Dyson Asteroid Shells: Hollow Worlds from the Outside-In

By A.C. Charania[1)]

[1)]*SpaceWorks Engineering, Inc. (SEI), Atlanta, Georgia USA*

A new formulation of a human asteroid habitat referred to as a Dyson Asteroid Shell (DAS) is presented. This concept involves completely enclosing a small body such as an asteroid (potentially focused on rubble pile compositions) in a rigid or semi-rigid shell. Such a shell could then be pressurized with a potential breathable atmosphere enabling more efficient surface activity and asteroid utilization by humans. The shell could also be used to maintain the overall integrity of the asteroid while processing of it continues inside the shell, allowing human-led activities to proceed in less bulky suits (given a pressurized shell). Astronauts on the sub-surface would not have to be as concerned about radiation or impact events (being protected by some measure by the exterior shell). Such a framework would form the backbone of a new solar system infrastructure node (station). Two specific unique shell development technologies are presented. One method is that of acoustic shaping, using sound waves to create solid structures from surface material. The other method is to utilize an advanced attachment technology known as NanoFoil®. The Dyson Asteroid Shell concept involves looking at the asteroid habitation issue from the outside-in rather than inside-out.

Key Words: asteroid, dyson, sphere, habitat, station

Nomenclature

DAS Dyson Asteroid Shell

1. Introduction

Asteroids, comets, and the planetary moons have been advocated as potential destinations for human exploration. From the science to be obtained on these bodies to the incredible resources available there, there are many motivations for such exploration. Sustainable human exploration of the solar system will rely on use of indigenous resources. Long duration bases will have to be self-reliant. Bodies such as asteroids provide the avenue for that self-sufficiency. Asteroids, comets, and small moons may be easier objectives in terms of orbital energy and trip times than planetary surfaces. In addition, these bodies have resources that would be useful to humans (in-space and on earth), ranging from water ice to platinum.

The ultimate goal of human exploration is to create artificial worlds that replicate many of the properties of Earth. There are multiple philosophies related to the creation of these artificial worlds or infrastructure nodes. Let us suppose that we want to build an artificial world. One could build these worlds piece by piece starting from the smallest elements and building a large orbiting structure. Alternatively one could use an existing object in space and then use that as foundation to build a world. This paper advocates just such a philosophy using both novel types of materials and space construction techniques.

This development path referred to as the Dyson Asteroid Shell (DAS) is presented here as a novel thought experiment for how to transform asteroids into usable space infrastructure nodes. This paper presents the historical context, the concept in general, and associated technologies. This concept is based upon a combination of previously advocated approaches to human colonization. Future studies may be needed to further examine the concept from a quantitative perspective.

2. Influences

The main influence for this concept comes from the ideas of Freeman Dyson and specifically the Dyson sphere[1)]. Dyson proposed that a very advanced civilization could create an artificial shell around a star consisting of collectors and/or habitats, thus capturing enormous amounts of energy. Fictional accounts portrayed the concept as an enclosed sphere (see Figure 1). Dyson himself did not agree with this interpretation, stating: "A solid shell or ring surrounding a star is mechanically impossible. The form of 'biosphere' which I envisaged consists of a loose collection or swarm of objects traveling on independent orbits around the star."[2)]

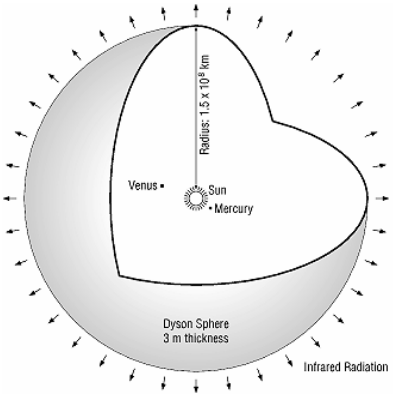

Fig. 1. Notional Representation of Dyson Sphere[3)]

Previous concepts have also included using such shells around Jupiter. In particular, the “Supra-Jupiter” concept by Paul Birch involved creating a new, solid super-surface around

Jupiter. The construction would be at such a radius that the surface gravity on the new surface would be similar to that of the Earth and that thermal energy of Jupiter would be extracted for useful purposes[4]. In particular, Burch's concept involved:

> Mass beams, in the form of dynamic compression members and dynamic orbital rings, [that] would be configured into a framework around the planet which would support platforms, which could in turn support a large biosphere. Individual platforms could then be extended into bands which could later be widened into a complete shell. In most ways the details of the biospherics are similar to those of other space habitats. Airwalls at the edges of the platforms keep the biosphere in place until the shell is completed and supporting the shell with orbital rings avoids the need for 'unobtainium'[5]

Additionally, there have been previous studies looking at habitation inside an asteroid. There have also been multiple analyses of asteroid mining ranging from examination of possible materials to the economic impact of such mining. Previous studies from others, including Gerard O'Neill, have examined megastructures, associated energy systems, and mass driver concepts for such structures.

