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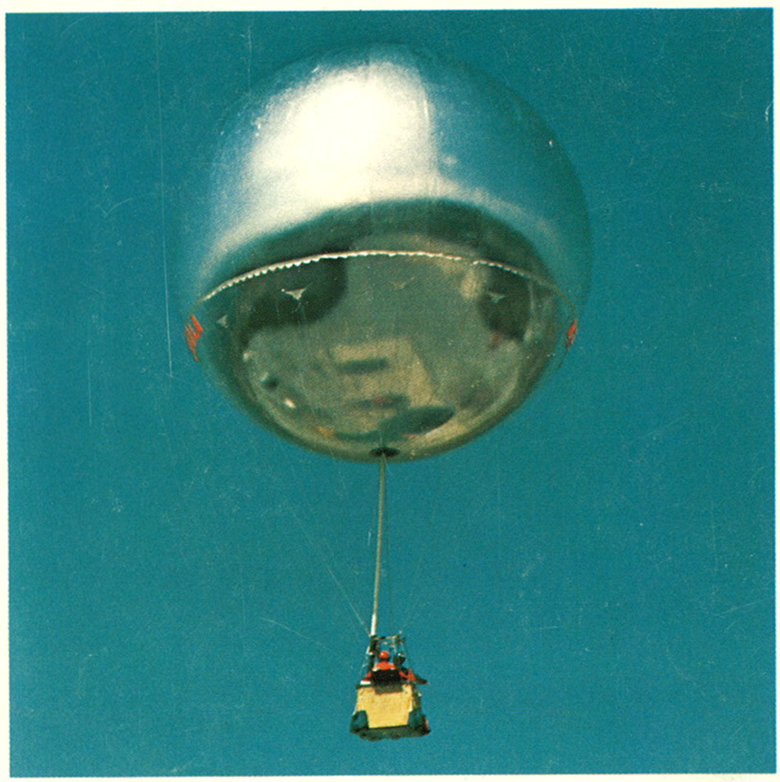

ATMOSAT

a new measurement platform for air quality monitoring

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The first manned superpressure balloon has been developed to provide a means for accurately following a parcel of air, making physical and chemical measurements en route. The use of new high strength fabrics allows the construction of a balloon that contains its lifting gas (helium) under pressure, thereby providing long term flight stability unachieved by any other method. Three flights, each in excess of 30 hours duration, have already been achieved, demonstrating the ability of such vehicles to remain stably in a parcel of air without perturbing air chemistry in any way. Such a platform will allow the precise determination of air trajectories over many hundreds of miles. The use of trained observers on board will facilitate the collection of atmospheric data: ozone, NO_x, SO_2, temperature gradients, turbulence, and other.

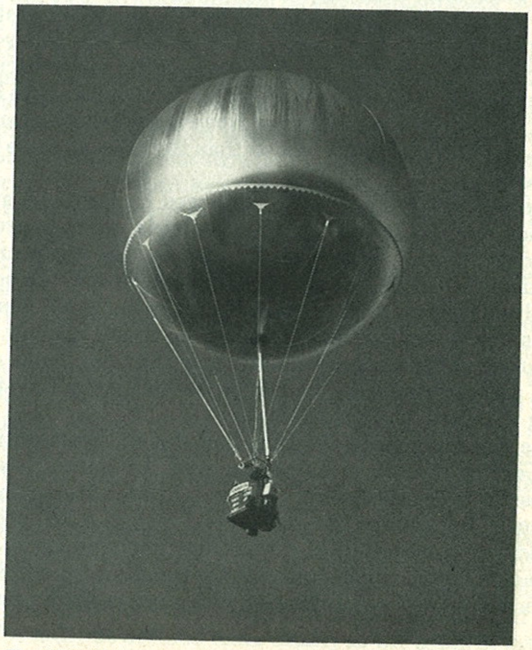
The vehicle that first fulfilled man's age-old dream—to rise above the earth and fly—can now be effectively mobilized in the battle against air pollution. A manned superpressure balloon, the first of its kind, has already made successful flights actually following a parcel of air and making physical and chemical measurements en route.

Adding the latest breakthrough of modern technology to the nearly 200 year tradition of scientific application of manned balloons, the new craft has been developed as a forerunner of an ambitious experiment planned for later in the decade—a balloon that would support an unmanned 1 ton payload at altitudes of 60,000 feet. Such flights in the stratosphere would be undertaken to analyze the heat balance between the earth, lower atmosphere and the stratosphere.

Called "America," the first production 10 meter ATMOSAT (for Atmospheric Satellite) balloon has been used for extensive ground and low altitude testing and now is committed to a series of manned atmospheric monitoring flights.

