Saving Eden
Strategies and Concepts for Planetary Defense
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Introduction

ASTE 527 - Course Description

ASTE 527 provides students with programmatic/conceptual design synthesis/choice creation methods for complex space missions. It is designed to give Aerospace system engineering/Architecture tools to the students so they can create innovative projects. The Student Projects are evaluated by faculty, industry, and NASA experts.

ASTE 527 - Final Design Problem

- Final design problem topic - planetary defense
- Create an original idea in the team project topic October 13th, 2013
- Refine it through iteration - debate, discussion and dialog
- Present it using your preferred media - must be WebEx friendly!
- 10 minutes for each participant
- Dry run on December 3rd, 2013
- Final Presentations on December 17th, 2013

Evaluation Criteria

On a scale of 1-10, with 10 being excellent, please evaluate participant performance on the following qualitative criteria.

1. Originality
   Imagination, Creativity, Vision, Innovation, simple, clear, plain, clever. Does the concept architecture stimulate further thought? Have you seen or heard about a similar idea before? Are there new and original parts to this particular idea?

2. Rationale
   Does the motivation behind this idea appeal to you? Possibilities are positive and problems are negative?

3. Clarity and Follow-Through

4. Presentation
   Do you like the presentation? The way the story is told? The sequence in which the idea was revealed? Black and Whites, the Visuals, the Package?

5. Context and History
   Depth of Research. Understanding of Context in which the concept is proposed. Understanding of Real World Constraints.

6. Technology Integration
   Is this a viable concept architecture?(Extrapolation allowed) Understanding of Fundamentals?

7. Complexity
   Is this a difficult concept to present? In that context, does presentation handle complexity well and address the most important parameters? i.e. positive attributes include: Strong Bones, Alternatives, Scalability, Manageable System-Subsystem Interfaces, Evolution and Growth Potential, Critical Systems Redundancy.
### Tonight’s Schedule

<table>
<thead>
<tr>
<th>Time</th>
<th>Student Project</th>
<th>Title</th>
</tr>
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<tbody>
<tr>
<td>6:40</td>
<td>Madhu</td>
<td>Studio Activities and Guest Introduction</td>
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<tr>
<td>6:50</td>
<td></td>
<td>Project Introduction</td>
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<tr>
<td>7:00</td>
<td>Jason</td>
<td>PINT/GLASS</td>
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<tr>
<td>7:10</td>
<td>Madlenne</td>
<td>Art DECO</td>
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<tr>
<td>7:20</td>
<td>Will</td>
<td>The Trojan Defense</td>
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<tr>
<td>7:30</td>
<td>Michael</td>
<td>Directed Energy System Concepts</td>
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<td>7:40</td>
<td>Bea</td>
<td>Solar Power Satellites for Planetary Defense</td>
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<tr>
<td>8:00</td>
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<td>Refreshment Break</td>
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<tr>
<td>8:10</td>
<td>Chelsea</td>
<td>DISARM</td>
</tr>
<tr>
<td>8:20</td>
<td>Nick</td>
<td>Moisture Farming</td>
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<tr>
<td>8:30</td>
<td>Dr. Stuppy</td>
<td>Monitoring Astronaut Crew Health</td>
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<tr>
<td>8:40</td>
<td>Angella</td>
<td>Starship Earth Revisited</td>
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<tr>
<td>8:50</td>
<td>Madhu</td>
<td>Closing Remarks</td>
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<tr>
<td>9:00</td>
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<td>Open Mic Discussion</td>
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<td>9:20</td>
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### WebEx Information

To Join Our Meeting Go To:  
https://den.webex.com/den/j.php?ED=236563647&UID=482092012&PW=NNDdkOGI4MzQ3&RT=MiM0  
The Meeting Number is: 926 355 849  
The Meeting Password: astethang  
If you have questions or difficulties connecting to WebEx, please contact DEN Network Control at 213-740-0130.
Invited Guests and Reviewers:

