to the stars
ad Astra
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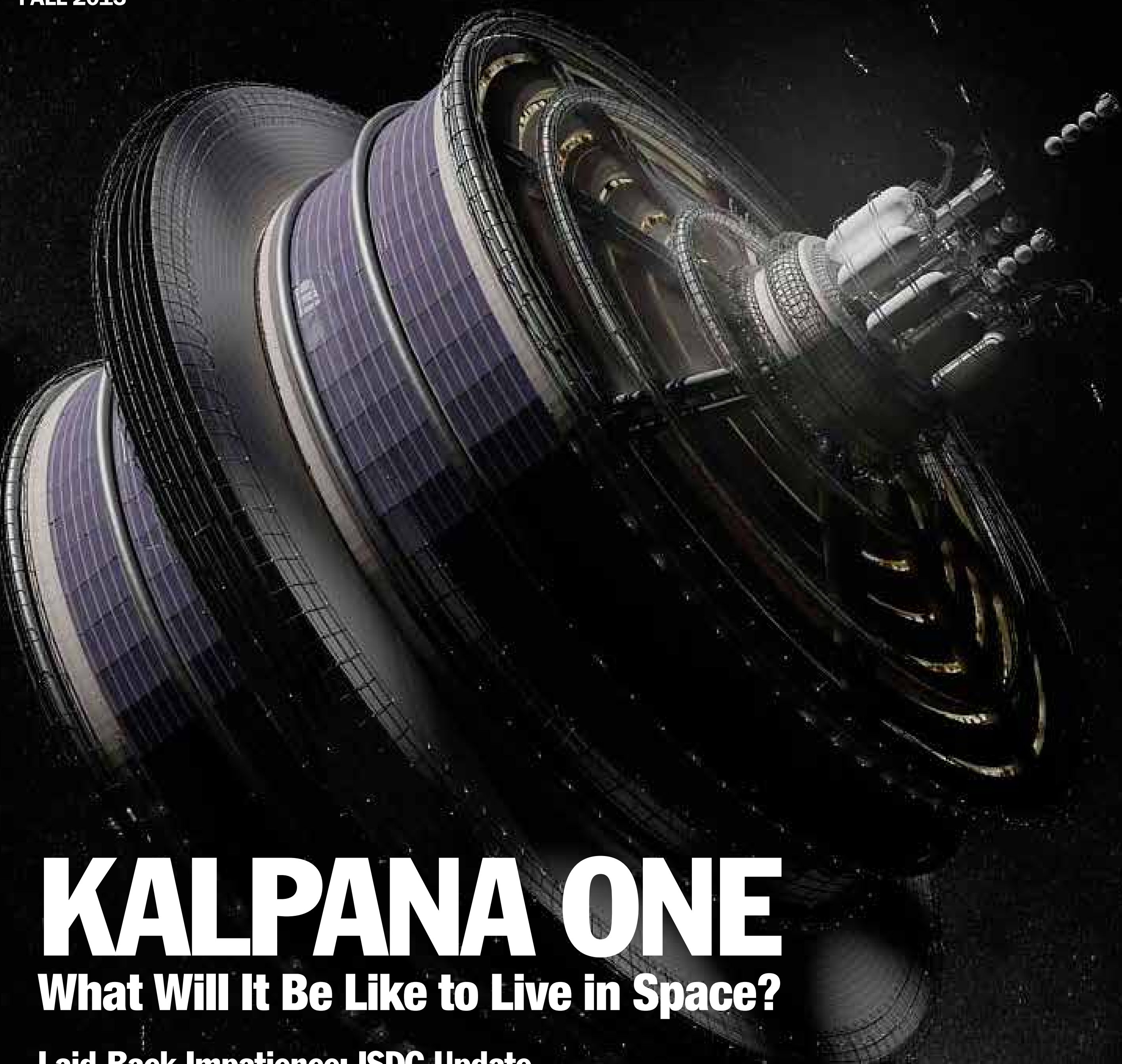
FALL 2013



KALPANA ONE
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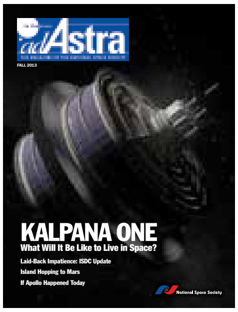

Cover Image

Kalpana One is intended to improve on the orbital space settlement designs of the mid-1970s. The Kalpana One structure is a cylinder with a radius of 250 meters and a length of 325 meters. The population target is 3,000 residents.

