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COMETARY CAPTURE MISSIONS: BENEFITS FOR HABITATION AND MATERIALS PROCESSING ON THE LUNAR SURFACE; A. J. Bauman and Fun-Dow Tsay, Jet Propulsion Laboratory, Pasadena, California.

The lunar surface appears to be a poor source of metallic materials of construction, except for the 0.5% submicron free iron of soils[1] which might be recovered electromagnetically. The chief obstacle to preparing aluminum or titanium from lunar soils and rocks lies in the insignificant levels of chemical reducing agents, such as carbon and hydrogen present in surface soils only to about 50 and 10 ppm,[2] respectively. Large-scale high-temperature metals recovery processes[3] on the moon will thus require the uneconomical transportation of carbon or hydrogen from earth. Within this context, a recovery mission to land a portion of a cometary nucleus (CN) as a carbon source on the moon merits first priority consideration in the establishment of a Lunar Manufacturing Base (LMB). The CN would provide sufficient water, carbon dioxide, nitrogen compounds (such as hydrazine), hydrocarbons and C-1 chondritic carbon[4,5] to operate a base completely autonomous even to the synthesis of food from CO_2 and water[6]. Aluminum and titanium for deep space construction would be made from lunar soils using the CN carbon, (probably) halogens[3] and high solar energy temperatures. Silicon for photovoltaic devices would also be a major product. The initial base would be most effective underground for air-tightness and meteorite protection; it would adjoin a large enclosed, insulated crater which would hold the CN at a convenient pressure. The LMB should be regarded as a first and significant testing ground for the development of advanced technology to support large space colonies, such as the L-5 orbiters suggested by O'Neill.[7,8] It should be more economical to build than the "Orbiters", although its gravity well would be larger, because the underground bulk of it would consist of fused or sealed lunar material.

Is it feasible to capture, transport and soft-land cometary nuclei and, later, asteroids, on the regolith? Cometary nuclei appear to be fragile "dusty snowballs" comprised of frozen gases which readily ionize in the solar wind to yield the visible coma and tail. Typical nuclei weigh about 10^{12} - 10^{13} kg, have a diameter of a few Km or less, and include solids of indeterminate composition, such as carbonaceous chondrites.[4] It should be entirely possible to plug large numbers of very light reinforced plastic or paper rocket nozzle-"firing chamber" assemblies into the soft "snow" of the nucleus, probably by unmanned means. The nozzles, in arrays clustered at opposite ends of an axis through the nuclear center, would have gimbal-mounts and could be directed (by computer) in any direction. "Firing" and propulsion would occur when a focussing mirror directed sunlight into the "firing chamber" which would immediately cause gases to issue from the nozzle. The system as a whole would consist of a number of such assemblies plugged on opposite sides of the spherical nucleus along an axis such that the whole could be accelerated or decelerated on computer demand. If necessary, it should be easy to cut or shape very large nuclei into smaller units by means of powerful lasers. This approach is conceptually simpler than that of the "transport linear accelerator" (TLA) machine suggested by O'Neill,[7] but that device would probably be quite effective in transporting metallic asteroids from the belt with its adequate supply of "fuel". It should, of course, be feasible to transport an asteroid by carrying it "piggyback" on a cometary nuclear "engine" to lunar orbit for soft landing by means of chemical rockets.

A flyby to Comet Encke in 1980 and an encounter in 1984 have been suggested as scientific goals; we strongly support those missions in terms of their pragmatic value to the LMB concept. Comet Encke, and Comets Arend-Rigaux and Neujmin I, as well as asteroids - 1936 Adonis and 1566 Icarus may consist of carbonaceous residues and thus would be other suitable candidates. The "fast-moving object Helin" 1976 AA has an orbit between 0.79 and 1.14 au, appears to be a large carbonaceous planetesimal, and will approach to within close proximity to earth in 1996.[9] It appears to be about 1 Km in diameter and is typical of the Apollo asteroids also of interest for the LMB. An LMB based on these concepts would in the long term be a good prototype for an autonomous Martian colony which, in that case, would already have adequate amounts of CO_2.

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