Figure 1: Future City starts with a question—how can we make the world a better place? To answer it, 6th, 7th, and 8th grade students imagine, research, design, and build cities of the future that showcase their solution to a citywide sustainability issue

DESIGNING FUTURE CITIES

EDITOR'S INTRODUCTION

If ideas about "Cities we have vs Cities we need" are to be realized, then we need to insure that the next generation of talented students pursue careers in the planning, architectural and engineering professions.

Future Cities is one of several activities of DiscoverE (formerly the National Engineers Week Foundation) to encourage students to pursue studies and careers in science, technology, engineering and mathematics. Started in 1993, this privately funded completion is open to all public, private and home schooled pupils in grades 6 to 8. It challenges student teams to seek mentoring from engineering and planning professionals and then to conceptualize, plan and build a scale model of a new city with a horizon year a century into the future. In addition, a design theme is assigned each year. The 2015 - 2016 theme of "Waste Not, Want Not" was intended to stimulate the design of cities with innovative waste management systems.

The competition occurs during the school year. Participation in the competition is sometimes incorporated into regular classroom activities, and in other cases is extra-curricular, which means that students and teachers/mentors invest extra hours, similar to the participation in team sports. During the four month-long competition period, teams are guided to follow these steps: 1. Identification and understanding of the problem; 2. Brainstorming ideas; 3. Conceptdesign of the city developed using Sim City software; 4. Test and evaluate the initial design and refine/redesign as needed (using the Sim City software environment); 5. Build a scale model of their future city using recycled materials; 6. Prepare and submit a 1,500 word description of their city; and finally, 7. Orally present the model to a team of judges. Additionally, student teams are required to use project management software to guide their work during this process.

Judging is organized by regions with the one top regional finalist team from each region forwarded to compete in the national competition in Washington, DC over President's Day weekend. All judging is done by professional engineers, architects and planners.

The following are two of the many excellent projects presented during the Philadelphia Regional competition. The first, prepared by the St Cecilia's School team, envisions an ocean-based city developed to recycle plastic waste from the Pacific. The second, prepared by the Great Valley Middle School team, describes a future colony on Titan, a moon of Saturn. Both display the enthusiasm, inventiveness and high quality which typified all of the presentations at the regional competition.

