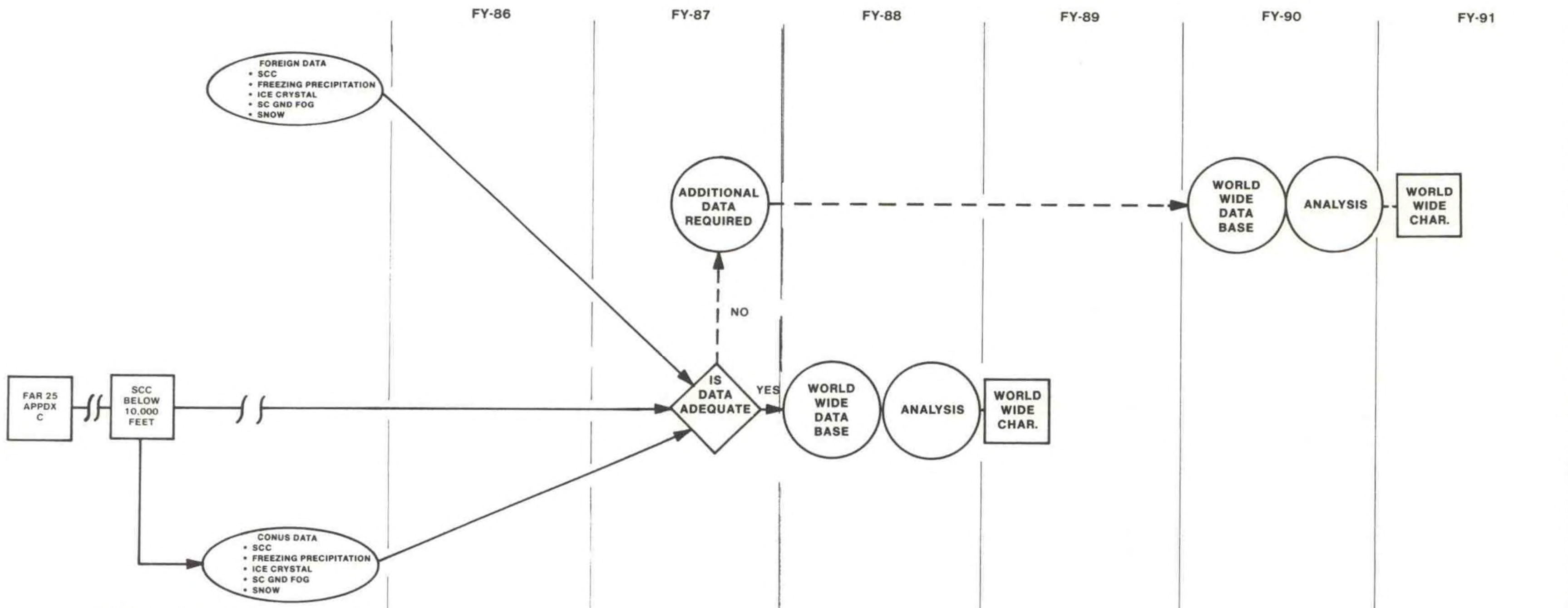
- o Redefinition and validation of the current supercooled cloud characterization used as the standard for aircraft icing design criteria.

- o Definition of all atmospheric icing conditions will allow the assessment of safety standards needed for aircraft design and operation in all icing conditions. Second, it will provide the data base for other areas of the aircraft icing problem; i.e., forecasting, instrumentation, protection system design, simulation training, and operations.

- o Increased operational capability of both civil and military aircraft as a result of better understanding of the icing environment.

3.2.5 Resources

Projected cost of data retrieval and analysis is estimated at $1.2M through 1989, $300K per year over the next 4 years. It is not feasible to compress this time schedule with augmented funds, but should additional data retrieval be required, additional funds of 1.3M from 1988 through 1991 would be necessary.



LEAD ORGANIZATION - FAA

FY	86	87	88	89	90	91
REQUIRED FUNDS ($Thousands)	300	300	400 (+300) *	200 (+300) *	(+500) *	(+200) *
MY'S (IN-HOUSE)	3	3	4	3	3	1

* ADDITIONAL FUNDING, IF ADDITIONAL DATA REQUIRED

FIGURE 2. ICING ATMOSPHERE CHARACTERIZATION

3.3 DETECTING, MONITORING AND FORECASTING

3.3.1 Needs

- Meteorological and climatological descriptions of the icing environment and the physical processes that produce them.

- Valid techniques for detecting, monitoring, and forecasting aircraft icing.

3.3.2 Objectives

- Maximize the use of ongoing and planned research and operational programs to further our knowledge of icing environment (especially those programs that utilize appropriately instrumented aircraft).

- Develop meteorological and climatological data bases that will supplement the data bases being developed by the FAA and the USAF, and be suitable for cloud physics studies, forecast technique development, validation and verification.

- Study and evaluate the accuracy and limitations of current forecast techniques.

- Identify and develop improved methods for forecasting aircraft icing environments (including modifications to existing models or new techniques that are based on improvements in observations and research results).

- Critically evaluate the operational feasibility, utility, and cost effectiveness of potential icing forecast techniques in a controlled environment such as at the NOAA/Environmental Research Laboratories (ERL) and then in real-time operational aviation forecast settings.

3.3.3 Discussion

The type and intensity of icing depends on meteorological and aircraft parameters. Meteorological factors include the number density of drops present (LWC) and the droplet size distribution which in forecasting may be handled implicitly as a function of cloud type, meteorological regime, topographical regime, etc. Other meteorological conditions that affect the type and intensity of icing are: entrainment and mixing which change moisture and temperature lapse rates; vertical motions which determine whether large drops can be sustained, and glaciation which reduces the amount of LWC.

Aircraft parameters which are important include the following: aircraft component geometry, attitude and speed which affect collection efficiency and aerodynamic heating; and ice protection equipment availability and use. Forecasters cannot be aware of all the aircraft parameters and, therefore, base the forecast on meteorological considerations and pilot reports.

Empirical rules and techniques developed in the 1950's (Air Weather Service, (AWS), "Forecasters Guide on Aircraft Icing") provide important guidance to aircraft icing forecasts which are stated as a subjective severity level defined in Section 3.7.3 based on the rate of ice accretion on an aircraft. But since the rate of accumulation of ice depends on aircraft parameters, forecasts really indicate atmospheric icing potential, and are not a literal indication of icing severity applicable to all aircraft types.

In addition to general area-type aircraft icing forecasts, military detachments provide mission-specific icing forecasts for military aircraft on request. The National Weather Service (NWS), which provides meteorological services for civil aircraft, limit their icing forecasts to general area-type products.

The Air Force is the only U.S. weather service that prepares specific aircraft icing guidance products. These products are manually prepared twice daily and consider the following elements: present and forecast temperature fields, dew point depression, vorticity advection, thermal advection, vertical velocity, location of synoptic features (fronts, highs, lows, troughs, thunderstorms, etc.), cloud coverage, visibility, and pilot reports. These parameters are integrated and compared to computer-derived products which show locations of clouds, freezing level and icing. Two icing products are considered: the first applies a rule described in AWS guidelines for predicting icing from radiosonde data and the second applies other empirical rules in AWS guidelines to a five-layer cloud model supplemented by satellite data and temperature data. Since these guidance products are updated only every 12 hours, air base weather forecasters must use other aids to assess whether the icing potential has changed. Aids include satellite imagery, radar summaries, weather depiction charts, and pilot reports.

The NWS icing forecasts are a subset of the 12-hour Aviation Area Forecasts centrally prepared by its National Aviation Weather Advisory Unit in Kansas City. The NWS Area Forecasters lack a specific icing guidance products, such as the integrated Air Force product, but apply a similar rationale in developing their area icing forecast. Since the forecast is constrained by time and could benefit from the Air Force icing guidance, steps are being taken to produce this support. Forecast updates are issued as SIGMETS or AIRMETS. When a pilot report indicates moderate or severe icing that was not included in the area forecast, it may trigger the issuance of a SIGMET which indicates a warning of severe icing or an AIRMET that indicates a warning of moderate icing. Since icing warnings only include areas where unforecast icing is expected to be moderate or severe, pilots will not receive updated information on areas of light or trace icing that are anticipated but were not in the area forecast.

While the Navy does not produce centrally prepared icing guidance, aviation support detachments develop and present icing guidance as appropriate for all preflight briefings. The forecaster uses manual methods similar to the Air Force procedures described above.

Aircraft icing forecasts tend to cover large geographic areas and deep layers of the atmosphere. Actual icing occurrences, though, often occur in smaller pockets within the large volume that is forecast. A recent Air Force verification study (reference 4) indicated that forecast "errors" are not limited to lack of precision within the forecast area, but include icing occurrences in areas where no icing was forcast.

A matter of concern is that today's aircraft icing forecasts do not consider aircraft parameters. Of concern, also, is the type and spatial resolution of the meteorological data that are available. Inputs to the forecasts come from widely-spaced radiosonde stations (about 200 miles apart) that provide data every 12 hours, satellite imagery, precipitation echoes from a weather radar network which has gaps in vital portions of the United States, a fairly dense network of surface observations over land areas within the United States, and pilot reports (which are scattered, asynoptic, and subjective). There are no direct measurements of LWC or drop-size distribution. In addition, there are no measurements by which one can infer entrainment processes or define mesoscale areas of dynamic lifting where the supply of liquid water in clouds could be enhanced. Better, more timely, measurements with improved spatial resolution are a key to better forecasts.

An additional key to better forecasts is timely assimilation of the data. Better forecasts and improved monitoring of icing conditions must be coupled with timely dissemination of the products.

There are many research and development activities that are related to aircraft icing detection, monitoring and forecasting, but they have not been part of a coordinated plan. Studies of the microphysical properties of clouds are being conducted by universities, NCAR, ERL, USAF, and others. Though these studies are not dedicated to aircraft icing, these efforts will add to the data bases needed for icing studies and provide input to analytic and forecast models.

