IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Utility Patent Application (Provisional)

TITLE: SOLAR THERMAL BALLOON WITH SOLAR TRACKING AND OPTIONAL ELECTRIC HEATING

INVENTOR: Matthew Mullin

REFERENCES CITED

U.S. PATENT DOCUMENTS

4,237,868 A	9/1978	Overton
3,220,671	7/1965	Ashman et al.
3,337,162	8/1967	Bauserman
4,174,082	12/1977	Eshoo
4,262,864	12/1977	Eshoo
7,997,264	8/2011	Sankrithi
2014/0352756 A1	6/2013	Lam
4,126,123	2/1977	Hall
9,650,122	11/2011	Chessel et. Al
1,866,079 A	12/1929	Blondin
9,033,274 B2	5/2015	DeVaul et. al

ABSTRACT:

The solar thermal balloon disclosed consists of a two-part envelope: one part being a clear film to let in sunlight and another part having a film with an inner reflective or black surface to either focus sunlight onto a heat absorbing material or to directly absorb sunlight, respectively, with an outer reflective surface to reduce thermal radiation loss. A control mechanism, which may consist of, but is not limited to stepper-driven pulleys and timing-belts, flywheels, aerodynamic flaps, and propellers, is used to orient the balloon in the direction of the sun from input from sensors including but not limited to GPS, accelerometers, gyroscopes, light sensors, temperature sensors, pressure sensors, human input, etc. The sunlight can be directed or absorbed in order to generate lift, heat, energy, or other utility, while the balloon also contains storage and backup

systems, which are not limited to but could include electric, thermal phase-change, or chemical in nature. The gas, which heats up and generates lift, can consist of air or another gas or mixture such as N_2, Argon, etc. Optionally, the balloon may also possess electric heating in order to generate lift on the ground or in the air via an electric source such as a battery when solar heating is not sufficient. The balloon can either be free floating or tethered.

BACKGROUND

The invention is primarily applicable to the field of High Altitude Balloons (HABs), High Altitude Platforms (HAPs), and Weather Balloons. There have been a few solar thermal hot air balloons for human flight and solar thermal recreational balloons intended for hobbyists and as children's toys, of which this invention also pertains.

Most, if not all, HABs, HAPs, and Weather Balloons use hydrogen or helium as the main lifting gas. As both hydrogen and helium are less dense than air, the volume of air which they displace in a balloon results in lift from the buoyant force. However, both gases have safety, cost, and environmental issues. While Hydrogen is theoretically a renewable resource, 95% of hydrogen comes from cracking methane CH_4, which releases carbon dioxide CO_2, as this process is more thermodynamically favorable than electrolysis and as a result more cost effective. Likewise, the energy cost to produce enough hydrogen for 1 *kgf* of lift is equivalent to the energy a typical American household uses in an entire day. Hydrogen is also extremely explosive and a hazard to use in HABs, which may be handled by untrained hobbyists or students.

Helium is also a byproduct of the fossil fuel industry and a finite resource, produced from the decay of radioactive isotopes underneath the Earth's crust. As such, helium prices have increased greater than the inflation rate over the decades, and as of the writing of this patent, the world is in a global helium shortage. Helium is critical to laboratories as a cooling agent and for cooling MRI magnets in hospitals, so it's preservation is vital to both the scientific and medical field. Helium, while safer than Hydrogen, presents safety concerns typical to any compressed gas, which again is a hazard to potential students or hobbyists handling it for the purpose of HABs.

Regardless of the lifting gas, most HABs, Weather Balloons, and some HAPs are single use, meaning the lifting gas is lost in the process and the envelope is destroyed. Because of the aforementioned issues and the environmental concerns of fossil-fuel powered conventional hot air balloons, a few inventors created solar thermal balloons.

The original patents for solar thermal balloons (filed between the 1960's and 1980's) have long since expired. Much of the field involves balloons in the conventional form of hot air balloons where solar thermal energy provides sole or supplementary lift. Some designs include implementation of solely solar photovoltaic panels, which resistively heat up air within the balloon as a mechanism for lift. Other designs include a completely black envelope with no actuating or control mechanisms, which results in increased heat loss to the outside environment. Some designs, which have not been implemented, include complex refracting materials such as Fresnel lens films. Previously invented solar thermal balloons tend to have poor control, poor insulation and thermal storage characteristics, low operating temperatures, are similar in design to fossil-fuel powered hot air balloons or require supplemental fossil fuel reserves, and as a result, produce little lift.

