Montgolfiere Aerobots for Titan

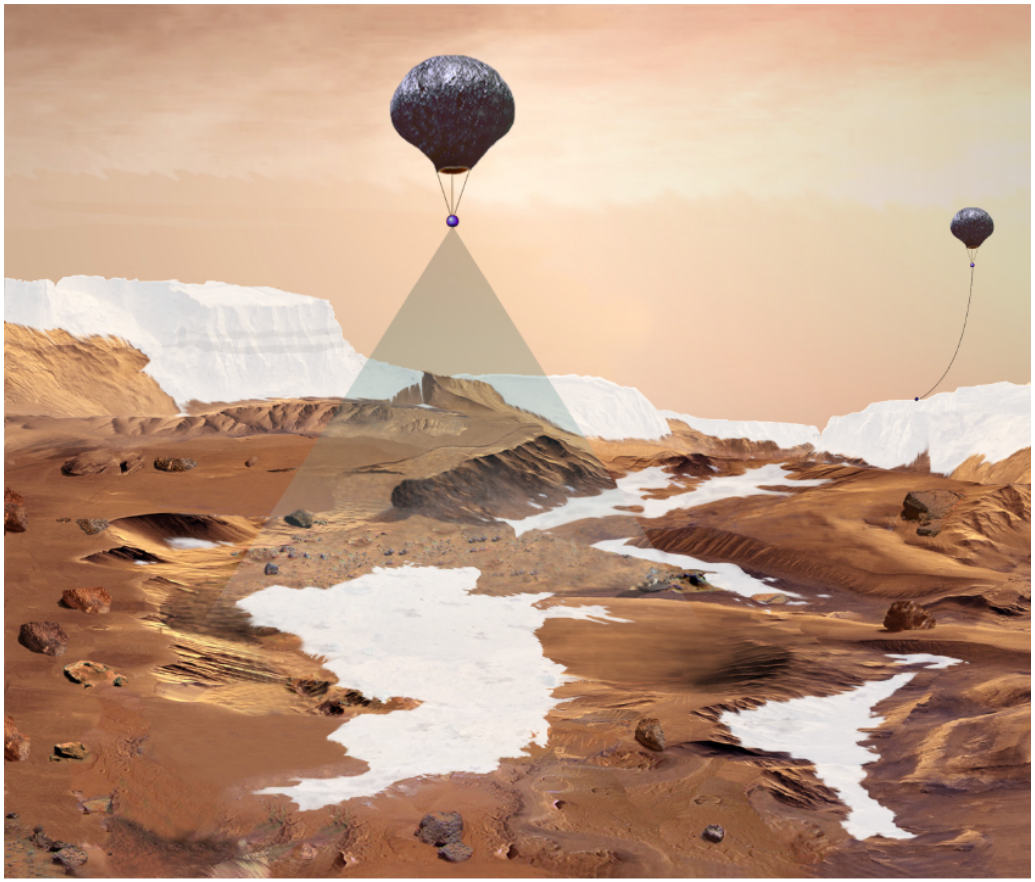
A Presentation to the Fourth
International Planetary Probe Workshop
Pasadena, California, USA
June 29, 2006

Jack A. Jones and Jiunn Jenq Wu
Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive, Pasadena, CA, 91109

Montgolfiere History

Montgolfieres, which are balloons that are filled with heated ambient atmospheric gas, were first flown in 1783 by the Montgolfier brothers in France. The original Montgolfiere used burning wool to heat air inside a balloon, while present commercial hot air balloons more commonly use burning propane.

Mars Solar Montgolfieres



The Jet Propulsion Laboratory (JPL) has been involved in the testing of solar-heated Montgolfieres for Mars since 1997. These balloons could potentially be used as lightweight parachutes to more gently land small payloads on Mars, or they could be used for multi-month missions during the polar summers, which are about 6 months long.

