"Earthrise" Image from
NASA 's Apollo 8 (1968)

THE UK SPACE DESIGN COMPETITION

NATIONAL FINALS

2019

PROUDLY SUPPORTED BY:

DANGOOR EDUCATION

RUBY

Dangoor Education provides opportunities across the learning spectrum with sponsorship of Westminister Academy, Open University Massive Open Online Courses, STEM university scholarships, the Dangoor Centre for Medical Education at the Royal Society of Medicine and the Dangoor Centre for Personalised Medicine at Bar Ilan University. Dangoor Education's sponsorship of the UK & EU Space Design Competitions and Galactic Challenges builds on the fantastic legacy of Sir Naim Dangoor, who supported the Competition for a number of years.

Global Space Design Challenge runs a summer camp for students from around the world. It offers varied series of lectures and workshops on STEM subjects, computer sciences, robotics, business, design, university preparation and medical. It culminates in a two day Space Design Competition. Students meet and travel to Oxford, Cambridge and London Universities. It uses its profits to help support the Space Science Engineering Foundation.

GSDC **Global Space Design Competition**

RUBY

The UK Space Agency has been a generous supporter of the UK and EU Space Design Competition and Galactic Challenge since 2013. They are at the heart of the UK efforts to explore and benefit from space.

UK SPACE AGENCY

EMERALD

For 60 years the Trustees of the Garfield Weston Foundation have supported local charities across the UK. These small to medium organisations are often un-sung champions

W Garfield Weston FOUNDATION

EMERALD

Didymus

GARNET

Didymus is a small grant making charity. Their funding helps organisations in England, Wales, Africa and South America.

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At Rolls-Royce we believe in the transforming potential of technology. We create amazing products and services that have a real positive impact on the world and people's lives.

THE UNIVERSITY of EDINBURGH

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BEDE'S

CARDIFF UNIVERSITY PRIFYSGOL CAERDYDD

GSDC Global Space Design Challenge

Imperial College London

UNIVERSITY OF OXFORD

UNIVERSITY OF LIVERPOOL

Department of Earth Sciences
Imperial College London

The Foundation Society

Office of the President **16 March 2054**

GREETINGS AND SALUTATIONS!

This is the year **2054.**

You have been called to this meeting because your company is considering bidding on a contract to design and construct an ambitious project in cis-lunar space. The agency that will award the contract is the **FOUNDATION SOCIETY**, an organization founded for the specific purpose of establishing settlements of its members in space.

YOUR TASK this weekend is to design facilities for a **SPACE SETTLEMENT** where thousands of people will live in orbit around the Earth-Luna L5 libration point. Your team must agree on a design that satisfies requirements specified in the Request for Proposals (RFP) defined by the Foundation Society. You will prepare a **35 MINUTE presentation** describing your proposed design, which will be presented by one or more of your team members. The presentation must include dimensioned drawings of your design, and define areas designated for specific activities. You will be expected to justify facility sizes and locations, explain how the structure will be built and populated, estimate cost and schedule for construction, and show systems that will enable the residents to live and work in their new community. At the conclusion of your presentation, members of the Foundation Society will have the opportunity to ask questions about your design for 10 minutes. They will then evaluate your design versus those of the companies competing against you, and choose a winner.

Successful development of your proposal will require coordination of design details with engineers from four major departments in your company. Your company's management has the responsibility to ensure that communication is both effective and timely, in order to assure that all of the RFP requirements are met, and that all parts of your design are compatible.

This is much to accomplish in a short time, so **GOOD LUCK**!

Edward Smith
President

Timetable - Saturday

Time	Activity	Room
08:15	Arrive at Imperial College London Exhibition Road entrance Registration Meet CEOs	
09:00	Welcome to the Space Design Challenge!	CG 200 *
09:20	The Space Quiz Show – Anita Gale	CG 200
09:45	You're in the future now! - What will happen this weekend? Trisha Saxena	CG 200
10:15	How companies work – Anita Gale	CG 200
10:25	You're a professional now! Trisha Saxena	CG 200
10:35	Groups move from lecture theatre to Department of Earth Science & Engineering Students move to company headquarters Accompanying adults retire to Teachers' Lounge	2.28
10:45	Organisation assignments in companies (Students): Dougledyne Fletchel Rockdonnell Grumbo Aerospace Vulture Aviation	 G.39 G.20 G.01 G.38 G.41
11:15	Technical training sessions (Accompanying Adults welcome): Structural Engineering Operations Engineering Human Engineering Automation Engineering Management	 G.38 G.39 G.01 G.41 G.32
12:30	Companies occupy headquarters to begin designs (Students) Retire to Teachers' Lounge (Accompanying Adults)	As above 1.31
12:30 - 13:30	Lunch - Groups will be called to lunch on a rota system. Please remain in your company headquarters until you are called.	G.35
18:00 - 19:00	Dinner - Groups will be called to dinner on a rota system. Please remain in your company headquarters until you are called.	G.35
22:00	Students proceed to overnight accommodation with accompanying adults.	

Timetable - Sunday

Time	Activity	Room
08:00	Company representatives submit finished design proposals to the Foundation Society on USB at the main entrance to the Royal School of Mines on Prince Consort Road	
08:45	Assemble for design presentations	CG 200
09:00	First design presentation All teams and accompanying adults present in audience. All teams must be present at all presentations throughout the day.	
09:45	Second design presentation	
10:30	Third design presentation	
11:15	Comfort break	
11:25	Fourth design presentation	
12:10	Fifth design presentation	
12:50	Groups move from lecture theatre to Department of Earth Science & Engineering	
13:00 - 14:00	Lunch for participating students and accompanying teachers. Groups will be called to lunch on a rota system. Please remain in your company headquarters until you are called.	G.35 1.31
14:00	Groups move from Department of Earth Science & Engineering to lecture theatre	CG 200
14:30	Judges' debriefing and announcement of winning design	CG 200
15:45	Winning company moves back to their company headquarters	As per Saturday
16:00 – 16:30	Adjourn and participants depart	

* All presentations on Sunday will take place in the main lecture hall in the City Guilds Building ground floor Lecture Theatre CG 200.

Competition Description

Space Settlement Design Competitions are industry simulation games for secondary school students, set in the future. The Competitions emulate, as closely as possible, the experience of working as a member of an aerospace industry proposal team. This year's UKSDC Finalists will design a settlement in orbit around the Earth-Moon L5 libration point. To help them accomplish this challenging task, each team is provided with managers from industry to serve as Company CEOs. The participants then receive technical and management training to prepare them for the Competition. They must design an overall structure, define sources of construction materials, specify vehicles used for transportation, determine sources of electrical power and water, design computer and robotics systems, specify allocation of interior space, show attributes of pleasant community design, and provide estimated costs and schedules for completion of the project. The Competition concludes with the teams' presentations of briefings describing their designs to a panel of judges. The experience of participating in a Space Settlement Design Competition teaches young people optimism for the future, technical competence, management skills, knowledge of space environments and resources, appreciation for relationships between technical products and human use, teamwork, and techniques for preparing effective documentation. It requires that students integrate their knowledge of and utilise skills in space science, physics, maths, chemistry, environmental science, biology, computer science, writing, speaking, art, and common sense. The Space Settlement Design Competition concept is sponsored by

Aerospace Education Competitions, and the National Space Society (NSS) in the United States. The winning team will select members to proceed to the Finalist Competition at NASA Kennedy Space Center in the USA in July.

In 2018 we celebrated **10 years of UKSDC**

Standards of Conduct

The Competition Venue has graciously allowed us to use their facilities. In return, the Competition organisers have established some guidelines that we must follow while we are here:

General

1. Any behaviour not normally permitted in a work place (e.g. smoking, consumption of alcohol, or use of other controlled substances) is not permitted in any of the buildings or facilities we occupy for the Competition.

2. Leaving designated Competition sites during the Competition is not permitted, except in the presence of a Competition organiser or team advisor. Please understand that your family considers the Competition to be responsible for your safety and well-being during the event; you expose the Competition to unacceptable risk if you leave designated areas.

At Venue

3. The Competition Venue operates seven days a week. Please do not venture out of areas designated for Competition participants or open to the public.

4. You may encounter equipment operating unattended. Do not touch any equipment that has not been allocated to the Competition. If you are not sure if a piece of equipment is intended for use by the Competition, please ask a Competition organiser.

Competition organisers and/or team advisors will be available at all times throughout the day at the venue. If a circumstance arises that is not explicitly covered by these guidelines, please ask a Competition organiser, and/or use common sense in your choice of actions. Remember, you are a professional now. Your cooperation in following these guidelines is greatly appreciated. Your responsible behaviour will enable use of these facilities for future Competitions.

Rules of the Game

The Competition may be conducted **ONLY** with the information and tools available onsite, whether provided by Competition organisers or brought by the participants. No off-site assistance is permitted after participants arrive.

You are working for a Company. Companies do all sorts of things besides creating products, and so can yours. Remember, however, that only a few people can make binding commitments for the company - and if you make a promise or commitment on behalf of your company without your CEO knowing about it, you may be fired. This applies especially to personnel decisions.

You can have food and drink in your company headquarters, but you must maintain a clean and professional working environment (wrappers, uneaten food and rubbish must go in the bin).

Your Product

Your Company must hand in a USB memory stick with your final presentation to the event organisers by the deadline listed in the timetable. Presentations not meeting the deadline **WILL BE PENALISED**, and the later the submissions, the more severe the penalty.

YOUR COMPANY'S PROPOSAL PRESENTATION MUST MEET THESE REQUIREMENTS:

- The first page must have your company name on it.
- It must be in PowerPoint (Microsoft), Keynote (Apple), or PDF format.
- No more that **35 slides** may be submitted, any additional slides or hand-outs will be disregarded.
- Models, artwork, and transparency slides are permitted, but images/scan must be included in your presentation.
- Last for no more than the allocated time given to you at the morning briefing.
- All slides, and graphics must be readable. Illegible text and faint line drawings may be disregarded.

You do not need to present every slide. Any additional slides (within the 35 slide limit) can be used to answer judges' questions or to provide supplementary data for the judges' consideration (at their discretion).

Event organisers print paper copies for the judges before the presentations starts. Your originals will remain the property of the Competition organisers, who reserve the right to reproduce or publish the images thereon.

Failure to follow any of the above rules may result in your company being **penalised** or **disqualified** from the Competition. If you have any questions or issues, please ask a Competition organiser.

History of the Competition

Your presence here is part of a long history of Space Settlement Design Competitions.

It all started in 1983, when plans were being made by the Boy Scouts of America for the 1984 National Exploring Conference. The steering group for the Science and Engineering Cluster decided it would be great to do something neat about space. Evelyn Murray from the Society of Women Engineers (SWE) contacted **Anita Gale**, who worked on the Space Shuttle program, and along with Rob Kolstad (a member of the steering group) they outlined the basic structure of the event, that it would be both a design competition and a management simulation game. Anita and Dick Edwards wrote the materials for the game, and the first Space Settlement Design Competition was conducted at Ohio State University (between thunderstorms and tornadoes) in **August 1984**, with about 75 participants. It was wildly successful. Even astronaut Story Musgrave stopped by to watch design presentations.

The Explorers' Science and Engineering Cluster was so impressed by this event, they decided to make sure it would continue in some form. Eventually, the Boy Scouts Space Exploration Post at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, agreed to try it out on a local level. The first SPACESET was held in 1986. Eighteen SPACESET competitions were conducted at the JPL, with as many as 160 students participating each year.