The invention also makes use of solar position algorithms (SPAs) created by the Department of Energy (DOE) and the National Renewable Energy Laboratory (NREL), which calculate the elevation angle and azimuthal angle (angle from true north) of the sun based on latitude, longitude, time, and elevation. The SPAs from the DOE fall under the copyright policies of the DOE, but are generally free to use if given the DOE and respective organizations are credited.

SUMMARY

It is an object of the present invention to fulfill flight characteristics similar to that of a typical HAB, weather balloon, human-flight balloon, recreational balloon, or HAP using chiefly solar, electric, a combination, or another renewable energy source, while additionally and optionally performing flight characteristics that allow the balloon to return to its original or determined launch location. It is another object of this invention to have a two-axis control mechanism, aligning the balloon with the azimuthal and elevation angle of the sun to efficiently absorb solar energy for lift and energy storage/generating purposes, and more precisely control internal pressure and temperature, elevation, latitude, longitude, and lift.

In the preferred embodiment of the invention, the balloon envelope consists of two parts: a clear plastic film and a reflective film, which focuses sunlight onto a high solar absorptivity focusing rod, suspended within the balloon's envelope. In order to control altitude and lateral movement, a timing belt actuated by a stepper motor and an inertial flywheel control the azimuthal and elevation angles, respectively, and two-way air pumps, electric heating, and a pressure relief valve also adjust the gas in the envelope. In other embodiments, the focusing rod may contain but is not limited to phase-change materials or materials with high thermal capacitance. Other actuators may control the elevation and azimuthal angles such as fans, propellers, belts drives, chain drives, motors, etc. The reflective surface in the preferred embodiment may be replaced with a solar absorptive surface in other embodiments, and in other embodiments, electrical energy may be obtained from sources which may include but are not limited to solar-thermal, solar-photovoltaic, and wind-power.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG **1** shows the back view of the solar thermal balloon.

FIG. **1**A shows a cross-sectional view of the solar thermal balloon, which exposes a preferred embodiment of the invention using a focusing rod.

FIG. **2** shows the front view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics.

FIG. **3** shows the side view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics. In this view, the motor and bearing can be seen.

FIG. **4** shows the top view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics.

FIG. **5** shows an isometric view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics.

FIG. **6** shows the back view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics.

FIG. **6**A shows the cross-sectional view of the preferred embodiment of the payload and control mechanism for orienting the balloon and storing most of the electronics. In this view, the flywheel, electronics, and double-walled viewport can be seen.

FIG. **7** shows the bottom view of the preferred embodiment of the bottom cap of the balloon, an airport, a two-way air pump, a pressure-relief valve, a port for electronics, and an adjustable hook for the tensioning wire suspending the focusing rod.

FIG. **8** shows an isometric view of the preferred embodiment of the bottom cap of the balloon, an airport, a two-way air pump, a pressure-relief valve, a port for electronics, and an adjustable hook for the tensioning wire suspending the focusing rod.

FIG. **9** shows the front view of the preferred embodiment of the bottom cap of the balloon, an airport, a two-way air pump, a pressure-relief valve, a port for electronics, and an adjustable hook for the tensioning wire suspending the focusing rod.

FIG. **10** shows the side view of the preferred embodiment of the bottom cap of the balloon, an airport, a two-way air pump, a pressure-relief valve, a port for electronics, and an adjustable hook for the tensioning wire suspending the focusing rod.

FIG. **11** shows the software flowchart of the preferred embodiment.

DETAILED DESCRIPTION

The solar thermal balloon generally seen in the back view FIG. **1** and cross-sectional view FIG. **1**A, in the preferred embodiment, consists of a clear plastic film **10**, which is preferably biaxially-oriented polypropylene but can be any clear plastic. The clear plastic film makes up the hemispherical top half of the balloon, which lets in most of the solar radiation, but is largely opaque to reradiated infrared radiation, acting like a greenhouse. Biaxially-oriented polypropylene was chosen in the preferred embodiment because it is a clear thermoplastic and gores of polypropylene can be thermally welded together to form hemispheres or paraboloids when inflated. However, any other clear film can be used for the top half **10** of the balloon, which can be a heat sealable film or glue-able film, including PET, nylon, graphene, etc.