IMAGE CREDIT: © BRYAN VERSTEEG / SPACEHABS.COM

The Kalpana One interior living space has Earth-normal pseudo-gravity provided by the twice-per-minute rotation of the settlement.

IMAGE CREDIT: © BRYAN VERSTEEG / SPACEHABS.COM

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This artist's rendition shows the Kalpana One space settlement end cap docking port exterior view.

IMAGE CREDIT: © BRYAN VERSTEEG / SPACEHABS.COM

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What Will It Be Like to Live in Space?

BY AL GLOBUS

ILLUSTRATED BY BRYAN VERSTEEG

What will it be like to live in space? Not explore for a few months, but move into a space settlement, raise your family, and perhaps stay there for the rest of your life. Would you move to a cold, ugly place with a handful of people? No, it will have to be a beautiful place to live with neighbors, friends, and family. Why? Because otherwise, people like you—the technically savvy, capable folks needed to run it—won't want to live there.

The images in this article and on the cover of this issue of *Ad Astra* are intended to give you a taste of living in the Kalpana One space settlement. Kalpana One was designed to be one of the earliest, if not the first, orbital space settlement. To be one of the first, Kalpana One is as small as we dared make it and can be put in the most convenient place when the time comes, whether that be Earth orbit, lunar orbit, around Mars, or co-orbiting with an asteroid.

Kalpana One is in free space, in orbit—not on a planet or moon. There are good reasons for this. One of the most important is Earth-normal pseudo-gravity so the kids will grow up strong. And if there are no kids, it's not a settlement.

Size is tied to generating one-g pseudo-gravity: the larger the size, the smaller the rotation rate. But it can't rotate too quickly or life will be very unpleasant. Kalpana One spins at two rotations per minute, giving you Earth-normal pseudo-gravity at about a 250 meter radius (two and a half American football fields), which means walking all the way around is roughly a 1,600 meter stroll (one mile). For stable rotation, Kalpana One can only be 325 meters long. This is just a bit smaller than the very nice California beach town where I currently live.

Earth-normal pseudo-gravity is very important. On the Moon or Mars, your children will grow up in either one-sixth or one-third gravity. No child has ever experienced this. We don't know much about what will happen but it is all but certain they would be too weak to visit Earth without being wheelchair- or bed-bound. That is not what I would want for my family.

There are other reasons to build space settlements in free space rather than on a planet or moon. Communication, resupply, and trade are all easier. As an added bonus, solar energy is much more abundant—there is no night! The only essential that isn't easier is access to bulk materials, but by co-orbiting with a convenient near-Earth asteroid, the materials problem can be elegantly resolved. There are around 20,000 near-Earth asteroids big enough to supply materials for at least one settlement the size of Kalpana One. Another option is to bring asteroid material to cislunar space. Deciding whether to build Kalpana One from asteroid or lunar material, or a combination of both, will require extensive trade-off studies, and will also depend on the extent to which these resources are developed for other purposes.

Here is an interior cutaway of Kalpana One. One end cap has been cut away to give a view of the other end cap and most of the one-g interior living space, including substantial sports facilities. The space inside the bright interior cylinder can be used for storage, agriculture, partial-g industry, and low-g recreation and performance arts.

This artist rendition shows the interior, complete with golf course, as viewed from part of the way up an end cap.