Constructed with a new high-strength material (Kevlar) the balloon can be placed into immediate service in air pollution control. The first four manned flights conducted thus far have already demonstrated the craft's value. Although Kevlar is the primary structural element, the balloon is really made of a "sandwich" of materials: an inner layer of Kevlar cloth to sustain the pressure loads; a layer of bilaminated Mylar to contain the helium; an outer sheet of aluminized Mylar to limit variations of helium temperature and to protect the inner Kevlar layer from ultraviolet radiation (see Figure 1).

"America" is part of the ATMOSAT project of the Aerospace Corporation, an El Segundo, CA, non-profit organization. Thus far the project has cost some $250,000 and is pro-



The ATMOSAT (Atmospheric Satellite) balloon "America" in flight.

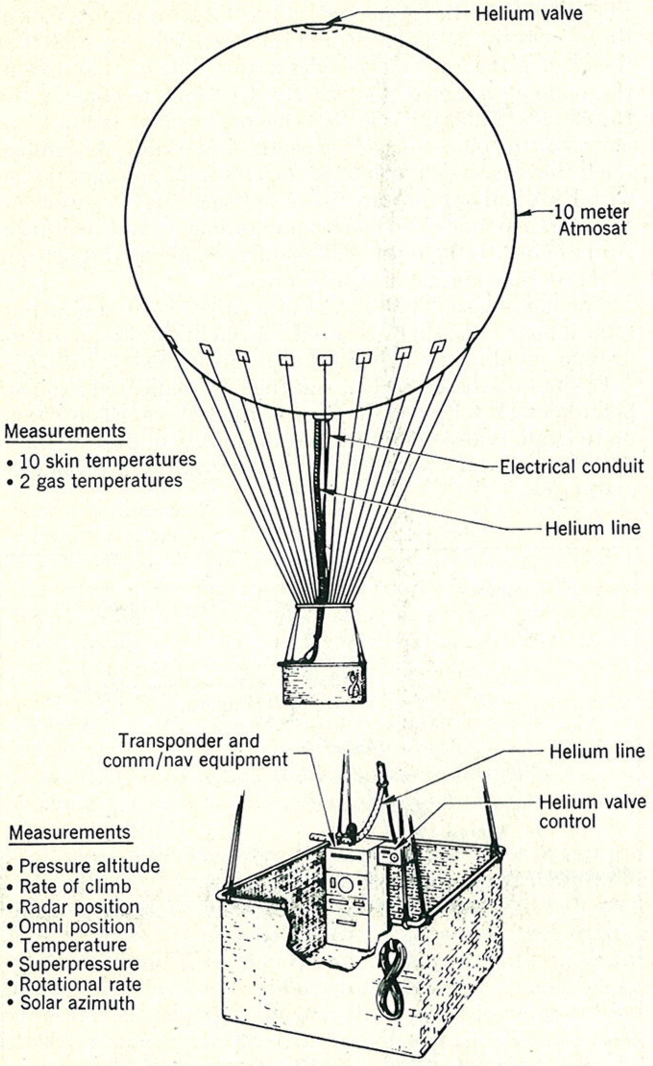


Figure 1. The 10 meter ATMOSAT flight train.

vided as an internal scientific program and as a public service by Aerospace.

The first manned expedition was undertaken in Feb. 1976. It proved immediately that the superpressure sphere was particularly suited for air pollution monitoring. The entire balloon's performance displayed extreme stability, the internal pressurization being sufficient to allow it to overcome any atmospheric perturbations which might otherwise have caused the balloon to change altitudes and disturb the measurements.

The silvery sphere offers an unlimited number of uses for air pollution work. Being an unpowered free balloon, there is no interference from exhaust gases, as is the problem with fixed-wing aircraft or helicopters. Further, the balloon moves with the air flow rather than flying across a given pollution stream, such as a stack.

A flight in Dec. 1976, following a plume from the Four Corners Power Plant, proved that manned balloon flying and tracking could be done anywhere, even in some extremely rugged and primitive terrain. It also proved that sulfur compounds could be smelled at a high altitude (6500 MSL) near Aneth, UT, indicating that this remote area of Utah was affected by the Four Corners Plant. New Mexico air pollution officials, prior to this flight, expected the balloon to travel down the San Juan River and not northward into Utah.

The assistant chief of New Mexico's Environmental Improvement Agency, Air Quality Division, Robert Harley, said the ATMOSAT flight has stimulated much interest among the control agency people in the state, and the EPA in Dallas. "This balloon with its attendant capabilities opens up new areas that can now be explored in the field of air pollution control," he said. "I feel we will soon be able to refine and improve our theoretical predictions of atmospheric chemistry and geographic destiny of manmade pollutants."