The bottom half of the balloon **9**, in the preferred embodiment, consists of a highly reflective metallized film that reflects the sunlight onto a focusing rod **8**, suspended by two heat-resistant wires **11 12** at the focal point of the balloon. The metallized film can consist of an aluminized or silvered polyamide or a mylar on one or both sides. In the preferred embodiment, the aluminized polyamide film is aluminized on both sides, which serves to not only reflect sunlight onto the focusing rod **8** but also prevent radiative heat-loss to the outside environment. The envelope **9 10** must also be made of a film, which can withstand relatively high temperatures (~400 K). For a balloon in the preferred embodiment, which approximates a spherical shape, the focusing rod is located at a distance of one-half the radius from the bottom of the mylar, along the optical axis, which correlates to the focus of a concave hemispherical mirror. For a balloon in another embodiment, which approximates a paraboloidal shape, the focusing rod is located at the focus of the parabola. Mathematically, a parabola can be described in vertex notation as $y = a(x - h)^2 + k$, where the point (h, k) is the focus. In other embodiments of the invention, the inner surface of the bottom half of the balloon **9** is black and absorbs sunlight directly, where the outer surface can be either black or reflective. In other embodiments of the invention, the balloon envelope **9 10** is not restricted to specific geometries and can include but is not limited to pyramidal, cylindrical, and rectangular envelopes.

In the preferred embodiment, the focusing rod **8** consists of a graphite rod (operating temperature of ~700 K), which has been machined to have fins to increase the convective surface area and attachment points for the high-temperature nichrome wire **11 12** (operating temperature of ~1400K), that suspends the graphite rod along the optical axis and at the focal point of the balloon. The nichrome wire, which can be substituted with other high temperature wire in other embodiments, is also used to heat up the balloon, using electrical heating. When an electrical current is passed through the nichrome wire, due to the greater resistance of the focusing rod, the focusing rod heats up due to resistive heating, according to the I^2R law. The nichrome wire attaches to the top and bottom of the balloon to laser-cut caps **5 6**, which contain adjustable tensioning springs. Additionally, in other embodiments of the balloon, the focusing rod **8** can consist of finned or unfinned geometries, not restricted to cylindrical shapes. The material can be, but is not limited to, aluminum, glassy carbon, titanium, or stainless steel, and coated in a black paint to increase solar absorptivity. The focusing rod **8** can also contain a cavity for a phase change substance such as paraffin wax or a eutectic salt for additional heat storage. In other embodiments of the invention, at or near the focusing rod **8** or other parts of the balloon envelope **9 10** or payload **2**, photovoltaic cells or thermoelectric cells or other energy generating devices can produce electricity for use in the balloon or other purpose.

The gas, which fills the envelope **9 10** in the preferred embodiment is air. However, in other embodiments, other gases such as Argon and N_2 can be used to increase the working temperature of the focusing rod. Additionally, lighter than air gases such as helium and hydrogen can also be used in other embodiments to achieve greater amounts of lift than in conventional balloons, by increasing their average temperature within the envelope **9 10**.

In the preferred embodiment, the payload box **2** is made out of a light-weight and insulative foam, which houses and protects the electronics from the harsh outside environmental conditions. The distance between the payload **2** and the bottom of the envelope **3** is meant to be as small as possible to reduce weight and drag but can vary arbitrarily. The belt **1**, in the preferred embodiment, is a natural rubber timing belt capable of withstanding extreme cold (~210 K) and acts to both attach the payload to the balloon and to also precisely control the elevation angle. In other embodiments, the timing belt is not limited to a particular material and can be replaced with a v-belt, chain, flat belt, or cord. Additionally, cords **13**, in the preferred embodiment, attach to the payload box to provide additional stability and are made of low-temperature (~210 K) resistant silicone rubber. In other embodiments, the cords are optional or can be similar to the timing belt **1** to precisely control the azimuthal angle.