Dr. William Ailor - Center for Orbital and Reentry Debris Studies, Aerospace Corporation
Dr. Buzz Aldrin - Apollo 11 crew member
Walt Anderson - Venture Capitalist
David Barnhart - Director Space and Technology ISI/USC
Dr. Joseph Bermudez MD - Anesthesiologist, Alta Bates Summit Medical Center
Dr. Andy Betts - Anesthesiologist
Rick Boehner - Composite Structures Group, NGC
Prof. Bob Brodsky - USC Astronautics
Prof. Anders Carlson - Director Building Science, USC School of Architecture
Dr. Marc Cohen - Space Architect, Habitability Lead, NGC, Astrotecure Inc.
John Constantinou - Dept. Mgr, RF Syst. Integration & Test, Raytheon Space & Airborne Systems
Leonard David - Space News
Bob Davis - Marketing, Space Systems - NGC
Dr. David Dearborn, Lawrence Livermore National Laboratory
Dr. Alex Diaz - EVA Specialist, Advanced Space Exploration, The Boeing Company
Prof. Graham Dorrington - Aeronautics Dept., Queens College, UK RMIT
Prof. Dan Erwin - Chair, USC Astronautics
Marybeth Edeen - ISS National Lab Manager, NASA JSC
Prof. Bernard Foing - Executive Director, ILEWG, Chief Scientist, European Space Agency
Jack Fox, Chief, Surface Systems Office, NASA KSC
Boris Fritz - Rapid Prototyping and Manufacture Laboratory - NGC
John Fujita - Principal Director, MILSAT, Aerospace Corp
Lt. Col. Peter Garretson - USAF, Futurist and Space Strategist, NSSO - The Pentagon
Prof. Gene Giacomelli - Director, CEAC, University of Arizona
Prof. Mike Gruntman - USC Astronautics
Jonathan Hofeller - Marketing SpaceX
Dr. Scott Howe - Senior Projects Manager JPL
Robert Jacobson - President, 62 Mile Club
Dr. Alvar Kabe - Structures Division, Aerospace Corp
Prof. Behrokh Khoshnevis - VSoE, USC
Peter Kohl - President Moon Society, Editor MMM
Prof. Tom Kovac - School of Architecture, Royal Melbourne Institute of Technology
Prof. Joe Kunc - USC Astronautics
Dr. Larry Kuznetz - New Generation Spacesuit Design Group, NASA JSC
Col. Scott Larrimore - Commander SBIRS, US Space Command, El SEgundo
Prof. Neil Leach - School of Architecture
Dr. David Livingston - The Space Show
Prof. Philip Lubin - Experimental Cosmology Group, UC Santa Barbara
Prof. Quingyun Ma - Dean, School of Architecture
Prof. Azad Madni - Systems Architecting Program, VSoE
Eric Mankin - USC Engineering News
Taber MacCallum - CEO, Paragon Space Development Corp.
Bob McMillan - Wired Magazine
Carl Meade - Director, Space Systems - NGC
Dr. Philip Metzger - Materials Division, NASA Kennedy Spaceflight Center
Prof. Doug Noble - Director Ph.D Program, USC School of Architecture
Thom Patterson - CNN Atlanta
Dr. Ken Phillips - Curator, Los Angeles Aerospace Museum
Mike Potter - Paradigm Ventures, ISU Board of Directors
Prof. U.R. Rao - Director General Emeritus, Indian Space Research Organization
Ed Repic - Retd. Advanced Projects Manager, Rockwell International
Rex Ridenoure - CEO, IZUP Inc.
Dr. Joe Ritter - Lab Director, University of Hawaii Institute of Astronomy
Gene Rogers - Chief Technologist Boeing
Dr. Nicola Sarzi-Amade - Microcosm, Programs Chair, AIAA LA-LV Section
Prof. Marc Schiler - Director MBS Program, School of Architecture
Dr. Anita Sengupta - Mars Science Lab, Venus Balloon Project JPL
Prof. Stan Settles - Chairman Industrial Systems Engineering, VSoE
Brent Sherwood - Strategy Management - JPL
Lt. Col. David Smith, USMC (R.), NASA Research Pilot, Aircraft Operations Division, Johnson Space Center
Col. M. V. Coyote Smith - USAF, Professor of Strategic Space & Cyber Studies, Air University, Maxwell AFB
John Spencer - Space Tourism Society
Jess Sponable - Project Manager DARPA
Prof. Jill Tarter - USC & Director of Center for SETI Research
Prof. Fiorella Terenzi - Physics & Astronomy Dept., Florida International University
Rick Tumlinson - Founder, Space Frontier Foundation
Prof. Douglas Vakoch, SETI
Dr. Leslie Wichman - Space Architecture Group, Aerospace Corp / APU
Dr. Harvey Wichman - Dir., Aerospace Psych. Lab, Claremont McKenna Col.
Prof. Bong Wie, Asteroid Deflection Research Center, Iowa State University
Prof. Peter Will - ISI / USC
Prof. Firdaus Udawadia - Aerospace/Mechanical/Civil/Systems Eng & Math
Prof. Yannis Yortsos - Dean, USC Viterbi School of Engineering
Presentation Abstracts:
While most current planetary defense methods focus on protecting Earth from impact by near-Earth objects (NEOs), the PINT/GLASS system proposes a unique approach to the defense of Earth: protecting the persistence of Earth’s memory.