The Air Force Environmental Technical Applications Center is attempting to establish a worldwide climatological data base for deterministic evaluations that specific flight profiles can be made without encountering aircraft icing. This is being done by merging a temperature data base and a liquid content data base in the Smith-Feddes atmospheric moisture model. The Smith-Feddes model has been used experimentally for preparing aircraft icing forecasts using the Air Force Global Weather Central (AFGWC) cloud models as input, but the results have not been verified systematically. A recent Navy project has been evaluating the accuracy of that atmospheric moisture model.

Other relevant Air Force studies are the following: AWS Headquarters efforts in forecast technique development in aircraft icing are continuing; the AFGWC is continuing to conduct studies to improve its cloud analysis and forecast models and its icing guidance products; another study is assessing the value of satellite mounted lidar, radar, and radiometers as inputs to the AFGWC cloud models.

In another remote-sensing application, NOAA's ERL Wave Propagation Laboratory has been investigating the use of profiler radiometer data (LWC and temperature) as an indication of aircraft icing potential, using pilot reports for verification; the FAA is investigating the feasibility of developing an algorithm that would use NEXRAD data to detect and monitor aircraft icing. Associated with development of a NEXRAD icing algorithm the FAA sponsored a workshop on aircraft icing detection in January 1985. This winter they sponsored a field measurement program at Grand Forks, North Dakota, utilizing a 5 cm Doppler weather radar and instrumented research aircraft. During the fall of 1986 and winter of 1986/87, this program will be conducted in eastern Colorado where it will use the support facilities of NOAA/ERL and NCAR and participate in a new initiative.

This new initiative will begin this year in eastern Colorado where the tools are in place and the technology is available to provide:

- o real-time measurement of conditions conducive to icing;
- o rapid data assimilation, monitoring, analysis and forecasting;
- o operational evaluation of product validity and utility.

Other related programs (sections 2.2 and 3.5.3) will enhance the data base portions of this effort, the cloud microphysics portions, and provide necessary support facilities.

NOAA will be the lead agency and will work with NSF (especially NCAR), DOD (especially the Air Force), and the FAA in implementing the plan. Experiments dealing with a wide range of cloud sensing devices and a number of cloud physics projects are planned. NOAA facilities offer a unique opportunity for icing research and the operational validation of new techniques. The PROFS facility has an excellent mesoscale observing capability with a network of surface observing sites and profilers; plus satellite, radar, and pilot report ingest capabilities; sophisticated processing and display capabilities; and real-time data links to the Denver Air Route Traffic Control Center.

The Colorado sites currently available for long-term continuous profiler measurements are at Denver, Fleming, Flagler, and Platteville. Radiometers currently in operation at Denver measure temperature plus vapor and liquid water. Vapor/liquid radiometers at Fleming, Flagler, and Platteville will be supplemented by temperature radiometers from the Jet Propulsion Laboratory. Cloud observations will be available at one location from a variety of ground-based sensors. These will include K-band and X-band radars, lidar, a steerable microwave radiometer, IR radiometer, and an all-sky camera. Instrumented aircraft will make in situ measurements for verification of cloud properties and an instrumented tower 25 km east of Boulder will be useful when the freezing level and cloud base are low. Measurement periods will begin in 1986. The FAA field program for NEXRAD algorithm development will be shifted to Colorado during the fall of 1986 and lend support to the National program. These facilities, operated continuously during spring and autumn will test the utility of the emerging new remote sensors and in situ sensors, employed singularly or in combination, for providing timely measurement and real-time monitoring of icing conditions.

Studies of in situ sensing for real-time applications will include the feasibility of LWC and drop-size instrumentation as adjuncts to radiosonde and automatic aircraft reporting systems. One candidate system would be the ultra-lightweight sensor developed by NSF.

Remote sensing and in situ measurements will provide an excellent data base of high resolution information that will be applicable to icing prediction technique development and validation, and provide inputs to the meteorological and climatological data bases. Input to the data base will be available, also from GALE, MIST, and PRE-STORM which will be conducted in other geographic areas.

This is a phased program where NOAA will participate jointly with other agencies and take advantage of facilities in place. Direct and immediate validation of detection and prediction methods are feasible by taking advantage of existing real-time links to operational FAA and NWS facilities in Colorado and the experimental forecast center that is being established in Boulder, Colorado later this year.

By 1987 the PROFS Mesoscale Analysis and Prediction System will automatically assimilate data from all sources and produce forecasts on a 3-hour cycle. These forecasts will include aircraft icing parameters.

In the initial phase, existing facilities will be used to evaluate the accuracy and limitations of current forecast methods, evaluate new forecast techniques and assess the utility of remote sensors. Doppler radar will provide information on cloud boundaries, LWC, freezing level, wind fields in cloud and surrounding the cloud. Profilers will provide rapidly updated information on cloud bases and tops, wind fields, temperature, humidity profiles and LWC. Satellite imagery and soundings will provide information on cloud boundaries, cloud tops, temperature and humidity profiles, and LWC. With the establishment of an experimental forecast center at Boulder, ERL will have the capability to integrate all these data, present them in a form that will facilitate analysis and forecasting, make the forecasts and evaluate the results. Evaluation of current techniques will be conducted in 1986 and initial test of aircraft icing forecast techniques in eastern Colorado will begin in FY 1987. An experimental forecast center will be located in an operational forecast office at Denver in 1987/1988. During this period techniques will be developed by ERL and tested and refined with inputs from cloud microphysics studies.

In a second phase, an expanded 30-station network of ground-based profilers will be operating in the central United States on a continuous basis. This demonstration network should contain at least ten six-channel radiometers measuring temperature, humidity, and LWC. Planned implementation is in 1987/88 with operations continuing through 1989. This phase would involve brief intensive observational periods during early spring and autumn when icing is prevalent using aircraft and additional ground-based sensors to supplement profiler data.

The third phase would begin in 1989/1990 and coincide with the STORM Central program. It would involve a much expanded area covering the Central United States and include the establishment of two additional experimental forecast centers at operational NWS offices. Data collected during all three phases would be used to develop and evaluate aircraft icing prediction techniques in operational forecast settings. This will include an evaluation of an improved icing severity index, when developed.

Techniques developed for the Colorado and Central United States regions will be tested in other regions including the marine environment, to determine if the techniques are applicable. Technology transfer from test and evaluation to operational application will begin in 1989 although full impact will require nationwide implementation of the new technologies; e.g., NEXRAD, profilers, VAS, and Automated Weather Information Systems. This program is summarized in Figure 3.

3.3.4 Benefits

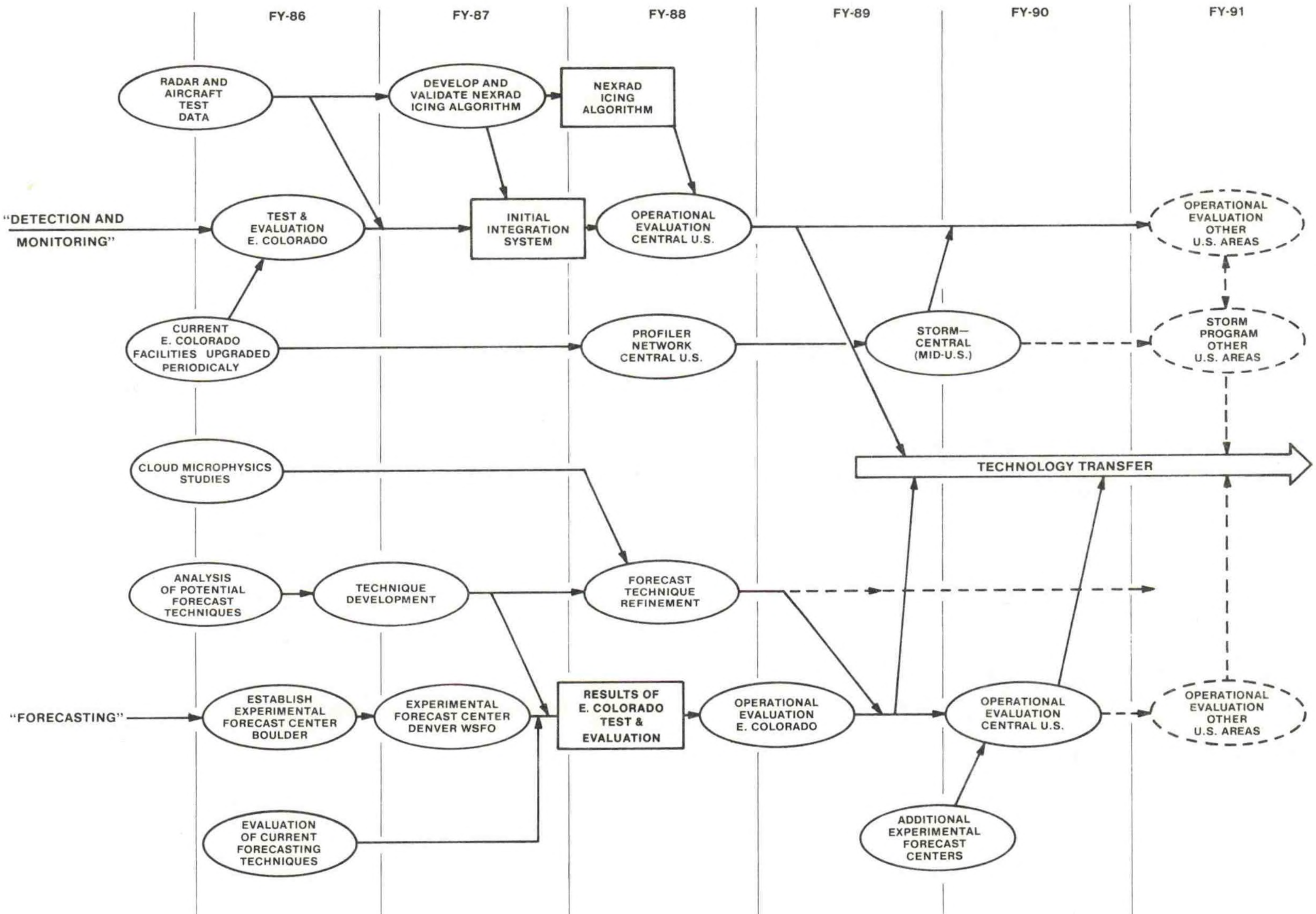
- Accurate, timely delineation of icing areas and expected icing areas by altitude, severity, and longevity, resulting in:
  - fewer flight disruptions, especially for VFR-only operations,
  - fewer accidents and less damage.

o Understanding of cloud microphysics and the related physical processes that can lead to improved:

- detecting, monitoring and forecasting capabilities,
- basis for certification and design,
- guidance for pilots.

