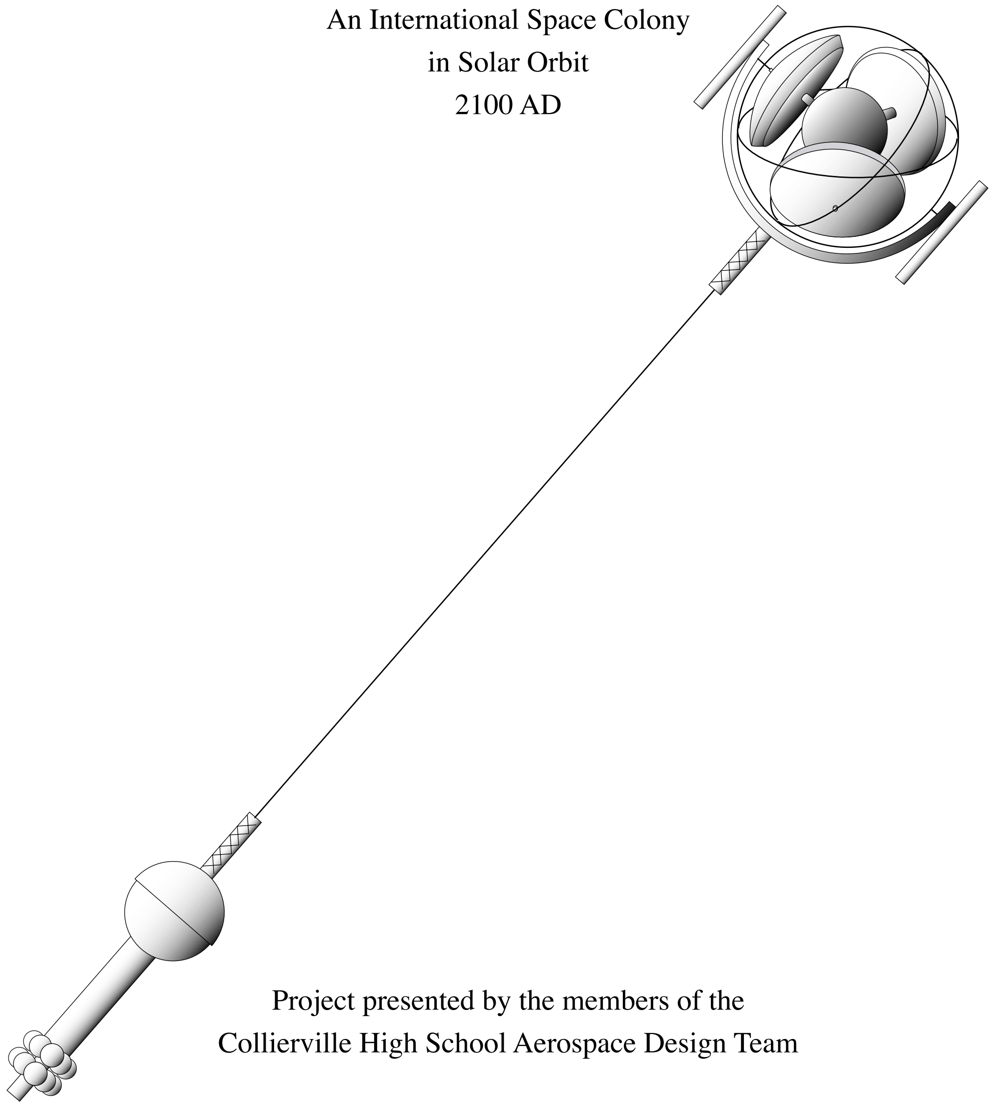
Triangulum Cluster

An International Space Colony
in Solar Orbit
2100 AD



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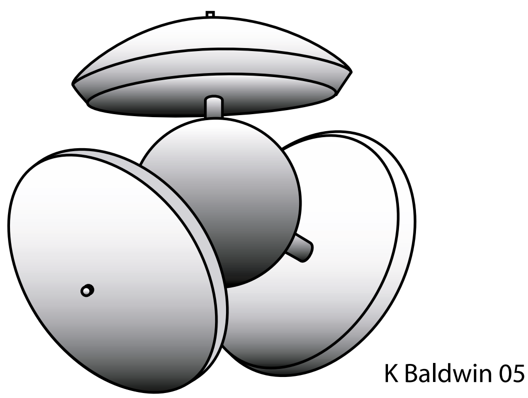
Preface

The Collierville Aerospace Design Team has been together since 1999, beginning in middle school. Team members have come and gone over the years but Jennifer Baldwin, Kelly Baldwin and Drew Conner have been on the team from the very beginning. Alex Vranas joined the team in 2000-2001. Ashley Kucsmas was a member of the 1999-2000 and the 2000-2001 teams, then rejoined the team for 2003-2004 and 2004-2005. Morgan Darden has been on the team since 2003. Will Nixon joined the team in 2005. Aerospace Design Team (ADT) members meet year-round with planning meetings during the summer months, and work sessions beginning with each new school year. Before winter break, one-hour, informal sessions were held every Saturday morning at 8:00 at Starbucks®. After winter break the sessions stretched to 2-hour meetings every Saturday morning at the Collierville Public Library. Based on individual talents and interests, each team member researched and developed particular sections of "The Triangulum Cluster" and emailed those sections to one member, who compiled and edited the project.

You are invited to sit back and enjoy a journey through our solar system, with the crew and citizens of "The Triangulum Cluster", a colony of 5,000 individuals (men, women and children), who have chosen to dedicate their lives to the exploration of our solar system.



01 Purpose of Triangulum Cluster

The Triangulum Cluster was established as a command center, research facility, and resupply vessel for the human colonies in our solar system. Although habitation of space has been underway for many decades, there are still many mysteries to be explored and concerns to be addressed. The scientists of the Cluster are conducting research on the effects of space radiation on space travelers. Cluster engineers continue to develop interstellar propulsion systems as a precursor to journeys to Cancri 55 and Alpha Centauri during the next century. The Triangulum Cluster is on its first grand tour of our solar system, with logistical and strategic stops at all of our permanent manned outposts and colonies. The crew and citizens of the Cluster will complete this twenty-four year tour and will have an option of staying onboard for another tour of the solar system or accepting Earth retirement.

02 Human colonies in our solar system

As we near the dawn of the twenty-second century, human colonization in our solar system has become almost routine. Since the days of the International Space Station (ISS) in the late twentieth and early twenty-first centuries, nations of Earth have banded together to explore the vast reaches of our solar system. As we set our sights on interstellar space travel during the twenty-second century, let us take a look at how far we have come thusfar. We have more than 25 colonies and outposts (both manned and unmanned) dotting the map of our solar system. Our first great endeavor beyond the ISS was the Lupus colonies on the lunar surface. Our latest endeavor is the Triangulum Cluster. Here is a recap of all major human colonization projects of this century.

02a 2015—Lupus: manned colonies on the Moon

Our oldest space colony, Lupus was originally established as man's return to human exploration of space beyond the International Space Station. Over the years Lupus has developed into an invaluable manufacturing and processing colony. Deuterium and 3He (Helium 3) are found in abundance on the lunar surface. The primary function of the inhabitants of the Lupus colonies is to collect and process 3He for transport to Earth, BioMat, and the Triangulum Cluster (when we are in parking orbit for resupply and redeployment). 3He is vacuumed from the lunar surface by robotic workers and broken down into its components at the Lupus processing plant. The resulting hydrogen fuel is then lifted from the lunar surface by space elevator, loaded onto tankers, and transported to its final destination as consumable fuel. BioMat serves as the primary communication point for Lupus. The secondary function of the Lupus colony is as a training facility. Off-Earth training is conducted at the Lupus colonies for potential travelers to other surface colonies (on Mars and Europa).

02b 2020—Scorpius: unmanned outpost on Mercury

The unmanned outpost on Mercury was established to monitor and study solar flares and to harvest solar radiation for distribution to Earth, the Moon, BioMat, and the Triangulum Cluster as supplemental power. The temperatures on Mercury range from 800ºF on the daytime side to -280ºF on the nighttime side. Mercury completes it's orbit around the sun in only 88 Earth days. It takes 58.6 Earth days, exactly two-thirds of an orbit, for Mercury to revolve once on its axis. The combination of those motions means that one Mercurial day (sunrise to sunrise) requires three full orbits, or 176 Earth days. Mercury and Venus are the only known worlds where the day in longer than the year. Considering the unusual circumstances of Mercury's daytime, the extreme temperature range presents unique work environment concerns, the robotic colony of Scorpius is housed inside a dome constructed of highly-reflective, highly-insulated amorphous metal. Robotic drones and rovers venture outside the dome when the temperatures on the surface are -15ºF to 130ºF. Radiation collectors/microwave transmitters are in operation at all times.

INSIDE INFORMATION: AMORPHOUS METAL (GLASSY METAL)

A typical two-element ally consists of iron atoms and born atoms, which naturally arrange themselves into a crystalline pattern upon cooling. The repeating spaces between the atoms are grain boundaries. Crystals can shift across these boundaries, allowing oxidation and deterioration. Introducing a third element with a dramatically different atomic radius (such as yttrium), frustrates the alloy's tendency to crystallize, so it solidifies in a random, or amorphous, pattern similar to that of glass. Moldable like plastic but stronger than conventional alloys, amorphous metals can be configured into intricate shapes capable of withstanding high stress, yielding lighter, stronger, and more durable materials than their conventional alloy counterparts. The surface of solidified amorphous metal is reflective, like a mirror, for the same reason the surface of liquid reflects–the amorphous atoms form a smooth skin that bounces light uniformly.

02c 2022—Sagittarius: unmanned outpost around Venus

Water vapor in the Venusian atmosphere absorbs infrared radiation. Sulfur dioxide and other sulfur gases in the atmosphere block still other infrared wavelengths. Together these greenhouse gases make the atmosphere of Venus partially transparent to incoming solar radiation but nearly completely opaque to outgoing thermal radiation. Consequently, the surface temperature is three times what it would be without and atmosphere. Because if the extreme atmospheric conditions of Venus, an unmanned outpost [Sagittarius] was placed in orbit around Venus to conduct atmospheric studies and study the effects of Venusian sulfuric acid on metal design. Studies in metallurgy are conducted by robotic workers and Impactor probes [learn more about Impactor probes in Section 8.d]. Research data is transmitted to BioMat for analysis.

02d 2025—Phodei: manned colony inside the orbits of Martian moons, Phobos and Deimos

The primary functions of Phodei are: [01] provide training for colonists being deployed for Martian terraforming duty; [02] serve as a supply depot for materials being delivered from Earth by supply vessels and the Triangulum Cluster; [03] deliver supplies to the Martian surface via a space elevator connected directly to Gemini; and [04] study, harvest and process resources found on the Martian moons, Phobos and Deimos.

02e 2030—Gemini: manned colonies on Mars

Gemini was established to begin terraforming operations on the Martian surface. Dozens of unmanned robotic missions and ten manned missions to Mars have determined that Mars is a good candidate for permanent human presence. Biodomes have been established on the surface, crops are being grown in altered Martian soil, fuel is being produced from local resources [some power is also imported from Lupus and Scorpius], and terraforming experiments are underway. The first Martian city has been established at the base of Olympus Mons. The scientific community of Gemini has begun studies of the Martian magnetic poles.

02f 2040—Europa 2: manned colony around the Jovian moon, Europa

Europa 2 was placed into orbit around Europa to oversee the water mining operations on the surface of Europa. Europa is the sixth moon of Jupiter, and (from space) appears to be smooth. At closer look, you can observe that Europa is covered with cracks. Models of Europa's interior show that beneath a thin 5 km (3 miles) crust of water ice, Europa may have oceans as deep as 50 km (30 miles) or more. The visible markings on Europa could be a result of global expansion where the crust could have fractured, filled with water and froze. Europa's oceans are the source of water for Europa 2's mining operations. These oceans cover a rocky core. The water is heated by the core, which is like the bottom of the Earth's oceans. Vents on the Earth's ocean floor eject seawater filled with hydrogen sulfide and minerals, and few animals can survive in such conditions. We continue to search for life in the oceans of Europa. Europa 2's future includes plans to mine minerals from Europa's core.

02g 2045—Corvus: manned colony around Saturn's moon, Titan

Impactor probes bombard the surface of Titan on a regular basis. Floaters drift in the dense low-gravity as Corvus scientists analyze the surface. Methane collectors ride the carbon nanotube ribbon of the space elevator connecting Corvus with the upper atmosphere of Titan. Robotic workers swarm the cold, dirty orange surface of the moon, as a steady methane rain falls, and rivers of tholins flow like syrup. Argon collectors sniff out the gas and separate it from the methane before loading it into the elevator tanks. Corvus processors transform the argon and methane gases into usable fuels for the colonies of the outer planets. Fuel shuttles, that look like freight train tankers, transport fuel to BioMat for refinement and shipment to Earth. Titan's methane, along with the 3-He harvested on Earth's moon, have become invaluable fuel supplies for the people of Earth.

Water for the inhabitants of Corvus is supplied from the water-ice on the surface of Titan. Robotic workers collect large blocks of the ice and transport it by elevator to the colony for processing and filtration.

02h 2050—BioMat: manned research/training complex between Earth and the Moon

BioMat (Biological Mechanical and Technical) Colony was established as a logical next step in the exploration of space. In preparation for journeys to planets and moons in our own solar system and eventual manned expeditions across the galaxy, BioMat is providing a stepping stone to the future. The men and women of BioMat are immersed in space. They observe, analyze, calculate, design, plan, live and breathe with space in mind. Many observatories, laboratories and research facilities are housed at BioMat. Space habitation studies and procedures are being conducted daily in the colony. New propulsion systems are tested at BioMat, in addition to preparing humans for deployment to lunar mining operations (including the mining of Helium 3 [3He]), and deployment on deep space missions. Fuel processing facilities on BioMat collect fuels from resources located throughout the solar system and prepare them for shipment to Earth, and its colonies.

BioMat is located at LaGrange point L1 based on an earth/moon relationship. This places BioMat between the earth and the moon, in earth orbit. This point was chosen because of its close proximity to both the moon and the earth, with easy accessibility to the moon for 3-Helium mining operations and establishment of light-pollution free observatories.

02i 2055—Orion: unmanned outpost in the Main Asteroid Belt

More than 70,000 rocks orbit the sun in the Main Asteroid Belt. Orion provides an invaluable service to Earth and its colonies. Orion monitors the major asteroids, keeping track of movement, direction, velocity, and composition. Impactor probes transmit data to Orion for analysis. The main asteroid belt lies between the orbits of Mars and Jupiter, but stragglers cross Earth's orbit (and sometimes collide with Earth) or revolve in sync with Jupiter. The inner main belt consists mainly of stony or stony-iron asteroids. Farther out the asteroids are darker, redder and richer in carbon. Although Orion is an unmanned outpost, human visitations to asteroids occur on a regular basis. A modified capsule docks with Orion, then several astronauts take 60-day "vacations," spending a few weeks getting to a near-Earth asteroid, a few weeks studying the body from a safe distance and perhaps taking a few exploratory space walks.

02j 2057—Regulus: unmanned outpost around Uranus

Regulus is currently an unmanned outpost, but in the near future, the Triagulum Cluster will deliver the first semi-permanent human crew to Regulus. Most of the planets spin on an axis nearly perpendicular to the plane of the ecliptic but Uranus' axis is almost parallel to the ecliptic. Uranus' polar regions receive more energy input from the Sun than do its equatorial regions. Uranus is nevertheless hotter at its equator than at its poles. The mechanism underlying this is unknown. This is one reason a manned crew will inhabit Regulus. It is time for more intense study of Uranus and it's unusual orientation.

There is an ongoing battle over which of Uranus' poles is its north pole! Either its axial inclination is a bit over 90 degrees and its rotation is direct, or it's a bit less than 90 degrees and the rotation is retrograde. A manned crew will help determine which pole is north.

Uranus is composed primarily of rock and various ices, with only about 15% hydrogen and a little helium. Uranus is similar to the cores of Jupiter and Saturn minus the massive liquid metallic hydrogen envelope. Uranus does not have a rocky core like Jupiter and Saturn but rather that its material is more or less uniformly distributed.

Uranus' atmosphere is about 83% hydrogen, 15% helium and 2% methane. Uranus has bands of clouds that blow around rapidly, showing drastic changes due to seasonal effects. Uranus' blue color is the result of absorption of red light by methane in the upper atmosphere. Uranus' colored bands are hidden from view by the overlaying methane layer. Uranus has rings composed of fairly large particles ranging up to 10 meters in diameter in addition to fine dust. There are 11 known rings, all very faint. Regulus is conducting intense studies of the rings of Uranus as well as magnetic field studies. Uranus' magnetic field is odd in that it is not centered on the center of the planet and is tilted almost 60 degrees with respect to the axis of rotation.

02k 2058—Cetus: unmanned outpost around Neptune

Neptune's composition is similar to that of Uranus: various "ices" and rock with about 15% hydrogen and a little helium. Like Uranus, it has a distinct internal layering with uniform composition. There is most likely a small core (about the mass of the Earth) of rocky material. Its atmosphere is mostly hydrogen and helium with a small amount of methane.

Like a typical gas planet, Neptune has rapid winds confined to bands of latitude and large storms or vortices. Neptune's winds are the fastest in the solar system, reaching 2000 km/hour. One of the primary missions of Cetus is to study the weather patterns of Neptune as well as the source of the planet's radiation. Neptune has an internal heat source which radiates more than twice as much energy as it receives from the Sun. Neptune's rings are very dark but their composition is currently unknown. Impactor probes study the rings and send data back to Cetus for analysis.

Neptune's magnetic field is, like that of Uranus, oddly oriented and probably generated by motions of conductive material (probably water) in its middle layers. At some point in the near future the Triangulum Cluster will deliver the first semi-permanent human explorers to Cetus to enhance the studies of the robotic workers and Impactor probes.