Another set of concepts (seen in Figures 2 and 3) were proposed by Dandridge MacFarlan Cole of Martin Co. in the 1960s[6), 7), 8)]. He suggested using nickel-iron asteroids to make human colonies. One specific concept involved drilling a hole, pumping water into the holes, and then sealing up the hole. Subsequent heating from reflected sunlight (using large mirrors) would make the water boil, the nickel-iron soft and malleable, where it would blow up like a balloon. These "bubbleworlds" could be used as human arks for solar system or interstellar travel. As commentators have observed:

> Dandridge Cole was one of the first scientists to draw the broad outlines of such a mission. In the early 1960s, he studied the possibility of using Apollo hardware for a mission to Eros, during its close approach to Earth in 1975…Cole and Cox [Donald Cox] also outlined many of the robotic precursor missions to the asteroids that have largely inspired those that were realized over the past few years (such as NEAR and Hayabusa) and those yet to be flown (such as the Dawn mission to Ceres and Vesta). In addition, they saw the importance of establishing beachheads on the Martian moons Phobos and Demos to facilitate the exploration of the planet…In 1963, Cole wrote 'Exploring the Secrets of Space: Astronautics for the Layman' with I. M. Levitt. In this book they suggested hollowing out an ellipsoidal asteroid about 30 km long, and rotating it about its major axis to simulate gravity. By reflecting sunlight inside with mirrors, and creating, on its inner surface, a pastoral setting an asteroid could be transformed into a permanent space colony. Cole and Cox also envisioned that asteroids would provide the raw materials to form the basis of a spacefaring civilization. And, that asteroidal materials would also serve terrestrial needs. In their view these materials could be transported using mass drivers or linear motors. Cole's work largely presages that of Gerard K. O'Neill by more than a decade….A year later, Cole and Cox elaborated this idea further. They went on to consider the possibility of using asteroids as interstellar arks or generation ships. The "nomadic pseudo-earth," as Cole and Cox called their conception, would be the hollowed out space inside a captured asteroid. The result would be a "gigantic geodesic interior chamber," created "in much the same way as a glassblower shapes a small solid lump of molten glass into a large empty bottle." Thus Cole, like Konstantin Tsiolkovsky and Robert Goddard before him, envisaged that asteroids would be the stepping-stones paving the path to the outer solar system and beyond. Cole in his 1961 book 'The Ultimate Human Society' also argued that huge space colonies might evolve into new organisms called "Macro-Life" composed of innumerable living creatures. Cole wrote: "Taking man as representative of multicelled life, we can say that man is the mean proportional between Macro-Life and the cell. Macro-Life is a new life form of gigantic size which has for its cells individual human beings, plants, animals, and machines . . . Society can be said to pregnant with a mutant creature which will be at the same time an extraterrestrial colony of human beings and a new large-scale life form."[9)]