3.3.5 Resources

This $1.0 to $1.7M annual cost of this program represents the incremental cost needed to be added on to the national investment in other major research and development programs.



LEAD ORGANIZATION - DOC

FY	86	87	88	89	90	
REQUIRED FUNDS ($Thousands)	1100	14[illegible]	1700	1000	1000	
MY's (IN-HOUSE)*	4	6	7	6	4	

* ICING DEDICATED ONLY - NSF FUNDING NOT SHOWN

FIGURE 3. DETECTING, MONITORING, AND FORECASTING

3.4 ANALYTICAL SIMULATION TECHNIQUES FOR AIRCRAFT ICING

3.4.1 Needs

- Validated two- and three-dimensional analytical models of trajectories, impingement, accretion, and shedding; and the impact on performance and handling qualities in icing environments;

- Validated scaling relationships for icing environment parameters and test models;

- Validated analytical models and codes for designing ice protection systems and predicting their performance;

- A forward looking perspective to anticipate simulation tools required for future aircraft design.

3.4.2 Objectives

- Define scope and target accuracies for computer simulation and scaling laws;

- Complete and validate two-dimensional techniques currently under development;

- Complete and validate model scaling laws currently under development;

- Develop and validate three-dimensional extensions to current two-dimensional codes;

- Evaluate utility of completed computer programs and scaling law for application to design, certification, and future needs.

3.4.3 Discussion

Given the high cost and long lead time to design, build, and certify a modern aircraft for operation in icing environments, its required icing performance capabilities must be factored into the design from the outset. The designer must explore icing effects and ice protection concepts before making irretrievable commitments to the actual construction and flight testing of a prototype design. Valid analytical simulation models for aircraft icing can provide such capabilities to designers and certifying authorities, while offering substantial savings in cost and time at each stage of aircraft design, testing, and certification. While significantly reducing the overall time for development and certification, valid analytical techniques will provide for focusing attention on conditions that testing is very difficult.

Ground-based icing simulation facilities and airborne simulators available today are not large enough to accommodate entire aircraft, or can they fully duplicate the natural icing environment. Only some full-size components or scale models can be run with current facilities. Icing scaling relationships are currently used in testing scale models and converting test results to the airspeed, altitude, and cloud conditions of the designed test. To utilize these facilities, it is required to use analytical scaling laws for conversion of results. However, while current scaling relationships appear to have merit, they have not been thoroughly validated.

If validated ice scaling relationships in both artificial and natural conditions are developed, tests of models of complete aircraft and components could be conducted in small-scale facilities with confidence and attendant time and cost savings. Both NASA and the Air Force are working on ice scaling relationships. Until valid scaling laws are available, complete aircraft performance and handling qualities in an icing environment can be determined only through actual flight tests.

The ultimate goal of analytical technique development is to make possible the design, development and certification of aircraft for icing environments with a minimum requirement for natural icing environment testing. In late 1984, an effort was initiated by the FAA for development of a plan to achieve aircraft icing certification with minimal or no natural icing testing. This plan is due in early 1986 and will identify needed improvements of simulation facilities, computer codes, and testing methodologies for all icing conditions. It should highlight and document current certification practices and techniques where simulation and analyses could be acceptable.

Because of the large potential savings in design and testing, aircraft manufacturers, with university researchers, have been working on flow and performance computer programs. Many increasingly versatile programs are being developed, and some will be applicable to icing analysis. Considerable effort is currently underway in developing programs for two-dimensional airfoils and axisymmetric components. The longer range goals are to develop and validate three-dimensional programs for airfoils and components, and ultimately, general models for entire aircraft. These are much more difficult challenges for the builders of analytic models. Although work has already begun on three-dimensional modeling, the bulk of the research efforts lies ahead and will require continuous support well into the 1990's.

Most of the promising simulation computer programs currently being developed by industry are proprietary; therefore, consideration should be given by the Government to the cost and schedule advantages resulting from the purchase of the best of these programs.

Key analytic model development efforts now underway and planned for continued improvement include the following Government conducted and funded programs:

o NASA is supporting the development of models for two-dimensional viscous flow around glaze ice shapes.

o Several two-dimensional and axisymmetric three-dimensional trajectory and impingement programs have been developed but the best are proprietary. A three-dimensional water droplet trajectory and impingement program being developed in industry will become available to NASA and FAA for icing research during FY 1986. An experimental data base is also being assembled to test and validate this program. Such programs will be used in determining the susceptibility of modern airfoils and engine inlets to the accretion of ice.

o NASA is developing ambitious two-dimensional ice accretion programs. Once the two-dimensional problem is solved, the three-dimensional problem should become tractable by the end of FY 1989.

o Efforts to validate two-dimensional ice scaling laws have so far been unsuccessful, but progress in the analysis of ice accretion should lead to progress in this area also.

o NASA also supports adaptation and verification of icing performance programs. Useful programs for two- and three-dimensional airfoil and component performance could become available by the end of FY 1995. With incorporation of empirical knowledge, programs for the entire aircraft could possibly become a reality in this time frame.

o NASA is also conducting model development for selected ice protection systems such as the electro-thermal deicer and the freezing-point-depressant systems.

o Concurrently, NASA supports an active icing wind tunnel research program to develop validation data bases for these analytical models and ice scaling laws. Its test program addresses collection of data for verification of models of droplet trajectories, ice accretion, performance penalties, and ice protection systems. Its icing flight test program also directly supports the validation of these analytic simulation methods.

There are a number of other needed analytical modeling tools that are not currently being addressed, which have been identified as important to the aircraft industry. These analytical simulation needs include models for: internal flow-field ice accretion for engines and inlets; rotor ice accretion and performance; models for the electro-impulse and pneumatic boot ice protection systems; and models of ice shedding and trajectories from propellers, rotors, and inlets.

As NASA and FAA pursue their programs in analytical simulation modeling, the National Aircraft Icing Technology Plan must ensure that these new technical advances are targeted to meeting design and certification needs. In particular, a concerted effort is needed now to develop simulation tools for rotorcraft. At the same time, a forward-looking perspective is needed to anticipate the simulation tools that will be needed to address the icing problems of future aircraft designs which may pose very different modeling demands. Figures 4 and 5 outlines the analytical simulation program.

3.4.4 Benefits

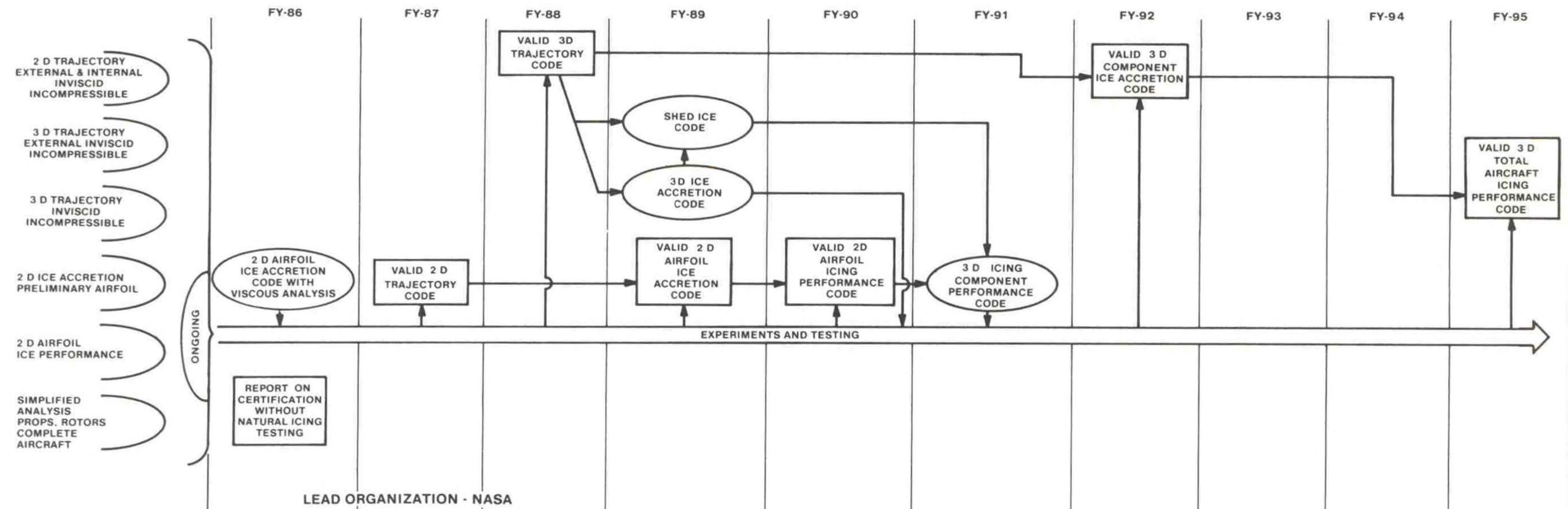
o Analytical techniques offer great potential for improving aircraft ice protection capability through increased knowledge and for reducing the total time and cost associated with ice protection system development, certification, and approval.

o Provides the tools that allow computers to be employed in aircraft and ice protection system design, testing, certification, and approval. This will result in improved designs and less total time to go from design to development, testing, final approval, and production.

o Can provide the needed technology to make the certification and qualification process more thorough and precise and reduce the need for expensive and time-consuming testing.