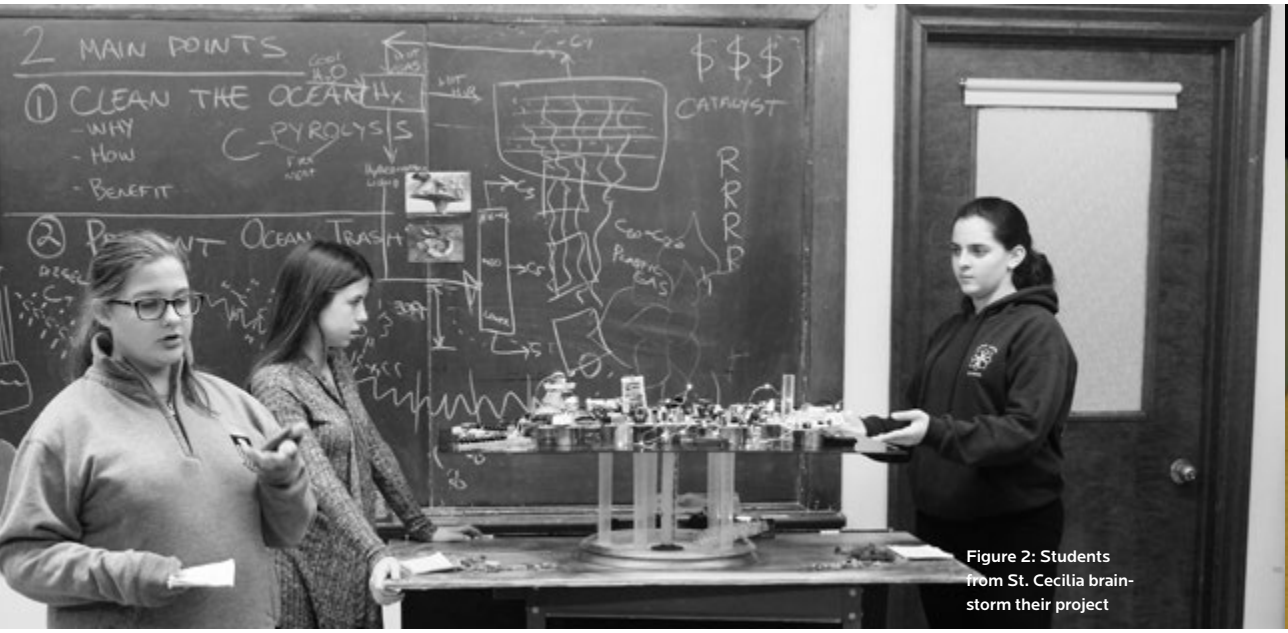

Figure 2: Students from St. Cecilia brainstorm their project

Figure 3: Students display the deflection booms on a portion of the Insula Inexhausta Model

AN OASIS IN A SEA OF TRASH: PRESENTED BY THE SAINT CECILIA SCHOOL FUTURE CITY TEAM

The new city of Insula Inexhausta (ININ) is a man-made chain of floating islands, imagined, planned and created by a multidisciplinary engineering team to clean the world's oceans. After 70 years of continuous improvement, this city has emerged as a model of sustainability and environmental stewardship.

With a warm, semi-humid climate year round, the 42,000 residents of ININ enjoy living an active, outdoor island lifestyle. Located in the North Pacific Ocean, in an area known as the subtropical convergence zone, the city hosts a wide range of industries and is the world leader in developing innovative methods to convert waste into re-imagined products. What started as the largest oceanic clean-up effort in 2015 resulted in the most advanced manmade floating structures ever built. Due to its unique design, ININ has become a favorite tourist destination for adventure seekers and watersport enthusiasts.

IN THE BEGINNING

As North America's consumption of Pacific-caught seafood increased (as part of a heart healthy dietary initiative), it was discovered that alarming levels of phthalates and bisphenol-a contaminated the fish supply. A team led by marine biologists and materials engineers, was commissioned to identify the source of contamination. The plastic byproducts were traced back through the aquatic food chain to the North Pacific Gyre, better known as the North Pacific Garbage Patch (NPGP).

It is estimated that there are at least 100 million tons of floating solid waste trapped in the rotating ocean currents of the North Pacific. Ninety percent of the trash floating in the NPGP is plastic, primarily low-density polyethylene (plastic bags), polypropylene (bottle caps) and polyethylene terephthalate (water bottles). Estimated to be twice the size of Texas, 10 meters deep and containing at between seven to over 100 million tons of trash, the NPGP is the largest accumulation of marine trash on earth.

These plastics do not biodegrade but photodegrade. The plastic is broken down by the sun through a process called photodegradation. This results in tiny floating particles that marine scientists call nurdles, of which 80% having a size < 1 mm. Marine life mistakes the plastic pieces for food and ingests them, along with any chemicals the plastic absorbed. These organisms and small fish are consumed by larger fish and the contamination ends up in the human food chain. Traditional means of skimming floating trash proved to be inefficient and ultimately ineffective.

ENGINEERING A SOLUTION

A project team consisting of marine, chemical, mechanical, electrical and civil engineers was assembled to develop a long-term, sustainable solution to eliminate the growing ocean trash problem. Due to the wide spread and ever changing nature of this issue, the traditional approach of bringing the problem to the solution was infeasible - so the team brought the solution to the problem. Their innovative plan was to utilize natural ocean currents to convey floating debris to a consolidation structure and guide the material to a centralized location for removal, processing and conversion.

The original plan consisted of a network of four spar platforms tethered to the sea floor. Roughly one city block in size, each of the recycled spar platforms, once used in deep-sea oil exploration, became the building blocks of the city. The spar platforms are connected to one another by a system of rigid structural causeways that provide lateral stability to the network. The causeways also provide the infrastructure for travel between platforms as well as a means to distribute utilities to each platform.