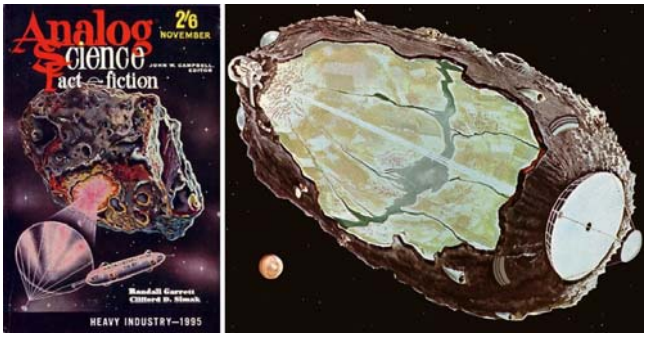

Fig. 2. Dandridge Cole Asteroid BubbleWorld - 1

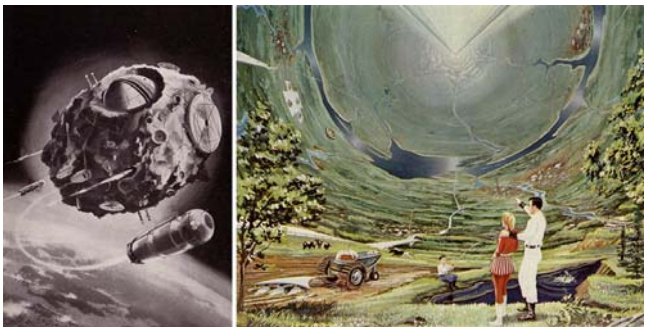

Fig. 3. Dandridge Cole Asteroid BubbleWorld - 2

There may be issues associated with some of the above approaches. Finding a candidate asteroid suitable for the drilling and subsequent processing to develop an interior base would be difficult. The composition of these bodies varies widely. Some of these bodies can be extremely unstable due to

being a conglomeration of loose material. Extreme temperature changes may also have an effect on the integrity of such a body. In addition, many of the previously discussed concepts involved very grand and elaborate plans for large bodies that are relatively infeasible in the near term time frame. More modular and smaller scale versions of these visions are potentially worthy of examination. Beyond technological advancements, we now have new knowledge about asteroids and comets; beyond that available to Cole and others in the past that may help one make better informed decisions relative to asteroid habitats.

3. Dyson Asteroid Shell (DAS) Overview

The new asteroid habitation concept introduced here is referred to here as a Dyson Asteroid Shell (DAS). The DAS involves completely enclosing a small body such as an asteroid in a rigid or semi-rigid shell (see Figure 4). Such a framework would form the backbone of a new solar system infrastructure node. Such a shell could then be pressurized with a potential breathable atmosphere enabling more efficient surface activity by humans. The shell could also be used to maintain the overall integrity of the asteroid while processing of it continues inside the shell. Once such a shell is formed then multiple activities can be enabled. Processing of asteroid material could be made easier by allowing human-led activities to proceed in less bulky suits (given a pressurized shell). Astronauts on the sub-surface would not have to be as concerned about radiation or impact events (being protected by some measure by the exterior shell). The shell could also give the asteroid structural stability as potential mining activities are taking place. This concept involves looking at the asteroid habitation issue from the outside-in rather than inside-out.

Fig. 4. Notional Representation of Construction of a Dyson Asteroid Shell

The ultimate objective of the DAS concept is the development of a space station composed of an enclosed body. On a fully enclosed DAS asteroid, humans could work on the surface or inside. Slowly over time interior material could be excavated and processed to produce some type of hollow habitable volume.

A trade-off is made of the DAS concept versus previous concepts. There is less overall drilling and interior processing, in its place there is more surface processing. Deep interior drilling would perhaps not be effective against very porous asteroids and would be difficult against hard asteroids.

Various sections of the shell could be added in an incremental approach to reach complete enclosure. A scaffolding framework could be developed to act as the initial superstructure of the shell. Indigenous materials could be used for the actual sections of the shell structure using multiple technologies. Two technologies for shell development include discussed here include in-situ acoustic shaping and NanoFoil®. Acoustic shaping is a technology where sound waves are used to create solid structures from asteroid material, easier to perform in low gravity environments[10), 11), 12)]. This effect has been examined in sounding rocket experiments and in KC-135 micro-gravity flights. Recent acoustic shaping experiments indicate that both flat and curved shapes can be produced. The material for the shell would come from the asteroid itself. These shell panels could be attached to each other or potentially bonded to the surface of the asteroid. For this latter approach, recently development attachment/surface processing technologies such as NanoFoil® could be utilized. NanoFoil® is a nano-engineered material that has a property that allows for an instantaneous release of heat energy for reaction initiation and joining applications. It can be used to bond dramatically dissimilar kinds of materials without causing the materials to crack. As seen in Figure 5 the shell could be made from a surface layer of panels bonded to the surface (using NanoFoil® for instance) or a scaffolding approach. The shell could also be made of synthetic materials created for recent inflatable habitats.

An incremental or phased approach can be used to realize the full potential of this concept. A starting phase would examine the potential ways of capturing and surrounding a small test body though the use of an independent assortment of satellites that may not necessarily fully enclose the body (Phase A). The second phase would look at performing the encasement using surface structures on a slightly larger body (Phase B). The third (long-term) phase would perform the process with humans-in-the-loop on a much larger body with a more useful gravitational field (Phase C). This phase would also use a shell constructed from the surface.

