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sunstat: A BALLOON THAT RIDES ON SUNBEAMS

by Dick Brown

Airborne propane-powered burner systems have been the name of the game in hot air ballooning ever since Ed Yost lifted off the ground near Sioux Falls, South Dakota on October 22, 1960. Ed sustained thermal flight for about a half hour and thus marked the beginning of a new era of ballooning.

Since then, little has been done to change the basic concept of a hot air balloon. It survives as a very simple flying machine — ascending by heating and descending by cooling. It willingly responds to the whims of the wind and begrudgingly responds to the desires of the pilot. It is unfortunate that our wind-stirred ballet is so rudely interrupted by the periodic blast of the burner and that our fantasy voyages must come to an end within only a few hours of launch.

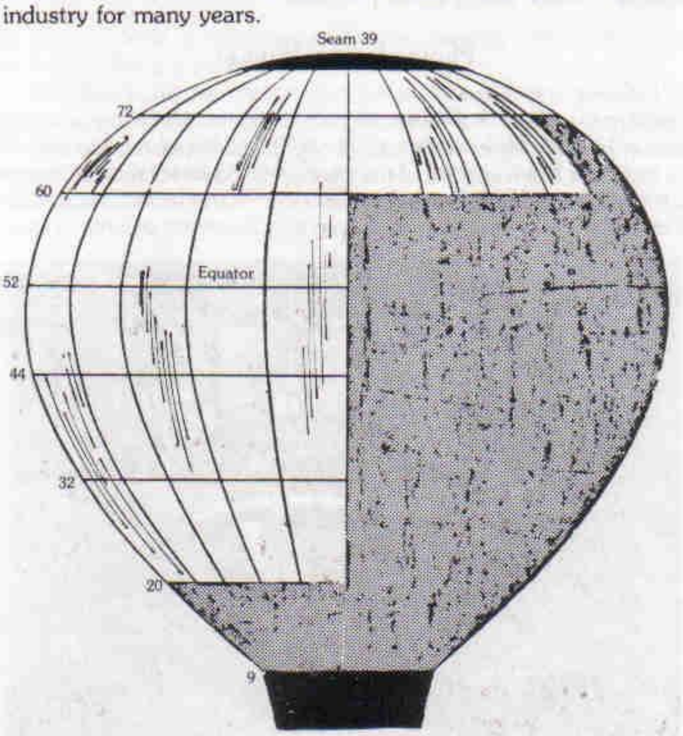
Ah! But there is a change in the wind. Fredrick Eshoo of Iran has designed and developed a revolutionary balloon system, the *Sunstat*, deriving its name from the heat source (sun) and the technical term for the balloon (aerostat). Based on solar radiation as the source of heat and consequently the lift, a significant milestone in the advancement of sport ballooning has been reached. On February 6, 1978, near Minneapolis, Minnesota, Fredrick sustained thermal flight for about a half hour. Successful manned flights in solar balloons of simpler design had been accomplished five years earlier, but the *Sunstat* flight by Fredrick Eshoo demonstrated a new technological improvement in solar balloon design.

Fredrick, who is both a creative engineer and a seasoned balloonist, started work on his first prototype more than two years ago. Researching solar energy principles and applications, performing parametric studies of various solar collector configurations, and utilizing the engineering resources of his manufacturing plants in Tehran to perform fabric tests, he explored ways to harness the sun's energy to power the hot air balloon. His goals were a step beyond the requirements of greater endurance and silent flight. Fredrick sought practical balloon flight while preserving the simplicity of the balloon. He cast aside the simple "black bag" and "double envelope" comcepts as impractical, but he employed the principles of both. When he had perfected his design, he chartered the services of Raven Industries to build the prototype system.

