A LONG-DURATION STAND-ALONE VENUS LANDER MISSION : SCIENTIFIC AND MISSION DESIGN CONSIDERATIONS. R. D. Lorenz.[1], [1]Space Department, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 21046 ralph.lorenz@jhuapl.edu).

Introduction: This work examines how a lander mission on Venus might look if it could survive indefinitely. While there has been discussion elsewhere (e.g. the Venus Flagship study [1]) of top-down scientific goals for Venus exploration, the novel paradigm considered here is a technology demonstrator for a Radioisotope Stirling generator and cooler. While the concept of a long-lived lander has been advanced before (e.g. the VISM Discovery concept of 17 years ago [2]) it is worth considering anew, and in particular, how long should such a mission last.

Rationale: The science enabled by long duration falls into two principal categories: that science enabled by duration directly, and that enabled by mobility which is in turn enabled by duration. This exercise considers only the first : there has been ample consideration before of mobile science on Venus and elsewhere, yet introducing mobility brings substantial technological requirements with their attendant costs and risks. A further refinement of the science goals is that they should not be attainable by a short-lived lander. This, then, opens four main avenues:

- Allow larger data return (e.g. acquire descent imagery, then trickle data back to Earth - this may allow a much higher imaging science content than is typically considered)
- Improved signal-to-noise for counting measurements (e.g. gamma ray spectroscopy or neutron-activated measurements)
- Observe dynamic phenomena such as weather, seismic activity and magnetic fields
- Allow time for ground control interaction e.g. acquire sample with an arm from a spot near the lander identified in panoramic imagery.

The third of these considerations argues for the longest duration, and in principle has fairly modest instrumentation requirements, so is an attractive framework for the 'technology demonstrator' paradigm. Descent imagery is likely to be of high interest, and documentation of the landing site is likely to be considered essential in any case. Gamma-ray or similar measurements are improved by longer counting intervals (only ~1-2 hours on missions to date, which rely on the thermal transient from an initial cool state) but the incremental science value is modest compared with e.g. making the first seismic measurements on the Earth's sister planet.

Earth Visibility and communication: Earth visibility may be critical - it is of course easy to relax this constraint by introducing an orbiter relay, but for the most affordable mission concept, we consider direct-to-Earth communication. For simplicity, we consider that Venus has zero obliquity and that the heliocentric Earth and Venus orbits are coplanar. Furthermore, let us assume our lander sits at the Venusian equator (visibility of Earth will degrade at higher latitudes). Then the Earth elevation simply relates to the longitudes of Earth and the lander, the former obtained from an ephemeris.

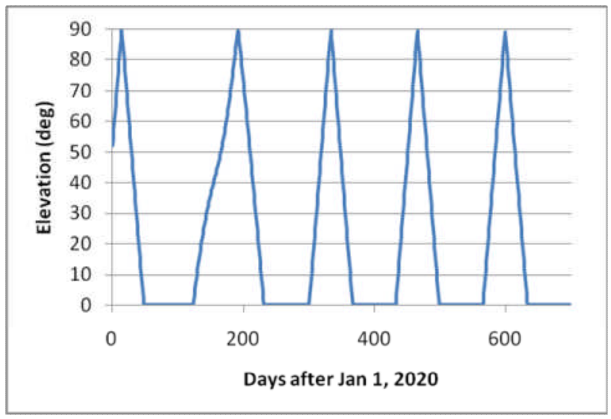

Figure 1. Earth elevation from a point on the Venus equator.

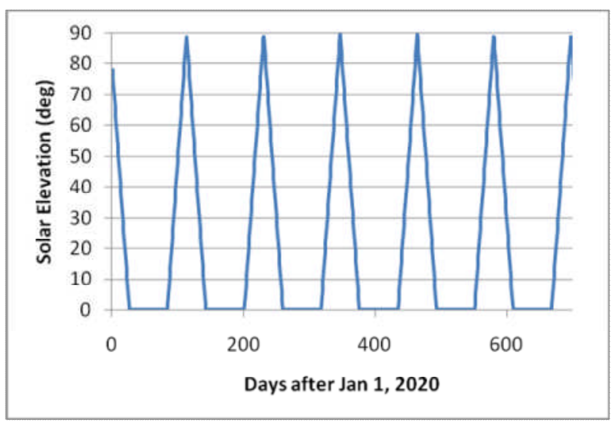

Figure 2. Solar elevation from the same point on the Venus equator. Clearly, Earth visibility from a given point and its solar time history are related

Earth is typically (see fig.1) above the horizon for ~100 days: applying a 20^{o} elevation mask reduces the usual window for communications to ~50-60 days, with intervals of usually ~80 days between opportunities.