Southern California air pollution officials have already suggested a number of sophisticated flights over the South Coast Air Basin. The flights run the gamut from following stack plumes to determine source-receptor relationships, to conducting light scattering experiments in order to measure the effect of pollution on visibility. Although great strides have been made in abating air pollution in Southern California, reduced visibility, a local inherent condition, continues to make some people skeptical. A better understanding of visibility reduction could be achieved by mounting lightweight reflectors on the balloon and placing a krypton or argon laser with a grating analyzer on nearby Mt. Wilson. The relative change in wave lengths would give quantitative and qualitative measurements of light scattering.

Four manned flights of "America" have been undertaken thus far, and more are planned. The maiden flight took place on Feb. 18, 1976 (See Figure 2). The ATMOSAT rose from its launch site on the Palos Verdes Peninsula (a suburb of Los Angeles) and hovered over the Los Angeles Air Basin for the first 6 hours of its mission before drifting south along the Southern California coast. The slow movement in the early hours of flight offered an excellent opportunity for the crew to simulate a series of pollution monitoring experiments which would be performed in later flights. The pressurized sphere

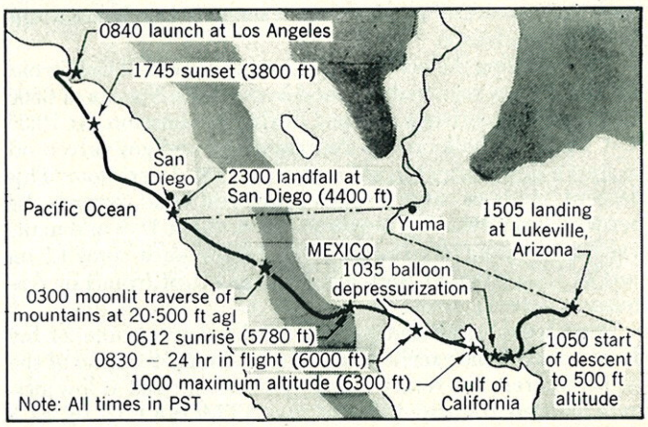


Figure 2. Trajectory of 1st ATMOSAT launch Feb. 18–19, 1976 (All times in PST: GMT-8).

was brought to precise altitudes, simulating a ride along the famous Los Angeles inversion layer. At each altitude, the performance of the balloon was measured: its internal superpressure, angular rotational rate, altitude stability, helium temperature, balloon skin temperature (in 10 places throughout the envelope), ambient temperature, and the aerostat's position. This process was repeated during horizontal flights at six different flight levels between 1500 and 3000 ft. At each level, exchanges of data were conducted between the flight crew and the ground stations of the FAA (which provided radar data and air traffic control information) as well as with the chase crew who were following in two ground vehicles.

Once this segment of the mission was completed, the crew jettisoned ballast and rose to meet the northwest winds which took the "America" out into the Santa Catalina Channel and along the coast towards San Diego. A superb sunset while cruising at 4500 ft some thirty miles at sea was followed by the darkness of a moonless night.

The flight crew continued its series of observations into the night, with particular emphasis on the changes in balloon pressure and temperature at sunset. The thermal response of the balloon to its environment was noted by periodically measuring the helium gas and envelope skin temperatures.

At 11:00 P.M. PST, the trajectory veered to the east, as had been predicted by the preflight weather analysis jointly conducted by the then Southern California Air Pollution Control District and the Aviation Weather Service.

After moonrise, over the mountains of Baja California, the moonlit terrain was followed, as the balloon moved up slowly to maximum overland altitude. At times, the balloon flew well below the level of the moonlit peaks and the hooting of owls and the howling of coyotes as it glided within 20 ft of the mountainous desert were heard. "It was so quiet," Co-pilot Peter Neushul said, "we could hear our own heartbeats. Any noise in that kind of stillness was magnified manifold and an insignificant sound, we found, could become a concern just in imagination."

At the end of the night, false dawn found the ATMOSAT at the edge of the 6000 ft high cliffs which mark the eastern edge of the Baja Peninsula. A sound "like Niagara Falls" was heard as the air rushed downwards through the canyons at speeds in excess of 80 knots. The resulting turbulence caused the balloon's rate of climb indicator to be repeatedly pinned at plus and minus 1000 ft/min, but the inherent stability of the pressurized sphere kept the violent drafts at bay—and the altitude oscillations which initially swung from 6400 ft down to 4800 ft steadily decreased in amplitude as the craft moved away from the cliffs and towards the Sea of Cortez. As the sun rose, the "America" was once again serenely floating over the Mexican landscape.

