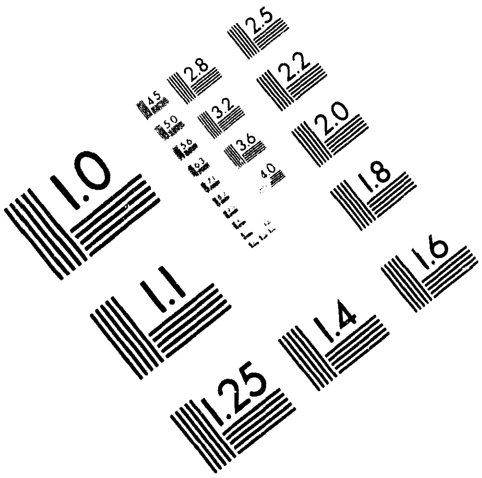

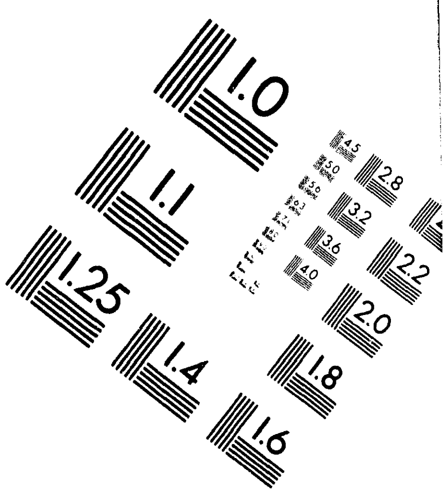

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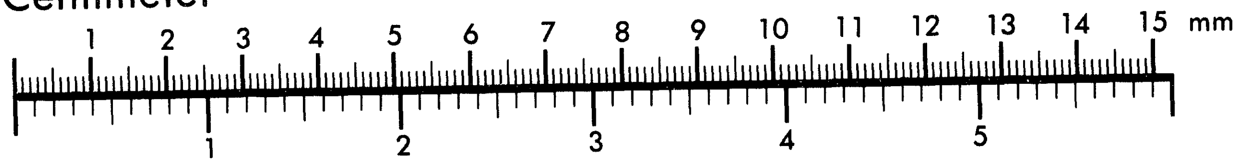

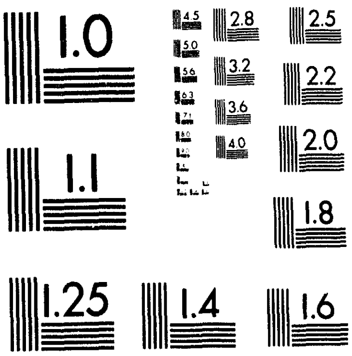

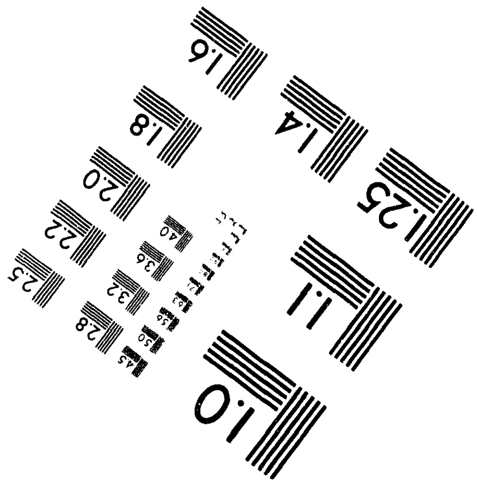

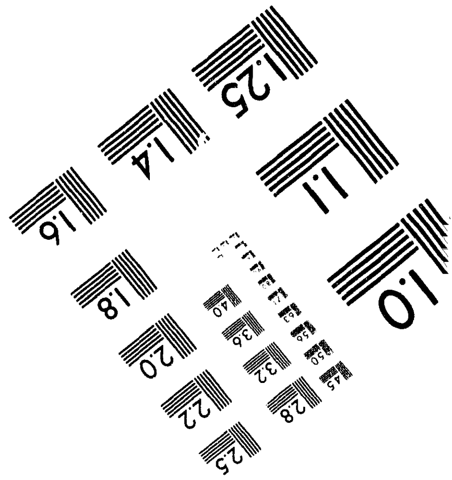

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CALIOPE and TAISIR Airborne Experiment Platform

Clifford J. Chocol

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CALIOPE AND TAISIR AIRBORNE EXPERIMENT PLATFORM

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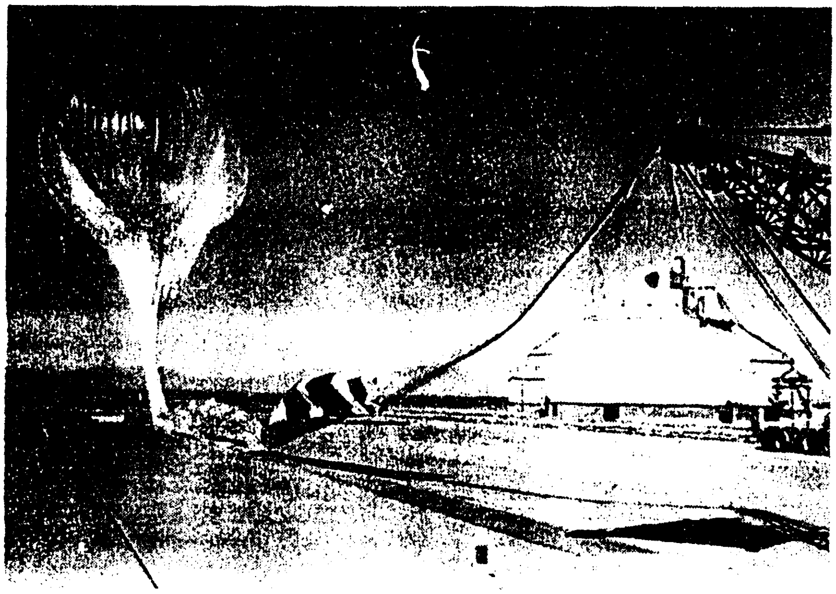
Abstract. Between 1950 and 1970, scientific ballooning achieved many new objectives and made a substantial contribution to understanding near-earth and space environments. In 1986, the Lawrence Livermore National Laboratory (LLNL) began development of ballooning technology capable of addressing issues associated with precision tracking of ballistic missiles. In 1993, the Radar Ocean Imaging Project identified the need for a low altitude (1 km) airborne platform for its Radar system. These two technologies and experience base have been merged with the acquisition of government surplus Aerostats by Lawrence Livermore National Laboratory. The CALIOPE and TAISIR Programs can benefit directly from this technology by using the Aerostat as an experiment platform for measurements of the spill facility at NTS.

