Phobos and Deimos
Living on the Moons of Mars

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In a series of recent essays I have sketched out a viable theory of space development and colonization. Within this framework almost any asteroidal or planetary body within the orbit of Mars is suitable for immediate development of its regolith, for spacecraft and habitat shielding, where the smaller cometary derived and volatile rich carbonaceous bodies with enough solar irradiance are suitable for destinations. Volatiles may be extracted from the regolith of these bodies in small amounts by the novel technique of pressurized space encapsulation and optical and solar irradiation, with the residue bagged for shielding. The extremely low gravity of small asteroid bodies makes it quite easy to transfer the asteroid tunneling and mining equipment onto the asteroid, and subsequently transfer the resultant volatile fluids and any asteroid slag off of the surface, but it also has an added disadvantage in that it makes mining operations more hazardous, due to the ease in which processing dust and debris may escape the surface entirely.

Unless the object is small enough (~10 meters) to capture, encapsulate and derotate the body in one swift operation, as described by the Keck asteroid bagging scheme, and then double bagged into mildly pressurized space as indicated by my own Asteroid Redirect Mission proposal, the process of materials extraction from the surface of the asteroid becomes much more problematic since the gravity of small asteroids approaches negligible as their size and mass decreases. However for larger asteroids, where the acceleration of dust and debris is such that it can be kept below the orbital and escape velocity of the body, processes may be developed where loss of dust and debris can be eliminated completely or greatly reduced, while still retaining the ability to process large boulders on the surface, tunnel into the surface, and deliver equipment to do so, in addition to removal of mined volatile fluids and shielding slag. It is not presently known what the size and mass cutoff is for this particular mining scenario, but it is expected to be in the range of 10 to 15 kilometers or so, where orbital velocities are expected to be measured in meters per second and escape velocities at ~10 meters per second - Phobos and Deimos.

Since there are virtually no objects inside the orbit of Mars of this size, both Phobos and Deimos are the ideal candidates for the testing of these concepts of asteroid mining, tunneling and the manipulation of large boulders on their surfaces. The more promising aspects of Phobos, and particularly Deimos, is that they are both tidally locked to Mars, in roughly the equatorial plane of Mars, and thus they both have well defined seasons at their poles exposing large areas of their surfaces to continuous sunlight over long periods of time, with slow migration of these areas of continuous sunlight over their surfaces. Obviously then both the surfaces and the poles of Phobos and Deimos are expected to be strategically valuable for any upcoming landing, development and colonization of the surface of the planet Mars. They both provide heavily shielded low gravity refugia above the surface of Mars, where the gravity is large enough to firmly settle large structures onto their surfaces, debris ejection hazards are minimized or eliminated entirely, regolith collection and tunneling operations can be started immediately, sunlight is readily available, and all areas of the surface may be quickly connected by rolling out cable spools across their surface to adjacent areas where continuous sunlight is available, at most tens of kilometers.

I will examine these concepts here in more detail and describe the ramifications for space colonization.

Clearly very large and tall structures can be settled onto the surface of Deimos and moved around with relative ease using wheels, treads and tracks. With a surface gravity of 1/3 of one thousandth of a gee, it is conceivable that actual rails could be built where extremely large solar power arrays and space hotels could be transported continuously across the surface near the poles and remain in continuous sunlight. Phobos has a very large planetary occultation factor, but Deimos is ideal for immediate development.

Manned space habitats require solar and cosmic ray and impact shielding, and that mass must be added to these structures, which then requires ever more structural engineering, and then ever more energy to transport those structures across the surface, or alternatively in free space, moving from asteroid from asteroid for instance in the asteroid belt. Therefore the more prudent approach to the development of Deimos would be to drill vertically into the moon, and then use any lightweight external structures as temporary access habitation into the deep tunnels, which essentially provides maximum impact and cosmic ray protection. Ideally then near the poles of the moons of Mars, these access structures could extend as high as the structural engineering permits, which realistically could be a kilometer or more.

Very tall hyperengineered structures on the moons of Mars could then be easily wired together at the surface, to provide electrical power from areas which happen to be in continuous sunlight, to areas that are not currently illuminated, and to any habitation deep inside the moon. The topography of the moons of Mars are irregular, so to adequately cover four Martian seasons or a single polar day, it requires at least four mid latitude locations per pole, highly dependent upon the local polar topography, for at least ten solar array locations per moon, including the equatorial regions which have normal daily sunlight. Alternatively, large landed articulating solar array systems sitting on the surface of Phobos and Deimos can be flown from one location to another periodically, in order to remain in the continuous sunlight. That would require fuel, and even then, topographically preferred locations would still be required to host the drilling operations, which would still require outer access ports and large permanent structures, and thus a permanent supply of electricity. That power will require large articulating solar arrays for either horizontal polar sunlight or conventional daily sunlight, where the Deimos day is 30 hours long.

