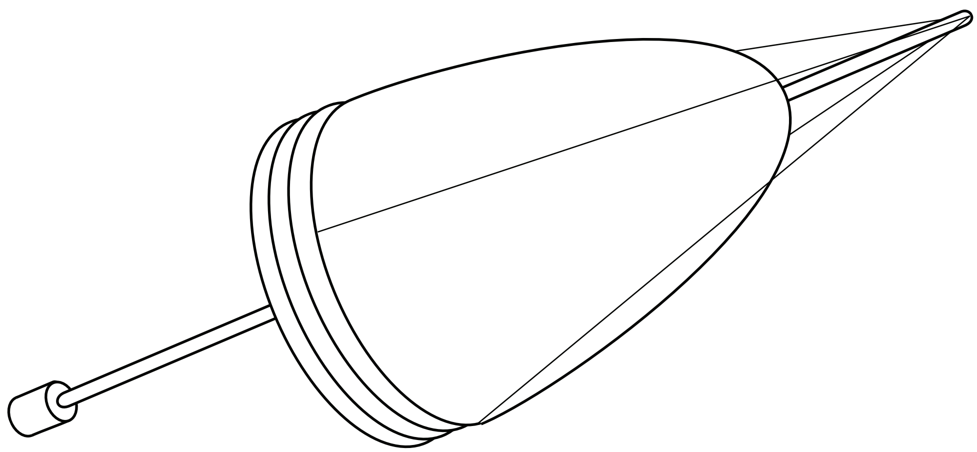
Vision:2020

A Self-sufficient Transient Space Colony

Touring Our Solar System

2038 AD



Presented by the members of the

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01 MISSIONS OF VISION:2020

On January 14, 2004, President Bush announced a new vision for NASA as he presented the American Vision for Space Exploration. He set our course for an ambitious mission of landing humans on the moon before the year 2020 with eventual manned explorations of Mars and beyond. Just two years following that announcement, we are well on our way to making the Vision for Space Exploration a reality. Using the knowledge gained in previous manned missions to the moon, and expanding the engineering and technological advances of the Space Shuttle program, plans for NASA's Crew Exploration Vehicle have been unveiled.

As this Space Colony entry is being submitted, a plan is in place to return the Space Shuttle fleet to flight and complete the International Space Station (ISS). Comet samples returned to Earth by the Stardust probe are being analyzed. The robotic missions of Spirit and Opportunity continue to feed us data from the surface of Mars as the Mars Reconnaissance Orbiter prepares to send us data from Martian orbit. The New Horizons spacecraft is racing across the solar system to its eventual rendezvous with Pluto.

The stage has been set for the future of space exploration. The inevitable future of human space exploration must include manned colonies in remote regions of our solar system. Preliminary exploration by robotic rovers will pave the way for human explorers to establish outposts and continue the work that only humans can do.

Vision:2020 is presented by the Collierville High School Aerospace Design Team (ADT) as our plan for the future of space exploration. If all of the economically powerful governments of Earth were to pool their resources and skills together, Vision:2020 could be our near-future reality. The events, procedures and calculations outlined in these pages are based on current or near-future technologies.

01.A. MISSION ONE

Develop new launch systems for space planes and cargo ships. A variety of launch systems were considered for the Vision:2020 project, including: launch from high altitude, turntable centrifuge launch, slingshot launch, spin launch, and roller coaster launch. Launch systems chosen for the final project were roller coaster launch for cargo ships and conventional shuttle-type launch systems for small group space taxis and large group space planes.

01.B. MISSION TWO

Establish a permanent Earth-orbit outpost to train personnel for long-term deployment to outposts and colonies in other regions of our solar system; and a permanent transient colony to provide transport from Vision:2020 to colonies and outposts, and from colonies and outposts to Vision:2020.

Vision Outpost, in Earth-orbit, was established in 2020 at L5 lagrange point and provides a base of operations for the Vision:2020 permanent colony. Construction of Vision:2020 began at the same time construction of Vision Outpost began, in 2015. Vision:2020 became active in 2020, and fully operational in 2025.

Based on information gained in the early robotic explorations of Mars, the Red Planet was chosen as the first destination for a permanent planetary surface colony. Vision:2020 provides a means of transport from Vision Outpost at L5 for these first Martian colonists. The Martian colony has been established and a temporary crew of 25 explorers have been busy for the past year, constructing bio-domes and green houses, in preparation for the first permanent colonists. The first Martian colonists are onboard Vision:2020 at this time, and we are in route to their new home. 100 explorers will inhabit the Mars Colony for an indefinite period. Vision:2020 will make periodic supply runs to the colony. Additional explorers will arrive at Mars Base with each Vision:2020 visit. Some explorers will be rotated off with each Vision:2020 visit.

01.C MISSION THREE

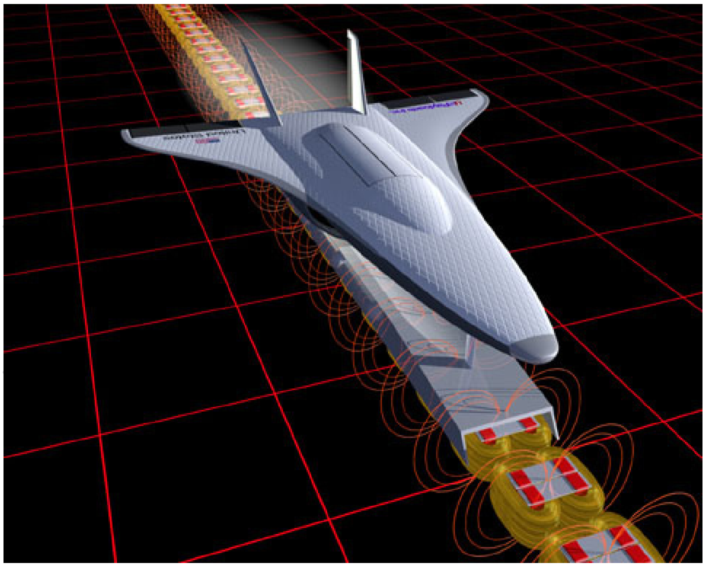
Deploy robotic exploration packages to specific planets and moons in our solar system. For more information on robotic exploration packages, please see Section 11.L (Planetary Exploration) of this report.

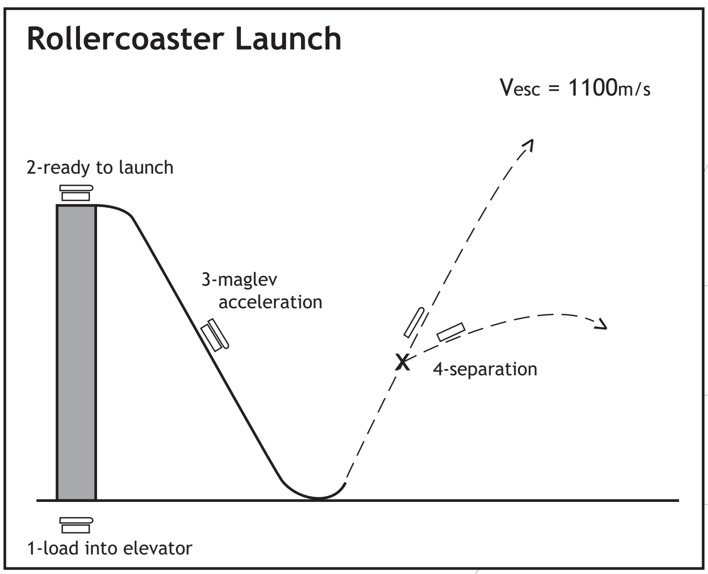
01.D MISSION FOUR

Research and development of new technologies by providing permanent housing, laboratories and production facilities for Vision:2020 colonists.

02 LAUNCH SYSTEMS AND SPECIFICATIONS

02.A ROLLER COASTER MAGLEV LAUNCH





02.A.a. Launch system

For cargo, a new launch system has been developed for Vision:2020–the roller coaster maglev launch. The system consists of 4 components: (01) the bullet-shaped cargo shuttle; (02) the magnetic carrier unit; (03) elevator; and (04) the maglev track. To begin the launch process, the magnetic carrier is loaded into the pre-launch bay of the elevator. The cargo shuttle is then moved into elevator above the carrier and the two are connected. The elevator moves the carrier and shuttle to the top of the roller coaster launch system. Conveyors transfer the carrier and shuttle to maglev tracks, where the maglev system takes over. Activation of the maglev levitates the carrier and shuttle. Magnetic acceleration and gravitational acceleration begins. When maximum maglev acceleration occurs, the carrier and shuttle leave the track. The shuttle and carrier separate, forcing the shuttle slightly upward and the carrier slightly downward. When shuttle attitude reaches +60°, air-breathing engines take over and begin the second stage of acceleration. When air becomes too thin, air-breathing engines shut off and on-board liquid oxygen (LOX) supply is used for the remainder of the journey. As carrier attitude approaches horizontal, glider wings deploy to control descent and bring the carrier back to the launch system. The carrier/glider lands at the launch system, ready to be loaded into the elevator for reuse.

Magnetic levitation - or maglev - launches spacecraft into orbit using magnets to float a space vehicle along a track. Magnetic levitation uses an ordinary electrical motor which normally converts electricity into rotary energy. But in this case the motor - formed from magnets - is unrolled so that it is flat. If a metal object is then held above the spaced-out magnets, it will float in the air, levitated by the magnetic fields. The most expensive part of any mission to low-Earth orbit is the first few seconds - getting off the ground. Maglev is a low-cost alternative for space transportation because it leaves the first-stage propulsion system on the ground. A maglev launch-assist system drives a space vehicle down a track at speeds of 600mph. A rocket engine takes over to enable spacecraft to reach orbit. The maglev system is virtually maintenance-free because it has no moving parts and there's no contact. Spacecraft can be launched from a 5,000-foot spaceport runway to low-Earth orbit every 90 minutes.

02.A.b. Cargo shuttle

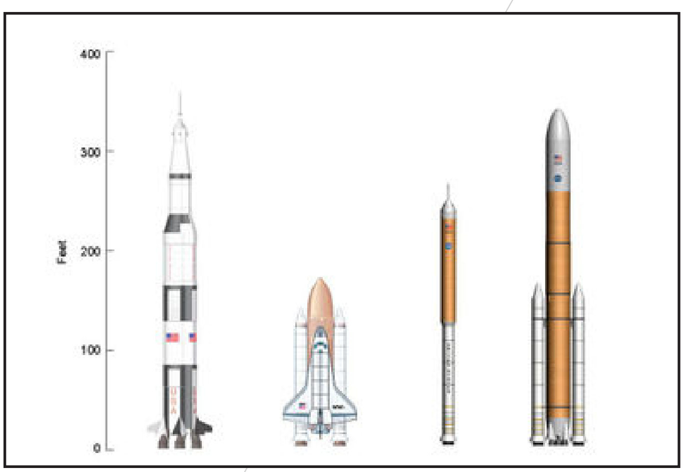
Bullet-shaped cargo shuttles are reusable vehicles designed to carry housing and office modules, building materials, and other materials and supplies to the colony.

02.A.c. Parking capsules for future use

Parking area for reusable cargo shuttles is located along the spindle connecting Vision:2020's fusion engine with the main torus of the colony. One-man space tugs are used to tow cargo shuttles (by magnetic connection) from the docking port to spindle parking. Once a cargo shuttle arrives in the parking area, magnets pull the cargo shuttle into the parking cell, where it is held in place by magnets. Workers in this area are required to work no more than two days on EVA shift with seven days off EVA, to avoid medical implications of exposure to space radiation and 0G.

02.B CONVENTIONAL LAUNCH

Two conventional space craft and launch delivery systems were chosen for the Vision:2020 project. The space taxi is launched atop the Ares I rocket, while the space plane is launched atop the Aves V rocket.



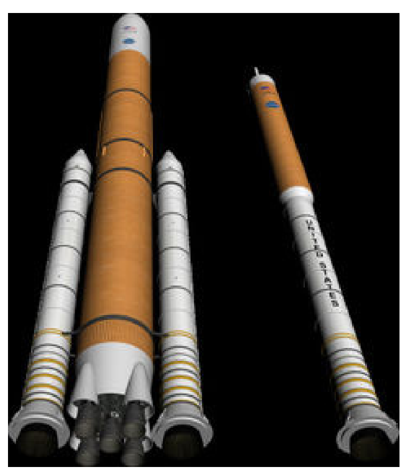


Illustration at left shows comparison of Apollo, Shuttle and new launch vehicles.

Illustration on the right shows Aves V and Aves I rockets.

02 LAUNCH SYSTEMS AND SPECIFICATIONS

02.B.a. Small space taxi for small groups

A 7-passenger space taxi has been developed to deliver small groups and replacement crews to the L5 Vision Outpost. The space taxi is launched atop the Ares I booster. Ares I uses a 5-segment Space Shuttle Solid Rocket Booster (SRB) for its first stage, with a liquid-fueled second stage powered by an Apollo derived engine called the J-2S. The space taxi and its escape system would be the primary payload, although the Ares I could also be used for unmanned cargo launches.