In the preferred embodiment, both the belt **1** and cords **9** are attached to the circumference of the balloon at the hemispherical laser-cut caps **4 7**. In the preferred embodiment, the caps are made of a relatively low thermal conducting and lightweight material such as wood, acrylic, titanium, or steel and attach to both the outer and inner surface of the balloon using bolts. However, in other embodiments, the belt **1** and cord **9** attachment points do not necessarily need to be circumferential and can be made of a variety of materials and use different attachment methods such as glue, suction, magnetic force, etc.

FIG. **2**, FIG. **3**, FIG. **4**, and FIG. **5** show the front, side, top, and isometric views of the control mechanism and payload box **2**, respectively. The attachment points on the payload box **2** for the cords **9** are simple screw clamps **19** in the preferred embodiment but can be any other type of clamp or holder in other embodiments. The preferred embodiment also contains a viewport **18** for taking pictures and video.

In the preferred embodiment, the control mechanism consists of a stepper motor **14** attached to the payload box **2** with a motor mount **15**. The motor's shaft is attached to a timing belt pulley **17** to interface with the timing belt **1** and precisely control the elevation angle. To support the radial load on the stepper motor shaft and reduce the moment, a bearing **24** and bearing mount **16** support the end of the shaft. Additionally, an enclosure **22** prevents the timing belt from slipping in the case of a loss of tension but has enough tolerance to allow the belt to freely move. In other embodiments of the control mechanism, the stepper motor **14** can have a gearbox and is not restricted in motor variety. Additionally, the timing belt pulley **17** can be replaced by other pulleys or gears when interfacing with non-timing belt belts **1**. In other embodiments, tensioning pulleys and springs can be used to keep the belt **1** taught.

In the preferred embodiment, the top of the payload box has a payload sheet **20** that is made from a low-temperature (~210 K) resistant material such as acrylic, wood, or any metal such as aluminum or titanium. The payload sheet **20** is epoxied or glued to the payload box **2** and has mounting holes and sections machined out to reduce weight and attach other parts of the control mechanism such as the motor mount **15**. In order to open and close the payload box **2**, the bottom of the payload box **23** can be removed and secured using wires or cords that wrap around the payload box **2** and by screws **21**. In other embodiments, a separate payload sheet **20** could not be included and is not limited to be attached to the payload box **2** by glue. Additionally, the bottom of the payload box **23** does not need to be the (only) entrance into the payload and is not limited to other mechanisms.

In the preferred embodiment, the payload **2** houses a high speed brushless motor **25**, which controls a flywheel **26**. Depending on the speed and direction of the flywheel **26**, the balloon will turn in the opposite direction, controlling the azimuthal angle. The motor **25** is mounted to the top of the payload box **2**, such that it does not interfere with the electronics **28**, which consist of GPS tracking devices, resistive and chemical heaters, temperature and pressure sensors, microcontrollers, batteries, electronic speed controllers, etc. The viewport **27** for cameras consists of two pieces of acrylic separated by air, which acts as insulation. In other embodiments, control of the azimuthal angle (and the elevation angle) could be controlled by a timing belt mechanism similar to the belt **1** controlling the elevation angle or by aerodynamic flaps, actuators directly on the envelope of the balloon, or motor-driven propellers. Additionally, the electronics carried in the payload are not limited to the aforementioned ones and can be found on the outside of the payload or in other parts of the balloon such as within and outside of the balloon envelope.