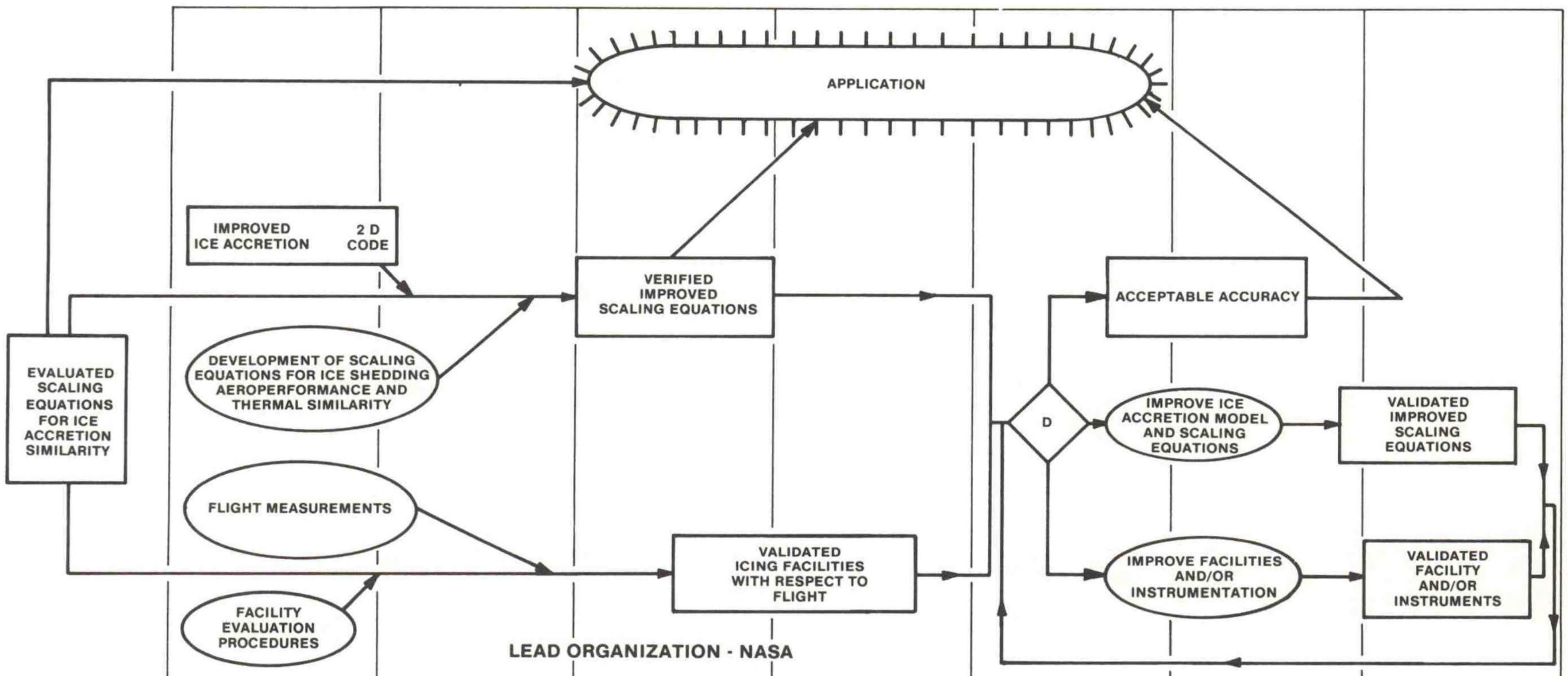
3.4.5 Resources

The projected annual costs of the analytical simulation model development programs, as currently planned, requires $1.0M in FY 1986-1991, and then decreases to about $0.5M per year thereafter. These estimates include the costs of testing and evaluation by use of tunnel and flight test facilities, but do not include the costs of developing or maintaining these facilities.



FY	86	87	88	89	90	91	92	93	94	95
REQUIRED FUNDS ($Thousands)	700	1000	1000	1000	1000	1000	1000	700	700	500
MY'S (IN-HOUSE)	6	6	6	6	6	6	6	6	6	6

FIGURE 4. ICING ANALYSIS



FY	86	87	88	89	90	91	92
FUNDING $ THOUSANDS	60	100	200	150	100	100	100
MY's	1	2	5	3	2	2	2

FIGURE 5. ICING SCALING EQUATIONS

3.5 ICING ENVIRONMENT SIMULATION FACILITIES AND RESEARCH AIRCRAFT

3.5.1 Needs

- Validated ground and in-flight facilities and techniques that simulate natural icing environments to support research and certification/qualification;

- Industry access to ground and in-flight test facilities;

- Instrumented aircraft to provide data on icing environments.

3.5.2 Objectives

- Reassessment of current facilities and establish requirements for needed improvements and new facilities;

- Develop and implement planned facility improvements and additions.

3.5.3 Discussion

This program element addresses both ground and flight facilities used to simulate icing conditions and instrumented research aircraft that are used to validate facility capabilities, to validate analytic models, to test aircraft performance and handling qualities in icing conditions, and to provide inputs for data bases.

An FAA report documents the capabilities and deficiencies of the current ground and in-flight facilities that are used for simulation of aircraft icing conditions (reference 5). This report also contains details on research aircraft available for aircraft icing programs. Details include aircraft ownership, aircraft type, airspeed and altitude capability, instrumentation and data acquisition systems, primary use and availability to outside users. Agencies will review this report and consider whether additional action plans are needed to correct facility deficiencies.

3.5.3.1 Validated Ground and In-Flight Icing Environment Simulation Facilities

Even with significant progress in analytical simulation methods, ground and in-flight icing research and test facilities will remain indispensable tools for design, development, test, and certification. In addition, these facilities provide a data source for analytical model development and validation. Icing test facilities generate artificial icing conditions that allow the study of:

- how ice accumulates and sheds from aircraft,
- how aircraft respond to ice accumulations,
- how well ice protection and detection system and methods work.

3.5.3.1.1 Ground Icing Facilities

Ground icing test facilities allow testing of aircraft systems, components and scale models in controlled icing tunnels or chambers. This permits early design revisions and a much more rapid cycle for research, development and testing of new concepts and materials. Supporting services in the test facility can facilitate the maintenance of vital data audit trails and rigorous quality assurance procedures.

Within limitations imposed by facility size, capabilities for cloud droplet generation and other test parameters, tests can be performed to support design and validate analytical models, to define aircraft operational icing envelopes, to evaluate anti-ice or deicing equipment, and to calibrate ice measuring instruments. Ground facilities can offer realistic environments for evaluating aircraft icing hazards and mitigation measures. They provide a cost effective empirical step that relates icing envelopes predicted analytically to the aircraft's actual reponse in icing conditions.

Ground facilities are of several types:

- Facilities to Test Instrumentation - There are several excellent small Government and industry facilities for test and evaluation of icing instrumentation. Several have the advantage of being able to cover broad ranges of air speed, altitude, and cloud conditions. In addition, larger facilities often can run instrumentation tests concurrently with other tests.

- Engine Test Facilities - A large number of engine test facilities are available for icing tests. Many have excellent capabilities for testing engines over the whole FAR Part 25 design criteria. However, very few facilities can generate engine damaging solid ice such as hail and ice chunks. Snow, which is a problem for some engine inlets, cannot be simulated in any facility now. These engine test facilities have only limited capabilities for turboprop or general aviation propeller engines, because of prop size and very high airflow. Even the largest of the present engine facilities cannot handle very large jet or large turboprop engines.

- Low Velocity Facilities - There are fan-blown or wind-blown spray rigs that create icing clouds in a large refrigerated cold chamber or outdoors in winter. Typically the test aircraft or engine is tested statically (tied down in some manner). Helicopters can also be tested outdoors.

- Icing Wind Tunnels - Most of the existing icing tunnels canot simulate altitude. Virtually, all produce adequately small supercooled droplets but only a few produce larger droplets such as occur in freezing rain. None can produce solid ice particles or snow. The liquid water content and droplet size ranges of the icing clouds produced are generally adequate. Certification tests can often be performed at severe icing conditions but none of the wind tunnels can cover the full icing envelope. Most importantly, these wind tunnels are too small to accommodate entire aircraft, so only limited full-scale components of the aircraft can be tested. Helicopter rotors or aircraft wings are simply too large. Models of aircraft can be used by applying icing scaling laws to convert tunnel results to the size, airspeed, and altitude of the full-size aircraft, but these scaling laws have not been adequately verified. Extensive validation of such scaling laws is needed to ensure full-scale confident applicability over all ranges of icing conditions.

The principal U.S Government ground icing facilities are the NASA Lewis Icing Research Tunnel (IRT) and the engine test chambers at the Air Force Arnold Engineering and Development Center. NASA and the Defense Department coordinate a variety of test programs in the above ground icing facilities, plus the Climatic Chamber at Eglin Air Force Base and the Navy Propulsion Center at Trenton, New Jersey.

Recent or current major research and development programs underway in Government-supported ground icing facilities include:

- o Engine icing tests;
- o Improved methods for evaluating aerodynamic effects of simulated ice shapes for dry air tests;
- o Measurements of convective heat transfer rates around artificial ice shapes;
- o Studies of aerodynamic performance degradation due to icing of modern airfoil designs;
- o Experiments concerning icing scaling law;
- o Tests of ice-phobic coating materials;
- o Improved cloud simulation capabilities;
- o Evaluation of upgraded spray tanker nozzles before installation in the tanker systems.

Needed improvements in ground facilities include: broader simulation ranges of LWC and droplet size distributions to meet certification and qualifications requirements, higher effective speeds, and larger, more uniform icing clouds.

