# The Atmospheric Radiation Measurement Unmanned Aerospace Vehicle Program: An Overview

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## Introduction

This paper and the one that follows describe the start-up of the ARM-Unmanned Aerospace Vehicle (UAV) program. This program has its origins in the Atmospheric Radiation Measurement (ARM) Program's long recognized needs for in-situ airborne measurements of radiative fluxes, flux divergences, selected cloud properties, and upper tropospheric water-vapor profiles. While manned aircraft have and will continue to provide many useful measurements, the need to fly above the tropopause (18 km in the tropical Pacific) for multiple diurnal cycles (48 to 72 h) and at a sufficiently low cost to permit sustained coverage (over 1000 h per year) appears to be met best by an emerging new generation of UAVs specifically designed for climate studies. Thus in 1992, the Department of Energy (DOE) proposed the ARM-UAV program to *complement* manned aircraft measurements and to provide an observational system for sustained high-altitude measurements over the Cloud and Radiation Testbed (CART) sites.

Two factors are now enabling us to start the ARM-UAV program. The first is that the DOE has received initial funding from the Strategic Environmental Research and Development Program (SERDP) to develop improved atmospheric remote sensing techniques that are compatible with both UAVs and small satellites. While the SERDP program emphasizes instrument development, it also provides for measurement flights for calibration/validation and initial data gathering and evaluation. The second enabling factor is that there are now several possibilities for leased UAV operation over the next year. Examples include, but are not limited to, the existing Gnat 750-45, with its 7-8 km ceiling, as well as the planned FY93 demonstration of two 20 km capable UAVs—the Perseus-B and the Raptor.

Thus the funding of some initial flights and the availability of leased UAVs will enable us to start up the ARM-UAV program. Additional funding will be required to continue this program.

## Interim Science Team

These ARM-UAV activities will ultimately be guided by a science team selected through a peer-reviewed competitive process. However, to ensure a smooth and efficient startup, an Interim Science Team (IST) has been formed to provide initial scientific guidance. The IST members, drawn primarily from the existing ARM community, met in December to formulate a near-term strategy for the first year's activities and to identify key scientific questions underlying the long-term ARM-UAV program.

The meeting identified two broad classes of missions for ARM-UAV: "quasi-continuous missions," which emphasize consistent long-term observations of key radiation-cloud parameters as part of a continuous ARM data stream, and "investigative missions," which change with time and focus on testing specific hypotheses. The basic quasi-continuous mission is the continuous/near-continuous measurement of radiative fluxes along with both in situ and remote sensing measurements of water vapor and cloud properties. Representative investigative missions include testing of specific hypotheses on the role of deep convection in the tropical Pacific, the drying/moistening of the upper troposphere, the source of the asymmetry in water vapor concentrations in the northern and southern hemispheres, ozone chemistry near the tropopause, etc.

To address these missions, one ultimately needs a UAV capable of autonomous operations above the tropical tropopause (20+ km) for multiple diurnal cycles (48-72 h) with payloads of 150-200 kg at sufficiently low cost to allow extended operations (over 1000 h per year). However, we see two key phases preceding this "full capability" phase. The first is a "demonstration phase" meant to establish our presence quickly by using "existing" instruments and leasing the most capable UAV to get some scientifically important data by the end of FY93 or early FY94. The second or "interim capability" phase would provide an operational capability at the Southern Great Plains (SGP) CART site, i.e., 14+ km for a minimum of 24 h with either line-of-sight or autonomous control. The third and final phase is full-capability operations and would allow for autonomous operation over the tropopause in the tropical Pacific for multiple days.

## UAV Demonstration Flights

Particular attention has been given to defining the first or demonstration phase. The demonstration mission must be scientifically important and along the path to the long-term missions; at the same time, it must make use of "existing" equipment and be relatively simple so as to be flown within a year with a good likelihood of success. Following the recommendation of the Interim Science Team, these UAV demonstration flights (UDF) will emphasize flux divergence measurements, a key building block for many future missions.

The basic idea is to make up- and down-looking broadband hemispherical flux measurements from a UAV and combine these with similar measurements made from the ground (actually tower and tethersonde) and from satellites to obtain the flux divergence. These measurements would later be expanded to include multiple UAVs to provide flux divergence measurements between different atmospheric levels.

These flux divergence measurements are key to ARM-UAV interim and long-range goals which focus on the relationship between atmospheric heating and cloud and water- vapor distributions. When completed, the UDF will be the first demonstration of climate measurements from a UAV and will provide accurate measurements of flux divergence and selected radiative properties for testing models.

The succeeding papers provide additional descriptions of the UDF science mission, strawman payload, and systems operation concepts. Though we have made much progress UDF is still in an evolutionary state and subject to change. We welcome your feedback!