Use of Ceres in the Development of the Solar System

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Abstract

While much study, both speculative and direct, has been conducted toward the issues involved in the settlement of the moon and Mars (currently the most likely sites for initial development), there are a number of other sites that also bear great promise, both as locations for colonization and as keystones for system-wide expansion. One such place is Ceres, the target of NASA's Dawn mission, which is scheduled for launch in the summer of 2006.

As the largest world in the main asteroid belt and a place rich in water, it should make the best base for exploring and exploiting asteroidal resources, in support of development throughout the solar system, especially within and beyond the belt. Because of the planetoid's very low escape velocity (0.51 km/s), the great amount of water on Ceres would not only be a resource for a colony's own use, but would also be an exportable resource, supplying fuel, oxygen, and water for ships going through and beyond the main belt. This water, together with metal structures built in zero gravity from asteroidal materials, would allow colonists to trade for raw materials and refined products that are needed but not available in the main belt. Living on Ceres will, of course, be a challenge, even more so than living on the moon or Mars, due to significant isolation, limited resources, and low gravity. All of these, however, are surmountable challenges, and this paper will begin to outline how people can get to, live on, and make use of Ceres, for their own benefit and the benefit of others who are exploring and settling the solar system.

This paper will address current knowledge about Ceres, technological aspects of deep-space travel and colonization, and the role of Ceres as a base of operations for utilizing the resources of the main asteroid belt.

Introduction

Humans have traveled into space numerous times over the past 45 years, but none to stay. That may well change in the near future, with pioneers establishing outposts in orbit, on the Moon, or on Mars. The goals may be one or more of many possible, including conducting scientific research, developing economic opportunities, or bolstering national pride. The settlements may be highly reliant on, or relatively independent of, Earth. Success, especially for more independent communities, will require sufficiently diverse and abundant resources.

If the frontier is opened, many of those looking to move out into it will be those looking for a place to be, both figuratively and literally. Those who emigrate from Earth will do so because, for whatever reason, they are not satisfied with life as it is; they will seek something more, something better. Some will be “freelanders”, those for whom freedom to live as one would and a land from which to derive one’s living are intertwined concepts; for these, independence is necessary to success, because to be materially, politically, or otherwise dependent would be a tenuous existence, excessively subject to forces beyond one’s control. For such people, the resources of a potential site for settlement are critical. Mars is a far better location in this regard than either the Moon or free space, but it is not the only one. Another is Ceres, the largest of the Main Belt asteroids. This paper is a brief presentation of some ideas relating to the settlement of Ceres.

Current knowledge of Ceres[1]

Since the submission of the abstract for this paper, the Dawn mission has been both cancelled and renewed. Scheduled for launch in 2007, its arrival at Ceres (about nine years later) should vastly expand our knowledge of this minor planet.

Orbit

The orbit of Ceres has a perihelion of 2.54 AU, an aphelion of 2.99 AU, and an inclination of 10.6 degrees. The orbital period is 1,680 Earth-days (4.6 Earth-years).

Day

The Cererian day is just over nine hours long.

Size

Ceres is fairly spherical, with a diameter of greater than 900 km. The surface area, therefore, is greater than 10 million square kilometers (approximately the combined area of France and Spain). Ceres, at 9.5*10^20 kg, contains about a third of the mass in the main belt, which totals less than 5% of the mass of Earth's moon. The surface gravity is 0.27 m/s^2 (a little less than 3% of Earth's), and the required escape velocity is only 0.51 km/s.

Composition

Ceres is spectrally described as a G-type asteroid, a form of carbonaceous asteroids. It likely has a differentiated interior, with a rocky core and an icy mantle. It may have a thin atmosphere.

Origins

The Dawn mission is so named because, compared to more dynamic bodies like Earth and Mars, Ceres and other asteroids are relatively unchanged since the formation of the solar system.

[1] Specific figures from Wikipedia.

Getting to Ceres

Ceres' distance from Earth and Mars is relatively close, compared to any point in the outer solar system, but far enough that settlers would be preferable to itinerant workers.

From Earth

It has been remarked that low earth orbit is halfway to anywhere in the solar system. While imprecise, the principle remains that getting into space is the first big hurdle to getting anywhere else in the system. The lower the cost to LEO, the more affordable everything in space becomes.

In spaceflight, direct travel has many advantages, and so the best way to get from Earth to Ceres is to go to Ceres, without waypoints (be it station, moon, or planet) in between.

From Mars

With the escape velocity for Mars being less than half of that for Earth (5.027 km/s versus 11.186 km/s), a Martian civilization would have a significant advantage in its ability to conduct trade with other locales in the solar system, including Ceres.