Scientific ballooning contributed a vast amount of information regarding the atmosphere, effects of space-like environment, and a host of other areas, to the scientific community between 1945 and 1975. Payloads like Stratosphere I and II in the 1960's studied astronomy from a near space condition and allowed some of the first ultraviolet images to be taken. Project Skyhook was instituted by the Navy in the 1960's to develop sea launched balloons for fleet communications. In addition, both NASA and many Universities have developed sensor systems in the infrared, ultraviolet, cosmic ray and other regions of the electromagnetic spectrum and have used the National Scientific Balloon Facility at Palestine, Texas or Holloman Air Force Base, New Mexico for a ride into the stratosphere (see Figure 1). Today, miniaturized electronics and lightweight materials allow highly-sophisticated payloads to be flown with high reliability.



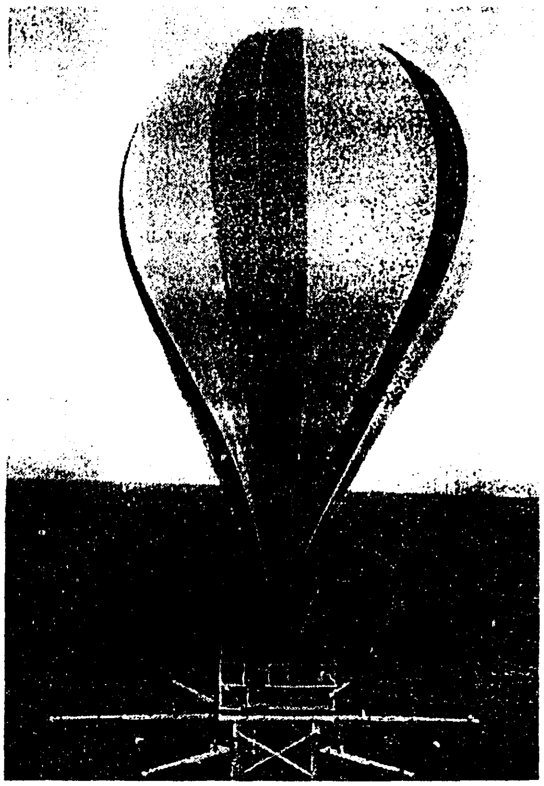


Figure 1. Typical Scientific Balloon Launch

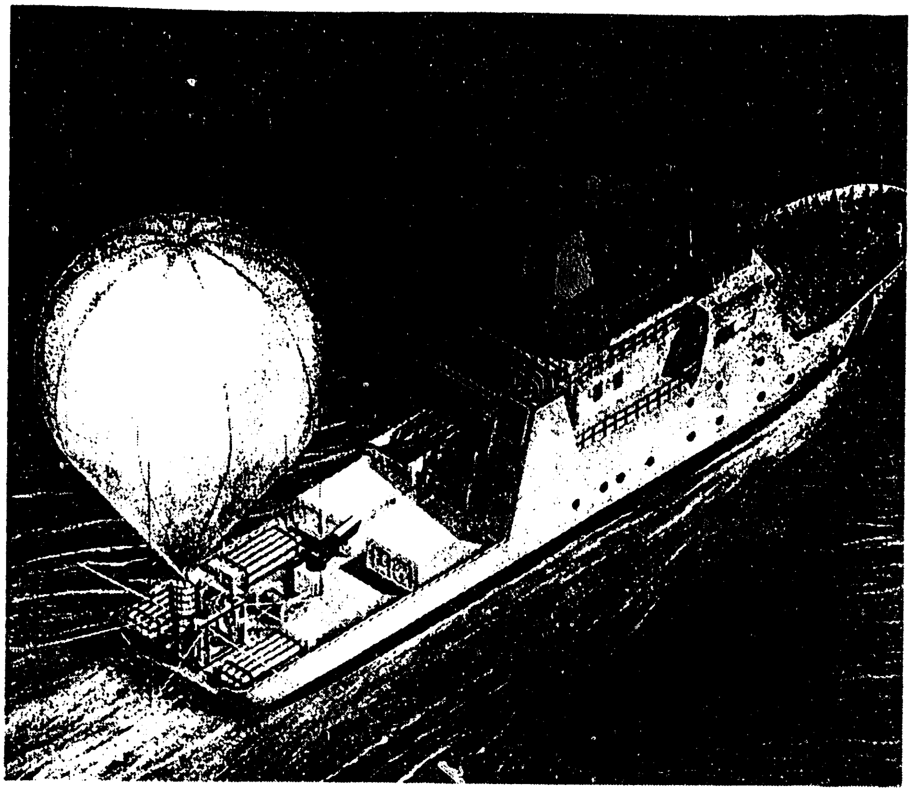


Figure 2. The Kestrel Balloon System

Figure 3. Kestrel Mission Profile

In 1986, the Lawrence Livermore National Laboratory (LLNL) began development of a ballooning technology capable of addressing issues associated with precision tracking of ballistic missiles. This system was called Kestrel (see Figure 2). The Kestrel system allowed a small team to launch a large balloon at sea or on land with a minimal effort by using a tow balloon to carry the payload and main balloon canister to low altitude where the main balloon could be deployed safely. This system also allowed the balloon to be launched "On-call" as most wind effects could be negated by motion of the ship. Upon reaching float altitude, the tow balloon remained on top of the main balloon as an appendage and the mission proceeded (see Figure 3). At termination of the mission, the payload canister was released from the main balloon and would free-fall under a drogue chute to an altitude of about 6000 feet where a main parachute was deployed for a water recovery. For land recovery, a steerable paraglider can be used in conjunction with GPS to land the payload in any small body of water that is inland.