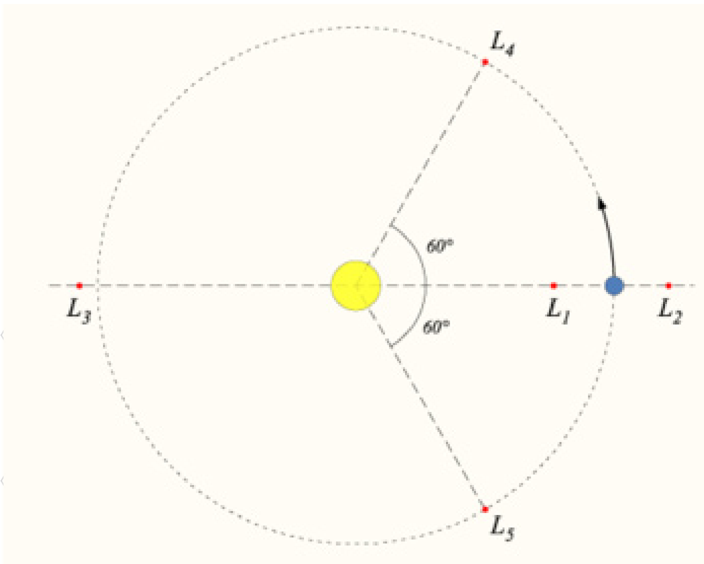
02.B.b. Larger space plane for large groups

A 30-passenger Concorde-style delta wing shuttle has been developed to deliver to the L5 Vision Outpost. The space plane is launched atop the Ares V booster. The Ares V uses two 5-segment Space Shuttle Solid Rocket Boosters (the Space Shuttle uses 4-segment SRBs) attached to a liquid fueled central booster (based on the space shuttle external tank) which has 5 SSME rocket engines, the same ones used on the Space Shuttle. A different configuration substitutes those with 3 RS-68 engines (used in the Delta IV launcher) for heavier payloads. The second stage features two (J2-S) rocket engines which maneuver the payload into final orbit. The capacity (125 t) is in the same class as the Saturn V rocket and is capable of supporting manned expansion to Mars as well as the moon.

02.C SPACEPORT CONFIGURATION

The United States Spaceport is located in White Plains, New Mexico. Components of the spaceport include: the roller coaster launch rail; 7 launch silos; and 2 5000-foot east-west runways.

03 LAGRANGE POINTS



03.A WHAT ARE LAGRANGE POINTS (also known as "libration points" or "L-points")?

These are all jargon for places where a light third body can sit "motionless" relative to two heavier bodies that are orbiting each other thanks to the force of gravity.

For example: imagine the Earth going around the Sun in a circular orbit. Then there are five Lagrange points where we can put a satellite. Three of them lie on a line through the Sun and the Earth. L1 is between the Sun and Earth, L2 is in the same direction as the Earth but a bit further out, and L3 is opposite the Earth:

The other two Lagrange points are less obvious. L4 lies in the Earth's orbit 60 degrees ahead of the Earth, while L5 lies in the Earth's orbit 60 degrees behind the Earth.

The really interesting thing is that the Lagrange points L4 and L5 are stable equilibria as long as the heavy body - the Sun in our example - is more than 24.96 times as massive as the intermediate-sized one. In other words, a small body put in orbit at the right speed at either of these points will tend to stay there! If you nudge it a little, it will drift back.

On the other hand, L1, L2, and L3 are unstable equilibria: the slightest nudge will make a satellite at one of these points drift away. To keep it there, you'll need to equip it with thrusters that keep correcting its orbit now and then.

03.B THE INTERPLANETARY SUPERHIGHWAY

The Lagrange points are useful for much more than just parking a spaceship - they also play a crucial role in a clever system for travelling around the Solar System while using almost no fuel! It's called the "interplanetary superhighway", or IPS for short. The unstable Lagrange points L1 and L2 are the important ones here, since you can easily slip onto them and then back off. They're like stepping-stones in a game of interplanetary hopscotch!

In fact, we have already used the IPS for a number of space missions, including the Genesis mission - the one that collected samples of solar wind, then came back to Earth... and then crashed into the desert in Utah at 320 kilometers per hour because of a faulty switch.

It turns out that the L1 and L2 points act as "gateways" for very low-energy transfer orbits. The IPS works by transferring between unstable and stable manifolds winding off and on unstable orbits like at L1 and L2.

The recent Genesis probe, the one that crashed, used such an orbit. It went out to the Earth-Sun L1 point, made 5 orbits on a curve to collect the solar wind, then returned back to Earth, passing by the L2 point to delay reentry until daylight in Utah for the planned helicopter capture - all without deterministic trajectory changes! NASA did have to use engines to correct the orbit, since they didn't get it exactly right and there were other requirements of the spacecraft, but in principle NASA could have established an orbit like this that would have completed the entire Genesis mission and returned the probe to Utah without any course corrections past the initial boost.

In fact, you can design an orbit that goes around the Sun some number of times, the Earth-Sun L1 point some number of times, the Earth some number of times, the L2 point some number of times, and the region outside the Earth's orbit some number of times - for any list of numbers you want!

It is now popular to put satellites in "halo orbits" at Sun-Earth Lagrange points. NASA has also used the IPS to design a Jovian "Petit Grand Tour" mission to visit four of the Jovian moons on a trajectory that has it orbiting each moon a certain number of times and going on to the next, using little or no fuel.

03.C LAGRANGE POINT 5 (L5)

The L4 and L5 points lie at the third point of an equilateral triangle with the base of the line defined by the two masses, such that the point is ahead of, or behind, the smaller mass in its orbit around the larger mass. L5 was selected as the location for L5 Vision Outpost because it is trailing the Moon's path around the Earth. Should any catastrophic events occur which might cause the outpost to be bumped in position L5, it would not consequently be in danger of interfering with the Moon's orbit.

04 ARTIFICIAL GRAVITY

04.A METHODS OF ACHIEVING ARTIFICIAL GRAVITY

Artificial gravity could be created in several ways, including rotation, acceleration, mass, tidal forces, or magnetism. Below you will find explanations of how artificial gravity could be accomplished in each of those situations. After considering our options, we determined that: (01) we could not maintain and sustain the proper acceleration to accomplish 1G; (02) the colony would have to be too large to create it's own gravity; (03) the colony would not be close enough to it's host heavenly body and the heavenly body would not to large enough to generate gravity due to tidal forces; and (04) creating artificial gravity by means of magnetism would have major adverse effects on the crew and residents of the colony. Therefore we chose the most logical means of generating artificial gravity-rotation.

04.A.a ROTATION

The colony could rotate so that anything inside will be forced toward the outside by centrifugal force. Artificial gravity by rotation has the following side effects:

- Coriolis forces produced by rotation could cause dizziness, nausea and disorientation. Experiments have shown that slower rates of rotation reduce the Coriolis forces and its effects. It is generally believed that at 2 rpm or less no adverse effects from the Coriolis forces will occur, at higher rates some people can become accustomed to it and some do not, but at a rates above 7rpm few if any can become accustomed. It is not yet known if very long exposures to high levels of Coriolis forces can increase the likelihood of becoming accustomed. The nausea-inducing effects of Coriolis forces can also be mitigated by restraining movement of the head. Head restraints are perhaps practical for exercising in artificial gravity (an artificial gravity gym), but not for much else. To avoid the adverse effects of coriolis forces, Vision:2020 will be constructed large enough to counteract those effects.
- Gravity gradients: Artificial gravity levels vary depending on distance from the center of rotation. With a small radius of rotation the amount of gravity felt at one's head would be significantly different from the amount felt at one's feet. This could make movement and changing body position awkward. To establish an environment in which gravity gradients are minimal, the Vision:2020 radius has been set at .5 miles.
- Angular movement: As noted high angular velocities produce high levels of Coriolis forces, angular moment (the amount of energy to spin) would require a propulsion system of some kind to spin up (or spin down). Also if parts of the colony are intentionally not spinning, friction and torque will cause the rate of spin to decrease (as well as cause the otherwise-stationary parts to spin). Fly wheels and thrusters would be needed to keep the appropriate sections of the colony spinning or not. Angular inertia can also complicate

space craft propulsion and attitude control. Vision:2020 has been designed to spin as one unit, therefore minimizing the complications of angular movement. Power sources have been developed to maintain the Vision:2020 spin, and propulsion systems are in place to provide directional controls for the colony.

Theoretical colony designs using artificial gravity have a great number of variants with intrinsic problems and advantages. To reduce Coriolis forces to livable levels a rate of spin of 2 rpm or less would be needed. To produce 1g the radius of rotation would have to be 224 m (735 ft) or greater, which would make for a very large colony. To reduce mass, the support along the diameter could consist of nothing but a cable connecting two sections of the colony, possibly a habitat module and a counterweight consisting of every other part of the colony. It is not yet known if exposure to high gravity for short periods of time is as beneficial to health as continuous exposure to normal gravity. It is also not known how effective low levels of gravity would be to countering the health effects of weightlessness. Artificial gravity at 0.1g would require a radius of only 22 m (74 ft). Likewise at a radius of 10 m about 10 rpm would be required to produce earth gravity (at the hips, gravity would be 11% higher at the feet), or 14 rpm to produce 2g. If brief exposure to high gravity can negate the health effects of weightlessness then a small centrifuge could be used as an exercise area. Based on studies conducted on the effects of artificial gravity on humans in small craft, Vision:2020 will be a large spinning colony.

04.A.b ACCELERATION

The colony could continuously accelerate in a straight line, forcing objects inside the spacecraft in the opposite direction of the direction of acceleration. Most rockets already accelerate at a rate to produce several times earth's gravity, but can only maintain these for several minutes because of a limited supply of fuel. Theoretically a propulsion system with a very high specific impulse and high thrust-to-weight ratio could accelerate, producing useful levels of artificial gravity for long periods of time. In addition, constant acceleration would provide relatively short flight times around the solar system. A colony accelerating (then decelerating) at 1g would reach Mars in 2-5 days, depending on the relative distance. In a number of science fiction plots, acceleration is used to produce artificial gravity for interstellar spacecraft, propelled by as yet theoretical or hypothetical means.

04.A.c MASS

Another way artificial gravity may be achieved is by installing an ultra-high density core into a colony so that it would generate its own gravitational field and pull everything inside towards it. Technically this is not artificial gravity—it is gravity. An extremely large amount of mass would be needed to produce even a tiny amount of gravity.

04 ARTIFICIAL GRAVITY

A large asteroid could produce several thousandths of a G and by attaching a propulsion system of some kind would qualify as a spaceship, though gravity at such a low level might not have any practical value. In addition, the mass would obviously need to move with the spacecraft; if the spacecraft is to be accelerated significantly, this would greatly increase fuel consumption.

04.A.d TIDAL FORCES

In an Earth orbit a small artificial gravity can be obtained from the tidal force, by two spacecrafts above each other (or one spacecraft and another mass), connected by a tether.

04.A.e MAGNETISM

In science fiction artificial gravity (or cancellation of gravity) is sometimes present in spacecraft that are neither rotating nor accelerating. It is not possible with current technology to create artificial gravity of this type, although a similar effect can be created through diamagnetism, but it would involve avoiding any non-diamagnetic materials near the strong magnetic field required for diamagnetism to be evident. It would also require magnets with incredibly powerful magnetic fields. At present such devices have been made that could levitate at most a frog, and thus produce up to 1g; yet requiring a magnet and system that weighs over 1000 kg and is keep superconductive with expensive cryogenics.

04.B GRAVITY CALCULATOR

04.B.a ABOUT THE GRAVITY CALCULATOR

Artificial gravity, as it is usually conceived, is the inertial reaction to the centripetal acceleration that acts on a body in circular motion. Artificial-gravity environments are often characterized in terms of four parameters:

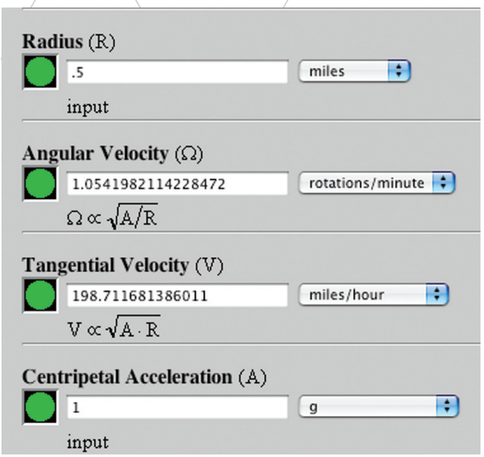
- Radius from the center of rotation.
- Angular Velocity or "spin rate".
- Tangential Velocity or "rim speed".
- Centripetal Acceleration or "gravity level."

These four parameters are interdependent: specifying values for any two of them determines the values of the other two as well.

The artificial gravity calculator, developed by Theodore Hall, Department of Architecture, Chinese University of

Hong Kong, assigns a priority to each parameter. Whenever you input a value, that parameter receives the highest priority. The calculator recomputes the two parameters with the lowest priorities - the two values least recently specified by you. It displays text beneath each parameter to describe how it determined the value.

You can select the measurement unit for each parameter. When you change a parameter's unit, the calculator converts the numeric value while holding the physical quantity constant. If you want to specify a parameter value in a unit other than the current selection, select the unit first, and then input the numeric value.



The calculator displays the formulae as proportions, designated by the symbol. If the angular velocity unit is radians/second, and if the other three parameter units are consistent (all meters and seconds, or all feet and seconds), then the proportion is actually a numeric equality. (You can verify this by selecting consistent units.)

The colored "LED" in front of each parameter indicates how its value compares to the "comfort zone" for artificial gravity, as proposed by several gravity research authors:

- ▼ The value is too high for comfort.
- ▼ The value may be too high for comfort - authors disagree.
- ● The value is in the comfort zone.
- ▲ The value may be too low for comfort - authors disagree.
- ▲ The value is too low for comfort.

04.B.b RADIUS

Because centripetal acceleration - the nominal artificial gravity - is directly proportional to radius, inhabitants will experience a head-to-foot "gravity gradient". To minimize the gradient, maximize the radius.

04.B.c ANGULAR VELOCITY

The cross-coupling of normal head rotations with the habitat rotation can lead to dizziness and motion sickness. To minimize this cross-coupling, minimize the habitat's angular velocity.