After crossing the northern portion of the Gulf of California, the flight crew regained the land in northern Sonora at 6500 ft, the highest altitude reached during the mission. At 10:35 A.M. PST, the balloon was depressurized and gas valved off to start a slow descent to within 100 ft of the desert floor. This descent, made to catch a south-southwest wind towards the border, allowed the flight crew to return to the U.S. and make a smooth landing 50 yd north of the border fence, some 1.5 mi east of Lukeville, AZ and 30½ hr after liftoff from Los Angeles.

The superpressurized portion of the flight (some 24 hr) demonstrated the excellent stability and long duration of the flight, whereas the final 6 hr spent unpressurized at low altitude showed the capability of the ATMOSAT to fly as a classical unpressurized balloon. This is of consequence for air pollution monitoring because it allows both constant level flights in which the balloon is immersed in an air parcel, as well as repetitive vertical sounding of temperature, humidity, and air contaminant concentrations.

Incidental to "America's" scientific mission, its flight record (30 hr, 36 min) has been submitted and was certified by the National Aeronautic Association as a new American endurance record.

Flight 2 took place April 18, 1976, from San Angelo, TX, landing in Goodland, KS after 31 hours and 44 minutes, a straight line distance of 920 km., reaching a high altitude of 7700 (ft MSL) (See Figure 3).

In addition to demonstrating the flight-worthiness of the system, it also proved that the airborne and ground elements could be transported to a remote site and the operation conducted with a minimum of local facilities and personnel.

Flight 3, launched at the same Rancho Palos Verdes site as Flight 1, found the "America" sailing its pre-planned trajectory across the 25 mi basin, and then ascending to 3000 ft at the edge of the San Gabriel Mountains. During that ascent, the balloon assumed a southerly drift and re-entered the Basin. Near Fullerton, the craft, having reached within 10 mi of its starting place, turned eastward. As darkness descended, the balloon ascended to 4500 ft. As a result of precoordination with FAA and appropriate use of onboard VHF transceiver, radar transponder, navigational equipment, and nocturnal strobe lights the flight was successfully completed through one of the world's busiest air traffic areas.

The landing took place in Death Valley 32 hr and 30 min after launch. The flight covered a straight line trajectory of 323 km, climbing to its highest altitude of 8300 (ft MSL).

Flight 4 discussed earlier, was the first dedicated to an air pollution task, following the Four Corners Power Plant plume up to Utah. It also demonstrated the ability of the system to launch upon short notification from unimproved (even desolate) sites.

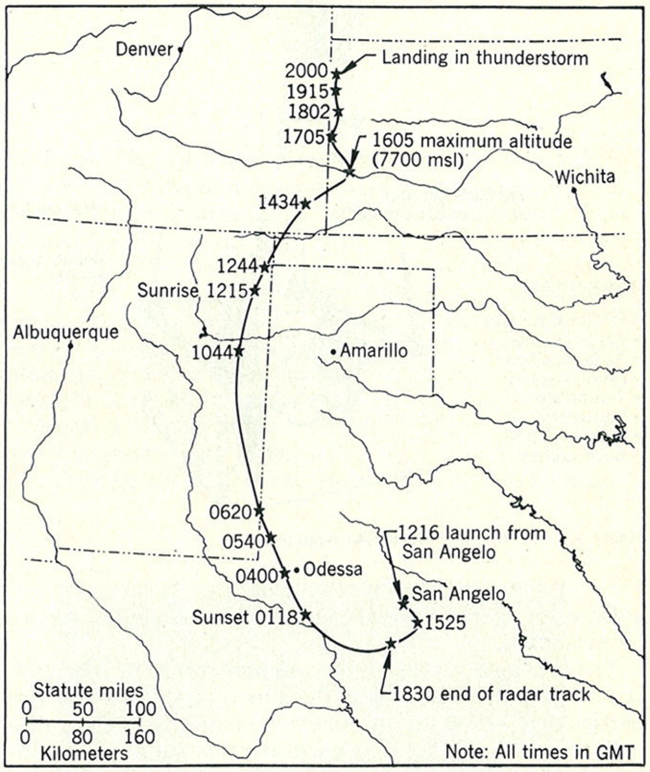


Figure 3. Trajectory of 2nd ATMOSAT launch April 18–19, 1976 (All times in GMT: CST +6).