Motivated by the Radar Ocean Imaging Project, LLNL has acquired two government surplus Aerostats and all associated handling hardware. These Aerostats can carry about 450 kg. to 1 km and are tethered for station keeping (see Figure 4 & 5). The tether as shown in Figure 6, carries power (10KVa) to the Aerostat from the ground station and also carries commands to and from the Aerostat/experiment via three fiber optic links each capable of 900 megabits/second. One link is used for the Aerostat housekeeping and the other 2 for the experiment. A typical Radar payload is shown in Figure 7. The experiment platform is a two axis steerable gimbal and can also be used for optical/laser types of payloads. Standard hardware upgrades to this system can improve the 200μ radian stability of the gimbal platform and lengthen the tether to 2 or 3 km.

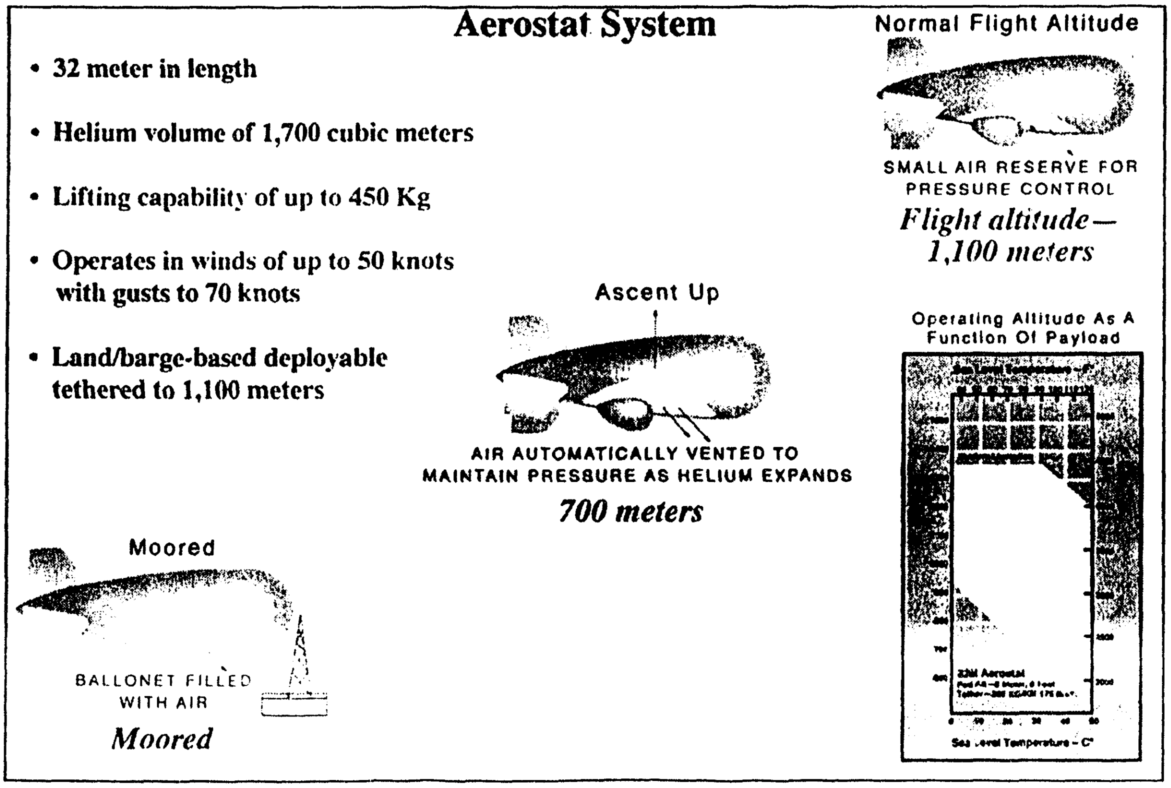


Figure 4. Low Altitude Aerostat System

- **Aerostat**
  - **Overall length:** 32M (97 Ft.)
  - **Hull diameter:** 10M (30 Ft.)
  - **Hull volume:** 1700 M^3 (60,000 $Ft.^3$)
  - **Weight:** 400 Kg
- **Tether**
  - **Length:** 1,400 M (4,200 Ft.)
  - **Power:** 208 VAC 30, 400 Hz
  - **Lightning protection**
  - **Fiber optic cable transmission**
  - **Breakstrength:** 6,400 Kg

Land-based mooring system

- **Land, barge, ship based mooring system**
  - **Self contained**
  - **360° rotatable**
  - **In haul/out haul speed 200 ft/min**
  - **Hydraulic winches**

- **System: 32 M Aerostat**
- **Operating altitude: 165—1,100 M (500—3,500 Ft.)**
- **Aerodynamic for good stability**
- **Payload**
  - **300—450 Kg (650–900 Lb)**
  - **16 Ft., 1/2 sphere area**
- **24 hours per day**
- **All weather operation (50 knot wind, gusts up to 70 knots)**
- **Ship power available**
- **Minimal crew availability**

Figure 5. Aerostat System Parameters

Breakstrength:

6,400 Kg
(14,000 Lbs.)