The first annual National Competition was organised when SpaceWeek organisers thought it would be appropriate to include a Space Settlement Design Competition in commemorating the 25th anniversary of the first lunar landing, in July 1994. The first National event took place in Washington, D.C. Astronauts and cosmonauts who attended were so impressed with its educational value that they insisted that it continue as an annual event. Although it soon became evident that SpaceWeek International was unable to sponsor subsequent National Competitions, the promise made by Anita and Dick was accomplished in 1995 at Epcot in Walt Disney World, and the Third Annual Finalist Competition moved to Kennedy Space Center in 1996, where it continued until moving to the Johnson Space Center in 2006.

The idea of a UK Semi-Final was first suggested by **Dr Randall Perry** of Imperial College, London whilst on a Grand Canyon raft trip with Anita and Dick where he heard their descriptions of the Competitions.

Dr Perry set up the Space Science & Engineering Foundation to run the competition from Imperial College London in **2008**. The UK's first entry to the International Competition was a team from Riddlesdown Collegiate in 2009. The next year, the UK competition expanded to involve 160 pupils from 12 schools. The winning company, composed of students from Wallington County Grammar School, Pate's Grammar School, and City of London Academy, Southwark, sent a team of 13 students to represent the UK in the International Competition. They came back from Houston as winners!

The UK competition has grown from strength to strength. The first regional competition was held in Cardiff in 2013 and the 2017-2018 programme comprised of ten regional heats. The micro competitions were replaced with the **Galactic Challenge** for ages 10-14 with Bede's School hosting the first GC of 2018 with 85 students and an audience of nearly 200, which has now expanded to competitions of up to 120 students with over 400 people attending the presentations.

Reality vs SSDC

Like Industry

A statement you may hear several times during your Space Settlement Design Competition experience is "Now you know what it's like in industry!" This is, after all, an industry simulation game. You will have too much data in some areas, too little in others, not enough time to search out what data are available, personnel conflicts in your organization, technical conflicts between departments, difficulty in describing your entire design during the time allowed, and questions from the judges that you consider unfair (or "I forgots" revealed). All of these are challenges faced by real engineers in real companies (and have been faced by many of the volunteers you will meet). Of course, a lot of the Space Settlement Design Competition is pure fabrication: it describes, as history, things that haven't happened yet. So, what is real, and what is Design Competition speculation?

Speculation

The basic products, vehicles, and structures described for the Space Settlement Design Competition are technically possible, within the timeframes indicated. They do, however, represent ambitious technical, economic, and political commitments. Some will never happen, some will. Some are projects that Competition participants who become engineers will work on during their careers.

The Design Competition companies, including their product lines and histories, are based on composites of real corporations, projected into the future. No Competition company, however, is based solely on a single real company. Company names do not indicate any similarity to real corporations. The recommended Design Competition organization chart is a true reflection of part of a generic organization structure used by many companies.

There is no such organization as the Foundation Society (too bad!). The described efforts by the Foundation Society to foster commercial space infrastructure development could, however, be accomplished by other existing organizations.

Mostly Real Life

The Request for Proposals and proposal process reflect, as closely as possible, the system by which real corporations propose and win contracts for new business.

Information about space, asteroid, and lunar environments and resources is based on numerous references. Articles and other materials provided for background information are genuine technical documents that have appeared in print, or were specifically prepared for the Design Competition but are based on serious research. Sources are clearly marked where possible, and are genuine. "Department Descriptions" represent a summary of the types of tasks, analyses, and factors that similar real groups address.

The insidiousness, abrasiveness, and just plain nastiness associated with lunar and dust are real. It is incredibly fine, gets into everything, defies all attempts to completely remove it from anything that has been outdoors, and will ultimately destroy any mechanical equipment it gets into. Long-term habitations on Luna or asteroids must take every grain of tracked-in dust seriously; gradual accumulation over time will result in serious problems.

Future

Descriptions of specific future commercial products manufactured in space, space-based businesses, and health benefits of life in space are pure speculation. Global economic benefits from expanding human activities in space are wishful thinking, although the described triggering events for largescale infrastructure development in interplanetary space are plausible. "Silicon buckystructures" manufactured in the space environment and their amazing material properties were invented for the Competition.

If, during this experience, you have any questions about NASA or the aerospace industry, feel free to ask your company's CEO or another adult volunteer--many of whom do the same things in real life that you have the opportunity to do here.

How companies work

Beginnings

Projects as huge as the space settlement being designed for this competition are excellent examples of how large companies came to be.

For most of human existence, the things that people used could be produced by individual people, or by small groups of people. Technology was simple enough that if a product was required in a place, somebody could be found nearby to replicate it. Exceptions were large public works projects: government buildings, aqueducts, roads, city walls, bridges, cathedrals, and temples. Construction of these structures was controlled through government or church bureaucracies.

Transition

Advances in technology changed all of this. Machines were developed that could do work better and more quickly than muscle. Complex machines could not be replicated easily, so demand for products meant that the suppliers were encouraged to grow to meet the needs of their customers. Giant corporations evolved that could complete huge projects. When companies do not have what they require to do a task, they subcontract and combine resources with other companies.

As organisations grew, they had to adopt new ways of doing business, adopting replicated military patterns that had been used for millennia to coordinate the efforts of huge numbers of people. This worked reasonably well in early corporations, where the intelligence resided at the top, and the other workers could do their jobs adequately just by following orders.

Management Evolution

In only the past few decades, the nature of the products produced by large corporations has been changing, and their organisations have been evolving to adapt. To stay in business, corporations must now rely on the intelligence of employees at all levels, not just at the top. Employees determine the very nature of the products that can be offered by the corporation.

The whole science of management is changing to accommodate this new type of employee. It includes recognition that communication is the lifeblood of the organisation, each individual employee has unique skills to offer, employees at all levels are more productive if they enjoy their work, and employees enjoy their work best when they feel it is important.

Communication is the greatest challenge faced by top management. The sheer size of some organisations illustrates the problem - 20,000 workers at one plant is not uncommon. Some firms have dozens of divisions world-wide, and employ hundreds of thousands of people. Effective operation requires, however, that people working on different parts of a project share information. Sometimes a problem on one project can be solved by a person on another project.

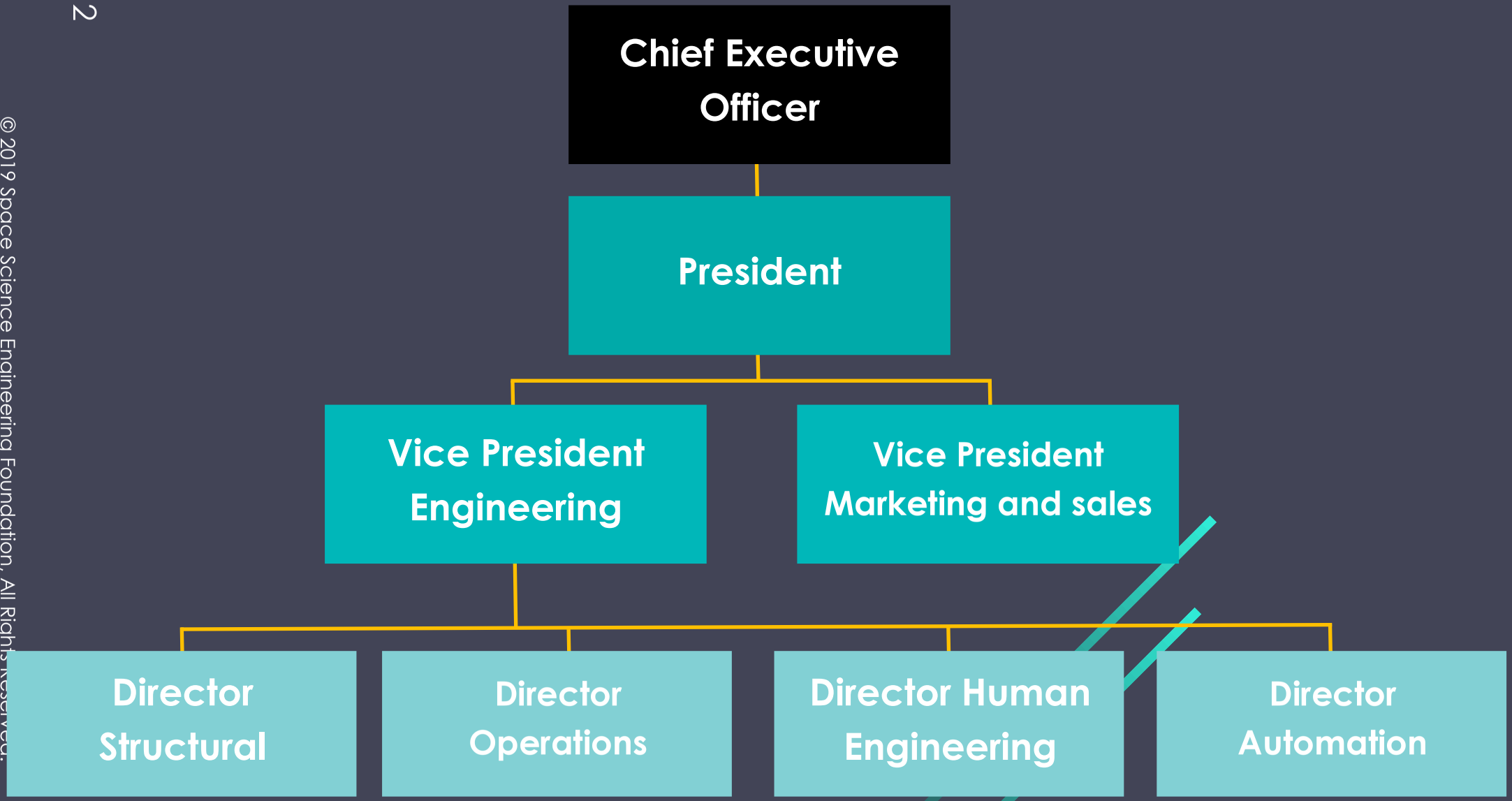
Money

Professional people are expensive. To support one engineer, a company typically pays up to $200,000 each year for the salary, supplies, utilities, and other overheads including the secretaries, janitors, guards at the gates, fire department, first aid station, and computers.

Your turn

This all seems very intimidating when you have just accepted a first job in a huge corporation. Your first assignments will be relatively straightforward tasks you were hired to do. If you get stuck, you will find lots of other people in your group, including your manager, who will help you. After a few years, you will establish your niche in the organisation, and in a few more years you could become an expert in your field. You will become more valuable as you know and are known by more people with other special knowledge.

COMPANY ORGANISATION CHART



Leadership Roles

CEO

CEOs are responsible for overseeing the company. They will guide you to the correct rooms for working, lunch and presentations. They will also run the leadership elections early in the day and outline the schedule for the competition. CEOs are also available all day for technical help.

President

The President of the company has a lot of responsibility. They are ultimately responsible for delivering the final product to the judges. The president must ensure the rest of the company is working efficiently and on time. They may want to call meetings between their departmental heads at periodic intervals. They will have the final say on any decisions and will most likely want to co-ordinate with the CEO closely.

