OVERVIEW OF NASA/MARSHALL SPACE FLIGHT CENTER'S PROGRAM ON KNOWLEDGE OF ATMOSPHERIC PROCESSES

by

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I. Introduction

The Marshall Space Flight Center (MSFC) is charged with the responsibility of contributing to advances in aviation safety through improved understanding of various atmospheric phenomena. To meet this responsibility, a four part specific objective has been defined and is being pursued by MSFC. This objective is the definition, modeling, and simulation of steady-state wind and turbulence environments for (1) aiding aircraft accident investigations; (2) assessing aircraft operating hazards; *(3)* advancing fundamental knowledge of the effects of buildings and the landscape on low level atmospheric winds; and *(4)* enhancing the natural environment design criteria relative to aeronautical system design. To accomplish the objective, four basic tasks have been defined. The first of these tasks is to determine and define the turbulence and steady-state wind environments induced by buildings, towers, hills, trees, etc., over and around airports. The information developed as a result of this task could be very beneficial for other locations also. The second task is to identify, develop, and apply natural environment technology for the reconstruction and/or simulation of the natural environment for aircraft accident investigation and hazard identification. Task three is to develop basic

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information about free atmosphere perturbations. The fourth task is to develop and apply fog modification mathematical models to assess candidate fog modification schemes and to develop appropriate instrumentation to acquire basic data about fogs.

To accomplish these four tasks, MSFC has developed a well-rounded program involving field data acquisition, wind tunnel studies, theoretical studies, data analysis, and flight simulation studies. In the following sections, a brief discussion will be presented concerning the tasks and work being accomplished by MSFC both inhouse and under contract relative to these tasks.

11. Definition of Induced Wind Environments

As seen in Figure 1, this task has a twofold objective; namely that of the determination and definition of turbulence and steady-state environments induced by obstructions such as buildings, towers, hills, trees, etc., and to apply the first part of the objective to defining aircraft operating hazards. The immediate goal for the task objective is first to determine capability and reliability of mathematical and experimentally derived models. A second goal is the comparison of full scale and wind tunnel results.

The first goal is being performed as a combined effort by NASA/Marshall Space Flight Center and University of Tennessee Space Institute (UTSI) personnel. Many articles on results of this work have been reported in various publications (Refs. 1-6).

MSFC personnel are responsible for the data collection and initial data reduction and are assisting UTSI personnel with the data analysis. Two items are of prime importance from the effort with UTSI. These are the wind environment definition and a computer simulation of aircraft dynamics

DEFINITION OF INDUCED WIND ENVIRONMENTS

TASK OBJECTIVES

- DETERMINE AND DEFINE TURBULENCE AND STEADY-STATE ENVIRONMENTS AS INDUCED BY OBSTRUCTIONS (BUILDINGS, TOWERS, HILLS, TREES, ETC.)
- APPLY ABOVE OBJECTIVE TO DEFINING AIRCRAFT OPERATING HAZARDS AND AIRPORT DESIGN

GOALS

- DETERMINE CAPABILITY AND RELIABILITY OF MATHEMATICAL AND EXPERIMENTALLY DERIVED MODELS
- COMPARISON OF FULL-SCALE AND WIND TUNNEL RESULTS

EFFORTS

- FULL-SCALE FIELD MEASUREMENT PROGRAM
- WIND TUNNEL INVESTIGATION
- ANALYSIS OF DATA FROM FIELD PROGRAM AND WIND TUNNEL INVESTIGATION

RELATED EFFORT

- NATURAL WIND ENVIRONMENT CRITERIA FOR DESIGN OF WIND MACHINE

Figure 1

in variable wind fields. Since, as indicated above, many articles have been published on these efforts, no indepth discussion will be made. However, a few remarks are in order concerning the work. The full-scale field measurement program is being conducted at MSFC's eight-tower facility. Figure 2 is a pictorial illustration of this facility. From this figure, it can be seen that the terrain is quite flat, less than one (1) meter variations from the low to the high level, and has few natural obstructions which could influence the flow.