Note, however, that judicious choice of coupled timing and longitude can increase the window to ~90 days or interval can increase to ~120 days around opposition). However, if strong scientific constraints on these choices (either for specific geological provinces, or for local solar times) exist, these advantageous opportunities may not be available over a desired mission epoch.

The combined solar and communications geometry is such that the shortest communications range occurs near local midnight. Assuming daylight measurements are desired, simultaneous communication will require transmission over distances that may exceed 1 AU (fig 3: NB conjunction must be avoided too). Note that while temperature variations over the course of a Venus day will be small, they are likely not zero, and winds (especially slope winds) may vary substantially. (Note that a Venus solar day is ~117 Earth days).

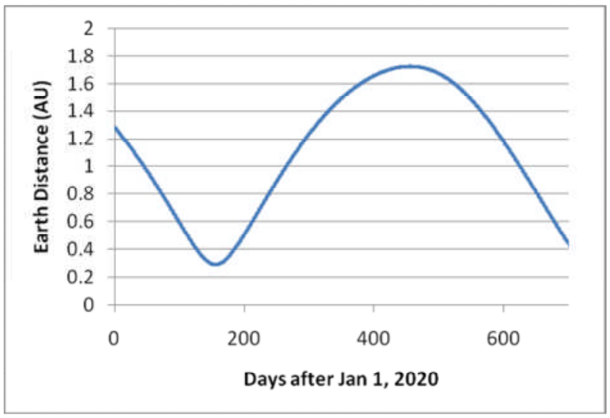

Figure 3. Distance to Earth. Naturally, closest approach occurs at opposition (here, day ~155), where by definition if a lander can see the Earth, it cannot see the sun.

Payload Resources and Accommodation: The payload resource requirements for meteorology and seismology etc. are not especially demanding, and have been considered in various Mars network missions, both conceived and flown (e.g. Viking, Mars-96, Netlander, etc.). ~10W and ~10kg should be adequate, including a descent camera.

The Huygens dataset (~100 Mbit) defines a basic descent/landing data volume 'debt' which should be worked off over the duration of the surface mission, plus ~ 3Mbit per day (as for Mars network missions) for magnetic, meteorological and seismic monitoring.

The most crucial accommodation consideration is likely to be isolating a seismometer from the lander (to mitigate vibrations from the Stirling converter and refrigeration system) and from wind-induced disturbances which plagued Viking. Simple release onto the ground beneath the lander, with a wind cover, will likely suffice. Anemometer measurements can be strongly influenced by lander effects : a deployable mast is likely an expensive challenge; an alternate approach may be to install several body-fixed sensors at different azimuths, such that one is always 'upwind'.

Conclusions and Downlink Data Demands: An efficient, novel and scientifically-worthwhile mission can be conducted on Venus with a modest payload and direct-to-Earth communication. A natural timescales for such a mission are ~50 days (the length of a communications window) or ~200 days (embracing two such windows) or more. Science return, due to both observing opportunity and downlink capability, increases with time. Thus if a radioisotope power source and cooler is used (so incremental resource demands for increased duration are minimal), there seems no logic in a mission duration of less than 50 days. A 200-day mission, to observe and transmit meteorological variations over a full solar day would be a worthwhile goal.

If the data volume suggestions above are adopted, the corresponding scientific data rate requirements to Earth (assuming a ~6 hour DSN pass per visible day) are 250 bps for a 50 day mission, and ~350 bps for a 200 day mission (wherein the data acquired while out of contact is stored onboard until the second window opens). Of course, scientific return is increased if realized data rates - which will depend on the distance (fig 3) - exceed these minimum requirements.

References: [1] Venus Science and Technology Definition Team, Venus Flagship Mission Study, JPL, April 2009. [2] Stofan et al., Venus Interior Structure Mission (VISM): Establishing a seismic network on Venus, Workshop on Advanced Technologies for Planetary Instruments, p23-24, Lunar and Planetary Institute, 1993

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