Vice President Engineering

The Vice President of Engineering, reports to the president on the progress of the engineering teams. Departmental heads will report to the VP Engineering. They have to help co-ordinate the different departments and in the process, help resolve technical problems between departments. The VP Engineering should have strong leadership and presentation skills. They must also ensure that the team completes all the RFP points.

Vice President Marketing

Vice President of Marketing will work closely with individuals in the company to compile the presentation. They may want to create several drafts or an active draft using Google Docs. The VP Marketing is responsible for the final presentation and must ensure that it meets all the requirements of the final presentation standards.

Departments

Departmental Heads

Each department listed below has a departmental head. They have the role of setting individuals within their departments tasks to complete . They must also be acutely aware of the RFP points that have been completed and particularly to those which have not.

Structural

The structural department determines the overall physical design of the base, along with exterior dimensions. They must provide dimensions and measurements to other departments. They should also be able to justify how their design meets the requirements of occupant capacity, cargo capacity and demographic requirements in the RFP.

Operations

Operations department has to design or subcontract some of the systems of the base. These Include life support, atmosphere control and power delivery. Operations must provide information to other departments on the systems they've designed and how they integrate with other departments. The RFP often also includes communication requirements in operations.

Human

Human Engineering often has to design a modern community environment for settlers. They will be asked to provide a variety of consumables, as well as quantities of consumables. They will be asked to design floor plans for typical residential homes. They will also be asked to procure or design spacesuits an specify their use and numbers. Entertainment is also an important part of Human engineering's task.

Automation

Automation has to specify and design the computing systems of the base. These could include servers, personal computers and network devices. They will also have to design robotics and specify systems for maintenance, repair and safety functions. The RFP will also ask for systems that enhance liveability in the community.

How to play the game

Space Settlement Design Competitions are industry simulation games that both show and require use of corporate communication techniques to get the job done. Your disadvantage is that you have an inexperienced staff lacking in technology and management skills - but so do all of your competitors.

In order for your company to create an effective design, the people in all four of your engineering disciplines must communicate with each other. Every department **influences the work of all the others**. You must be cautious, however: if you carry communication to the limit, with everybody working on the same part of the challenge all at once, you will be wasting time. You need to find a balance between doing the most things at once by having different people doing them, and having people working together to make sure the whole project fits together.

Your CEO is a manager where he or she works, and does this all the time. Your President, Vice Presidents, and Department Directors will have to learn this quickly. Everybody in your company needs to focus on the common goal: to provide a unique design that meets the **customer's requirements** and is **effectively communicated** to the judges.

You win the same way any company wins a proposal bid:

- Create a design that meets the customer's requirements
- Show in your presentation that your design meets the requirements

The Customer's requirements are described in the Request for Proposal (RFP):

- The RFP describes EXACTLY what the customer desires
- The winning design should address every issue or point included in the RFP
- There is plenty of latitude for innovation: show HOW your design meets the RFP

Think about the presentation as soon as you start the design process. Your Vice President of Marketing and Sales makes sure designs are portrayed in the most effective manner. Share the vision; get the judges excited about living in your design. **The best design in the world is worthless if you don't communicate it.**

Remember that the judges will look for weaknesses in your design, so be sure you can explain why the design is the way it is. "On the spot" engineering when being questioned usually only makes things worse.

Although innovation is encouraged, **feasibility is essential**. Base your design on the level of existing technology defined by the Competition organisers, laws of Physics, and common sense. Justify any technologies assumed in your design which exceed those described in the Competition materials.

We hope you enjoy the experience and learn a lot too, because we know that somewhere, right now whether it be late at night or the middle of the weekend - there are people in industry doing exactly the same thing, but for real money in real jobs. You may join them someday, and this is a great opportunity to learn how the game is played.

Space Characteristics

Space is not a friendly place. Mostly, it is nothing: vacuum, and apparent lack of gravity. What little there is in space is mostly hazardous, even the things that are assets.

Resources / Assets Cis-Lunar Space	Hazards to Humans and/or Structures in Cis-Lunar Space
Solar energy can be converted to electrical power by solar cells. (130W/ft2)	**Solar radiation** long-term exposure is deadly; solar flares are deadly in minutes.
Van Allen Radiation Belts provide protection in Low Earth Orbit from solar / cosmic radiation environment.	**Van Allen Radiation Belts** deadly to unprotected humans; two belts approx. 2000mi and 9000-12000mi.
Cosmic Radiation scientific study reveals clues about the universe.	**Cosmic Radiation** deadly to unprotected humans.
Lack of Atmosphere enables optimum viewing of distant objects for astronomy studies.	**Vacuum** survival requires life support systems; tiny amounts of atomic oxygen damage exposed materials.
Lack of Gravity enables manufacturing techniques and products not possible on Earth.	**Lack of Gravity** long stays in "zero g" cause bone loss and muscular deterioration.
Orbital Mechanics* enables satellites to stay at high altitudes "forever	**Space Debris** paint flecks do damage; small bolts cause holes.
Asteroids present opportunities for mining--can contain nickel, iron, water, carbon, carbon compounds	**Asteroids** small rocks can puncture spacecraft cabins; large body impact with settlement could be devastating.
Comets present opportunities for harvesting water ice.	**Comets** impact with spacecraft or colony would cause casualties.
Lunar Materials opportunities for mining oxygen, silicon, iron, aluminium, calcium, magnesium, titanium	**Lunar Dust** gets into and damages machinery, making long-term operations on the Moon difficult.

* The primary law of space is Orbital Mechanics, which determines where things can stay and where they can go. Everything in space is moving, attracted by gravitational fields (usually interacting) of every major object in the vicinity. Which orbit an object is in depends on its position and velocity at any particular time. Orbits are changed with acceleration due to thrust, usually from rockets. Satellites are constrained to be far enough above most of any atmosphere that an orbit can be sustained for a few days before decaying through friction with the atmosphere (about 100 miles above Earth's surface; a 150-mile Earth orbit can be maintained for about five years, a 250-mile orbit for about ten, with variations depending on solar activity and other factors that can cause the atmosphere to expand or contract). Objects with bigger cross-sections experience faster orbital decay. Higher velocities put objects in higher orbits; an object achieving "escape velocity" (25,000 mph for Earth) will leave the influence of its "host", and go into orbit around something else. Orbits are also not perfectly stable. Satellites use small rockets for "station-keeping" to stay where desired. Some quirks of orbital mechanics cause gravitational forces of large bodies to be in balance at some locations, creating "Libration Points" that are either very stable (L4 and L5) or are unstable in one plane (L1, L2, and L3), and require substantial station-keeping to maintain spacecraft in position.

Existing space infrastructure

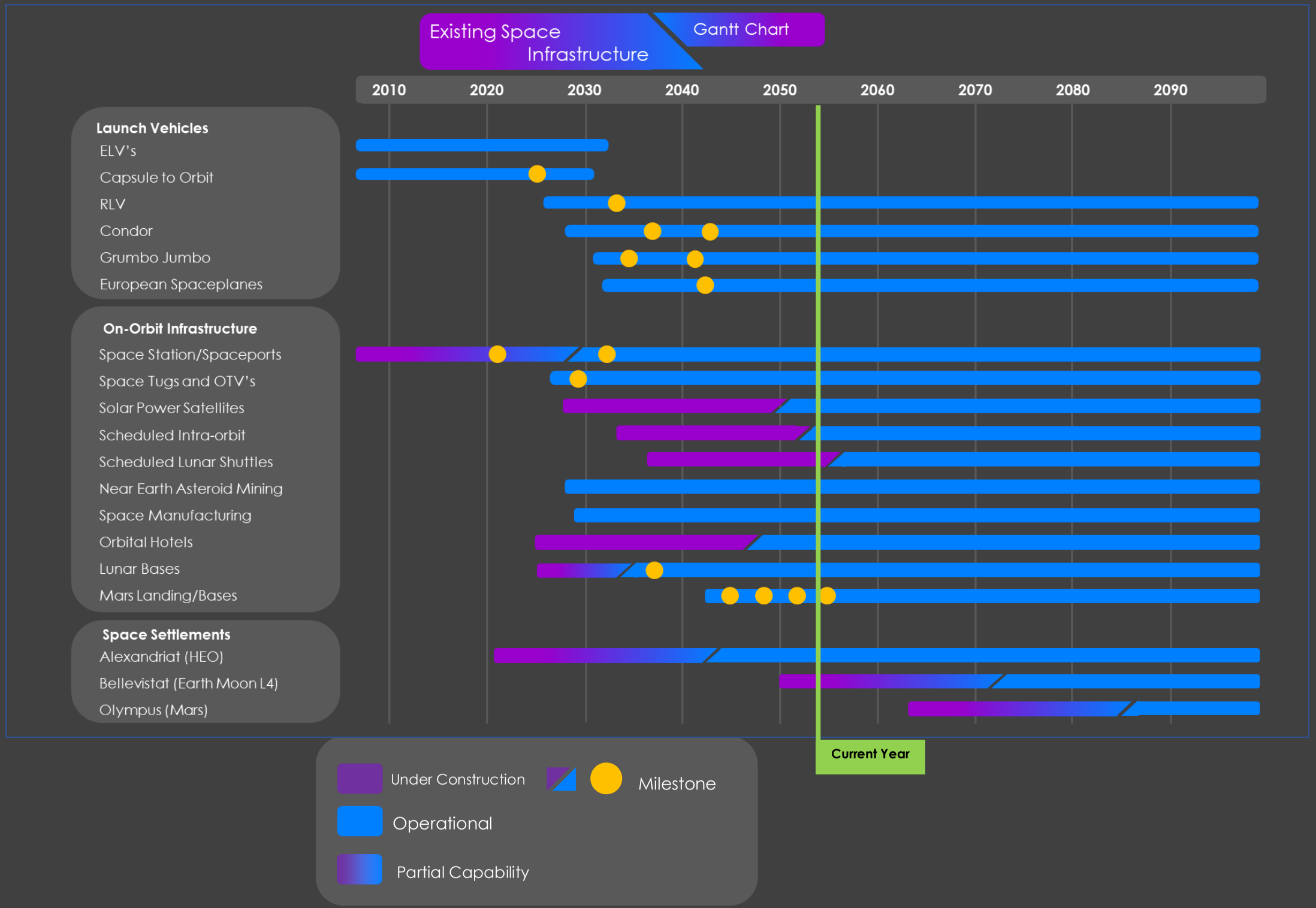
Earth orbit in 2054 is a very busy place, with thousands of satellites serving the seemingly insatiable human appetite for communication, navigation, observation, manufacturing, and energy. Cis-lunar space has become the domain of commercial enterprise. Launch costs from Earth are as low as $750 per pound, and scheduled transportation services run between various locations in Earth orbit.

The commercial space economic boom started with suggestions in the early 20-teens that there was a business case for repairing, refurbishing, and upgrading satellites on orbit--launching just the lightweight parts needing replacement, and installing them on heavy satellite structures with lifetimes limited only by what can be installed on them in the future. In 2023, several major aerospace companies formed the Space Enterprise Applications Consortium (SEAC), which pooled corporate resources to develop space infrastructure components, and all SEAC companies agreed to buy each others' services in space. The companies turned to the Foundation Society--then a venture capital investor organization funding entrepreneurial space tourism launch vehicles--to lead the project. Government partners in the International Space Station (ISS) turned over ISS ownership and operations to SEAC, which renamed it Space Station Freedom. In exchange, SEAC agreed to develop capability to capture space debris, some of which it uses for parts and materials for building new spacecraft and refurbishing old ones. SEAC partners adapted existing ISS component designs to quickly produce space tugs, depots, transfer vehicles, and lunar landing craft.