02l 2063—Canis Minor: unmanned outpost around Pluto

Pluto's orbit is highly eccentric. At times it is closer to the Sun than Neptune. Pluto rotates in the opposite direction from most of the other planets. Pluto's orbital period is exactly 1.5 times longer than Neptune's. Its orbital inclination is also much higher than the other planets'. Thus though it appears that Pluto's orbit crosses Neptune's, it really doesn't and they will never collide. Like Uranus, the plane of Pluto's equator is at almost right angles to the plane of its orbit.

The surface temperature on Pluto varies between about -235 and -210 C (38 to 63 K). Pluto's composition is a mixture of 70% rock and 30% water ice much like Triton. The bright areas of the surface are covered with ices of nitrogen with smaller amounts of (solid) methane, ethane and carbon monoxide. The darker areas of Pluto's surface are due to primordial organic material and photochemical reactions driven by cosmic rays.

Pluto's atmosphere consists primarily of nitrogen with some carbon monoxide and methane. It is extremely tenuous, the surface pressure being only a few microbars. Pluto's atmosphere exists as a gas only when Pluto is near its perihelion; for the majority of Pluto's long year, the atmospheric gases are frozen into ice.

Because of the extreme conditions of Pluto, there will probably never be permanent human explorers there. The robotic workers and Impactor probes of Canis Minor keep a constant watch on the conditions of Pluto. Experiments are currently being conducted on Canis Minor to attempt to reach absolute zero. Observatories have also been established on Canis Minor to search for extrasolar systems around neighboring stars.

02m 2070—Rasalhague: unmanned outpost around Quaoar

The unmanned outpost of Rasalhague closely orbits Quaoar in the Kuiper Belt. Quaoar is composed mostly of ices mixed with rock, something like the makeup of a comet, although 100 million times greater in volume than an ordinary comet. Even though Quaoar is smaller than Pluto, it is greater in volume than all the asteroids in the Solar System combined. On the other hand, Quaoar probably amounts to only about one-third the mass of the Asteroid Belt, because it's icy rather than rocky.

The primary mission of Rasalhague to monitor the apparent decomposition of Quaoar. The ices of this body are melting. Rasalhague is on a quest to discovery the reason for this phenomenon.

02n 2083—Argon One and Two: manned colonies around Europa

Argon One is in geostationary orbit above the northern pole of Europa. Construction of Argon Two is underway now in geostationary orbit above the southern pole of Europa. The missions and goals of Argon One are many. Listed here are the primary missions of the colony: [1] Development of robotics for deep space application; [2] Research and development of Europan resources; [3] Study sediment deposits; [4] Map Europan ocean floor; [5] Study ion radiation and the effects of radiation on Argonians; [6] Study Europan/Jovian chemical reactions; [7] Develop alternative power sources including plasma collection, ion radiation collection and the electrolysis of water-hydrogen collection; [8] Harvest asteroids for carbon, iron, magnesium, nickel, and diamonds; [9] Research, development and preservation of Earth species-plants and animals]; and [10] Provide a shield of protection for Argon.

02o 2090—Alpha-Omega Complex in the Jovian mini-system

Alpha-Omega consists of a series of outpost colonies in orbit around the moons of Jupiter and beyond. The center of government, education, and culture is located at Outpost Alpha in orbit around Europa.

02.o.1. OUTPOST ALPHA: manned colony around Europa. One of the primary functions of Outpost Alpha is to harvest and process deuterium (heavy hydrogen) and helium 3 (a lighter version of ordinary helium) as a source of fuel for the nuclear fusion engines of the Triangulum Cluster and other solar system craft.

02.o.2. ALPHA-THETA: manned colony around Europa

This colony was designed to explore the solar system and beyond, to develop new astronomical technologies, calculate plans for future outpost locations, and study the composition and inhabitability of the planets and moons of our solar system as well as extrasolar locations.

02.0.3. FLI (Frozen Liquids Inc.): manned colony around Europa

This first all-commercial colony is in orbit around Europa, and was established to explore and mine water on the surface of Europa. Most of the water supplied to Outpost Alpha and the other colonies of the Jupiter mini-system is supplied by FLI.

02.o.4. SIGMA IOTA: manned colony around Io

Sigma Iota was established to harvest radioactive energy from the vast energy sources of Io and provide power resources to Sigma Iota and the other colonies of the Alpha-Omega.

02.o.5. TRITAN: manned colony around Callisto

In orbit around Callisto, Tritan was established to explore energy resources and harvest energy from the volcanic surface of Callisto. Power harvested on and around Callisto is distributed to other Callisto outposts as well as outposts in orbit around Europa, Io, and Ganymede.

02.o.6. BIOZONE: manned colony around Callisto

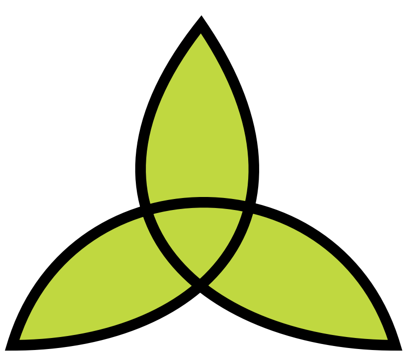
BioZone took on the task of ensuring the survival of animal and plant species from Earth. Through the use of cryogenics, embryos from Earth animals have been preserved in earlier colonies and transported to BioZone for reintroduction into controlled biomes. Research and development of food production processes is also being accomplished at BioZone.

02.o.7. SURVIVOR: manned colony around Europa

Survivor was established to provide security and protection for all colonies of the Alpha-Omega complex. Survivor monitors asteroid movements, solar storms, space debris, comets, and other space hazards. Survivor is equipped to send out crews to intercept objects on a collision course with any of the Alpha-Omega colonies and alter those courses.

02p 2095—The Triangulum Cluster

You have completed an overview of the colonies and outposts currently in place in our solar system. The Triangulum Cluster was established as a link between these colonies and outposts. As new technologies have been and continue to be developed for the Cluster, people throughout our solar system reap the benefits through new products, new processes, and better ways to perform the tasks of our everyday lives.



THE TRIANGULUM CLUSTER ICON

The icon pictured here is prominently displayed on the uniforms of all Triangulum Cluster crew and citizens.

The icon symbolizes the link between the Triangulum Cluster, human colonies, and unmanned outposts in our solar system. The icon also symbolizes the bond among the inhabitants of the three domes of the Triangulum Cluster.

J BALDWIN/K BALDWIN 2005

03 Construction/Assembly of Triangulum Cluster

03a Space Elevator: The space elevator is a physical connection from the surface of the Earth to a geostationary Earth orbit (GEO–in the case of Earth) above the Earth at roughly 62,000 miles in altitude. Several space elevators are currently in use on Earth, based near Sri Lanka and near Ecuador. A space elevator is currently in place at the Lupus Lunar colony. Another space elevator is currently in use on Mars, connecting the Gemini colony with the surface of the planet, and another space elevator is in use on Europa, connecting Europa with the Europa 2 colony. Travelers on one of the two Earth elevators reach a low-Earth destination (240 miles) in less than three hours inside climbers. Climbers are economically mass produced on Earth and can transport people and materials at a fraction of the cost of rocket transport. Some rocketplane transports are still in use by corporations and government agencies, but the majority of spacebound endeavors begin with a ride on a space elevator.

An Earth-orbit space elevator is constructed of a carbon nanotube composite ribbon 62,000 miles long, three feet wide and thinner than a newspaper page. The competing forces of gravity at the terrestrial end of the elevator and centripetal acceleration at the deep-space end keep the ribbon taut and stationary over a single position at Earth's equator. A fleet of climbing vehicles (powered by photovoltaic cells on the climbers' undersides that are energized by a laser beamed up from the anchor station) haul cargo and people to various orbits. Cargo or passenger vessels released by a climber at the far end of the ribbon, have enough velocity to travel to the Moon, Mars, Venus or the asteroids. Ascent vehicles (climbers) vary in size, configuration and power, depending on function. All climb via tractor like treads that pinch the ribbon like the wringers of an old-fashioned washing machine.

Initially, a deployment booster, carried aloft by spaceplanes and assembled in low Earth orbit, deployed two spools of 10-inch-wide ribbon into geosynchronous orbit, 22,000 miles above the equator. The ribbons unwound down toward Earth as the spools simultaneously ascended to 62,000 miles into space. Once the strips were anchored to a site on Earth, 230 unmanned climbers zipped together and widened the strips. These climbers remain permanently at the far end of the ribbon, just below the deployment booster, to serve as a counterweight. The completed ribbon and counterweight can support a steady stream of climbers, each capable of hoisting 13 tons of cargo and/or people at 125 miles per hour and reaching geosynchronous orbit in seven days.

Space elevators are being utilized as a transportation and utility system for moving people, payloads, power, gases and liquids between the surface of the Earth, the Moon, Mars or Europa and space. It makes the physical connection from the surface to space in the same way a bridge connects two cities across a body of water. Several entertainment companies have established space hotels along the routes of the Earth elevators. Similar endeavors are planned for space elevators on the moon and Mars. Materials for the Triangulum Cluster were transported to low-Earth orbit in climbers, where they were picked up by space tugs and pulled to the final assembly area by tether.

INSIDE INFORMATION: THE EXPRESS CAR FROM EARTH

The spaceplane is an ear-splitting, bone-rattling ride, beginning with eight minutes of inertial forces peaking at three g's (three times the passenger's weight) followed by a near-instant, stomach-churning flip to zero gravity.

By contrast, the space elevator offers gracious access from Earth to space.

The first five miles seem familiar to air travelers, but at the seven-mile mark, Earth's curvature becomes noticeable, and by 30 miles the sky turns black and stars are visible, even in daytime, on the climber's shaded side. Windows are thick and coated for pressure containment and radiation protection. High resolution television screens provide travelers with panoramic views.

At 100 miles, Earth appears as a partial sphere. By 215 miles, gravity drops by a noticeable 10 percent; by 456 miles, it drops 20 percent. At around 1,642 miles (roughly 13 hours into the trip) it drops by 50 percent. Just as mountain climbers and backpackers must sometimes become acclimated to high altitudes, space elevator travelers sometimes slow the reduction of gravity by making the journey a multi-day event. This approach significantly reduces the number of people adversely affected by zero gravity by the time they reach the geosynchronous orbit station.

As a final destination for some tourist travelers, a permanent hotel is affixed to the space elevator at 8,700 miles, where the gravity level is one-tenth that of Earth's.

At the 22,000-mile-high geosynchronous orbit stop, Earth appears the size of a baseball held at arm's length. A permanent station floating nearby offers a variety of tourist attractions, such as zero-gravity ball games, and free-flights with arm wings.

03b **Components of the Cluster:** The Triangulum Cluster consists of three mushroom-shaped domes, connected to a central hub by stems. Stem trains transport residents and visitors to and from the hub and the mushroom domes. Once travelers disembark at the mushroom terminals, transportation throughout the mushrooms is accomplished either by foot, hoverboard, hover Segway or moving walkways. Electric carts and conveyors are used to transport materials throughout the Cluster.

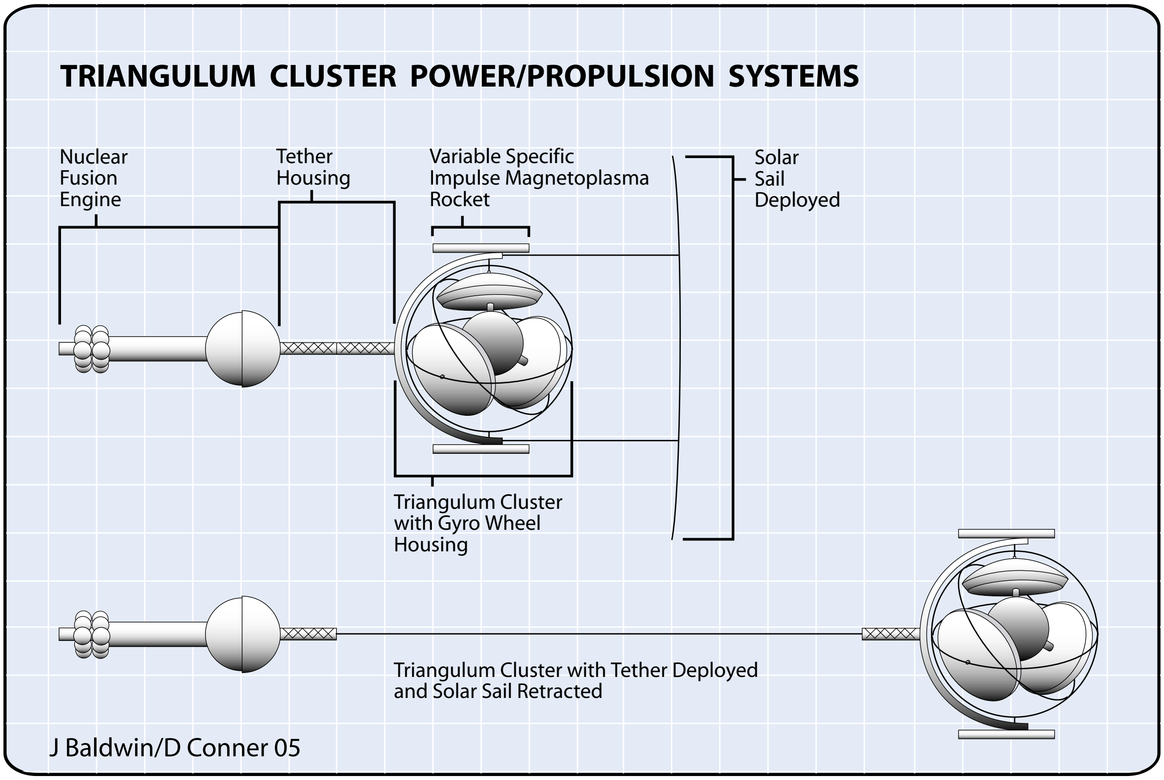
Components for the Triangulum Cluster were constructed at lunar manufacturing facilities and lifted into near-Moon orbit for final construction. Final construction of the Cluster was accomplished primarily by nanobots. For security reasons, nanobot workers were programmed to be less intelligent than humans. Nanobot workers were programmed and controlled by human counterparts at the Lupus lunar camps and command centers on Earth. After construction, inspection, crew and inhabitant training, and a few short test maneuvers, the Triangulum Cluster was launched on its first tour of our solar system.

03c Timeline: Construction/assembly timeline for Triangulum Cluster:

04.2089	Preliminary construction began near the BioMat colony
12.2091	Skeletal structure of all three mushrooms and stems completed
02.2092	Propulsion and power systems activated
02.2092	Control systems operational
06.2092	Docking and connecting capabilities established in the hub
06.2092	Stem train operational
07.2092	Supplies arrive for the first crew members
07.2092	Cooling fans, fire extinguishers, smoke detectors installed
07.2092	Escape pods operational
09.2092	Propulsive attitude controls operational
10.2092	Data and communication systems connected
10.2092	Living modules/office modules installed
01.2093	First permanent crew members arrive; secure gear; check instrumentation
01.2093	Refuse systems installed
04.2093	Control gyros and hydroponics installed
10.2093	Solar arrays operational; conversion and regulation of power complete
11.2093	Labs/experiment racks installed (human life science; materials research; commerce)
02.2094	Optical gem installed for high quality photo/video equipment
02.2094	Logistics module installed
03.2094	Robotic arm installed along rails covering the entire length of station
06.2094	Robotic delivery system [Triangulum Cluster Manipulation System--TCMS] activated
06.2094	Public facilities installed
01.2095	Citizens and additional crew arrive

04 Power/propulsion systems of Triangulum Cluster

The Triangulum Cluster employs a variety of power/propulsion systems. Among them are: (01) Variable specific impulse magnetoplasma rockets; (02) fuel cells; (03) hydroelectric motors; (04) solar sails; (05) nuclear fusion reactor engine; (05) tether; and (6) solar panels. It is necessary to have several power and propulsion systems in place, because of the complexity of the Cluster's mission–traversing the solar system continuously. Fuel cells, hydroelectric motors and solar panels provide power for the internal demands of the colony. Propulsion needs are met by magnetoplasma rockets, solar sails, nuclear fusion reactor engine, and tether. For internal power, fuel cells are the primary source, with back-up power provided by hydroelectric turbines. Power is collected and stored by solar panels when the Cluster is touring the inner planets. Primary propulsion is provided by variable specific impulse magnetoplasma rockets and solar sails. When an extra burst of acceleration is needed, the nuclear fusion reactor engine is employed, and when the Cluster is traveling near a planet with a strong electromagnetic field, tether propulsion is employed. This combination of power and propulsion ensure a successful voyage, no matter where the Cluster might be traveling.



04a **Variable Specific Impulse Magnetoplasma Rocket:** The Variable Specific Impulse Magnetoplasma Rocket (VASIMR) not only allows for faster space travel than conventional 21st century chemical-powered rockets, but it yields incredible side benefits, as well. VASIMRs allow the Cluster to refuel at every stop along its route through the solar system, without having to keep an enormous amount of fuel onboard. The VASIMR engine also helps protect space travelers from the dangerous effects of radiation during their trip.

VASIMR is a plasma-based propulsion system. An electric power source is used to ionize fuel into plasma. Electric fields heat and accelerate the plasma while the magnetic fields direct the plasma in the proper direction as it is ejected from the engine, creating thrust for the colony. The engine can even vary the amount of thrust generated, allowing it to increase or decrease its acceleration. It even features an "afterburner" mode that sacrifices fuel efficiency for additional speed. Fuels for the VASIMR engine include hydrogen, helium, and deuterium.

The use of hydrogen as the fuel for the VASIMR has many side benefits. Hydrogen can be found anywhere we go in the solar system. What this means is that under the power of VASIMRs the Cluster can be launched with only enough fuel to get to its next destination, such as Mars, and then pick up more hydrogen upon arrival to serve as fuel for a journey to Jupiter. Hydrogen is already generated as a byproduct of the Cluster, thus providing a ready source of fuel for the engine. Another benefit of hydrogen fuel is that hydrogen is the best known radiation shield, so the fuel for the VASIMR engine is used to protect the inhabitants of the Cluster from the harmful effects of radiation exposure during the flight.

Electrical power sources for the VASIMR engine include a nuclear fusion power system and an array of solar panels. For long-range flights nuclear power has been determined to be the most efficient. While solar power is not practical for flying farther out into the solar system, it is a very viable source of power for travel in the area from Mercury to the Asteroid Belt.