To better meet these needs, NASA is currently investing $3.6M for an initial upgrade of the IRT, which is the world's largest refrigerated icing tunnel, with a 6-foot high by 9-foot wide test section that operates to airspeeds up to 300 knots and temperatures down to -30° F. The IRT is one of NASA's most heavily scheduled wind tunnels (1000 hours/year) and it normally has a 2-year backlog of work. Additional upgrade of this 40-year old facility will provide a new drive motor and solid-state motor controls, a completely new water spray distribution system, and improved flow quality, a modern distributed process control system, a larger control room, and new floors. These upgrades will improve the facility's productivity, reliability, and the cloud generation capability should match the full Civil and DOD aircraft design criteria. The improved and calibrated IRT is scheduled for completion in late 1989.

3.5.3.1.2 In-flight Icing Facilities

In-flight icing simulation test facilities are specifically configured airborne spray tankers generating icing clouds behind spray booms. In-flight simulation allows full-scale testing of selected aircraft components in a variety of controllable icing conditions with supercooled LWC. Tests are conducted at altitude rather than the sea-level conditions as in the typical ground facility. Until such time as analytical simulation methods evolve enough to support certification without testing, in-flight icing facilities will remain an indispensable tool for aircraft certification and approval authorities. In-flight testing in natural conditions provide benchmark test data to validate simulation of the aircraft icing processes, performance, handling qualities, and ice protection systems.

The principal Federal in-flight facilities are the Army's Helicopter Icing Spray System (HISS) which is used in the winter season for testing rotorcraft and other aircraft with limited speed and altitude capability, and the Air Force's NKC-135 Icing Spray Tanker which supports icing tests of many fixed-wing aircraft that need testing at higher altitudes and greater speeds.

The Army's HISS is now installed on a JCH-47C, and is a valuable flight test facility for expediting the qualification of Army helicopters and other aircraft for flight into icing conditions and for other research and development. The current HISS is being modified to provide an expanded JCH-47C performance envelope, improved HISS dynamics, increased airflow to the spray boom, and increased cloud size, uniformity, and depth.

In the longer term, the Army has initiated action to develop and deploy a new palletized self-contained system known as the improved HISS for use with any CH-47D helicopter, so the system can be easily removed and installed in other aircraft in the event of aircraft mechanical failure. It will have a redesigned boom configuration to achieve the following ambitious design goals for icing clouds: variable LWC, with a range of 0-2 g/m^3 and droplet size of 10-40 microns at altitudes of 0-12K feet; airspeed of 30-150 knots; and cloud size of 30 feet by 60 feet so the entire test aircraft or selected components can be immersed in the spray.

The Air Force is proceeding with several programs to improve its spray tanker capabilities. The current NKC-135 Spray Tanker water system is being refurbished to achieve a more reliable and safer system with improved technical adequacies including a telescoping water tube, new water pump, heat exchanger, air control valves, and a centralized data acquisition system. The USAF Palletized Airborne Water Spray System (PAWSS), under development, is a fully self-contained water spray system designed to be carried by a C-130 at a speed range of 100-180 knots, and intended to complement the NKC-135's speed range of 180-300 knots.

3.5.3.3 Research and Test Aircraft

The DOD, NASA, NOAA, NSF (NCAR), universities, and industry have specially instrumented aircraft which can support all aspects of the aircraft icing program. These organizations are sources of data for improved knowledge of cloud microphysics, climatology data bases, characterization of the icing environment, forecast improvements and validation, testing of ice protection systems and analytic models, testing performance and handling qualities in icing conditions, certification testing, and verification of ground facility and tanker improvements. The aircraft which are treated as support costs in the other program elements are discussed in reference 5.

3.5.3.4 Industry Access to DOD and NASA Facilities

3.5.3.4.1 Department of Defense Facilities

Department of Defense Directive 3200.11 provides policy guidance used by the Army, Navy, and Air Force to furnish test facilities and services to private industry in support of icing certification and qualification. Support to industry, which includes in-flight facilities such as the Army HISS, the Air Force NKC-135 tanker, and Air Force and Navy ground test facilities, is subject to military priorities and based on charging industry direct and indirect costs in accordance with DOD Instruction 7230.7. The individual DOD components have established internal regulations to meet particular requirements. Through Army and FAA Interagency Agreements, the Army has been providing its HISS in test and evaluation support for FAA certification of specific civilian helicopters. The Navy and Air Force also provide test and evaluation support but do not have existing interagency agreements with FAA. In all cases, however, major range and test facility base capabilities have been put at the disposal of industry when similar capabilities were not available in the private sector.

These range and test facility capabilities were established to meet military requirements and not the needs of the civil aviation industry. Consequently, military funding is not authorized to create or improve facilities to meet commercial requirements. Therefore, industry use is based on existing military capabilities, unless a civilian agency funds the upgrades. For example, the Army's current HISS improvement program takes into account FAA technical goals for upgraded artificial icing capabilities to support FAA certification requirements for industry, since the FAA has provided the entire funding needed to support improvements to the HISS capabilities for civil use. This cooperative program between the FAA and Army benefits all agencies and the aircraft icing test and evaluation capabilities without expenditures of military funds. It is an excellent example of the interagency synergism associated with a National Aircraft Icing Technology Plan.

3.5.3.4.2 NASA Facilities

Outside requests for use of the NASA IRT or the NASA icing research aircraft (a deHavilland HC-6 Twin Otter) are considered on a case-by-case basis after interested parties contact the NASA Lewis Research Center. In the past, many joint test programs in the IRT have been successfully conducted by NASA/industry/university teams. NASA's policy on the use of its wind tunnels is detailed in NASA Management Instruction 1300.1 entitled "DEVELOPMENT WORK FOR IN NASA WIND TUNNELS" dated October 4, 1978. According to that instruction, the IRT falls under the category of "All other wind tunnels." As such, the IRT "will be used primarily for NASA research. However, all of these wind tunnels may be used for industry work when it is in the public interest either in joint programs with NASA or on a fee basis." Other Government agencies also may have access to the IRT. Government projects include work by industry or universities which are either under contract with or supported by a letter of intent from a Government agency. The work must be requested by the Government agency and the work must be within the scope of the tests requested by the Government agency. No fee will be charged for this type of work in the IRT. A fee may be charged for industry projects if the work is not done under contract to a Government agency or if it is beyond the scope of interest of the Government.

In a proposed test program in which a U.S. company may be involved in a consortium with foreign companies, the NASA Director of International Affairs must review the request for test support to ensure that is is consistent with current U.S. foreign policy and compatible with the National Aeronautics and Space Act. A fee is normally charged for these consortium projects unless it is determined that a cooperative sponsorship with a U.S. Government agency warrants a non-fee arrangement. Foreign company requests for wind tunnel use are generally not granted if they are not related to U.S. Government or industry interests or programs.

Users of NASA's IRT and icing research aircraft include the DOD, National Safety Board, the FAA, and the private sector. Private sector users have included rotorcraft, transport aircraft, general aviation aircraft companies, icing instrumentation companies, and numerous university users for a variety of icing and icing-related disciplines. Figure 6 outlines the major facilities schedule currently planned for upgrading simulation facilities.

3.5.4 Benefits

Ground Facilities

- Improved and validated ground simulation and test facilities will improve productivity in research, development, and certification.

- Expanded capability for simulating icing environment and speed range with greater reliability.

- Fewer requirements for testing in natural icing conditions will reduce the cost and time associated with aircraft design, development, and certification/qualification; in addition, reduced flight time in natural icing conditions is a safety factor.

In-flight Facilities

- New spray system will provide a better representation of natural icing conditions with more representative drop size distribution and larger cloud size.

- Palletized units contribute to less down-time due to unscheduled maintenance as units can be installed on alternate platforms.

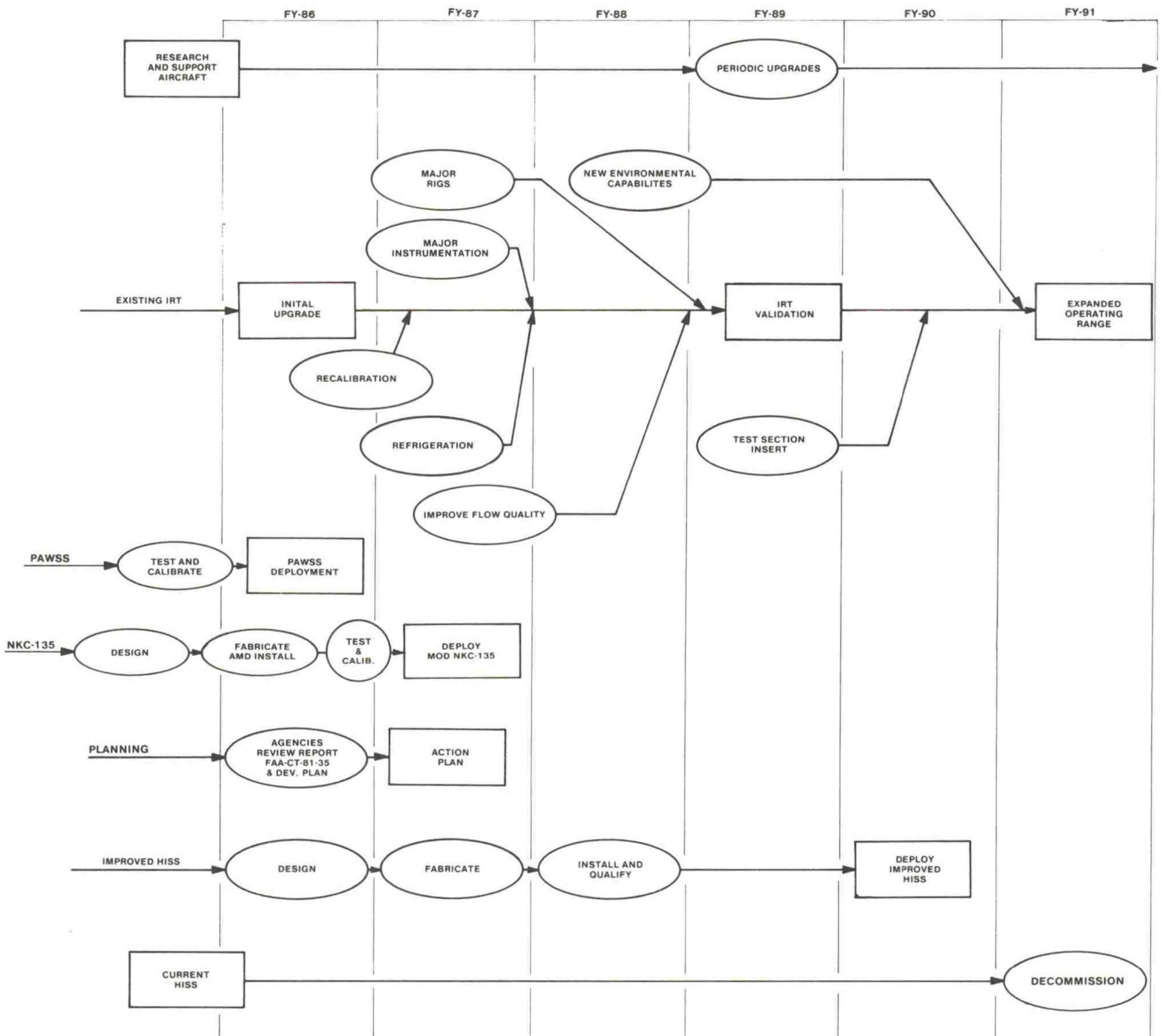
- Estimated to reduce normal time for test by 1/3 and decrease costs.