The wisdom of aggressive commercial cis-lunar infrastructure development was proven when lunar base residents discovered new materials and products that could only be created from lunar resources. Private companies established multiple commercial operations on Luna, and have solved many of the technical challenges associated with living there. The Foundation Society invested in a new habitat--essentially an orbital industrial park--for refining of lunar and asteroid materials, on- orbit manufacturing, and assembly; declared it the first permanent human settlement in space; and named it Alexandriat. SEAC added LEO spaceports Liberty and Independence, which serve as transfer ports for exports, imports, and passengers between Earth and space. Demand for increased traffic between Earth and space justified commercial development of more cost-effective launch vehicles; passengers fly to one of the three LEO spaceports for $500,000 per person, with a 250 lb weight allowance for person and possessions. Increased commercial responsibility for space services, and resulting reduced costs, enable governments to invest more in exploration beyond cis- lunar space, including human missions to Mars.

In the early 2030s, the Foundation Society established lunar habitats to assess resources and identify products that can be made from lunar materials. The exploration and experimentation conducted at these habitats confirmed the abundance and variety of lunar minerals, and established processes that enabled the beginnings ot an entire industry supplying commodities in space. Mining of near-Earth asteroids provides pure ores of nickel and iron, and carbon compounds.

Alexandriat and SEAC changed humans' relationship to space. People living in space make things in microgravity and vacuum that are difficult or impossible to make on Earth's surface. The most profitable space products are nanobots, microscopic robots that perform tasks at the molecular level. Although envisioned for decades, they were impractical until an Alexandriat lab grew them. They originally modified molecules to form an airtight seal on the settlement's interior surfaces; with experience, more uses are being developed, including fusing coatings on surfaces and separating the elements mixed in metallic asteroids. Nanobots are a major export category, spurring increased production of space manufacturing facilities and vehicles to get them to dirtside customers. Most satellites and products used in space are now made in space of lunar and asteroid materials. Although dirtside governments do not tax products imported from space, many space products are components in goods manufactured on Earth, resulting in increased economic activity--and hence tax revenues--eradicating government debt and enabling balanced budgets world-wide.


Existing Space Infrastructure
Gantt Chart
2010
2020
2030
2040
2050
2060
2070
2080
2090
Launch Vehicles
ELV's
Capsule to Orbit
RLV
Condor
Grumbo Jumbo
European Spaceplanes
On-Orbit Infrastructure
Space Station/Spaceports
Space Tugs and OTV's
Solar Power Satellites
Scheduled Intra-orbit
Scheduled Lunar Shuttles
Near Earth Asteroid Mining
Space Manufacturing
Orbital Hotels
Lunar Bases
Mars Landing/Bases
Space Settlements
Alexandriat (HEO)
Bellevistat (Earth Moon L4)
Olympus (Mars)
Current Year
Under Construction
Milestone
Operational
Partial Capability

Milestone Listing

Infrastructure Type	Milestone Number	Year	Description
Capsules to Orbit	1	2024	Manned capsules become available
RLV	1	2034	Development of "Mid-Size" RLV capable of 45,000 lbs to LEO
Condor	1	2037	Scheduled service to Alexandriat begins
	2	2044	Condor Max introduced, capable of lifting 50,000 lbs to LEO.
Grumbo	1	2036	Block II Jumbo first flight, capable of 120,000 lbs to LEO.
Jumbo	2	2040	Block IV Jumbo First flight, capable of 200,000 lbs to LEO.
European Spaceplanes	1	2043	First flight of Weltraumreiseflugschiff capable of 80,000 lbs to LEO.
Space Stations / Spaceports	1	2021	ISS renamed "Space Station Freedom" & turnover to SEAC.
	2	2028	Space Station Freedom expansion completed.
	3	2030	Space Station Liberty construction completed and brought online.
	4	2033	Deep Space Gateway completed allowing for orbital mission launch.
Space Tugs/ OTV	1	2029	Dedicated LEO docking station completed and brought online.
Solar Power Satellites	1	2050	Construction of first SPS array complete, test of Laser power delivery successful.
Scheduled Intra-orbit service	1	2053	Support infrastructure completed for service between orbital Space Stations, and start of scheduled service.
Scheduled Lunar Shuttles	1	2055	First flight of Lunar shuttle service after completion of Lunar Base Aphelion, spaceport on the lunar surface.

Milestone Listing

Infrastructure Type	Milestone Number	Date	Description
Orbital Hotels / Resorts	1	2033	Rockdonnel brings "Cove" online, the first Space Hotel online.
		2044	Planned completion of "Tranquillity" space resort, a resort comprised of two halves orbiting 200ft from each other.
Lunar Bases	1	2026	Completion of "Armstrong", first Lunar settlement, and first permanent Human settlement on another Celestial body.
	2	2027	Completion of "James Town", first Lunar Settlement capable of hosting families, with dedicated paediatric hospital.
	3	2036	Completion of "Hephaestus", first off-planet Spacecraft and booster manufacturing facility.
Mars Landing	1,2,3 & 4	2041 - 2044	First landings of man on the planet Mars, expeditionary visits without permanent habitation.
Alexandriat	1	2034	Completion of first habitable module and first crew move in.
	2	2039	Completion of station, with full complement of crew.
Bellevistat	1	2049	Completion of first habitable module and first crew move in.

THE FOUNDATION SOCIETY

The Customer

The **FOUNDATION SOCIETY** is an organization founded for the specific purpose of **establishing settlements** of its members in space

The Foundation Society first gained recognition for its successful lobbying efforts with the governments of spacefaring nations to establish property rights in space. The system it caused to be enacted is based on the Homesteading laws of the American frontier: a corporation or even a person can claim an orbital location, an asteroid smaller than 10 miles in diameter, or a plot of land up to 10 miles by 10 miles in size, so long as it does not interfere with other active claims. A claim remains valid so long as the claiming entity actively uses its claimed property; claims not in active use for four Earth years revert to unclaimed status and are available for another entity to claim.

Foundation Society executives saw the request to lead the SEAC consortium as a major step toward their true goal of developing large settlements where thousands of people could live in space, and sponsored a modest space manufacturing facility as a small community orbiting just below the Van Allen radiation belts. The Society's engineers created a modular design for a small community that would grow with expanding business opportunities. With a high-orbit Orbital Transfer Vehicle to manoeuvre target satellites to the facility and return them to their operational locations, a crew of 20 experimented with satellite recovery, repair, and upgrade processes.

The Foundation Society encouraged the crew at their growing orbital manufacturing facility to tinker and experiment with materials and processes in zero g and vacuum. The crew represented the largest pool of unscheduled hours ever experienced in space, and their creativity quickly produced results, including innovations in processing lunar materials. Their most stunning success was a form of silicon resembling the structure of carbon nanotubes; dubbed "buckystructures", the material is extraordinarily strong in tension, and can be formed into flexible strands and cables of unlimited length, or vast nets and sheets of fabric. Colours range from milky white to quartzlike transparency, properties of different forms and with various introduced impurities include thermal insulating qualities, electrical conductivity, sound transmission, adhesion, or light refraction The most exciting variant so far is a bright white fabric that tolerates the space environment and prevents penetration by space debris up to two inches in diameter (although

Anticipating that large quantities of cargo will be shipped in cis-lunar space, the Foundation Society established a standard for space cargo containers that is compatible with SEAC members' launch and space vehicles. Cargo Accommodation in Standard Space Shipping Container (CASSSC) units are 30 feet (9.144 meters) long with nearly-square 15-foot (4.572 meters) cross-sections (corners of the cross-section are rounded with a 1-foot radius). Depending on launch vehicle capability, CASSSCs allow maximum weight varying between 25,000 and 35,000 pounds (11,340 to 15, 876 kg). CASSSC weight is counted as part of the vehicle, not charged against cargo.

The Foundation Society expanded the orbital facility and supporting infrastructure, pushing it to become the first true space settlement. It was named "Alexandriat", acknowledging Alexander the Great's expanding his empire into unknown territories. Its population has grown to over 10,000 people, and the Foundation Society is establishing the University of Space Engineering Industry and Technology (USE IT) at Alexandriat, to service the research and higher education needs of the growing spacer population. Large-scale materials refining, heavy industry, and mass production moved to the settlement Bellevistat in Earth-Moon L4 orbit, specifically established for these purposes. Arial, a settlement in lunar orbit, improves transportation to and from the lunar surface. Alaskol, under construction on the lunar surface, will provide improved access to, processing of, and transportation for lunar resources. [Note: in the Foundation Society's system for naming its communities, a suffix indicates location, and communities with the same suffix receive names in alphabetical order. Suffixes currently or soon to be in use are "at" = "(in orbit) around Terra, "al" = (in orbit) around Luna, "ol" = on Luna, and "as"=(in orbit) around the sun Sol.]

DOUGLEDYNE
ASTROSYSTEMS

Specialise in:

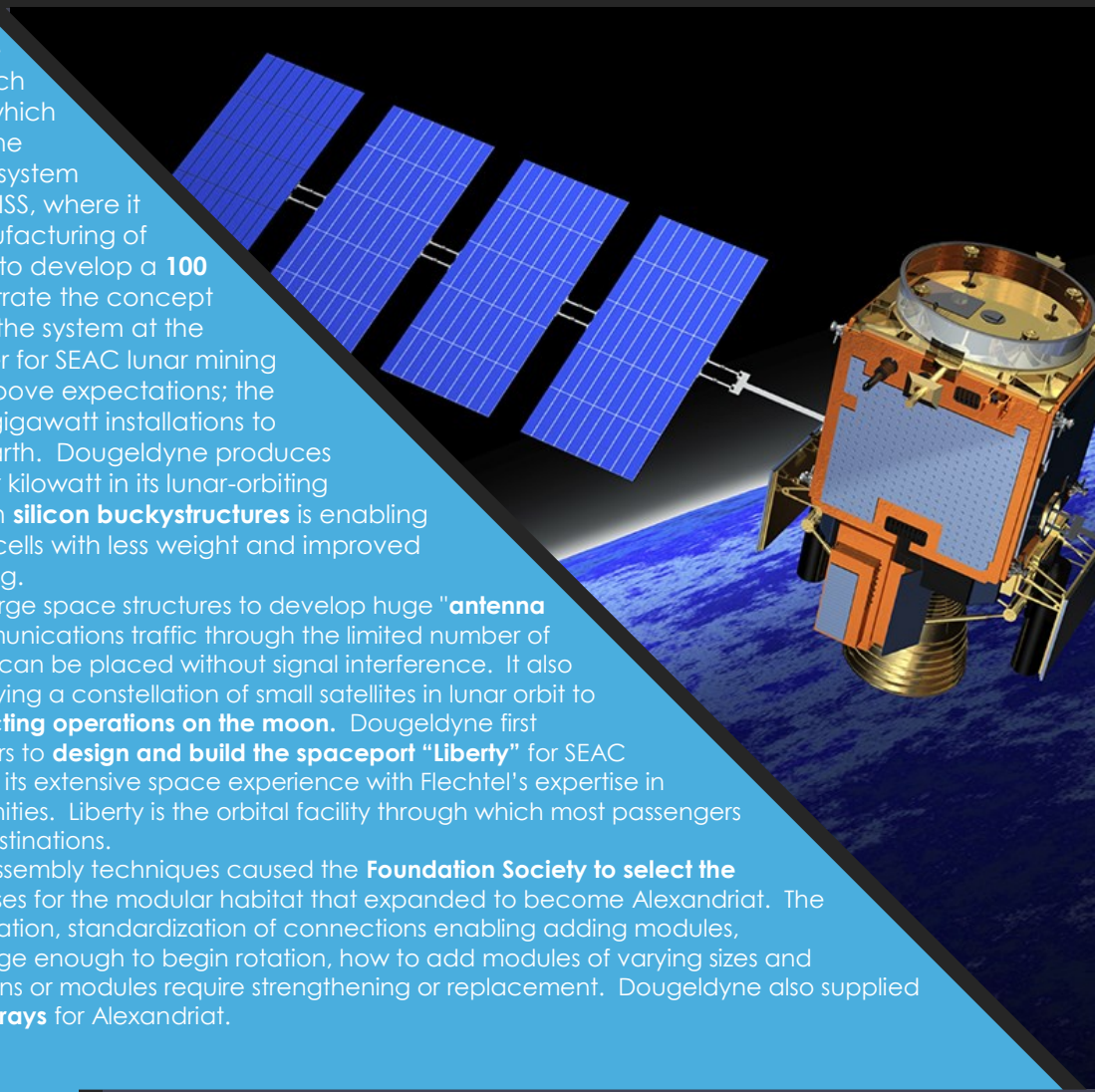
- Unmanned power systems
- Solar power Satellites **(SPS)**
- On orbit Assembly of large space systems (Alexandriat)