The four platforms created a system named GRACE, short for gather, remove, accumulate, convert and export. The Gather phase is accomplished by two deflection booms, extending 2 miles out and 10 meters deep, which are deployed at 45 degree angles to the platform network. Aimed into the prevailing ocean current to divert floating material toward the leading platform. All floating material is directed to the Removal platform and passes through an aeration zone where fine air bubbles are introduced below the debris layer, forcing less buoyant material to rise and concentrate at the surface.

Once gathered, the floating trash moves through the Accumulate steps of the process. A series of sumps gather the material where it is sent through a bank of Muffin Monster grinders and then transferred topside by trash pumps. Once topside on the Removal platform, the waste stream passes through a series of rotating strainers that separate the solids from the water. The water is collected and sent to our desalination process to produce potable water for the city.

The solids are collected and conveyed to an adjacent Conversion platform which houses the pyrolysis units including reactors, heaters, pumps, compressors, exchangers, fractionation columns and storage vessels. In addition to this process, the Conversion platform has a nitrogen plant that extracts nitrogen from the air where it is used to maintain an inert atmosphere in the pyrolysis reactor. With plastic being 90% of the material recovered, the design team chose a recycling technique based on a thermochemical

Figure 4: St. Cecilia students and faculty advisor showing the completed Insula Inexhausta Model

conversion process called pyrolysis. Heated in an oxygen-free environment, the recovered plastic is converted to a gas and sent through a reactor where it contacts a catalyst that breaks down the long hydrocarbon chains into shorter ones in a process called catalytic cracking. The gas stream is directed through a series of heat exchangers that use desalinated water to remove heat from the vapor and condense most into a liquid. The cooling water picks up waste heat from the exchangers and is sent to process boilers where it is converted into steam for use in turbine driven pumps, generators and compressors.

Separation of the liquid mixture occurs in distillation columns where the principle of varying boiling points of each hydrocarbon liquid is used to separate the hydrocarbon streams into four main products: 1) diesel fuel, 2) gasoline component, 3) fuel gas and 4) char.

The liquid hydrocarbons are stored on the Export Platform and sold and removed via tanker ships. The fuel gas is sent back to the beginning of the process for use as the main fuel for the thermal process. The fuel gas is also the heat source used in our process boilers. The unvolatilized solid byproduct called char left in the reactor has a BTU value and is sold as fuel to other industries. Although heavily energy dependent, this integrated pyrolysis process is a renewable energy technology that reduces greenhouse gas emissions by 70% when compared to traditional forms of crude oil extraction and refining.

DEVELOPMENT OF THE CITY

Four (4) floating platforms serve as the Industrial area of the initial city. In addition, there were several special purpose platforms. The Feedstock platform provides the main ocean cleanup function where trash is corralled, consolidated, grinded, dried and stored. The role of this platform is to provide an acceptable feedstock to the Conversion platform for the continuous pyrolysis process.

The Utilities platform provides all water, steam, condensate, wastewater and compressed air for the entire city. Here, high pressure pumps at the desalination plant forces salt water through a reverse osmosis membrane where all dissolved solids are removed. This water is used for drinking, cooling and boiler feedwater. The boilers utilize the fuel gas produced during pyrolysis to boil pre-heated cooling water to provide 680# steam to the city. Turbine generators utilize excess steam to produce power for the entire process making it self-sufficient. All primary rotating equipment in the city is turbine driven with electric motor backup.

The Maintenance platform contains all tools, material and equipment for repairs to the city.

This platform is also home to all city municipal services including sanitation, police, fire, etc.

Due to the predominantly industrial design of the initial development, a number of multi-purpose buildings were built up from the platform and also built down below the platforms into the ocean. The submarine structures not only provided a unique living experience but they added the benefit of increased buoyancy and lateral stability. To make the system self-powering, all platform spars with wave energy generators. Each spar houses a stationary generating coil and is surrounded by a magnetic sleeve and float assembly. Waves raise and lower the float/sleeve assembly over the spar coil, generating electricity.

