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The Small Aerostat System:
Field Tested, Highly Mobile and Adaptable

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The 15M® Class aerostat concept began as a system to lift a 150 pound payload to 1000 feet ASL. A mooring system that is highly mobile with the safety of a three-point, weathervaning platform. A system flexible enough for multiple inflation/deflation cycles but rugged enough for long term deployment. An aerostat designed to carry various payloads: cameras, antennas or radars. Over 40 aerostats later, the 15M®, and its variant, the 17M, has proven itself as a commercial system flying above race tracks and Olympic venues, as a military system from border surveillance to theater support around the world, and as a test platform for various applications. The development of this system, with focus on its uses around the world, is presented.

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I. Introduction

TCOM, L.P. is in it's forth decade of Lighter-Than-Air design and production. TCOM's major emphasis is in the design, production and support of every component of an aerostat system. An aerostat, as its name implies, is an aerodynamically static, helium filled balloon. Its primary means of lift is buoyancy derived from the helium. Its ability to station keep, as well as its means of power and data relay, is through a tether securing the aerostat to a mooring system. The mooring system provides power to the aerostat, controls the aerostat launch and recovery and provides a means of access to the aerostat for maintenance activities.

TCOM first worked with two basic sizes of aerostat to meet various requirements. Each class of aerostat grew in size and capability into what are today the 32M® and 71M® Aerostat Systems and will be referred to throughout this document as the medium and large aerostat systems. The medium system is designed with a mooring system that is transportable with minimal on-site construction and can be deployed anywhere from a few hours to a few days. The mooring system is capable of multiple deployments with regular maintenance while the aerostat is capable of perhaps ten inflations with regular maintenance. The large system is designed with a fixed-site mooring system with deployment taking a few weeks to complete. The mooring system is designed for a single deployment while the aerostat is capable of perhaps five inflations with regular maintenance and repairs.

The small aerostat system idea grew out of the need for a highly mobile platform that can be deployed often with minimal maintenance and without extensive training. The platform must be small enough that the aerostat and mooring system can be towed by a single vehicle on and off road without special vehicle or permit requirements. The aerostat must be designed independent of a specific payload so that any aerostat could carry multiple payloads without additional modifications.

II. Development

In the mid-1990's, the first aerostat concept made use of a commercial off-the-shelf coated material that met the flexibility and helium retention requirements. The aerostat was sized with this material in mind and such that it could be handled during inflation, deflation and flight with two to four people. The shape was a basic TCOM shape of a spun airfoil. The design utilized the same material for the hull, fins, ballonet and reinforcements. The fins were filled with helium from the hull.

The aerostat rigging and hardware was simple. Commercial links and ropes with simple eye splices. The payload was suspended within the flying (confluence) lines so that a variation in the payload weight did not affect the aerostat's pitch angle. A continuously running fan kept the ballonet filled at its stall pressure. A quick-disconnect fitting for helium inflation was installed in a plate bolted to a ring set; the plate was removed for deflation.

The mooring system was a tether winch mounted on the back of a truck along with a generator and slip rings to provide power and signal to and from the aerostat. The tether made use of commercially available technology. When the aerostat was not flying, this compact design required the aerostat to be moored away from the truck on a cable bridle.

Design and testing continued with this concept. The mooring system equipment was moved to a trailer so that the truck could be driven away during operations while also providing greater storage capability. The aerostat was modified with different fin shapes and sizes to improve the flight characteristics while the material was changed to improve its ruggedness and the rigging was improved to increase its reliability.

III. First Production

Finally, by 1996, the 15M® Aerostat System was coming together.