Living on Ceres

The technology needed to settle on Ceres is, for the most part, is the same as that needed to settle most worlds in the solar system. Particular environments will dictate particular requirements, but the development work needed to open one world, such as Mars, to settlement, can open many more, especially if there is an emphasis on creating a "Conestoga" level of technology. Just as the Conestoga wagon was used by pioneers in many different environments during the settlement of the American West, so too can habitats and other technologies be designed to serve throughout the solar system. An open architecture would allow for modular components to be interchanged according to differing needs (for example, a Mercury-bound craft would use solar power, whereas one that headed for Titan would use nuclear power, instead). Simplification and standardization, where possible, would give colonists a greater ability to modify and adapt the technologies as necessary; this is the antithesis of the reinventing-the-wheel approach that led to Apollo 13 having incompatible carbon dioxide filters in its lunar and command modules.

Energy

Energy is crucial to survival and growth anywhere. Energy on and about Ceres will come from one of three sources: solar, chemical, and nuclear.

At aphelion, Ceres is about three times as far from the sun as the Earth is, meaning that sunlight would be a little more than 150 W/m^2, a ninth of its intensity at 1 AU (over 1360 W/m^2). Photovoltaic panels would have some use, but would be more difficult to produce locally than heat engines using parabolic reflectors. Despite the diminished strength of sunlight in the Main Belt, such solar engines would have a number of advantages over such devices on Earth: abundant metal resources provide the materials, low (or no) gravity simplifies the construction, and low temperatures improve the operation.

The significant water resources of Ceres and other asteroids can provide the hydrogen and oxygen to power ships, rovers, habitats, and more. Obviously, another energy source would be required to get the hydrogen and oxygen into a usable form, but once processed, the chemical fuel has certain advantages over other energy sources; for example, the storage of hydrogen and oxygen would be easier than storing electricity via batteries.

Nuclear power will likely be an important initial source of power, such as that provided by radioisotope thermoelectric generators (RTG's) onboard the original habitats. Over the long term, manufacturing the technology and mining the fuel may each present serious difficulties to the expansion of nuclear power in the Main Belt.

Shelter

The initial shelter, of course, will be provided by the habitats that the first settlers arrive in (as well as those that might precede/follow, unmanned).

Growth of the settlement will be facilitated through the use of locally or regionally available materials. On Ceres, the surface might be covered with regolith, solid rock/ice, or a mixture. A solid surface could allow for excavated structures, as well as built structures using excavated materials. A regolith surface could be used in "sandbag" type structures, or, perhaps, provide raw material (i.e., carbon) for processed forms (i.e., carbon-fiber rods and sheets). Regionally available material includes, most importantly, iron and other metals from elsewhere in the main belt. A metallic asteroid 10 m in diameter contains over 500 m^3 of material, enough to build a 5 m diameter tube, with walls 2 cm thick, over 1500 m in length.

Air

Abundant water means a ready source for oxygen, and carbon would also be at hand on a carbonaceous surface, but other atmospheric components would be more difficult to come by. Nitrogen, which constitutes 77% of Earth's atmosphere, would be hard to acquire.

The treatment of air is integral to the food supply, because the carbon that humans and other animals exhale (in carbon dioxide) is that which the plants sequester in their tissues, and which will then be consumed or otherwise degraded.

Water

The mantle of Ceres has, perhaps, as much as 200 million cubic kilometers of water, which is more than four times the amount of fresh water on Earth. Despite this abundance, water recycling would still be a key technology, as it would be on drier worlds (such as Earth's moon), because it would be integral to air, food, and other systems.

Food

Food, for the most part, would mean plant material, due to the inefficiencies and other difficulties of growing food for animals and animals for food. "Greenhouses" could be on the surface, taking advantage of natural light, or buried, benefiting from additional insulation. The effect of a nine-hour day on plant growth is a (seemingly) unexplored topic.

Animals raised for food would tend to be small, such as trout, rabbits, and chickens. Besides food, these animals would ideally have other uses as well, such as recycling plant waste (such as converting straw to rabbit pellets) or providing other resources (such as leather for clothing).

Gravity

While settlers could initial deal with Ceres' low gravity (<3% of Earth's) by means of exercise and other strategies that have been employed by astronauts in Earth orbit, in the long term, new approaches are needed.