As ocean clean-up and energy production increased, so too did the population of the city. In 2106, the population of the City was 42,000 people. Due to the scalability of our city, additional platforms were added to accommodate the needs of a growing workforce and their families. Schools, churches, recreation centers, open spaces, commercial/retail areas, hotels, restaurants and entertainment complexes were developed, which improved the quality of life. Crime and unemployment was below the national average and the energy export sector provided substantial tax revenue to fund all city-run services.

A high speed transportation system called the Dynatube was built on the ocean floor to link ININ to California and Hawaii with the commute to either destination taking less than 1 hour. Locally sourced vegetables are grown in vertical farming towers year round and the main protein source comes from aquaculture farms located under the platforms where fish and other aquatic organisms are cultivated and farmed to provide a sustainable source of seafood.

CLEANUP EFFORTS FALL SHORT

Environmental Engineers from the National Oceanic and Atmospheric Administration (NOAA) performed a study to determine the effectiveness of the Insula Inexhausta cleanup efforts after five years of operation. They reported that despite the success of the project, the size of the garbage patch had increased and cited poor global source control as the major contributor. Graduate biochemical engineers from the ININ Institute of Technology researching bioplastics made from seaweed and kelp developed a commercially viable method to mass produce biodegradable plastics. When fully implemented, a large percentage of plastics produced in the world will be plant-based and biodegradable. Education about the impact plastics have on our environment is a first step in cleaning up the world's oceans. However, by implementing engineering controls, worldwide ocean garbage patches will naturally reduce in size, regardless of land based source control.

EVIMERIA: PROSPERITY IN A NEW LAND : PRESENTED BY THE GREAT VALLEY MIDDLE SCHOOL FUTURE CITY TEAM

No person has ever set foot on Saturn, but with a large leap in space travel technology the Saturn's moon, Titan, was colonized. Nestled within the hidden valleys of Titan's topography, the new city of Evimeria rests in a vast plain with surrounding clouds above. Inhabitants enjoy life with the city's dome providing protection from the inhospitable environment, allowing citizens to enjoy the same activities they took part in on Earth, such as shopping and going to parks. Evimeria is about reusing resources to give back to the community, enabling the city to provide a stable government, homes, schools, and jobs for its citizens. Everyone is an equal on Evimeria, a utopia for any and all to enjoy.

DEVELOPMENT OF THE CITY

Evimeria was founded in the year 2116 when a brave pioneer by the name of Heather McGovern decided to try living on the previously uninhabited Titan. She began with her own shelter made of bio-fabric, a resilient material composed of entirely organic materials. Soon after, a geodesic Alpha dome was constructed, inspired by the works of Buckminster Fuller. The triangular structure of the dome is stronger and more resilient than any rectangular shape. Today that original dome is still in use in the center of Evimeria, which consists of multiple domes connected by transit tubes, to remind the population of what it took to create the life they are enjoying today.

The designers and builders wanted a civil

Figure 5: Model of Evimeria prepared by the Future Cities students Great Valley Middle School

design that would enforce safety but also give a futuristic design. The core element of the city consists of domes, with smaller domes circling the outside. As the city expanded more domes were built.

In this place with little gravity, no oxygen, and a harsh outer climate, the new version of the Alpha dome is used for protection. Stronger than a regular spherical dome, this hexagonal structure is virtually indestructible. The dome is covered by a membrane of shock absorbent substance which can withstand high amounts of bombardment. It will disperse any impact around the entire dome, providing maximum safety for the Evimerians inside. Coupled with the natural resilience of the dome, it can withstand nearly any impact. In case of an emergency, there are safety pods underneath the city to fly individuals to the nearest colonization.

The second design element of the city is its transportation system. Evimeria has introduced a transportation system utilizing pressurized air which can safely transport citizens to their destinations in other domes. This system gives off no harmful gasses. Passengers enter the transport capsules through the opening of part of a large tube, which lifts itself when passengers are boarding and closes when they are safely inside the capsule. Then, once everyone is safely secured with seat belts, the capsules begin to move to the next destination when air pressure is exerted in one direction or another. Air pressure is exerted both in the direction the capsule is moving, and in the opposite direction. This is so the capsule does not suddenly begin to quickly move one way and crash or become out of control. When the capsule must come to a stop, pressure is slowly reduced as the strong magnets on the capsule begin to connect with the magnets at the next capsule stop. From here, the operators must ensure that the capsule is not moving and completely secure in place. Then, the doors open and the citizens may safely exit.