Other reasons to build in free space involve taking advantage of weightlessness. There are at least two advantages that really matter: the size of your settlement and recreation. It's easier to build big things in a weightless environment. It's much easier to move big bulky parts around. This, combined with the minimum sizes for a reasonable rotation rate, means free space settlement structures will tend to be bigger than those on the Moon or Mars. Wherever your space settlement is located, going outside will require a spacesuit and expose you to a lot of radiation, so you really want something big to live in—the bigger the better. You're going to spend a lot of time inside. You do not want a place so cramped that you will not enjoy living there.

Almost anyone who has been in space will tell you weightlessness is great. The freedom of movement is spectacular. Except for Skylab, which was big enough for some truly amazing gymnastics, people in space haven't had enough room for a whole lot of dance and sports (although there have been some). Kalpana One creates pseudo-gravity by rotation, which means that near the center (the axis of rotation) you experience weightlessness. Kalpana One is more than big enough for weightless dance, gymnastics, and sports—with propeller-driven brooms, you could even play Quidditch.

Kalpana One is named in honor of Dr. Kalpana Chawla, a NASA astronaut born in India who died in the Space Shuttle Columbia accident. For a few years, she was in the office next to mine at NASA Ames Research Center where we occasionally worked together to solve computational fluid dynamics problems.

The Kalpana One design was first published in 2006 at an AIAA conference, co-authored by myself and two students from Punjab Engineering College (Nitin Arora and Ankur Bajoria). Joe Straut found a flaw in the original paper and is listed as co-author of an updated version available on the NSS website (see *nss.org/kalpana*).

The purpose of the paper was to improve on the space settlement designs of the 1970s (see p. 19) and the Lewis One design of the early 1990s. The smaller Kalpana One could be built earlier and also solves some problems with the other designs.

The paper shows that of all feasible shapes, a cylinder maximizes one-g living area per unit mass if you assume radiation shielding is most of the material needed for the settlement. This is almost certainly the case if you want to have children, as pregnant women and infants are particularly vulnerable to radiation and ample shielding mass is a robust and effective way to limit radiation exposure. Compared to a torus, a cylinder also has the advantage of containing the center, where weightless recreation is possible, and one can insert smaller cylinders in the center—significantly increasing the surface area available, albeit at lower pseudo-gravity levels. Kalpana One uses these interior cylinders for low-g agriculture, storage, manufacture, and recreation.

Another interior view from part of the way up an end cap is shown. A soccer game is in progress, complete with spectators.

Single long cylinders are rotationally unstable. Give a long skinny cylinder rotating in zero-g a few little pushes and it will eventually rotate end-over-end, which would be bad for real estate values. Kalpana One is a stubby cylinder, only 325 meters long with a radius of 250 meters, so that it naturally 'prefers' to rotate around the right axis. It would be possible to overcome the end-over-end problem with active controls, but it's almost always better to work with physics rather than against it.

A significant problem with the Bernal Sphere and Stanford Torus designs (see p. 19) is that the habitat area would

An interior view showing a large section of the one-g living area and a small air car.

rotate inside a massive stationary radiation shield, making it very tricky to design against the possibility of a catastrophic failure should the two collide. Kalpana One, like the much larger O'Neill Cylinders, has sufficient radiation shielding built into the hull structure.

Kalpana One could be the start of something really big. Ceres, the largest asteroid, has enough materials to make Kalpana One-like settlements in sufficient numbers so that the total living area would be between 100 and 1,000 times the surface area of Earth (the different numbers reflect different assumptions). Thus, the expansion capability of free space settlements in this Solar System is vastly greater than the Moon and Mars can provide.

Furthermore, when it comes time to travel to another star, a civilization living in free space settlements won't even need a planet, much less an Earth-sized planet in the habitable zone. All the distant descendants of Kalpana One will need for interstellar settlement is some junk (e.g., asteroids) orbiting the star. The trip can take as long as necessary since free space settlements make fine generation ships. Your friends and family can all be on board. Kalpana One is designed for 3,000 residents, but long before we send settlements to the stars we will almost certainly make them much bigger and with larger populations.