Deploying electrical and anchor cables across small low gravity moons is quite simple, you simply roll the cable spools out slowly across the surface and provide occasional access points. Depending on the dielectric characteristics of the soil, the cables could either be bare and suspended above the surface, or insulated and laying directly onto the regolith. The cable spools themselves can easily be made to be self propelled and can be provided with power from the same electrical cables that they are deploying. Yearly migrations from one pole to the other are inevitable on the moons of Mars, but one benefit of synchronous lunar poles with a moderate solar inclination (24 degrees), is that the year long darkness provides for long term astronomical observations in alternate hemispheres for up to a year at at time. Once the moon is wired up for full equatorial and polar power the logistics of habitation are simplified.

Upon arrival at the poles of Deimos, radiation and impact shielding are imperative, and so drilling large deep vertical holes directly down into the interior of the moon is desired for any initial habitats, as well as collecting surface regolith into bags with can be stacked up on grates to provide vertical shielding. The primary process is the very slow removal and transport of regolith up a shaft, or into mounds and onto scaffolding and into bags, providing straight down cosmic and solar radiation protection for small habitats located at the top and in the central portions vertical drilling shafts on the surface of Deimos. With a surface escape velocity of 5.6 meter per second, great care must be taken in order to prevent the vigorously propelling of dust off into deep space, rather allowing it to gently settle back down onto the surface well under the orbital and escape velocity of the body. Since the body has no atmosphere at all to induce friction and turbulence within the particle flow, very precise experiments must be performed to ensure that the orbital velocity of stray particles do not even begin to approach the regime of escape.

Stray dust minimization procedures can consist of something as simple as a large deployable thin film umbrella with defeats the majority of the ballistic ejection of dust particles by mere inelastic collisions. The prospect of deep drilling is particularly attractive because once deep enough the drilling shaft can be capped which can greatly speed up the process. In this case, the bags of removed regolith can exit periodically from a vacuum lock at the top of the shaft and then transported away much more quickly. Presumably deep shafts would be cased as they are excavated and dust suspension behaviors could be monitored to more fully understand the dynamics of these materials under ambient Deimos gravitation. Once excavation and casing is complete, the mining and bagging equipment can be extracted, and then a complete habitation system can be installed. This would consist of top and bottom pressure vessels with airlocks, and deployable inflatable habitats with intervening airlocks and hatches between them. In any case, the low gravity of Phobos and Deimos makes the insertion of large mobile habitats and excavation equipment in and out of both vertical and horizontal cased tunnels fairly straightforward. In fact, large, deep cased holes in the surfaces of any of these moons could serve simply as landing pads for any large spacecraft needing refugia and services between the surface of Mars and the planet Earth.

One of the interesting and useful aspects of the planet facing side of equatorial Phobos, with respect to high energy galactic cosmic rays, is the angular extension of Mars itself will shield the most vulnerable exposed regions of any tunnel habitats, their airlock and docking port caps, straight down from above. If electrical power could be provided and wired in from elsewhere on the moon, this constitutes the most desirable planetary viewing spot in the entire inner solar system, besides the poles of the moon. For other areas of the surfaces of the moons of Mars, extremely tall towers on the poles of the moons can provide constant communication with Earth and Mars, using the surface wiring I have described. Alternatively equatorial and polar observation and communications nodes can be interspersed across the surfaces of the moons and networked together, again using the cable deployment scheme described. Perhaps the most interesting prospect of the concept of the wide scale tunneling and regolith extraction from within the interiors of the moons of Mars, is the possibility of 'hyperloop' types of transportation. Once the active sequential drilling and ongoing regolith excavation and extraction from the interiors of Phobos and Deimos begins, there is really no reason to stop, and long and even circular interior tunnels can eventually enable rapid 'across the moon' transportation and variable gravity hypertube trains. With Phobos, it has recently been realized that the seismic geology of the interior of the moon may very well be active, since evidence of its geologically imminent breakup is already revealed on its surface. This may well become an important factor in its future development, although the geological timescales are enormously long compared to the relatively short timescales involved with the development of Mars.

In conclusion, I have outlined out a viable development plan and scheme for both of the moons of Mars – Phobos and Deimos, and I have sketched out the various physically and technologically possible and probable components of such a moon wide development scenario. I have described how such a project is complementary and relevant to further development of the asteroids as sources of materials, and also as future development destinations using these operational procedures tested and developed near Mars. The development of the surfaces and interiors of the moons of Mars is a persuasive precursor to the all out colonization of the surface of Mars, as a location where servicing of spacecraft may be performed, and where radiation protected and variable gravity habitats can safely stage any Mars surface activities.

Reference

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