Throughout history, man has built on his experience. It is therefore instructive to recall two previous developments in solar ballooning: the Solar FireFly of Tracy Barnes and the double balloon of Dominic Michaelis. In May of 1973, Tracy, working closely with associates Karl Stefan and Dodds Meddock, accomplished the first manned solar balloon flight. Aboard his 203,000 cubic foot black tetrahedron, Tracy flew for about ten minutes and made a safe landing in a small field. For the first time in aviation history, solar energy provided the sole source of lift, but a major drawback was the balloon's limited maneuverability or slow response between the time of venting or cooling and regaining lost altitude. The following year, Dominic Michaelis, in conjunction with Cameron Balloons of Bristol, England, designed and developed a solar balloon which employed a double envelope configuration. The inner balloon consisted of a black envelope with a volume of 105,000 cubic feet. The outer balloon consisted of a transparent 150,000 cubic foot envelope. Although Dominic's application of the so-called greenhouse effect was good in principle, his double envelope system was too heavy and cumbersome. The balloon has never flown on solar power alone.

Fredrick Eshoo pursued a more scientific approach in his development of the *Sunstat*. A standard hot air balloon of proven design was used as his basic balloon system. He selected Raven's S-60A envelope pattern with a volume of 105,000 cubic feet. The balloon is 60 feet in diameter and stands 70 feet high and is classified in the AX-8 size category. It features standard vertical gore and panel construction, circular rip panel deflation system, and a two-point control maneuvering vent. From here, Fredrick departed from the standard design by specifying and employing special materials for the envelope construction.

The *Sunstat* envelope is characterized by two non-symmetric sections, one of lenticular design using transparent plastic, the other of opaque design using ripstop nylon. The transparent fabric is reinforced with a nylon fiber mesh sandwiched between two layers of bonded mylar. This material has been used for many years in the scientific ballooning community where high altitude balloon flights endure extreme temperatures and intense ultraviolet radiation for long periods of time. The ripstop nylon, which is black on the inside and silver on the outside, has been used in the sport ballooning industry for many years.



The radiant energy of the sun passes through the clear side of the envelope and strikes the black interior surface on the opposite side of the envelope which forms an ideal solar collector. Hot air balloonists with conventional burners have noticed decreased fuel consumption with dark colored balloons. This is the same effect that takes place in the *Sunstat*. As the incident rays of the sun are absorbed by the black fabric, the heat is transferred to the air immediately surrounding the black surface. This reradiated energy is of such a wavelength that it will not pass through the clear plastic.

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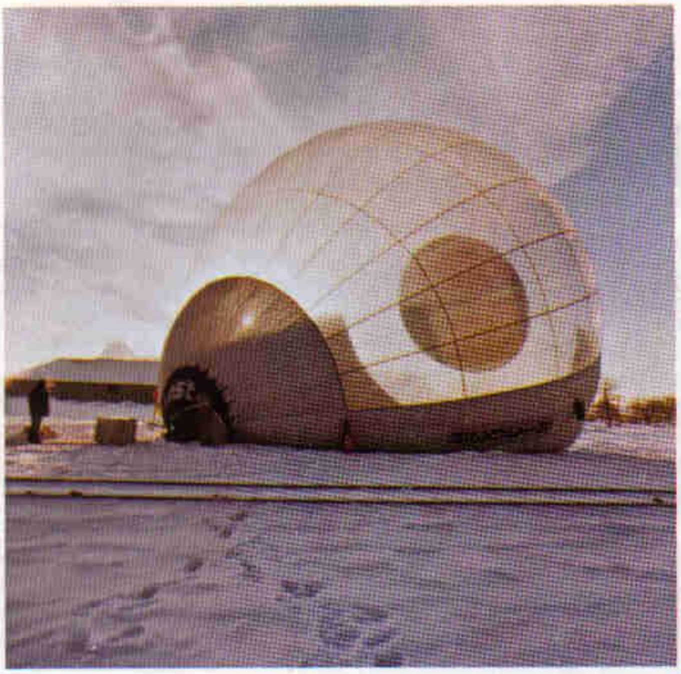

The *Sunstat* consists of two non-symmetric sections, one of lenticular design using transparent plastic, the other of opaque design using ripstop nylon.

First inflation of the *Sunstat* at Sioux Falls, South Dakota. The envelope design features nylon fabric which is black on the inside and silver on the outside, except on the top panel where this color scheme is reversed.