The use of "doughnut trains" is one approach. Surface or subsurface habitats could be constructed to run on a circular track that is angled inward, so that as the habitat moves around, the occupants experience the reactive centrifugal force as if they were in a higher-gravity environment, which could be set to approximate the gravity of Mars, the Earth, etc. The habitat would be built to cover the whole track, and so form a continuous loop. It is similar to various proposals for orbital colonies, but does not need to include all of the living space: settlers might spend only half of their time in the train, with the rest being in low-g work environments elsewhere about the surface, such as in greenhouses, shops, and mines.

Permanent Cererians are preferable to temporary workers from Earth (or other higher-g environment), in that settlers would only need to maintain their health for their environment, whereas a worker planning to return to a higher-g world would need to work at keeping up sufficient muscle mass, bone density, and so on for that more stressful environment.

Radiation

Radiation in hard space is a significant concern. Being on a planetary surface (even a minor one) immediately cuts the radiation in half, because of the mass underfoot. Spending even half of one's time in a sufficiently buried habitat or other structure would halve the risk again. Ultimately, there will probably be an increased risk of death by cancer for settlers on Ceres (and elsewhere about the system), but this would be partially offset by a decreased risk of death by McDonald's, Mack trucks, and other terrestrial hazards.

Bombardment

As with radiation, the risk from bombardment by micrometeoroid is halved by being on a planetary surface, and further reduced by spending time underground.

Surface transport

Point to point surface transport may be by means of rovers, railways, or rockets. Rovers would offer more flexibility than railways, but if a particular route is traveled enough, the greater efficiency of a railway would make it the logical choice. The low escape velocity of the planetoid makes the concept of VTOL rocket transport attractive, particularly over longer distances.

Spaceports

Launch from the surface to elsewhere, within or without the Main Belt, is facilitated by the low escape velocity (0.51 km/s). The low escape velocity, along with the thin-to-no atmosphere, also helps to make a space elevator a simpler proposition than on Earth.

Worldhouse

Ceres has been suggested as a candidate for the worldhouse concept, which is the terraforming of a world by total enclosure. Certainly, the local life-sustaining environment(s), even if only beginning with a single habitat, would grow with the colony, but to cover 10 million square kilometers would be a far off proposition.

Culture

Upon the opening of the frontier, various groups will move into it, sometimes cooperatively and sometimes independently. Mars, for instance, will likely have many different groups inhabiting it, due to its relative proximity to Earth and abundance of resources. What about Ceres, though? Further out and less resource rich, it will not attract the same attention as the red planet, potentially allowing the first group to inhabit the world to also be the only one. That group would benefit from cultural homogeneity, so that culture is a unifying, rather than a dividing element. If, however, more than one group does arrive at Ceres, even this little world has enough space to reasonably provide for a number of settlements. The risk of conflict is thereby increased, but there would be corresponding advantages, as well.

Making use of Ceres

A base for exploring and exploiting the Main Belt

The Main Belt has many resources that will be useful to a civilization growing throughout the solar system. Ceres provides the best base from which to operate an extensive program of using both robotic and manned craft to explore and exploit those resources. A settlement on Ceres would certainly not have an exclusive claim on the resources of the Main Belt, but if it had far better information on the resources than anyone else, then that information would be a valuable commodity. More valuable yet would be resources already extracted and made available in ready form.

A waystation for ships heading into or beyond Main Belt

The energy of the sun, the metal of the asteroids, the weightlessness of free space, and the talents of the Cererian settlers would allow for tremendous structures to be built in the Main Belt, including space habitats, surface habitats, industrial structures, and transport craft. These could be used in the region, or loaded with fuel, water, air, and food in preparation for a journey to the outer system. Colonists heading outward could arrive at Ceres with minimal ships, trading what is relatively cheap to send from Earth (such as electronics, spacesuits, grad students) for what is relatively expensive (such as behemoth spaceships loaded with carbon, hydrogen, and oxygen in various combinations). For those on Ceres, the relative values are reversed.

A place to be

Regardless of recognition by nations of the Earth, property rights will exist in the colonized worlds of the solar system, although how they are applied will doubtlessly vary. The homestead principle is generally understood to give rights to one who makes use of that which was unused; but does that mean a settler on Ceres has rights to the ground under his habitat, to 160 acres around it, or to the whole planetoid? As with many laws on Earth, such concepts will be hashed out after the issue has been on the ground.

Various people have debated various reasons for the opening of the frontier and the settlement of the solar system, and many of these involve benefit to Earth. One of the primary reasons seems to be underrepresented, however: to have a place to be. While Old World powers sent expeditions across the ocean for national benefit, people came to the New World of the Americas in hope of having a place to be, in terms of both freedom and land. So, too, will others seek out the same in the new worlds beyond Earth. Of which Ceres will be one, one of thousands.