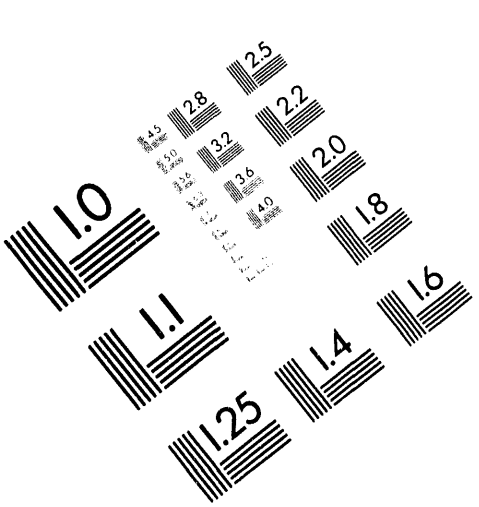
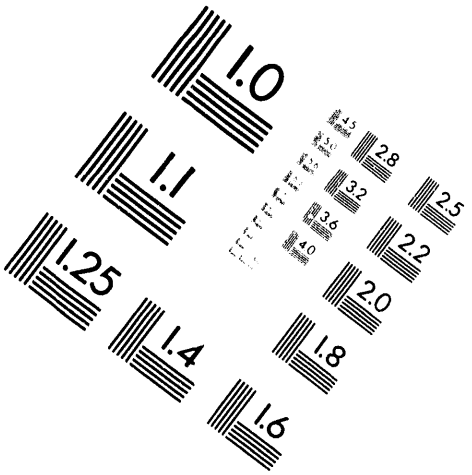
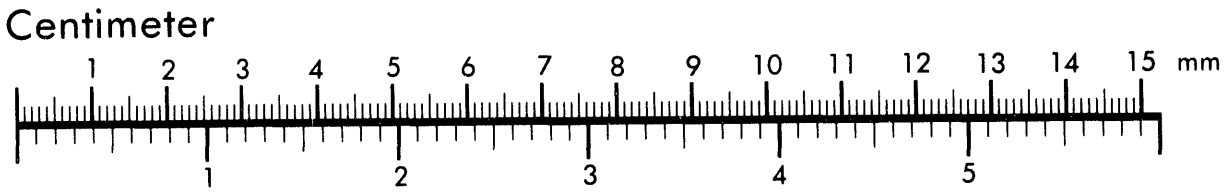


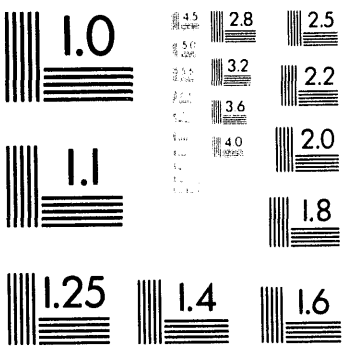
Association for Information and Image Management

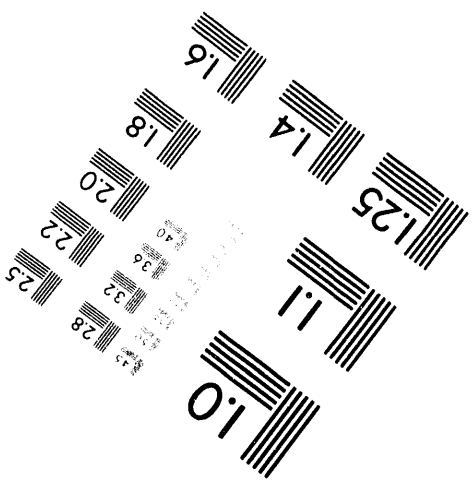
1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

