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**Title:** Science Requirements and Feasibility/Design Studies of a Very-High-Altitude Aircraft for Atmospheric Research

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## 1. Introduction

Recent successes of the NASA ER-2 aircraft in missions to study polar ozone and stratosphere-troposphere exchange have highlighted the strengths of aircraft measurements as a complement to other atmospheric research platforms (e.g. spacecraft, balloons, and rockets). Specifically, aircraft provide a fine spatial resolution and range of measured constituents and meteorological variables (as required for process studies, for example) that cannot be achieved solely by remote measurements from space. And they provide a controllability, launch frequency, choice of launch sites, and probability of payload recovery that cannot be matched by large-payload balloons.

In spite of these strengths, the recent missions have also pointed out shortcomings of aircraft currently available for atmospheric research. Specifically, the ER-2 ceiling of 21 km (70,000 ft), allowed range of 3,200 nautical miles, and restrictions on flight over oceans and into the polar night have prevented flights with existing and planned payloads that could answer important questions now facing atmospheric science.

The advantages and shortcomings of currently available aircraft pose the question of whether to develop advanced aircraft for atmospheric research. To answer this question, NASA conducted (1) a workshop to determine science needs and (2) feasibility/design studies to assess whether and how those needs could be met.

## 2. Science Requirements Workshop and Report

The Workshop on Requirements for a Very-High-Altitude Aircraft for Atmospheric Research was held in Truckee, California, July 15-16, 1989. Participants included experts in stratospheric theory and measurements (by spacecraft, balloons, and aircraft), aircraft operations, and aircraft design and development. The focus of the workshop was on stratospheric science and measurement needs, with secondary attention to broader atmospheric science needs, such as climate change by radiatively active gases ("greenhouse gases").

The Workshop participants defined key questions now blocking progress in atmospheric science and related policy decisions. They then defined aircraft missions needed to address those



questions, and deduced the aircraft characteristics needed to conduct those scientific missions. Examples of key questions include:

- What causes ozone loss above the dehydration region in Antarctica?
- To what extent are dehydration, denitrification, and ozone loss transmitted to midlatitudes?
- What maintains the geographical distribution of polar stratospheric clouds, and how do they transform the chemical balance as a function of temperature and pressure?
- What is the chlorine content, and what are its chemical forms, in the tropical middle stratosphere?
- How do volcanic injections, especially in their first few months, affect the chemistry of trace gases (including ozone) and radiation and temperature fields? How do particle chemistry and physics evolve during this period?
- What do stratospheric profiles of radiative fluxes and radiatively active constituents, in conjunction with tropospheric profiles, reveal about the onset and predicted evolution of the greenhouse effect?

The aircraft missions required to answer these questions pointed to a need for an aircraft with the following characteristics: cruise altitude of 30 km (100,000 ft), subsonic cruising speed, range of 6,000 n mi with vertical profiling capability down to 10 km (33,000 ft) and back at remote points, and a payload capacity of 3,000 lb. A capability to "pop up" to 35 or 40 km altitude (115,000-130,000 ft), even with a considerably reduced payload, is highly desirable. Required operating characteristics imply a need for both manned and unmanned operations.

### 3. Feasibility/Design Studies

Designing an aircraft to meet the above requirements presents a unique challenge to aeronautical engineering. The regime of low Reynolds numbers combined with Mach numbers near 0.7 is not well explored. Fundamental to the problem is the extremely low air density at 100,000 ft and above. This implies challenges in aerodynamics, structures, propulsion, and propeller design. To address these challenges and establish a level of confidence that a vehicle could be built to meet the Workshop specifications, NASA Ames has managed several inhouse and contractor design studies. These studies have addressed questions of the optimum aspect ratio, wing and propeller airfoil designs, turbocharged and supercharged reciprocating engines vs. turbojets, low-wing-loading aerodynamics, heat rejection, cooling drag, and a phased development of ground-test, flight-demonstrator, and mission vehicles. A technology risk assessment based on these studies assigned a rating of "Low Risk" to the task of designing a vehicle to cruise subsonically at 100,000 ft, but a rating of "High Risk" to cruising or "popping up" to 120,000 ft.

The poster will show the conceptual designs and other considerations on which these risk assessments are based.

Current efforts are directed toward expanding the assessment of science needs to cover all of Earth science (i.e., land, ocean, cryosphere, weather and climate--not just stratospheric science). The broad range of aircraft approaches to meeting those needs will then be explored. The goal is to define the most cost-effective way of meeting the advanced aircraft needs of the combined Earth science community.