04b **Fuel cells:** By combining hydrogen fuel with oxygen, fuel cells produce plenty of electric power while emitting only pure water as exhaust. They're so clean that inhabitants of the Cluster actually drink the water produced by fuel cells. Fuel cells are used in the Cluster to provide electrical power for the inner workings of the colony (living areas, production and processing areas, labs and work stations). The solid oxide fuel cells of the Cluster operate at approximately 500°C. The heart of the fuel cell, a sheet of electrolyte that controls the flow of electrically charged ions, is a thin film only one micron thick. The thinness cuts down internal resistance to electric current, so we can get abundant power output at lower operating temperatures.

04c **Hydroelectric motors:** Water plays a major role in the Cluster. Since water must be recycled and reused, an onboard hydroelectric power plant, located in the hub levels, passes the water through a turbine/generator assembly. Water entering the turbine flows through a series of louvers, called wicket gates, which are arranged in a ring around the turbine inlet. The amount of water entering the turbine can be regulated by opening or closing the wicket gates as required. This allows the operators to keep the turbine turning at a constant speed even under widely varying electrical loads. Maintaining precise speed is important since it is the rate of rotation which determines the frequency of the electricity produced.

The turbine is coupled to an electric generator by a long shaft. The generator consists of a large, spinning "rotor" and a stationary "stator". The outer ring of the rotor is made up of a series of copper wound iron cells or "poles" each of which acts as an electromagnet. The stator is comprised of a series of vertically oriented copper coils nestled in the slots of an iron core. As the rotor spins its magnetic field induces a current in the stator's windings thereby generating electricity.

04d **Solar sail:** A solar sail is a very large mirror that reflects sunlight. As the photons of sunlight strike the sail and bounce off, they gently push the sail along by transferring momentum to the sail. Because there are so many photons from sunlight, and because they are constantly hitting the sail, there is a constant pressure (force per unit area) exerted on the sail that produces a constant acceleration of the Cluster. Although the force on a solar-sail craft is less than a conventional chemical rocket, the solar-sail craft constantly accelerates over time and achieves a greater velocity. It's like comparing the effects of a gust of wind versus a steady, gentle breeze on a dandelion seed floating in the air. Although the gust of wind (rocket engine) initially pushes the seed with greater force, it dies quickly and the seed coasts only so far. In contrast, the breeze weakly pushes the seed during a longer period of time, and the seed travels farther. Solar sails enable the Cluster to move within the solar system without bulky chemical rocket engines and enormous amounts of fuel.

For a solar sail to be practical way of propelling a spacecraft, it must have the following characteristics: (01) Large area–It must collect as much sunlight as possible, because the larger the area, the greater the force of sunlight; (02) Light weight–The sail must be thin and have a minimal mass, because the more mass, the less acceleration that sunlight imparts to the sail; and (03) Durable–It must withstand the temperature changes, charged particles and micrometeoroid hazards of outer space. To meet these characteristics, the Cluster solar sails are made of thin, aluminum-coated, durable Mylar, has a thickness of 0.0002 inches or 5 microns (ordinary Saran Wrap is about 0.001 inches or 25 microns thick) and an area of 2 square miles.

04e **Nuclear fusion reactor engine:** Beyond Mars, the Triangulum Cluster employs a combination of tether and fusion propulsion. Fusion propulsion is used in the long stretches between the outer planets. Fusion is the process that powers the sun and the stars. It is the reaction in which two atoms of hydrogen combine together, or fuse, to form an atom of helium. In the process some of the mass of the hydrogen is converted into energy. The easiest fusion reaction to make happen is combining deuterium (or "heavy hydrogen) with tritium (or "heavy-heavy hydrogen") to make helium and a neutron. Deuterium is plentifully available in ordinary water. Tritium can be produced by combining the fusion neutron with the abundant light metal lithium. Thus fusion has the potential to be an inexhaustible source of energy.

To make fusion happen, the atoms of hydrogen must be heated to very high temperatures (100 million degrees) so they are ionized (forming a plasma) and have sufficient energy to fuse, and then be held together i.e. confined, long enough for fusion to occur. The sun and stars do this by gravity. A strong magnetic field holds the ionized atoms together while they are heated by microwaves or other energy sources, and inertial confinement, where a tiny pellet of frozen hydrogen is compressed and heated by an intense energy beam, such as a laser, so quickly that fusion occurs before the atoms can fly apart.

For a closer look at the Triangulum Cluster fusion reactor engine, please see the fusion reactor section (06: Triangulum Design – 06g: Fusion Reactor Engine) of this document.

04f **Tether:** When traveling in close proximity to planets with sufficient electromagnetic forces, the Cluster tether system is incorporated. The Cluster uses the natural gravitational pull of the nearby planet as a slingshot to propel it towards its next destination. In order to take advantage of tether propulsion, the Cluster assumes an orbit around the nearby planet, establishes a tether rotation and proceeds with slingshot when escape velocity has been reached. As portrayed in the illustration on page

17 of this document, the two tether masses are the Cluster at one end and the fusion reactor engine at the other. The Cluster tether is stored in a truss beam unit which connects the Cluster assembly with the fusion reactor engine. When needed, the tether is automatically reeled out from truss storage. The longer the tether is deployed, the more acceleration can be increased. While utilizing tether propulsion, the rotational tumble of the Cluster can be reduced to compensate for the rotation of the tether.

Gravity-gradient forces are fundamental to the general tether applications of controlled gravity, and the stabilization of tethered platforms, such as the Cluster. When it is oriented such that there is a vertical separation between the two masses, the upper mass experiences a larger centrifugal than gravitational force, and the lower mass experiences a larger gravitational than centrifugal force. The result of this is a force couple applied to the system, forcing it into a vertical orientation. This orientation is stable with equal masses, and with unequal masses either above or below the center of gravity. Displacing the system from the local vertical produces restoring forces at each mass, which act to return the system to a vertical orientation.

The gravitational and centrifugal forces (accelerations) are equal and balanced at only one place: the system's center of gravity (CG). The center of gravity (or mass), located at the midpoint of the tether when the end masses are equal, is in free fall as it orbits the planet, but the two end masses are not. They are constrained by the tether to orbit with the same angular velocity as the center of gravity. Since the gravity-gradient force and acceleration in orbit vary with GM/ro3 (where M is the planetary mass), they are independent of the planet's size, and linearly dependent on its density. The acceleration is largest around the inner planets and the Moon (0.3-0.4 x 10-3g/km for low orbits, where g is Earth gravity), and about 60-80% less around the outer planets. The gravity-gradient acceleration decreases rapidly as the orbital radius increases (to 1.6 x 10-6 g/km in GEO).

In low orbit, as an electrically conductive tether passes through a planet's magnetic field, an electron current is induced to flow toward the planet. This current in turn experiences a force from the planet's field that is opposite the tehter's direction of motion. That produces drag, decreasing the tether's energy and lowering its orbit. Alternately, reversing the direction of the tether current (using a solar sail or other power source) would reverse the direction of the force that the tether experiences.

For any object in a stable orbit, the outward-pushing centrifugal force is exactly balanced by the inward-pulling gravitational force. In the Cluster tether system, all forces balance at the system's center of mass. But at the Cluster, the cetrifugal force is slightly larger than the gravitational force. As a result, Cluster inhabitants feel a slight downward force away from the planet–a force of artificial gravity (local down). The situation is precisely reversed for the fusion reactor engine mass of the tether system. For a system with a 50-kilometer-long tether, the force would be about 1/100 the magnitude of the planet's gravity. The force is approximately proportional to the tether length.

05 Considerations for human habitation of space

05a Permanent and guest inhabitants

05.a.1 RETINA SCAN: Along with iris recognition technology, retina scan is perhaps the most accurate and reliable biometric technology. For this reason retina scan was selected as the primary means of quick identification for all permanent and guest inhabitants of the Triangulum Cluster.

INSIDE INFORMATION: THE RETINA AND SCAN TECHNOLOGY
The patterns of blood vessels on the back of the human eye are unique from person to person. With the exception of some types of degenerative eye diseases, or cases of severe head trauma, retinal patterns are stable enough to be used throughout one's life. The retina, a thin nerve (1/50th of an inch) on the back of the eye, is the part of the eye which senses light and transmits impulses through the optic nerve to the brain - the equivalent of film in a camera. Blood vessels used for biometric identification are located along the neural retina, the outermost of retina's four cell layers. Retina scan devices read through the pupil - this requires the user to situate his or her eye within 1/2 inch of the capture device, and to hold still while the reader ascertains the patterns. The user looks at a rotating green light as the patterns of the retina are measured at over 400 points. By comparison, a fingerprint may only provide 30-40 distinctive points (minutia) to be used in the verification process.

Retina scanners are located at all arrival and departure docks in the Central Hub. Retina scans are routinely performed and identities matched to full-body bio scans on file in the Security Center. Bio scans are performed off-site at BioMat before departure for the Triangulum Cluster. Bio scans may also be performed in the Cluster Health Center. Once a bio scan is on file with the Cluster, an occasional retina scan will verify identity for entry to restricted areas, classified zones, arrival to and departure from the Cluster. The movements of all occupants of the Cluster are monitored using RFID readers. RFID monitors are not security monitors; they are convenience monitors. Through RFID monitoring, Cluster citizens and crew can obtain directions, medical assistance, and other helpful information (such as time, appointment and scheduling advice based on their physical location in the colony).

05b Medical issues

The "human" issues and problems associated with civilian space travel and tourism are no less important than the technological challenges of getting them to/from space. There is the need to identify the accommodations that is required to support the general public; the need for experienced crew and attendants and their functions; the need for life support equipment that is required in passenger vehicles and habitats; space sickness, its effects, and its countermeasures and their implications; as well as flight and hull insurance.

There appear to be a variety of options called for beyond terrestrial, and lower atmosphere space travel and tourism, including varying costs, accommodations, and levels of preparedness and acceptable risk-taking by various kinds of spacefaring passengers. These could include:

- short-term stays at LEO (Low Earth Orbit) facilities
- long-term stays at lunar and planetary outposts
- long-term deployment onboard The Triangulum Cluster
- resort packages (with stays at LEO hotels, lunar and planetary outposts, in conjuction with The Triangulum Cluster)
- EFAs (extra-facility activity) by crew members, citizens and visitors at space facilities

For any of these cases, the transport vehicle and in-space facilities must provide accommodations with certain minimal personal and social standards. These include: safety, privacy, baggage handling, entertainment, training and exercise facilities, and easy to operate toilets, showers, eating-drinking facilities, and medical capabilities (including telemedicine).

05.b.1 SPACE SICKNESS: One of the major issues concerning space travel and tourism is the prevention and/or the control of space sickness in “zero gravity”. Nearly half of all people who have gone into space have experienced nausea and become ill because of the lack of gravity. Untreated, nausea and other effects can last for period ranging from a few hours to several days. However, there are steps that can be taken. First, medication exists which will help almost all individual travelers. Although this medication is inappropriate for space pilots because of its side effect of drowsiness, there is no present reason to believe that it cannot provide relief to many/most passengers. In addition, for longer term stays (including Triangulum Cluster flights and all current colonies and outposts, artificial gravity has been created which prevents essentially all space sickness. For the latter case, technological-operational approaches range from spinning centrifuges or turntables operating inside an otherwise “zero-gravity” habitat for short stays, all the way to large-scale rotating habitats that provide as much as Earth-normal gravity on long stays.

05.b.2 BONE DEGRADATION: Bone degradation is a complex problem for travelers on long-duration space missions, such as the Triangulum Cluster. Typically, travelers lose one to two percent of bone mass each month that they are in low-gravity space, especially in the lower halves of their bodies.

In a weightless environment, there is little or no stress on the skeletal system; bones do not have to provide support for locomotion or for maintaining body posture. This lack of stress on the bones may be a key factor in a traveler’s progressive bone loss in space. Another key factor in bone loss is that a lack of ultraviolet radiation from sunlight decreases the synthesis of vitamin D.

Taking on extra calcium will not decrease the effects of microgravity on bone loss because calcium loss exceeds the amount of calcium that your body can absorb during spaceflight. Thus, bone loss in space is increased, while bone building is decreased. The recommended daily amount of calcium is 1,000 mg. Typically, the body absorbs 40 to 50 percent of the daily dosage on the ground but only 20 to 25 percent in space. The recommended daily allowance of calcium is supplied in a traveler's planned menus, however, additional supplementation may increase the risk of kidney stones from increased urinary calcium.

Along with the artificial generation of gravity in the Cluster, the ingestion of foods which cause the hormone glucose-dependent insulintropid peptide to increase in the bloodstream is very beneficial to eliminating the problem of bone loss. This hormone attaches to "receptor" molecules on bone cells and decreases bone-destroying activity while increasing bone creating activity. This hormone is given to travelers as a supplement to prevent bone loss. Nutraceuticals and pharmaceuticals as well as vitamin D- and calcium-fortified diets also help solve the problem of bone loss in space.

05.b.3 MUSCLE ATROPHY: Workers in the central hub and each of the three hub levels experience weightlessness for extended periods. Shifts in weightlessness are limited to four hours per day, three days per week, with a day of 1G work between each day of 0G work. There is an increased interest in the reaction of muscles to disuse and weightlessness in space. Muscle studies in the Cluster investigate temporal changes in morphological, biochemical, and physical characteristics of slow and fast muscles as they are produced by disuse. Fast muscles, as the name suggests, are muscles that contract quickly and are used by the body for ambulation. Likewise, slow muscles contract slowly and work as antigravity muscles. In 0G, the slow muscle undergoes a change to take on the characteristics of the fast muscle. This change causes workers to experience difficulty with walking and circulation once back in 1G.

Cluster studies are underway to help understand the nature of muscle atrophy in 0G and to find ways in which this process can be prevented or reversed. Current studies concern the following: (01) Histology in fast and slow muscles such as fiber type distribution and size; (02) Levels and activities of high energy nucleotides such as ATP, and creatine phosphate and scavenger enzymes such as superoxide dismutases and proteolytic enzymes; (03) Changes in pre- and post-synaptic events at the neuromuscular junction involving release of acetylcholine, acetylcholinesterase, and the distribution of the acetylcholine receptors; and, (04) Changes in muscle physiology such as twitch tension, maximum rate of rise of tension, and tetanic tension.

Studies of the effects of weightlessness on muscle function and fatigue and on the activity of muscle sympathetic afferents can be determined quantitatively. Magnetic resonance spectroscopy measures phosphorus compounds (energy state) in muscle. The rectified integrated electromyogram provides a running average of total electrical activity, allowing the determination of the number of motor units recruited to maintain a force. Magnetic resonance imaging is available for evaluating morphological changes in muscle and surrounding tissues. These non-invasive measures are coupled with information obtained by direct measurement of muscle sympathetic nerve traffic with microneurography. Isometric and isotonic exercises are being used to stimulate muscle sympathetic afferents during acutely induced fluid shifts.

05.b.4 SPACE RADIATION: Space radiation is made up of three kinds of radiation: particles trapped in the Earth's magnetic field; particles shot into space during solar flares (solar particle events); and galactic cosmic rays, which are high-energy protons and heavy ions from outside our solar system. All of these kinds of space radiation represent ionizing radiation. (See Section 8a: Missions of the Triangulum Cluster: Space Radiation Research.)

05c Mission training and exercise

Appropriate and thorough passenger preparation is essential, which includes specialized training in some cases. For example, a working familiarity with the systems in the residential facilities of the Cluster is a useful aspect of assuring health and safety. Preparation activities are a valued part of the overall civilian space travel and tourism experience (much like attending a space camp). Preliminary training camps in Alabama, California, Florida, Japan, France and Germany provide pre-flight training programs for all potential citizens of the Triangulum Cluster. Once training is completed at one of these camps, potential Cluster citizens move on to the BioMat facility in orbit between the Earth and the Moon. A three-month stay at BioMat will acclimate travelers to the rigors of spaceflight, while exposing them to a battery of medical and psychological testing. The results of this three-month ordeal will determine the suitability of each individual for life onboard the Cluster.

Even though the technologies needed to make travel and tourism service affordable have matured and the systems have been developed, tested and deployed, uncertainties and risks still remain. This is true for in-space facilities, but it is especially true for Earth-Orbit (EO) and Deep-Space (DS) transports. Passenger, crew and vehicle insurance is available, but practices similar to those employed on other so-called "adventure travel" trips (such as mountain climbing in the Himalayas where tourists sign a waiver of liability and proceed at their own risk) are currently applied to all space-faring crew and civilian travelers.

All transports, colonies, outposts and hotels have been designed, developed and are operated with basic general public physical, psychological and social considerations in mind.

05d Life support systems

Life support systems of the Cluster include: (01 thermal control; (02) solid waste; (03) food systems; (04) crop systems; (05) water recovery; and (06) air revitalization. The proper operation of space hardware requires a robust and efficient thermal control system to reject waste heat generated by equipment and crew. Once collected from the source, waste heat that is not intended for reuse must be rejected to space. Radiators are heat rejection devices commonly used on space hardware. Radiator systems are in place in the Cluster to collect and reject heat. The remaining areas of life support are discussed in Section 07: Cluster details.

05e Accommodations and crew size

Overall, the issue of accommodations, life support and other amenities provided for the crew, permanent citizens and space tourists all require careful consideration. These can be expected to vary in scale and type depending upon the character and expectations of the travelers (especially the ones who could be identified as "adventure tourists") and on the duration of an individual's stay in space.

Another important consideration is the size and skills of the crew providing support and personal services to the travelers. In order to assure confidence in comfort and safety a relatively large crew maintains the Triangulum Cluster. For a civilian population of 5,000, the Triangulum Cluster employs a crew of no less than 500 people. Members of our crew have exceptional people skills to handle the situations that are bound to arise in such an "alien" situation -- informing without alarming, and calming without isolating when there are problems. All of our crew members have appropriate medical training. In addition, a hospital wing and adequate satellite medical facilities have been provided onbaord the Cluster. Because of the long duration of travelers' commitment to duty in the Cluster, trained and experienced physicians, nurses, therapists and exercise trainers are available to all crew and citizens. As new civilian needs are identified, crew members are added to the staff of the Cluster, some from within the civilian populus, others transported from Earth or one of the many colonies in our solar system.

