Abstract for Space Resources Roundtable

Helium-3 Mining Aerostats in the Atmosphere of Uranus

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The Helium-3 resources of the Solar System offer the possibility of clean D-He3 fusion power for primary electrical generation and starship fuel. If fuel costs represent the same fraction of energy cost in the D-He3 fusion economy as in the fossil fuel economy, the value of He3 would be in excess of $3M/kg. In this paper, we examine the possibility of distilling He3 from the atmospheres of Jovian planets, with an emphasis on Uranus since the delta-vee required to transport He3 cargo into planetary orbit is half that of Jupiter, and the atmosphere of Uranus is ~5x richer in helium than that of Saturn. We examine the physics of a nuclear hot-air balloon concept in which a 30 MWt fission reactor heats the ambient, principally hydrogen, atmosphere inside an envelope and provides lift for a 100-ton complex composed of a He3 distillation plant, He3 transport dewar, and tanker dock. The aerostat operates at the 150 K, 10 bar level of Uranus, with the lift gas ~300 K, and thus generates unit lift equal to that of low troposphere helium balloons on Earth. The aerostat suspends a distillation plant which first discards the 85% of the atmosphere which is not helium, then enriches the He3/He4 ratio from its primordial value of 10^{-4} to 0.9. In the He3/He4 enrichment stages, we find that a still temperature of 1.2 K, attainable by rough pumping on He4, is adequate, which considerably reduces the complexity and reliability problems posed by lower distillation temperatures. The He3 reservoir in the transport dewar is heat-shielded by a He4 reservoir, and no He3 evaporation occurs until the He4 is exhausted. The hold time of the He4 in deep space exceeds the moderate-energy Uranus-Earth transit time of 5 yr using a cryostat design similar to that of SIRTF, the Space Infrared Telescope Facility. Each distillation plant could supply a fusion power plant of $2x10^9$ We capacity. Balloon probes heated by the radioisotope Pu238 could test the balloon and deployment concepts and collect outer planet atmospheric data necessary to engineer such mining aerostats.