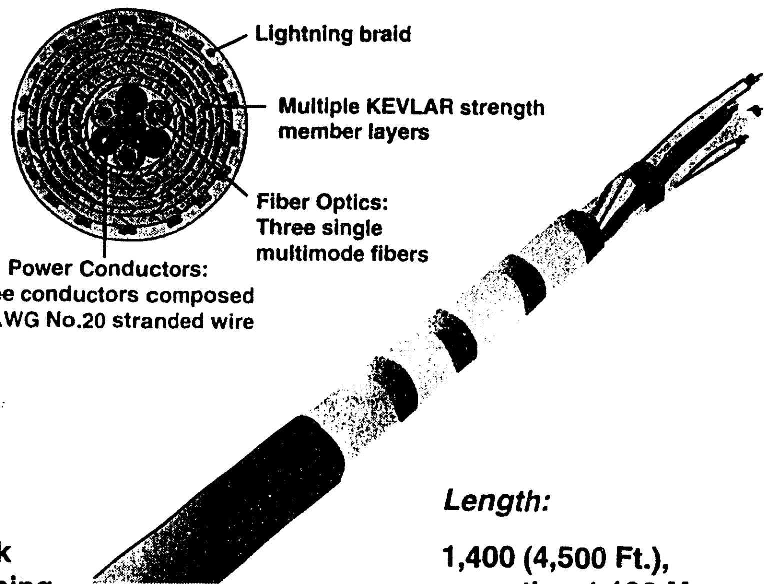
Lightning protection

Power:

10 KVa
120/208 VAC
3 phase
400 Hz

3 serial data link:

900 M bits/second per link
1 link Aerostat housekeeping
2 links for experimental payload



Length:

1,400 (4,500 Ft.),
operating 1,100 M
(3,500 Ft.)

Serves both as a means of securing the Aerostat
and as a source of power and communication

