INFLATABLE VEHICLES FOR IN-SITU EXPLORATION OF TITAN, TRITON, URANUS, NEPTUNE
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Background: Space inflatable vehicles have been finding popularity in recent years for applications as varied as spacecraft antennas, space-based telescopes, solar sails, and manned habitats [1]. Another branch of space inflatable technology has also considered developing ambient-filled, solar balloons for Mars as well as ambient-filled inflatable rovers [2]. More recently, some of these inflatable technologies have been applied to the outer solar system bodies with the result that there are some rather unique and compelling inflatable mission capabilities for in situ explorations of Titan, Triton, Uranus, and Neptune.

Titan: Titan is the largest moon of Saturn and the only moon in our solar system with a significant atmosphere. The atmosphere is composed primarily of nitrogen and has a surface pressure of about 1.4 bar with a temperature of about 93K [3]. With a density of about four times that of Earth’s surface atmosphere, Titan is ideal for ballooning. A relatively small helium balloon (3-m diameter) can easily lift a 50-kg payload to 10-km altitude. For one balloon mission on Titan, JPL has proposed filling helium into three large spherical tires (2-m diameter) of a 50-kg inflatable rover, such that the rover could be flown as a controllable aerovehicle. Using periodic venting and ballasting, the balloon could land and re-ascent numerous times before ultimately replacing the helium with ambient atmosphere (Figure 1). The heavier-than-air vehicle could then conduct an extensive amphibious surface exploration of Titan's solid surfaces, as well as of its anticipated liquid methane/ethane lakes and seas. A prototype inflatable rover presently exists at JPL and is being evaluated for airborne, as well as liquid mobility.

Triton: The atmosphere of Neptune's largest moon, Triton, is also constituted primarily of nitrogen, although it is very thin (~ 17 microbar) and cold (38 K). Surface winds have been estimated to be about 5-15 m/sec [4], with locally stronger winds possible. Although an inflatable rover would generally be expected to function well on Triton's surface, the atmosphere is much too thin to support any balloon activity. One intriguing possibility for Triton, however, is to encase a small payload inside a spherical “beachball” that acts as a both a descent vehicle and a landing vehicle. A 3 m diameter sphere (~ 3 kg) could land a 3 kg payload with a terminal descent speed of about 100 m/sec, while a 10 m diameter thinner sphere (~8 kg) would have a terminal velocity of about 43 m/sec. After acting as parachutes, the spheres could then act partially as airbags. Furthermore, upon landing, moderate winds could propel beachball payloads to explore new locations on Triton.

Uranus and Neptune: Previous work has shown balloons may be possible at Jupiter and Saturn by using solar heat [5], but that Uranus and Neptune receive much too little sunlight. Of all the moons and planets in our solar system, however, only Uranus and Neptune possess the unusual characteristic that the molecular weight of the atmosphere in the upper stratosphere is significantly lower than that in the lower troposphere. This unique characteristic, which is due primarily to methane condensation, allows balloons to be filled while falling in the stratosphere, and then to be fully buoyant in the troposphere [6]. For example, a 5kg balloon filled in the Neptune stratosphere can be used to easily float a ten-kg payload in the troposphere, from where deep atmosphere sondes could be dropped. These balloons are, in fact, the only practical manner yet proposed to allow long-term in situ exploration of Uranus and Neptune.

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