Photos by Jim Winker

In essence, the balloon is an energy converter. Solar radiation is converted to heat in a thermodynamic process involving selective transmission of short wave sunlight by the clear plastic, absorption by the inner black surface of the envelope, and reradiation as longer wavelength infrared. As the air near the black fabric is warmed, convection currents cause mixing so that the entire volume of air in the envelope is heated. The transmission of restorative energy through the transparent envelope and the subsequent trapping of reradiated and reflected energy by this envelope is the familiar greenhouse effect. There is also a lens effect whereby the curvature of the clear plastic forms a spherical refracting surface and the incident sunlight is focused. An added feature of the transparent portion of the envelope is the significant increase in upward visibility for the pilot.

***Sunstat* designer Fredrick Eshoo of Tehran, Iran tests solar lift for the first time. His balloon is a Raven AX-8 with a solar twist.**

Flying solo and solar, Fredrick tethers the *Sunstat*, a balloon anxious to be unleashed and allowed to demonstrate its sparkling performance.

Fredrick attaches one of the electric trim motors to the *Sunstat* equatorial band as the balloon is prepared for its maiden voyage at Crystal Lake, Minnesota.

Fredrick Eshoo has taken his solar design several steps further. He takes advantage of the dual insulating features of the silver side of his envelope. This is actually an aluminum-coated surface which prevents excessive heat loss caused by air currents cooling the exterior surface of the balloon and impedes the flow of heat energy through the thin balloon skin and out of the aerostat. The top panel of the *Sunstat* is reversed, that is, the outside is black and the inside is silver. The inner surface improves heat retention by reflecting heat back into the center of the balloon. But in addition, air flowing across the top of the balloon is heated above ambient by the black surface. This is a heat-saving feature because the silver inner surface of the top panel is not cooled down.

Ideally, if sun rays were directed at the balloon only in the horizontal direction, exactly one vertical half of the envelope could be clear while the other half could be opaque. Likewise, if the sun was always located directly overhead, the radiation could pass through an upper hemisphere of clear material and be absorbed by a

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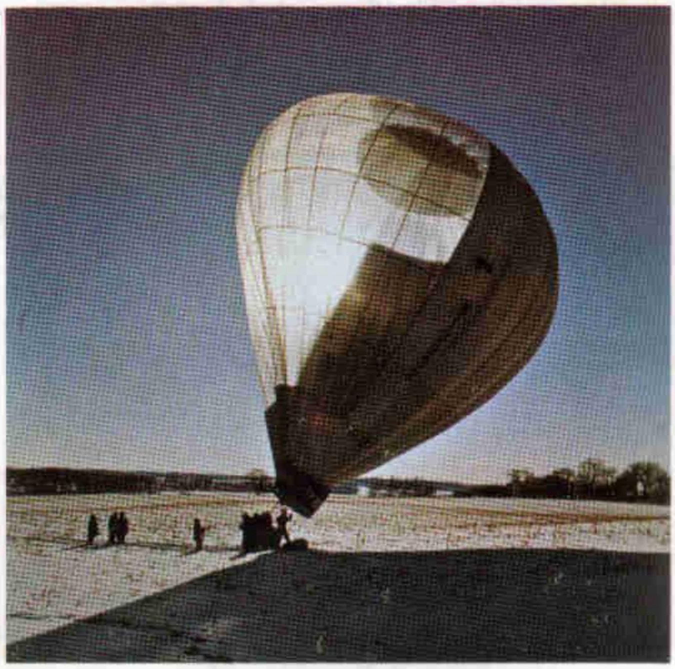
With the national flags of Iran and the United States waving from its lower envelope, the *Sunstat* slowly ascends on solar power.