Solar Montgolfiere Deployments

JPL low altitude deployments of solar Montgolfieres

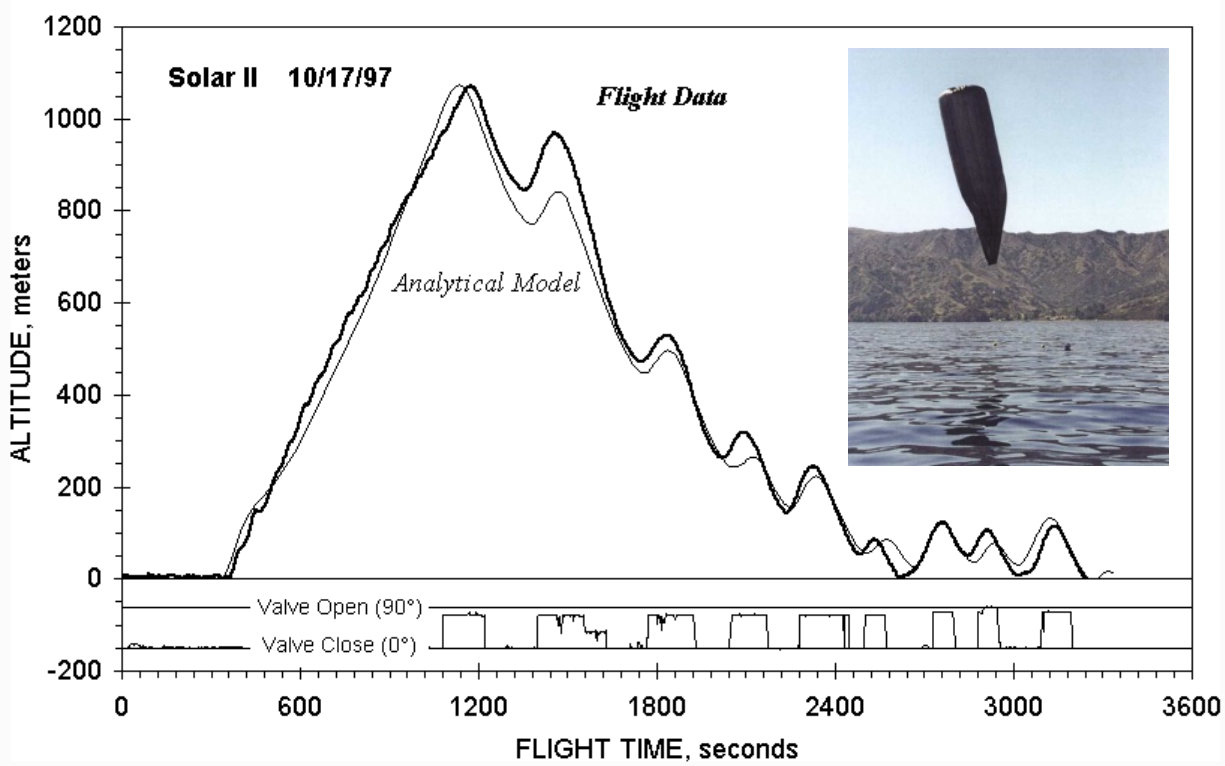
- Since the 1970s, the French Centre National d' Etudes Spatiales (CNES) has flown over forty large solar and infrared-heated Montgolfieres in the Earth's upper stratosphere, which is similar to the Martian atmosphere, for periods of up to 69 days.

- JPL deployed many dozens of low altitude 3–5 meter diameter solar Montgolfieres during 1997–1998. These balloons had a small opening at the bottom of the balloon that allowed them to fill while falling. All balloons that had a means to hold the bottom hole open were successfully deployed

- JPL has also successfully deployed several stratospheric Montgolfieres up to 15-m in diameter, and we are now testing stratospheric deployment for Montgolfieres up to 30-m diameter. The Titan Montgolfieres would be over 100 times stronger than the Montgolfieres for Mars.

Montgolfiere Altitude Control

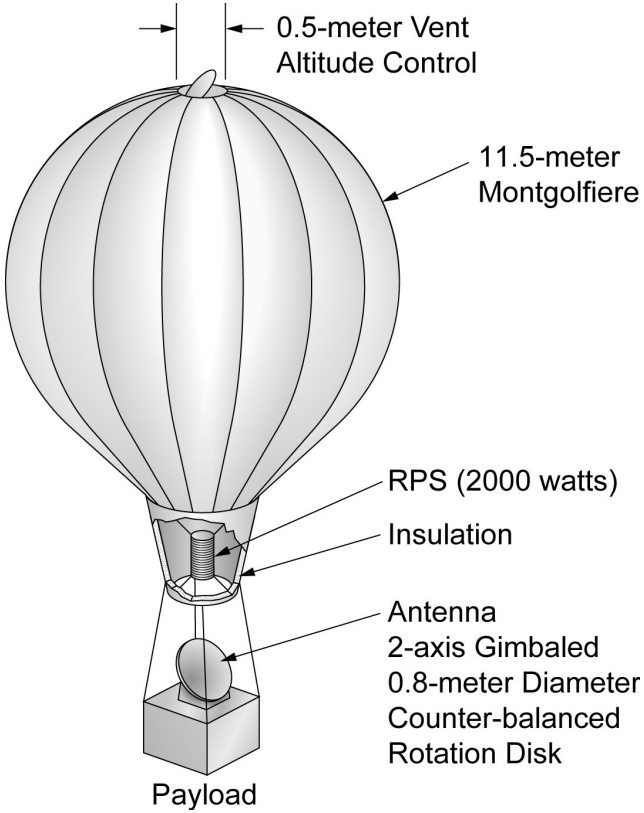
Commercial Montgolfieres hovering over water