The DAS concept could be potentiality better applied to rubble pile asteroids. Such objects have a very high porosity making surface activities difficult. A DAS concept could make the body's exterior more rigid to allow easier development of the interior. The acoustic shaping technology may be more appropriate to apply on rubble piles as well.

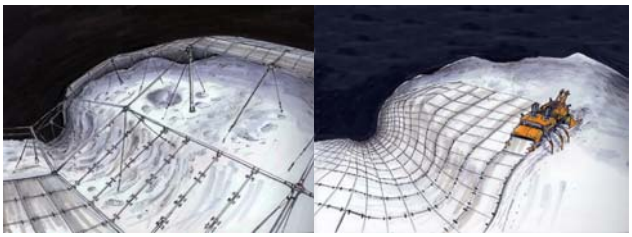

Fig. 5. Notional Shell Construction Techniques (Scaffolding Approach or Surface Bonding Approach)

The eventual result of such a development process would be to create an artificial world with both a usable interior and exterior (see Figure 6). Such a station could have additional systems to enhance the rigid/semi-rigid structure including solar arrays, propulsion systems, and docking adapters (for visiting spacecraft).

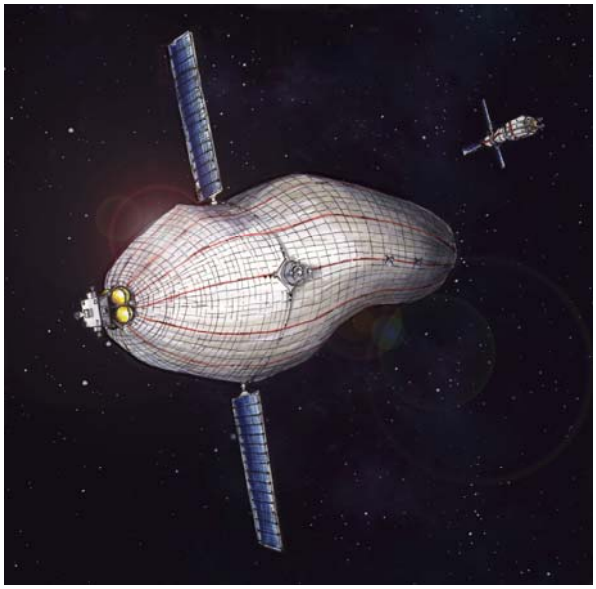

Fig. 6. Completely Enclosed DAS Concept

4. Acknowledgments

The authors gratefully acknowledge the contributions of colleagues at SpaceWorks Engineering, Inc. (SEI) who contributed to this paper. Mr. Mark Elwood, head of Space Media Group (SMG) at SEI, developed several of the illustrations of the concept.

5. References

1) Dyson, F., "Search for Artificial Stellar Sources of Infrared Radiation," Science, 1959.
2) http://en.wikipedia.org/wiki/Dyson_sphere.
3) http://upload.wikimedia.org/wikipedia/en/8/8c/Dysonspheredia gram.gif
4) Birch, P., "A Visit to SupraJupiter," Analog, December 1992.
5) http://www.orionsarm.com/tech/Supramundane_Worlds.html
6) Cole, D. M. and Levitt, I. M. Exploring the Secrets of Space. 1963.
7) Cole, D. M. and Cox, D. W. Islands in Space. 1964.
8) Cole, D. M. and Scarfo, R. G. Beyond Tomorrow. 1965.
9) Anonymous, “Islands in Space: The Challenge of the Planetoids, the Pioneering Work of Dandridge M. Cole,” http://discoveryenterprise.blogspot.com, 08 August 2007.
10) Wanis, S., Sercovich, A., Komerath, N., “Acoustic Shaping In Microgravity: Higher Order Surface Shapes,” AIAA Paper 99-0954. 1999.
11) Ganesh, B., Matos, C.A., Coker, A., Hausaman, J., Komerath, N.M., “A Costing Strategy for Manufacturing in Orbit Using Extraterrestrial Resources,” Space Resources Roundtable II. 2000.
12) Komerath, N., “Acoustic Shaping, Inc.: Business Plan for Space-Based Manufacturing.”