A hull material was developed by TCOM specifically for this aerostat. Designated F40, this material uses the same polyester scrim used in the ballonets and fin spars of TCOM's large aerostat. This material had already demonstrated its flexibility and strength though years of use in these applications. White polyurethane coatings are used to maintain the material's flexibility while minimizing solar heating. A UV inhibiter is added to the exterior layer of urethane to minimize the material's degradation in the sun. A laminated fabric with an environmental barrier like TCOM uses on the medium and large aerostats increases the structural and gas-retention longevity of the material; however, a laminated fabric such as that cannot withstand multiple inflation cycles without damage that eventually makes the aerostat useless for operation.

The final dimensions of what came to be known as the 15M® Aerostat are roughly 6 meters in diameter and 16 meters in hull length. This additional length, making it not actually 15 meters long, was a result of the material used, the hardware choices made and the flight performance required (150 lb payload to 1000 ft ASL). Load patches were designed that could be pulled away from the hull surface as well as tangent. The rigging is designed to be pulled tangent to the hull surface, but having greater capability in the load patch design insures that the patches and hull are not accidentally damaged during handling.

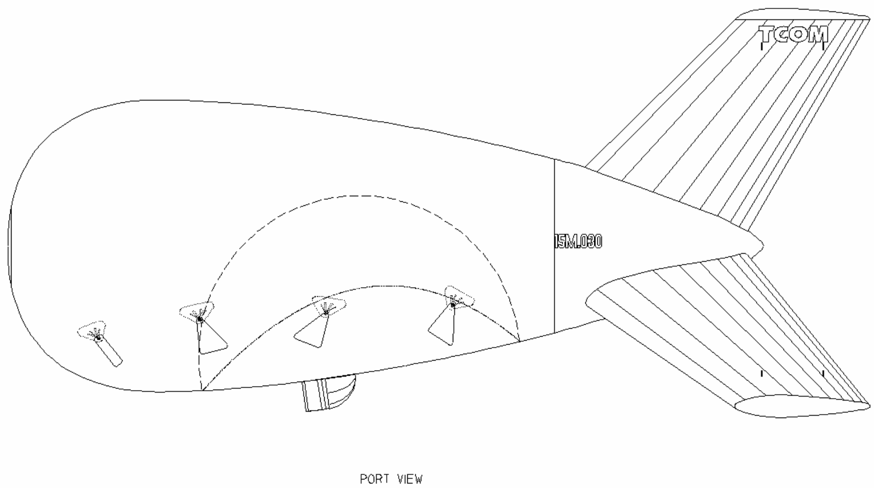

Figure 1. 15M® Aerostat Flexible Structure

The aerostat is designed with a ballonet. A ballonet of course is an air-filled compartment within the helium compartment that varies in volume through the use of blowers and valves to maintain the pressure in the hull during changes in altitude, environmental conditions, or helium gain and loss. Designing a ballonet into a system that does not see much of an altitude change seems to unnecessarily increase the complexity and weight of the aerostat, but in reality, the operational benefits and safety margin exceed these penalties. The ballonet is sized for an altitude variation of up to 1500 feet while allowing for extremes in temperature and pressure. A ballonet access port is provided to view the ballonet curtain and determine the amount of helium in the hull as well as access to the ballonet for maintenance activities.

As stated earlier, the fins are open to the hull and are therefore helium inflated. This helps to maximize the helium volume and optimize the center of buoyancy with respect to the aerostat's center of gravity. Through the development of the fins, a trailing edge sweep angle was incorporated into the design in order to move the fins center of pressure farther back. The appearance of the aerostat also seemed to be improved by this design feature. As with all current TCOM aerostats, the fins are based on a truncated NACA airfoil with eight internal spars to yield a total of 9 cells.

Provisions are made for additional equipment if required by the customer. These may include forward and aft navigation lights, antennas, heading indicators, etc. Provisions are also made for aerostat flight hardware, including a deflation port, inflation port, Automatic Rapid Deflation Device (ARDD), ballonet blowers and a ballonet valve, as well as the payload and the Airborne Power and Telemetry Unit (APTU).