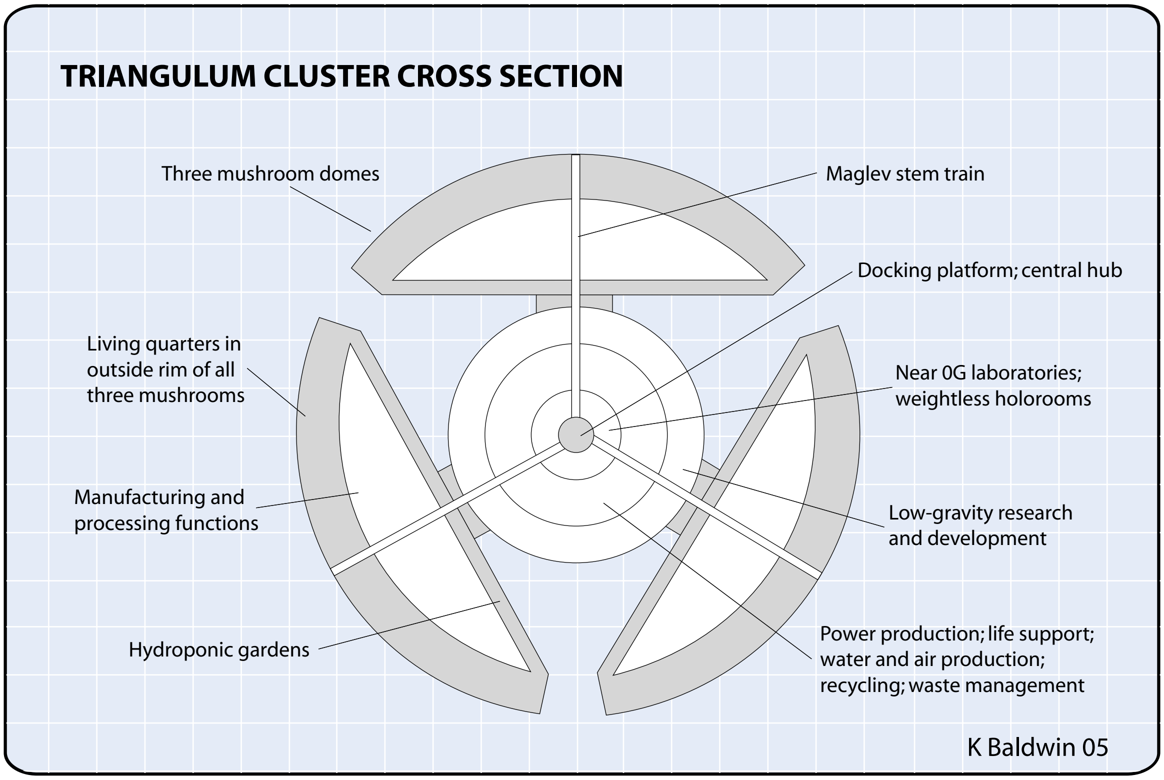
05f Safety

Safety is one of the main concerns in the Cluster. RFID monitoring helps ensure the safety of all Cluster inhabitants. If unsafe or potentially dangerous data is received, preventive or evasive action is implemented immediately. Safety patrol officers cruise the streets of the Cluster on hover Segways continuously. Escape planes are attached to the perimeter of each mushroom at regular intervals. Each plane is capable of carrying 100 passengers, complete with rations and life support for two years. 20 escape planes are tucked away along the perimeter of each dome, for a total of 60 escape planes. Each inhabitant is also equipped with a personal communicator, which must be with him/her at all times outside the home.

05g Entertainment

The physical and psychological well-being of Cluster inhabitants is vital. Entertainment plays a major role in this aspect. Inhabitants have ample opportunities in engage in entertainment. Whether your need is a shopping spree or a night at the movies, a walk in the park or an adventure in the holoroom, dinner for two at a quaint little French restaurant or pizza for the whole family, a swim at the YMCA or a workout at one of the small fitness centers, the Cluster has what you looking for. The circadian cycle of the Cluster makes it possible for you to watch the sun come up or enjoy a beautiful sunset. The children of the Cluster enjoy hoverboarding at Central Park while the adults much prefer a stroll through the neighborhood on a hover Segway built for two. Every effort has been taken to make the Cluster an enjoyable place to live and work. Even the classrooms are entertaining as well as educational. Rather than staying at a hotel unit, visitors to the Cluster enjoy a home environment. One multi-family living unit in each community is designated as a visitor home. Community is important.

06 Triangulum design



06a Three mushroom domes

The Cluster tumbles at a speed of 51.2m/sec which creates a gravitational force due to angular acceleration of 1G at ground level in each mushroom dome, based on a dome diameter of 1755 ft.

$$r = \left(\frac{1520\sqrt{3}}{3}\right)\left(\frac{1m}{3.2808399}\right) = 267.484m$$

$$a = 9.8\ m/s^2$$

$$a_c = \frac{v^2}{r}$$

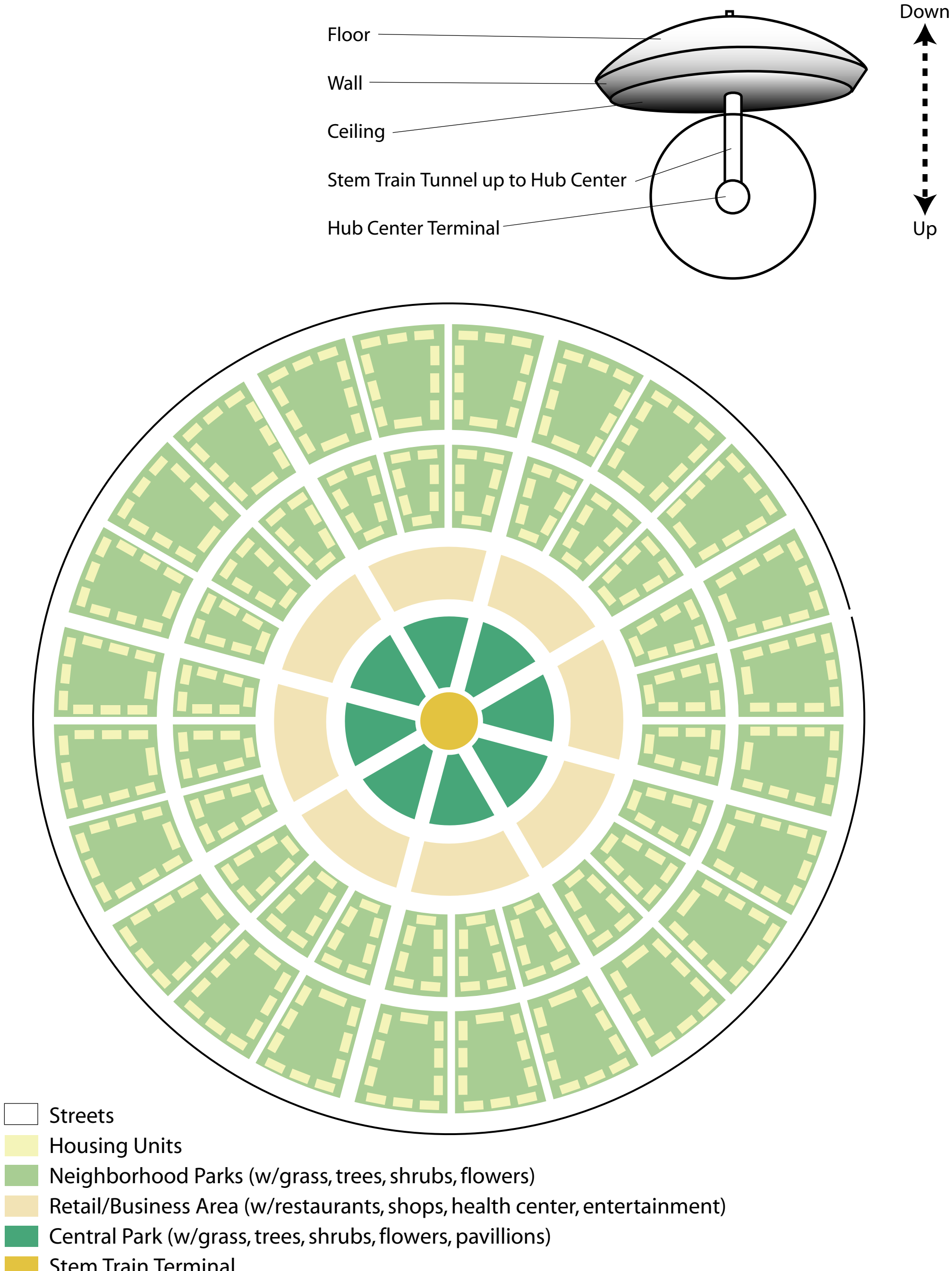
$$v = \sqrt{a_c r}$$

$$v = \sqrt{(9.8m/s2)(267.484m)}$$

$$v = 51.2\ m/s$$

Each mushroom dome is identical in layout to the other two. At the center of each dome lies the Maglev Stem Train Terminal. Each terminal is surrounded by a central park, which is complete with trees, shrubs, flowers and picnic pavilions. Tennis courts, basketball courts and soccer fields are conveniently located in one segment of each central park. Community teams play at the central park fields. Beyond the central park area are shops, restaurants, entertainment centers, video theaters, community theatres, YMCA facilities, fitness centers, libraries and small businesses. Beyond the business/entertainment district lies the communities of the Cluster. Each community has an abundance of community parks for walks, jogging, friendly games of frisbee in the shadow of an abundance of shade trees. Flower gardens adorn the common yards of each community. Church and school facilities are located in the community, rather than in the business district.

TRIANGULUM CLUSTER AERIAL VIEW OF LIVING AREA



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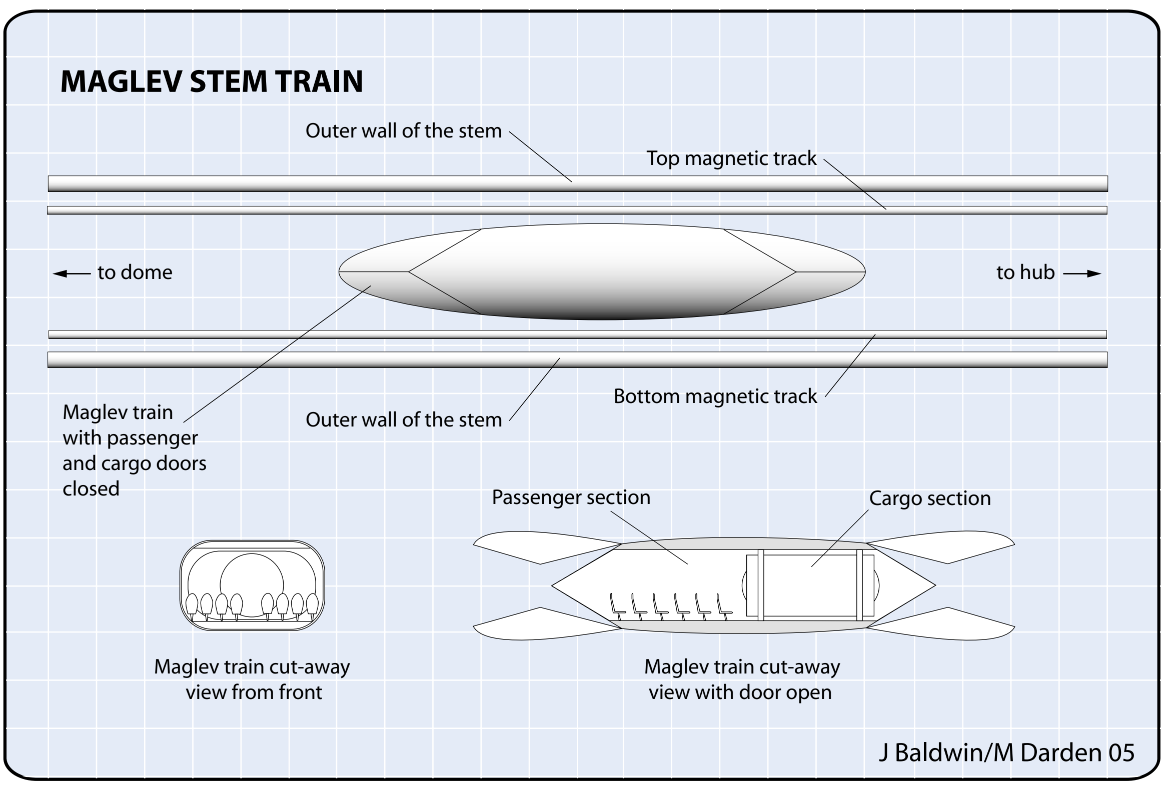
06b Stems

Robotic workers travel on wall tracks of each stem, monitoring stem train operation. Maintenance and minor repairs are performed by these robotic workers. Human workers who must make repairs and periodic visual checks of the stem trains must wear suits equipped with life support.

06c Maglev stem train

There are three maglev stem trains operating in the Cluster. Each one is identical to the others. Maglev stem train terminals are located in the central hub (docking platform area), hub level one (near-0G laboratories and holorooms), hub level two (power production, life support, water and air production, recycling, and waste management) hub level three (low-gravity research and development labs), hydroponic gardens, and main level. Maglev trains operate remotely. Terminal stops are determined by the passenger/cargo manifest. The trains levitate between top and bottom magnetic tracks. Motion of the trains is created by pulsating electromagnetic current in the tracks. Passenger/cargo doors at the front and back of the trains open up and down, allowing the uploading and downloading of passengers and cargo. Each train is capable of carrying two cargo canisters, or 98 passengers, or 48 passengers and one cargo canister.

Due to the fact that passengers are traveling from 0G (in the central hub) to 1G (in the outer domes) passengers travel backwards on the hub-to-dome segment of the train route. If passengers were to face forward while traveling hub-to-dome, they would feel as if they were falling face-first into the dome floor. Traveling backwards helps eliminate that sensation.



06d Central hub; hub levels one, two and three

Business of the Cluster is performed in the hub. The docking platform is located at the central hub. As a craft arrives or departs from the central hub, the outer door opens to allow entry or departure. If a craft is too large to travel into the hub, a shuttle will be deployed to pick up passengers and cargo and transport them into the hub. Near 0G laboratories and weightless holorooms are located at the first hub level. Weightless holorooms are a very popular entertainment destination. Space-based adventures can be programed in these rooms. Low-gravity research and development is conducted at the second hub level. Cluster power production, life support, water and air production, recycling and waste management are located at the third hub level.

06e Docking platform

The docking platform is located in the central hub of the Cluster. All cargo and passenger ships arrive and depart from the docking platform. Incoming vessels establish a parking orbit outside the revolution of the Cluster. A laser guidance system in the Cluster must establish a lock on the incoming vessel (tractor beam) and pull the vessel into matching orbit with the Cluster. Once the vessel is in matching orbit, it may continue to the docking platform, where contact is made with the capture ring. The capture ring's function is to mate with the berthing mechanism of the incoming vessel and establish an airtight seal. After a seal is established, the ring deploys 24 structural hooks to latch the two vessels together. Convertor tracks in the docking area allow cargo and passenger cylinders to be uploaded to or downloaded from parked vessels.

06f Solar sail propulsion array

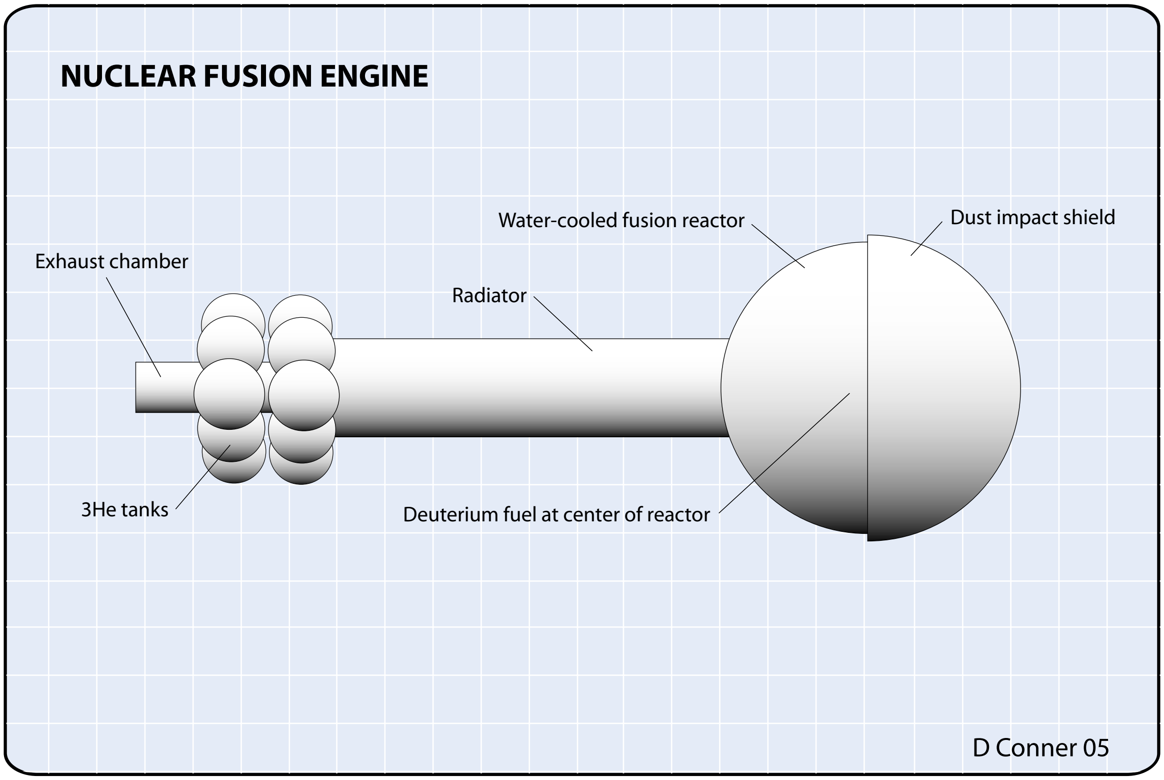
Maneuvering the Cluster by solar-sail requires balancing two factors: the direction of the solar sail relative to the sun and the orbital speed of the Cluster. By changing the angle of the sail with respect to the sun, you change the direction of the force exerted by sunlight. The Cluster solar sail array is located at the front of the colony and is only deployed when the Cluster is traveling near the inner planets and/or the Main Asteroid Belt. Beyond that point, the effectiveness of solar sails is diminished.