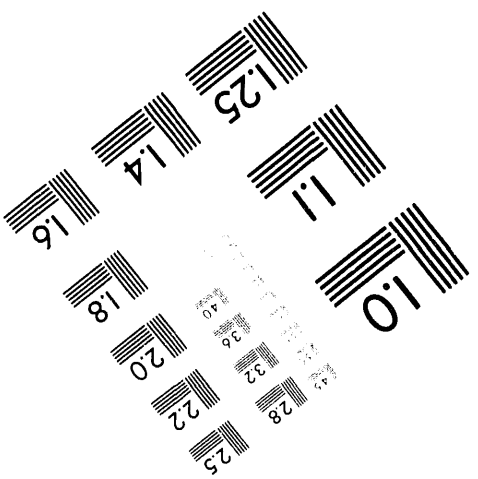
301/587-8202











MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

SAND--94-8640C
CONF-9405146--1

UAVs IN CLIMATE RESEARCH: THE ARM UNMANNED AEROSPACE VEHICLE PROGRAM

W.R. Bolton

ARM-UAV Deputy Technical Director
Sandia National Laboratories
Livermore, Ca. 94551-0969

RECEIVED
MAY 23 1994
OSTI

Introduction

In the last year, a Department of Energy/Strategic Environmental Research and Development Program project known as "ARM-UAV" has made important progress in developing and demonstrating the utility of unmanned aerospace vehicles as platforms for scientific measurements. Recent accomplishments include a series of flights using an atmospheric research payload carried by a General Atomics Gnat UAV at Edwards AFB, California, and over ground instruments located in north-central Oklahoma. The reminder of this discussion will provide background on the program and describe the recent flights.

Background

A top priority goal in the United States Global Change Research Program is improved understanding of atmospheric solar and thermal radiation and its interaction with clouds. This area represents the major uncertainty in current climate models. In 1990, DOE initiated the Atmospheric Radiation Measurement (ARM) Program to contribute to understanding this important area. The initial phase of ARM emphasizes ground-based measurements at a number of intensively instrumented sites, known as Cloud and Radiation Testbed (CART) sites. These sites will be located in key climate regions of the world with the first site now operational in the Southern Great Plains in north-central Oklahoma.

In addition to the ground-based measurements provided by the CART site, there is a major need for airborne measurements of the radiative fluxes, water vapor profiles, and cloud-top properties in the atmosphere. The endurance and altitude requirements for these measurements (multiple days at or above the tropopause) appear to be best met by an emerging class of small, long-endurance, high-altitude unmanned aerospace vehicles (UAVs) complementing the capabilities of manned aircraft and satellites. With funding provided by the Strategic Environmental Research and Development Program, the ARM-UAV program is developing miniaturized instruments suitable for use with such small UAVs and will use the resulting system to

MASTER
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

make unprecedented atmospheric measurements. The ARM-UAV Program strategy emphasizes meaningful scientific activity embedded in the development activities and has three phases of increasing system capability:

* Demonstration flights in the first year emphasize early scientific results and initial operational experience with UAVs in an atmospheric research role. Because of the desire for an early demonstration, this activity will be conducted with existing UAVs and instruments.

* An interim measurement capability in the second and third years will make use of improved UAV and instrument capabilities to provide sustained operations at a continental US location, for example, the Southern Great Plains CART site. The system used for Interim Operations will consist of near-term UAVs assumed to be capable of 14 Km altitude and endurance in excess of 24 hours carrying existing and near-term instruments.

* The full-capability ARM-UAV system will follow in the third and fourth years, capable of sustained and autonomous operation in remote locations, for example, in the Tropical Western Pacific. The UAVs will be capable of 20 Km altitude and multi-day endurance and will carry instruments tailored for UAV application.

"Core" Instrument Payload

The primary scientific objective of UDF is a radiative flux profiling measurement accomplished by measuring flux and *in situ* atmospheric characteristics at several altitudes. The "core" instrument list for UDF was selected to match this radiative flux profiling objective. The radiative instrument payload has been developed and includes scientific instruments, interfaces, diagnostics, and a telemetry system which transmits to the ground station for recording and display. Primary instruments include up and down-looking hemispherical field-of-view broadband solar and IR radiometers, and a total diffuse direct radiometer provided by NASA Ames Research Center. Supporting instruments include a meteorological package (temperature, pressure, and water vapor concentration), and a solar and IR narrow band radiance instrument provided by Colorado State University.