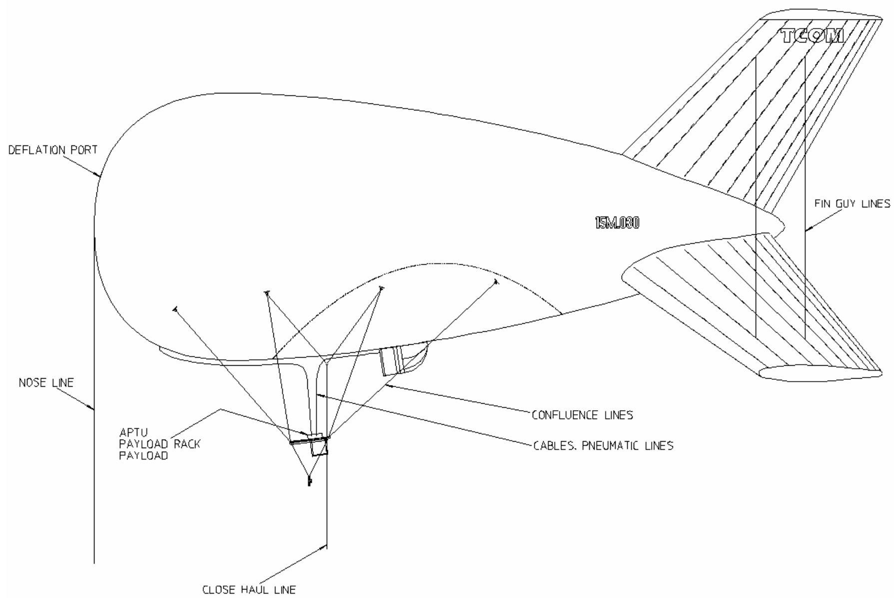

Figure 2. 15M® Aerostat Installation

The nose line is secured to a probe suspended between three load patches at the nose of the aerostat. These patches are in a Y-configuration and are designed to withstand much of the aerodynamic loading while the aerostat is moored. A buffer is laced to the hull outside of this probe so that a nose cone located on the tower of the mooring system can be held firmly against the aerostat without causing damage.

The flying lines, commonly referred to as confluence lines, are attached to four load patches on either side of the aerostat. These lines transfer all of the buoyant and aerodynamic forces of the aerostat down to the tether during flight. Mooring lines connect to the last three lines on either side while the aerostat is moored in order to transfer most of the buoyant forces and some of the aerodynamic forces from the aerostat into the mooring system. The eight confluence lines come to four attachment points at which the payload is located. The payload is simply suspended within this area with four links allowing the payload to be easily removed from the system for maintenance or replacement. In fact, the aerostat does not even need to fly with a payload installed.

Close haul lines are suspended from the center pair of confluence line load patches. These lines allow the aerostat to be controlled by the mooring system during launch and recovery.

Snubber lines are often suspended from the last load patch on either side of the aerostat. These lines allow the aerostat to be further controlled during maintenance activities or while inflating and deflating.

Fin guy lines are suspended between the fins so that aerodynamic forces acting on any one fin are transferred to the other fins.

All of these lines are sized for their strength, but also for comfortable handling and minimum risk to the aerostat.

A deflation port is located above the nose of the aerostat. This port is opened when the aerostat needs to be deflated. A blower duct is then inserted to fully evacuate the helium and prepare the aerostat for folding and packing. The location of the port means that it can be reached from the mooring system tower while still maximizing the outflow of helium.

An inflation port is installed on the chin of the aerostat. This port has two fittings on it. One fitting is a quick-disconnect for attaching a high-pressure helium hose. Internal to this fitting is a diffuser so that the high-pressure gas does not damage the aerostat. The other fitting is for the attachment of a pneumatic line which is feed to the ARDD and the APTU in order to monitor helium pressure.