Researcher Ashton Graybiel conducted a series of experiments in a 15-foot-diameter "slow rotation room" and observed: In brief, at 1.0 rpm even highly susceptible subjects were symptom-free, or nearly so. At 3.0 rpm subjects experienced symptoms but were not significantly handicapped. At 5.4 rpm, only subjects with low susceptibility performed well and by the second day were almost free from symptoms. At 10 rpm, however, adaptation presented a challenging but interesting problem. Even pilots without a history of air sickness did not fully adapt in a period of twelve days.

04.B.d TANGENTIAL VELOCITY

When people or objects move within a rotating habitat, they're subjected to Coriolis accelerations that distort the apparent gravity. For relative motion in the plane of rotation, the ratio of Coriolis to centripetal acceleration is twice the ratio of the relative velocity to the habitat's tangential velocity. To minimize this ratio, maximize the habitat's tangential velocity.

04.B.e CENTRIPETAL ACCELERATION

The centripetal acceleration must have some minimum value to offer any practical advantage over weightlessness. One common criterion is to provide adequate floor traction. The minimum required to preserve health remains unknown. For reasons of cost as well as comfort, the maximum should generally not exceed 1 g.

05 COLONY SIZE AND CONSTRUCTION

05.A COLONY SPECIFICATIONS

Based on artificial gravity calculations, Vision:2020 statistics are as follows:

Radius of colony = .5 mile

Angular velocity = 1.0541982114228472 rotations per minute

Tangential velocity = 291.44379936614945 feet per second

Centripetal acceleration = 1G

Population = 10,000 souls

05.B CONSTRUCTION

All components of Vision:2020 are privatized endeavors. Specifications for modules are provided to vendors of restaurants, entertainment facilities, office and home module construction, manufacturing and retail modules. All modules are prefabricated at Vision Outpost in L5 Earth orbit, or on Earth and transported by Cargo Shuttle to Vision:2020.

Launching materials from Earth is very expensive, so bulk materials for the colony came from the Moon and Near-Earth Objects (NEOs - asteroids and comets with orbits near Earth) where gravitational forces are much less, there is no atmosphere, and there is no biosphere to damage. Our Moon has large amounts of oxygen, silicon and metals, but little hydrogen, carbon, or nitrogen. NEOs contain substantial amounts of metals, oxygen, hydrogen and carbon. NEOs also contain some nitrogen, but not necessarily enough to avoid major supplies from Earth.

05.C WEAVERS

Robotic spider-like workers (called weavers) were/are used to construct the parabolic sail, colony shell, and other components for Vision:2020 which require exposure to the elements of space weather. Weavers are preprogrammed with construction schematics and instructions. Human involvement is limited to programming and monitoring construction operations. These procedures are accomplished remotely, from Earth, L5 Vision Outpost, clean rooms within the Vision:2020 colony, and/or specially-equipped space planes parked at the colony. All construction is accomplished in L5 orbit, near Vision Outpost.

06 CREW AND CITIZEN TRAINING

Crew and citizens of Vision:2020 are required to spend three months at the L5 Vision Outpost training facilities. During their stay at the outpost, potential Vision:2020 residents undergo complete medical and psychological testing, while becoming acclimated to the rigors of long-term space habitation. Applicants perform EVAs, work in 0G facilities, attend orientation classes and undergo on-the-job training to perform the tasks and assignments awaiting them on-colony. Once applicants pass muster at L5 Vision Outpost, a high-speed shuttle will deliver the new citizens to Vision:2020.

07 MEDICAL CONSIDERATIONS (BIOASTRONAUTICS)

Bioastronautics is the study of the biological and medical effects of space flight on living organisms. Due to the scope of the Vision:2020 multi-part mission, many of our crewmembers and colonists will be exposed to the dangers and concerns of long-term space flight. For this reason, we are dedicated to the research and development of bioastronautics procedures and solutions. The considerations mentioned in Section 7 of this report are not exhaustive. The bioastronautics labs of Vision:2020 look at all aspects of spaceflight.

07.A ACCELERATED BONE LOSS AND FRACTURE RISK

Osteoporosis associated with age-related bone loss may occur at an earlier age due to failure to recover bone lost during space flight.

This risk may be influenced by age, baseline bone mass density (BMD), gender, nutrition, or muscle loss.

Crewmembers lose bone during long-duration space flight, especially in weight bearing bones. Calcium and bone metabolism are altered, and failure to recover lost bone (mission- and age related), can lead to increased risk of fractures at a younger age. Crewmembers IN conventional spacecraft will be affected to varying degrees. Bone loss is not considered a significant problem on a 30-day mission to the Moon. Mars Exploration crews will be affected to varying degrees. Exploration crews to the outer planets and beyond will be greatly affected by bone loss. Although this is a major concern for colonists at the Vision outpost in Earth-orbit, bone loss will not be a significant problem in the Vision:2020 colony, if a centripedal acceleration of approximately 1G is maintained.

Countermeasures:

- Biophysical modalities
- Crew Screening
- Exercise and fitness regimens
- Hormone replacement therapy
- Nutrition
- Pharmacological (including bisphosphonates)
- Rehabilitation strategies
- Spacesuit design
- Artificial gravity

7.B IMPAIRED FRACTURE HEALING

Bone fractures incurred during and immediately after long duration space flight may require a prolonged period for healing, and the bone may be incompletely restored due to changes in bone metabolism associated with space flight.

Space flight associated bone loss may increase the risk of traumatic and stress fractures. Inflight risk of injury should be minimized through design of hardware and procedures. Risks may vary between individuals.

Bone loss associated with space flight may result in additional risk of fracture. Threat to crew health and mission will depend on fracture site, severity and treatment options available. Risk of fracture in the L5 outpost is considered extremely low. In the Vision:2020 colony, there is a risk of serious health or performance consequences may be greater because of lack of return capability to Earth.

Countermeasures:

- Minimize bone loss to lessen fracture risk
- Rehabilitation procedures
- Crew return capability (emergency evacuation shuttle)
- Hardware design and procedures to reduce the likelihood of injury
- Biomechanical and pharmacological measures to promote more rapid healing
- Ultrasound and electrical stimulation
- Minimize bone loss
- Development of treatment options

7.C OCCURRENCE OF SERIOUS CARDIAC DYSRHYTHMIAS

Serious cardiac dysrhythmias may occur due to prolonged exposure to hypogravity or asymptomatic cardiac disease.

Other physiological changes, such as altered neural and hormonal regulation, diminished cardiac mass and cardiac remodeling, and fluid and electrolyte alterations, may affect occurrence of dysrhythmias. Flight duration, gender, and pre-existing cardiovascular disease are also risk factors.

Cardiac rhythm disturbances have been observed on several occasions during space flight but the occurrence of space flight induced arrhythmias has not been documented. Recent flight and ground-based data demonstrate alterations in cardiac electrical activity, which may indicate altered cardiac electrical stability. If space flight increases the risk of serious cardiac dysrhythmias this could lead to syncope and/or death posing risk both to crewmembers and to the mission.

Countermeasures:

- Limited exposure to <1G and >1G environments
- Resuscitation equipment, including onboard defibrillator
- Crew medical screening
- Onboard monitoring
- Electrical cardioversion (Equipment currently on board)
- Nutritional countermeasure
- Pharmaceutical countermeasure
- Pre-flight/in-flight testing/monitoring to assess susceptibility to dysrhythmias

7.D DIMINISHED CARDIAC AND VASCULAR FUNCTION

Diminished cardiac function, orthostatic or postural hypotension, and the impaired ability to perform strenuous tasks on a planetary surface may occur due to prolonged exposure to hypogravity.

This risk may be influenced by altered neural and hormonal regulation, flight duration, or gender.

Some, but not all, studies suggest that prolonged exposure to microgravity may lead to reduction of cardiac mass and reduced cardiac function. Carefully controlled inflight studies are required to document this finding and determine the clinical significance.

Countermeasures

- In flight and in colony exercise
- Limited exposure to <1G and >1G environments
- Drugs that affect cardiac mass and function
- Improved exercise and conditioning program

7.E CONTAMINANTS IN AIR AND WATER

Colony crew and occupants' health and performance may be jeopardized due to the inability to define acceptable limits for contaminants.

This risk may be influenced by remoteness, crew health, or crew susceptibility to degree of system closure.

Excessive pollutant levels (including microbial contaminants) can jeopardize crew health and/or impair mission success. The severity and likelihood of any adverse effects depends on the specific pollutant and its measured concentration.

Countermeasures

- Identification of possible contaminants
- Restriction on types of materials allowed on colony
- Preflight off-gassing of certain materials

7.F IMMUNE DYSFUNCTION, ALLERGIES AND AUTOIMMUNITY

Atopic and autoimmune diseases may occur due to long-term space flight effects on immune-regulatory pathways or on specific immune cells.

This risk may be influenced by radiation, microgravity, isolation, stress (e.g., sleep deprivation, extreme environments, and nutritional deprivation), or crewmember genetics.

In vitro studies have demonstrated that contributing risk factors of space flight collectively have a powerful effect upon the cells of the immune system: T cells, particularly CD4+ (helper) T cells, B cells, NK cells, monocyte/ macrophages/dendritic cells, hematopoietic stem cells and cytokine networks can be negatively affected. Alterations in one or more immune system regulatory network (i.e. cells or cell products) could affect homeostasis, which could result in allergic (atopic) or autoimmune disease. The relatively short time of the lunar mission (10-44 days) would tend to reduce the risk of developing immunodeficiency or atopic disease. The long-term exposure (>1 year) to deep-space radiation, to microgravity (> 2 years), and to other conditions of space flight during long missions would offer the greatest challenge to the host immune system.

Countermeasures

- Assessment of crewmembers for prior autoimmune or atopic disorders.
- Limited exposure to <1G and >1G environments
- Radiation shielding
- Monitor and limit exposure to radiation and other environmental factors
- Definition of surrogate markers of immune function that will allow for the monitoring of immune cells and/ or immune system compartments during a long-duration space flight
- Definition of the background of crewmembers to identify individuals more likely to develop autoimmune or atopic disease
- Detection systems for assessment of immune function

7.G ALTERATIONS IN MICROBES AND HOST INTERACTIONS

Alterations in microbes and host interactions due to exposure to space flight conditions may result in previously innocuous microorganisms endangering the crew and life support systems.

This risk may be influenced by extreme environments, isolation, microbial contamination, microgravity, nutritional deprivation, radiation, sleep deprivation, or stress.

Long-duration space flight may result in alterations in the host/microbe relationship that may lead to a difficult to control, or severe, infection. In particular, the long-duration and severe nature of space flight conditions on a Mars mission might increase the risk. The short-duration of the Lunar mission is not likely to provide sufficient time for significant alterations in the host/microbe relationship.

Countermeasures

- In-flight environmental monitoring and bioburden reduction procedures (cleaning, filtering etc.)
- Comprehensive microbial identification technology
- Pre-flight screening
- Routine in-flight microbial identification/monitoring capability

7.H REDUCED MUSCLE MASS, STRENGTH AND ENDURANCE

Performance of mission related physical activities may be impaired due to loss of muscle mass, strength, and endurance associated with prolonged exposure to hypogravity.

Decreased loading of skeletal muscle during space flight is associated with decreased muscle size, reduced muscle endurance, and loss of muscle strength. The risk may be influence by sensory-motor deficits, contractile protein loss, changes in contractile phenotype, reduced oxidative capacity, bone loss, poor nutrition, or insufficient exercise.

There is a growing database demonstrating that skeletal muscles, particularly postural muscles of the lower limb, undergo atrophy and undergo structural and metabolic alterations during space flight. These alterations, if unabated, may affect performance of mission tasks. Exercise countermeasures do not fully protect muscle integrity.

Countermeasures

- Limited exposure to <1G and >1G environments
- Cycle ergometer
- Moderate resistance exercise
- Treadmill
- New programs of heavy resistance exercise (e.g., expanded exercise and loading capabilities) and/or bio physical interventions
- Pharmacological interventions
- Biophysical interventions
- New/improved programs of endurance exercise
- Nutritional interventions

7.1 IMPAIRED SENSORY-MOTOR CAPABILITY TO PERFORM OPERATIONAL TASKS

Operational performance may be impaired by spatial disorientation, perceptual illusions, and/or disequilibrium which may occur during and after g-transitions due to maladaptation of the sensory-motor systems to the new gravito-inertial environment.

This risk may be exacerbated by vehicle/habitat designs that do not maintain consistent architectural frames of reference or those presenting ambiguous visual orientation cues. It may also be exacerbated by low visibility situations (smoke, landing weather, poor lighting), environmental vibration, or unstable support surfaces (floors, seats).

Transitions between gravitational and dynamic acceleration environments are associated with sensory-motor adaptation mechanisms and potential adverse sensory conflict reactions. These may be problematic during periods requiring crew control of vehicles or other complex systems. These mechanisms and reactions are expressed with a high degree of individual variability due to crew training, crew experience, and other factors not well understood. Crew performance of routine and critical actions during launch, landing, and the periods immediately following these events may be compromised.

Countermeasures

- Limited exposure to <1G and >1G environments
- Heads Up Display
- Education and Training
- Vehicle architecture and layout to establish a sense of artificial vertical for individual modules (luminous exit placards to mark emergency egress paths, rack orientation and module layout, surface labels)
- Preflight education and training in module simulators
- EVA training in neutral buoyancy chambers
- Virtual reality techniques
- Auto-land and launch capability on planetary landing and return vehicles
- Determine efficacy of re-adaptation head movements during entry
- Improved standards for workstation and spacecraft interior architecture
- Improved teleoperator displays
- Pre-flight or in-flight g-specific pre-adaptation techniques
- Pre-flight visual orientation training for IVA activities using VR techniques
- Preflight training, including high fidelity simulators
- Spatial ability tests should be developed and validated to predict and improve individual performance
- Evaluate in-flight maneuvering rehearsal simulators

7.J MOTION SICKNESS

Crew work capacity, vigilance, and motivation may be impaired by motion sickness symptoms occurring during and after g transitions.