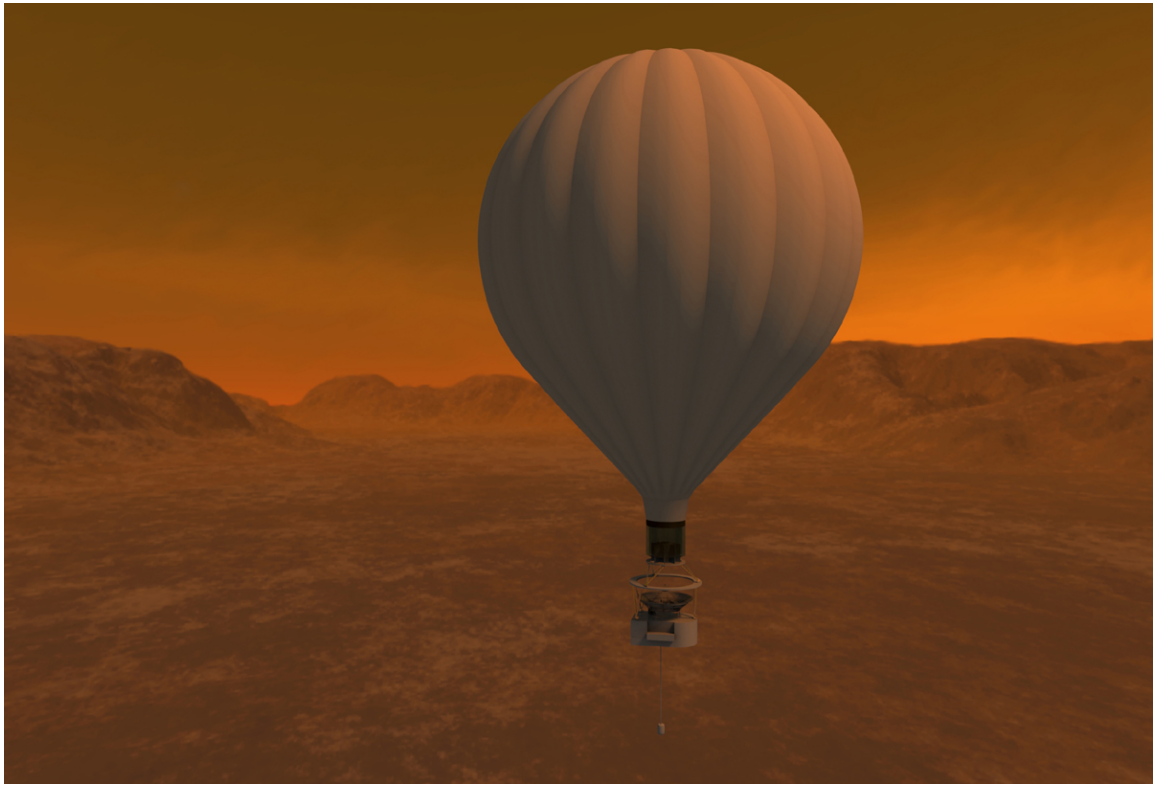


JPL solar Montgolfieres hovering over water, while landing several times.

Montgolfieres are well-known for precision altitude control, and our solar Montgolfieres have also demonstrated reasonably accurate control by means of a radio-controlled vent in the top of the balloon. The performance very closely matched thermal analyses.

RPS-Heated Titan Montgolfieres





One of the simplest and most reliable altitude-controlled atmospheric missions for Titan is that of a radioisotope power source (RPS)-heated Montgolfiere. This type of balloon is heated by the RPS, which has a half-life of 88 years, and the balloon is extremely forgiving to numerous small leaks. The Titan atmosphere is ideal for ballooning, since its density is four times that of earth (1.46 bar, 93 K), and turbulent weather is extremely rare and likely avoidable.

Why do Montgolfieres on earth require 100 times more power than on Titan?

- On earth, a 17-m propane Montgolfiere requires about 200,000 watts to float a 400-kg payload at 0.9 bar (8 km)
- On Titan, a 17-m RPS Montgolfiere requires only about 2,000 watts to float a nearly similar payload of 330-kg at 0.9 bar

Heat = (Hr+Hc)*A*(T-Tamb)