Research Aircraft

- Provide more complete data on atmospheric icing conditions and aircraft data regarding effects of ice build-up on performance and handling qualities.
- Validate ice protection system concepts in natural icing conditions.
- Validate airborne tankers and icing tunnel environments.
- Validate instrumentation in natural icing environments.
- Validate aircraft performance and handling quality codes.

3.5.5 Resources

The current estimates of $1.2 to $2.1M over the next four years are considered the minimum needed cost to maintain the schedule shown in Figure 6.



LEAD ORGANIZATIONS - NASA, DOD*

FY	86	87	88	89	90	91
REQUIRED FUNDS ($Thousands)	1245	2220	1600	1750 *	250	250
MY'S (IN-HOUSE)	25	25	25	19 *	19	19

NASA MAJOR REHABILITATION COST 3.6 M FY-85

* NO DOD COST PROJECTIONS BEYOND FY-88

FIGURE 6. ICING ENVIRONMENT SIMULATION FACILITIES AND RESEARCH AIRCRAFT

3.6 ICE PROTECTION AND DETECTION SYSTEMS

3.6.1 Needs

- o Lightweight, low cost, low power, reliable and easily maintainable ice protection systems that permit safe, reliable operations in icing environments;

- o New concepts in ice protection for advanced aircraft designs, components and materials.

3.6.2 Objectives

- o Identify new concepts for ice protection;

- o Establish evaluation criteria;

- o Demonstrate concepts and evaluate utility for application to aircraft and flight operations.

3.6.3 Discussion

Ice protection systems are designed to provide safe operation of aircraft in certain icing conditions. The capability of an aircraft to safely operate in icing environments requires the use of adequate ice protection systems.

Aircraft that are certificated for flight into known icing conditions are equipped with ice protection systems that meet certification requirements. Many believe that current systems are too heavy, require excessive aircraft electrical or engine power, and sometimes impose aerodynamic penalties which translate into more costly aircraft operations. Application of new technology could result in improvements.

Many aircraft are not certificated for icing because they cannot tolerate the penalties imposed by currently available ice protection systems. For example, helicopters and general aviation aircraft have relatively low power and payload margins. In addition, moderately priced aircraft must have low cost ice protection systems. These constraints result in relatively few rotorcraft and general aviation aircraft having icing certification.

Future large transports face a different set of problems. New high-bypass fan engines and advanced turboprop engines will have core engines which have very little engine bleed air to spare for ice protection. Therefore, new aircraft ice protection concepts should be identified and developed, primarily by industry and university research, to overcome these deficiencies.

Current ice protection systems include pneumatic boots, electrothermal systems, engine bleed air and anti-icing fluid systems. These systems, in general, do not protect the bottom of the wing where ice can accrete when drops are large, and when the angle-of-attack is high, such as during climb. These types of ice protection systems have been essentially optimized for each aircraft type and only minor improvements can be expected based on current technology and materials. The requirement for anti-icing or deicing for major rotating components on rotorcraft complicates the design of these ice protection systems. One concern is asymmetric shedding of ice which affects vibration and performance.

New concepts and methods such as electromagnetic impulse, ice phobic materials, induced vibration and microwave may offer, in different ways, solutions to the problems of ice protection for all categories of aircraft. Specifically, such methods may offer weight savings, power savings, cost savings, improvements in effectiveness, increased reliability, and reduced complexity and design complications. Analytic models will play a key role in designing ice protection systems for advanced aircraft designs, engines, propellers, wings and materials.

Ice detection systems are installed on some operational aircraft. These systems provide icing severity level indications to the pilot when aircraft are operating in icing conditions. But more importantly, they can regulate the cycle times of ice protection systems. Current detection systems have limitations, particularly when LWC is high and the outside air temperature is relatively warm, though less than 0°C. New and much better ice detection systems are, therefore, critically needed to display to the pilot the actual icing severity level as well as to provide improved operation of ice protection systems throughout all icing conditions.

Since industry is the main beneficiary of ice protection systems, the burden for concept development should be borne by them, except for unique military applications. There is also a role for universities with the support of industry and Government in developing concepts. Some NSF grants should be used in this area. National Aeronautics and Space Administration (NASA) should also continue to support the development of new ice protection concepts through joint NASA/industry/university teams to assure that key issues are identified and that needed fundamental research is conducted.

The Federal Government's role in ice protection systems is limited. After demonstration of the concepts by NASA, industry should assume the responsibility for applying the new concepts and technologies. The FAA will provide appropriate guidance needed to prepare a plan for certification of ice protection systems. The FAA will also assure that regulations allow the introduction of safe new technology ice protection systems. Government facilities are available for the test of concepts and for demonstration and test of new technology systems (see Section 3.5.3). To support this element of the icing program, these facilities must be maintained and staffed by the Government. Figure 7 shows the process and the schedule associated with this program.

3.6.4 Benefits

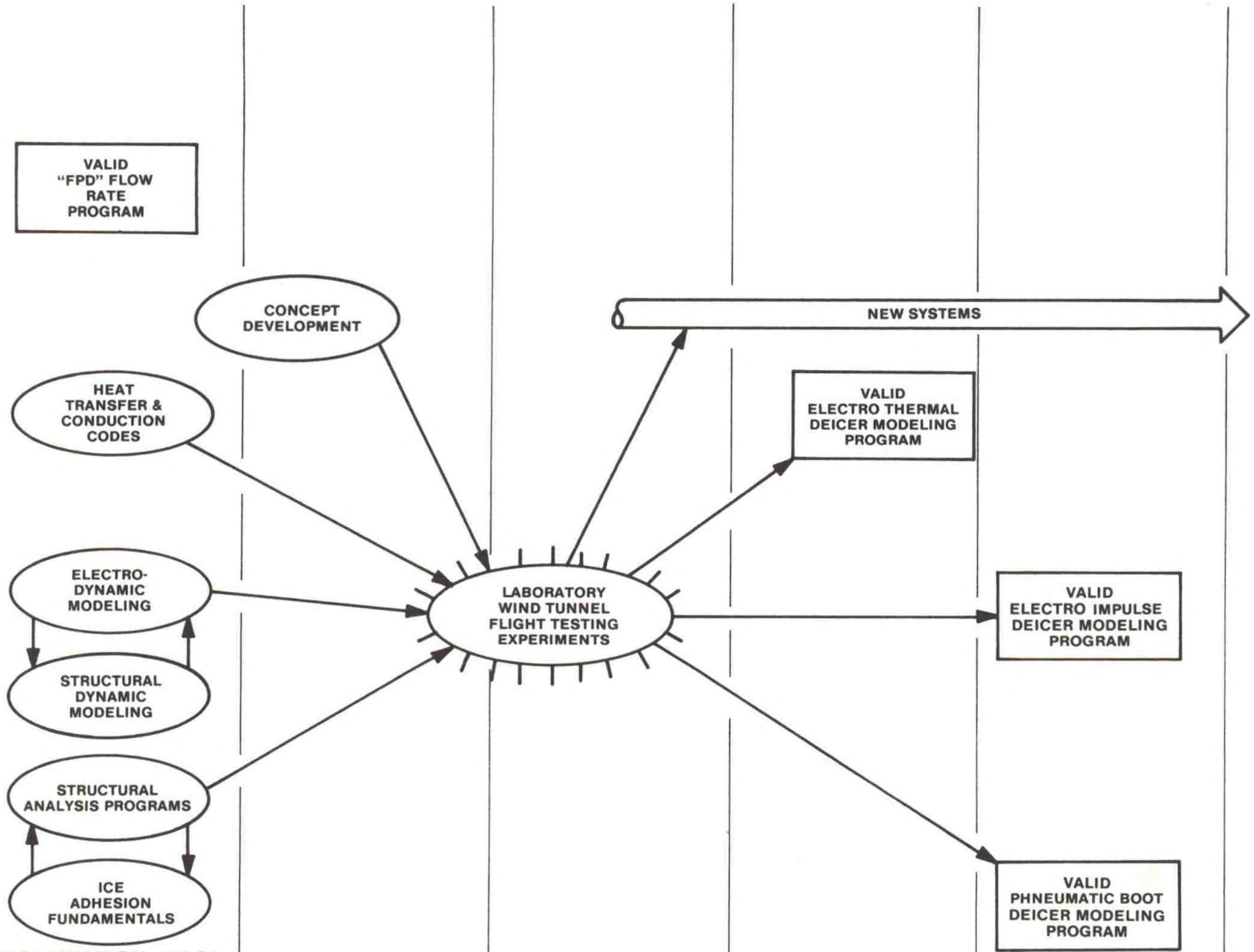
- Provides for overall enhanced efficiency of aircraft performance via lower power requirements, lighter weights, reduced aerodynamic performance degradation and enhanced anti-ice capability;

- Provides for increased system utility via reduced system complexities, easier operational procedures, and increased reliability;

- Makes ice protection capability practicable for lower cost general aviation aircraft, through development of low cost ice protection system.