ALEXANDRIAT
Assembled by Dougeldyne

Dougeldyne AstroSystems is the world's most prolific manufacturer of **unmanned satellites**. With humble beginnings making aircraft parts, the company entered the spacecraft business in the 1960's with a reputation for quality manufacturing of specialized products, and a few key employees.

Dougeldyne has been involved in the whole gamut of unmanned satellite systems, from complex scientific **satellites for NASA**, to simple "micro-sats". Beginning in the mid-1980's, the company has concurrently offered two or three different "standard" **communications satellite** models, designed for different parts of the space communications market.

The company was a pioneer in developing **constellations of small satellites** in low orbits for communications and navigation services. It built systems that enable use of hand-held satellite telephones, **global wireless Internet** services, and tracking of conventional shipping containers at any location on the Earth's surface; it also provided communications services for ISS, using it's proprietary QUANTUMN LINK© technology. The technology allows for communication channels which are **practically invulnerable** to interception.



A spinoff from the company's satellite business was a very successful research program in solar panel technology, which the company capitalized on to win the contract to develop the solar power system for ISS. It later leased facilities on the ISS, where it perfected techniques for low-g manufacturing of solar panels. The company planned to develop a **100-megawatt prototype SPS** to demonstrate the concept in the mid-20-teens, but instead built the system at the Earth-Moon L1 point to provide power for SEAC lunar mining operations. The system performed above expectations; the company is currently marketing ten-gigawatt installations to provide power for communities on Earth. Dougeldyne produces space-quality solar panels for $50 per kilowatt in its lunar-orbiting manufacturing facility. Research with **silicon buckystructures** is enabling development of more efficient solar cells with less weight and improved opportunities for space manufacturing.

The company applied its research of large space structures to develop huge "**antenna farms**" in GEO to handle growing communications traffic through the limited number of "slots" where communications satellites can be placed without signal interference. It also added to SEAC infrastructure by deploying a constellation of small satellites in lunar orbit to provide navigation services for **prospecting operations on the moon.** Dougeldyne first collaborated with Flechtel's Constructors to **design and build the spaceport "Liberty"** for SEAC infrastructure development, leveraging its extensive space experience with Flechtel's expertise in designing human systems and communities. Liberty is the orbital facility through which most passengers transition between Earth and space destinations.

Dougeldyne's knowledge of on-orbit assembly techniques caused the **Foundation Society to select the company** to develop assembly processes for the modular habitat that expanded to become Alexandriat. The company defined the original configuration, standardization of connections enabling adding modules, determining when the structure was large enough to begin rotation, how to add modules of varying sizes and purposes, and when original connections or modules require strengthening or replacement. Dougeldyne also supplied **communications antennas and solar arrays** for Alexandriat.

Fletchel
Construction

Involved in:

- Design and construction of **entire cities** on earth
- Lunar habitat and mining operations development
- Extraterrestrial materials refining and prospecting
- Spaceport **Liberty** and **Alexandriat** interior design

Nobel Laureates 2029

The company has been in business since the 1920's, when it designed and built **facilities for energy and chemical** companies. Until the late 1960's, Fletchel Constructions products were primarily oil refineries and factories producing industrial chemicals, fertilizer, and household cleaning products. The company has skills, however, for designing nearly any **industrial, commercial, or government** facility, and has been involved with concepts for power plants, ground transportation infrastructure, farming, logging, amusement parks, harbors, and airports. A consistent company philosophy is that every customer is important, and **no project is too big, too small, or too strange.**

Flechtel's fortunes changed dramatically in the 1970's, when its development of facilities to support the burgeoning mideast oil business led to contracts to design entire cities in the Saudi Arabian desert, including airports and water desalination plants. The "oil bust" of the 1980's caused some hard times for the company, until the collapse of the Soviet empire created renewed demand for its skills. Flechtel expanded rapidly during the 1990's and 20-aughts with contracts to upgrade Russian and Kazakhi oil industry and petrochemical plants, modernize the ground transportation infrastructure of Russia, Ukraine, and (European) Georgia, clean up environmental damage in Eastern Europe and Northern Asia, and rejuvenate several Eastern European cities.

Low-cost and high-quality construction techniques were applied after the year 2015 to bring about rapid development in poor countries. The company assisted in generating capital for major building projects, exploiting each nation's workforce skills and natural resources. This program was of such great benefit to developing nations that **Fletchel Constructions was awarded a Nobel Peace Prize in 2029**.

Fletchel Constructions has been associated with the aerospace industry since the late 1990's, when it researched requirements for construction of human habitats on the lunar surface. This work **defined standards** for light filtering and radiation shielding for different types of human activity on the Moon. A recent extension of this work is a **silicon buckystructure** white film that when placed on windows or helmet visors is transparent from the inside, and filters direct sunlight in daytime but provides visibility at night. The company used its lunar design experience to develop mining processes and equipment for SEAC. Its innovative designs for this project included **mining equipment that was assembled in place on the lunar surface**, using some components made from local materials. Despite its success with lunar mining, the company recognizes that metallic asteroids contain far more lucrative resources, and developed micro-g refining systems that are delivered to appropriate near-Earth asteroids by an Orbital Transfer Vehicle.

Fletchel Constructions also designed the **interior spaces and passenger transfer areas** for the Liberty spaceport, applying its experience with city design, and **advised Dougeldyne and the Foundation Society** on interior design of Alexandriat. Despite a limited selection of available materials and short construction schedules to build both projects, Fletchel Constructions created pleasant environments with ample recreational opportunities. Indeed, these attributes are credited for the interest in Alexandriat as a vacation destination for wealthy dirtsiders.

Fletchel Constructions teamed with Dougeldyne AstroSystems to help with concept development of SPS. Engineers from the two companies worked together to develop an efficient **microwave power transmission system**, and Fletchel Constructions built receiving antennas to collect the microwave energy and deliver it to the power grid. Dougeldyne's experience with orbital systems provides a strong complement for Fletchel Constructions's experience with **community development**; this synergy was put to good use when Fletchel Constructions designed the habitation modules for Dougeldyne's assembly of Spaceport Liberty, and is expected to put the team in a good position to win the Bellevistat contract.

GRUMBO AEROSPACE

Logo to celebrate **50 years** of Grumbo Aerospace

- Specialise in :
  - Multi-purpose "**F1M8**" Robots
  - **Launch Vehicles** and space tugs
  - Transportation services and robots for infrastructure projects
  - Lunar surface vehicles

Grumbo Aerospace is **one of four** major business groups of Grumbo International. The other three business areas are ground transportation products, electronics systems, and general industries.

The products of the General Industries business area include F1M8 Robots. Although F1M8s are available for a variety of uses, they all share a proprietary "**artificial intelligence**" capability that enables them to recognize commands in human speech and "learn" through experience. When **the company joined SEAC**, Grumbo developed F1M8s with capabilities needed to support space infrastructure development. The company's robots were sent to the Moon to build habitats at mining sites before humans arrived; they didn't last long in the highly abrasive dust, but replacements were sent frequently to keep production going.

The most successful products of the Electronics Systems Group are **data storage systems** that replaced traditional computer disks and hard drives. These systems fit in a pocket, have no rotating parts, generate so little heat that they require no cooling, tolerate severe environments and other abuse, will not destroy data if their few moving parts fail, and can be connected in groups to grow storage capacity almost indefinitely. They enabled the evolution of personal computers to the ubiquitous "dumb boxes" into which users plug in their own "smart guts".

The Ground Transportation Group **builds vehicles customized for operation in space**, with technical assistance from the Aerospace division. Grumbo ground vehicles are used for transportation near lunar bases.

F1M8 "intelligence" in control systems of vehicles used for construction enables significant reductions in costs and schedules through **autonomous operations capability.**

Grumbo did some of the earliest work on a space tug concept to **move satellites and cargo between orbital locations**. It intended to build the first unit for use at Space Station Freedom, and instead found itself in full production to **meet the needs of inter-orbit transportation** for SEAC infrastructure development and Alexandriat construction. The company quickly developed "supertug" versions suitable for moving materials to lunar orbit, with capabilities to deliver mass anywhere in cis-lunar space. Grumbo was also the first company to build an inter-orbit vehicle capable of carrying personnel to L5 and L1. Recent Grumbo research pioneered use of **silicon buckystructure** fabric to create additional habitable volumes on spacecraft and lunar facilities.

The company's most well-known product is the **Reusable Launch Vehicle (RLV)**, adapted from a design that lost a proposal in the mid-1990's. When SEAC infrastructure development greatly expanded the demand for launch services, Grumbo developed a mid-size RLV (25,000 lbs. payload capability to the existing spaceports, and 43,000 lbs to LEO) to transport construction crews and fragile equipment. This 200-foot-long vehicle was also the first to be compatible with the **Foundation Society's CASSSC cargo containers** now standard for all launch and space vehicles. Subsequent RLV versions meet the needs of various niche markets for launch services. RLV was briefly threatened by competition from the more economical Condor when it entered service two years later--until commercial operators realized that there were plenty of launch customers for fleets of both vehicles. Grumbo also developed designs for the "**Grumbo Jumbo**", a heavy-lift reusable Single Stage to Orbit design (100,000 lb. payload capability), which went into production for the Alexandriat project. This launch vehicle became the workhorse of cargo launchers to support settlement construction; its cargo launch costs are now **down to $1000 per pound**

ROCKDONNEL

Involved in:

- Mining, Space refining and manufacturing
- Supercomuters and "micro-abacus" modular computers
- Lunar Landing craft
- Alexandriat construction integration

Cove branding, for the companies private spaceport and hotel, a one bed suite costs $570,000 per night.