Hr=Radiation Coef, Hc=Convection Coef

A = Balloon Surface Area

$(Hr+Hc)_{Earth}/(Hr+Hc)_{Titan}=(7+2)/(0+1)=9$

$A_{Earth}/A_{Titan}=1$

Buoyancy~Density*(T-Tamb)/T. Since Density=P/RT

Bouyancy ~$(T-Tamb)/T^2$

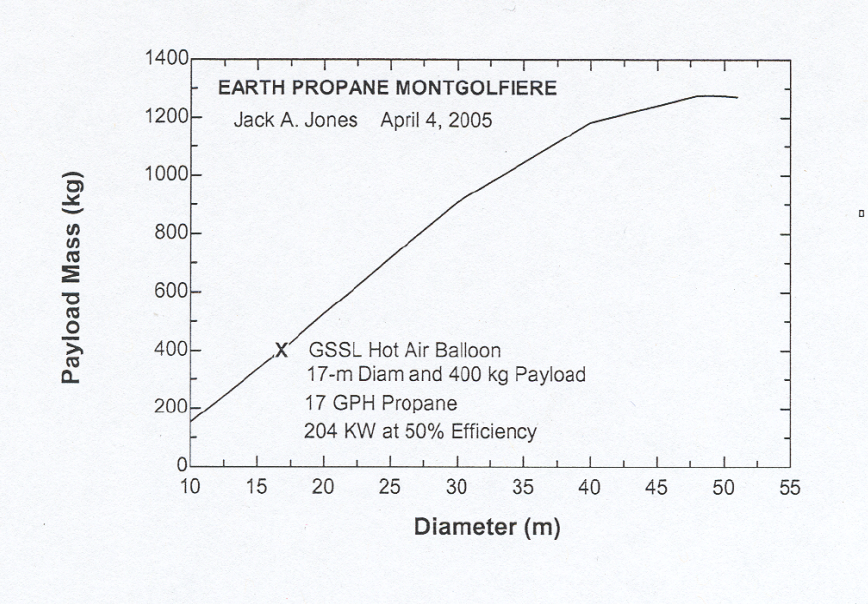
Thus, (T-Tamb)~Buoyancy*T^2

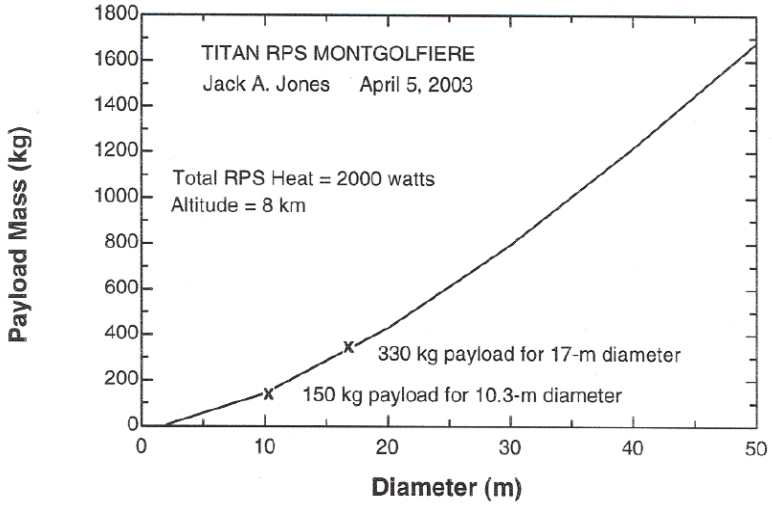
For similar Buoyancy, then

$(T-Tamb)_{Earth}/(T-Tamb)_{Titan}=(293K)^2/(85K)^2=12$