In the preferred embodiment of the balloon, FIG. **7**, FIG. **8**, FIG. **9**, and FIG. **10** depict the bottom, isometric, front, and side views of the bottom cap of the balloon **6**, respectively. The bottom cap of the balloon **6**, along with the top cap **5** and hemispherical caps **4 7** is made of acrylic or wood or a light-weight, low thermal conductivity metal such as titanium or steel. The bottom cap **6** consists of three sheets of material sandwiched together **35** with an O-ring around the perimeter that clamps onto the balloon material and creates a gas-tight seal. The bottom cap **6** seal design **35** is similar to the top cap **5** and hemispherical caps **4 7**, which are not shown in detail. Gas enters and exits the balloon through both the tapped port **32** and the two-way air pump **30**. The two-way air pump **30** is controlled by the electronics **28**, which can be used to gain or lose elevation by adding or removing air from the envelope **9 10**. Additionally, an adjustable pressure relief valve **29** keeps the balloon at a set pressure and prevents the balloon from over-inflating or popping as it gains altitude and the outside air pressure decreases. There is an electronics port **31**, which allows cables to run from the payload to the sensors inside of the balloon and provides a place to mount sensors within the balloon. Additionally, the attachment point for the nichrome wire **33** allows for the nichrome wire **12** to be looped or knotted to the bottom cap, with a tensioning spring in series, and the attachment point **33** sits on an adjustable thread **34** for loosening or tightening the tension on the focusing rod **8**. In other embodiments, the geometry of the bottom cap **6**, top cap **5**, and hemispherical caps **4 7** can be different, as well as the placement and implementation of the pressure-relief valve **29**, air-pump **30**, and port **31 32**. The bottom cap **6** was chosen, in the preferred embodiment, for the placement of most of the additional components as compared to the top cap **5** and hemispherical caps **4 7**, because the bottom cap **6** does not optically obstruct sunlight from hitting the focusing rod **8**.

FIG. **11** depicts the general software flowchart for the balloon in the preferred embodiment. In parallel, the balloon receives sensor data from GPS, real time clock (RTC), accelerometers, gyroscopes, temperatures sensors, and absolute pressure sensors, and computes a variety of variables such as the current solar elevation and azimuthal angles, the optical orientation of the balloon, the absolute and gauge pressures of the balloon envelope, and the temperature of various components such as the focusing rod **8**, the envelope **9 10**, and the payload **2**. Based on the sensor input and calculated variables, the microcontroller and balloon electronics **28** relay commands to the various actuators on the balloon **14 25 30**. Other embodiments of the invention may have different control algorithms based on the intended flight characteristics, and FIG. **11** is not encompassing of all the software used in the preferred embodiment, which also consists of data collection, altitude and lateral control, and other purposes.

To return to the ground, in the preferred embodiment, a parachute (which is not modeled) is attached to the outer surface of the bottom of the payload box in FIG. **5 23**. However, in other embodiments, the parachute can be located in other areas, which may include but are not limited to the top cap **5**. In other embodiments, the two-way air pump **30**, as well as other actuators, which may include but are not limited to aerodynamic flaps, the stepper motor **14**, and flywheel motor **25**, are sufficient to control the balloon's elevation and land the balloon to the original location or another location relative to where it launched.

In the preferred and alternative embodiments of the invention, the power source powering the electronics **28** of the balloon can include but are not limited to solar photovoltaics, batteries, wind turbines, propellers, and capacitors. While the payload **2** detailed in the preferred embodiment is designated for HABs, HAPs, and weather balloons, in other embodiments the payload can take various forms and be used to carry things which may include but are not limited to people, cargo, or communications equipment.

CLAIMS

While the preferred embodiments of the invention have been detailed with references to the attached Figures, for those skilled in the art, other embodiments and variations of the invention are possible within the scope and spirit of the invention.

What is claimed:

1. A solar and electric-thermal balloon, comprising:

An envelope;
A payload suspended from the envelope;

A part of the envelope that is transparent or clear, allowing solar radiation to easily pass through but opaque to reradiated infrared radiation;
A part of the envelope that is highly reflective on both the inner and outer surfaces to both focus solar radiation and reduce radiative heat loss, respectively;
A focusing rod located within the envelope along the optical axis, which can withstand high temperatures and convects heat to the gas within the balloon