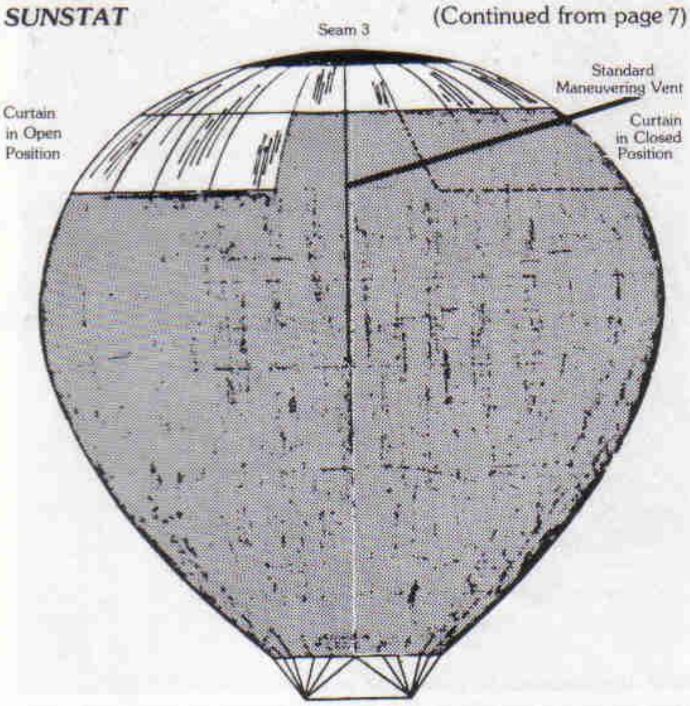
Photos by Rick Souther

Resembling a giant parabolic antenna, the black interior of the *Sunstat's* collector absorbs the radiant energy of the sun as the balloon climbs aloft on its 31-minute maiden voyage.



With a sparkling sun-drenched envelope, the *Sunstat* returns to Earth, heralding the end of a successful first flight and the beginning of a new era in solar ballooning.

SUNSTAT (Continued from page 7)



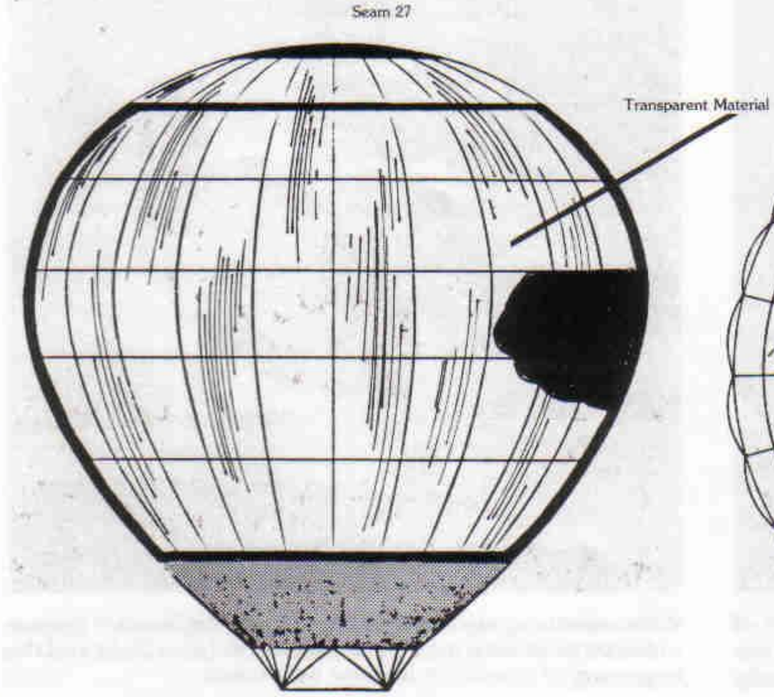
lower hemisphere of black material. In reality, the sun shines at various angles and this would be the case in balloon flight.