The Automatic Rapid Deflation Device (ARDD) is a box laced to the aerostat surface that senses helium pressure and switches on a current from a battery to a burn wire when the helium pressure exceeds a set limit. A resistance, or burn wire, is located outside of the ARDD box and held firmly against the hull surface. When the burn wire is heated by the ARDD, the hull material is locally damaged, causing a tear to begin, destroying the aerostat and bringing it rapidly to the ground. This device is in case of the unlikely event that the aerostat should break away from the tether during flight. The upward motion of the aerostat would result in a pressure increase causing the ARDD to engage.

The ballonet blower is a fan installed on the surface of the hull that is continuously running at a stall pressure equivalent to the operational pressure of the aerostat. A secondary blower is installed behind the primary blower in case power is lost to the aerostat or the primary blower fails to work. Battery power is provided to the secondary blower. These blowers are located inside of a scoop on the lower surface of the hull. This scoop keeps suction that would otherwise form on the hull surface due to airflow from reducing the performance of the blowers.

A spring-actuated valve is located behind the scoop to act as a safety when helium is being added. If helium is added too rapidly and the ballonet blower cannot react fast enough, the valve will open before the aerostat is harmed.

The Airborne Power and Telemetry Unit (APTU) provides the means of transferring power and signal (electrical and fiber optic) from the tether to the aerostat and payload. The APTU also monitors the helium pressure, environmental conditions, as well as motion of the aerostat and status of the electrical components.Information from the payload, as well as telemetry from the aerostat, is then sent back from the APTU and down the tether to equipment on the ground.

All of this hardware, with the usual exception of the ARDD box and the ballonet valve, remain on the aerostat when it is folded and packed. This means that the aerostat is easily inflated and deflated in as little as an hour by two people.

The aerostat, fully packed with it hardware, weights just over 300 pounds and fits within a container much like a body bag to be carried by four people or lifting equipment.

The tether is the structural means of holding the aerostat to the mooring system. The termination at the top provides an attachment point for the confluence lines and feeds power and signal to and from the aerostat. The tether is routed down to a sheave, referred to as the flying sheave, and back towards the tether winch. The tether is nominally 1500 feet long for a 1000-foot flight altitude system. This hydraulic tether winch provides the means of storage of the tether as well as control of the aerostat height while in flight. The tether is terminated at this lower end to a slip ring that allows the transfer of power and signal from the ground to the tether.