Figure 6. Aerostat Tether System

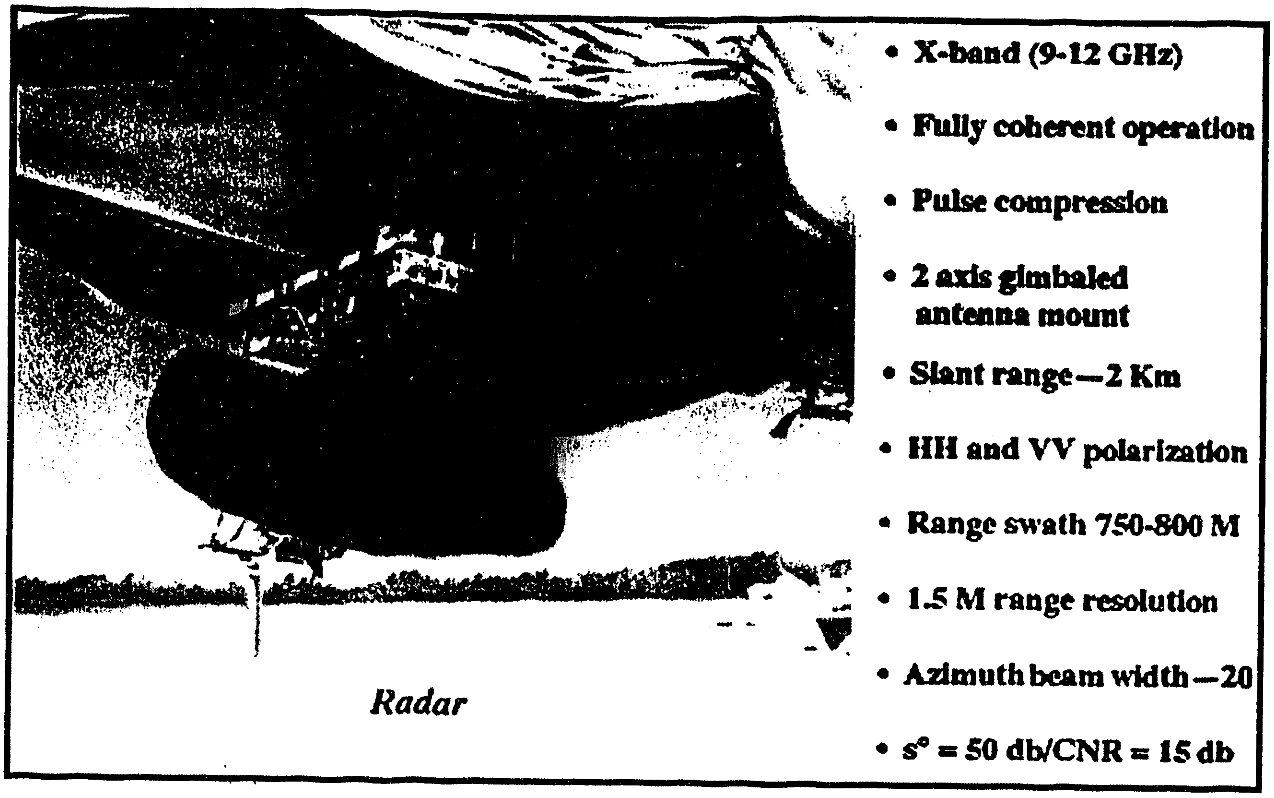


Figure 7. Typical Radar Installation on Aerostat

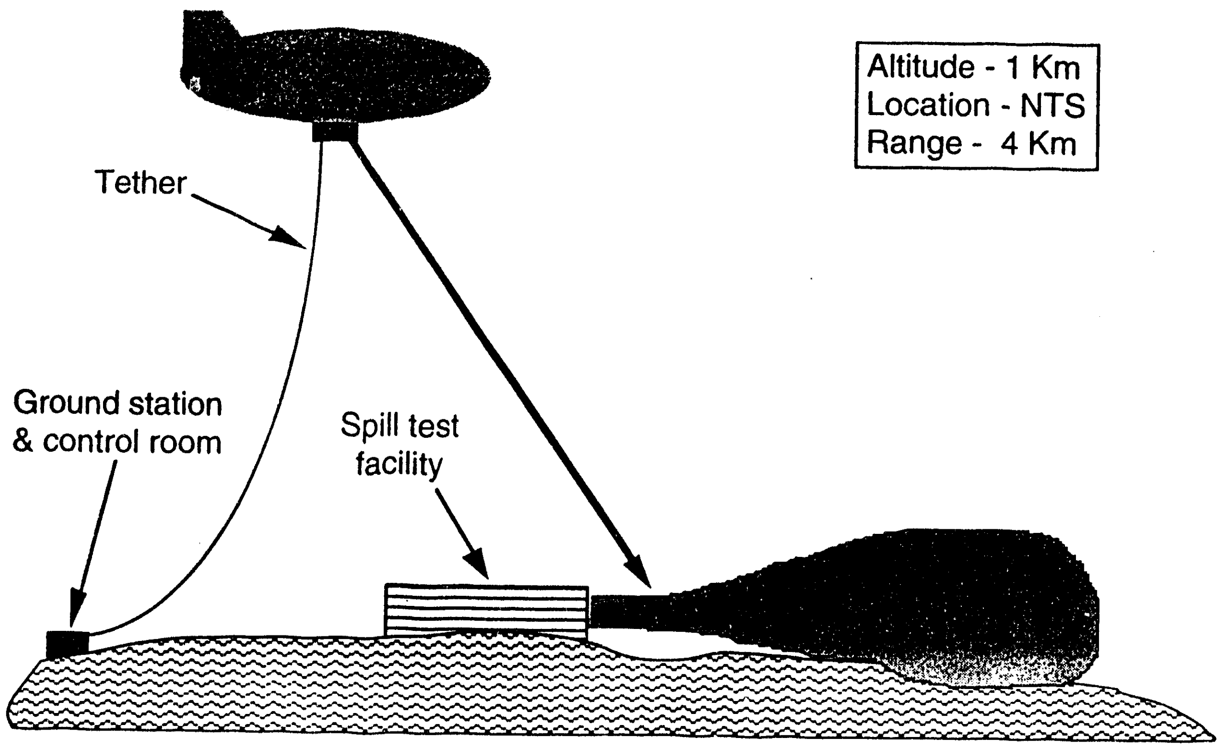


Figure 8. Aerostat Flight Test for CALIOPE.

The transition of the Aerostat and Kestrel technologies into the Solar-Electric Unmanned Lighter-Than-Air Vehicles, is of significant importance to LLNL. The Non-Proliferation Project at LLNL is interested in developing sensors to alert the U.S. of research or production activity of both chemical and nuclear weapons. Tests planned for the FY 94 through FY 97 time frame at the Nevada Test Site include measurements using imagery and Lidar of various effluents from the spill facility. These tests also include measurements from an airborne platform to determine the effects of background and to eliminate the ground effect of "seeing" on the data. The low altitude aerostat meets the requirements for these tests (see Figure 8).

Extending the aerostats capability to an operational vehicle for Non-proliferation, requires some development. The Solar-Electric Aerostat is a practical candidate for this mission (see Figure 9). Station keeping in the stratosphere over a suspected nuclear or chemical facility allows measurements 24 hours a day for months at a time. Wind models for specific locations that are of interest, have shown station keeping at about 85% of any 6 month period. The aerostat can be flown at altitudes between 18 and 20 km and brought back for servicing. For example, the wind profile at 20 km for the month of January is shown in Figure 10. The station keeping position is shown in Figure 11. When the wind exceeds the aerostat capability, the aerostat drifts off course until the wind subsides and then it returns to its station. The length of time "out-of-position" could be 3 to 4 days in January and 0 days in June. Communications links can be line-of-sight or by satellite relay, dependent on the area of interest.

- **Performance capabilities complement conventional UAVs**
  - **Payloads up to a few thousand pounds**
  - **Altitudes up to 20 km (69,000 ft)**
  - **Wind speed up to 30 m/s (67 mi/hr)**
  - **Endurance of a year or more possible**

- **Several recent technology advances make this performance feasible**
  - **high-density energy storage**
  - **amorphous-silicon solar cells**
  - **composite structural materials**
  - **balloon materials**
  - **computational aerodynamics**

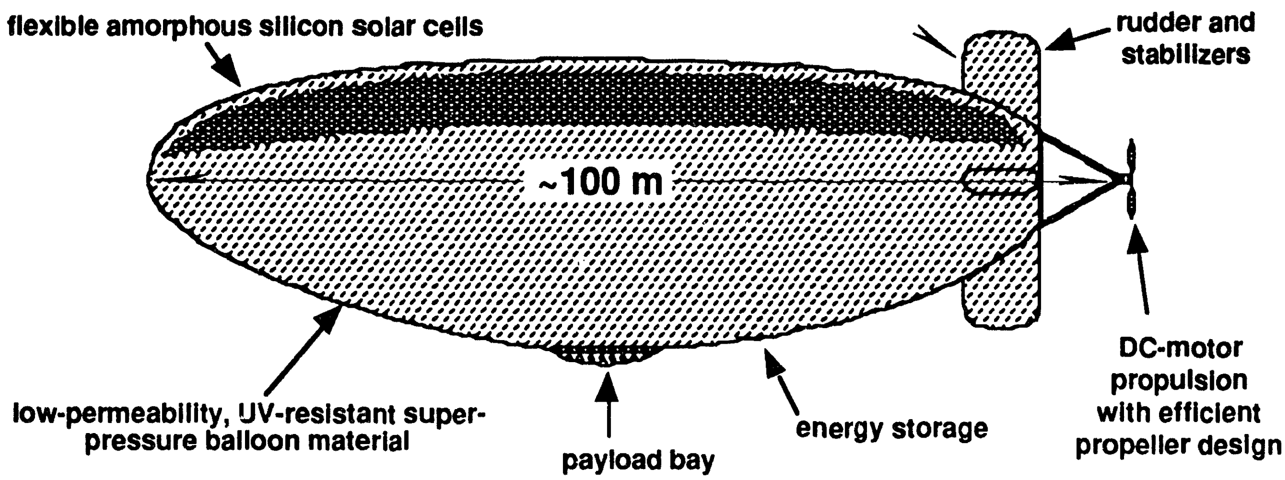


Figure 9. The emergence of critical technologies make high-altitude solar-electric ULV flight feasible.

