QUESTIONS ABOUT VENUS AND MEASUREMENTS NEEDED TO ADDRESS THEM FROM FUTURE MISSIONS TO VENUS. S.S. Limaye[1] and K. L. Jessup[2], [1]University of Wisconsin, 1225 W. Dayton Street, Madison, WI 53706, SanjayL@ssec.wisc.edu, [2]Southwest Research Institute, Boulder, CO, jessup@boulder.swri.edu

Introduction: Past and current missions to Venus as well as new acquisition and interpretation of data obtained during historical and recent Venus Space Exploration eras have raised some old as well as new questions about the planet and its atmosphere that will require capable missions in the coming decades to gather appropriate measurements from new atmospheric and surface based platforms. Some of these questions are contained in the "Goals, Objectives and Investigations" document prepared by the Venus scientific community [1] through the Venus Exploration Analysis Group (VEXAG), but the nuances and details need some specific emphasis in the future updates.

Old and New Questions: Many of the old and new questions about Venus that remain open relate directly to properties that are essential for our understanding Venus' circulation and weather patterns, atmospheric superrotation, and climate evolution. These questions range from basic properties of Venus - what is the precise albedo of Venus at present and, is the neutral atmosphere of Venus truly well mixed? Results obtained from the Pioneer Venus Large Probe showed a vertical gradient between 52 and 42 km [2]. Recent Analysis of MESSENGER data from the neutron spectrometer yielded a higher abundance of nitrogen at 60 km [3], extending the measured altitude range of the observed gradient in the abundance. This gradient defies the accepted belief that the neutral atmosphere should be well mixed in the primary constituents. However, the fact that both carbon dioxide and nitrogen, the two constituents of the Venus atmosphere should be in super-critical state has not been previously considered and may be the cause of this gradient. Laboratory measurements with supercritical mixtures of carbon dioxide and nitrogen also have been discovered to have such a gradient [4].

The nature and identity of the ultraviolet absorber in the clouds remains unknown, but a consideration of spectral, physical and chemical properties of terrestrial bacteria warrant questioning whether bacteria may be the absorber [5]. Recent research [6] suggests that Venus may have harbored liquid water on its surface for as long as two billion years – long enough to have evolved life, as is being increasingly considered as a possibility for Mars. Terrestrial clouds also have been discovered to harbor bacteria at altitudes as high as 41 km [6] and survive ultraviolet radiation [7] in conditions similar to those found in the Venus atmosphere. Cockell [8] has previously examined the possibility of bacteria in the clouds of Venus. Further, some exoplanet atmospheres may also be capable of harboring life [9], so examining whether or not Venus clouds may harbor life will be useful. No mission to date

The albedo of Venus was inferred from ground based observations by Irvine [10] over 30-160° phase angle range and interpreted using a model by Travis [11]. Recently Mallama [12] used spacecraft observations to extend the phase angle coverage at the low and high phase angles and inferred a much higher albedo, leading to some questions about the energy absorbed by Venus atmosphere.

The length of day on Venus also appears to vary considering that the value the inferred rotation rate from Venus Express from the rotation rate adopted from Magellan radar results [13]. The exchange of momentum between the atmosphere and the solid planet is critical.

The connection between the sun and Earth climate has been a focus of some attention for a long time, but key questions remain in establishing a causal link. Monitoring Venus climate for several solar cycles should be useful in understanding the interaction between the sun and terrestrial atmospheres, which should also be useful for understanding Earth of Venus like exoplanets.

Finally, a recent study undertaken to learn about the interior of Venus also included some measurments from atmospheric platforms including balloons [14]

These and a number of other open questions prioritized by VEXAG require new capabilities to make measurements from within the atmosphere and surface from capable platforms.

Future platforms needed: Long lived aerial platforms capable of sampling the Venus atmosphere within the cloud layer (50-72 km altitude) such as Venus Atmospheric Mobile Platform [15] and below it will enable measurements and monitoring of the atmospheric behavior in the most enigmatic altitude regions over a full Venus day. Monitoring of this altitude region

over this time scale has never been successfully done without temporal or spatial ambiguity, yet this type of monitoring is critical for the interpretation and contextualization of the data gathered.. If such platforms are capable of carrying a significant payload, they will also enable monitoring the surface for any changes by repeated passes over time.

Concepts for altitude changing balloons have been suggested previously, but not yet flown on other planets. Below 50 km altitude, phase change balloons or other options may be feasible but little development has taken place for such platforms.

Some new innovative concepts using ambient wind to generate electrical power and incorporating high temperature electronics for instrument operations, data collection and transmission as are being developed in US and Europe for long lived platforms capable of making some elementary meteorological measurements near the surface will also be very useful.

Such platforms can be considered for a future Venus flagship mission. Development efforts are needed for maturation of the required platforms and instruments in the coming decade.

References:

[1] Herrick et al., (2016) *www.lpi.usra.edu/vexag/ reports/goals-objectives-2016.pdf*. [2] Oyama et al. (1980), J. Geophysical Research, 85, 7891-7902. [3] Peplowski and Lawwrence (2016), LPSC Abstract No. 1177. [4] Hendry et a. (2013), International Journal of CO2 Utilization s 3–4:37–43 · December 2013 [5] Limaye et al. (2017) To be submitted to Astrobiology. [5] Hendry et al (2012), International Journal of CO2 Utilizations 3–4:37–43, DOI: 10.1016/j.jcou.2013.09.002 [6] Way, M. Jet al. (2016), Geophys. Res. Lett., 43, 8376–8383, doi:10.1002/2016GL069790. [7] Wainwright et al. (2002), FEMS Microbiology Letters,10778, 1–5. [8] Cockell. (1999) *Planetary and Space Science, 47, 1487-1501, 1501, 1999. DOI:10.1016/S0032 -0633(99)00036-7*. [9] Irvine, W. (1969)J. Atmos. Sci. 25, 610-616. [10] Yates et al. (2016), https://arxiv.org/abs/1611.09074v1. [11] Travis, L.D. (1975), J. Atmos. Sci. 32, 1190-1200. [12] Mallama, et al. (2006), Icarus, 182, 10-22.[13] Mueller et al. (2012), Icarus, 474-483. [14] Venus Seismology Study Team, http://kiss.caltech.edu/study/venus/2015_KISS_Venus_Final_Report.pdf [15] Polidan et al. (2015), American Astronomical Society, DPS meeting #47, id.217.03.