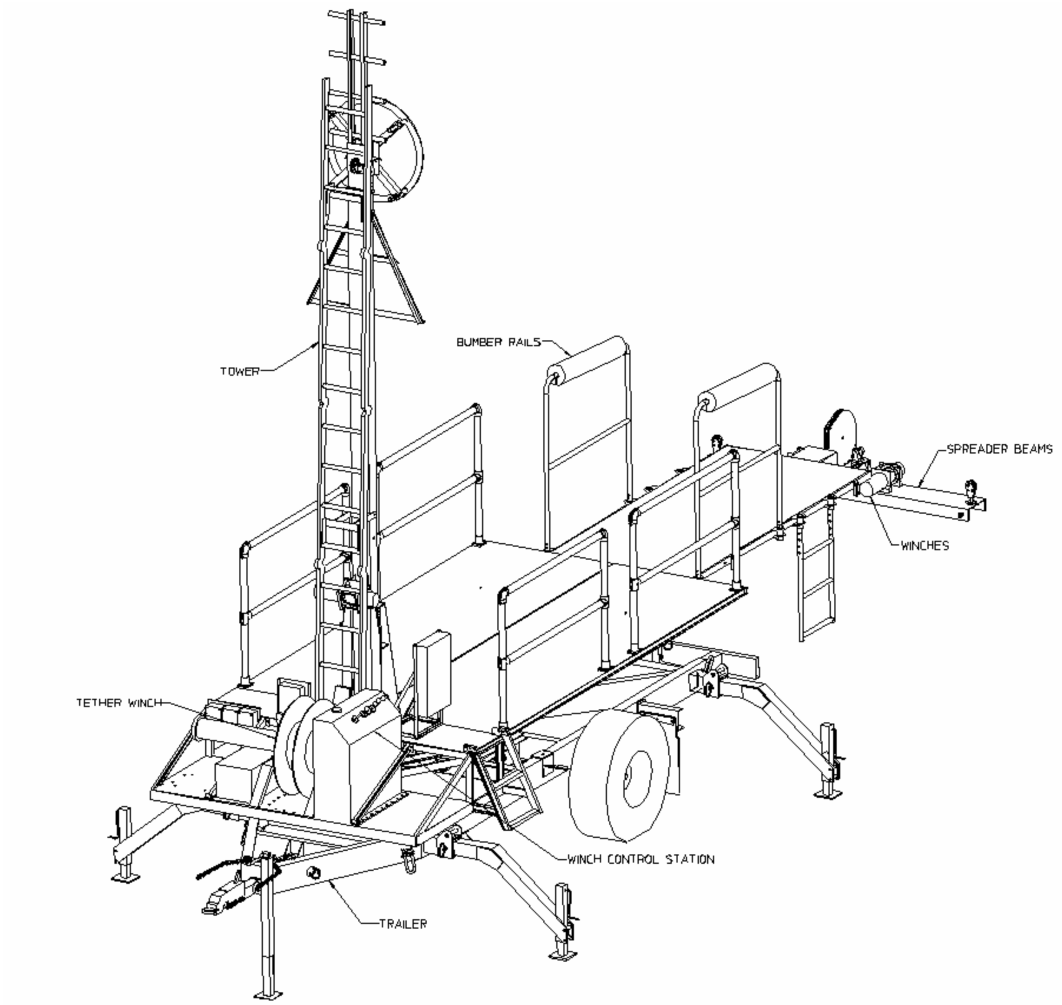

Figure 3. Mooring System Deployed

The mooring system is based on a small boat-style trailer, either made of steel or aluminum to which a rotating platform is mounted. Through this bearing are slip rings for ground power and payload signal. Above the bearing is a platform that contains everything necessary to operate the aerostat.

The electric nose winch and tower secures the aerostat nose during launch and recovery and holds the aerostat in place while moored.

The winch control station allows a single person to control the tether, nose and close haul winches with simple joysticks. A generator is mounted on the work platform, if necessary, to provide power to the system in the absence of ground power. The work platform allows access to the aerostat and payload during maintenance operations such as adding helium or replacing/repairing equipment. Bumper rails are located to contact the aerostat (in reinforced areas) during high wind conditions such that the aerostat or payload isn't damaged through contact with the ground or sharp points on the mooring system.

Spreader beams extend beyond the sides of the flying sheave to provide attachment points for the mooring lines and routing of the close haul lines. Electric close haul winches control the aerostat during launch and recovery.

The payload rests on the end of the work platform or often in a cradle at the end of the platform when the aerostat is moored. The system weathervanes with changes in wind direction when the aerostat is moored in this manner. This reduces the stresses induced into the lines or aerostat and keeps the equipment safe. Ladders on either side of the system provide access to the work platform.

The mooring system is designed to control the aerostat in an efficient and safe manner while still being packaged for minimum setup/tear down time and being light enough to be towed by a standard pick-up truck or similar military vehicle such as a HMMWV (Humvee). Two people can deploy the mooring system in as little as an hour. The packed system appears as shown:

Figure 4. Mooring System Packed

IV. Performance

The basic purpose of the system is to carry a useful payload weight to a useful altitude. From the beginning, the goal was a 150-pound payload carried to an altitude of 1000 feet above sea level during standard day conditions. The following chart demonstrates the aerostat's capability for different payload weights with respect to temperature.