Officials of the new South Coast Air Quality Management District (SCAQMD), the state-mandated agency that now has jurisdiction over air pollution control activities in the four counties of Los Angeles, Orange, Riverside, and San Bernardino, consider the superpressure balloon uniquely suited for a number of air pollution studies. J. A. Stuart, executive officer of SCAQMD, said his agency would like additional information on the source-receptor relationships for contaminants originating near the coast. "Launched from a point near the shore in the Long Beach area, the balloon would be flown below the inversion layer, travelling with the prevailing wind flow," he said. "This would be done on a typical moderate to heavy smog day. The progress of smog buildup in a single parcel of air as it moved over the basin would be monitored."

The parameters measured could include time, position, temperature, humidity, ozone, and oxides of nitrogen, sulfur and carbon. Grab-bag samples could also be taken for later gas chromatographic analyses of hydrocarbons. Observations of visibility and odors could also be made.

Another flight the District would desire, would have the balloon flying through the centerline of a power plant stack plume so that data for a mathematical model could be obtained. This information would complement data collected at ground level. A better evaluation of pollutant dispersion models, when applied to a point source such as a power plant stack, would then be possible.

This would require the launching of the balloon to take place just downwind from the point source. The balloon would rise into the plume in a vertical plane while monitoring contaminants and taking samples which would later be analyzed for the tracer gas. A quantity of SF_6 tracer gas should be released into the stack. An occasional, short excursion into the inversion layer could determine the amount of diffusion that occurs at that level. Complementing the airborne mission would be the District's air monitoring van which would take a number of samples directly below the balloon.

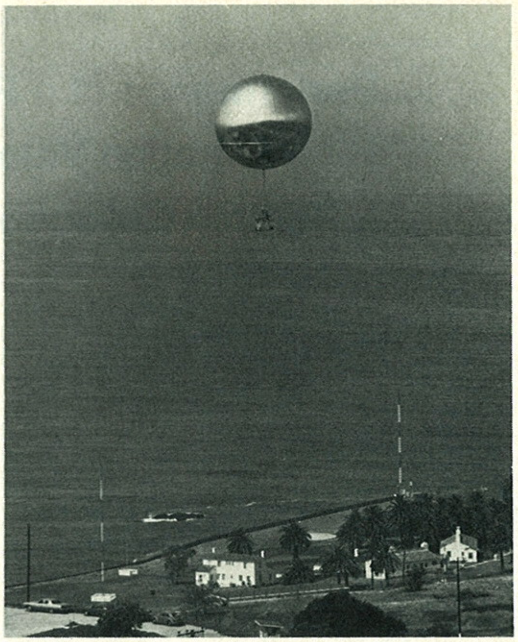
In another potential application, the balloon could be launched to fly over an extended source such as a major refinery. This would help define not only the source-receptor relationship of refinery-related contaminants, but could also demonstrate the effect of a large heat source on the inversion layer. This experiment was suggested by the crew following their July 2, 1976, flight in which the balloon passed over a chemical plant and experienced updrafts that took it from 600 ft to 1200 ft. Although there was no visible pollution seen emanating from the plant, there apparently was considerable thermal updraft.

Measuring the conversion rate of SO_2 to sulfate and providing added information of source-receptor relationships for these contaminants could be done by releasing the balloon in Los Angeles County's South Bay area where there exists a major concentration of SO_2 sources (power plants and refineries) on a day when sulfate-prone weather conditions are forecast. Drifting with the prevailing winds between 500 and 1000 ft above ground level, the instruments on the craft would continuously measure SO_2 and sulfates. Those readings would be compared to surface air quality readings and meteorological data to yield a more complete understanding of the formation and transport of sulfates.

In order to conform more closely with present midnight to midnight readings of sulfates, the flight would be started around midnight and continued as long as prevailing winds keep the balloon in the Basin.

The uses of ATMOSAT are many. The four air pollution information flights have already demonstrated the balloon's uniqueness in pursuing a parcel of polluted air in order to obtain precise measurements, as well as the wind's trajectory over a period of hours to days and over a distance of hundreds of miles.

ATMOSAT is also a low cost, recoverable vehicle that neither contaminates the air by any propellant fumes, nor agitates it by propeller wash, thus gathering accurate data and providing a new dimension in today's multi-faceted air pollution control effort.



The ATMOSAT over the Pacific Shore, July 2, 1976. Launched fully pressurized, the balloon flies stably from the very start.

Dr. Heinsheimer is the Director of the Aerospace Corporation's ATMOSAT project and pilot of the scientific balloon, "America". He is also the Vice Chairman of the South Coast Air Quality Management District Board, the newly-created agency that has jurisdiction over air pollution control activities in the four Southern California counties of Los Angeles, Orange, Riverside, and San Bernardino, 9420 Telstar Ave., El Monte, CA 91731.