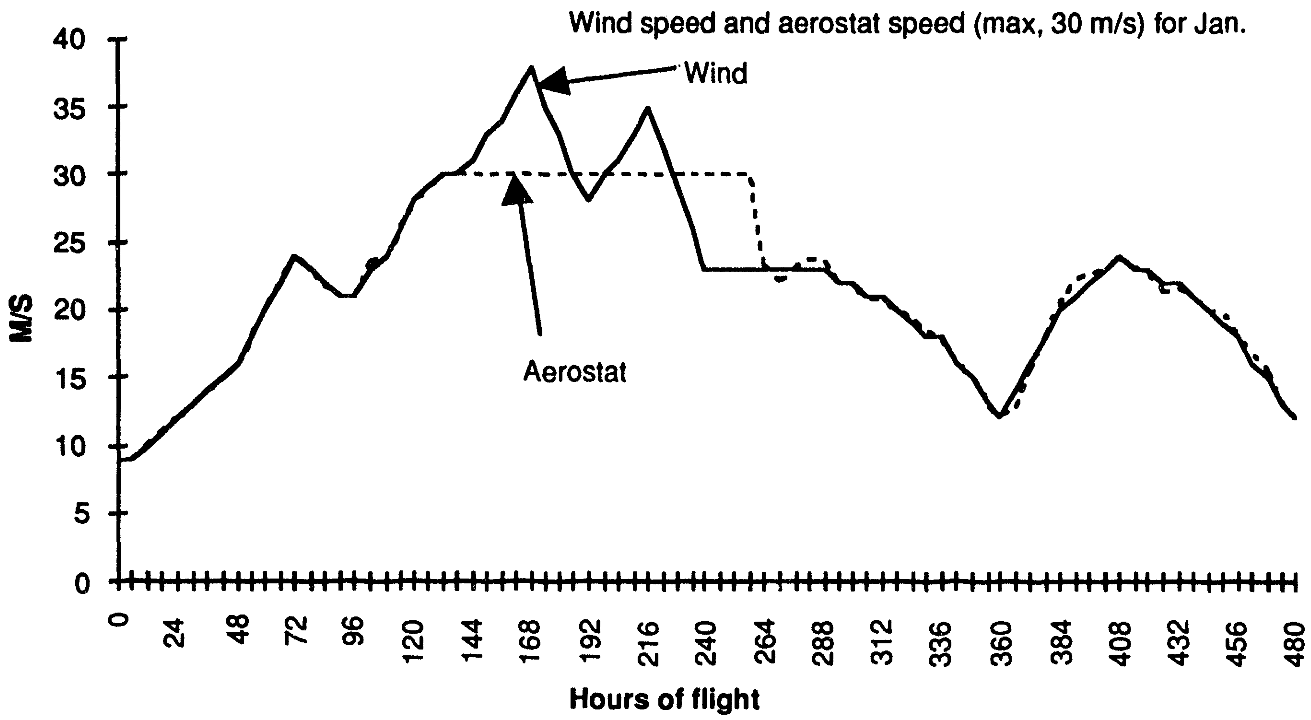


Figure 10. Wind and Aerostat velocity.