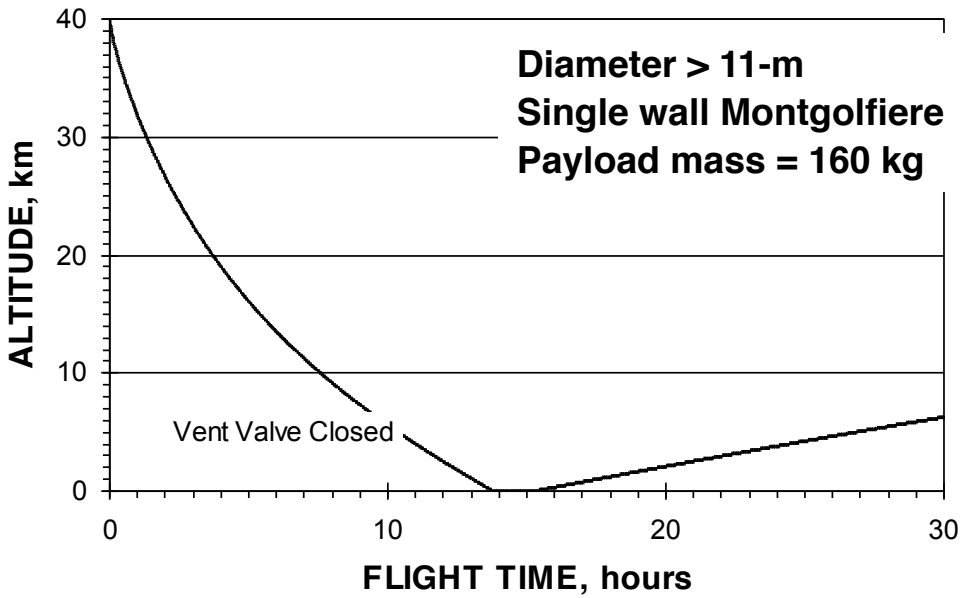
Thus,

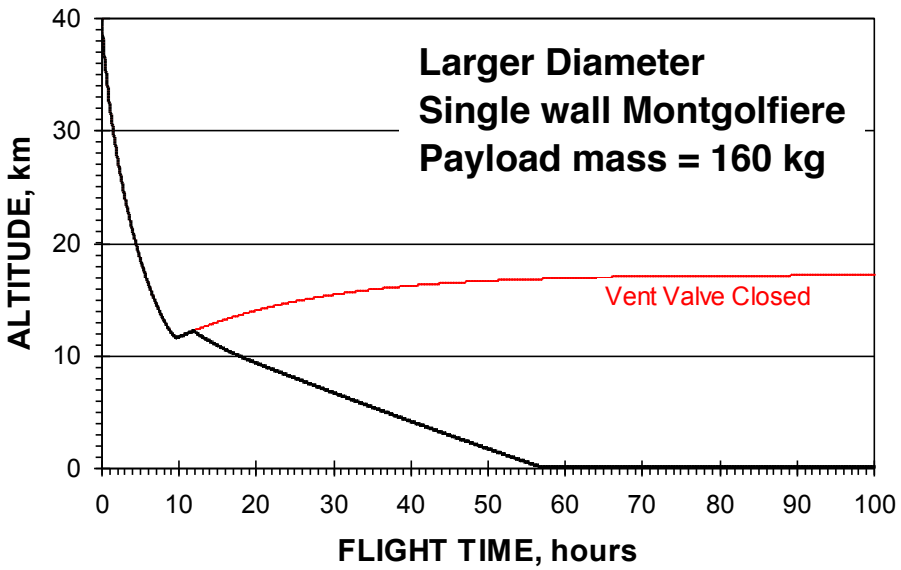
$Heat_{Earth}/Heat_{Titan}=9*1*12=108$





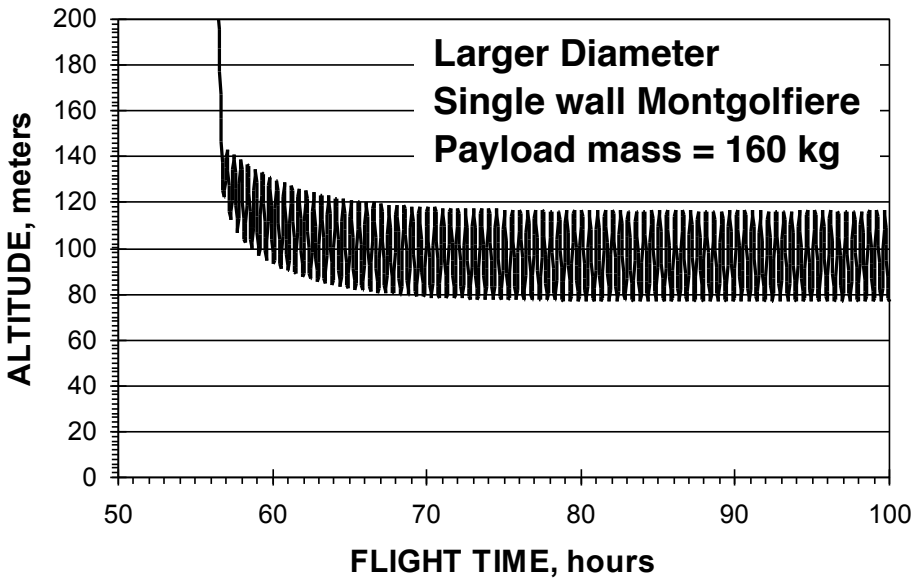
Titan RPS Montgolfiere Thermal Analyses

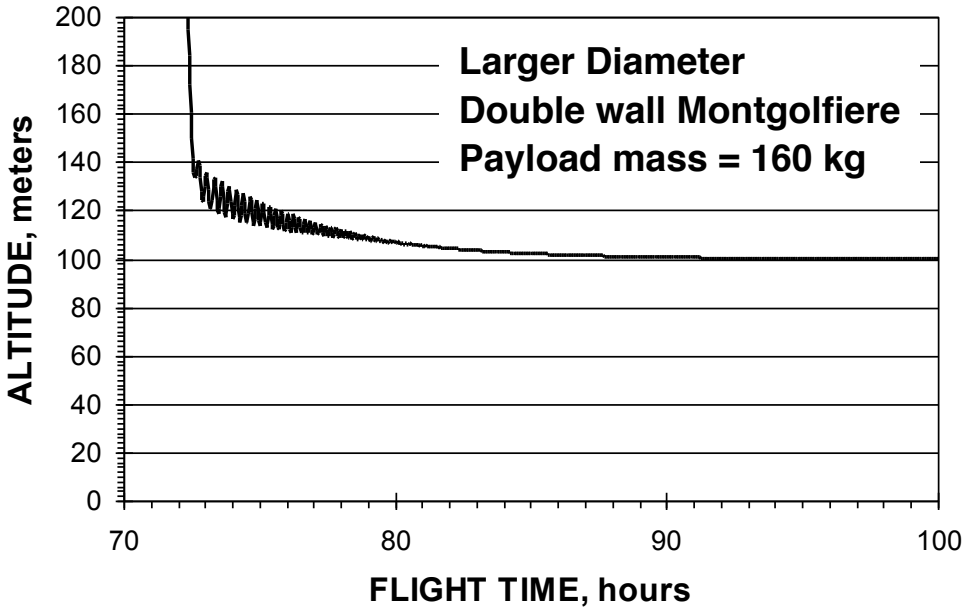




Large diameter Montgolfieres are required to obtain positive buoyancy before they hit the ground. Their maximum altitude is higher, unless the upper vent is open.

