Growing Large Glass Structures in Space

Project Abstract

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Presented is idea of producing spherical glass habitats and other structures in space by melting and growing initial glass spheres. With initial diameter in 1m – 2.5m range, final sphere can reach 4.5m – 18m diameter maintaining 8mm mantle. Growing based on simple physical principle takes place in a solar-powered furnace capable of steady production with outputs in 1000's of m^3 *of habitable volume per year. Glass spheres can be efficiently processed to habitats for space tourist or research complexes on LEO, or utilized on the surface of Moon.*

Space is an ideal environment for growing large structures made of glass. First, without gravity and any preferred direction, a small glass sphere will grow uniformly, taking initial shape and glass material properties are maintained. And, secondly, the sphere, driven by small amount of pressurized gas inside it, will grow practically to any deliberate size as long as glass temperature is above the softening point – the driving gas pressure is always positive over the vacuum environment outside.

On the other hand, controlling initial shape, material properties, or distribution of heat supplied to the glass, or centrifugal forces due to any rotation during growing process, one can grow non-uniform and still well-reproducible shapes. And vice versa, by applying such procedures, the glass sphere could grow to perfection by eliminating any possible irregularities in glass thickness or shape in the closed-loop growing plant.

One-meter-sized initial glass sphere, with size and mass well in limits of today's space technology – especially the rocket technology of emerging private space-access sector – can be grown into 4.5-meter sphere with 8-mm thick mantle – enough to maintain secure structural integrity with normal air pressure inside, to perform as human habitat in space with excellent viewing properties (see graphs in Figure 1). 3 starts of a 10-ton LEO vehicle can supply enough initial glass spheres with potential for building more than 1000 m^3 habitable volume in space – far beyond the capabilities of largest present-day carriers delivering solid habitats. In comparison, ISS offers 425 m^3 of habitable volume (December 2006).

Glass can be easily handled – drill, bond, match – with inexpensive technologies, mainly by applying heat to the glass shape. This can be done by human force or using relatively simple remote-controlled technology. The spheres could be made non-transparent or non-translucent in part or as whole, to maintain necessary light conditions or privacy when asked.

Glass spheres or more complex shapes can be bound together by flexible tunnels equipped with doors that act as corridors for inhabitants and supply energy and other infrastructure into the glass modules; then, with some extra equipment like attachment nodes, power and oxygen generators etc., a hotel or a research station in space can be built. Larger, heavier spheres, with more than 10 meters in diameter, could be utilized as rooms for space sports of any kind, as conference rooms, viewing lounges etc., while smaller, lighter spheres, with extra secure glass material, serve as personal habitats. Even not “easily” built, this could be done by far less resources than any present-day technology offers!

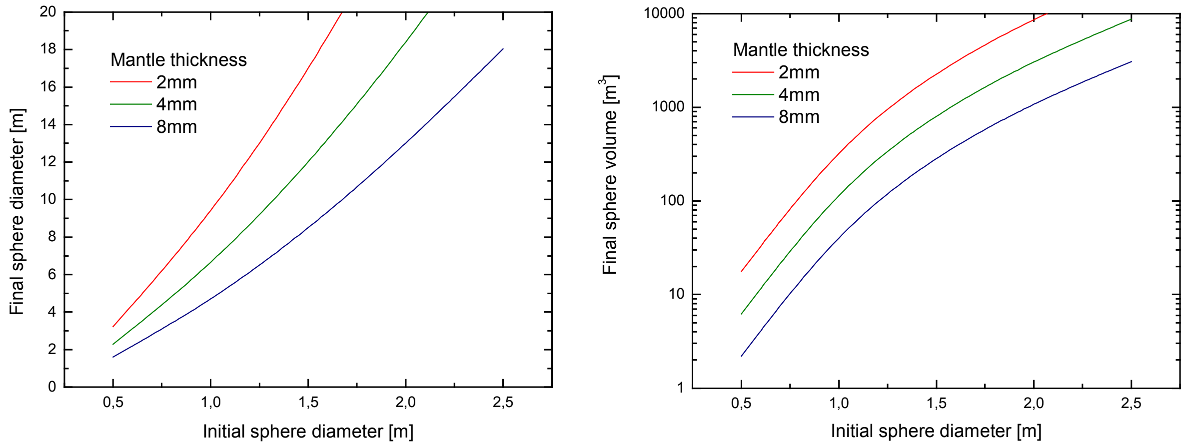

Figure 1a. Final sphere diameter and b. sphere volume versus initial sphere diameter for various mantles.