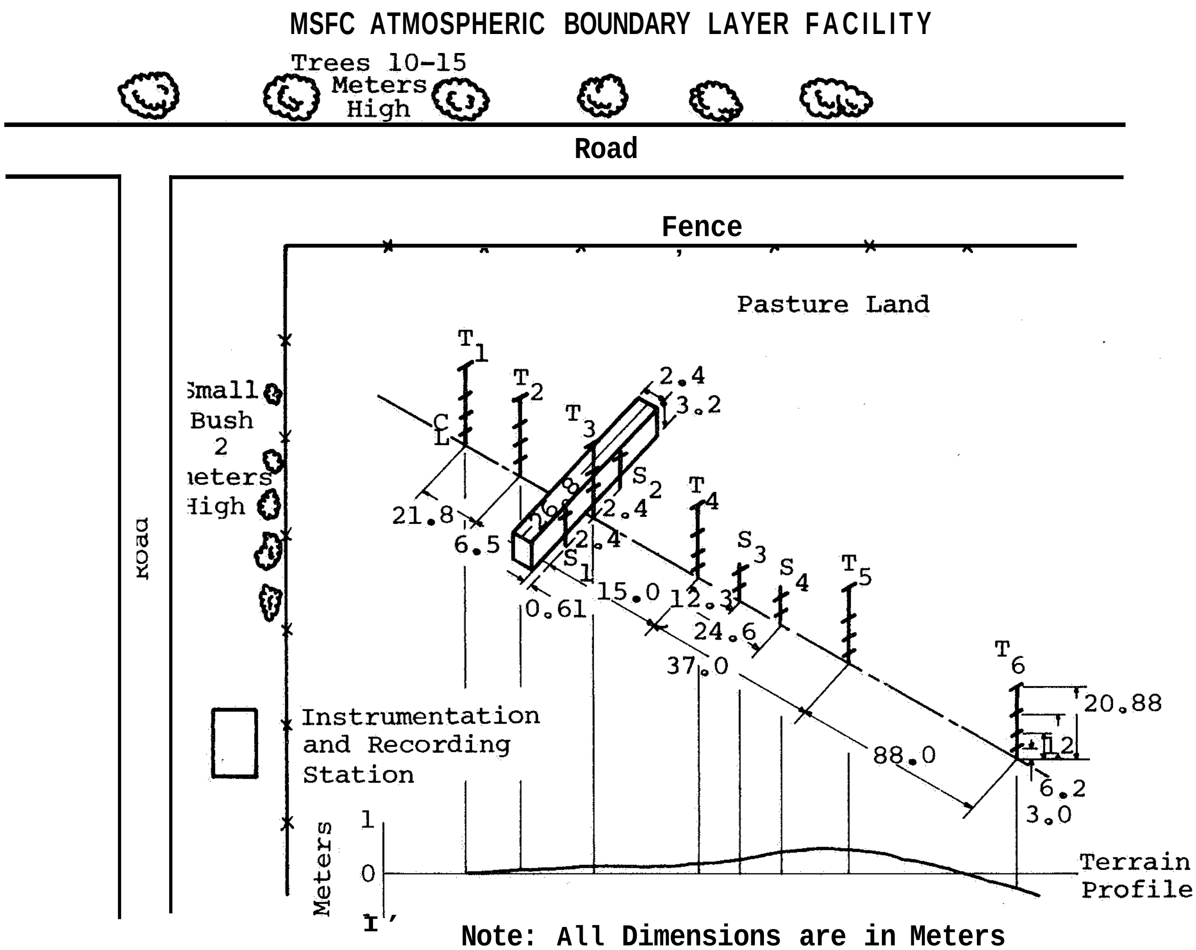

Figure 2

The wind tunnel effort accomplished so far has been done by the Colorado State University. A discussion of this effort is given in Reference 4. The wind tunnel effort so far has been primarily concerned with modeling the full scale (eight-tower) facility, conducting wind tunnel tests on the model, and making a flow visualization study.

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111. Natural Environment Reconstruction for Accident and Operating Hazard Investigation

Figure 3 presents an overview of this specific task. However, a few comments are in order with regard to the present status of the effort, who is accomplishing the work, and what are the future plans. The two objectives of this task are (1) the determination of those aspects of the natural environment which result in aircraft incidents, and (2) the examination of natural environment conditions to determine those conditions which pose hazards to aircraft operations. As seen in Figure 3, there are three goals for this task. Namely, the development of a nonhomogeneous turbulence simulation model, the reconstruction of natural wind environment for a selected set of aircraft accidents, and the identification of needed atmospheric technology development.

In order to accomplish the goals there are at present three efforts being performed under contract. The Pennsylvania State University is conducting an investigation of the nighttime stable boundary layer. This effort will result in the development of a mathematical model for the nighttime stable boundary layer.