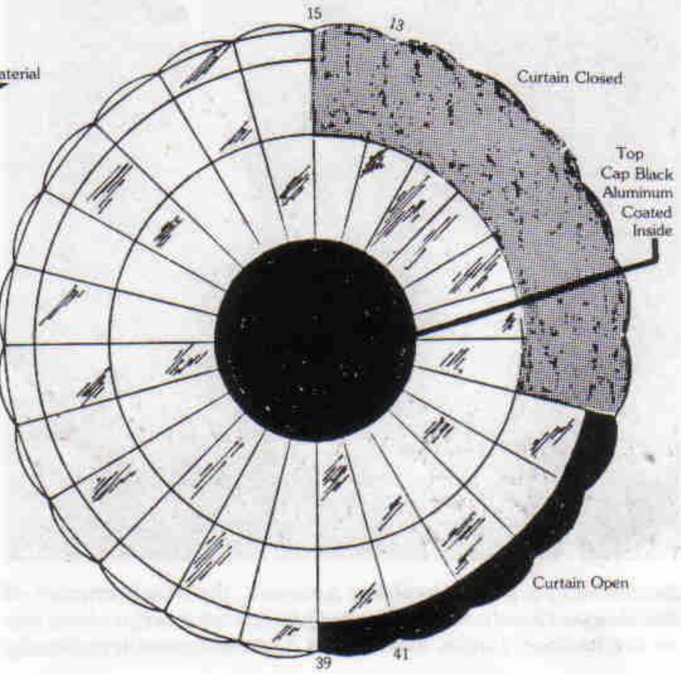
Consequently, the configuration of transparent and opaque envelope surfaces for the *Sunstat* has been optimized to take advantage of both low and high sun angles in the latitudes between 30 and 60 degrees where most of the world's ballooning activities take place. A unique feature of Fredrick's design is the provision for an opaque portion of the upper envelope to be opened, thus exposing transparent fabric and widening the window for collecting solar energy. There are two panels or curtains, one on each side of the maneuvering vent, which can be peeled down on the outside and tied off by control lines. When the sun is high, these opaque portions of the envelope would shade the part of the black collector surface that is on the upper curvature of the envelope. The panels are left in place during winter flying when sun angles are low.

A necessary breakthrough in vertical balloon maneuverability was achieved by attaching two small trim motors to the outer periphery of the envelope, positioned on the equator at opposite sides of the balloon. These trim motors are battery-powered propellor fans which can be individually controlled from the gondola. By actuating a push-button control, the pilot can rotate the balloon on its vertical axis to face the lens side more or less into the sun. By turning the balloon so that more energy is captured in the envelope, the balloon can be heated and maneuvered upward. In essence, altitude can be increased by permitting an increase in the amount of insolation or altitude can be decreased by effecting a reduction in insolation. If too much rotation is used, the opposite motor can be actuated to accomplish the slightest correction in balloon orientation. An improvement in this concept can be achieved by the application of sun-seeking controls, that is, sensors installed at discrete intervals around the circumference of the envelope and a signal processing circuit that automatically actuates the appropriate trim motor, thus leaving nothing for the pilot to do during level cross county flight. If the pilot desires an altitude change, he can override the control system and manually operate the balloon. Thirty seconds of running time correspond to 180 degrees of rotation.

The *Sunstat* underwent two test inflations and a tether flight at Sioux Falls, South Dakota. The first, on January 29, 1978, was part of the normal inflation checkout by Raven factory personnel. The second test was conducted on January 31st. At that time, Fredrick experienced solar lift at 150 feet per minute when the *Sunstat* made its first tether flight. There were no backup heating systems on board and the tether line was slack.

It is important to emphasize that in the *Sunstat* design, Fredrick has preserved all of the features of a standard hot air balloon. With a propane fuel system on board, the *Sunstat* is not restricted to flying only on sunny days. It is an extremely versatile and resouceful balloon. While there is sufficient free lift derived from solar power, there is also the exciting opportunity to allow the sun to generously contribute to the heating process in a conventional propane-powered balloon system.





After the test inflations by Raven, the *Sunstat* was transported to Minneapolis, Minnesota with the hope of participating in the annual St. Paul Winter Carnival Balloon Rally. Marginal weather conditions prevented a balloon flight during the rally, but on the following day, February 6, 1978, Fredrick Eshoo accomplished the first free flight of the *Sunstat*.