2. The balloon of claim 1 in which the focusing rod is suspended by high temperature-resistant wire.
3. The balloon in claim 2 in which an electric current can be supplied through the wire to resistively heat the focusing rod.
4. The balloon in claim 1 in which the focusing rod contains a phase-change substance or substance to store thermal energy.
5. The balloon in claim 1 in which the orientation of the balloon is controlled one or more axes by a belt and pulley system.
6. The balloon in claim 1 in which the orientation of the balloon is controlled on one or more axes by a flywheel.
7. The balloon in claim 1 in which the orientation of the balloon is controlled on one or more axes by aerodynamic flaps.
8. The balloon in claim 1 in which the orientation of the balloon is controlled on one or more axes by motorized propellers, fans, or jets.
9. The balloon in claim 1 in which the inner surface of the reflective part of the envelope is replaced with a black or highly absorptive surface to solar radiation
10. The balloon in claim 1 in which the balloon contains a pressure relief mechanism to release air as the balloon increases in altitude to prevent the envelope from rupturing.
11. The balloon in claim 1 in which the balloon contains a gas-pump to control the amount of gas within the envelope for ascent and descent.
12. The balloon in claim 1 in which the balloon contains a payload which may carry cargo, scientific equipment, or passengers.
13. The balloon in claim 1 in which the balloon contains a temperature sensor to control the temperature of the balloon using the balloon's actuators
14. The balloon in claim 1 in which the balloon's elevation and location are controlled by adjusting aerodynamic flaps, motorized propellers, two-way air pumps, or any other of the balloon's actuators.
15. The balloon in claim 1 in which the balloon's electronics are powered by renewable resources such as solar photovoltaic, thermoelectric, wind-powered, etc., which are mounted on or within the envelope or payload or focusing rod.