NATURAL ENVIRONMENT RECONSTRUCTION FOR ACCIDENT AND OPERATING HAZARD INVESTIGATION

TASK OBJECTIVES

- DETERMINATION OF THOSE ASPECTS OF THE NATURAL ENVIRONMENT WHICH RESULTS IN AIRCRAFT INCIDENTS
- EXAMINATION OF NATURAL ENVIRONMENT CONDITIONS TO DETERMINE THOSE CONDITIONS WHICH POSE HAZARDS TO AIRCRAFT OPERATIONS

GOALS

- DEVELOPMENT OF NONHOMOGENEOUS TURBULENCE SIMULATION MODEL
- RECONSTRUCTION OF NATURAL WIND ENVIRONMENT FOR A SELECTED SET OF AIRCRAFT ACCIDENTS
- IDENTIFICATION OF NEEDED ATMOSPHERIC TECHNOLOGY DEVELOPMENT

EFFORTS

- INVESTIGATION OF THE NIGHTTIME STABLE BOUNDARY LAYER
- AIRCRAFT ACCIDENT RECONSTRUCTION
- AIRCRAFT ICING INVESTIGATION

RELATED EFFORT

- PROGRAM TO PROVIDE WIND SHEAR PROFILES FOR HAZARD DEFINITION

Figure 3

The second effort is being performed by the Aeronautical Research Associates of Princeton, Inc. Specifically, this effort has as its purpose to perform an analysis of wind shear and turbulence present at the time of several aircraft accidents (Ref. 7). The accidents were investigated using a one-dimensional, unsteady planetary boundary layer model and/or a two-dimensional model. The results from this analysis were compared with the available recorded data from the National Transportation Safety Board (NTSB) or the National Weather Service (NWS). References 7-9 present some of the results of this effort. The next phase of this effort is to use the existing two-dimensional transport model to perform calculations for both warm fronts and the cold gust front created by the cold outflow from a thunderstorm. The goal of the calculations is to determine what boundary conditions lead to the strongest wind shear within 500 meters of the surface.

The third effort is being conducted at the University of Dayton Research Institute and is concerned with the build-up of ice and/or frost on the surface of an aircraft. Specifically, the effort is to perform a parametric analysis to assess the amount of water vapor which will sublimate onto aircraft during the roll-out, take-off, and climb-out flight phases. The analysis is to be restircted to the winds and shall be performed with dimensional techniques such that the results are applicable to a variety of aircraft and can be summarized in nondimensional form. Like the first effort, this is a new undertaking, and no results have as yet been reported.

A related effort, concerning operating hazards, is also being performed. This one is a joint effort between the MSFC and FWG Associates, Inc., and is being conducted for the Federal Aviation Administration (FAA). This effort has as a general requirement the development of a comprehensive set of wind profiles and associated wind shear characteristics which encompass the full range of wind shear environments, potentially encounterable by aircraft in the terminal area and to provide the mathematical wind shear scenario in a form for direct engineering application. The initial results of this effort have been submitted to the FAA (Ref. 10) for publication. The report presents a discussion of the various types of wind shear which cause problems to aircraft operations. In the report it is noted that the condition affecting aircraft operations is not one shear parameter but *a* combination of several; for example, horizontal shear, vertical shear, wind direction change, and height of shear above ground level.

IV. Atmospheric Perturbations

Atmospheric perturbations include such phenomena as wind gusts, wind turbulence, thunderstorms, etc. The objectives, goals, and efforts of this task are noted in Figure *4*. As seen, the objectives are, first, to develop basic information about atmospheric perturbations and turbulence in the lower 18 kilometers of the atmosphere and ,second, to analyze vertical wind velocities and their relationship to aeronautical operations. As a result of these two objectives, three goals were established. These are, first, to complete the determination of the intensity, time of occurrence, and prevailing conditions relative to the peak vertical gust; secondly, to complete Richardson number statistics and comparison of critical Richardson number exceedance probabilities with clear air turbulence occurrence statistics; and, thirdly, an analysis of dynamic response Characteristics of balloons to clear air turbulence.

The first of the goals is being accomplished inhouse, and it is expected that a report documenting this work will: be published by the fall of 1977. The data for this work were obtained from the 150 meter meteorological tower facility located at the Kennedy Space Center, Florida (Refs. 11 arid 12).

The University of Dayton Research Institute is working on the second goal under contract to the NASA/Marshall Space Flight Center. It is to be noted that parameters other than Richardson number are also being investigated. Like'the first goal, it is expected that a documented report concerning this work will be forthcoming in the latter part of 1977.