Rockdonnel was formed as a joint venture between two major firms to operate the re-purposed Space Station Freedom for SEAC, including making modifications for port operations. The Foundation Society later enlisted Rockdonnel's expertise for integration of Alexandriat construction; this task entailed assigning and keeping track of the diverse detailed design efforts, and making sure that all of the pieces would work together when they were assembled. When some tasks fell behind schedule, Rockdonnel assigned its own engineers to solve the problems. One parent company is a large aerospace firm with several divisions. The Spacets Division built the Space Station Freedom Laboratory Modules and many other large and small spacecraft.

The Rockonetics Division is a major producer of rocket engines. In a technical coup in late 2022, Rockonetics test-fired the first air-breathing engine that could honestly achieve Mach 25 in the upper atmosphere, which ultimately resulted in Vulture Aviation's Condor launch vehicle. The Compsec Division produces supercomputers used by the aerospace and entertainment industries, and builds a line of "micro-abacus" computers, advertised as fast, rugged, and transportable; a space-hardened version has become standard for use in crewed launch vehicles and space habitats. An especially appealing feature of these machines is that they can be customized to fit particular applications; they are built up of small modules that can be separated or combined to provide a range of computers.

When SEAC infrastructure development was announced, it was realized that carbon is not readily available from lunar materials, although it is essential for settlement operations. The Spacets Division completed the first successful mining operation on an asteroid, an Earth-crossing carbonaceous body about a mile across, accessible with cis-lunar Orbital Transfer Vehicles. This Division also built a small fleet of lunar landing craft, based on designs that had been maintained as a Research and Development project.

The other parent company is a large diversified firm with interests in infrastructure, real estate, hotels, and construction. This organization initiated a joint project with the aerospace parent company to build a small private spaceport and resort hotel in Earth orbit that began operations in 2030. The company used very aggressive marketing strategies to establish a public image for providing the ultimate in "status" vacation opportunities. All of the private suites are designed to provide stunning viewing of Earth below, and cater to guests' preferences to stay in zero-g, half-g, or intermediate acceleration environments.

Rockdonnell identified promising space manufacturing opportunities, as a result of Space Station experiments owned by the aerospace parent company. Its research with silicon buckystructures produced a structural net that maintains stability of rotating space structures and connection to a central hub without the need for spokes, enabling more reliable design and less expensive construction techniques. Space manufacturing capability was offered to other corporations on the condition that Rockdonnell design and build on-orbit space factories for commercial production of these products, and that 2% of profits from these operations be paid as a royalty to Rockdonnell. These space facilities manufacture pharmaceuticals, electronic components, genetically engineered organisms, and other high-value, low-weight-and-volume products. This capability is especially attractive for genetic engineering projects, which are prohibited by many nations on Earth that fear ecological damage if a process goes awry.

Vereinigten Flugfahrten GmbH

Specialise in:

- **Satellites and Upper stages**
- Orbital refining, manufacturing, and research using lunar materials
- **Launch Vehicles** and orbital transfer vehicles
- Automated manufacturing

Vereinigten Flugfahrten is a **major builder of commercial aircraft**, and the European Union's most prominent manufacturer of spacecraft. The company entered the spacecraft market in the 1970's, to satisfy the German government's requirement for military satellites without having to employ a foreign source for space technology. In 2023, the EU opted to fund production of a vehicle derived from Vereinigten Flugfahrten's Sanger Spaceplane design. Design development was slow, until SEAC infrastructure development increased demand for launch services. Sanger's small payload capacity limited its commercial value; most of its flights were quick missions to get **critical components to the spaceports in**

The company currently is developing the Weltraumreiseflugschiff to replace Sanger; it will evolve into a family of launch vehicles with **payload capabilities to 80,000 lbs**. The company sees a major future customer for Westraumreiseflugschiffen in European Space Lines, which plans to provide **passenger service** to orbiting hotels catering to guests from Europe, Japan, China, Africa,and developing countries.

Vereinigten Flugfahrten has a tradition of success through self-sufficiency, so **it makes many products that most spacecraft manufacturers would acquire through subcontracts.** An example was the company's own development of computers and cockpit displays for its launch vehicles. An internal "Synergy Department" adapted some of the vehicle technology to develop new computer systems for offices, whereupon the Marketing Department recognized a commercial opportunity: a Vereinigten Flugfahrten subsidiary surprised the global computer industry last year by introducing computers built into office desks, with a screen occupying the entire desk top. Touch-screen control of files enables handling computer files like papers on a desk, with many documents visible and "shuffleable" simultaneously. This design became an **"instant" success** in the retail market.

Vereinigten Flugfahrten designed and built European modules for **Space Station Freedom** and lunar bases, and for SEAC **built the "Independence" spaceport** through which most cargo from Earth is transferred for use in space. The company leveraged these contracts as opportunities to develop expertise in producing a variety of products in microgravity, and in extracting useful materials from lunar ores and asteroids. In order to assure complete privacy in its development of spacemanufactured products, Vereinigten Flugfahrten established its own **orbital refining and research facilities**, supplied by its own lunar mines, and serviced by its own fleet of on-orbit transfer and lunar landing vehicles to move goods to orbital construction sites. Following a tradition of "better late and better", the company observed the experiences of other companies before planning these operations. Vereinigten Flugfahrten is known to be researching **silicon buckystructures**; although the exact nature of the products it is considering has not yet been revealed, it has been observed that the Synergy Department is showing interest.

Even after decades of western European unification and although Vereinigten Flugfahrten is a SEAC member, European spacecraft ventures are primarily **government-sponsored endeavors**. This limits the company's access to resources for improving its technology for large-scale space projects, due to government priorities elsewhere.

VULTURE AVIATION

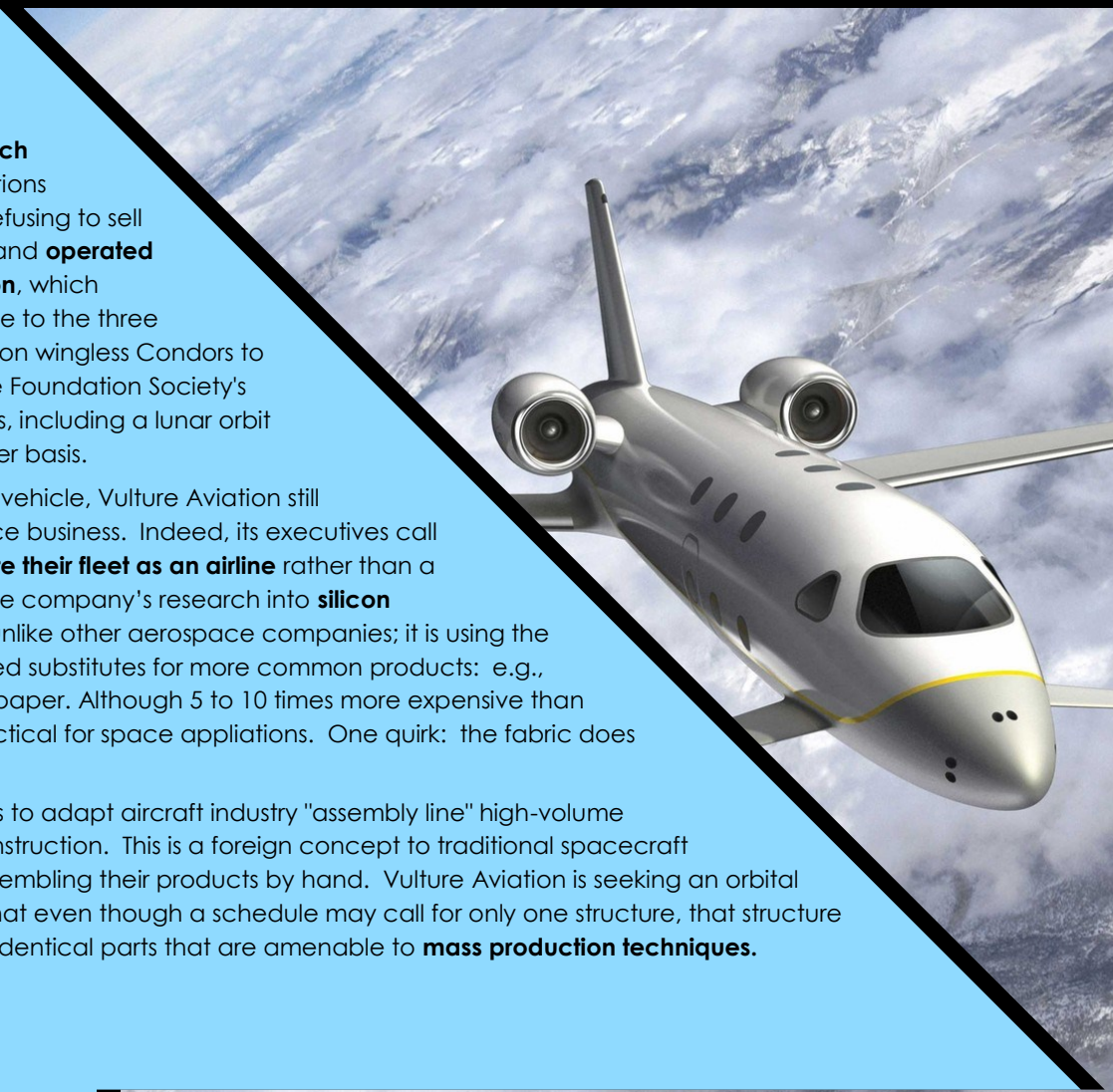
Involved in:

- 50% of **world commercial aircraft production**
- **Condor** launch vehicles
- Assembly-line production techniques
- Space subsystems, including radiators and windows

CONDOR
Freight Services

Vulture Aviation built 50% of the commercial jet, propfan, and supersonic aircraft operating in the world. Commercial versions of transport aircraft are in operation by **airlines world-wide**, and specialized variations have been sold to over 30 foreign governments. The company's executives were concerned at the turn of the millennium that their bottom line was overwhelmingly dominated by aircraft production; they saw human activities in space as a natural expansion of Vulture's business base, and figured if they want to be doing business in space in 50 years, they need to start doing business in space now. A modest **Space Division** was established, and its engineers were encouraged to bid on RFPs for space hardware.

Vulture finally became a major player in the space business--and a SEAC member--through its purchase of Consolidated Dynamics, a respected but poorly managed manufacturer of **satellites and orbital transfer vehicles**, and a supplier of radiators and windows for ISS. The Space Division was also, however, quietly using company Research and Development funds to develop a launch vehicle. The successful test of the Rockonetics air-breathing Mach 25 engine provided the needed breakthrough, and Vulture Aviation surprised the aerospace industry by introducing a commercial reusable crewed **Single Stage To Orbit vehicle, the Condor**. The timing of Condor introduction was excellent; SEAC infrastructure development relied on Condor for its early **transportation needs into orbit**.



Launch prices are coming down as the original investment is amortized; a new Condor with 40,000 lb payload capability offers **$1100 per pound launch costs**. Vulture is protecting the innovations involved in production of Condor by refusing to sell any units. The growing fleet is owned and **operated by the company's SpaceFreight Division**, which schedules cargo and passenger service to the three spaceports. Transfer service is offered on wingless Condors to major earthorbit facilities, including the Foundation Society's Alexandriat. Service to smaller facilities, including a lunar orbit transfer station, is arranged on a charter basis.

