Chapter 14
Tumbleweed: A New Paradigm for Surveying the Surface of Mars for In-situ Resources

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14.1 Introduction

Mars missions to date have interrogated the planet at very large scales using orbital platforms or at very small scales intensively studying relatively small patches of terrain. In order to facilitate discovery and eventual utilization of Martian resources for future missions, a strategy that will bridge these scales and allow assessment of large areas of Mars in pursuit of a resource base will be essential. Long-range surveys of in-situ resources on the surface of Mars could be readily accomplished with a fleet of Tumbleweeds - vehicles capable of using the readily available Martian wind to traverse the surface of Mars with minimal power, while optimizing their capabilities to perform a variety of measurements over relatively large swaths of terrain. These low-cost vehicles fill the niche between orbital reconnaissance and landed rovers, which are capable of much more localized study. Fleets of Tumbleweed vehicles could be used to conduct long-range, randomized surveys with simple, low-cost instrumentation functionally equivalent to conventional coordinate grid sampling. Gradients of many potential volatile resources (e.g. H₂O, CH₄, etc.) will also tend to follow wind-borne trajectories thus making the mobility mode of the vehicles well matched to the possible target resources. These vehicles can be suitably instrumented for surface and near-surface interrogation and released to roam for the duration of a season or longer, possibly on the residual ice cap or anywhere orbital surveillance indicates that usable resources may exist. Specific instrument selections can service the exact exploration goals of particular survey missions. Many of the desired instruments for resource discovery are currently under development for in-situ applications, but have not yet been miniaturized to the point where they can be integrated into Tumbleweeds. It
is anticipated that within a few years, instruments such as gas chromatograph mass spectrometers (GC-MS) and ground-penetrating radar (GPR) will be deployable on Tumbleweed vehicles. The wind-driven strategy conforms to potential natural gradients of moisture and potentially relevant resource gases that also respond to wind vectors. This approach is also useful for characterizing other resources and performing a variety of basic science missions. Inflatable and deployable structure Tumbleweeds are wind-propelled long-range vehicles based on well-developed and field tested technology (Antol et al., 2005; Behar et al., 2004; Carsey et al., 2004; Jones and Yavrouian, 1997; Wilson et al., 2008). Different Tumbleweed configurations can provide the capability to operate in varying terrains and accommodate a wide range of instrument packages making them suitable for autonomous surveys for in-situ natural resources. Tumbleweeds are lightweight and relatively inexpensive, making them very attractive for multiple deployments or piggybacking on larger missions.

14.2 History and Development of Tumbleweed Vehicles

Tumbleweeds are large, lightweight, spherically shaped wind-propelled vehicles that can enable exploration of vast areas of Mars. A variety of vehicles referred to as Tumbleweeds and inspired by the Russian thistle (Salsola tragus) have been investigated by numerous groups of investigators. Jacques Blamont of NASA’s Jet Propulsion Laboratory (JPL) and the University of Paris originally conceived the first known Mars wind-blown ball in 1977, shortly after the Mars Viking Landers discovered that Mars has a thin CO₂ atmosphere with relatively strong winds (Blamont, 1977). Blamont’s “Mars Balls” were conceived as relatively large, 3- to 10-meter diameter inflatable balls that could carry payloads, of 20-30 kg for distances of at least 100 km (Janes, 1989). These proposed balls could be powered either by the wind or powered and steered by an inner drive mechanism.

Fig. 14.1 Original 3-wheeled inflatable rover shown with inventor, Jack Jones, NASA Jet Propulsion Laboratory (Jones et al., 1999).