As a dual-segment system, the small constellation of PINT/GLASS spacecraft would perform two missions in support of planetary defense, each focused on a different timescale.

The primary, long-term GLASS mission would provide a hardened and highly reliable, long-life cache of information about humanity and Earth, as well as a catalog of genetic material from Earth’s life-forms for future retrieval after a cataclysmic event. Coupled with a high gain transmitter, each PINT/GLASS spacecraft would be designed to communicate its location throughout the local neighborhood of possible habitable exoplanets (within 50 light-years), only after radio communications with Earth have ceased.

In addition, due to the persistence of the PINT/GLASS constellation, the secondary, short-term PINT mission would be designed to transmit low-precision navigational signals throughout the Solar System, providing for rough positioning in support of future science, human exploration, and planetary defense missions.
Making Dedicated Earth-Crossing Observations and maintaining an Awareness of Relative Trajectories of potentially hazardous objects is actually more of a science than an art, but there is still room for improvement in a globally networked system for Space Situational Awareness. There has been a renaissance of rapid advances in the computing power of processors and algorithms, the agility of data banks, and the versatility of state-of-the-art information systems. These advances need to be leveraged into global communications, comprehensive modeling, and automated data mining to analyze large volumes of data for threat detection. We could commission an effective multilayer information and guidance system that would enhance our ability to sense changes in the vicinity of our solar system in a timely manner to avert an imminent asteroidal or cometary fragment impact.
The asteroid impact in Chelyabinsk, Russia on 15 February 2013 precipitated renewed interest in planetary defense from small Solar System bodies scattered about the asteroid belt as well as extrasolar objects. This new found interest culminated in NASA announcing a “Grand Challenge” on 18 June 2013 whereby industry, academia, and even members of the general public were solicited for ideas on how to improve current rogue asteroid contingency plans.

Geological evidence indicates that the extinction of the dinosaurs over 65 million years ago was the result of an asteroid impact. While the probability of an extinction-class body colliding with the Earth is extremely small, the consequences of such an impact are cataclysmic. For the first time in history, the human species has the knowledge and means to mitigate the impact risk of a global killer. This concept aims to prevent mankind’s extinction through timely deflection of a threatening body.