3.6.5 Resources

Industry pays for most of the cost of this program element. Required federal costs are estimated to be $300K per year for this program.



LEAD ORGANIZATION - NASA

FY	86	87	88	89
REQUIRED FUNDS $ THOUSANDS	100	100	100	100
MY'S	1	1	1	1

FIGURE 7. ICE PROTECTION SYSTEMS

3.7 GUIDANCE

3.7.1 Needs

- o Consistent education and guidance provided to the aviation community that reflect current knowledge of aircraft icing.

- o Standard aeronautical and meteorological terms to describe aircraft icing environments.

- o Regulations, standards, and guidance that are safety-specific and allow new technology for certification and operations to be introduced.

- o Technical data to be used in review of regulations and guidance in aircraft icing.

3.7.2 Objectives

- o Develop and maintain Aircraft Icing Handbook which contains documentation on aircraft icing technology and a glossary of terms.

- o Develop new standard objective terms and definitions of aircraft icing severity.

- o Incorporate aircraft icing-related handling qualities and performance effects into aircraft simulators.

- o Review and revise relevant civil and military regulations, guidance material, and training courses, and revise as necessary.

3.7.3 Discussion

The bulk of the work identified in this plan is aimed at solving unknowns in aircraft icing technology and providing for better testing, facilities and methods. Therefore, in this last section of the plan, it is appropriate to recognize that to be effective and complete, the subject of guidance or distribution of the knowledge gained is important.

It is important that manufacturers and operators understand icing phenomena, the limitations of icing forecasts, the meaning of icing severity forecasts, the impact of aircraft icing on aircraft performance and handling qualities, and the meaning of "known icing" in the FAR.

Periodically, the FAA provides documentation to assist civil manufacturers with information to simplify the process of showing compliance with the FAR. Examples of such documents are: "Engineering Summary of Airframe Icing Technical Data," FAA Technical Report No. ADS-4 (1963); "Engineering Summary of Powerplant Icing Technical Data," FAA Report No. RD-77-76 (1977); and the FAA Advisory Circular No. AC-20-73 on "Aircraft Ice Protection," (1971).

Much of the information contained in these documents is now old and seriously outdated. Thus, aircraft and equipment manufacturers face again the same dilemma that confronted them many years ago: "What design guidance, testing procedures, and analysis methods can be used to minimize the time and costs associated with design, development, testing, and analysis for demonstrating compliance with FAA regulatory requirements?" In the interim, however, considerably more useable and updated information from many sources has become available from recent research investigations and experience.

In 1985, the FAA awarded a $900K contract to compile all available and appropriate data and information into a new Aircraft Icing Handbook by mid-1987 for the benefit of the entire aviation community. It will serve as an updated, more comprehensive, combined version of FAA Reports No. ADS-4 and RD-77-76, and will include reference material on the following: atmospheric icing design criteria, ice protection technology for airframes and powerplants, ice detection technology, icing simulation technology using facilities, icing simulation technology using analytic techniques; and effects of icing on performance, flight, and handling qualities.

The handbook will represent all types and categories of aircraft and other pertinent related material. An important consideration will be the standardization of the document structure, terms, style, and format to permit the timely and periodic inclusion of updated information.

The Aircraft Icing Handbook will contain a glossary of standardized aeronautical and meteorological terms used in aircraft icing. Today's standard definitions for aircraft icing severity adopted in 1968 by the Office of the Federal Coordinator for Meteorology have serious shortcomings. The terms used currently are defined as follows:

- Trace - Ice becomes perceptible. The rate of accumulation is slightly greater than the rate of sublimation. It is not hazardous even though deicing/anti-icing equipment is not utilized, unless encountered for an extended period of time - over 1 hour.

- Light - The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/antiicing equipment is used.

- Moderate - The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or diversion is necessary.

- Severe - The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate diversion is necessary.

These definitions are used by pilots when providing pilot reports on aircraft icing encounters, by civilian and military forecasting agencies, and by some aircraft manufacturers in their flight manuals and military equivalents of flight manuals. Since rate of ice accumulation is a function of airframe component geometry, airspeed, and attitude, as well as atmospheric icing potential, these definitions — whether used in a pilot report or icing forecast — must be interpreted. Military icing forecasts are usually aircraft-specific and tailored for a specific mission while civilian icing forecasts are prepared without respect to the aircraft type.

The lack of objectivity in the definitions of icing severity is a recognized shortcoming, especially in interpreting forecasts. Pilot reports indicate the type of aircraft providing the observation, though not the type of ice protection equipment on the aircraft or the status of such equipment. Flight manuals are aircraft specific, but operators usually have to interpret the meaning of a forecast intensity for that aircraft. Further, there is currently no easy way to correlate ice accretion rates on one aircraft with rates on another aircraft. An objective definition of icing severity is needed. One approach could be an index approach use of the present forecasting guidelines discussed in section 3.3.3 essentially results in an index with four levels of severity (trace, light, moderate, and severe) that apply to 1940's transport aircraft used in developing the guidelines. Many pilots do not know this limitation and assume that the severity level applies to their aircraft. It would be more objective to issue a numerical index where higher index values indicate higher potential rate of accumulation than by issuing the current icing intensity levels. With validated analytic models, these indices could be related to the icing potential for each aircraft type, including impacts on performance and handling. These data could also be used to improve the information on aircraft icing in current flight manuals.

The FAA will be the lead agency in this area and will work with the Interdepartmental Committee for Meteorology Services and Supporting Research and the National Aircraft Icing Program Council in developing and evaluating an objective icing severity index.

Guidance material for aircraft operators should be reviewed to incorporate the latest knowledge on aircraft icing and to assure consistency among the various publications. The FAA program includes reviewing and keeping current the following relevant aircraft icing guidance publication:

- "Aviation Weather" (AC 00-6A);
- "Aviation Weather Services" (AC 00-45C);
- "Instrument Flying Handbook" (AC 61-27);
- "Flight Training Handbook" (AC61-21);
- "Pilot's Handbook of Aeronautical Knowledge" (AC 61-23B);
- "Cold Weather Operation of Aircraft" (AC 91-13);
- "Water, Slush and Snow on the Runway" (AC 91-6);
- "Airmen's Information Manual," Chapter 6 (Safety of Flight) section 1 (Meteorology).

During 1986, the FAA will begin development of updated material for use at safety seminars and pilot training schools operated under FAR Part 141. At a minimum, this will lead to a standardized presentation to be used by fixed-base operators, pilots training schools, and accident prevention specialists.

standardized presentation to be used by fixed-base operators, pilot training schools, and accident prevention specialists.

Air transport simulators can introduce aircraft icing effects into training programs by such actions as changes in performance, handling qualities and known effects on aircraft instrumentation. With increased knowledge gained through analytic models and flight test, it will be possible to improve the aircraft icing training in these simulators. No Government program, however, is planned in this area. It is a private sector role to improve the training; it is a Government role to approve the scope and type of training.

Figure 8 shows the schedule and plan for this important program area.

3.7.4 Benefits

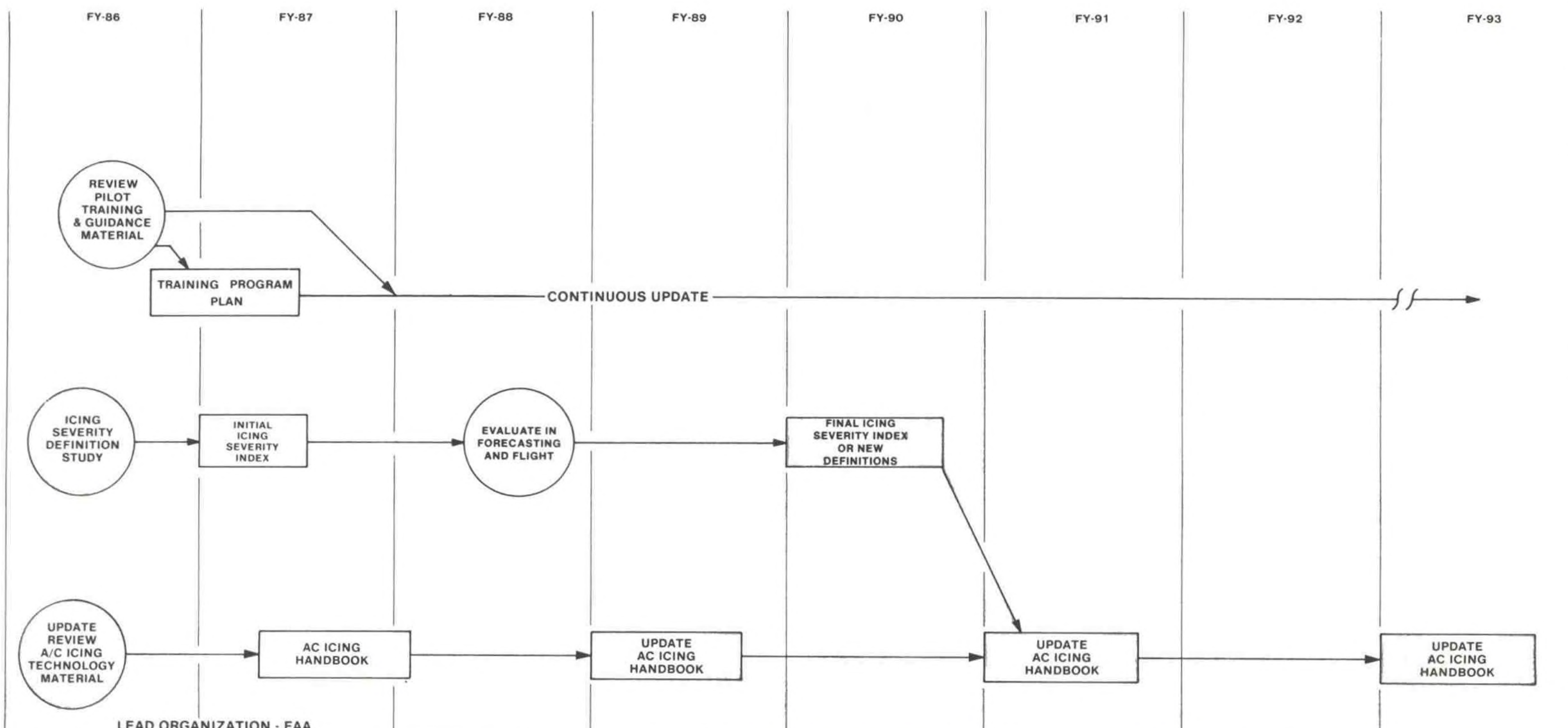
- Provides current design guidance, testing procedures, and analysis methods related to aircraft icing to assist manufacturers and those involved in the certification/qualification process with impacts on safety, time, and costs.