This risk is influenced by individual susceptibilities, spacecraft size and room available for movement. It does not appear to be correlated with susceptibility to terrestrial motion sickness. Symptoms are repeatable but often attenuated from flight to flight.

Space motion sickness (SMS) is a common component of human space flight. For Shuttle crews, 70% experience symptoms for the first 2-4 days in 0-g, with emesis occurring in 10-20%, and many experience similar symptoms for hours to days after landing. Several crewmembers have remained symptomatic during flight for up to two weeks. Current anti-motion sickness treatment with IM Promethazine is highly effective and allows nominal space flight operations in spite of the high incidence of SMS. However, this drug has potentially significant side effects that may further complicate acute adaptation to space flight and prevent regular prophylactic use. Readaptation motion sickness may occur during entry and landing, prompting similar symptoms and possible impairment. In both situations, head movements, which may be required for normal operations, may be provocative.

Countermeasures

- Limited exposure to <1G and >1G environments
- Oral Promethazine/Ephedrine
- Oral Scopolamine/Dexedrine (rare)
- IM Promethazine
- Head and body movement restriction, heads-up-display (HUD) for maneuvering
- New administration methods of medicines for rapid, reliable relief with fewer side effects
- Techniques to quantify cognitive deficits as a side effect of medication
- Technique for providing a form of stroboscopic vision to reduce incidence of motion sickness

7.K INADEQUATE NUTRITION

Maintenance of crew and colonist’s health depends on a food system that provides all of the required nutrients.

Nutritional requirements for space include fluids, macronutrients, micronutrients and other elements required to optimize health status. Requirements must take into account any changes in the sensory system that might influence taste, smell, intake, and the role that countermeasure- and space flight factor-induced alterations may have on nutrient requirements. This risk may be influenced by psychosocial factors, elevated stress and boredom, or compliance with diet.

Nutritional deficiencies may lead to an increased health risk as the duration of space flight increases. Inadequate micronutrient or vitamin intake could adversely affect crew health. Furthermore, adequate nutrition may play a role in counteracting the negative effects of space flight (e.g., radiation, immune deficits, and bone and muscle loss). While all long duration crewmembers have lost body mass, the cause of weight loss is not yet fully understood. For long-term missions, such as Vision:2020, there are additional challenges to provide a variety of fresh, palatable, and nutritious foods.

Countermeasures

- Provision of adequate diet through use of proper food system and vitamin supplements
- Improved dietary compliance and counseling
- Enhanced food system
- Diet and nutritional supplementation that ensures and/or enhances the effectiveness of other countermeasures
- Refined nutritional requirements
- Understanding and implementing an acceptable food system

7.L MAJOR ILLNESS AND TRAUMA

Lack of capability to treat major illness and injuries increases the risk to crew health and mission.

Risk of trauma will vary according to mission activities and risk of illness will increase with mission duration. Equipment and activities are designed to minimize risk of injury.

For the Vision Outpost in Earth orbit, the risk for major trauma is considered low. For Vision:2020 missions, there is a significant risk of trauma associated with EVA. There is a risk for development of major illness.

Countermeasures

- Return to Earth for definitive care
- Establish on-board emergency medical facilities

- On-board treatment capability (ventilator, IV fluids, medications, etc.)
- Preventive measures
- Autonomous capabilities for monitoring and treatment of identified conditions, because quick return is not an option for long-term missions

7.M AMBULATORY CARE

Impaired performance and increased risk to crew health and mission may occur due to lack of capability to diagnose and treat minor illnesses.

Risks may vary depending on mission activities.

Minor illnesses and injuries have been documented during space flight. Capability to diagnose and treat minor medical conditions will ensure crew health remains good and the mission is not impacted.

Countermeasures

- Crew Screening
- Crew training to recognize and treat medical conditions
- Design of equipment and procedures to reduce the likelihood of injury
- Medical kits with capability to diagnose and treat minor illnesses and injuries
- Extensive telemedicine capability
- Real-time ground communication with medical experts
- On board autonomous medical diagnostic and therapeutic aids
- Establish on-baord emergency ambulatory and surgical facilities

7.N MONITOR AIR QUALITY

Lack of timely chemical and microbial detection in the crew atmosphere, or elsewhere in the air processing system, can lead to delayed response by the crew or by automated response equipment, leading to increased hazards to the crew.

Chemical and microbial detection in the crew atmosphere, or elsewhere in the air processing system, can indicate the buildup of microbial contaminants, hazardous chemicals, pre-combustion reaction products, malfunction of life support equipment, or other hazardous events such as accidental release from an experiment. This risk may be influenced by accidental events such as fire or leak, or a malfunction in the life support system, which may be gradual or sudden.

Technologies must be able to detect both anticipated and unanticipated events and identify the problem source. Gradual buildup of toxic chemicals may take months, calling for highly sensitive detection at slow intervals, perhaps daily. Leakage or pre-combustion events are expected to occur more rapidly, requiring more rapid detection (minutes), though less sensitive detection may be necessary. Existing technology is critical resource intensive and requires substantial improvement in efficiency, reliability, and functionality. For example, no single technology currently can address all Spacecraft Maximum Allowable Concentration (SMAC) chemicals, combustion in micro gravity is very different from combustion on Earth and has different pre-combustion indicators, and harmful foreign matter may be inadvertently brought in following extravehicular activity (EVA). The same monitoring technology may be useful for helping diagnose crew health by providing breath-monitoring data.

Countermeasures

- Compound Specific Combustion Product Analyzer
- Crew indicators such as reports of odor, nausea
- Ground analysis of returned samples from planetary missions
- Major Constituent Analyzer
- Volatile Organic Analyzer
- Materials selection for on-colony construction
- Scheduled maintenance and housekeeping
- Network of rapid, small detectors throughout the colony and the outpost
- Highly sensitive analyzer suite

7.O MONITOR WATER QUALITY

Lack of timely information about the build-up of chemicals or microbial growth in the crew water supply, or elsewhere in the water reclamation system, can lead to a delayed response by the crew, or the automated response equipment, and pose a hazard to the crew.

This risk may be influenced by an accidental event such as a leak of ammonia from the cooling system into the water supply through the heat exchanger, or a malfunction in the life support system, which may be gradual or sudden.

Gradual buildup of toxic chemicals may take months, calling for highly sensitive detection at slow intervals, perhaps daily. Leakage events are expected to occur more rapidly, requiring more rapid detection (minutes), though less sensitive detection may be necessary. Technologies must be able to detect both anticipated and unanticipated events and phenomena. Localized information is needed to identify the problem source. Existing technology for ground-based measurement is massive, power hungry, needs hazardous reagents, requires significant crew skill and time and is sensitive to micro, lunar, or Martian gravity multiphase issues.

Countermeasures

- Crew report of odor or taste
- Ground analysis of returned samples from planetary missions
- Manual plate culturing at ambient temperature with visual estimate
- Water conductivity measurement
- Total Organic Carbon Analyzer
- Compact online chemical water analyzer suite
- Microbial analysis instrument

7.P MAINTAIN FOOD QUANTITY AND QUALITY

Crew nutritional requirements may not be met and crew health and performance compromised due to inadequate food acceptability, preparation, processing, and storage systems.

This risk may be influenced by sub-standard food intakes, chemical or microbial contamination of food, crew psychological and physiological changes, elevated stress and boredom, inadequate food packaging, inadequate food processing/preservation, inadequate quantity of food, inadequate shelf life, inadequate storage conditions and environmental control, inadequate variety, product formulation, or undefined nutritional requirements.

There must be means to provide the crew a sufficient, balanced, nutritious diet.

Countermeasures

- Establish hydroponic gardens for natural food production
- Establish tree groves for natural fruit production
- Hazard analysis critical control point processing
- Increased menu cycle and menu variety
- Menu developed based on daily nutritional requirements
- Preflight food tasting and selection
- Vitamin and nutrient supplementation
- Assessment of food psychosocial importance
- Determine effects of space radiation on food
- Development of extended shelf life food through improved food preservation technologies
- Enhanced food system with increased variety and acceptability
- Hazard analysis critical control point processing
- High barrier and low mass food packaging materials
- Refined nutritional requirements

7.Q MAINTAIN ACCEPTABLE ATMOSPHERE

Crew health may be compromised due to inability of currently available technology to monitor and control spacecraft atmosphere. Risk may be mitigated by development of new technologies that will be integrated into the life support systems.

This risk may be influenced by complexity of systems and increase in the number of systems (e.g., additional solid waste processing, plant growth, food processing, etc.), insensitivity of control system to contaminants leading to toxic build-ups due to a closed system, remoteness, or severely constrained resources (such as mass, power, volume, thermal, crew time).

The inability to control and condition the atmosphere and maintain the makeup & composition, limits the ability of the crew to perform basic functions and can present an immediate threat to the health, life and success of crew and mission.

Countermeasures

- Consumables re-supply

- Technology development to further close the air loop and increase carbon dioxide reduction, which includes testing, modeling and analysis
- Bioregenerative Life Support
- CO2 Moisture Removal System
- Improved Carbon Dioxide Removal and Reduction System
- In-Situ Resource Utilization
- Regenerable Trace Contaminant Control System
- Better models to identify contaminant load

7.R MAINTAIN THERMAL BALANCE IN HABITABLE AREAS

Crew health may be compromised due to inability of currently available technology to provide colony and outpost thermal control. Risk may be further mitigated by development of new technologies that will be integrated into the thermal control system.

This risk may be influenced by location of colony in space, orientation of the colony during flight, sources of heat for the colony and outpost, and use or availability of local planetary resources.

Humans cannot live and work in space without a thermally controlled environment.

Countermeasures

- Thermal Control system
- Improve the reliability and life, or decrease the mass, volume, or power required for thermal control system hardware (e.g. heat rejection devices, heat transport fluids, heat acquisition devices, heat transfer devices)

7.S MANAGE WASTE

Crew health may be compromised due to inability of currently available technology to adequately process solid wastes reliably with minimum power, mass, volume. Inadequate waste management can also lead to contamination of planetary missions.

This risk may be influenced by crew health, crew susceptibility to the degree of system closure, mission duration, the microgravity environment, failure of other systems such as diminished or failed power supply, or remoteness.

Inadequate waste management can result in crew health and safety concerns, including reduced performance and sickness. Inadequate waste management can also lead to contamination of planetary surfaces, or significant increases in mission costs in terms of system mass, power, volume and consumables.

Countermeasures

- Adsorbents are used for odor control
- Crew manually compacts waste and/or stores waste in bags
- Feces is mechanically compacted
- Waste is returned to Earth in expendable logistics modules to be destroyed on entry into the Earth's atmosphere
- Provide a system for adequately collecting waste
- Provide a system for adequately transporting waste
- Provide a system for processing waste for storage , resource recovery or disposal of trash generated (including clothing) throughout the mission, reliably and efficiently with minimum power, mass and volume.

7.T PROVIDE AND MAINTAIN BIOREGENERATIVE LIFE SUPPORT SYSTEMS

Sustaining crew health and performance may be compromised by lack of bioregenerative systems.

This risk may be influenced by the effect of radiation on plants, reduced atmospheric pressure, reduced sunlight, limited availability of water, limits on power availability for artificial lighting, reduced gravity, or remoteness.

Very high life support resupply costs would be necessary for a long-term Vision:2020 missions without bioregenerative systems. Bioregenerative systems would be the only means of producing food and a primary contributor for CO2 removal, O2 production, and H2O purification and achieving high degree of autonomy.

Countermeasures

- Development of Vegetable Production Units
- Screen acceptable cultivars for space systems
- Fresh Earth-grown fruit and vegetables included on current re-supply missions to Vision and the Outpost

- Integrated Bioregenerative / PC test bed
- Low pressure greenhouses and hydroponic hanging gardens
- Mixed cropping systems for continuous production evaluated
- Provide Vegetable Production Unit
- Scale system to meet all O2 and CO2 requirements for surface habitat, and to meet partial food requirements
- Scale gravity-based salad production module to meet all water and O2 requirements for surface missions, and to meet food requirements

7.U PROVIDE AND RECOVER POTABLE WATER

Crew health may be compromised due to inability of currently available technology to adequately provide and recover potable water.

This risk may be influenced by crew health, crew susceptibility to the degree of system closure, or remoteness.

Lack of potable water is a health risk. The lack of immediate re-supply and increased reliance on water recovery systems compounds the risk.