Titan RPS Montgolfiere Thermal Analyses



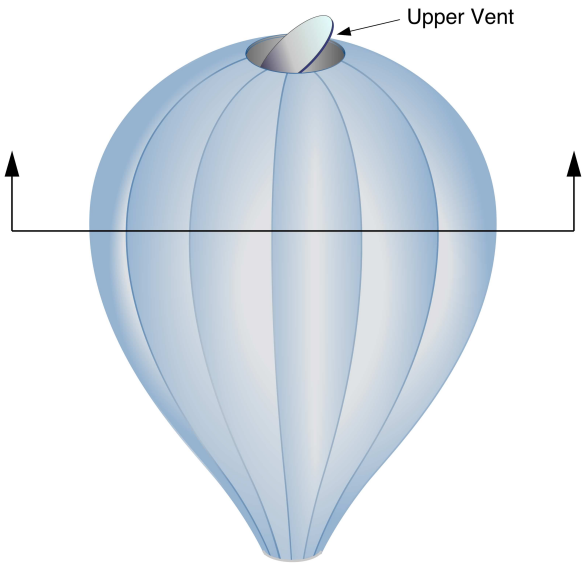


A double-walled Montgolfiere can obtain a much more stable altitude, since it's temperature and buoyancy are much less affected by vertical motion. It can also be smaller, since it is better insulated.