Instead of trying to destroy an oncoming object, the goal is to deflect the body just enough to alter its trajectory to avert impact with Earth. This concept will utilize small (10m diameter) Trojan asteroids to engage an oncoming object in essentially a game of cosmic billiards. Pre-selected Trojans will be equipped with propulsion devices that, when activated, will propel the Trojan on an intercept course with the oncoming object. The kinetic energy transferred to the body will result in a small amount of change in velocity, which will in turn alter its course. One or many pre-positioned Trojan defenders will be deployed depending on the size, trajectory, location, and composition of the body. In addition, other factors such as orbital geometry and intercept trajectory as well as precise Earth miss time and distance analysis will be employed to determine the final attack strategy.

Defenders will be targeted for a 50-75 year design life. The defenders propulsion device will utilize solid propellants because it is easily (and safely) stored for long periods of time. Defenders will be fielded at approximately four per year with the goal of maintaining a fleet of at least 100 defenders at any given time. Lastly, additional areas for concept refinement and future studies include selection of the initial launch vehicle for of the defenders, identification of a range of asteroidal assets in strategic locations around the solar system including suitable, strategic Trojan defenders, extremely long-life, agile and reliable spacecraft systems, and a robust and secure communication architecture with the defenders.
Asteroids and other threats to Earth naturally occur in the Solar System ranging from solid monolithic and metallic bodies, to large conglomerates of Solar System rubble, loosely held together by weak gravitational forces. It goes without saying that some of these bodies will be able to pierce the Earth's atmosphere and cause cataclysmic destruction if they are not stopped well enough in advance. Fortunately, the majority of these bodies in the Solar System have a few unique properties that can be exploited by Directed Energy Systems.

Directed Energy Systems are an emerging feasible concept in mitigating the threat of Near-Earth Objects (NEO). Directed Energy Systems are scalable architectures that focus energy on a target's surface through the use of phased arrays. The energy is typically used for the purpose of ablating the surface of the target, or generating substantial ablative thrust to alter the trajectory of the asteroid to a new innocuous path. The technologies involved are fast maturing and it is expected that such directed energy systems could be used at astronomical distances up to 1 AU.

This conceptual study explores innovative strategies for directed energy system application to potentially hazardous asteroid threats. Two alternative methods to pure vaporization and trajectory alteration exist because of the intense physical reactionary forces associated with ablative thrust produced by the focused energy on the surface of the target. Tapping into the natural frequency of the asteroid in order to resonantly fracture it into harmless fragments is one such method, and potentially the most effective against the larger monoliths. Additionally, large rubble piles could be spin-destabilized by applying a torque and overcoming the force of gravity through centripetal acceleration. Both methods attempt to produce a field of much smaller debris fragments that could further be diverted, vaporized by the directed energy system, or allowed to burn up in the Earth's atmosphere.

Whether the scalable Directed Energy System is built in orbit or here on the ground, it will provide strategic options for protecting humanity. Further modeling will be necessary to identify the correct option for the specified threat, but if we detect the threat early enough, this system could be the human race's best bet to thwart a potential asteroid impact.
Directed energy concepts have been proposed for planetary defense. These concepts require very large space-structures to be launched, assembled and certified for reliable operations, at large expense. A relevant area of research is space solar power: satellites that collect solar energy in space and transmit it to the ground using microwaves or lasers. There is a large overlap between solar power satellite and solar-powered directed energy planetary defense concepts—both require large amounts of power, large space structures, efficient solar energy collection, efficient energy conversion, precise pointing, and long transmission distances. Thus, geometries based on recent SPS concepts are presented for planetary defense. The geometry of the Modular Symmetric Concentrator, a microwave SPS concept, is adapted for use with a laser phased array. It concentrates sunlight without overheating the photovoltaic cells and decentralizes the power conversion chain. Inspired by this concept’s philosophies, free-space phase-locked loops are presented. A reference signal can be beamed through empty space instead of optical fibers. These techniques can save significant mass for kilometer-scale structures, bringing them one step closer to being practical.
Geologic evidence proves that planet Earth is always at risk of a catastrophic asteroid impact. Current studies question the rate of impacts and suggest shorter intervals between such city-killer episodes. In recent years there has been a greater focus on finding and tracking these near-Earth objects that threaten humanity, but there are still many Earth crossing potentially hazardous asteroids (PHAs) yet to be discovered. Many concepts exist for deflecting asteroids when they are found several years before they are due to collide with Earth, but what if a catastrophic threat is discovered less than one year before its predicted impact? 