Countermeasures

- Stored potable water onboard colony and outpost
- Water recovery system performance monitored
- Re-supply of potable water from Earth
- Biological systems
- Possibility of in-situ resource utilization
- Redundant systems

08 FOOD CONSIDERATIONS (CONSUMPTION AND PRODUCTION)

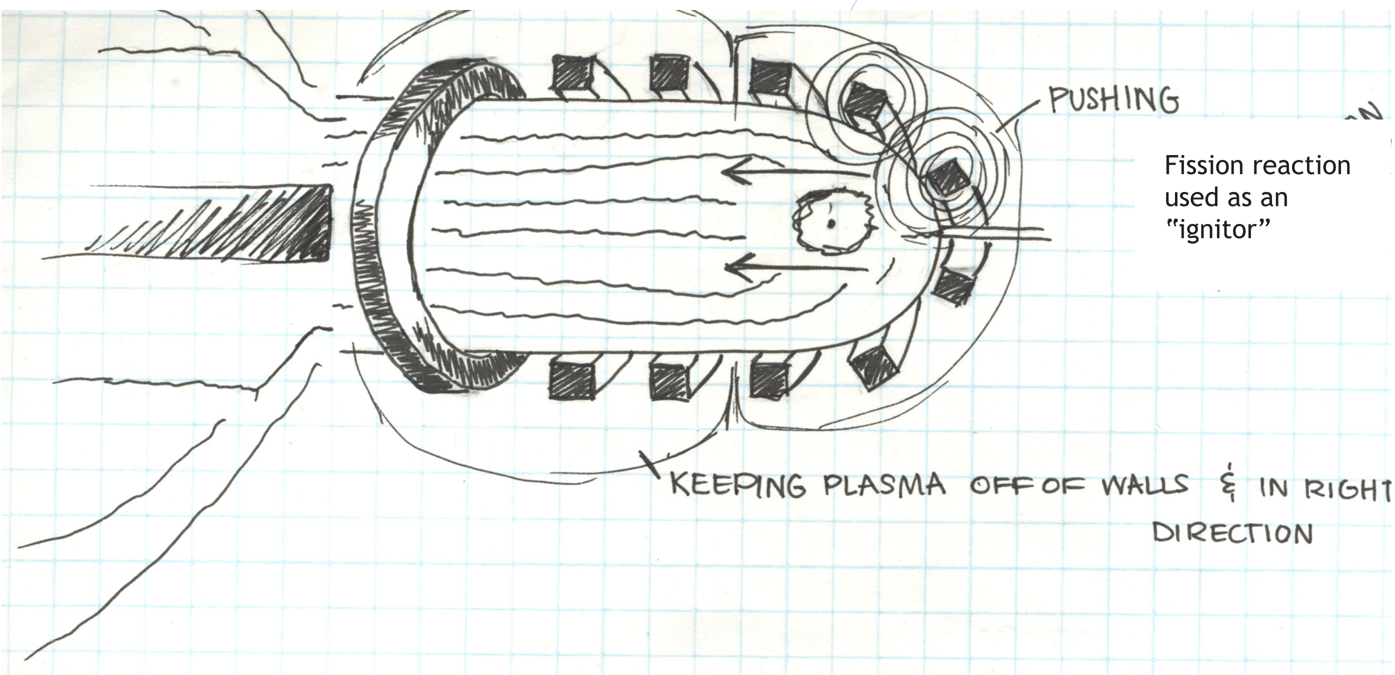
Efficient food consumption is vital to the welfare of Vision:2020 crew and colonists, and to the precise production, processing, and storing of food in the colony. To ensure that residents maintain a well-balanced, healthy diet, personal health of each resident is monitored daily. Based on vital signs, biorhythms, metabolic, physical and mental markers of each resident, personal diets and menus are provided via each individual's Personal Communication Device (PCD). A variety of menu selections are provided, based on the preferences provided by the individual. Once menu selections for the day have been entered into the PCD, prepackaged and fresh foods are delivered to housing modules via the Vision:2020 conveyor delivery system.

09 TRAVEL CONSIDERATIONS (TIMELINES AND CALCULATIONS)

Vision:2020 is considered to be a generation ship, which means that there are no limits set on where and when the colony may travel. The colony will span generations of human occupancy. Crew members and colonists who begin their new life on-colony, may very well marry, have children and grandchildren on-colony. One concern of a generation ship is that the humans onboard might loose sight of their goals over time. People remaining on Earth might loose interest in the mission of Vision:2020. For this reason, constant contact with Earth is maintained. Video transmissions are aired daily on Earth, keeping the people of Earth informed on the progress of Vision:2020. Video transmissions from Earth are displayed at regular intervals throughout the day, every day, on Vision:2020, providing the colonists with a cultural connection to Earth. A 24-hour day, 365-day year system of timekeeping is maintained on Vision:2020 to provide another link to Earth.

10.A FUSION REACTOR ENGINE

The Vision:2020 fusion reactor engine is actually a hybrid engine, combining fission and fusion. The main advantage of fusion is the very high specific impulse. A fusion rocket also produces less radiation than a fission rocket, reducing the mass needed for shielding. For the Vision:2020 propulsion system, a fission reaction is utilized as an ignitor for the deuterium fuel. Once the deuterium reaction has been established, those particles are accelerated into the combustion chamber, where a miracle occurs. The resulting plasma is pushed out of the engine by magnetic fields created by magnetic rings surrounding the chamber. These magnetic rings serve a dual purpose. They keep the plasma away from the chamber walls, while pushing the plasma toward the exhaust tube. The force exerted by the magnets propels plasma away from the engine. More miracles . . . the colony moves forward. Forward = the desired direction of travel.

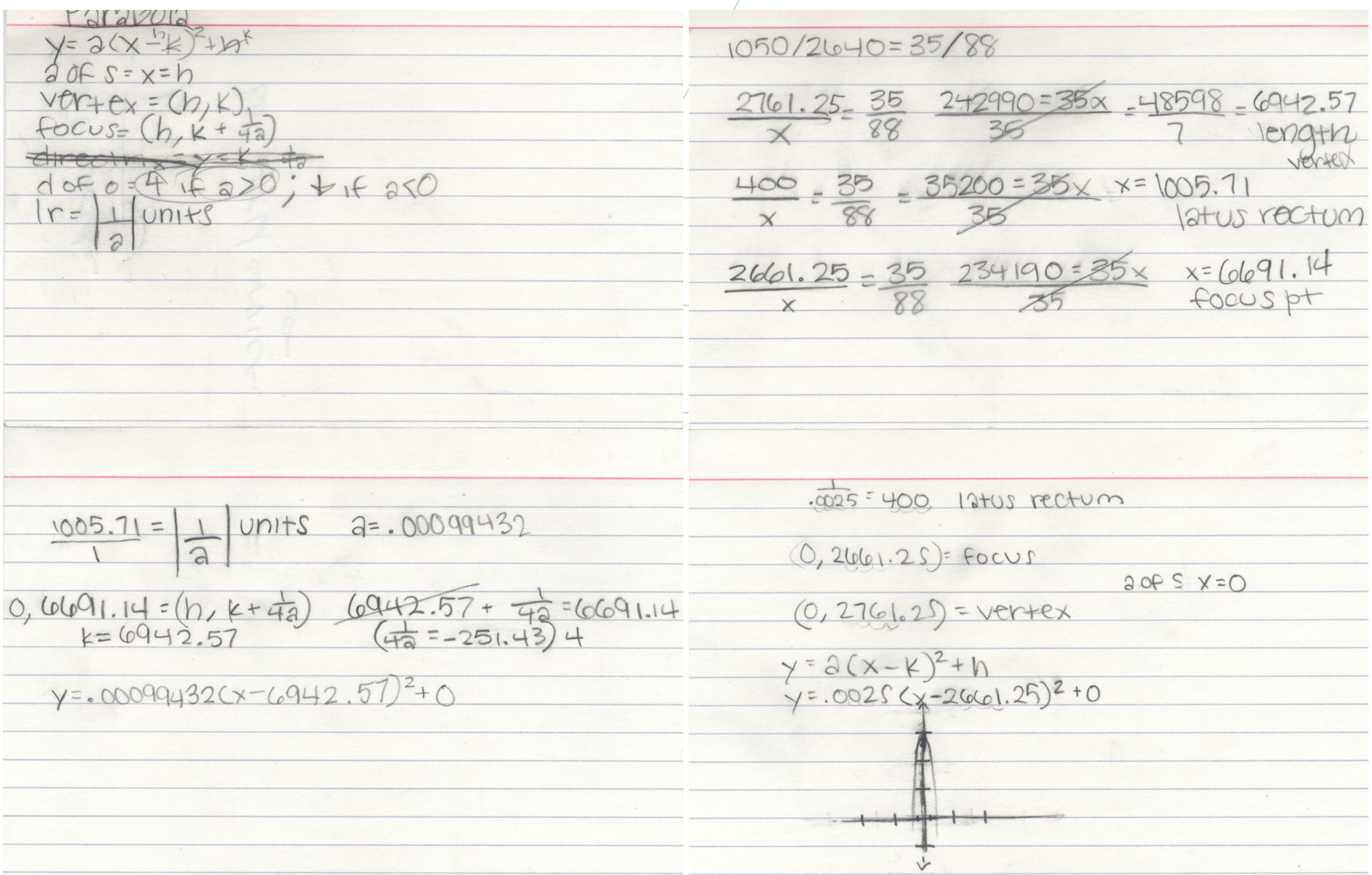


10.A.a MAGNETIC FUSION ENERGY

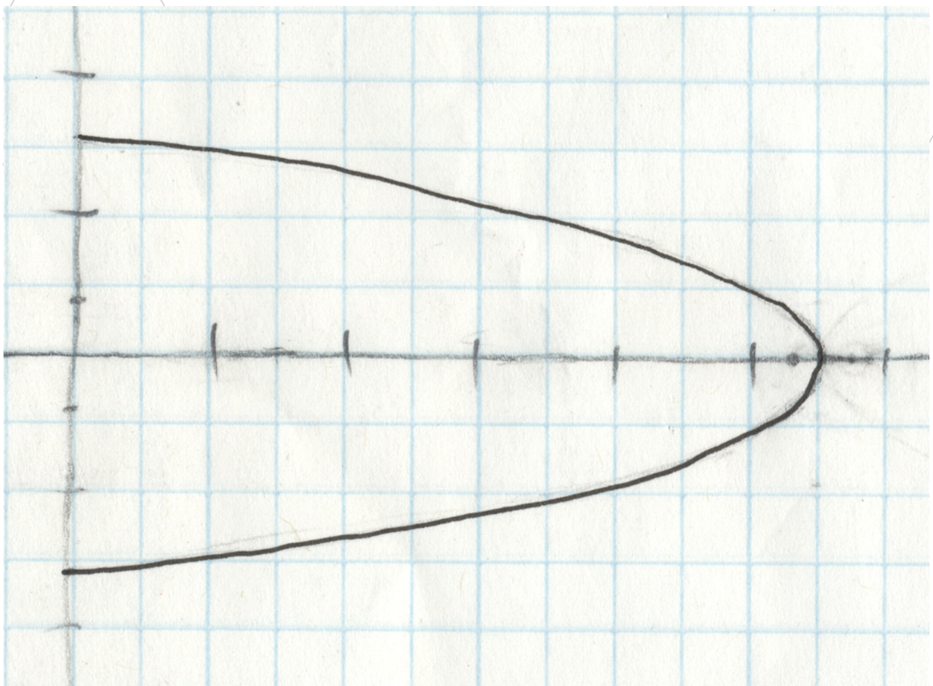
The magnetic fusion energy (MFE) program seeks to establish the conditions to sustain a nuclear fusion reaction in a plasma that is contained by magnetic fields to allow the successful production of fusion power. Progress in the past decade has been remarkable – both in the significant progress toward a "burning" plasma and in the advance of scientific understanding. Scientists continue to study the fusion power of Vision:2020 and the behavior of fusion products (alpha particles) in burning plasmas. Underlying this progress are strides in fundamental understanding, which have led to the ability to control aspects of plasma behavior. For example, scientists can now exercise a measure of control over plasma turbulence and resultant energy leakage, long considered an unavoidable and intractable feature of plasmas; the plasma pressure above which the plasma disassembles can now be made large enough to sustain a fusion reaction rate acceptable for a power plant. Electromagnetic waves are injected and steered to manipulate the paths of plasma particles and then to produce the large electrical currents necessary to produce the magnetic fields to confine the plasma. These and other control capabilities have flowed from advances in basic understanding of plasma science in such areas as plasma turbulence, plasma macroscopic stability, and plasma wave propagation.

10.B LASER SAIL

Laser sail technology was chosen as a source of energy for the colony as well as a source of propulsion. The laser light source for the sail system emanates from the colony itself. There is no need for a laser light source at both ends of the colony. The Vision:2020 laser is a completely self-sustainable beam able to rotate anywhere within the



sail to turn and steer the colony. The colony is propelled forward with no more than the pressure of light, with the potential of reaching one tenth the speed of light. The colony rides at the front of high-powered laser beams. Energy for the sail is collected from the focus point as well as from outside sources. Light collectors absorb light energy from solar panels and mirror devices deployed at various intervals along the Vision:2020 planetary highway to supplement laser sail light sources.



Based on the original engineering notes from Vision:2020 (as seen on page 39 of this report), the colony laser sail is 5280 feet in diameter, is 6942.57 feet in length (vertex), and the focus point is located 6691.14 feet from the rim of the sail.

The Vision:2020 cone-shaped laser sail is constructed of carbon nanotube fibers linked into a crisscross matrix that is mostly empty space, extremely light and relatively thick, with the ability to withstand temperatures much hotter than traditional sails (2500º C). Carbon nanotube construction was chosen because the fibers are somewhat rigid, can be folded and compressed, but the material pops back to it's original shape quickly. The sail is designed as essentially two cones joined at the rims. One carbon nanotube fiber cone with a highly reflective coating on the inside, and a second, clear cone capable of allowing laser light to pass through unimpeded.

10.C FUEL CELLS AND ELECTROMAGNETS

Utilities, manufacturing facilities, entertainment facilities, and transport systems are powered by fuel cells. A fuel cell converts the chemicals hydrogen and oxygen into water, and in the process it produces electricity. Vision:2020 uses proton exchange membrane fuel cells. The proton exchange membrane fuel cell (PEMFC) uses one of the simplest reactions of any fuel cell. There are four basic elements of a PEMFC:

- The anode, the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst.
- The cathode, the positive post of the fuel cell, has channels etched into it that distribute the oxygen to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.
- The electrolyte is the proton exchange membrane. This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons.
- The catalyst is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum powder very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

Chemistry of a Fuel Cell

Anode side: $2H_2 \Rightarrow 4H^+ + 4e^-$

Cathode side: $O_2 + 4H^+ + 4e^- \Rightarrow 2H_2O$

Net reaction: $2H_2 + O_2 \Rightarrow 2H_2O$

Pressurized hydrogen gas (H_2) entering the fuel cell on the anode side. This gas is forced through the catalyst by the pressure. When an H_2 molecule comes in contact with the platinum on the catalyst, it splits into two H^+ ions and two electrons (e^-). The electrons are conducted through the anode, where they make their way through the external circuit (doing useful work such as turning a motor) and return to the cathode side of the fuel cell.