To accelerate the Cluster, the solar sail is angled, with respect to the sun, so that the pressure generated by sunlight is in the direction of the Cluster's motion. In contrast, to decelerate, the sail is angled, with respect to the sun, so that the pressure generated by the sunlight is opposite the direction of motion. The pressure of sunlight decreases with the square of the distance from the sun. Therefore, sunlight exerts greater pressure closer to the sun than farther away. The Cluster may take advantage of this fact by first dropping to an orbit close to the sun -- a solar fly-by -- and using the greater sunlight pressure to get a bigger boost of acceleration at the start of the mission. This is called a powered perihelion maneuver.

06g Fusion reactor engine

The fusion engine draws power from smashing atomic nuclei together rather than blasting them apart. Fusion reactors produce less unwanted radiation than other types of reactors. They run on deuterium (heavy hydrogen) and helium 3 (a lighter version of ordinary helium), both of which exist in large quantities on the surface of the moon and in the atmosphere of Jupiter. Our fusion-powered colony must visit refueling stations at BioMat (between the Earth and the moon) and Outpost Alpha (near the Jovian moon, Europa) every few years to replenish both the deuterium and helium 3 (3He).

Charged particles generated by this reactor are harnessed and piped through a magnetic nozzle. The spray of particles from this fusion reactor are used to propel the Cluster.



06h Tether

As the Cluster enters the magnetic influence of planets throughout the solar system, a tether system of propulsion in employed. For example, as the Cluster and its attached tether system glide through space between Europa and Callisto, the tether harvests power from its interaction with the vast magnetic field generated by Jupiter. By manipulating current flow along the kilometers-long tether, mission controllers can change the tether system's altitude and direction of flight.

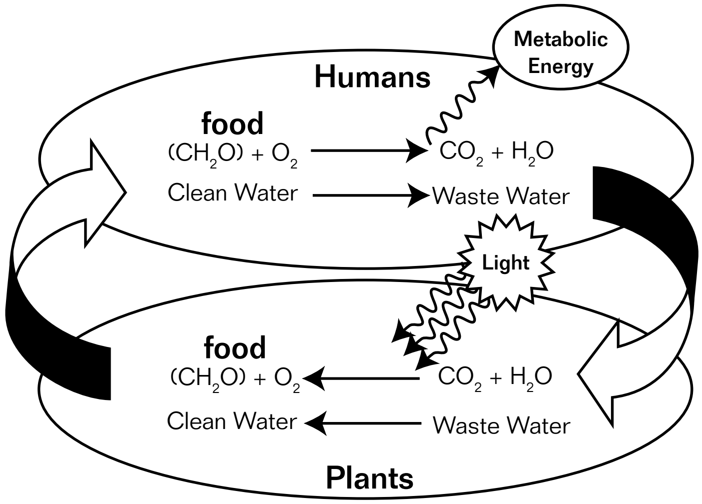
The tether's Plasma Motor Generator is designed to provide a low impedance bipolar electrical current between the Cluster and the magnetic field of a nearby planet. The 500m-long tether provides a complete separation between the grounded ends (the Cluster at one end and the fusion reactor engine at the other), forcing current closure through the megnetosphere rather than with local overlap of plasma clouds. In order to function properly, an electrodynamic tether needs to be effectively "grounded" on both ends. This configuration functions either as a orbit-boosting motor or as a generator converting orbital energy into electricity,

07 Cluster details

07a Food production and storage

07.a.1 HUMAN FOOD REQUIREMENTS: The Triangulum Cluster has an onboard research staff, facilities, and materials to process foods that address the unique requirements of long-term space missions. Our staff aspires to provide a diet that is safe, satisfying, flavorful and nutritious. A Triangulum Cluster meal consists of a combination of packaged foods that have an extended shelf life of 10+ years (items which can be resupplied during near-Earth visits) and foods grown and processed in the colony (regenerables). The food system onboard our transit shuttle includes a combination of packaged foods and salad crops grown during flight in a microgravity environment. In the 1G gravity of the Cluster, prepackaged foods play a smaller part in the diet with the majority of foods coming from grown crops.

To receive the best yield per space, Cluster crops are grown in near-natural Earth-lighting, complete with day and night cycles. Based on the assumption that each crew member and citizen needs 0.97 kg food/day, 345 kg/person must be produced annually. To provide a healthy, balanced diet, half of the food consumed in the Cluster is produced in our hydroponic gardens. At least 177 kg of crops are produced per person annually in the Cluster. To produce this amount of food, the lower level of each Mushroom is dedicated to crop production and food production (both synthetic and natural). 28.333 m^3 of space is needed for crop growth alone. 16,000 m^3 is dedicated to hydroponic gardens in the Cluster. The majority of the gardens are in the lower levels, although each home module has its own hydroponic garden area and plants and trees also grow in community parks.



THE CROP CYCLE

Humans take in plants, oxygen and water, producing byproducts of CO_2 and waste water.

Plants take in light, CO_2 and filtered waste water producing byproducts of O_2 and water.

A KUCSMAS 2005

Hydroponic gardens are located on the lower level of each dome. The gardens are maintained by robotic workers which are supervised by human food engineers.

A byproduct of growing plants is oxygen. As the oxygen is dispelled from the plants, it is pumped out through the filtration system above the growth beds, ready for human consumption.

A byproduct of human breathing is CO_2. CO_2 is pumped into the growth beds at mid-level, ready for plant consumption.

Plants are grown in modular growth beds. As plants mature, the beds are harvested by robotic workers, and new growth beds are slid into place.

Water is pumped into the growth beds near floor level. Wastewater is filtered through hub level two before being consumed by humans.

PHOTO CREDIT: NASA 2005

07.a.2 PHOTOSYNTHESIS AND TRANSPIRATION: Through the process of photosynthesis, plants (crops) are used to regenerate the atmosphere and produce food for the citizens of the Cluster. In addition, through the process of transpiration, crops and their root zone microflora are used for wastewater processing and purification.

07.a.3 FOOD SYSTEM REQUIREMENTS: Certain unique requirements have been developed for colonial and outpost food systems:

- Small, lightweight containers for packaged foods
- Minimized usage of energy and water for processing foods in the Cluster
- Packaged food products with a shelf life of ten years or more. Packaging materials with high barrier properties help ensure longer shelf life. Better food preservation methods have been developed to help extend shelf life and improve quality of packaged foods.
- A food supply that heavily depends on regenerable crop production (crops grown in the Cluster include beans, beets, bell peppers, broccoli, cabbage, carrots, cauliflower, chickpeas, cucumbers, dandelions, herbs, lettuce, onions, peanuts, potatoes, radishes, rice, soybeans, spinach, strawberries, sweet potatoes, tomatoes, and wheat)
- Food-processing systems that operate in reduced gravity
- Miniaturized food-processing equipment utilizing carbon nanotube technology.
- New food recipes for colony-grown crops

INSIDE INFORMATION: FOUR RECIPES FROM THE CLUSTER COOKBOOK

LENTILS WITH RICE (5 servings)

3/4 cup rice
3/4 cup lentils
5 endives
1/2 cup kale
1/2 cup swiss chard
1/4 cup onion
salt and pepper

— Shred endive, kale and swiss chard by hand and place in a ziplock bag.
— Chop onion and add to the bag
— Place rice and lentils in a closed, squeezable cooking container; add water to cover them, and heat until ingredients are soft. Squeeze out the water.
— Combine rice and lentils in the bag with the vegetables and shake to blend.
— Add salt and pepper to taste.
— Serve hot or warm.

VEGETABLE LASAGNE (6-8 servings)

3-4 pounds sweet potatoes, 1/8" slices
1/2 cup lentils
1/2 cup chickpeas
1 potato
1 carrot, julienned
1 onion, sliced thin
2 tomatoes, chopped
2 chili peppers, chopped
1 head of broccoli florets
1 head of cauliflower florets
1/4 cup butter
1/4 cup peanuts, chopped

— Microwave lentils and chickpeas in water until soft. Cook potato, carrot, broccoli, and cauliflower in microwave.
— Combine onion, tomatoes, and chili peppers in a ziplock bag.
— Mash together potato, lentils, chickpeas, and salt until sticky.
— Stick sweet potato slices to the bottom of a buttered 9 x 12 inch dish. Add salt, pepper, and more butter.
— Spread on a layer of mashed vegetables. Add broccoli and cauliflower. Add a layer of sweet potato slices. Press onions, tomatoes, chili peppers, and peanuts on top.
— Microwave for 10 minutes and serve.

SAVORY COMBO (3 servings)

3/4 cup lentils
3/4 cup chickpeas
3 carrots, chopped
1 cup kale or chard, cut into 2-inch strips
1 head of garlic, smashed and peeled
3 peppers, chopped
2 handfuls of broccoli (sprouts and florets)
salt and pepper

— Place lentils in squeezable cooking container. Inject water to fill, and cook for 5-6 minutes in the microwave. Do not boil.
— Squeeze out and reserve the water, and add the chickpeas. Add more water to fill container and cook for 15 minutes. Do not boil.
— Squeeze out water into the reserved liquid. Let lentils and chickpeas float in container after cooking.
— Put carrots, kale or chard, garlic, peppers, and broccoli into the reserved liquid, adding more water to fill the container. Cook for 12 minutes. Drain.
— Add vegetables to lentils and chickpeas.
— Add salt and pepper to taste.
— Eat with raw peanuts.

SPACE SALAD (servings vary)

A selection of any (or all) available vegetables

— Sliver, grate, dice, slice or chop produce.
— Combine with plenty of fresh herbs.
— Process peanuts into peanut oil to use as dressing

07.a.4 HARVESTING AND PROCESSING: Onboard the Triangulum Cluster (as with all other colonies and outposts) crops must be harvested and processed into edible ingredients and menu items. In order to harvest and process foods, miniaturized processing technologies have been developed. Environmental constraints require that this equipment be compact, multifunctional, and lightweight. The Cluster's post-harvest food-processing equipment manufactures palatable food ingredients and finished products from raw crops grown in hydroponic gardens. Processing equipment is used to produce multiple food ingredients from one piece of equipment. This equipment requires minimal crew time and energy for operation and cleaning. Robotic workers are utilized whenever possible. Our equipment produces minimal solid waste, air pollution, and odors, demands low levels of consumable energy, generates minimal waste water and can be easily cleaned and sanitized. Our list of miniaturized processing equipment includes: ovens and microwaves; extruders, mixers, grinders, and extruder-expellers; fermentors/bioreactors; general-purpose mills; soybean processors; wheat processors; refrigerators and freezers.

07.a.5 FOOD PACKAGING: To meet the challenge of food packaging, processed food is stored in reusable/recyclable packages, which are flexible for easy storage, and microwave-compatible for ease of use. Pre-packaged food products for the Cluster must safely maintain a shelf life of ten years or more under ambient storage conditions. Some storage for refrigerated and frozen food items is available for our long-term missions, but the majority of resupply items are stored in ambient temperatures. Technologies used to ensure the safety of resupply-foods include high and medium pressure processing, ohmic heating, ultrasound, pulsed electric field, arc discharge, light pulse, ultraviolet light, oscillating magnetic field, induction heating, ozone, modified atmosphere system, chemical and biochemical methods, radio frequency, plasma, and microwave sterilization. More conventional means of processing resupply-foods include hot fill and hold, membrane filtration, aseptic processing, irradiation, dehydration, refrigeration, and freezing.

INSIDE INFORMATION: THE ART OF EATING IN ZERO G

Crumbs are a big consideration in developing food items to be used in space flight. The quality of the air during a space flight is directly dependent upon the amount of contamination that is released into the cabin during the flight. Foods that produce a lot of crumbs can be a big problem and a big contributor to "pollution" of the air quality during a mission. For this reason, bite-sized cookies and crackers that can be placed in the mouth all at once are used, rather than larger versions which would require the crewmember to consume in multiple bites.

07.a.6 SUPPLEMENTAL FOOD: SPIRULINA

Spirulina (fast-growth, concentrated green superfood) is a single-celled, spiral-shaped blue-green microalgae that is grown in the warm culture beds of the Triangulum Cluster by artificial farming methods. Spirulina yields 20 times more protein per acre than soybeans, and is a substantial vegetable protein source, with a protein content of 65%, higher than any other natural food. An even greater value is found in its concentration of vitamins, minerals and other unusual nutrients. Three to ten grams of spirulina per day delivers impressive amounts of beta carotene, vitamin B-12 and B complex, iron, essential trace minerals, and gamma-linolenic acid. Beyond vitamins and minerals, spirulina is rich in phytonutrients and functional nutrients that demonstrate a positive effect on health.

Vitamins and minerals in foods are bound to natural food complexes with proteins, carbohydrates and lipids. The human body recognizes this entire food complex as food. Most supplements, however, are synthetic combinations of isolated USP vitamins and minerals. Although the synthetics are often formulated to claim 100% of the Daily Value (DV), these vitamins and minerals are not bound to anything, and may have an entirely different chemical structure than those found in foods. It is better to get nutrients from natural foods, such as spirulina and other green superfoods. These whole foods offer functional nutrients and phytochemicals, as well as providing disease prevention.

Spirulina has the highest protein of any natural food (65%); far more than animal and fish flesh (15-25%), soybeans (35%), dried milk (35%), peanuts (25%), eggs (12%), grains (8-14%) or whole milk (3%). Protein is composed of amino acids. Essential amino acids cannot be manufactured in the body and must be supplied in the diet. Essential amino acids, plus sufficient nitrogen in foods, are needed to synthesize the non-essential amino acids. A protein is considered complete if it has all the essential amino acids. Spirulina is just that, a complete protein. Over 100% of the daily essential amino acid requirements for a typical adult male are supplied by using only 36 grams of spirulina, about 4 heaping tablespoons. Spirulina has no cellulose in its cell walls, which makes it easily digested and assimilated. It is 85 to 95% digestible. Spirulina’s fat content is only 5%. Ten grams has only 36 calories and virtually no cholesterol. One tablespoon (10 grams) of spirulina contains only 1.3 mg of cholesterol and 36 calories. In contrast, a large egg yields about 300 mg of cholesterol and 80 calories, while providing only the same amount of protein as the tablespoon of spirulina.

Spirulina is used as a daily dietary supplement to the natural and processed foods common and customary in the meals of Cluster citizens and crew.

07b Water production and recycling

Having to launch everything necessary for life support for any extended period of time, long duration space travel (such as the Cluster missions) are cost prohibitive. Components of closed-loop life support systems that are necessary to reduce the dependency of space settlements on support launched from Earth have been developed. Being able to reuse human wastes also helps to avoid space and planetary environmental pollution issues. Closing the water loop means purifying shower water, crop water, and waste water. Highpowered lasers provide the power for isolation chambers in the Cluster which condense vapor in the air and reprocess waste water. An initial supply of water was delivered to the Cluster from Earth. Water is continually recycled and reused in the Cluster. As additional water is needed to help replenish our supply, water stations on BioMat, Europa 2, and Outpost Alpha are utilized. For the most part, water is plentiful in the Cluster. Chemical fusion and/or separation processing plants are located in the hub levels of the Cluster. Production of water takes place at these processing facilities. All waste water is cycled through the hydroponic gardens in the upper dome levels. Water used to grow plants is recycled through condensation and filtration.

07c Oxygen production/cycling

07.c.1 MICROSCOPIC PHYTOPLANKTON: Phytoplankton are one-celled algae that normally thrive and circulate in the upper currents of Earth's oceans and provide the basis for all marine life. Phytoplankton cells are seldom larger in diameter than a few tenths of a millimeter, but as they photosynthesize and grow, they generate more than half of the oxygen in the atmosphere that humans need to breathe on Earth (the rest comes from trees and plants on land). During this process, phytoplankton absorb forty percent of the carbon dioxide greenhouse gases which contribute to global warming. Based on the importance of phytoplankton in the ecology of Earth, these one-celled algae are being grown in the nutrient-rich waters of the Triangulum Cluster's aquaculture gardens. Aquaculture gardens maintain a temperature-controlled habitat for nearly 1,700 microscopic marine species of phytoplankton cultures.

Phytoplanktons use artificially-produced sunlight, carbon dioxide (CO^2) and water, in the process of photosynthesis, to produce organic compounds which they use for food and to make their cells. One waste product of phytoplankton is oxygen. The oxygen is not needed so it leaves the cell. These cells also absorb almost as much carbon dioxide from the air as plants.

07.c.2 AIR FILTRATION/CIRCULATION CYCLE: To make the most efficient cycle of air throughout the Cluster, air is separated into carbon dioxide (CO_2), water (H_2O), oxygen (O_2), and nitrogen (N_2). Nitrogen, oxygen, and half of the water is recycled directly back into the main living areas of the Cluster, while the other half of the water and the CO_2 is cycled to the hydroponic gardens. The water keeps the air moist in the gardens (watering the plants), and keeps proper humidity in the living areas. The CO_2 is converted by the plants in the gardens into carbon (to keep the plants alive) and into oxygen, which is sent out to the living areas. This allows the concentration of gases to stay at proper levels with the least amount of wasted materials.

Separation chambers are used to break air into its components. These chambers separate the air into two basic gases. One is composed of oxygen and nitrogen. The other is composed of carbon dioxide and water. Some of the nitrogen from the oxygen/nitrogen mix is split off to be used to enrich the hydroponic garden soil. Carbon dioxide and water (along with most other gases in the air) are stored together. All air that passes through the chamber is scanned for impurities. Impurities are neutralized before the air is sent to either the gardens or the main living areas.

The atmosphere of the Cluster contains ozone (O_3), as does the atmosphere of Earth. The Cluster ozone is accomplished by ionizing the air in the separation chambers. This ionization not only produces ozone, but also purifies the air and destroys impurities. Air is ionized as it enters the chamber, and as it is dispelled from the chamber.