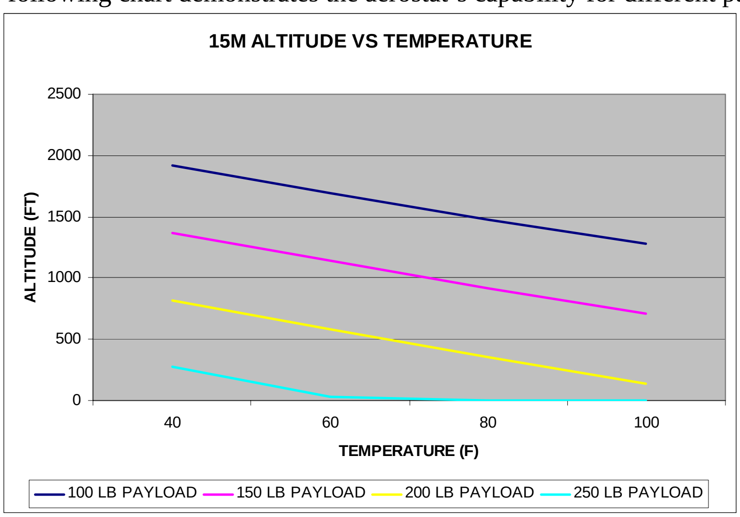

Figure 5. 15M Altitude vs. Temperature

V. Deployment

The first 15M® Aerostats for production were completed in March 1998. The United States military used them for demonstrations, carrying various payloads ranging from radars to cameras to communications relays.

Figure 6. 15M System in Front of Pentagon

Figure 7. 15M System Ready for Deployment

The Israeli military was the first to put the systems to actual use. Through their use of the systems, often for extended periods of times in remote locations, improvements were made to the system. The improvements included safer access to the work platform and aerostat, stronger load patches and nose cone attachment points, better protection of the ballonet from abrasion as well as improved performance of the ballonet blowers. Aerostats were expected to fly for a year or more without deflation and subsequent detailed maintenance and were designed to meet this requirement.

Figure 8. 15M System Being Completed

While these improvements were being made and Israel continued to purchase systems, a commercial customer started to use the system as well.

Figure 9. 15M Aerostat for ACS

Airborne Camera Systems, or ACS, began using 15M® Aerostats in August 2000. This application differed from the military in that the deployment might be for only a few days at a time, enough to cover a local sporting event. Where the Israeli military tested the long-term flight durability of the systems, ACS tested the system's ability to be deployed often, with aerostats often operating beyond 50 inflation cycles. From this experience, improvements were made to the deployment procedures to make deploying the system safer and quicker.

From this experience came the chance for the small aerostat system to be deployed in a larger scale. A complete system was packaged for use in Afghanistan beginning in 2003. Another addition at this stage was a compact helium trailer that could travel with the mooring system making the system even more self-sufficient.

Aerostats and mooring systems continued to be built for use in Afghanistan and later in Iraq. By May 2005, thirty 15M® aerostats were produced for customer use before further changes were made.

Figure 10. 15M Demonstration for UAE

VI. Increased Flight Performance

Customer's payload requirements (and weight) were now increasing and higher pad altitudes were taxing altitude performance. A modification was required to the aerostat that would have little or no impact on the mooring system or support equipment and have minimum impact on the production schedule. A target payload weight of 200 lbs was considered for flight up to 1000 feet. Existing projects would have the benefit of increase performance, such as higher tether tension, when flying from a higher pad height.