Meanwhile, on the cathode side of the fuel cell, oxygen gas (O_2) is being forced through the catalyst, where it forms two oxygen atoms. Each of these atoms has a strong negative charge. This negative charge attracts the two H^+ ions through the membrane, where they combine with an oxygen atom and two of the electrons from the external circuit to form a water molecule (H_2O).

This reaction in a single fuel cell produces only about 0.7 volts. To get this voltage up to a reasonable level, many separate fuel cells must be combined to form a fuel-cell stack.

PEMFCs operate at a fairly low temperature (about 176 degrees Fahrenheit, 80 degrees Celsius), which means they warm up quickly and don't require expensive containment structures.

Electrically charged magnets are used to start the colony spinning and to keep it spinning. A combination of power harvested from the fusion engine, solar sail, and fuel cells are used to charge the magnets.

10.C.a FUEL CELL EFFICIENCY

A fuel cell typically converts the chemical energy of its fuel into electricity with an efficiency of about 50%. The efficiency is however very dependent on the current through the fuel cell: the more current drawn, the lower the efficiency. For a hydrogen cell the efficiency (actual power / theoretical power) is equal to cell voltage divided by 1.23 volts. A cell running at 0.6V has an efficiency of about 50%, meaning that 50% of the energy content of the hydrogen is converted into electrical energy.

In "combined heat and power" applications (such as Vision:2020), a fuel cell is placed in a location where heat is also needed. A lower fuel-to-electricity conversion efficiency is tolerated (typically 15-20%), because most of the energy not converted into electricity is utilized as heat. Some heat is lost with the exhaust gas just as in a normal furnace, so the combined heat and power efficiency is still lower than 100%, typically around 80%. In terms of energy however, the process is inefficient, and one could do better by maximizing the electricity generated and then using the electricity to drive a heat pump.

11 INSIDE THE COLONY

11.A MANUFACTURING (ROBOTIC WORKERS)

Manufacturing and processing facilities are located below the floor areas of the three tori of Vision:2020. In general, these areas are unpressurized, unimproved areas, with no life-support. Robotic workers accomplish most of the work in these facilities. Colonists who work in these areas are required to wear EVA suits and life-support packs. Food processing facilities and water recycling and purification units are located in these areas as well.

11.B RESEARCH

Research and development of space technologies, biomedical and engineering experiments, new product development, propulsion systems, synthetic foods, micro-encapsulated fabrics, computer technology, and space hazard labs are located on Level 1 and the inner core of the colony. 0G experimentation is confined to the inner core.

11.C MEDICAL

Medical labs and research are taking place on colony in the following areas: (A) Accelerated bone loss and fracture risk; (B) Impaired fracture healing; (C) Occurrence of serious cardiac dysrhythmias; (D) Diminished cardiac and vascular functions; (E) Contaminants in air and water; (F) Immune dysfunction, allergies and autoimmunity; (G) Alterations in microbes and host interactions; (H) Reduced muscular mass, strength and endurance; (I) Impaired sensory-motor capabilities to perform operational tasks; (J) Motion sickness; (K) Inadequate nutrition; (L) Major illness and trauma; (M) Ambulatory care; (N) Monitor air quality; (O) Monitor water quality; (P) Maintain food quantity and quality; (Q) Maintain acceptable atmosphere; (R) Maintain thermal balance in habitable areas; (S) Manage waste; and (T) Provide and maintain bioregenerative life support systems.

11.D FOOD PRODUCTION

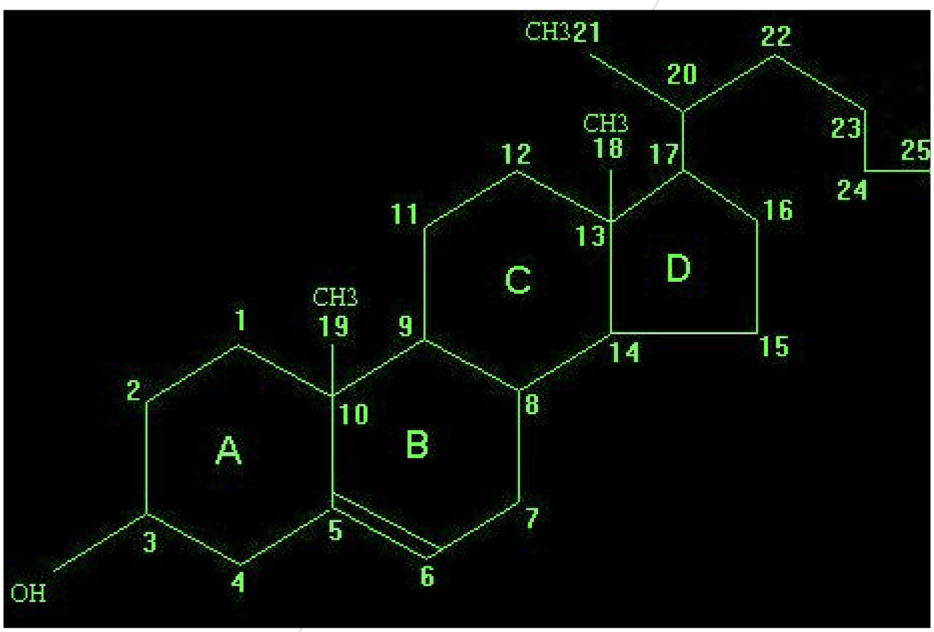
11.D.a. Fresh fruit and vegetables

Fresh fruit and vegetables are grown in three areas of the colony: (01) in the housing modules; (02) in aeroponic gardens located in low-gravity areas and under-developed sectons of the colony (produce is planted and harvested by robotic workers in these areas); and (03) in terraces and groves located on the promenade level of the colony. Trees grown in the promenade groves are nurtured in a low-density, high nutrient-rich soil maintained by human workers. The trees add to the ambience of the park-like setting of the promenade.

Aeroponic gardens allow the growth of plants in an air/mist environment without the use of soil or an aggregate media. Plant roots are in an environment saturated with a mist of fine drops of nutrient solution. Plants are grown with their roots suspended in a deep growth chamber, where the roots are periodically sprayed with a fine mist of nutrients. This high performance food production technology rapidly grows crops using 99% less water and 50% less nutrients in 45% less time than conventional farming methods. The Aeroponic system is used to produce a variety of food crops that can be planted and harvested year around without interruption. It is also applied to bio-pharming, pharmaceuticals and nutraceuticals.

11.D.b. Processed and synthetic foods

Approximately ten percent of the labs onboard Vision:2020 are dedicated to the research, development and production of synthetic foods. The production of synthetic foods has been so successful that one of the three daily scheduled meals on-colony consists of food pills and drinks, constructed of purified chemical compounds. Purified chemical compounds could be used to create the entire diet for colonists, but that would deprive our citizens of the "joy" of eating. Sitting down to dine at a nice restaurant with friends, or cooking a meal at home for the family are activities that sooth the soul and satisfy one's appetite. Many of the synthetic foods produced on-colony are constructed to resemble and taste like familiar foods (i.e., pancakes, pizza, scrambled eggs and bacon, etc.). Synthetic foods have been incorporated into the diets of Vision:2020 colonists, without sacrificing the aesthetics of dining. In the event of a catastrophic event on-board the colony, or in the event of reduced fresh food production, a one-year supply of purified chemical compound foods are stored in the 0G storage facilities of Vision :2020.



The composition of an artificial diet constructed entirely of purified chemical compounds might look like this:

Amino-acids:

l-Lysine·HCL (3.58 g)	Sodium L-aspartate (6.40 g)	l-Leucine (3.83 g)
l-Threonine (2.42 g)	l-Isoleucine (2.42 g)	l-Proline (10.33 g)
l-Valine (2.67 g)	Glycine (1.67 g)	l-Phenylalanine (1.75 g)
l-Serine (5.33 g)	l-Arginine·HCL (2.58 g)	l-Tyrosine ethyl ester·HCL (6.83 g)
l-Histidine·HCL·H20 (1.58 g)	l-Tryptophan (0.75 g)	l-Methionine (1.75 g)
l-Glutamine (9.07 g)	l-Alanine (2.58 g)	l-Cysteine ethyl ester·HCL (0.92 g)

Water-soluble vitamins:

Thiamine.HCL (1.00 mg)	d-Biotin (0.83 mg)	Riboflavin (1.50 mg)
Folic acid (1.67 mg)	Pyridoxine.HCL (1.67 mg)	Ascorbic acid (62.50 mg)
Niacinamide (10.00 mg)	Cyanocobalamin (1.67 mg)	Inositol (0.83 mg)
Choline bitartrate (231.25 mg)	p-Aminobenzoic acid (416.56 mg)	d-Calcium pantothenate (8.33 mg)

Salts:

Potassium iodide (0.25 mg)	Potassium hydroxide (0.83 g)	Manganous acetate (18.30 mg)
Magnesium oxide (0.38 g)	Zinc benzoate (2.82 mg)	Sodium chloride (4.77 g)
Cupric acetate (2.50 mg)	Ferrous gluconate (0.83 g)	Sodium glycerophosphate (1.67 mg)
Calcium Chloride·2H2O (2.44 g)	Ammonium molybdate·4H2O (5.23 g)	Sodium benzoate (1.00 g)

Carbohydrates:

Glucose (555.0 g)	Glucono-lactone (17.2 g)	

Fats and fat-soluble vitamins

Ethyl linoeate (2.0 g)	Tocopherol acetate (57.29 mg)	Vitamin A (3.64 mg)
Menadione (4.58 mg)	Vitamin D (0.057 mg)	

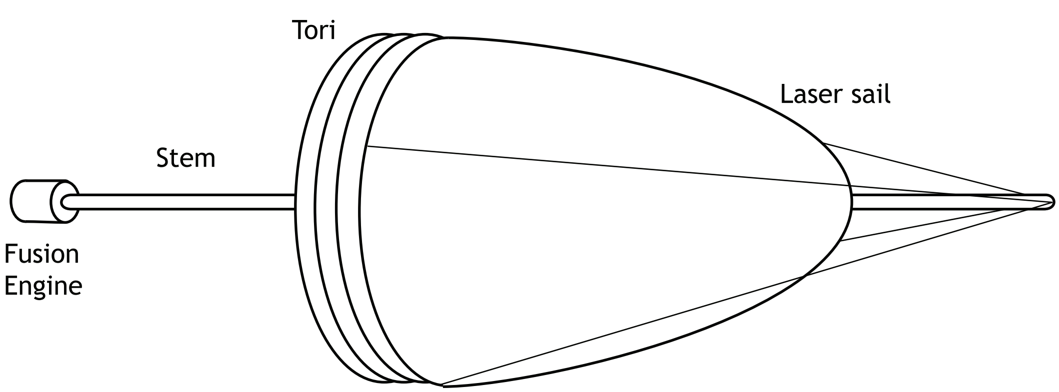
11.E QUALITY OF LIFE

Every care has been taken to ensure that the quality of life of colonists is high. Comfort, security and well-being are top priorities. Colonists wear health monitors embedded in their garments which can be accessed through their personal communication devices. Suggested diets and menus are emailed to colonists each night for the following day. Personal hygeine is another priority. Colonists' garments are made of carbon nanotube fabrics which are totally resistant to dirt and odors. Garments can be refreshed without the use of precious water. Biological enzymes and chemical processes remove any foreign matter that may have attached to the garments. Showers and toiletry water use is also controlled. Showers are timed according to the colonist's parameters and needs.

11.E.a HOUSING MODULES

The housing module shells are pre-fabricated on Earth and transported by cargo ship to the L5 Outpost where they are stored until needed by the colony. During the construction phase of Vision:2020, housing and office module shells were installed in the colony. Walls between modules are locked into place, but can be retracted if more than one module is required by the occupants. For example, if the population of a family increases, more space must be allocated to that family. Each colony resident is allocated 400 square feet of living space. A family of four would require 1600 square feet of living space. Colony residents can choose from a variety of interior options. Décor can range from Victorian to ultra-modern. Color options are available through OLED programming. All utilities are pre-installed in housing/office modules. The Vision:2020 colony was designed to take advantage of modular planning. As modules are lowered into the torus, they plug into the central utility lines much like plugging an appliance into a wall socket. Each module "plug" automatically activates power, communication, and plumbing lines. Furnishings and appliances for housing modules can be customized to match the aesthetic tastes of the occupants. An online catalog of choices is available for preorder prior to colonists' arrival on colony. Each housing unit is equipped with aeroponic garden boxes which help provide fresh fruits, vegetables and herbs.