Unmanned Aerospace Vehicle

The ARM-UAV program is developing applications of UAVs to augment manned aircraft and satellites. Ultimately, ARM-UAV needs UAVs capable of flying to the tropical tropopause at about 20 Km altitude, carrying a payload of approximately 200 Kg, and staying at altitude from one to several days. While such aircraft are being developed, ARM-UAV is establishing the utility of UAVs as a scientific measurement platform using existing vehicles. The ARM-UAV demonstration flights have been conducted with the Gnat 750-45 UAV provided by General Atomics Aeronautical Systems. The Gnat with its radiometric payload is capable of many important scientific missions, such as those conducted as part of the demonstration flights.

Demonstration Flights

The first ARM-UAV development phase is the UAV Demonstration Flight (UDF) series. In addition to the primary scientific objective of radiative flux profiling measurement, UDF has programmatic objectives which include obtaining operational experience with UAVs and addressing airspace and safety approval issues that must be resolved for later phases of the program. These objectives have been addressed through flights which have been conducted in two deployments: 1) an engineering checkout/data flight conducted at Edwards AFB, California, in November, 1993, and 2) a data flight series conducted over the Oklahoma CART site in April, 1994.

The engineering checkout flight was conducted from Rogers Lake at the Edwards AFB south lake area. The primary objective of the flight was to integrate the payload with the UAV and demonstrate the system in flight. The flight was conducted entirely within restricted airspace on November 13, 1993, and lasted $2^1/_2$ hours. Data was obtained from near the surface to a maximum altitude of 22,000 ft along flight profiles representative of those to be used in subsequent data flights.

The data flight series was conducted over the extensive ground-based instrumentation at the Southern Great Plains CART site near Lamont, Oklahoma. Flight operations were conducted from the Blackwell-Tonkawa Airport, a small general aviation airport located approximately 12 miles from the CART site. All ground support equipment, including the UAV ground control station, was located at the airport. UAV flight operations shared the single runway and were conducted in parallel with routine general and agricultural aviation operations. The data flight series in Oklahoma features the following accomplishments:

* Eight flights were completed totaling over 22 hours of flight time, including two flights in rapid succession on a single day.

* A total of 4 clear-sky, daylight, radiative flux profiles were measured under average and above average atmospheric moisture conditions. These profiles were measured at three altitudes from 5,000 ft to 22,000 ft above ground level.

* Heating of the atmosphere and surface was measured during a night-to-day transition from approximately 0.5 hour before to 2.5 hours after sunrise.

* All flights were conducted with excellent chase aircraft support by Ross Aviation, Inc..

* After close coordination with, and active support from DOE, FAA Central Region, and Vance AFB, Oklahoma, all flights were conducted in mixed-use airspace including operations from a general aviation airport shared with normal airport operations.

The quality of the data obtained from the UDF series is excellent and preliminary comparison between experimental measurements and atmospheric radiation transport model calculations is quite good. These scientific results and the operational capabilities demonstrated make UDF a

major step along the development path toward the goal of long duration, high altitude measurements from UAVs.

Subsequent Development Phases

UDF has provided important scientific data and demonstrated the utility of UAVs in an atmospheric research role. Subsequent phases will continue to provide meaningful scientific data while extending the capabilities of the UAV/instrument system. The Interim Measurement phase is planned to provide cloudy sky radiative flux profiles, investigate diurnal phenomena in extended duration operations, and explore global climate issues in the Tropical Western Pacific Ocean. The Full Capability phase will provide a system capable of contributing in many areas of atmospheric and climate research. Instruments for the Full Capability will be developed under grants awarded through competitive proposals. UAVs will be selected from the best available systems meeting the ARM-UAV requirements.

Summary

The three phase ARM-UAV program is designed to provide valuable scientific data while developing the full-capability ARM-UAV system. The demonstration flights have established the suitability of UAVs for an atmospheric research role and provided valuable scientific data. Subsequent phases will develop improved instruments and fully capable ground support equipment suitable for remote deployment, and take advantage of improved UAV capabilities. The result will be a substantial improvement in measurement capabilities leading to improved understanding of global climate change processes.

DATE
FILMED
6/29/94

END