- Provides training that stays abreast of state-of-the-art in aircraft icing technology.

- Provides a more objective definition of aircraft icing severity to give operators an indication of icing that requires less interpretation.

3.7.5 Resources

The resources estimated for guidance are roughly $250K per year. These funds are basically for efforts dedicated to tasks of compiling and publishing the results of all icing technology on a continuous basis as the technology develops.



FY	86	87	88	89	90	91	92	93
REQUIRED FUNDS ($Thousands)	250	350	250	250	100	250	100	250
MY'S (IN-HOUSE)	4	2	3	3	2	2	2	2

FIGURE 8. GUIDANCE

4. PROGRAM SUMMARY

Figure 9 summarizes the major efforts in the national aircraft icing technology programs and indicates the projected schedule. Details concerning each program area have been described in the previous chapter and reflected in Figures 1 through 8. The lead agency for each program area will monitor planning and implementation concerning that portion of the program and be responsive to the council's request for reports on progress and changes.

The following is a summary of proposed near-term actions:

Instrumentation - NASA will conduct a workshop in May 1986 leading to preparation during 1987 of a detailed plan for improvement of current and development of new aircarft icing instrumentation.

Characterization - FAA, with DOD and NASA support, will continue activities leading to characterization of icing environments, other than supercooled clouds (snow, freezing precipitation, mixed conditions, ice crystals, and supercooled ground fog). These are near-term milestones.

Detecting, Monitoring, and Forecasting - A detailed plan for activities in this program area will be published in June 1986. Program, led by NOAA, was initiated this year.

Analytical Simulation - The FAA will issue a plan in 1986 that will highlight and document those current certification practices and techniques where simulation and analyses could be acceptable. In addition, it will identify needed improvements of simulation facilities, computer codes, and testing methodologies for all icing conditions.

Simulation Facilities - During 1986, the initial upgrade of the NASA Icing Research Tunnel (IRT) will be completed, the USAF Palletized Airborne Water Spray System (PAWSS) will be deployed in a C-130, the USAF NKC-135 Spray Tanker Water System will be made more reliable and safer, and design activities will be completed for development of a palletized system for the US Army Helicopter Icing Spray System (HISS).

Ice Protection and Detection - NASA will continue to support the development of new concepts through NASA/industry/university teams and NSF grants will also be used in this area. These actions will assure that key issues are identified and needed fundamental research is conducted. There are no near-term milestones.

Guidance - Work will continue on preparation of an "Aircraft Icing Handbook" that will be issued by the FAA in mid 1987 to provide reference material on the following: aircraft icing design criteria, ice protection technology, ice detection technololgy, icing simulation technology, and effects of icing on performance, flight, and handling qualities.

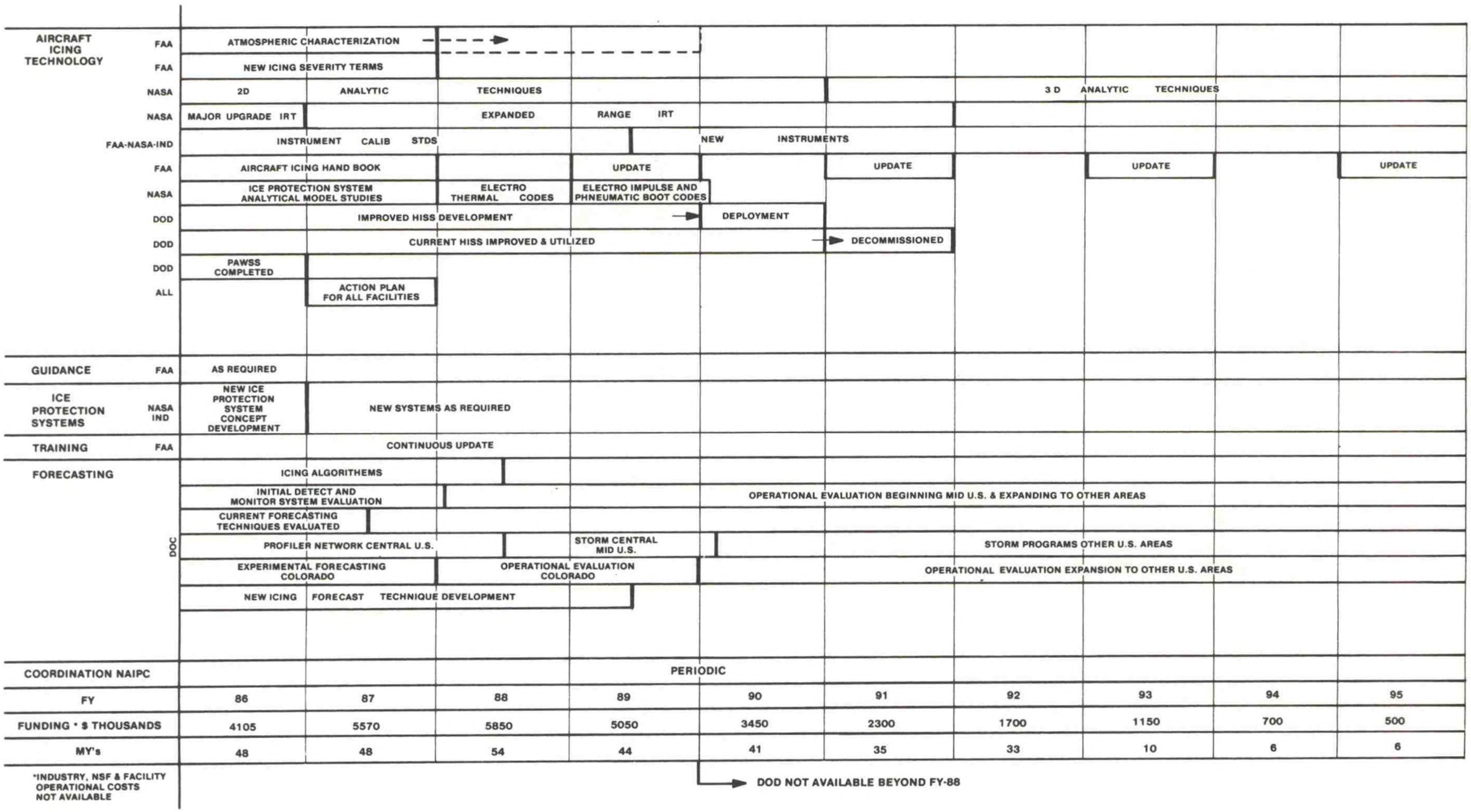


FIGURE 9. NATIONAL AIRCRAFT ICING TECHNOLOGY PLAN

5. REFERENCES

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4. Analysis of AFGL Aircraft Icing Data, U.S. Air Force Geophysics Laboratory, AFGL-TR-H3-0170, July 1983

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APPENDIX A

ABBREVIATIONS AND ACRONYMS

AC - Advisory Circular
AFB - Air Force Base
AFGL - Air Force Geophysics Laboratory
AFGWC - Air Force Global Weather Central
AIRMET - Airman's Meteorological Information
AWS -Air Weather Service
C - Centigrade, Celsius
DOC - Department of Commerce
DOD - Department of Defense
DOT - Department of Transportation
ERL - Environmental Research Laboratories
F - Fahrenheit
FAA - Federal Aviation Administration
FAR - Federal Air Regulation
FAR Part 23 - Federal Air Regulations: Normal, Utility and Acrobatic Category Airplanes
FAR Part 25 - Federal Air Regulations: Transport Category Airplanes
FAR Part 27 - Federal Air Regulations: Normal Category Rotorcraft
FAR Part 29 - Federal Air Regulations: Transport Category Rotorcraft
FAR Part 141 -Federal Air Regulations: Pilot Schools
FY - Fiscal Year
g - gram
GALE - Genesis of Atlantic Lows Experiment
HISS - Helicopter Icing Spray System
H_3 - Hertz
IR - Infrared
IFR - Instrument Flight Rules
IRT - Icing Research Tunnel
K - Thousand
LWC - Liquid Water Content
m - Meter
M - Million
MIST - Microburst and Severe Storms
MYs - Man Years
NASA - National Aeronautics and Space Administration
NCAR - National Center for Atmospheric Research
NEXRAD - Next Generation Weather Radar
NOAA - National Oceanographic and Atmospheric Administration
NSF - National Science Foundation
NWS - National Weather Service
OAT - Outside Air Temperature
OSTP - Office of Science and Technology Policy
PAWSS - Palletized Airborne Water Spray System
PROFS - Program for Regional Observing and Forecasting Services
SCC - Supercooled Cloud
SIGMET - Significant Meteorological Information
STORM - Stormscale Operational and Research Meteorology
U.S. - United States
USAF - United States Air Force
VAS - Visible and Infrared Spin Scan Radiometer Atmospheric Sounder
VFR - Visual Flight Rules

WSFO - Weather Service Forecast Office
WW - Worldwide
2D - Two Dimensional
3D - Three Dimensional