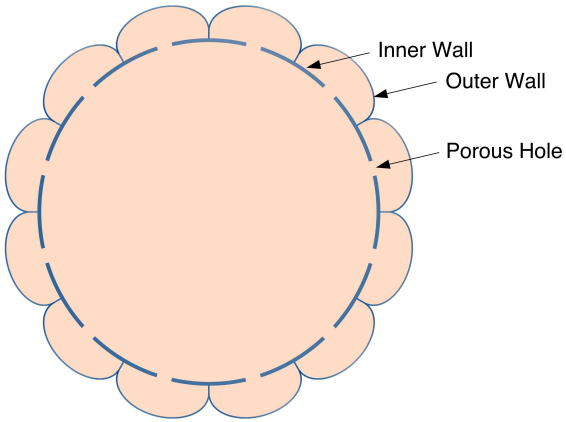
Double-Walled Montgolfieres

Rozier Balloons

Aerostar International Competition Montgolfieres



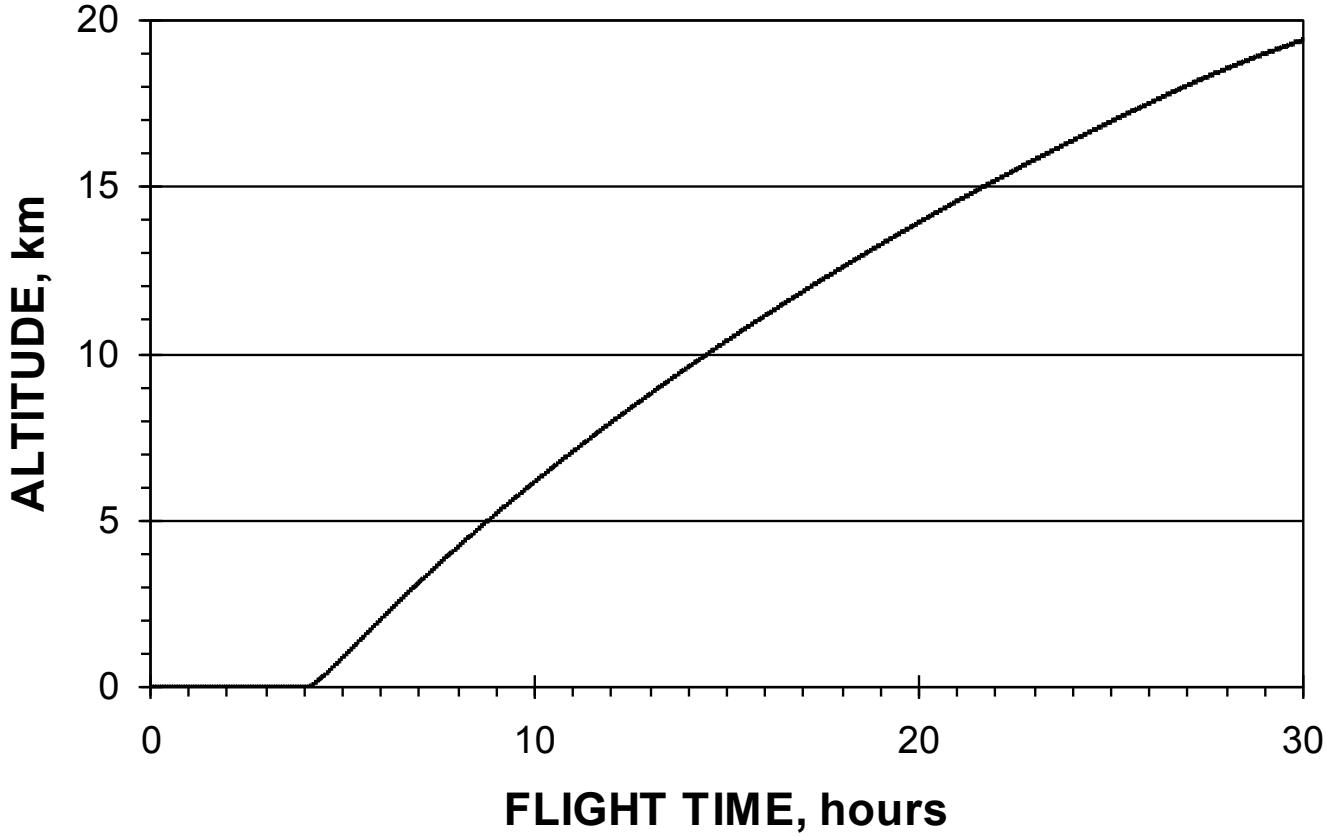
Montgolfiere Front View



Montgolfiere Mid-Cross-Section View

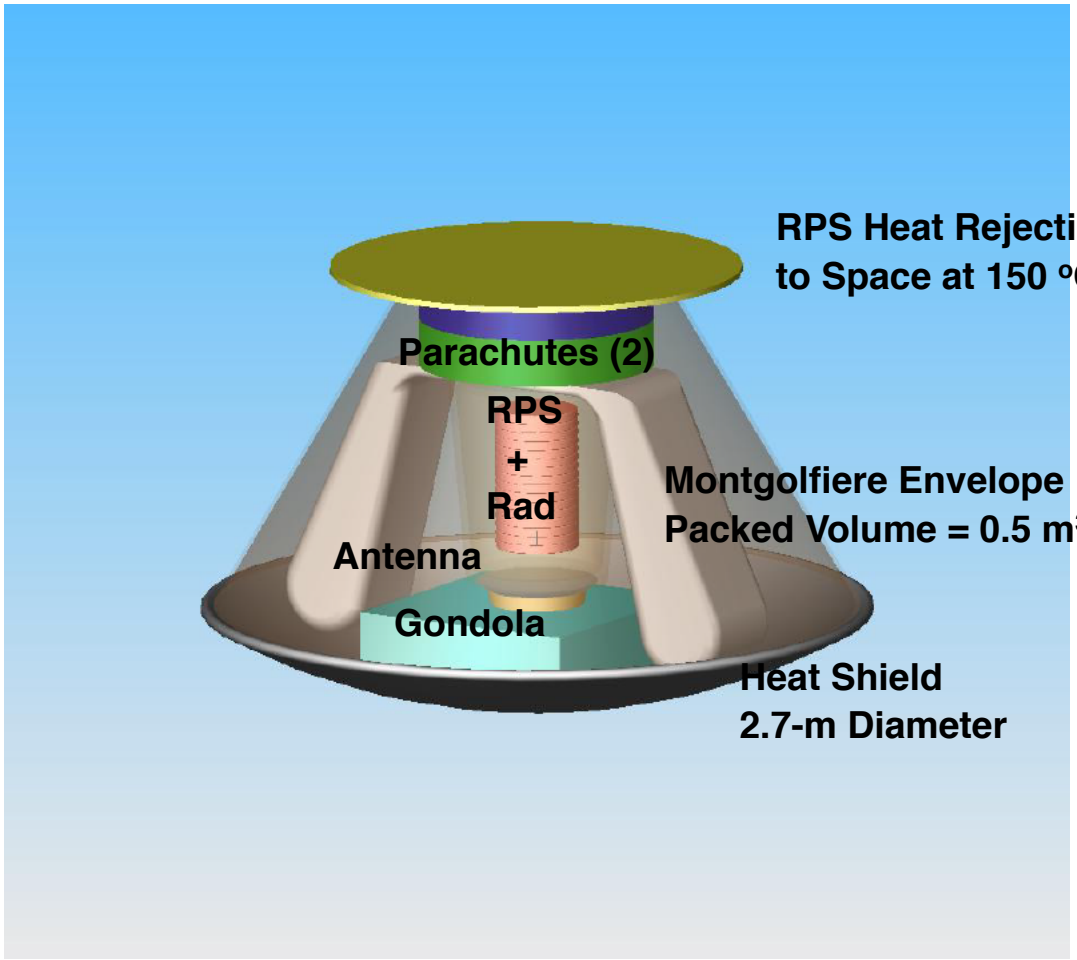
The double wall of the Titan RPS-heated Montgolfiere would be similar to the Aerostar design and would have an inner porous balloon, surrounded by a larger diameter balloon, which keeps an insulating gas layer in between.