Security and robustness of glass spheres can be multiplied by stacking glass spheres one on the other, isolated with a polymer material or simply by air gap. A something larger glass sphere, cut into halves and bound together again around a smaller sphere, with some 100-mm gap filled with normal-pressure air, will act as micrometeorite shield, and balance pressure forces acting on the smaller sphere and so eliminate potential changes in its size over larger periods of time. An emerging technological challenge is to prepare a heterogeneous initial sphere that can be grown into sphere with controlled stacked glass surface with superior robustness and stability. Nanomaterial coatings and enforcements of glass is another emerging research area with large potential.

Glass spheres can be grown in one space-borne fab, which is principally a furnace of the corresponding size. Contact, electromagnetic, UV and microwave heating can be utilized; the corresponding energy can be maintained by solar panels. The furnace may comprise two half-spheres, where each half-sphere is made of flexible rays with stretched aluminum-coated foil, equipped with inside-oriented heating emitters and outside-oriented small-impulse thrusters. Initial one-meter glass sphere is locked inside the furnace utilizing the thrusters, then, energy is supplied into the furnace volume and absorbed in the glass, the glass heats up, softens, and grows, driven by the pressure of the gas in the bubble in mid of the initial sphere. When target size is reached, controlled cooling phase is initiated, after that, energy supply is stopped, the furnace opens, and the final glass sphere is handled to other processing. A 20-meter-diameter furnace’s two half-spheres can be stored as some 18x2 meter cylinders during launch, due to the flexible rays and segmented solar panels. Solar energy from round 250 m^2 of solar panels is accumulated in hydrogen-oxygen fuel cells to enable processing one glass sphere in 2-week periods with yearly delivering potential 1000-10000 m^3 of habitable volume depending on the desired habitat sizes. An alternative approach with delivering approx 1 ton of chemical fuel for processing one 1.5-ton glass sphere can lead to a much larger furnace performance (even as large as 1 sphere per day).

Glass is by far not the only considerable material for this type of technology. A sphere made of polymer with proper temperature characteristics could also be grown by heating-up: this time, a ceramic microwave-absorbing core will heat the surrounding gas, and the gas heats the surrounding heat-conducting polymer sphere. As the polymer melts, the sphere will grow driven by the same force supplied by the pressurized gas in its inner. Because of lower softening temperatures and lower mass, the polymer spheres could be produced in larger amounts and shorter periods than glass ones.

The glass habitat whose launch costs are some 30 million USD and total production cost estimate is round 100 million USD, considering today's launch prices, is with 10-year amortization with daily price tag of 27,000 USD and suggested lease 50,000 USD per sphere and day definitively the most expensive apartment of the Universe – but with the space access price exceeding the tag by some orders of magnitude, it can be considered as negligible. And, as habitat costs will slide down with costs for space access, they will never dominate in the budget for the space complex construction and maintenance.

The initial glass spheres delivery, launch facilities, furnace maintenance, energy supplies, final processing of spheres to complex habitats, and maintenance and run of human-rated space complexes, can be done by individual, private companies by conditions incrementally nearing the standard market rules. This will fuel further development of private space sector and the corresponding field of subcontractors. Technologies developed here can found use in further human space presence developments like habitats for settlements on Moon or Mars – perhaps, space-grown habitat spheres can be delivered to Moon by less effort than building-up corresponding structures on the Moon alone. This may be done even cheaper utilizing Moon material, with a furnace placed on the Moon orbit.

Growing glass structures in space is a novel method that offers large amounts of habitable "real-estate" volumes in space by moderate costs and human resources. While some amount of applied research is necessary to enable this technology, including space-borne experiments, the idea is based on physical principles and therefore essentially simple and straightforward. No not-yet-known technology is needed. The technological process can be with advantage sequenced and provided by individual private subjects that could lead to emergence of the first human-space-presence-oriented business sector – a goal that humankind is still dreaming for.