Despite success of the Condor launch vehicle, Vulture Aviation still considers itself an "outsider" in the space business. Indeed, its executives call Condor an "airplane", and they **operate their fleet as an airline** rather than a finicky collection of exotic vehicles. The company's research into **silicon buckystructures** also took a direction unlike other aerospace companies; it is using the material to create space-manufactured substitutes for more common products: e.g., gaskets, tires, hoses, even fabrics and paper. Although 5 to 10 times more expensive than similar products on Earth, they are practical for space appliations. One quirk: the fabric does not take dye, so comes only in white.

Vulture Aviation also sees opportunities to adapt aircraft industry "assembly line" high-volume production techniques for on-orbit construction. This is a foreign concept to traditional spacecraft companies accustomed to literally assembling their products by hand. Vulture Aviation is seeking an orbital construction project to demonstrate that even though a schedule may call for only one structure, that structure can be assembled from thousands of identical parts that are amenable to **mass production techniques.**

PRELIMINARY
REQUEST FOR PROPOSAL
16 March 2054

"Columbiat" Space Settlement Contract

INTRODUCTION

The Foundation Society requests that contractors propose the design, development, construction, and operations planning of the third large space settlement in Earth orbit, which will primarily serve as a business and banking center in cis-lunar space.

STATEMENT OF WORK

1. **Basic Requirements** - Describe the design, development, construction, and planning for operations and maintenance of the Columbiat space settlement in Earth orbit.

2. **Structural Design** - Columbiat must provide a safe and pleasant living and working environment for 20,000 full-time residents, plus an additional transient population of business and official visitors, guests of residents, and vacationers. Specify uses and dimensions of interior "down surfaces", with areas allocated and drawings labeled to show residential, industrial, commercial, port facilities, and other uses.

3. **Operations and Infrastructure** - Columbiat design will show elements of basic infrastructure required for the activities of the settlement's residents, including food production, electrical power generation, internal and external communication systems, internal transportation systems, household and industrial solid waste management, and water management.

4. **Human Factors and Safety** - Columbiat will provide facilities for services that residents expect in modern communities, variety and quantity of consumer goods, and public areas designed with open space. Provide designs of typical residences. Clearly show room sizes. Spacesuits will be required for activities outside of pressurized volumes.

5. **Automation Design and Services** - Specify numbers and types of computing and information processing devices, multi-function personal electronic tools, servers, network devices, and robotic applications required for facility, community, and business operations. Specify automation systems for maintenance, repair, and safety functions. Specify automation systems to enhance livability in the community, productivity in work environments, and convenience in residences.

6. **Schedule and Cost** - The proposal will include a schedule for development and occupation of Columbiat, and costs for design through construction phases of the schedule.

7. **Business Development** - Columbiat will host various commercial and industrial ventures, which may change with time. The original configuration must accommodate three major business pursuits: transportation node and port, commerce and financial center, and provisioning and maintenance base for visiting spacecraft.

Subcontractors page 1

3D Logistics successfully 3D printed tools and components from a variety of feedstock materials at spaceport Freedom, and now has a production facility at Alexandriat. The company developed a 3D printing system that is flown on spacecraft to enable replacing failed parts, eliminating most of the need for on-board logistics inventory.

BeamBuilders, Ltd. is a European company which operates an automated manufacturing facility on a ferro-nickel asteroid in an Earth-crossing orbit. The company produces triangular trusses to customer-specified dimensions, at the rate of 500 linear feet per hour. Customers are required to provide their own transportation of these structures, although some limited assembly is permitted in the vicinity of this operation; orbital mechanics restricts practical delivery opportunities to twice per year. The company's standard triangular truss with 12-foot sections, suitable for zero-installations, typically sells for $1500 per linear foot. Custom orders are more expensive.

Blown Away specialises in making inflatable buildings per customer specifications, to enable quick construction of new communities. Although these structures are not intended for permanent or indefinite use, the provide shelter for residents to start new economic activities, until more durable solutions can be established. The company also has a product line of inflatable furniture, cheap to ship and simple to set up.

Bots4U offers purpose-built robots for home and office use. Currently available functions for robots are cleaning household surfaces, washing dishes, doing laundry, moving furniture and fetching household items for their owners. The company offers to build robots to customer specification.

BuckyBreakthroughs supplies windows made from silicon buckystructures materials use on space settlements. Windows can be ordered in any shape. With proper sealing, standard windows with no dimension greater than 3 ft (91cm) can retain up to 1 Earth atm pressure. If never exposed to direct sunlight, windows provide adequate radiation and thermal insulation.

Carbon Creations collaborates with Waste Products and Toss It To Me to receive carbon from their off world installations, from which it makes useful products ranging from fuels to plastics. The company is also researching forms of silicon buckystructures fabric that can be used to make a product similar to composite structures.

Clean Up Your Act recycles water from cleaning, kitchens and agriculture, and delivers potable water back into Space-based communities' safe water supply. The company also advises communities on maintenance of proper atmosphere composition, and provides air revitalisation when CO2 or other atmosphere components go out of balance. The company has an agreement with Waste Products that it can install its infrastructure simultaneously with sewer lines.

Custom Cargo Accommodations produces Cargo Accommodation in Standard Space Shipping Container (CASSSC) units, compatible with standard interfaces in all launch vehicles and interorbital spacecraft currently in use. CASSSCs are 30 feet (9.144 meters) long with nearly square 15-foot (4.572 meters) cross-sections (corners of the cross-section are rounded within a 1-foot radius). Generic CASSSC's are aluminium, fully enclosed and vented to permit pressure equalisation. Special order CASSSC's can be whatever customers choose within standard size and interface constraints, including pressurised, open framework or made of composite materials.

Dirtbuilders has contracted with CalEarth to be the supplier of SuperAdobe casings and robotic assemblers for extra-terrestrial applications. The company makes casings *for lunar* and orbital applications from silicon buckystructures fabric. In Lunar gravity, SuperAdobe structures can be built up to 70 feet (21.34 m) high and 50 feet (15.24 m) in diameter.

Subcontractors page 2

ElectroProtect builds components for circuitry that can withstand space environments and shielding or protective boxes for components and circuits that cannot be built to withstand local environments.

Extreme Survival Technologies (EST) build spacesuits, pressurised fabric impact protection systems (e.g. airbags and restraints) and portable emergency shelters. It's most popular products are hard shell spacesuits customised for Martian operations but frequently used for other applications. Efficiencies of line production enable $400,000 unit costs.

Fusion Founders serendipitously happened upon an apparently ideal combination of conditions and equipment to produce practical fusion power in 2032. The company has been busily producing power plants since that time, at it's manufacturing facility in Yukon Territory. Although it can assemble large municipal power plants at customer-specified sites, it's most popular product is a self contained unit that can be shipped in a modified version of a C-18 transport aircraft, and installed by local labour with supervision by a company engineer. The unit weighing 200,000 pounds includes a 17-foot diameter sphere, it's 80 foot long cooling *barn* and support *shed*. The system is shipped preassembled and generates 10 MW appropriate for non-industrial communities of about 5000 people. Fusion Founders has received several solicitations to develop a version of this unit that could be launched into space, but feels that it has achieved the theoretical; limit of smallness for a Fusion reactor, and cooling is not practical in Space.

Garden-A-Go-Go manufactures potable hydroponic and aeroponic eco-systems at Alexandriat for sustaining long duration spaceship crews. The modules attach to the exterior of a ship, over an airlock that would normally go vacuum; new inter-orbit spaceships are designed with appropriate interfaces. Sizes are available for crews of five ($3 million) eight ($4 million) or twelve ($5 million) and special orders are cheerfully filled. Use of a Garden-A-Go-Go system requires that two crewmembers be trained to work the farm for one hour per day on average, mostly to harvest food for each day's meals or chicken-based systems which deliver grains, vegetables, fruit and meat (or meat and eggs). The systems do require bi-annual maintenance to replenish water and nutrients, introduce non-inbred animals an replace plant species that have died off. Specialised installations for more than 1000 people can be ordered for $75,000 per person.

Hard Roll accepts ores from off world mining operations, refines the metals and produces rolled sheets, extruded beams and custom shaped car parts.

Holey Moley adapted designs of excavation equipment used on Earth, for use in low-g environments. It has created mining equipment, trench diggers, backhoes, dirt-movers, graders, drills and tunnelers and will create new machines on request. Some types of applications require more than one design solution depending on whether local conditions enable bracing the equipment to compensate for lack gravity.

Large Print adapted capability for 3D printing of large parts top the Lunar environment. The company Hard Roll provides metal feedstock for printing parts going into construction if the spacecraft, construction equipment and land vehicles. Large Print is experimenting with feedstocks and equipment to replicate "whole house machine" printing done with concrete on earth.

Subcontractors page 3

LightWorks provides soletta and lunette illumination for Lunar and terrestrial surface locations. The huge orbiting structures reflect sunlight, six lunettas (1 km^2 each $50 M cost) enable solar power plants to operate all night. The devices consist of sodium-coated fabric made from *lunar* materials stretched over lightweight composite structures and are placed in 2500 mile orbits.

Litigation Limiters is a law firm that created a niche market which virtually eliminates conflict-of-interest suits for it's clients, who usually are companies competing for the same contracts but in need if each others products and/or services, and their customers. The company has such agreements with all of the world's diversified corporations that have significant product lines applicable to space development. Litigation limiters charge a 2% fee on product of service value.

Lossless Airlocks has developed and sells airlocks that operate with almost no loss of atmosphere for each opening to space. Airlocks come in several sizes, including a single-person unit, a personnel transfer system that can simultaneously accommodate three people in adjacent chambers, and small versions for exposing experiments to vacuum without requiring an astronaut to go EVA. Although the company has designs for units that can accommodate more people and CASSSC's it will need to establish on—orbit manufacturing capability because they are too big to launch. The systems is somewhat disconcerting for people to use; when outgoing a coated Kevlar tube envelops the occupant who is then ejected rather forcefully when the outer doors are opened. It has, however, enabled retention of precious air in vehicles and habitats and helps preserve the fragile local atmosphere.

Lunar Adventures provides spacesuits and guide-operated vehicles for the low-g surface excursions. The vehicles provide a shirtsleeve environment for six passengers plus the guide and enable overnight *camping*. The electric-powered vehicles can be self sufficient for up to a week in sunlight with storage for two days of power in darkness and have a range of up to 200 miles per day. Passengers fees are $10,000 per person per day, or $50,000 per day for charter of a vehicle and a guide. Spacesuit rentals are $8,000 per person per trip , plus $1000 per day. Company owners hope to meet with Foundation Society officials to arrange basing of their operations at *Alaskol.*

Magnetic Propulsion Company was founded by three professors at Princeton who continued work with mass drivers originally started by Gerard O'Neill. The professors claim that they can develop 200,000 pounds if robots and equipment that can be operated by a crew of five and assemble a complete working two-mile long mass driver anywhere on the *lunar surface* in six months using *lunar materials.* The Foundation Society has contracted with the company to build mass drivers in Jovian orbit, for supply relay in and out of Alboroe. The mass-drivers are Leviathan class, capable of providing 45 GJ of energy to an object that requires accelerating almost instantaneously, this speed comes with limitations in the contents of the outgoing packages, due to the accelerations experienced by the CASSC'S.