Vision:2020

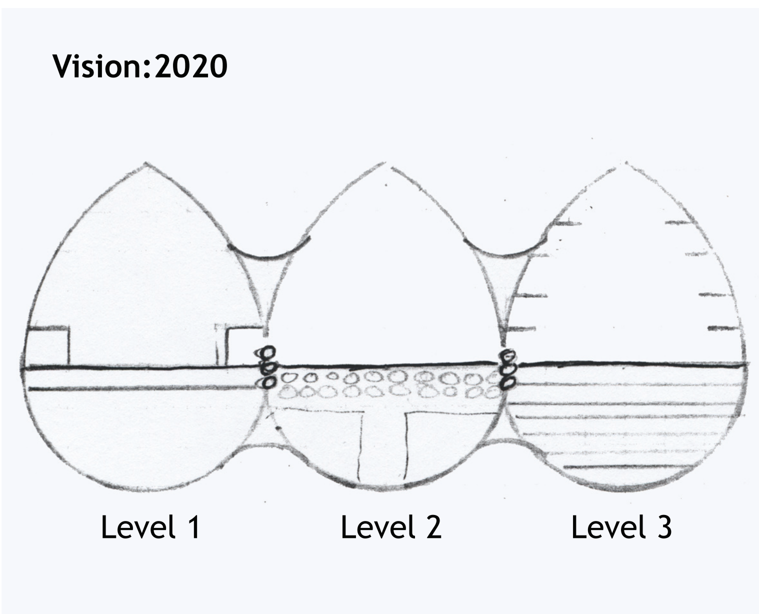


11.E.b TORI

The main focus of Vision:2020 lies in the tori (three inter-connected torus sections). Each one of the tori is a level of the colony. The three levels are connected by chambers which can be depressurized or sealed if needed. Connecting chambers are located approximately 200 yards apart, along the entire circumference of the tori. The torus shells were constructed in Earth orbit at the L5 Vision Outpost by human EVA workers, robotic worker and weaver robots. The outer shell of Vision:2020 is constructed of carbon nanotube fabrics. Beneath the floor of each torus contains a network of tracks on which remotely controlled movers transport supplies, equipment, and modules for the colony. Dormant housing, office and lab modules are stored in the area beneath the floor. As modules are needed, movers roll along the tracks, retrieve the modules, and move them into position beneath their final destination. The floor retracts and the module is pushed into position, where it is "plugged into" the utilities, and the floor beneath slides back into position, locking the module in place.

11.E.c LEVELS

Vision:2020 is divided into three levels: Level 1–living and working level; Level 2–transportation and kiosk level; and Level 3–promenade level. The circumference of Vision:2020 is approximately three miles. All levels are divided into three sectors, measuring approximately one mile per sector. Each sector of each level contains an emergency medical office and a security office.



11.E.c.i Level 1—Living and working level

All of the housing units for the colony are located on Level 1. Level 1 also contains many labs and offices, where the colonists are employed. OLED-equipped ceilings and walls provide the colony with a circadian atmosphere, complete with sunrise, daytime, sunset, and nighttime skies. A slight breeze and the appearance of clouds add to the ambience of Level 1. Aeroponic garden boxes line the walkways of Level 1. Walking is the only mode of transportation on Level 1, other than hoverboards which are utilized mostly by the children and youth of the colony. Walking and jogging are encouraged in the colony. Each sector of Level 1 contains a local library, a reading room and a neighborhood market.

11.E.c.ii Level 2—Transportation and kiosks level

Local transportation for the colony is based on Level 2. Level 2 is connected both Level 1 and Level 3 by entry chambers. Level 2 is the busiest level in the colony. Maglev transport pods move people and goods quickly from sector to sector. To access a transport pod, the user must login at one of many transport pads on level 2, and key in the coordinates of the desired destination. When the user's pod arrives in bay, the readout above the pod bay will flash the user's name and allow the user and up to four passengers to enter the pod. Passengers need only sit back and enjoy the ride as the pod enters the travel tube and automatically transports its passengers to their destination. Transport pods are plentiful, therefore wait time for transport is less than two minutes. Gold line pods travel east to west while purple line pods travel west to east.

To access the center core and points along the stem, colonists must use the maglev core train. The maglev core train terminal is located by escalator, below the transport pod floor of Level 2. The 20-passenger trains run every 15 minutes throughout the day. Access to the train is controlled. Colonists must be scanned, logged and access granted by security before entering the train. Colonists must arrive at least 5 minutes prior to departure time, to allow clearance for transport. Red line trains transport to the core and stem. Green line trains transport from the core and stem to Level 2.

Level 2 contains a variety of fastfood restaurants, video newsrooms and virtual reality entertainment kiosks. The walls of Level 2 are constructed of OLED materials programmed to display a variety of educational, documentary, travel and entertainment videos. One very popular feature of Level 2 is the fresh-water aquarium located in sector B.

11.E.c.iii Level 3—Promenade level (parks, restaurants, entertainment, tree groves, etc.)

Level 3 was designed for relaxation and entertainment. A babbling brook winds it's way along the center of Level 3 (the Promenade). Gold fish ponds and white sand beaches line the brook. The artificial white sand is constructed of silicone pellets which will not adhere to clothing or skin. Located on Level 3 are several fine restaurants, a performing arts pavilion, movie theater complex, virtual reality park, worship centers, gymnasiums and fruit tree groves. The groves are managed by colony scientists, who take care of cross-pollination, cultivating and harvesting fruits for consumption on colony. Aeroponic gardens, lush green walking trails, and a variety of shopping and museum destinations are located on the lower tier of Level 3 (accessible by escalator).

11 INSIDE THE COLONY

11.F TRANSPORTATION

Transportation on colony can be accomplished in a variety of ways: [01] transport pod for local horizontal sector-to-sector travel; [02] maglev core train for perpendicular travel from tori to core; [03] local taxi to transport travelers to and from the core terminal on colony to arriving and departing spacecraft in docking orbit; [04] tugs and local taxi for moving people from point-to-point in open space surrounding the colony; [05] space taxi shuttle for transporting small groups of people to Earth and L5 Vision Outpost; or [06] space plane for transporting larger groups to Earth and L5 Vision Outpost.

11.G IDENTIFICATION AND SECURITY

A full background check and top secret clearance is granted to each person who is chosen to live and work in Vision:2020. Biometrics are taken at L5 Vision Outpost during the training phase. Retina scans and thumbprint scans are the primary means of identification on colony. In addition to these scans, RFID (Radio Frequency Identification) is used on colony to identify where colonists travel throughout the colony. If a breach of security occurs on colony, the location of the breach is automatically locked down and the perpetrator is held on site until an interview is conducted, or security personnel arrive. Most incidents can be resolved through video interviews and biometrics.

11.H MONETARY SYSTEM

Monetary deposits and debits are performed electronically. There is no need for currency on colony. Banking is handled by personal communication devices (PCD). Monetary compensation is deposited into the occupant's account on the last day of each month. Online banking is accomplished by PCD. When purchases are made on colony, the resident's PCD is scanned and the appropriate amount deducted from his/her account.

11.I COMPUTER INTEGRATION

11.I.a. SUPER COMPUTER

Since all computers in Vision:2020 are internet-connected, the scientific and engineering communities of the colony utilize the combined network power of these computers. During idle time, all computers in Vision:2020 (personal and business) participate in scientific experimentation in the Search for Extraterrestrial Intelligence (SETI) by running a program that downloads and analyzes Earth-based radio telescope data. Idle computers are utilized in other scientific analysis as needed. Scientists and engineers rely on the availability of the Vision:2020 supercomputer's accessible information cyberinfrastructure (CI) to drive research and education. CI provides a broad and useful spectrum of integrated technologies to support complex, large-scale, cooperative scientific endeavors. Most science and engineering users work from a "home" research laboratory. When a research project's technological needs outgrows the capabilities of their home environment, cyberinfrastructure extends the reach of the scientist by providing needed databases, computation, and other resources remotely. Vision:2020 CI hosts a variety of projects in bioinformatics research and services, data mining, digital libraries and software development for grids and clusters.

Backup computers for Vision:2020 do not rely on the main power source. Auxiliary power units are provided for all backup systems on colony. Backup computers and auxiliary power are used for manual control of all systems in the colony and exploration packages. Backup computers are engaged if the colony should lose power, break down, or experience a catastrophic event.

Main computers and backup computers are logic-based. When a user enters a query, the computer searches databases and calculates the best function to accomplish the task. For example: enter the query, "I want to travel from our current position in Mars orbit to a parking orbit around Titan," and the computer will compute trajectory, while minimizing consumption of time and energy.

11.I.b. QUANTUM ENCRYPTION

All communications within the Vision:2020 network are encrypted using quantum encryption technology. Quantum encryption involves sending data by way of photons, the smallest unit of light. The photons are polarized, or oriented, in one of four different directions. Eavesdroppers cause detectable changes in the orientation, which in turn prevents them from getting secret information.

Disturbed photons in an encryption key prevent that key from being used. The photons are time-stamped so that the intended recipient can reassemble the message and differentiate between photons from the sender versus other sources, such as the sun.

The Vision:2020 system uses a network of computers processing at more than 500GHz to send data at 250 megabits per second.

11.I.c. OLED WALLPAPER

OLED stands for organic light emitting diode. OLEDs emit their own light directly from each dot of the screen, meaning no backlight is required. Displays using OLED can be viewed accurately from any angle, while using much less power than traditional LED backlit displays. Each cell of an organic LED display functions in a similar way to a regular LED. It is made up of a layer of emitting material sandwiched between a p-type and an n-type layer. The two sandwiching layers are very similar to the p- and n-type layers in transistors and diodes. The n-type layer is doped with a material that has an excess of electrons, while p-type layer is doped with a material with extra "holes" in the energy levels. When power is applied to the diode, the extra electrons in the n-type layer are repelled away from the electrons coming in from the negative side of the battery. They flow through the layer of emitting material where they combine with a hole from the p-type side. The electron drops to a lower energy state, giving off a photon. By making the emission layer with different compounds, the frequency of the emitted photon can be controlled, changing the color of the light. Three OLEDs, red, green and blue, are combined to make one dot on the screen. By controlling the brightness of each color, any color in the spectrum can be produced.

Because the OLED itself emits light, it only uses power when it is lit. This makes it much more efficient than LCD displays which have a backlight that is always on.

An OLED differs from a regular LED and other semiconductors in that it does not have to be made with compounds in a crystalline structure. Instead, it is made of carbon-based molecules. This means it is much easier and cheaper to manufacture, one of its greatest advantages over the LCD screens.

In order to use these OLEDs to create a picture, they must be arranged in a grid, spaced very close together. There are a number of ways of doing this. The simplest screen uses only one color of OLED. There is one cell per pixel on the screen. This type of display can be used for car radios, where full color is not needed. In order to get a full color display, capable of showing photos and videos, you can place red, green and blue cells very close next to each other. All three combined create one pixel of the image. By varying the brightness of each individual color, it is possible to create any color. When you want to show an image on the screen, you start with the top row. The top row is "activated" by applying a voltage, and then you can input which pixels you want to turn on by applying voltages to the appropriate columns. The top row is deactivated, and the second row goes next. Eventually, you reach the bottom row and start again at the top.

The reason you don't see the screen drawing itself in rows is because it all happens so quickly. The entire screen is scanned approximately 60 times per second. This type of display is called a passive-matrix display. On an active-matrix display on the other hand, each pixel can be addressed individually at all times. This means during one screen refresh, each pixel is on the whole time. This produces super sharp, full-motion video. An even more space-efficient method is to stack the red, green and blue cells on top of each other. Since they can be made transparent, this is not a problem. When the colors are stacked instead of next to each other, this means each pixel can be placed much closer together, allowing for much higher resolution displays than our current LCD panels.

The unique thing about OLED displays in contrast with LCD panels is that LCDs must be made of crystalline material, while OLEDs can be made with non-crystalline material, making OLEDs much cheaper and easier to produce. The production of LCDs is more like the production of semi-conductor chips. While this is relatively cheap and common, the manufacturing process for OLEDs is more like ink-jet printing, spraying ink down on a surface. This process is far less complicated, and is faster and cheaper than semiconductor manufacturing. OLEDs can be printed onto virtually any medium. This includes metal foil, paper, fabric, or even clear plastic. Because of this, the screens can be flexible.

The screens are also not limited to any particular size given their manufacturing process and addressing technique. Because of this late of size constraints, OLED displays are used throughout Vision:2020. The interior walls of all housing modules are constructed with a thin covering of OLED carbon nanotubes. The walls can be programmed to function as floor-to-ceiling, wall-to-wall photo displays, video monitors, movie screens or Technicolor wallpaper. The size of the display area can also be controlled, allowing the user to experience coverage ranging from full-wall video to 21-inch computer monitor to 3 x 5 calculator. This OLED wallpaper can be programmed to activate automatically at pre-set times, or set to a predetermined schedule. Here is one example of user programming:

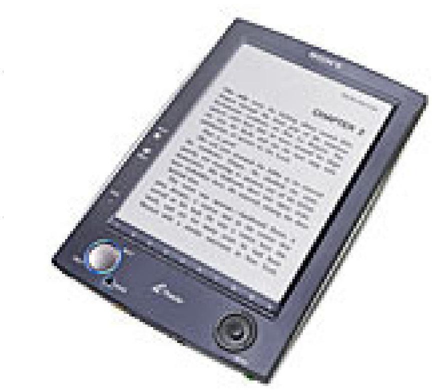
10:00pm	full-wall night-sky mode activated
6:00am	sunrise sequence mode with P-I-P (picture-in-picture) video newscast
7:30am	user-determined Technicolor wallpaper pigment activated
4:00pm	full-wall aquarium display mode activated
7:00pm	half-wall theater screen mode activated and movie automatically begins

User has complete override capabilities.

Offices and research laboratories are equipped with similar OLED wallpaper. Programming options vary dependent on the functionality and needs of the users.

11.J LIBRARY AND EDUCATION

Sector libraries are equipped with digital readers, which allow users to download any book or video currently online in any library on Earth. The digital reader uses a screen with technology that rivals text on paper. Weighing less than 9 ounces and at only ½" thin, the reader is more compact than many paperbacks. With built-in memory and multi-format support, the user can download many titles, documents, web newsfeeds and blogs (up to 150 titles) and take them with him/her. The paper-like six-inch display utilizes E Ink technology, presenting text as clear as if it were on paper. In addition, the screen can be magnified 200% making reading a joy, even for sight-impaired readers.