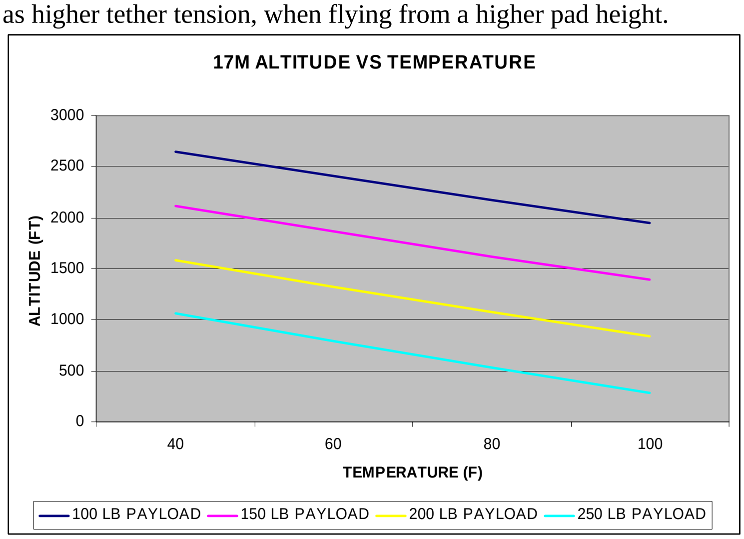

Figure 11. 17M Altitude vs. Temperature

The aerostat was modified with a 1.5 meter plug added at its maximum diameter and renamed the 17M™ System. To mate to the existing mooring system, the rigging, aerostat center of buoyancy, center of gravity and hardware attachment points were adjusted. The new aerostat also incorporated better access to the ballonet for maintenance, lighter, easier to splice fin guy lines, and an APTU that is RF shielded and mounted directly to the aerostat. The APTU used to be mounted in the same area as the payload, but now does not interfere at all with payload emplacement.

Figure 12. 17M in Jordan

The first orders of the new small aerostat system met requirements in Jordan and UAE with the first aerostat produced in June 2005. Since then a new system has been provided to ACS and a large order placed with the U.S. military for systems in Iraq. Sixteen mooring systems and thirty-two aerostats alone have been ordered for the U.S. military in addition to systems that have already been provided to replace damaged assets. TCOM is filling current orders for sixty aerostats and has already completed 15 aerostats at the time of this conference.

VII. Conclusions

The operational wind limit for these systems is 40 knots and the survival wind limit is 55 knots (steady state). These aerostats, on many occasions, have been pushed to these conditions and beyond. Though a small number of aerostats have been lost during operation, these loses have been when the customer has had to put the aerostat in harm’s way to get the job done. Customers from the military and civilian sectors have come to respect and admire what these small aerostat systems can do for them. Lately, aerostats have been damaged beyond what can be repaired in the field in Iraq and Afghanistan. These aerostats are sent back to TCOM for repairs and redeployment with minimum effort; as structurally sound as when they were new.

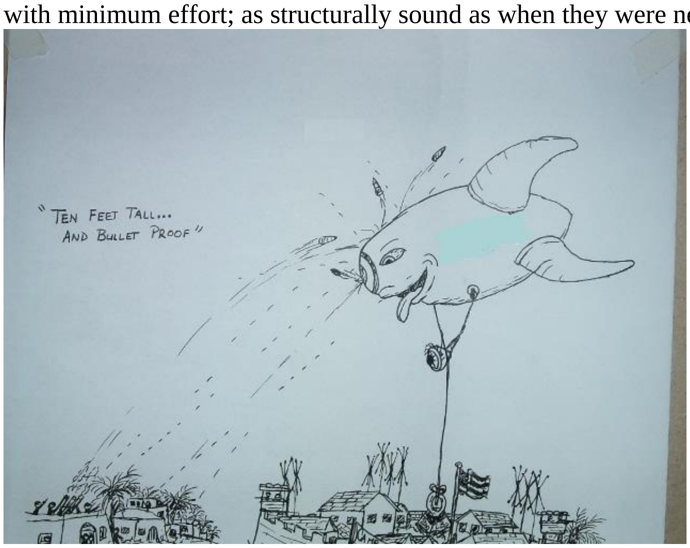

Figure 13. Drawing from U.S. Troops in Middle East

These aerostats have carried many different payloads in many different environments, be it desert, sea, mountains or developed areas. What TCOM envisioned as a mobile, easy to use and adaptable system that could be produced in large numbers is now a reality.