ATMOSPHERIC PERTURBATIONS (GUSTS, TURBULENCE, THUNDERSTORMS, ETC.)

TASK OBJECTIVES

- DEVELOP BASIC INFORMATION ABOUT ATMOSPHERIC PERTURBATIONS AND TURBULENCE IN THE FIRST 18 KM OF ATMOSPHERE
- ANALYZE VERTICAL WIND VELOCITIES AND THEIR RELATIONSHIP TO AERONAUTICAL OPERATIONS

GOALS

- DETERMINE INTENSITY, TIME OF OCCURRENCE, AND PREVAILING CONDITIONS RELATIVE TO PEAK VERTICAL GUST DATA
- DETERMINE INTENSITY DETERMINE STATISTICS AND COMPARISON OF VARIOUS CRITICAL ATMOSPHERIC PARAMETER EXCEEDANCE PROBABILITIES WITH TURBULENCE OCCURRENCE STATISTICS
- ANALYSIS OF DYNAMIC RESPONSE CHARACTERISTICS OF METEOROLOGICAL SENSOR TO ATMOSPHERIC PERTURBATIONS

EFFORTS

- ANALYSIS OF FLIGHT PROFILE DATA FOR AERONAUTICAL SYSTEM SAFETY
- INTEGRATING UPPER AND LOWER ATMOSPHERIC WIND PROFILES AND STATISTICS
- ANALYZE FREE ATMOSPHERIC PERTUBATION AND TURBULENCE
- LOW LEVEL WIND ANALYSIS

Figure 4

The third goal of this task was accomplished under contract to the NASA/MSFC by Science Applications, Inc. This work is documented in Reference 13. No additional work for this goal is anticipated at this time,

There are, as seen in Figure 4, four efforts for this task. These efforts are presently being worked on both inhouse and under contract by various organizations.

V. Fog Investigation and Studies

Similar to the other tasks, the one concerned with fog is being accomplished by efforts of inhouse personnel as well as under contract. From Figure 5 it can be seen there are three task objectives. These are, first, to to develop a haze nuclei counter, second, to develop a numerical fog program for parametric studies, and third, to conduct a field study on the effect of turbulence to the life cycle of fog. The objectives are being conducted by inhouse personnel, the University of Alabamain Huntsville, and the University of Tennessee Space Institute, respectively.

Since the first and third objectives are relatively new no publications have been generated as yet on them. However, an excellent paper has been written on the second objective (see Reference *14).* This paper presents a discussion of a mathematical model for the formation, development, and dissipation of advection warm fog.

FOG INVESTIGATIONS AND STUDIES

TASK OBJECTIVES

- DEVELOP HAZE NUCLEI COUNTER
- DEVELOP NUMERICAL FOG MODIFICATION PROGRAM FOR PARAMETRIC STUDIES
- CONDUCT FIELD STUDY ON THE EFFECT OF TURBULENCE TO THE LIFE CYCLE OF FOG

GOALS

- INVESTIGATE THE EFFECT OF TURBULENCE TO THE LIFE CYCLE OF FOG
- DETERMINE DROP SIZE DISTRIBUTION OF FOG NUCLEI
- DEVELOPMENT OF NUCLEI COUNTER FOR USE IN FIELD STUDY
- DETERMINE NUMERICAL SIMULATION OF FOG

EFFORTS

- LABORATORY STUDIES OF NUCLEI GENERATION AND USE OF LASER TYPE TRANSMISSOMETER FOR DROP SIZE DISTRIBUTION STUDIES
- DEVELOPMENT OF HAZE NUCLEI COUNTER
- FIELD STUDY OF ADVECTION FOG LIFE CYCLE, TURBULENCE MEASUREMENTS AND TECHNIQUES
- NUMERICAL SIMULATION OF WARM FOG

RELATED EFFORT

- PROPOSED LIDAR TECHNIQUE FOR OBTAINING SLANT RANGE VISIBILITY MEASUREMENTS

Figure **5**

It is expected that the third objective will be well under way by the summer of 1977. This objective will be conducted at the University of Tennessee Space Institute, specifically the area over and around Woods Reservoir.

A related effort, proposed by personnel of the University of Tennessee Space Institute, is to conduct a feasibility study relative to a lidar technique for obtaining slant range visibility measurements. It is expected this effort will be initiated in the summer of 1977.

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