As we said in the beginning, it is important that Kalpana One be a beautiful place to live. Conceptual artist Bryan Versteeg (*spacehabs.com*) created the images of Kalpana One you see on the cover and throughout this article. Take a few minutes to really examine them. Is this a place you might like to live? My answer: YES!

For more information, including videos, more pictures, and the full paper on Kalpana One, see www.nss.org/kalpana.

This image shows a close-up of a residence. It is safe to place furniture outside because 'rain' is computer-controlled not to fall where it's not wanted.

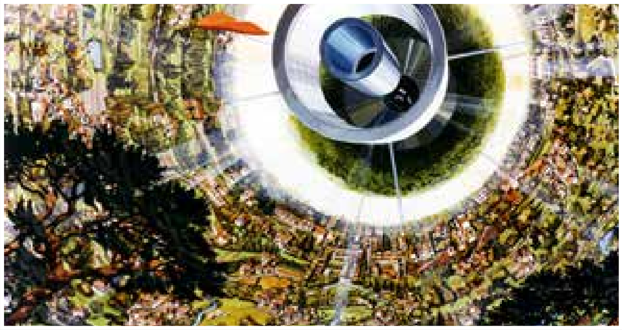
Space Settlement Designs

Built out of materials from asteroids or moons

Kalpana One

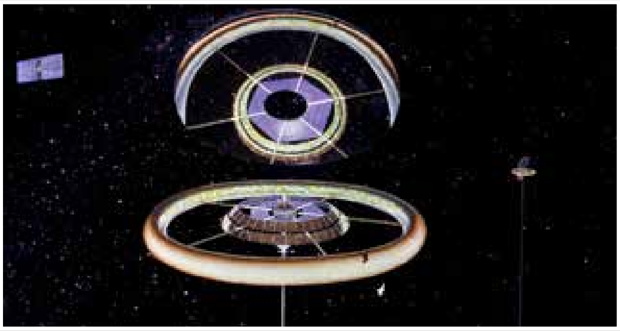
Diameter 1/3 mile — Population 3,000. (© Bryan Versteeg, spacehabs.com)

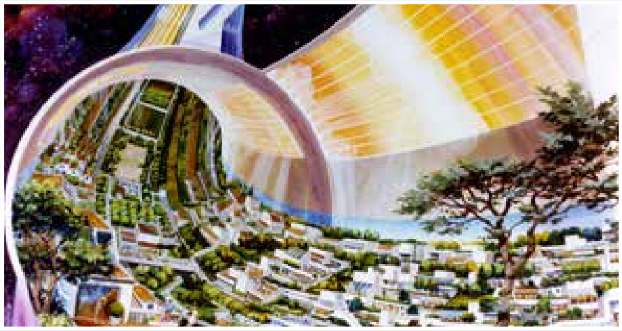
Bernal Sphere



Diameter 1/3 mile — Population 10,000. (Rick Guidice, NASA)

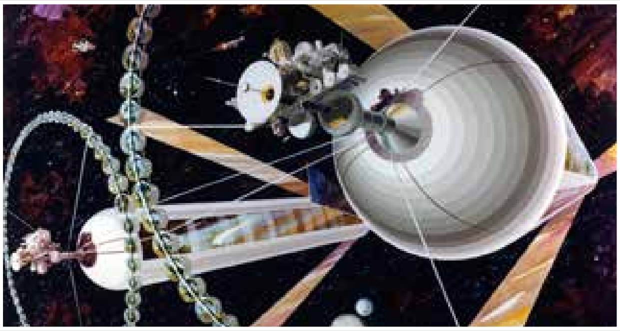
Stanford Torus





Diameter 1 mile — Population 10,000. (Don Davis, Rick Guidice, NASA)

O'Neill Cylinder



Diameter 4 miles — Population over a million. (Rick Guidice, NASA)