FIGURES

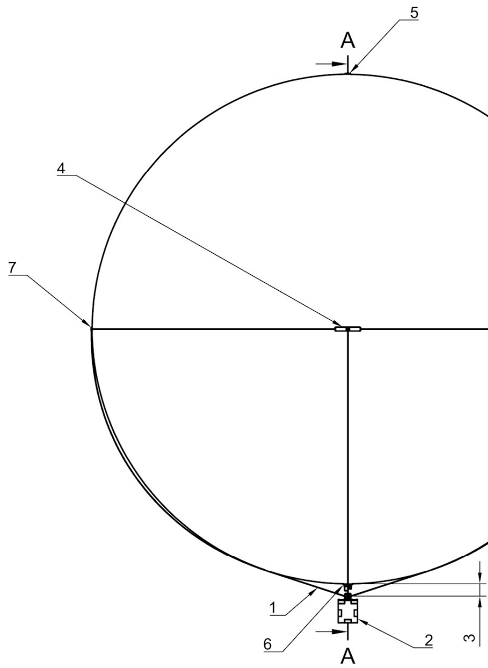


FIG. 1

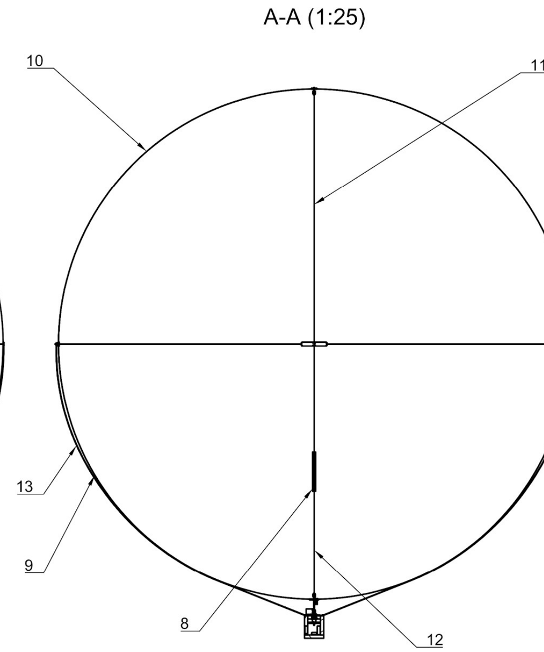


FIG. 1A

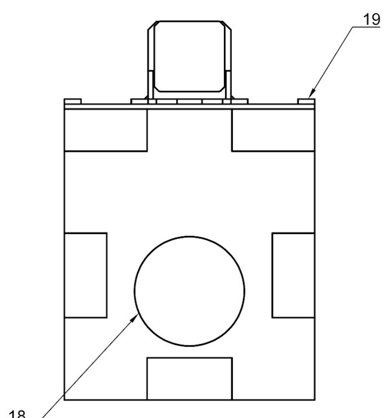


FIG. 2

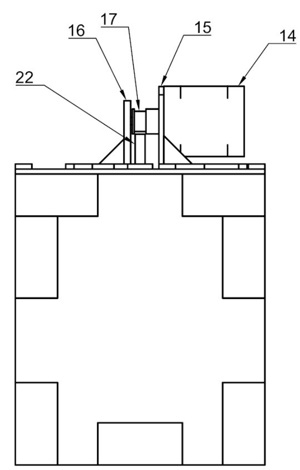


FIG. 3

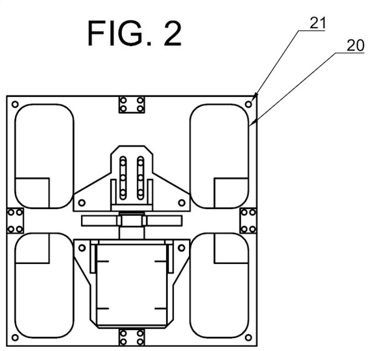


FIG. 4

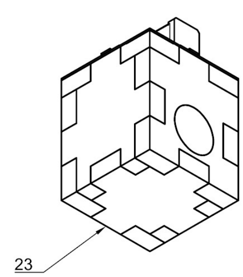


FIG. 5

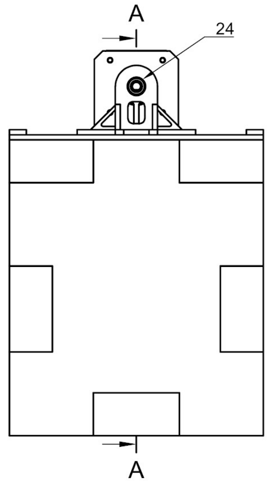


FIG. 6

A-A (1:2)