TECHNOLOGY FOR SELF-SURVIVAL

Building a colonization in the vast unknown would lead to many different obstacles and trials.

Titan's gravity, which is 1/10 of Earth's, caused issues. If the colonists would want to ever return to Earth, they would be victim to bone disease even with the low gravity produced by the Dome's rotation. We have developed several methods to reduce this problem.

We have created a specialized exercise center for the citizens to build back their bone growth and maintain the same strength that they had on earth. We also insure that citizens maintain their physical fitness in various ways. Another example is that our trains are solely

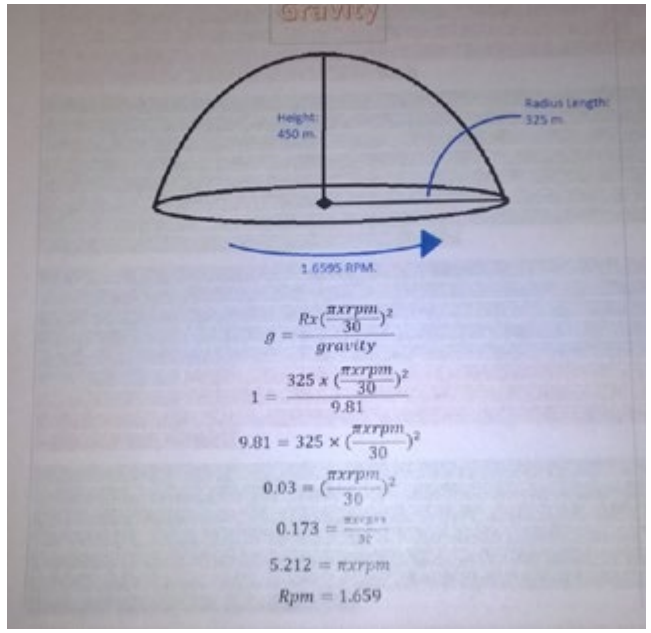

Figure 6: First concept sketch of Evimeria

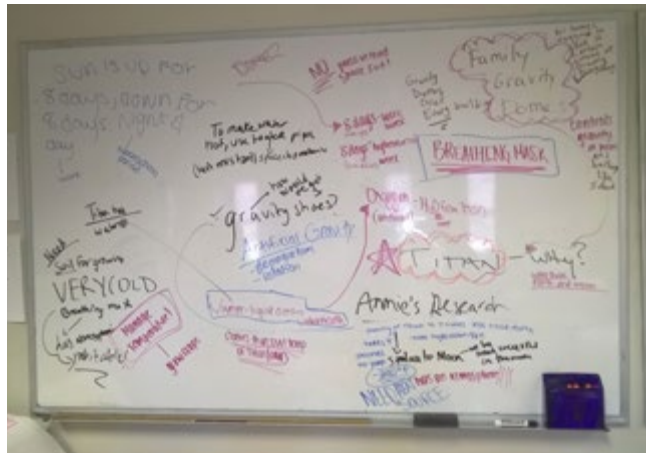

Figure 7: Concept notes from the development of Evimeria

Figure 8: Great Valley Middle School Future City team with their model of Evimeria

used to transport the citizens from dome to dome. While in a dome, the citizens must walk to their destination.

Despite the cold, 200+ mile per hour winds, and the lack of oxygen, there are many surprising benefits that can be found on Titan. For example, atmospheric methane gas is used as a natural insulation to protect our city from the sub-zero weather conditions. Another benefit is that the high speed winds on the Moon's surface which has been harnessed for energy.