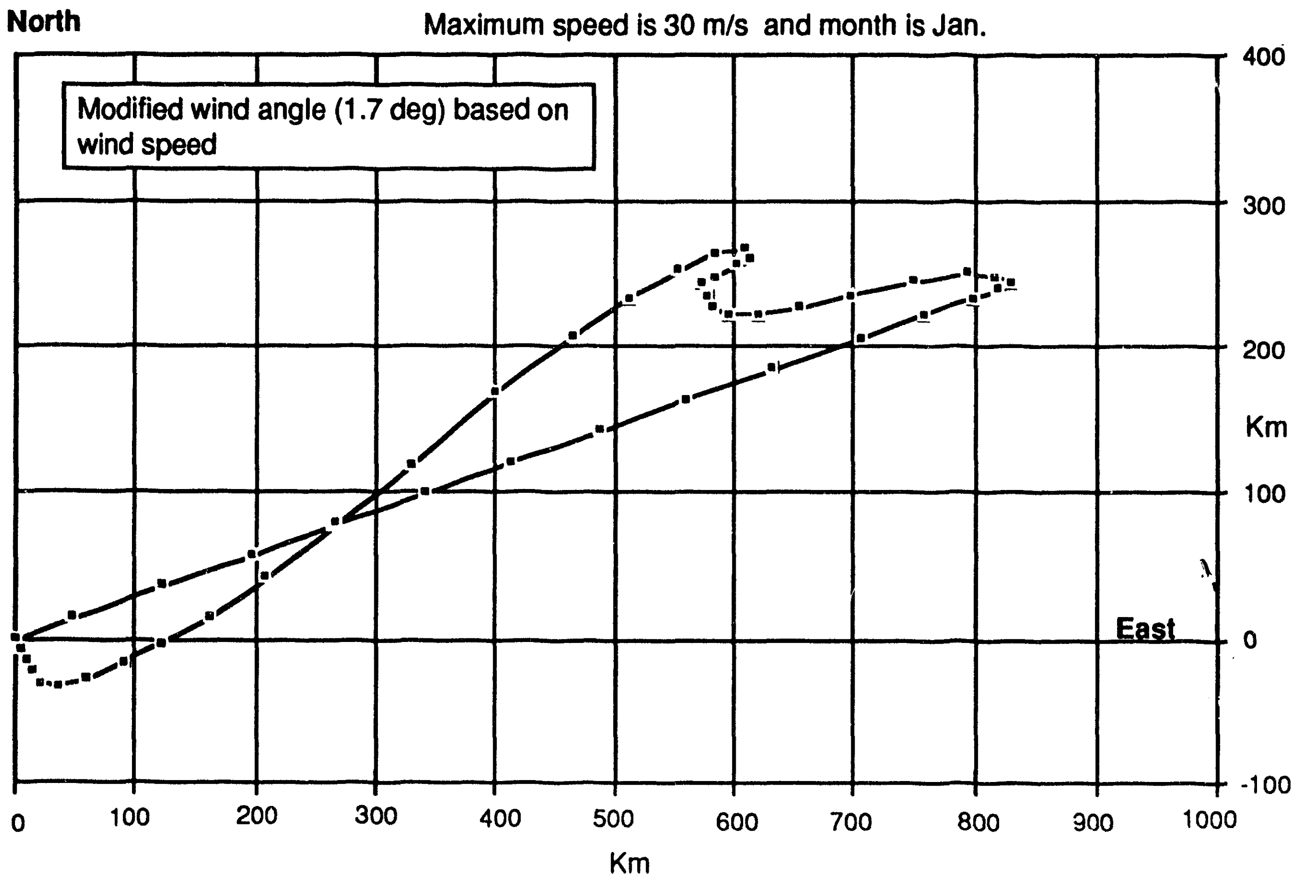


Figure 11. Wind Model for Aerostat.

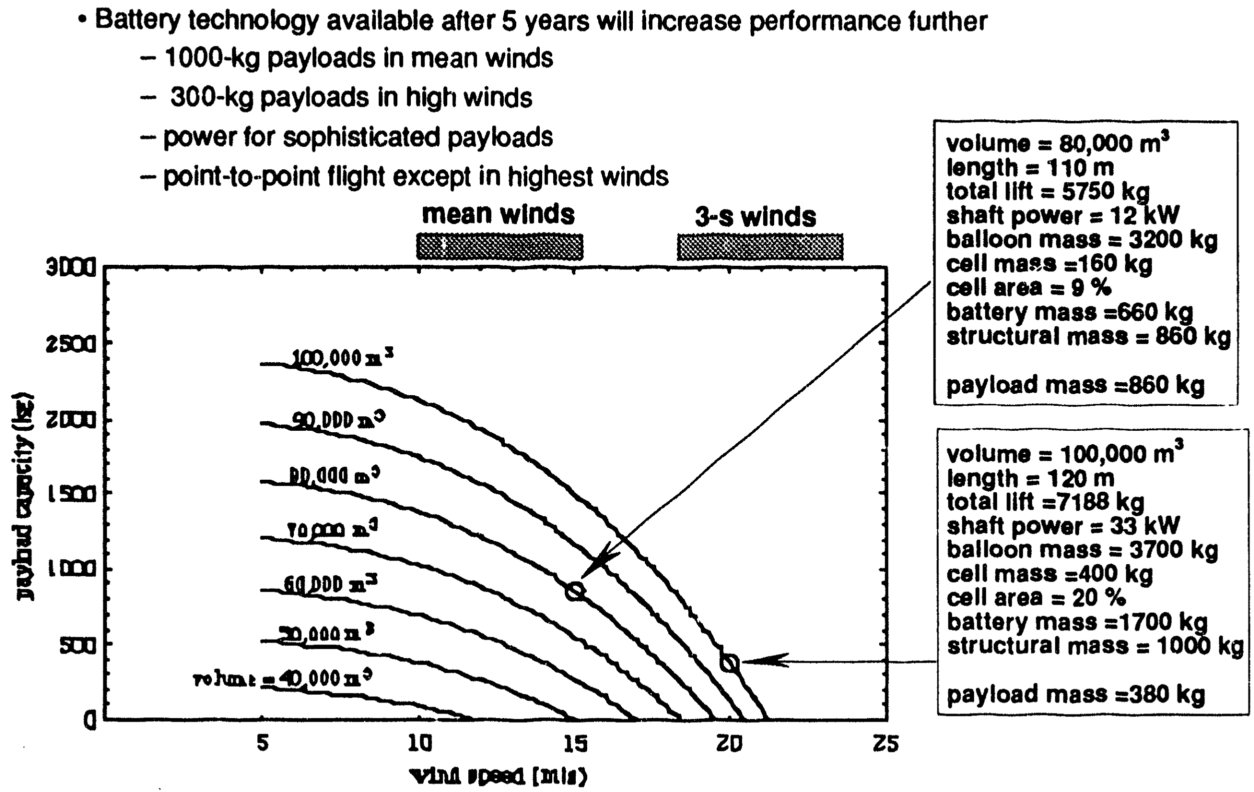


Figure 12. Operational-system payload capacity at 20 km: Li Solid Polymer batteries at 300 W-hr/kg – 1 kW payload.

