ALTITUDE-CONTROLLED BALLOONS FOR LONG-DURATION FLIGHTS ON VENUS. P. B. Voss, J. Nott, J. A. Cutts, J. L. Hall, P. M. Beauchamp, S. S. Limaye, K. H. Baines, B. Bennett, L. R. Hole, Smith College (100 Green St., Northampton, MA 01060, pvoys@smith.edu), Nott Technology LLC (Santa Barbara, CA, nott@nott.com), Jet Propulsion Laboratory (Pasadena, CA, James.A.Cutts@jpl.nasa.gov), Jet Propulsion Laboratory (Pasadena, CA, jeffery.l.hall@jpl.nasa.gov), Jet Propulsion Laboratory-Caltech (Pasadena, CA 91109, patricia.m.beauchamp@jpl.nasa.gov), University of Wisconsin (Madison, WI, sanjay.limaye@ssec.wisc.edu), Jet Propulsion Laboratory (Pasadena, CA, baines@jpl.nasa.gov), Smith College (100 Green St., Northampton, MA 01060, bbennett@smith.edu), Meteorological Institute of Norway (Bergen, Norway, lrh@metno.no).

Introduction: In situ observations in the upper atmosphere of Venus (65-77 km altitude) could answer many important questions (Limaye 2013, Crisp 2013). This region contains a time-variable absorber of unknown composition that controls many aspects of the heat balance on Venus. Understanding the composition and dynamics of this unknown absorber is an important science goal; in situ optical and chemical measurements are needed. Conventional in-situ measurement strategies are not able to make the repeated traverses over a mission lifetime of several months required to answer the science questions.

This paper examines several balloon designs that offer altitude control and the potential for long-duration flight in the upper atmosphere of Venus. Such balloons could repeatedly measure profiles, avoid diurnal temperature extremes, and navigate using wind shear. The balloons all take advantage of the fact that the atmospheric density around 60 km altitude on Venus is about 40% of the sea-level density on earth and the temperature is relatively moderate at 230 K. While the higher solar flux creates some thermal challenges for balloons, photovoltaic power is available in abundance.

The first balloon type considered, Ambient Gas Ballast (AGB), uses the surrounding atmosphere as gaseous ballast; pumping the ambient gas into a constant-volume balloon adds mass to the system and causes the balloon to descend, while releasing this gas leads to ascent. The second balloon type, Lift Gas Compression (LGC), comprises a zero-pressure balloon and a smaller constant-volume balloon. Compressing the lift gas into the small (superpressure) balloon reduces the volume, effective density, and altitude of the entire system. We also examine a hybrid design in which a zero-pressure balloon is coupled with an AGB system (ZP-AGB).

For an altitude range of 60-75 km on Venus, we find that the required superpressures for these three systems are similar in magnitude. However, superpressure volume and compressor energy consumption are approximately an order of magnitude lower for the LGC system. The LGC balloon has the one disadvantage that is must compress some lift gas at sunrise, but this can be managed by one of several strategies.

Hybrid ZP-AGB balloons share advantages and disadvantages of both systems.

While weight constraints are likely to be significant, LGC altitude-controlled balloons may be a viable platform for accessing the 60-75 km altitude range on Venus. The underlying concept of balloons on Venus was proven by the Soviet Union’s successful deployment of two superpressure VEGA balloons in 1981 operating at a fixed altitude near 55 km. Superpressure balloon concepts for similar altitudes and larger payloads have since been proposed for NASA’s Discovery program and ESA’s Cosmic Visions program. The LGC balloon would add a zero-pressure envelope and a compressor to the established superpressure design, allowing it to ascend above the deployment altitude and realize lossless altitude control over a range of multiple scale heights.