Technology has been developed to heat the otherwise below freezing city, to provide energy and water. Heat is provided through heat pads; 5ft by 5ft by 6 in pads located underneath the paved streets and buildings. These pads focus heat through electricity. We also create our water by using a molten carbonate fuel cell that takes in O2, CO2, and H2 and fuses O2 and CO2 into CO3-2 (carbonate) by using hydrogen to create an electrical current. This passes through the current again to create H2O and CO2. The carbon dioxide is used again while the water and heat is released. The heat and water is released while the carbon dioxide is used again. The Evimerians also burn methane found in the large lakes, and use the energy as electricity, which powers the solid waste into the tubes and into the agricultural center, which is one of the few areas where energy is needed for the trash collecting process.

Food is obviously one of the most drastically needed services vital to the city. Solid waste is used to fertilize crops, which acts as a stimulant, helps them thriveand grow several times faster than normal. This agricultural system also acts as a major job source and helps the economy thrive. While robotic, tractor-like machinery is used for most work, residents who wish to exercise can do so by helping out in various insulated greenhouses and get compensated for their efforts. One of the major crops grown on Evimeria is soy beans. This healthy, nutrient-dense food can be substituted for meat, grain, vegetables, fruits, and still taste and have all the benefits of the original food. To accommodate the agriculture and the aquaculture, space is maximized by designing building so that top floors are devoted to jobs while crops grow on lower floors

Evimeria recycles both water and waste. As Buckminster Fuller had said, "Pollution is nothing but the resources we are not harvesting. We allow them to disperse because we've been ignorant of their value." Our remote location has further encouraged us to recycle all that we can.

The toilets in Evimeria have two functions, both of which conserve the energy of later separation of excrement and urine. To flush urine, one button is pressed, and another for excrement. The urine enters the Urine Filtration System (U.F.S.), a highly technological system in which the urine is poured into a filter and comes out as clean drinking water almost instantaneously. The solids travel in another system of tubes, and are sprayed with bacteria to remove all negative by-products and possibly unhealthy materials from the waste. Then, the waste is delivered to the agricultural area and used a fertilizer.

Furthermore, a tradition has started to do "No Casket Funerals," where a deceased person is sprayed with bacteria and laid to rest in the agricultural area without being placed in any kind of box structure. Evimerians report a strong sense of peace and satisfaction knowing that their loved ones contribute to our city even after their death

One of the largest problems the Evimerian pioneers faced was properly disposing of solid waste. Living on a planet with very little space to dispose of garbage results in a large problem for the citizens. It takes a large amount of funding to engineer a system to dispose of the waste. Also, the garbage that is produced could possibly be hazardous and a host to diseases, which could start an outbreak of sickness.

The Evimerians are extremely ecologically advanced, hence, they use a system named C.O.B.S, the creation of biodegradable substances. Prior to the waste becoming garbage, any disposable item that has a chance of becoming unnecessary waste is instead created out of biodegradable materials. The main material that is used is gelatin which is created by boiling the unneeded parts of the sockeye salmon that are cultivated (for food) on Evimeria. This material is then infused with proteins and flash-frozen to make the material extremely strong. The end result is an industrial strength material that can be used, reused and molded into anything.

On Titan, the city's economy and success is built around the trust and cooperation of others. A key aspect to allowing the city to come together is communication. Citizens need to be able to communicate with each other to get things done. With holographic communication technology, the receiver and sender can both interact and see one another and their environments. This allows the citizens to be able to work more efficiently even when they are not there. There can be meetings and important discussions right from the comfort of their homes.

REFLECTIONS ON THE CITY DESIGN

Living on an entirely new moon comes with a multitude of good and bad things. One tradeoff that the citizens face is a small living area with public transportation. The citizens do not have much privacy, however, this preserves resources. The largest tradeoff that is unlikely to occur is a system failure, which may result in death. However, the citizens are aware of this and there are systems in place to prevent this from happening, which include safety pods and emergency domes. Living on a new planet comes with its highs and lows, however, the benefits outweigh the drawbacks by a large amount. Using innovative and futuristic solutions, Evimeria is the definition of the future. Prosperity in a new land comes to live in our future city. ◆