With the help of the Matt Wiederkehr family, Ron Moquist and Orv Olivier of the Raven factory, Henry Fisher, Mike and Chuck Ehrler, and a number of other interested balloonists, the *Sunstat* envelope was spread out on the frozen surface of Crystal Lake, south of Minneapolis, inflated with cold air, then heated with a conventional burner. The ambient air temperature was minus 3°F and the surface winds were less than 10 knots. With the burner shutdown, Fredrick dumped some of the artificially heated air. The balloon's transparent side was turned towards the rising sun and within minutes the envelope swelled back to life. At 9:16 a.m., with the national flags of Iran and the United States waving from its lower envelope, the *Sunstat* broke free from the snow-covered ice and slowly ascended on solar power. Except for a quick shot of the burner to avoid a line of trees, the balloon flew entirely on solar power.

Fredrick successfully controlled the *Sunstat's* altitude between 100 and 300 feet (AGL) by spinning the balloon like a newborn planet rotating in its very own solar system. With his burner 93 million miles away, the Iranian pilot voyaged in total silence, utilizing only the energy of the sun to stay aloft. The temperature at the top of the balloon never exceeded 45°F. Fredrick effected a controlled descent by careful rotation, then at 100 feet, the vent was opened. A squirt of heat from the relighted burner slowed the rate of descent and a triumphant landing in the snow marked the end of the 31-minute maiden voyage and the beginning of a new era in solar ballooning.

Within a week of the first free flight in Minnesota, Fredrick brought the *Sunstat* to New Mexico. With assistance from Sid Cutter and Paul Woessner, a tether test was accomplished on the outskirts of Albuquerque. Then, despite the city's record of receiving 80% of all available sunshine, Fredrick was forced to wait six days as a series of winter storms inched their way across the Southwest. On February 18th, a second free flight was accomplished, this time at a latitude of 35°, a ground elevation of 5000 feet, and an ambient temperature of 35°F, compared to the 45-degree latitude, 1000-foot elevation, and subzero temperatures of Minneapolis. Fredrick flew for an hour and 21 minutes, cruising as high as 6000 feet above sea level. With the sun glistening from its shiny fabric, the *Sunstat* drifted downwind, resembling a silver ball suspended in a clear blue sky. From the launch site, the two trim motors and the tiny aluminum gondola (borrowed from Sid Cutter's experimental *Small World* balloon) appeared to shrink into black dots on the periphery of the giant envelope. Fredrick landed comfortably on the Isleta Indian reservation south of Albuquerque.

The following day, the *Sunstat* flew for another two hours, and with World Hot Air Balloon Champion Paul Woessner at the controls, climbed to 12,000 feet above sea level. Rising at 500 feet per minute, Paul punched through a cloud layer and was able to peer over the Sandia Mountains to the eastern plains. Without the reassuring hiss of the pilot light, the *Sunstat* drifted in sparkling silence. A fourth free flight was accomplished on February 22nd by both Sid and Paul.

The first prototype of the *Sunstat* has been developed by modifying a standard balloon and making use of available off-the-shelf materials. This approach minimized technical risk and demonstrated the feasibility of the basic design concept. In the interest of protecting the design during this period of research and development, and with the intention of preventing premature copying of the system before it is completely prefected, a U.S. patent, under the registered name *Sunstat*, is now pending.

Fredrick foresees a number of design improvements that will be incorporated into a second balloon. In the meantime, the *Sunstat* is available for careful study and controlled use by American balloonists. Fredrick has dedicated the *Sunstat* to his friends — all of the balloonists around the world. He welcomes comments on design and ideas for improvement. He hopes that the balloon can make flights at different latitudes, seasons of the year, and times of the day so that data on the balloon's flight performance can be compiled and studied. Theoretically, the *Sunstat* could fly forever, if it could only follow the sun. In practice, the balloon should be able to fly for as long as 12 hours on a sun-drenched day. The future is bright. Without a doubt, the sparkling success of the first *Sunstat* heralds a new and important advancement in hot air ballooning. Someday soon, we will all be able to savor the serenity of silent flight that gas balloonists have long experienced.

Editor's Note: Feedback on this new concept in hot air ballooning is encouraged. Readers are invited to send comments, criticisms and ideas to Dick Brown, 2516 Hiawatha Drive N.E., Albuquerque, New Mexico 87112.