Air is either heated or cooled as it is cycled into the Cluster environment. Air temperature varies, based on the desired weather pattern. The average temperature is 72ºF during the day and 65ºF during the night with extremes to keep steady internal weather patterns. The hub is always at 65ºF to inhibit condensation. This also allows for a neutral environment for anyone passing through the hub. All three mushroom domes are set for the same weather patterns to prevent imbalances in the hub. The weather is maintained by computers and is controlled by light, heating, and air cycles.

There are two identical circulation and filtering systems in the Cluster. These systems switch on and off every two hours with only one system running at any given time. This procedure reduces wear on the mechanics of both systems and prevents overheating and malfunction. Should one system fail, the other system can take over for as long as is needed to repair the failed system. This prevents undesired weather patterns and unhealthy gas imbalances from occurring. If both systems should fail, an auxilliary system will activate, which is a basic fan system. The auxilliary system will keep CO_2 from building up in the simulated gravity (and microgravity at the hub) during the period of time in which the main system are undergoing repairs. This is a failsafe for a very unlikely event of the simultaneous failure of both air circulation/purification systems and will not be expected to maintain any weather balance or properly regenerate oxygen and dispose of carbon dioxide. If the auxilliary system is needed, it will flush the air in the gardens in order to keep safe oxygen levels. The consequences of activating the auxilliary system are weather imbalances and damage to other equipment in the Cluster (possibly due to weather imbalances).

The circulation and filtering systems are carefully monitored to keep them running at optimal speed and accuracy. Every two hours (when the two systems switch) clean dust and contaminant filters are installed. The used filters are cleaned and repaired by robot workers and inserted at the next change, four hours later. Each recyclable filter has a 1,000-use limit before disposal. Qxygen separation filters are checked after every use, and are serviced or replaced as needed. The separation filters are much more advanced, and are recycled indefinitely until they no longer function properly. These processes are controlled by computer and robot workers, but analyzed and logged by a human administrator.

07d Circadian cycle

The circadian cycle is the pattern of night and day (that we experience on Earth), and the subtle changes that occur over time in it and because of it. The circadian cycle drives our biological clock, which is prepared for small changes, such as the gradual change of seasons from one day until the next, or the effects of a cloudy day on our state of mind. Our biological clocks control our hormones, our sleeping habits, our eating habits, and our moods. Without contact with the circadian cycle, our biological clocks go off several times a day. Jet lag is a result of an interruption of the circadian cycle.

Over a long period of time, our perception of time can be altered or even reversed. Without the circadian cycle, time is harder to calculate because we are unable to know how many days have actually gone by. Clocks, watches and calendars can solve part of this problem. In order to keep our internal clocks balanced with the circadian cycle, an emulation of it is active at all times within the Cluster. LEDs (Light Emitting Diodes) are used to create an artificial cycle in the Cluster. LEDs constructed of carbon nanotubes allow the lights to display a more complex array of colors from each LED. This is done by combining the metals that produce cyan, magenta and yellow light. Computer-assisted manipulation of the LED lighting enables the inhabitants of the Cluster to experience the benefits of night and day, complete with the effects of sunrise and sunset. The artificial sky of Cluster is controlled remotely by a central computer, much like the pixels displayed on a computer monitor.

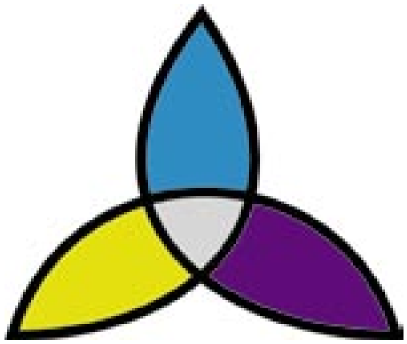
The advantages of this system is the ability to create an organized system of the sky, sun, and stars in a realistic cycle. The Cluster's circadian cycle can be programmed to randomly lower the light and produce images of a cloudy day. The colors of the sky are realistic throughout the day (at dawn, morning, noon, afternoon, dusk and evening). The morning cycle starts as a yellowish-blue, and dusk ends with a red/red-orange color. The Cluster sky is scattered with evenly spaced misters, simulating light rain. This will moisturize the air, and help provide water the plants and trees growing in the gardens and parks of the colony. At night, clusters of LEDs illuminate in different colors, sizes and positions in the sky to realistically emulate constellations, star patterns and celestial events such as meteor showers, lunar events and planetary phenomenon. Lunar phases are visible. This elaborate attention to detail of the circadian cycle is done in an effort to provide comfort and a feeling of home to the crew and citizens of the colony.

To provide the best quality for the sky, so that the use of LEDs is not visibly detectable, thin translucent "plates" cover the entire sky. Misters are mounted outside the plates. Plates are of carbon nanotube construction to provide maximum strength and durability.

Air temperature will vary slightly in the Cluster according to the season currently being experienced. Wintertime temperatures in the Cluster will normally be in the upper 60s while summertime temperatures will range in the upper 70s to low 80s.

07e Time zones

A day in the Cluster is composed of 24 Earth hours. Each one of the three mushrooms is a different time zone. The mushrooms are known by residents and crew as the Gold Zone, the Blue Zone and the Purple Zone. When it is 0800 in the Gold Zone, it is 1600 in the Blue Zone and 2400 in the Purple Zone. Zones were established in the Cluster to make optimum use of the facilities. Hallways and stem train terminals leading from the Central Hub are color coded with Gold Zone, Blue Zone and Purple. Color bars showing the time for each of the mushrooms are prominently displayed in the Central Hub. Time in the hub is audibly announced simply as X minutes past the hour.



HUB ICON

The icon pictured here is displayed on the ceiling of Hub Central.

The gold portion of the icon points to the Maglev Stem Train terminal leading to the Gold Zone. The blue portion of the icon points to the Maglev Stem Train terminal leading to the Blue Zone. The purple portion of the icon points to the Maglev Stem Train terminal leading to the Purple Zone.

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07f Communications

When communicating with Earth and the other Cluster colonies, time is based on the time of the colony being communicated with, since each colony has it's own time relative to the planet or moon that it is associated with. (i.e. when communicating with the Europa 2 colony, Europa 2 time is the basis for the communication).

All residents and crew members are equipped with wireless personal iCom units (devices similar in size and appearance to the Mini-iPod). iCom units can be used for communications, education, entertainment, health monitoring and research. iCom units also function as personal computer devices. Wireless iCom docking ports are located throughout the Cluster. Password access allows users to connect to iCom ports and utilize plasma monitors and touchpad keyboards at any location in the Cluster.

07g Living quarters

RFID (Radio Frequency Identification) is used extensively throughout the Cluster. A basic RFID system consists of three components: an antenna; a transceiver (with decoder); and a transponder (RF tag) electronically programmed with unique information. The antenna emits radio signals to activate the tag and read and write data to it. Antennas are the conduits between the tag and the transceiver, which controls the system's data acquisition and communication. Antennas are available in a variety of shapes and sizes; they can be built into a door frame to receive tag data from persons or things passing through the door, or mounted in a pantry or refrigerator to monitor inventory. The electromagnetic field can be activated by a sensor device.

Often the antenna is packaged with the transceiver and decoder to become a reader (a.k.a. interrogator), which can be configured either as a handheld or a fixed-mount device. The reader emits radio waves in ranges of anywhere from one inch to 100 feet or more, depending upon its power output and the radio frequency used. When an RFID tag passes through the electromagnetic zone, it detects the reader's activation signal. The reader decodes the data encoded in the tag's integrated circuit (silicon chip) and the data is passed to the host computer for processing. Living module RFID tags operate at a frequency of 50MHz with an operating range of one to two feet.

07.g.1 KITCHEN: Using RFID technology, the living quarters of the Cluster are efficient and user-friendly. Here are just a few of the amenities. In each kitchen module, the **dishwasher** is built into the sink. When the sink detects a capacity load, dishwasher detergent is dispensed, the lid slides into place, and the wash cycle begins. The lid will open automatically when the dishes are dry. Cluster **ovens** switch automatically from conventional to convectional. The built-in oven computer checks pantry inventory, displays recipes and suggested menus, and adjusts meal plans to take advantage of food inventory and dietary needs of each family member. **Refrigerator** RFID readers scan items as they are placed in the refrigerator. The kitchen computer keeps inventory, creates a grocery shopping list based on inventory, adjusts chill temperature based on needs, and emits an audible alert when food expiration dates are eminent. **Pantry** RFID readers scan items as the shelves are stocked. The computer tells the homeowner which shelf/bin to put items on or in. Items are automatically deleted from inventory when they are removed from the pantry. Items are automatically added to a grocery list as stock is depleted. The kitchen module utilizes carbon nanotube construction which is light weight, durable and as hard as steel. The self-cleaning counter tops and floors are embedded with sensors which detect organic material, decompose and dematerialize it.

07.g.2 BATHROOM: **Showers** in the living quarters are bioprinted to each person living there. By palming the sensor unit before entering the shower, the computer determines who has entered, and adjusts the shower controls (angle of showerhead, water temperature preference, amount of water dispersed, shampoo and soap dispenser preferences, and length of drying time). Upon completion of the shower cycle, drying jets provide warm air to the shower cubicle, eliminating the need for towels. **Sinks** operate automatically as hands are passed beneath the spigot, soap and water are dispensed and drying jets activated at the end of the cycle. Perhaps the most advanced component of the bathroom is the **commode**. An integrated bidet provides an adjustable, targeted spray plus a warm-air dryer, which eliminates the need for toilet tissue. Sensors in the bowl detect the amount and type of waste and adjust water volume for each person and every flush. Computer-modeled curves and wider trapways provide optimum carryout of waste. Nanocarbon construction of the bowl allows the bowl to be self-cleaning. With a clever seat, the lid raises as the user approaches. Sensors under the seat detect whether the user sits down, and the seat goes up if he doesn't. A health monitor built into the bowl checks waste for cholesterol levels and scans for signs of illness. Results are emailed to medical technicians. Sophisticated monitoring of plumbing allows less water to do the same work of conventional commodes.

07h Public facilities

07.h.1 HEALTH CENTER: Bioprint data and life-monitoring garment data is collected and analyzed by the Health Center. There are health centers located in the central area of each muschroom dome and on each level of the hub. Periodic check-ups and evaluations are scheduled automatically through the Health Center. Cluster inhabitants are notified by iCom of upcoming appointments with the Health

Center. Preventive medicine and examination is performed at the Health Center. A full-service hospital wing is located at each health center, in the unlikely event the hospital services are needed. Emergency medical personnel are stationed at each health center. EMPs can be dispatched by iCom or public call box, but they will dispatched automatically if bioprint or life-monitoring garment data is deemed to be life-threatening by health center analysis. Health centers are open 24/7.

Surgery is accomplished by non-intrusive means (no scalpels). Preprogrammed repairbots (microscopic nanobots) are injected into the affected area and monitored by human observers as they repair the tissue. Used repairbots deactivate and are expelled from the wound area.

07.h.2 IMMUNOLOGY LAB: The health professionals of the immunology lab specialize in space-related medicine and analysis. Radiation exposure is treated in the immunology lab. Cluster crew and citizens who must perform tasks by EVA in open space are subject to exposure to space radiation (i.e. solar flare exposure). Effects of radiation exposure can range from chronic infections to cancer to impending death. Upon first arrival in the Cluster, bone marrow specimens are collected from each individual. These specimens are stored in radiation-resistant vaults at the Hub Main Health Center. In the event of radiation exposure, the affected person's vial of bone marrow is infused for an immediate fix to what would otherwise be almost certain death within days.

Stress can also cause immune system damage. For this reason, the psychology of human space travelers is very important. The immunology lab provides evaluation for stress-induced factors such as: separation from Earth family and friends for extended periods; boredom and restlessness; loneliness; stress between crew members; food anxiety; isolation; clastrophobia; distress due to leaks or collisions with the Cluster. Pre-mission screening is done at BioMat to ensure that Cluster inhabitants excited about the mission, love to explore, are content in groups or alone, are well-balanced, self-starters, and emotionally stable. Personalities are subject to change over the duration of a long mission, such as the Cluster. Health center psychologists can provide exercise and diet counseling, as well as sleep sequence regimens and recreational counseling. Leisure-time and family activities are very important in the overall well being of Cluster inhabitants.

07.h.3 LOCOMOTION LAB: Gravity is essential. Without gravity, the human body deteriorates. Certain sections of the Cluster place workers in less-than-one-gravity (LT1) situations for extended periods. The locomotion labs, located on all LT1 levels provide workers with exercise sequences to help stimulate muscles and vital organs. Strap-down treadmills and workout equipment simulate a 1-G environment. All LT1 workers are required to work no more than one day in four in LT1 situations. All LT1 workers are required to visit a locomotion lab every four hours during a work shift to participate in an exercise sequence.

07.h.4 HOLOROOMS: Holorooms are located in the business/entertainment area of each mushroom dome, as well as on each level of the hub. 0G holorooms are located in the central hub area. Virtual adventures can be programmed to accommodate single users or small groups of users. Holoroom adventures are only limited by the imagination of the programmer. Adventures can range from a quiet dayhike through the forest to a pod race through the Asteroid Belt. From a backpacking expedition in the Appalachian Mountains to an undersea cave excursion. When a user first steps into a holoroom, it appears as a steel gray room with an overlying green grid. A touchscreen computer allows the user to select a preset adventure or custom design his/her own. Once the parameters have been entered, the room transforms into a virtual landscape. The carbon nanotube construction of the walls allow them to conform to the set parameters, causing the user to view the room as an illusion of the adventure.

INSIDE INFORMATION: THE HIDDEN TREASURE

My name is Srin. I am a student in the Gold Zone. Today is Saturday, and I have just finished an adventure in the holoroom. I want to tell you about it. When I stepped into the holoroom, I chose a preset Treasure Hunt. The instructions onscreen told me that all the gear I needed for the adventure had been ordered. In about 15 seconds, a drawer slid out of the wall near me and in it I found a swimsuit and goggles. I changed and placed my clothes in the drawer, which then retracted into the wall. As soon as the drawer disappeared, the room began to transform into a tropical island. I was standing on the edge of a cliff with a huge waterfall roaring past me into the lagoon below. I stepped to the edge of the cliff and dove into the water below. In the crystal clear water I saw hundreds of tropical fish swimming with me beneath the water. The sunlight shimmered on the surface above. In the distance I could see the mouth of an underwater cave. I swam for the cave, coming up for air once before I finally reached the entrance. I eased my way through the rocky underwater tunnel into a cool, dark passage ahead. Before long, I came to an enormous cavern. I could see the cavern even before I came to the surface of the water. On the banks of this underground pool, I could see coins glimmering in the sunlight, which was seeping in through tiny holes in the roof of the cavern. I pulled myself out of the water and followed the trail of coins, but before I know what was happening I heard movement. I turned to see a band of pirates, with gold sashes tied at their waists and black eyepatches. I heard the swoosh of metal as the pirates drew swords from their scabbards. I turned and ran, barefeet smacking on the cold, wet stone floor. I followed a passage up. I climbed higher, harder, but I could still hear the pirates right on my tail. One grabbed at my ankle. I kicked him away. He fell backwards into the rest of his band. The passageway opened into an almost blinding room, filled with gold, silver and jewels. Sunlight flooded the room from a large hole in the roof of the cavern. The pirates had regained their footing and came after me again. I stopped at the mountain of treasure, picking it up in my hands, hearing the jingle as it fell back into the pile. I couldn't hesitate for long. I had to run. I began to climb the rocks, heading for the hole at the top. The pirates began to climb too. Exhausted, I climbed harder, faster, hand over hand. I could feel myself slipping, but I held on. I scrambled along the final ledge and pulled myself through the hole. Lush, green trees and tropical birds greeted me as I emerged into the bright sunshine. The first of the pirates came out of the hole with a roar. I spied the waterfall straight ahead of me. I ran toward it. I could me the touchscreen a few yards away. The pirate dove forward. His hand grabbed my arm just as I hit the touchscreen. "End adventure" flashed on the screen as the pirates and all my surroundings melted away into a steel grey room with a green grid framework. The drawer slid out of the wall near me. I changed back into my own clothes and palmed the door. On my way home, I found one gold coin in my pocket. A souvenir from the adventure.

07.h.5 DV THEATERS: First-run movies are transmitted weekly from Earth. Multiple-screen DV theaters are located in each dome. There is no cost to users for viewing movies in the DV theaters. Refreshments are available at a nominal cost.

07.h.6 FITNESS CENTERS: Fitness and exercise programs and equipment are available in the fitness centers at no cost to the user. Inhabitants are encouraged to use these facilities often. Fitness centers are located in each dome. A larger YMCA facility is located in the hub. The YMCA features water sports, and an Olympic-size swimming pool. Sports fields are located in the central park area of each dome.

07.h.7 SPORTS COMPLEX: A multi-function stadium-style sports complex is located in the central hub area. intercommunity soccer, rubgy, swimming and track tournaments are held in the stadium. There are no fees for admission to events in the sports complex. Cluster citizens may join existing teams or establish new teams without cost. All uniforms and equipment and provided by the Cluster.

07.h.8 MINI-MALLS: Mini-malls are located in the business area of each dome. Small businesses and retail shops make up the majority of mini-mall space. Public health and services offices are located in the mini-malls. Retail stores and food stores provide Cluster citizens with a shopping experience much like those found on Earth. Once purchases have been made, the individual's personal account is debited and the purchased items are delivered to the residence. All the fun of shopping without the inconvenience of carrying packages home. Full service restaurants and fast-food kiosks are located throughout each mini-mall. Dine-in and take-out service is available at all food establishments.