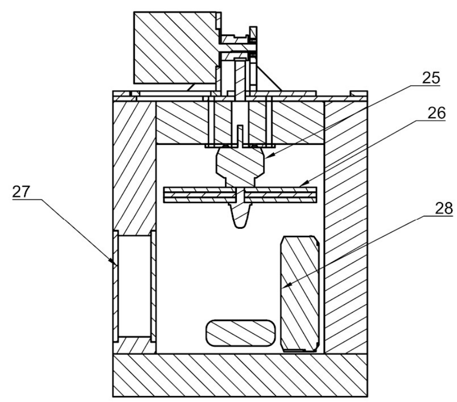


FIG. 6A

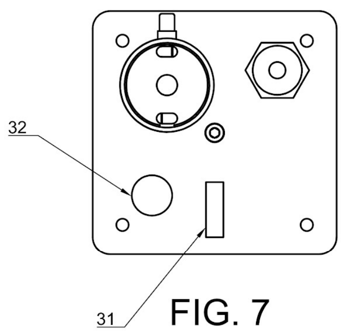


FIG. 7

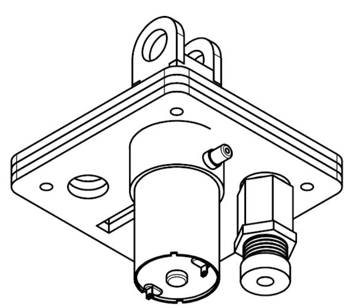


FIG. 8

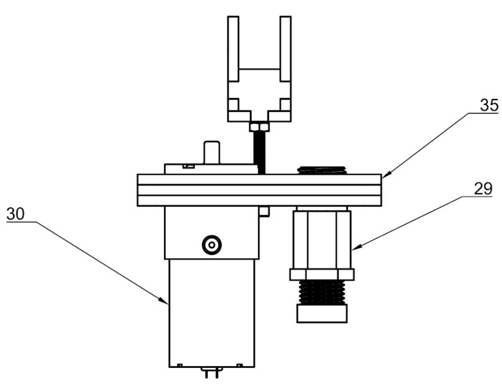


FIG. 9

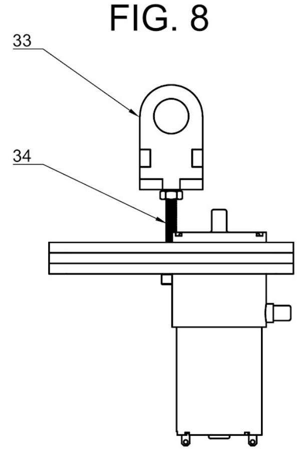
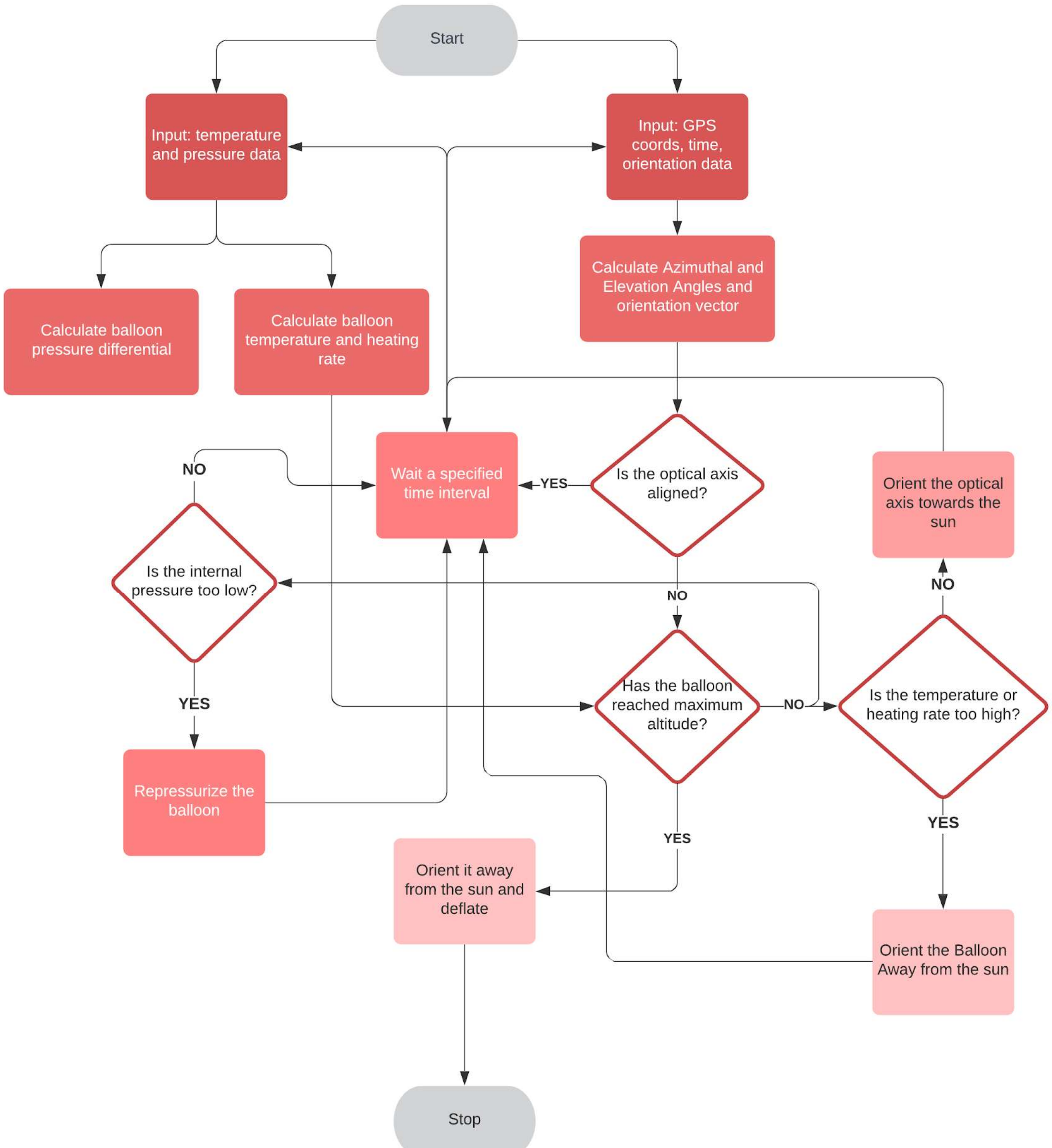


FIG. 10



Start
Input: temperature and pressure data
Input: GPS coords, time, orientation data
Calculate balloon pressure differential
Calculate balloon temperature and heating rate
Calculate Azimuthal and Elevation Angles and orientation vector
NO
Wait a specified time interval
YES
Is the optical axis aligned?
Orient the optical axis towards the sun
Is the internal pressure too low?
NO
NO
Has the balloon reached maximum altitude?
NO
Is the temperature or heating rate too high?
YES
Repressurize the balloon
YES
YES
Orient it away from the sun and deflate
Orient the Balloon Away from the sun
Stop

FIG. 11