Titan Montgolfiere Ascent/Descent Rates



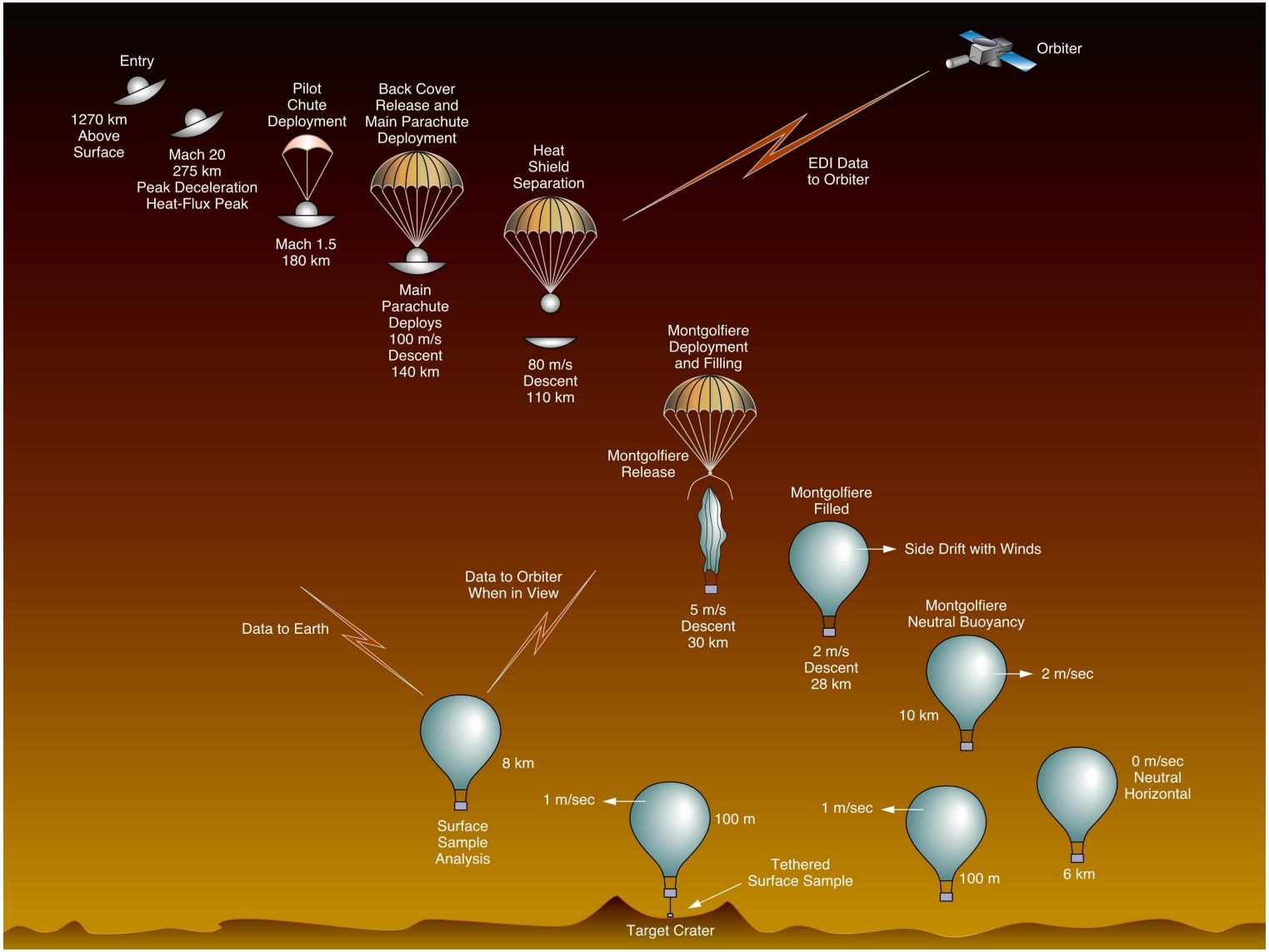
If the upper vent valve is fully closed, it takes about one hour to climb to 1000-m altitude. With a surface wind of 1 m/sec, this corresponds to a 15º climb angle. For a descending balloon, the allowable safe descent rate has been calculated to be at least 1 km/hr.

TITAN RPS ENTRY VEHICLE



The Montgolfiere envelope would be tucked to two sides to allow for last-minute placement of the RPS inside the entry vehicle prior to launch.

Titan Montgolfiere Deployment Scenario



SUMMARY AND CONCLUSIONS

- Titan is an extremely interesting moon, since it was at one time geologically and chemically very similar to the early warm Earth when life first appeared. Both had warm liquid water oceans and thick nitrogen/methane atmospheres. Life on Earth changed the methane portion of the atmosphere to oxygen and carbon dioxide, but Titan cooled quickly and became literally frozen in time. Titan is known to have at least one presently active volcano.

- The ideal means to explore vast areas of Titan is the use of aerobots, since Titan has a very thick atmosphere for buoyancy and rarely has turbulent weather, which can likely be avoided.

- The primary scientific goal of a global aerobot mission is to look for evidence of ancient biotic or pre-biotic activity in the atmosphere and in the frozen surface water ice of Titan. The balloon could also search for possible present biotic activity in recently discovered active volcanic region(s).

- The simplest and safest aerobot to explore Titan is the use of a RPS-heated, double-walled Montgolfiere. It should have a very long life (88 year half-life power source), is very forgiving to numerous small leaks, and can likely attain global coverage by flying with the various winds at different altitudes. By using a tethered sampler, it should be capable of examining numerous surface samples for evidence of past or present biotic activity.