TUMBLEWEED: A WIND-PROPELLED SURVEY VEHICLE FOR ASTROBIOLOGY. K. R. Kuhlman[1], A. Behar[2], J. Jones[2], D. W. Wilson[2], M. Coleman[2], P. Boston[3], J. Antol[4], G. Hajos[4], W. Kelliher[4], C. McKay[5], L. Rothschild[5], M. Buehler[6], R. Crawford[7], G. Bearman[8], [1]Planetary Science Institute, Tucson, AZ 85719, kim@psi.edu; [2]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109; [3]New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801; [4]NASA Ames Research Center, Moffett Field, CA 94035 USA; [5]NASA Langley Research Center, Hampton, VA 23681-2199; [6]Decagon Devices, 2365 NE Hopkins Court, Pullman, WA 99163; [7]Environmental Biotechnology Institute, Univ. of Idaho, Moscow, ID 83844-1052, [8]Snapshot Spectra, 974 East Elizabeth St., Pasadena, CA 91104

Introduction: Tumbleweeds are highly versatile, large, inflatable (Figure 1) or deployable-structure (Figure 2) vehicles capable of using the readily available wind to traverse the surface with minimal power, while optimizing their capabilities to perform a variety of measurements over relatively large swaths of terrain [1-5]. Seasonally receding frost at Mars' higher latitudes provides liquid water; transient on the surface and longer-lived below it. Addition of sunlight and evaporitic dust offer possible surficial habitats, albeit only seasonally, although subsurface habitats might support life longer. Surficial habitats might populate a large area, perhaps from 50 degrees to the poles themselves, and this in turn suggests the significant value of a long-range survey for high latitude habitats. Terrestrial analog site types particularly suitable for surveys include desert surfaces, duricrusts, pavements, ice surfaces and large flat-bottomed canyons. A fleet of Tumbleweeds could be used to accomplish such a survey. Tumbleweeds have been proposed to conduct long-range, randomized surveys of habitability equivalent to conventional coordinate grid sampling. These vehicles will be released to roam for the duration of a season or longer, possibly on the residual martian ice cap. In addition to being highly applicable for Astrobiology surveys, they can be configured to aid in the search for natural resources required for human exploration [6]

Proposed Tumbleweed Deployments in Earth Analog Enviroments: Field campaigns in the Mojave Desert, USA, Atacama Desert, Chile and the McMurdo Dry Valleys, Antarctica would demonstrate this approach on Earth and test the hypothesis: that water indicates habitability and microbial life will correlate with amount of water. Field campaign sites incorporating both snow surfaces and dry desert occur at high latitudes with more accessible hot deserts at mid to low latitudes. The Earth science objectives of these tests are to 1) document the heterogeneity of surface and near-surface habitability in these terrains and 2) measure the extent of biological activity within these habitats.

Instrumentation: The objectives of our proposed field campaigns will be accomplished by 1) outfittinga Tumbleweed vehicle with mature instrumentation, 2) following the GPS trail of the Tumbleweed with a chase team equipped with a suite of field-capable instrumentation and 3) collection of samples along the route for analysis using a variety of laboratory instruments. The instruments onboard Tumbleweed will include surface mounted soil moisture sensors (SMSMS) embedded in the skin of Tumbleweed will measure the soil volumetric water content (VWC) to a depth of 5 cm, a commercial gas monitor, the handheld VRAE gas surveyor from RAE Systems, capable of measuring oxygen, ammonia, carbon dioxide and hydrogen sulfide, and a tunable diode laser (TDL) detectors for other gases including water vapor, and a finally a Computed Tomography Imaging Spectrometer (CTIS) for multispectral imaging [6]. These are the first set of instruments selected, but other low-mass, low-power instruments may be considered as they become more miniaturized.

The suite of instruments carried by the chase team will include a portable gas chromatograph, ground penetrating radar (GPR) and a portable X-ray fluorescence/diffraction (XRF/XRD) spectrometer. Soil samples will also be collected and returned for in-depth laboratory analyses that will include direct microbial enumerations and phospholipid fatty acid (PFLA) analyses. Sequencing clone libraries from DNA extracted from the samples and performing phylogenetic analyses on these sequences will characterize the microbial populations. Exoenzyme assays *in situ* will also be performed to measure metabolic activity. Finally, analytical XRF and XRD will be performed to further characterize the concentrations and phases in which biologically important elements are present.

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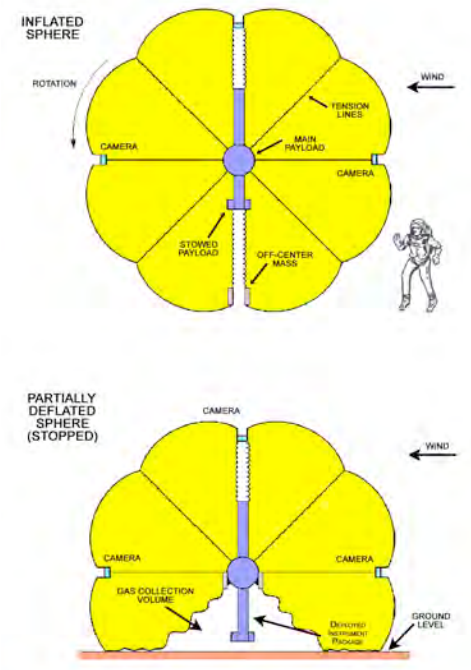

Figure 1. An inflatable Tumbleweed can be stopped by partially deflating the ball and pulling on one of the central payload tension cords to create the "Turtle mode." This mode of stopping also creates a collection chamber for gas measurements (Jones, 2001).

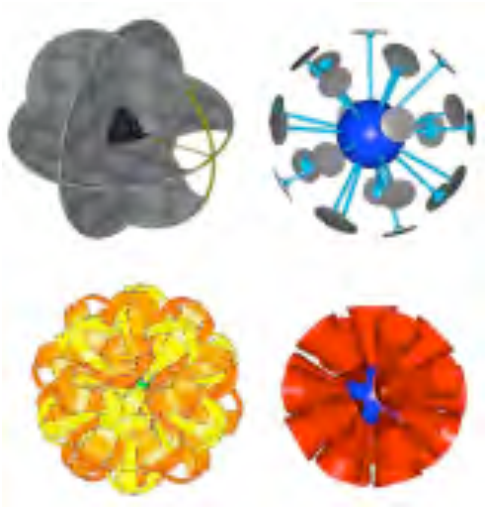

Figure 2. NASA LaRC Tumbleweed Deployable-Structure Concepts: Box kite, Dandelion, Eggbeater, and Tumble-cup. Image courtesy NASA/AMA Inc.