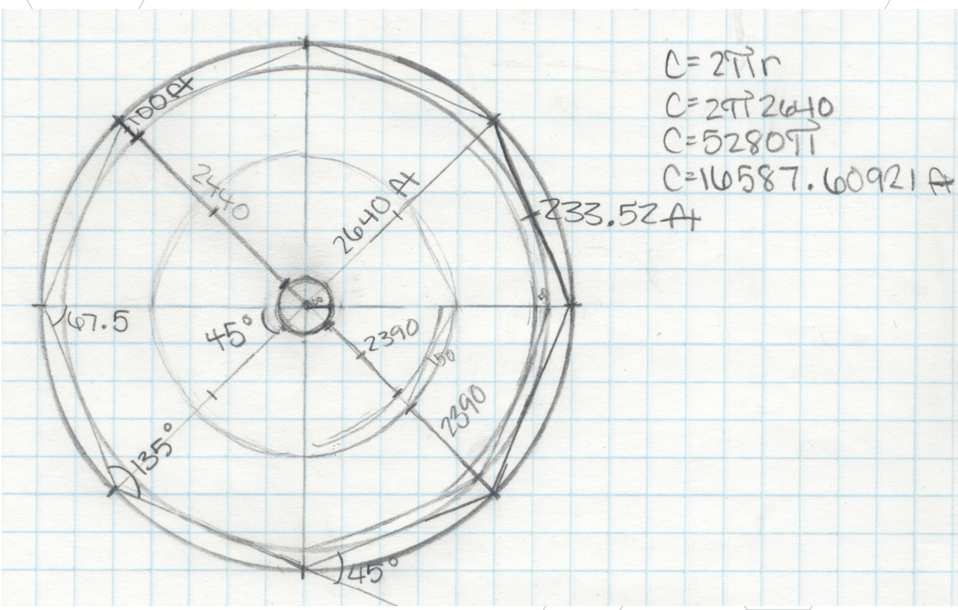
Public education for grades K-12 is provided through the library system. Classrooms are located at each sector library and distant learning is provided by direct linkup to classrooms on Earth, supplemented by interactive, holographic presentations. A class teacher/monitor is provided for each sector school. The school-age population of Vision:2020 is approximately 500 students. Nine sector library schools provide the education for all students on colony. The linkup for each student is grade specific for that student.

11.K PCD (PERSONAL COMMUNICATION DEVICES)

Each crew member and colonist of Vision:2020 is provided a Personal Communication Device (PCD) and holster. The PCD combines the functionality of a laptop computer, iPod, video player, camera, cell phone and walkie-talkie in one miniature device. The PCD is a compact, wireless device which measures 2.5" x 5" x .5". Some of the features of the PCD include:

- Voice recognition
- Personalized handwriting recognition
- OLED roll-out, flip-up screen and pull-out, flexible keyboard
- Projection (to take advantage of OLED walls and workstations)
- Video/still camera
- Instant messaging

- Walkie-talkie (short-range communication)
- Voice over internet protocol (VOIP) cellular phone (intra-colony, inter-colony, Earth-colony communication)
- Video/audio conferencing
- Internet access (including personal website development)
- Direct PCD to PCD wireless connection for gaming and personal computing
- Word processing
- Desktop publishing
- Database access
- Calendar and notes capabilities



11.L FLAT FLOORS

One of the unique features of Vision:2020 is the "flat floor". To eliminate the sensation of always walking on an upward curve, the engineers of Vision designed the floor of the tori as flat, rather than curved. A gentle curved transition connects the 467-foot-long flat sections of the floor.

11.M PLANETARY EXPLORATION

A major mission of Vision:2020 is the exploration of planetary systems in our solar system. Vision:2020 is equipped with robotic planetary exploration packages which will be deployed on demand. Research and analysis by scientists and engineers determines what is included in each robotic mission. Some missions are orbital missions while others are surface missions.

One of NASA's primary goals, in conjunction with the scientists and engineers of Vision:2020, is to design sets of future missions that will conduct robotic exploration across the solar system for scientific purposes and to support human exploration. In particular, explore the moons of Jupiter, asteroids, and other bodies to search for evidence of life, to understand the history of the Solar System, and to search for potential resources. The efforts of NASA and Vision:2020 address five scientific objectives:

1. Learn how the sun's family of planets and minor bodies originated
2. Determine how the Solar System evolved to its current diverse state including the origin and development of the Earth's biosphere
3. Explore the space environment to discover potential hazards and search for resources that would enable permanent human presence
4. Understand the processes that determine the fate of the Solar System and life within it
5. Determine if there is or ever has been life elsewhere in the Solar System

11.M.a. Planetary Exploration Packages

Prior to deploying surface probes, Vision:2020 deploys a series of hybrid surveillance planes. Each plane is equipped with rockets for maneuvering in no-atmosphere or low-atmosphere environments and jets for maneuvering in atmospheric conditions. Each plane contains video linkup as well as data acquisition and quick analysis capabilities.

Each exploration package is customized for the task. Each package contains telemetry which allows automatic monitoring, alerting, and record-keeping necessary for safe, efficient operations. Vision:2020 uses telemetry/telecommand systems to collect data from these operating spacecraft and satellites. Telemetry is vital in the deployment of each package because the system might be destroyed after/during deployment. Engineers need critical system parameters in order to analyze (and improve) the performance of the system. Without telemetry, this data would often be unavailable. A surface deployment package might include mining probes, while an orbital packages might include telescopes and cameras. Deep-space packages might include instrumentation to help detect potential life-supporting environments of extrasolar planets.

11.M.b. Target Sites

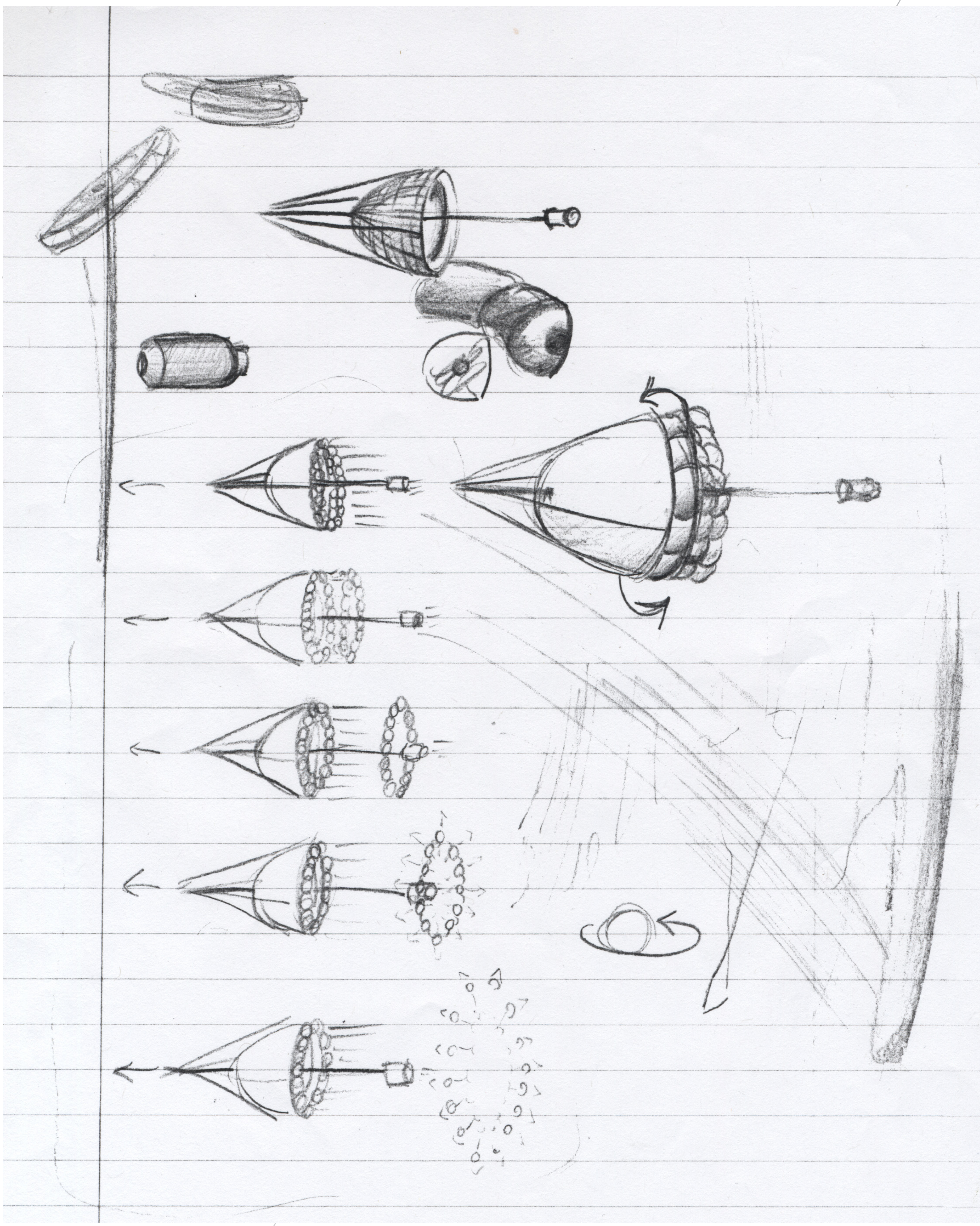
11.M.b.i Venus Surface Explorer: The Venus Surface Explorer (VSE) is a Design Reference Mission that is studying the composition and isotopic measurements of Venus's surface and atmosphere. Launched from Vision Outpost in 2020.

11.M.b.ii Jupiter Flyby with Probes: The Jupiter Flyby with Probes Mission is a Design Reference Mission that studies Jupiter's fundamental properties including gravitational and magnetic fields, atmosphere, and gross dynamic and structural properties. Launched from Vision:2020 in 2028.

11.M.b.iii Neptune/Triton Orbiter: The Neptune/Triton Orbiter with Probes Mission is a Design Reference Mission that studies Neptune and Triton's fundamental properties including gravitational and magnetic fields, atmosphere, and gross dynamic and structural properties. Launched from Vision:2020 in 2031.

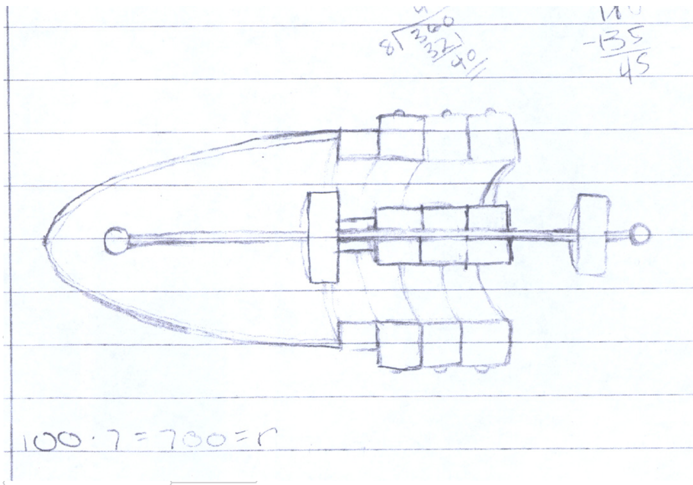
11.M.b.iv Titan Explorer with Orbiter: The Titan Explorer with Orbiter Mission is a Design Reference Mission that maps Titan with high-resolution radar, and studies pre-biotic chemistry and potential life. Launched from Vision:2020 in 2034.

11.M.b.v Europa Astrobiology Lander: The Europa Astrobiology Lander Mission is a Design Reference Mission that studies elemental Astrobiology and Geology on Jupiter's moon Europa. Scheduled for launch from Vision:2020 in 2040.

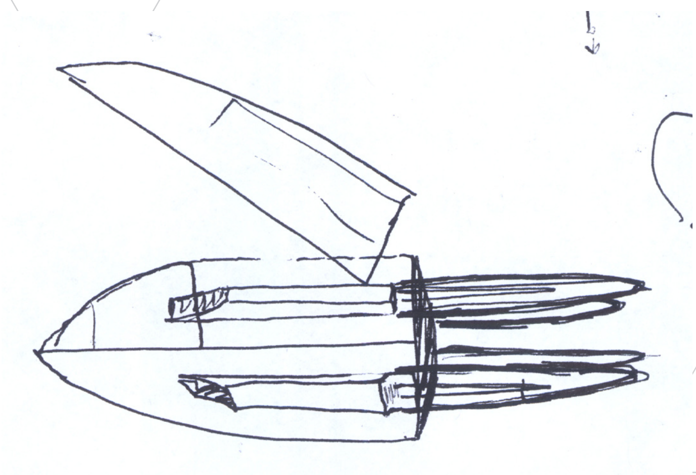


A series of sketches depicting the Vision:2020 colony with laser sail parabola and fusion engine in place. The pop-offs are our first idea for "parking" the reusable cargo vessels.

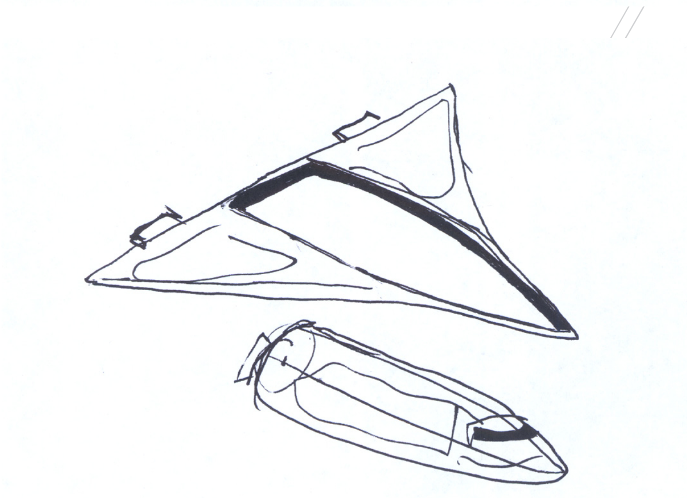
12 EARLY SKETCHES



Early sketch of the colony, December 2005, as the configuration of the tori, laser sail, and fusion reactor engine were beginning to take shape.



Sketch of the cargo shuttle with bay door open.



Sketch of cargo shuttle and reusable, detachable, delta wing.

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