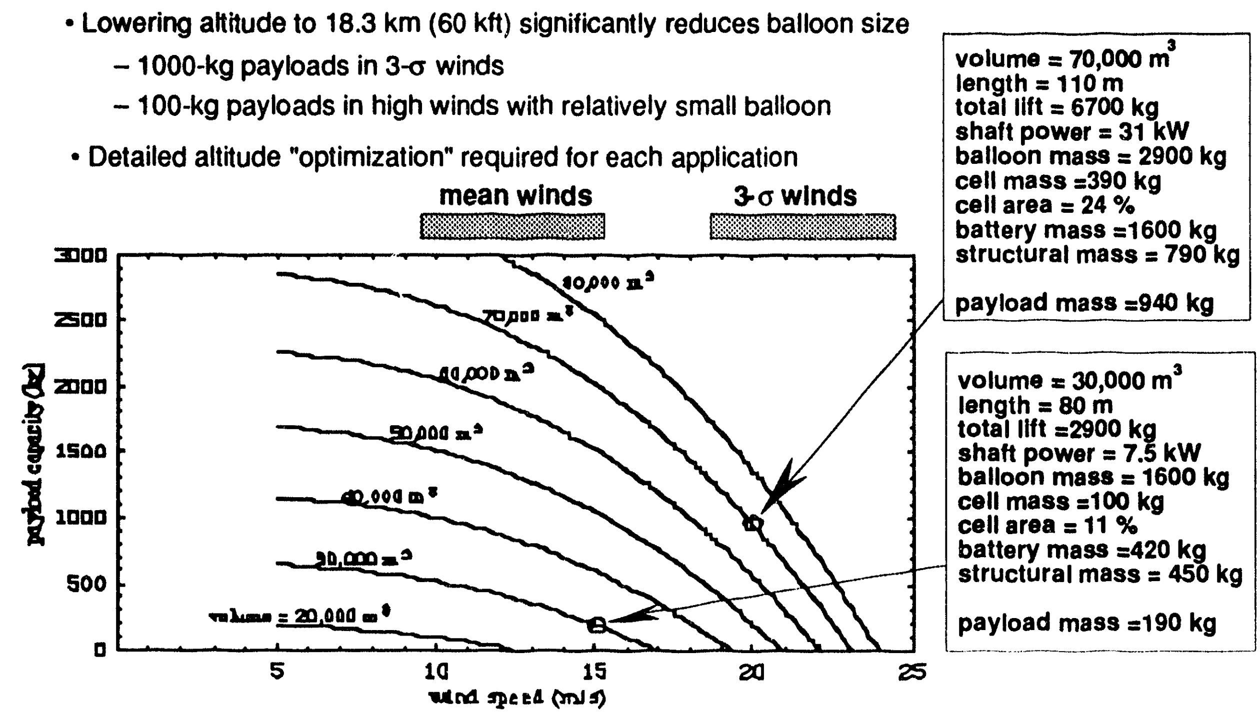


Figure 13. Operational-system payload capacity at 18.3 km: Li Solid Polymer batteries at 300 W-hr/kg – 1 kW payload.

Solar-electric balloons offer a unique solution to high altitude, long duration applications and provide a capability not offered by aircraft or satellites. The characteristics of the Solar-Electric-Aerostat are shown in Figures 12 through 14. As an example, an aerostat with a volume of 70,000 cubic meters can carry a 940 kg payload to an altitude of 18.3 km and station keep in winds up to 20 meters per second using emerging energy storage technology batteries. Energy storage technology and aerodynamic design improvements, are expected to enhance this performance such that winds up to 30 meters per second can be handled. The solar cell area would increase, however the available area used in the study was only 24% allowing considerable expansion.

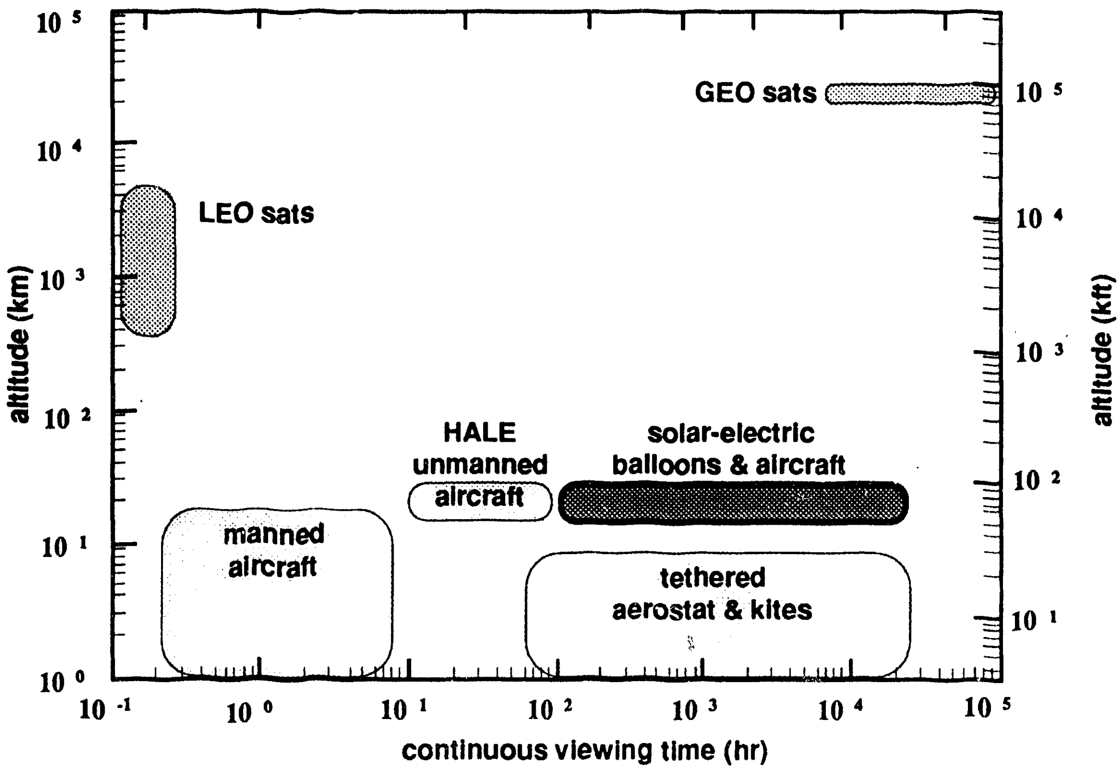


Figure 14. Solar-electric balloons and aircraft provide a unique capability for high altitude long endurance applications.

Acknowledgment

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