Studies show that it would be possible to completely fragment a 1-km metallic asteroid by launching an existing nuclear warhead to intercept it. However, such a high-stakes mission with little notice cannot be planned and executed unilaterally. International cooperation at the highest levels followed by accurate and reliable communications and agile executive action could make it a possibility. Taking advantage of all nations space and defense experience, research, and infrastructure enables a joint global program composed of many spacecraft able to take on such an asteroid threat. Advances in global communication and information technology have matured enough to make such a complex, highly coordinated endeavor viable.

This proposed architecture calls for reconnaissance spacecraft to fly by the oncoming asteroid and characterize it. Next, nuclear destroyer spacecraft would rendezvous with the asteroid. While the reconnaissance spacecraft watch, the nuclear weapon would detonate and fragment the asteroid. The reconnaissance craft then characterize the debris cloud, noting any large fragments that remain. The third class of spacecraft, strategic deflectors, communicate directly with the reconnaissance craft and use kinetic impactors or smaller nuclear devices to deflect or destroy any fragments that might still pose a threat.

Global involvement of many different nations and space agencies will allow all of these spacecraft to be built and flown by skilled operators simultaneously. It also opens up many different launch sites, enabling wider launch windows and choice of trajectories. More ground station facility options would exist for communication, and supercomputers around the globe could be shared for high-fidelity simulations that are key to hone and establish the procedures needed to execute such a mission.

Bipartisan support exists in Congress for space activities. A highly focused, goal-oriented program such as Global Planetary Defense provides a vehicle for nations, both space-faring and those aspiring, to join forces to collaborate peacefully on a mission of critical importance to humanity. Finally, it provides an avenue to utilize defense assets and weapons technologies and surplus nuclear arsenals in a peaceful way to protect our common global civilization and biosphere.
Human civilization on Earth has reached staggering levels of capability and connectedness after millennia of development. Despite recent decades of geopolitically-driven space exploration, humanity as a global collective has incomplete plans for how to survive a catastrophic event on the order of the asteroid strike which killed the dinosaurs. To avoid extinction, to become a spacefaring species, to continue life as we know it, we must develop tools for the productive use of resources in space so that, in an emergency, we may live out the undesirable, unspeakable destruction of Earth in space habitats beyond our worldly confines.

Water is a fundamental source for life on Earth and its bulk usage is inevitably necessary for any permanent human presence in space. Water can provide for a variety of uses. Potable drinking water is the application most fundamentally linked to health and survivability. Investigations are underway to quantify this precious resource in our solar system that has the potential to change the entire strategy for lunar and eventual Mars settlement development.

Concepts in the literature suggest alternative ways to beneficiate and extract water and volatiles, but most of them suggest strip mining strategies that are bound to irreparably damage and deface the pristine extraterrestrial surface terrain. This proposal looked for elegant solutions; cleaner autonomous operating system designs less prone to adverse surface effects like dust eliminate major concerns for lunar activities.

A robotic induction furnace presents a simple, robust, and promising method to harvest water for such purposes. The furnace would operate at a temperature to release water vapor. Induction allows heating from above without excavation by appropriately setting the skin depth of the magnetic field. The system must be designed to transport and store water given the tendency for H$_2$O to sublimate in the lunar surface vacuum environment. Assuming that the regolith is 2% water by weight and present in a 1 cm thick subsurface layer, a robot could collect the 12 kg per person per day necessary for a 100 person crew to become self-sustainable in just one month. Habitat architecture could incorporate water storage to provide radiation protection system and closed-loop water recycling to minimize water resupply requirements.