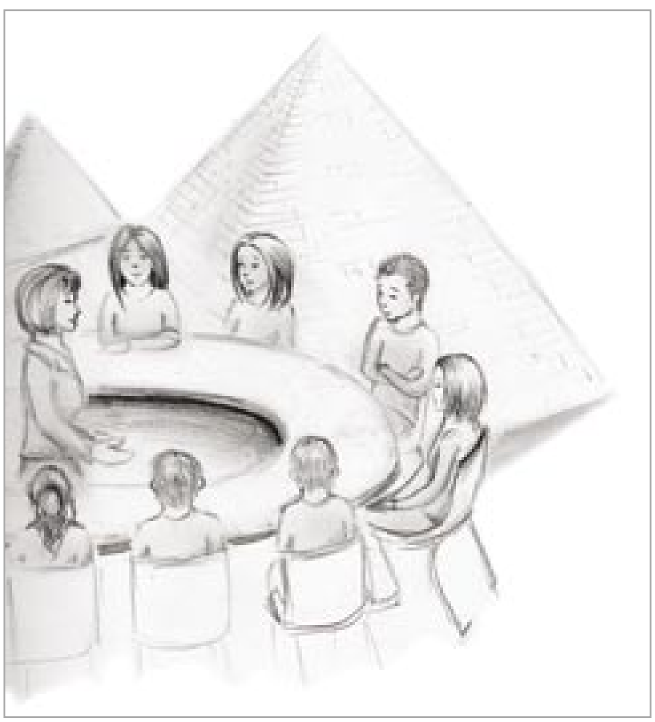
07.h.9 PARKS: Community parks are located in the center of every block in every community in the Cluster. There are no fenced in yards. Every backdoor opens up into a common park area, with an abundance of trees, shrubs, flowers and lawn furniture. Each community park has ample room for friendly neighborhood games of frisbee or tag. The area surrounding the stem train terminal in each dome is designated as a central park. Not only does the central park areas have all the amenities of community parks, but there are pavilions and sports fields also. Citizens are encouraged to use the parks and all of the facilities and services provided by the Cluster.

07i Educational units

When students first walk into a classroom in the Cluster, it looks like a normal classroom . . . until class begins. All four walls and the ceiling of all classrooms are equipped with nanoencapsulated plasma screens and LED lighting, covering the entirety of the room (except for the floor) with virtual images. Students are immersed in learning. History, science, literature . . . every subject comes alive as students are transported visually to the ancient ruins of the Mayans, or the first Olympic Games of Greece, or on a submarine voyage to the depths of the oceans. Surround sound transports students further into the environment of virtual learning.

Attendance is recorded via RFID readers as students enter the classroom. Class size is kept at 12-14 students per class. Touchscreen desktops permit students to proactively participate in classroom activities. Questions presented by the teacher are answered by touchscreen and recorded in the teacher's log. Wireless communications provide students with unlimited resources for research and study. The circular configuration of desks around the central teacher's platform ensures that all students have equal visibility. Actual human teachers provide classroom instruction most of the time. During those times when more detailed instruction is needed or special programs are presented, instruction is provided remotely. Guest professors from Earth, BioMat or the colonies of Europa appear in the classroom virtually through holographic projection on the center platform.

To enhance the creativity of students, digital tablets and styluses are provided for each student. Writing and drawing performed on digital tablets is recorded electronically for input to storage devices or paperless printers.



CLUSTER CLASSROOM

Class size in the Cluster averages 12 students. This class is busy learning about the ancient pyramids on Earth. As the teacher tells the students about the pyramids, holographic pyramid images appear in the room around them.

K BALDWIN 2005

07j Work environment

Ninety percent of the manufacturing and processing equipment used in the Triangulum Cluster has been miniaturized, using nanotechnology and carbon nanotube construction. Manufacturing and processing equipment is housed within the walls and other infrastructure of the Cluster (areas which have not been developed for human habitation–minimal heating, lighting and life support). These areas are operated and maintained by robotic workers. Robotic workers are monitored and programmed by human technicians and engineers located in the common areas of the Cluster. In the event that human interaction is required in the production facilities, adjustments and repairs are made by workers outfitted in life-support clothing. Humans monitor hydroponic gardens and harvesting procedures. Most work performed by humans in the Cluster is research, analysis, development, planning, monitoring and other intellect-based tasks. Most labor is performed by robot workers.

07k Mobility, transportation and tracking

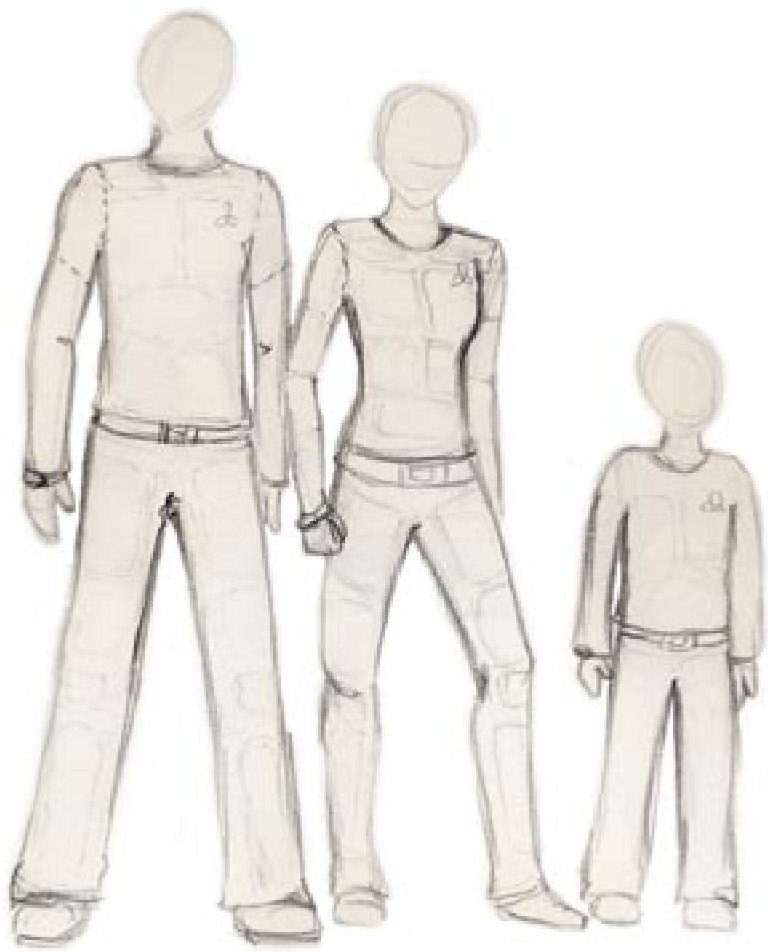
07k.1 RFID TRACKING: RFID technology is used to keep track of the location and mobility of Cluster crew and citizens. Dime-size RFID tags are embedded in the garments of all individuals. Tags have a dual purpose. Cluster officials know where Cluster citizens are at all times, for both safety and security reasons. Tags also serve the wearer. Destination coordinates can be keyed into the tag by users and RFID readers throughout the Cluster are alerted. As the user moves through the corridors of the Cluster, LED bands of color will light up along the walls to direct the user to his/her final destination. Audible directions will be broadcast in the user's earbud, in conjunction with the LED color bands along the wall. Flashing LED lights will mark the final destination for the user.

The RFID tags used in the Cluster are passive tags which operate without a separate external power source and obtain operating power generated from the reader. Passive tags are lightweight, inexpensive, and offer an unlimited operational lifetime. Cluster tags operate at a frequency of 600MHz to 850MHz with a range of several meters.

07k.2 LIFE-MONITORING GARMENTS (LMGs): All Cluster citizens and crew wear specially designed clothing called life-monitoring garments (LMGs). The garments are made of lightweight (8 oz.), comfortable, machine-washable, easy-to-use shirts, shorts and pants, which is worn during daily activities, such as going to work or school, exercise and sleep. To measure pulmonary function, nanosensors are woven into the shirt around the subject's chest, abdomen and other vital areas. The sensors measure cardiac function, posture, physical activity, blood pressure, blood oxygen saturation, EEG, EOG, periodic leg movement, core body temperature, skin temperature, and respiratory signs, such as end tidal CO, and cough..

LMGs can collect data on pulmonary, cardiac, and other physiologic data, and correlate them over time. The sensors gathers data during the wearer's daily routine, providing a continuous "movie" of the wearer's health in real-life situations (work, school, exercise, sleep).

Data from the LMG is uploaded to the Cluster Health Center, where computers analyze, process and score the incoming data. Daily reports are transmitted to the wearer's personal computer, along with suggestions for daily routine changes, exercise, diet and sleep adjustments.



CLUSTER WEAR

In living areas, inhabitants may wear whatever they choose, as long as a wrist communicator is part of their attire. The wrist communicator serves as both a communications device and a tracking/monitoring device.

During leisure activities, inhabitants may choose to wear LMG sports-wear.

During sleep periods, inhabitants may choose to wear LMG sleepwear, which will monitor sleep patterns and provide vital statistics.

At work or school, inhabitants are required to wear Cluster uniforms, which are fully functional.

In addition to communication, monitoring and tracking capabilities, security uniforms include biosensors which provide: instant tourniquet, chem filters, mylar/teflon/spandex shell, laser guidance, nigh vision, temperature controls and color change capabilities.

K BALDWIN 2005

07.k.3 TRANSPORT: Transportation in the Cluster is accomplished by one of three means: on foot, by hoverboard, and by stem train. Walking and jogging is encouraged in the communities. Each community is small enough to traverse by foot, without expenditure of too much energy. Each inhabitant of the Cluster is issued a personal hoverboard. Hoverboards can be utilized in all areas of the Cluster, including the Mushrooms, hydroponic gardens, hub levels one, two, three, and the central hub. Maglev stem trains must be used when moving from Mushroom areas to hub levels or from hub levels to Mushroom areas. Once passengers reach their final destination, hoverboards are permitted. Hoverboard backpacks are provided to all inhabitants. Optional hover Segways can be purchased.

07l Government

Management of the Triangulum Cluster is handled in much the same way as a corporation. At the top management level, a COO (Chief Operating Officer) has been assigned to duty in the Cluster. This assignment is made by appointment from the WSA (World Space Alliance), headquartered in Washington, DC, United States. Oversight of the Cluster is managed by the Cluster Board of Directors.

The board is composed of representatives from each community in the Cluster. Laws governing the Cluster are enforced by the Manager of Law Enforcement (MLE). Other managers on staff in the Cluster include: Manager of Industry (MI), Manager of Research and Development (MRD), Education Manager (EM), Leisure Time Manager (LTM), Manager of Food Production and Processing (MFPP), Transportation Manager (TM), Manager of Mechanics and Operations (MMO), Commerce Manager (CM), Manager of Power of Propulsion Systems (MPPS), Health Manager (HM), Manager of Chaplain Services (MCS), Manager of Life Support Systems (MLSS), Manager of Interplanetary Affairs (MIA), Missions Manager (MM) and other managers as needed. Sub-managers are assigned to each manager. Sub-managers are responsible for the day-to-day operations of their assigned sector (i.e. there are five sub-managers (SM) reporting to the Missions Manager: Space Radiation Research SM; Manned Colonies/Outposts SM; Unmanned Colonies SM; Experimental Probes SM; and Interstellar Propulsion Research SM).

The Cluster Board of Directors meets quarterly, rotating meeting locale. Q1 meeting is held in the Central Hub; Q2 meeting in the Gold Zone; Q3 meeting in the Blue Zone; and Q4 meeting in the Purple Zone.

08 Missions of the Triangulum Cluster

The Triangulum Cluster is a, state-of-the-art, multifunction facility, multipurpose laboratory. It provides a gateway to discovery, for scientific, technological or commercial purposes. Space investigators from industry, universities and government are able to take advantage of a rich diversity of facilities carried aboard the Cluster. “Remote Telescience”—meaning an interactive set of data and video links—offers the ability for scientists on Earth and in the other solar system colonies to have a direct connection with their experiments in the Cluster. The men and women who work and live in this permanent space science and technology research base devote themselves to carrying out a diverse set of jobs, from life science and microgravity science studies to Earth science and space science research. Year-round research is undertaken aboard the Cluster. Facilities are designed to yield a steady stream of findings from hundreds of high-quality science and technology experiments.

The Cluster has an exposed platform for experiments that require direct contact with the space environment. The module also has a small robotic arm for payload operations on the exposed platform. Listed below are just a few of the major missions currently underway in the Cluster.

08a Space Radiation Research

Space Radiation is one of the greatest dangers to space travelers. Because of this fact, scientists and doctors of the Cluster have devoted much time to the study of radiation and its effects on humans.

08.a.1 FLARES AND CORONAL MASS EJECTIONS: When a solar flare or a coronal mass ejection occurs (the two often occur at the same time, but not always), large amounts of high-energy protons are released. These high-energy protons can easily reach the Earth's poles and high-altitude orbits in less than 30 minutes. Because such events are very difficult to predict, there is often little time to prepare for their arrival.

08.a.2 GALACTIC COSMIC RAYS: Galactic cosmic rays include heavy, high-energy ions of elements that have had all their electrons stripped away as they journeyed through the galaxy at nearly the speed of light. Cosmic rays, which can cause the ionization of atoms as they pass through matter, can pass practically unimpeded through a typical spacecraft or the skin of an astronaut. Galactic cosmic rays are the dominant source of radiation that must be dealt with aboard the Cluster and all colonies and outposts within our solar system. Because these particles are affected by the Sun's magnetic field, their average intensity is highest during the period of minimum sunspots when the Sun's magnetic field is weakest and less able to deflect them. Also, because cosmic rays are difficult to shield against and occur on each space mission, they are often more hazardous than occasional solar particle events. They are, however, easier to predict than solar particle events.

08.a.3 EFFECTS OF SPACE RADIATION: The energy that ionizing radiation loses as it travels through a material or living tissue is absorbed by that material or living tissue. The ionization of water and other cell components can damage DNA molecules near the path the particle takes – a direct effect of which is breaks in DNA strands including clusters of breaks near one another; breaks that are not easily repaired by cells. Such DNA break clusters are much less frequent, or do not occur at all, when cells are exposed to the types of radiation found on Earth. Because it can disrupt an atom, space radiation also can produce more particles, including neutrons, when it strikes a spacecraft or an astronaut inside a spacecraft – this is called a secondary effect. One mission of the Cluster is conduct research to understand how initial damage to DNA and cells from heavy ions relates to increased risks for cancer or other health effects, and how biological countermeasures to such risks can be developed. On missions beyond the bounds of Earth there is less protection against ionizing particles, and the Cluster passes through the trapped radiation belts more often than do spacecraft in Earth orbit.

08.a.4 MEASURING RADIATION: The absorbed dose of radiation is the amount of energy deposited by radiation per unit mass of material. It is measured in units of rad (radiation absorbed dose) or in the international unit of Grays (1 Gray = 1 Gy = 1 Joule of energy per kilogram of material = 100 rad). The mGy (milliGray = 1/1000 Gray) is the unit usually used to measure how much radiation the body absorbs. However, because different types of radiation deposit energy in unique ways, an equivalent biological dose is used to estimate the effects of different types of radiation. Equivalent dose is measured in milliSieverts (mSv). The mSv, therefore, takes into account not only how much radiation a person receives, but how much damage that particular type of radiation can do – the greater the possibility of damage for the same dose of radiation, the higher the mSv value. Although the type of radiation is different, one mSv of space radiation is approximately equivalent to receiving three chest x-rays. On Earth, we receive an average of two mSv every year from background radiation alone. Crew members could receive higher doses of space radiation during space walks while outside the protective confines of the Cluster.

Materials that have high hydrogen contents, such as polyethylene, can reduce primary and secondary radiation to a greater extent than metals, such as aluminum. Cluster crew members and citizens each wear physical dosimeters, and also undergo a biodosimetry evaluation measuring radiation damage to chromosomes in blood cells. Active monitoring of space radiation levels is helpful to reducing the levels of radiation an astronaut receives by helping the astronauts locate the best-shielded locations in the colony. The monitoring also serves as a warning should radiation levels increase due to solar disturbances. Following a healthy diet and lifestyle, including the use of antioxidants following radiation exposure, should also reduce risks.

08.a.5 RADIATION MEASUREMENT DEVICES: There are many radiation measurement devices and sensors throughout the Cluster. Let's take a look at just a few of them.

Neutron Detector: Measures the amount of neutron radiation that enters the Cluster. Neutron radiation can affect the blood-forming marrow in bones.

Charged Particle Directional Spectrometers: Designed to record the direction from which radiation strikes.

Radiation Sensors: These sensors are being used to determine the levels of radiation space walkers receive in their skin, eyes and blood-forming organs. These sensors consist of active dosimeters that are read before and after a space walk. Data collected is used to help determine ways to reduce the amount of radiation astronauts are exposed to during space walks.

Passive Dosimetry: There are several types of radiation detectors aboard the Cluster. The radiation area monitor (RAM) is a small set of thermoluminescent detectors encased in Lexan plastic that respond to radiation – the amount of radiation they absorb can be revealed by applying heat and measuring the amount of visible light released. RAM units are scattered throughout the Cluster. The crew passive dosimeter is very similar to the RAM and is carried by each member of the crew. The Radiac Set (a high-rate dosimeter) is a compact, credit card size, pocket-carried device capable of quickly measuring doses of gamma or neutron radiation. Data readout and warning messages are provided by a liquid crystal display on the set.

Phantom Torso: This device measures the effects of radiation on organs inside the human body by detecting and measuring how much radiation the brain, thyroid, stomach, colon, and heart and lung area receive on a daily basis. Analysis of this type of information has lead to the development of better construction materials, shields and spacesuits, a very important factor for long-duration space flights such as the Triangulum Cluster mission.