Developing elegant, simple, yet robust water harvesting and storage capabilities closes a key technology gap for human exploration employing in-situ resource utilization. Systems for use on the Moon should be created first and tested on site as a testbed for eventual deployment at Mars. The promise of access to off-world habitats via space technology serves as both near-term and long-term planetary defense solutions, providing space-bound diaspora potential for humanity for the first time in our history.
Astronaut crew is constantly monitored for their health and mission fitness. Heart rate variability (HRV) is the gold standard by which in-flight crew are assessed. Recent studies show that all anomalies cannot be resolved or predicted using current methods of HRV alone. Complex feedback loops that sustain the dynamic equilibrium within the human physiology suggest that the Autonomic Nervous System (ANS) along with yet to be determined attractors play an ergodic yet significant role in homeostasis, or dynamic equilibrium of the active crew. This proposal argues that HRV analysis using Cosynchronous non-linear dynamics of two signal sets (RR/QT) is the next step in maintaining the homeostasis of the Astronaut Crew health during voyages. It seeks to build the case to observe, detect, and suggest real time wireless monitoring and feedback in crew physiology through the use of new tools and systems.
Starship Earth Revisited: Utilization of Geodesic Domes, Pneumatic and Tensile Structures in the Event of An Asteriod Impact

Angella Johnson
angelajo@usc.edu

Our planet is constantly bombarded by extraterrestrial objects. The most hazardous are those that cross the Earths orbit periodically which are called potentially hazardous asteroids or PHA. Current and proposed surveys aim to locate and track these objects with the intention of one day finding a way to avoid a cataclysmic event. Recent asteroid impacts include the 1908 Tunguska impact that devastated millions of square miles of Siberian forest and the 2013 event in Chelyabinsk that released more energy than some nuclear devices. These events remind us of how vulnerable our planet is from these extraterrestrial threats.

The effects of an impact are not fully understood, but may be comparable to large scale natural disasters caused by volcanic eruptions, tsunamis, and earthquakes combined. Immediate effects will include supersonic shock and heat waves that will incinerate large population centers followed by large debris missiles and huge dust and water vapor clouds that rise up into the stratosphere and blots out the sun for months. The atmosphere would become thick with dust and toxic agents and as a result water reservoirs will be polluted. The lack of sunlight will negatively affect agriculture as well, issues discussed in nuclear winter literature. Rapid changes in climate and weather will include cold snaps, hail and rain, and off season heavy snow and blizzards, even in equatorial latitudes, will quickly disrupt natural cycles. Cities along coastal areas and those linked to large rivers and waterways are most susceptible to swift surges, deluge and devastation. Hence such objects, events and effects are termed “city killers”.

Since it is an overwhelming task to move large populations to safe havens without ample preparation and time, the proposed concept explores state-of-the-art options to contain the disaster by quickly providing life-saving services for densely populated city centers in the aftermath of such an event. This concept proposes to provide high technology in-situ support for large population centers, metropolitan cities for a period till the Earth and natural cycles finds homeostasis. Specifically, this concept explores the use of large scale pneumatic membranes, geodesic domes and tensile structure technology to create vast protective shields around existing city infrastructure employing advances in HVAC, while quickly grafting the most advanced forms of power generation systems. It also discusses innovations in intensive agriculture, health care and deployment of efficient and portable communications infrastructure. All aspects of human preservation and survival must be considered. A temporary system for survival must be set in place that is compact and portable, that can be quickly constructed, which will address the needs of all survivors for an extended period of time estimated to be between eight months to an year. Ultimately, this strategy, in addition to a similar proposed global response initiative will allow us to successfully preserve and protect our species and rehabilitate our biosphere.