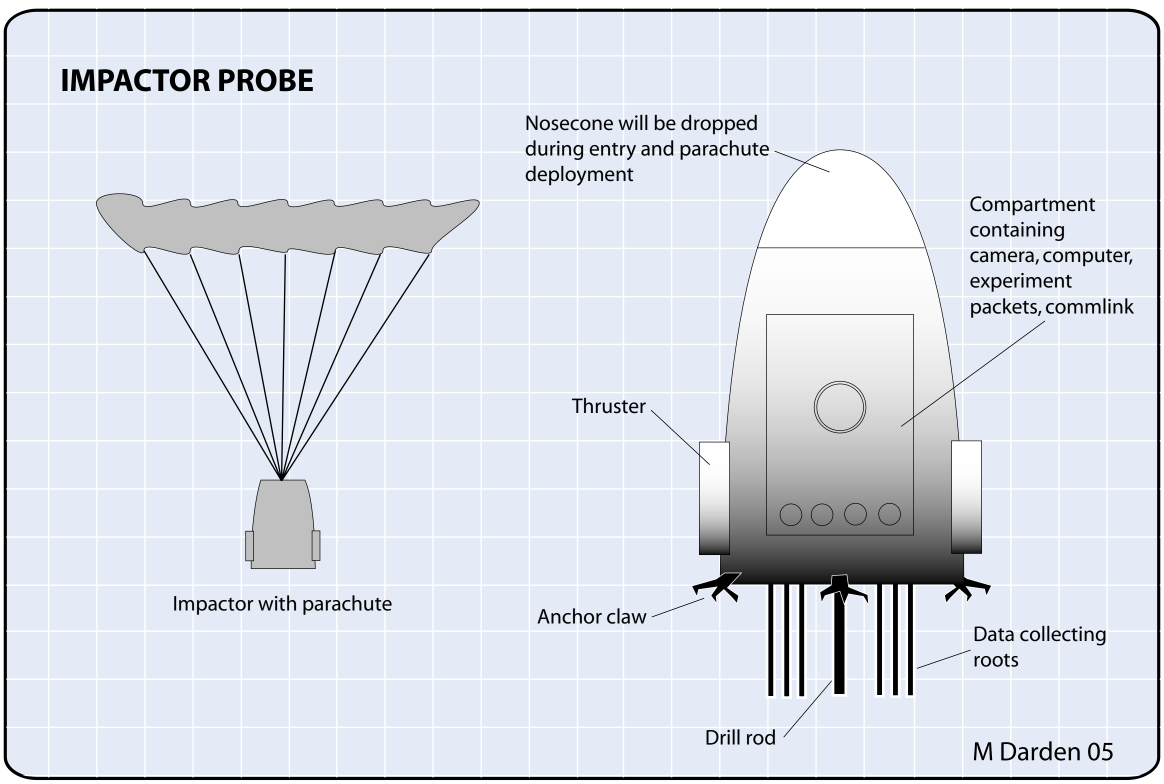
08b Monitor and resupply manned colonies and outposts

The majority of the colonies and outposts in our solar system are manned and each one of them require crew changes and supply enhancements. The Triangulum Cluster is scheduled to make one circuit of the entire solar system every twenty-four years. During that time, it is scheduled to make stops at each one of the Earth colonies, taking on goods and supplies from each one and distributing those goods and supplies at other colonies. As new crew members are trained at BioMat, they will be transported to the Cluster by ion-drive shuttle, where they will receive further orientation and study the components of the colony for which they are assigned. Transient crews are blended into the communities of the Cluster and enjoy all the benefits and considerations of Cluster citizens.

08c Transport crews to formerly unmanned outposts around Uranus and Neptune

Extra docktime has been scheduled for Cluster visits to the outposts of Uranus and Neptune, as this will be the first deployment of crew members to these outposts. The crews of Regulus (around Uranus) and Cetus (around Neptune) will be given time to acclimate to their new surroundings and perform thorough inspections and testing before the Cluster departs their locations. Small crews of 25 are scheduled to be deployed at each of these outposts.

08d Deploy experimental probes



As the Triangulum Cluster journeys through the solar system, it has encountered (and will continue to encounter) hundreds of heavenly bodies. It is both impossible and unneccesary to establish outposts or colonies on each of them. Therefore, the Experimental Probe Program was developed. As the Cluster passes by unexplored locations throughout the solar system, probes are deployed from the

Cluster launch platform. One, or dozens, of probes can be deployed simultaneously, much like being fired from a canon. Once deployed, the probes each contain onboard propulsion, guidance, and monitoring equipment.

Each probe consists of two main parts: a “fly-by” spacecraft and a smaller “impactor.” Once it is within range, the impactor will be released and instructed to land on the target body’s surface. Braking thrusters and parachute units are included in each probe. Onboard computers calculate drag and determine which landing method is best suited to atmospheric and ground conditions of the target. Once impact is made, anchor claws are deployed to secure the probe to the surface. Cameras, scientific instruments and drills are included in the Impactor’s tool kit. Experimentation and analysis can begin immediately upon impact.

The fly-by spacecraft will observe and monitor the impactor. Data collected will be transmitted to BioMat, Europa 2, Argon One, Outpost Alpha, Lupus, or Earth for analysis.

08e Develop interstellar propulsion systems

A rocket’s speed is limited to about twice the velocity of it’s nozzle exhaust. Conventional chemical rockets of the 21st century expelled exhaust at less than three miles per second, producing a maximum velocity of about six miles per second. At that rate it would take 120,000 years to reach Alpha Centauri. To get there in a human lifetime, a rocket would have to travel at least 3,000 times faster than the conventional chemical propellants, such as liquid hydrogen and kerosene, can thrust. The scientists and engineers of the Triangulum Cluster are working in conjunction with scientists and engineers of BioMat to research and test a variety of interstellar propulsion systems. The ultimate goal of the crew and citizens of the Triangulum Cluster is to be the precursor to interstellar flight. The nuclear fusion engine used to power the Cluster on segments of its journey began as a BioMat experiment.

PROPULSION SYSTEMS COMPARED:

[1] NUCLEAR FISSION: Pros–could be feasible soon; Cons–very heavy, needs processed fuel, requires massive radiation shielding; has limited top speed and range.

[2] NUCLEAR FUSION: Pros–lighter than a fission engine, less radiation, possibly refuelable; Cons–heavy, has a limited range, technology not yet practical.

[3] ANTIMATTER: Pros–most efficient rocket, best top speed, longest range of the three atomic engines (fission, fusion and antimatter); Cons–heavy, antimatter technology still under development.

[4] LASER SAIL: Pros–high speed, no fuel onboard, technology available now; Cons–massive laser infrastructure, can only go where laser points.

[5] FUSION RAMJET: Pros–near light speed, unlimited interstellar travel in any direction; Cons–requires major advances in physics and engineering knowledge.

09 Appendices

09a Motions within the solar system

The sun and planets each rotate on their axes. Because they formed from the same rotating disk, the planets, most of their satellites, and the asteroids, all revolve around the sun in the same direction as it rotates, and in nearly circular orbits. The planets orbit the sun in or near the same plane, called the ecliptic (because it is where eclipses occur). Pluto is a special case in that its orbit is the most highly inclined (17 degrees) and the most highly elliptical of all the planets. Because its orbit is so eccentric, Pluto sometimes comes closer to the sun than does Neptune. It's interesting to note that most planets rotate in or near the plane in which they orbit the sun, since they formed, rotating, out of the same dust ring. Uranus must have suffered a whopping collision, though, that set it rotating on its side.

09b Distances within the solar system

The most common unit of measurement for distances within the solar system is the astronomical unit (AU). The AU is based on the mean distance from the sun to Earth, roughly 150,000,000 km. Another way to indicate distances within the solar system is terms of light time, which is the distance light travels in a unit of time. Distances within the solar system, while vast compared to our travels on Earth's surface, are comparatively small-scale in astronomical terms. For reference, Proxima Centauri, the nearest star at about 4 light years away, is over 265,000 AU from the sun.

Light Time	Approximate Distance	Example
3 seconds	900,000 km	~Earth-Moon Round Trip
3 minutes	54,000,000 km	~Sun to Mercury
8.3 minutes	149,600,000 km	Sun to Earth (1 AU)
1 hour	1,000,000,000 km	~1.5 x Sun-Jupiter Distance
12.5 hours	90 AU	Voyager-1 (January, 2004)
1 year	63,000 AU	Light Year
4 years	252,000 AU	~Next closest star

09c Temperatures within the solar system

Kelvin	° C	° F	Remarks
0	-273.15	-459.67	Absolute Zero
20 nano-K	-273.15~	-459.67~	Lowest achieved in a lab
2.7	-270.5	-454.8	Cosmic background/microwave radiation
4.2	-268.95	-452.11	Liquid helium boils
14.01	-259.14	-434.45	Solid hydrogen melts
20.28	-252.87	-423.16	Liquid hydrogen boils

35	-235	-390	Neptune's moon Triton surface
63.17	-209.98	-345.96	Solid nitrogen melts
72	-201	-330	Neptune 1-bar level
76	-197	-323	Uranus 1-bar level
77.36	-195.79	-320.42	Liquid nitrogen boils
90	-180	-300	Saturn's moon Titan surface
90.188	-182.96	-297.33	Liquid oxygen boils
100	-175	-280	Planet Mercury surface, night
134	-139	-219	Saturn 1-bar level
153	-120	-184	Mars surface, night low
165	-108	-163	Jupiter 1-bar level
195	-78.15	-108.67	Carbon dioxide freezes ("dry ice")
273.15	0.0	32.0	Water ice melts
288	15.0	59.0	Mars surface, day high
288.15	15.0	59.0	Standard room temperature
373.15	100	212	Liquid water boils
600.46	327.31	621.16	Lead melts
635	362	683	Venus surface
700	425	800	Planet Mercury surface, day
750	475	890	Uranus hydrogen "corona"
1,337.58	1,064.43	1,947.97	Solid gold melts
3,500	3,200	5,800	Betelgeuse (red giant star)/photosphere
3,700	3,400	6,700	Sunspots
5,700	5,400	9,800	Solar photosphere
10,000	10,000	18,000	Sirius (blue-white star) photosphere
15,000	15,000	27,000	Saturn core
30,000	30,000	54,000	Jupiter core
2,000,000	2,000,000	3,600,000	Solar corona
15,000,000	15,000,000	27,000,000	Solar core

Melting and boiling points are shown to precision, for pressure of 1 atmosphere. Values for stars, planet cloudtops, surfaces etc. are shown as round numbers rather than precise conversions.

Temperature Conversions

°K = °C + 273.15

°C = (5/9) X (°F-32)

°F = (9/5) X °C+32

-40°F = -40°C

09d Planetary facts

09.d.1 Mercury

Radius: 2439.7 km
Mass: 3.3x1023 kg
Orbital Period: 87.97 Earth days
Rotation Period: 58.65 Earth day
Distance from Sun: 57.91 million km

09.d.2 Venus

Radius: 6051.9 km
Mass: 4.87x1024 kg
Orbital Period: 224.7 Earth days
Rotation Period: 243.0 Earth day
Distance from Sun: 108.2 million km

09.d.3 Earth

Radius: 6378.1 km
Mass: 5.98x1024 kg
Orbital Period: 365.26 Earth days
Rotation Period: 1 Earth day
Distance from Sun: 147.6 million km
Satellite: Moon

09.d.3.i Moon

Radius: 1737.4 km
Mass: 7.18x1022 kg
Orbital Period: 27.32 Earth days
Rotation Period: 27.32 Earth days
Orbit: 384,400 km from Earth

09.d.4 Mars

Radius: 3388 km
Mass: 6.42x1023 kg
Orbital Period: 686.98 Earth days
Rotation Period: 1.026 Earth day
Distance from Sun: 227.94 million km
Satellites: Phobos and Deimos

09.d.4.i Phobos

Mean Radius: 9.2 x 13.4 km
Mass: 1.08x1016 kg
Orbital Period: 0.319 Earth days
Rotation Period: 0.319 Earth days
Orbit: 9,378 km from Mars

09.d.4.ii Deimos

Mean Radius: 5.2 x 7.5 km
Mass: 1.8x1015 kg
Orbital Period: 1.262 Earth days
Rotation Period: 1.262 Earth days
Orbit: 23,459 km from Mars

09.d.5 Jupiter

Radius: 69,911 km
Mass: 1.90x1027 kg
Orbital Period: 11.86 Earth years
Rotation Period: 0.414 Earth day
Distance from Sun: 778.33 million km
Satellites: Io, Europa, Callisto, Ganymede, Amalthea, Thebe, Metis, Adastra, and many more small moons.

09.d.5.i	Amalthea	Mean Radius: 67 x 131 km Mass: 7.17x1018 kg Orbital Period: 0.498 Earth days Rotation Period: 0.498 Earth days Orbit: 181,300 km from Jupiter
09.d.5.ii	Thebe	Mean Radius: 50 km Mass: 7.77x1018 kg Orbital Period: .675 Earth days Rotation Period: .675 Earth days Orbit: 222,000 km from Jupiter
09.d.5.iii	Io	Mean Radius: 1830 km Mass: 8.94x1022 kg Orbital Period: 1.769 Earth days Rotation Period: 1.769 Earth days Orbit: 422,600 km from Jupiter
09.d.5.iv	Europa	Mean Radius: 1,562.09 km Mass: 4.8x1022 kg Orbital Period: 3.551 Earth days Rotation Period: 3.551 Earth days Orbit: 670,900 km from Jupiter
09.d.5.v	Ganymede	Mean Radius: 2,632.345 km Mass: 1.48x1023 kg Orbital Period: 7.155 Earth days Rotation Period: 7.155 Earth days Orbit: 1,070,000 km from Jupiter
09.d.5.vi	Callisto	Mean Radius: 2404 km Mass: 1.08x1023 kg Orbital Period: 16.689 Earth days Rotation Period: 16.689 Earth days Orbit: 1,883,000 km from Jupiter

09.d.6	Saturn	Radius: 58,232 km Mass: 5.69x1026 kg Orbital Period: 29.46 Earth years Rotation Period: 0.436 Earth day Distance from Sun: 1,426.94 million km Satellites: Dione, Enceladus, Iapetus, Mimas, Phoebe, Rhea, Tethys, Titan, and a number of other moons.
09.d.6.i	Dione	Mean Radius: 560 km Mass: 1.05x1021 kg Orbital Period: 2.737 Earth days Rotation Period: 2.737 Earth days Orbit: 377,420 km from Saturn
09.d.6.ii	Enceladus	Mean Radius: 256.2 km Mass: 8.40x1019 kg Orbital Period: 1.37 Earth days Rotation Period: 1.37 Earth days Orbit: 238,040 km from Saturn
09.d.6.iii	Iapetus	Mean Radius: 256.2 km Mass: 8.40x1019 kg Orbital Period: 1.37 Earth days Rotation Period: 1.37 Earth days Orbit: 238,040 km from Saturn
09.d.6.iv	Mimas	Mean Radius: 210.3 km Mass: 1.88x1021 kg Orbital Period: 79.331 Earth days Rotation Period: 79.331 Earth days Orbit: 3,560,800 km from Saturn
09.d.6.v	Phoebe	Mean Radius: 110 km Mass: 4.0x1018 kg Orbital Period: 550.48 Earth days Rotation Period: 0.4 Earth days Orbit: 12,952,000 km from Saturn
09.d.6.vi	Rhea	Mean Radius: 764 km Mass: 2.49x1021 kg Orbital Period: 4.518 Earth days Rotation Period: 4.518 Earth days Orbit: 527,100 km from Saturn

09.d.6.vii	Tethys	Mean Radius: 523 km Mass: 7.55x1020 kg Orbital Period: 1.888 Earth days Rotation Period: 1.888 Earth days Orbit: 294,670 km from Saturn
09.d.6.viii	Titan	Mean Radius: 2,575 km Mass: 1.35x1023 kg Orbital Period: 15.945 Earth days Rotation Period: 15.945 Earth days Orbit: 1,221,860 km from Saturn
09.d.7	Uranus	Radius: 25,362 km Mass: 8.69x1025 kg Orbital Period: 84.01 Earth years Rotation Period: 0.72 Earth day Distance from Sun: 2,870.990 million km Satellites: Ariel, Miranda, Oberon, Titania, and Umbriel, plus a number of smaller moons, including Puck, Cordelia, Ophelia, Bianca, Cressida, Desdemona, Juliet, Portia, Rosalind, Belinda, 1986U10, Caliban, Stephano, Sycorax, Prospero, and Setebos.
09.d.7.i	Ariel	Mean Radius: 578.9 km Mass: 1.27x1021 kg Orbital Period: 2.52 Earth days Rotation Period: 2.52 Earth days Orbit: 192,000 km from Uranus
09.d.7.ii	Miranda	Mean Radius: 235.8 km Mass: 6.30x1019 kg Orbital Period: 1.414 Earth days Rotation Period: 1.414 Earth days Orbit: 130,000 km from Uranus
09.d.7.iii	Oberon	Mean Radius: 761.4 km Mass: 3.03x1021 kg Orbital Period: 13.463 Earth days Rotation Period: 13.463 Earth days Orbit: 583,400 km from Uranus
09.d.7.iv	Titania	Mean Radius: 788.9 km Mass: 3.49x1021 kg Orbital Period: 8.706 Earth days Rotation Period: 8.706 Earth days Orbit: 438,000 km from Uranus

09.d.7.v	Umbriel	Mean Radius: 584.7 km Mass: 1.27x1021 kg Orbital Period: 4.144 Earth days Rotation Period: 4.144 Earth days Orbit: 267,000 km from Uranus
9.d.8	Neptune	Radius: 24,622 km Mass: 1.02x1026 kg Orbital Period: 164.79 Earth years Rotation Period: 0.67 Earth day Distance from Sun:4,497.07 million km Satellites: Triton, and smaller moons Naiad, Thalassa, Despina, Galatea, Larissa, Proteus, and Nereid.
9.d.8.i	Triton	Mean Radius: 1352.6 km Mass: 2.14x1022 kg Orbital Period: 5.88 Earth days Rotation Period: 5.88 Earth days Orbit: 355,000 km from Neptune
9.d.9	Pluto	Radius: 1,150 km Mass: 1.31x1022 kg Orbital Period: 247.7 Earth years Rotation Period: 6.39 Earth day Distance from Sun:5,913.52 million km Satellites: Charon
9.d.9.i	Charon	Radius: 593 km Mass: 1.90x1021 kg Orbital Period: 6.39 Earth days Rotation Period: 6.39 Earth days Distance: 19,640 km from Pluto

10 Illustration List

01 Triangulum Cluster with tether deployed
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27 Triangulum Cluster aerial view of living area
28 Maglev stem train
30 Nuclear fusion engine
31 Crop cycle
32 Hydroponic garden
39 Hub icon
44 Cluster classroom
46 Cluster wear
50 Impactor probe

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