Mirror Image makes mirrors from lunar materials that are used to reflect sunlight from crater rims into crater basins, and reflect sunlight into space settlements while allowing radiation to pass through. The standard size is 13.5 feet (4,11 m) by 30 feet (9.14 m); up to 175 panels can be shipped in a specially modified CASSSC.

Subcontractors page 4

Nano Solutions was established at Alexandriat to commercialise production and marketing of nanobots after techniques were developed to grow them in zero-g and vacuum. The company is constantly innovating new nanobot applications, and accepts challenges to design for custom uses. Programmed nanobots sell by the ounce at roughly 10 times the cost of platinum, when delivered they resemble a fine powder the customer applies as a thin layer to the working surface. Service life is one to five Earth years, depending on operating environment and application. The company reprograms nanobots for new tasks (compatible with their original application) for a modest fee.

OrbitLink Communications was established when the Alexandriat Space Settlement was under construction to augment standard communications channels. Individuals who insist on transmitting and receiving data-hogging video and interactive real-time data with Earth-based services do so by paying exorbitant fees to OrbitLink. The company has made arrangements to place one of its antennas and dedicated fibre optics links on every Foundation Society settlement.

Planetary Pavers operates customised autonomous road-building equipment on off-world settlements. The company's grading and paving machinery is solar powered with 14 Earth days of battery life for operation in darkness. Their capabilities include breaking rock to make gravel and sintering regolith to create a hard and smooth road surface. After a surface is levelled about 0.6 mile (1km) of paved surface can be completed every 24 hours.

Remotely Local Products is a spinoff of a Vulture Aviation team that commercialised manufacture of common household and office item out of mined materials. The company slogan is "give us carbon and silicon, and we'll give you home".

Seals it all makes paint and coatings from asteroid mined materials that provide air-tight surfaces on rock, SuperAdobe and other porous surfaces. Application is done with standard paintbrushes and the surface requires 2 Earth days to dry before being capable of retaining air.

SpaceTrans Inc. started as a business plan written for a college class project by an ambitious self-styled entrepreneur who idolises the founder of Federal Express. The company acquired financing to build vehicles in space that can provide regular but unscheduled transportations services between locations in Earth orbit, including space stations, major commercial sites and future settlements. Although primarily intended as a service for passenger compartments, or secured to the exterior of each vehicle. Rates average $20,000 per person per day of travel and $100 per pound of cargo per day of travel.

Stuff of life has developed processes to ship air and clean water from it's facilities. The company founder says "Don't ask where we get Nitrogen". Air and water are shipped in sealed CASSSC's, air can be liquified to reduce volume for shipping. The foundations society gave Stuff of Life a large plot on Alaskol, allowing for a larger production facility at there with the intention of being the primary supplier of air and water for human solar system wide activity over the last 50 years, and planning to expand toward the Jovian moons.

Toss it To Me has developed processes for recycling trash and garbage from lunar habitations. What it receives is diverse and variable; the company President says "what we do is almost like alchemy, and mist if what we recover to sell is by-products" Current processes manage to repurpose about 50% of input; a goal is to send no more than 10% to landfill. Each customer must allocate an interior area equivalent to 1% of the residential community's land area for a building where conversion processes can occur, a second unpressurised area and a third landfill area.

Subcontractors page 5

Totally Remote Ultimate Escapeways / Guest Requested Inner peace Treks (TRUE/GRIT) offers the ultimate get-away-from-it-all vacation. Guests enjoy luxuriously-appointed small spacecraft where up to four people can stay for two weeks. The company delivers each spacecraft and its guest(s) to an orbit with no hazards from known debris, where it remains either until its occupants request retrieval or supplies are nearly depleted. Privacy is guaranteed, although critical vehicle systems, oxygen depletion, and temperature are monitored to assure that occupants are not in difficulty. Guests may change the attitude of the vehicle for different views, but have no ability to change orbits. Rates are $9000 per person per day, or $30,000 per day for charter of a spacecraft. Extravehicular Activity (EVA) experiences are offered for $2000 extra per person per trip. These zero-g escapes are highly favoured by designers, authors, and artists who seek creative inspiration.

Tubular technologies based on Alexandriat, is the most prolific producer of carbon nanotubes for industrial and scientific uses, for both space and dirtside customers. The company has succeeded in making nanotube cross-linked strings up to a mile long, although most applications are in the one to ten foot range. Nanotubes add strength to conventional materials; primary customers are manufacturers of construction elements (e.g. for buildings and bridges) and components for machinery, vehicles and tools. Although the company is vigorously pursuing techniques to produce longer nanotubes, it is far from achieving the 1000-mile lengths required to build a cable that would withstand the loads of Space Elevator to Earth's surface. The company is a partner with Foundation Society in research of silicon buckystructures applications and manufacturing methods, to produce ribbons for space elevators at the Lunar surface.

Waste Products has developed toilets and sewage handling systems that work in reduced gravity, and convert human waste to recycled water, excellent fertiliser rich in phosphorus, and a source of carbon. The systems do require that users before each sitting decide whether they're doing a "#1" or "#2". The company works with the developers of new off-world habitations to design and install sewer systems, it requires uninhibited access to a building site for 100 homes for one month after the site is graded and prepared for construction.

Wheels of fortune builds vehicles for off-world exploration and long-distance cargo hauling. The vehicles have been built on and shipped from earth; a new production facility will be established at Bellevistat. Exploration vehicles can operate for up to three months away from civilisation with a crew of six. Cargo hauling vehicles can operate autonomously on *lunar roads* equipped with navigational aids, and can tow trains of up to ten trailers, each trailer supporting one filled CASSSC. Both types of vehicles are shipped in CASSSC's, an exploration vehicle completely fills a CASSSC, two tow vehicle's in one CASSSC and 6 trailers in one CASSSC.

ZAP! Industries is the leading supplier of wire harnesses for distribution of electrical power, and fiver optics for electronic signals on spacecraft. The company operates a system for Zero-g manufacturing of solar cells from materials available in silicate asteroids. ZAP! Sells each of these units for $40 million, not including transportation to deposit it on an appropriate asteroid where it produces 1 x 2 foot solar panels at the rate of 1000 per day, each of which is capable of generating 38 watts of power in Earth orbit and weighs 2 pounds, at a cost of $80 per kW (not including transportation to the user site). The company has researched adapting their processes for manufacturing with Jovian asteroid materials and has determined that similar production rates and capabilities can be attained with a one-time development cost of $120 million.

Glossary Page 1

Air-breathing engine: propulsion plant (motor) that acquires oxidiser from the atmosphere, rather than carrying it in tanks on the vehicle (as required by rocket engines)

Airlock : Chamber enabling people and things to move or be moved between volumes with different pressures; like a lock in a canal, the chamber starts at the pressure that the occupant is moving from, and changes to the pressure being moved to.

Attitude (of a vehicle): vehicle's orientation relative to earth , Sun or other objects; typically used to describe a desired view, observation target, or heating environment (e.g. "sun-facing" attitude assures that one side of the vehicle will always be hot, and the other side cool)

Avionics: literally "aviation electronics", mostly including commanding and monitoring of systems on aircraft and spacecraft.

Cargo: reason a vehicle flies; stuff carried by a vehicle from its starting point (ground or on-orbit) to the vehicle's destination; can include satellites, bulk materials, construction components or people.

Cargo container: standard unit in which cargo is installed; container interiors are configured for complex installations, and standard exterior container interfaces are quickly mated to the inside of a cargo vehicle (standard containers are used on ships, conventional aircraft, railroad cars, and trucks)

Consumables: stuff that is used up during the course of a mission or over a period of time, and hence must be replaced; includes everything from rocket fuel to pet food to pencils.

contract: legal agreement whereby a company (contractor) promises to build something or provide a service to a customer within a defined cost and schedule, and the customer agrees to pay the entire cost when the product is delivered, or partial payments over the course of a long delivery schedule

dirtside: of or referring to Earth, people living there, and things on it

down area: in a rotating space structure, the interior surfaces through which the force due to the rotation ("artificial gravity") appears to be vertical; conversely, surfaces inside a rotating space structure on which a person could stand or things could be placed, as if they were on the ground

Glossary Page 2

down weight: amount of payload weight carried by a vehicle from orbit to the ground

Expendable Launch Vehicle (ELV): vehicle launched only once; typically, it sheds components (stages) during ascent, with only a small portion of the original "stack" delivered to orbit

Extravehicular Activity (EVA): excursion by space suited person outside of a vehicle or habitat

fabrication: manufacturing; the process of making, building, and/or assembling

fiber optics: use of glass strands to transmit light representing electronic signals; can replace copper wire with less weight and expense, and greater reliability, but cannot transmit power

fines: tiny particles of lunar, Martian, or other extra-terrestrial soils; typically called "dust"

GEO: geosynchronous Earth orbit; objects in 22,300 mile orbits rotate around the Earth at the same rate that the Earth turns on its axis; when located above the Equator, these objects appear to be stationary in Earth's sky

hypersonic flight: flight through an atmosphere at greater than five times the speed of sound (Mach 5) for that atmosphere

launch vehicle: spacecraft capable of launching or flying through an atmosphere (e.g., Earth's) in order to get into space and achieve orbit

LEO: low Earth orbit; orbital locations above Earth's atmosphere and below the Van Allen radiation belts

libration points, or L1, L2, L3, L4, L5: in orbital mechanics, when one large body (e.g., the Moon) is in orbit around another large body (e.g., Earth), there are five points in orbits around the larger body where gravitational forces balance out to enable satellites to be placed where they could not stay if the smaller of the large bodies were not present (also called Lagrangian points, for Joseph Lagrange, the mathematician who developed the theory that predicts their existence)

low-g: acceleration environment with less than the acceleration due to gravity on Earth's surface

mass driver: device that electromagnetically accelerates small objects to very high velocities; can be utilized for efficiently launching material from airless surfaces

micro-g: accurate description of "weightlessness", the condition experienced in space when forces balance out and objects seem to "float"; true "zero-g" is theoretically not possible, because there are always tiny forces operating on all objects

Glossary Page 3

on-orbit: in space, in an orbit; usually refers to an orbit around Earth

orbit: path assumed by an object in space, due to balancing or "canceling out" of accelerations due to gravity and rotation; usually the elliptical path of a small body (e.g., satellite) around a very large body (e.g., planet, moon, or star)

outweight: amount of payload weight carried by a vehicle from Earth's vicinity outbound to another location in the solar system

overhead: the part of a budget not considered cost of work directly on a project, but charged to the customer as part of the hourly cost for direct work (i.e., a contractor is paid for each hour an engineer works on tasks directly related to the project; the customer is billed a cost for the engineer's hours that is greater than the salary paid to the engineer; the difference pays for computers, facility upkeep, janitors, utilities, and other costs needed to support the engineer's work)

payload: literally, "paying load"; cargo carried by a vehicle, for which a fee is paid in exchange for moving the cargo to its destination

payload capability: weight of payload(s) that a launch vehicle is capable of carrying to orbit

payload integration: process of safely stowing a payload (usually a satellite or complex device) on a launch vehicle and providing services (including electrical power, avionics, and thermal control) that enable the payload to survive the flight and accomplish its purpose; includes design of services, analysis of payload's ability to survive environments it will experience, and installation in the vehicle

profit: difference between the price charged by a contractor for providing a product, and the actual cost the contractor incurs to create the product

proposal: document prepared by a company or other entity, to convince a customer to select the entity to provide a certain product; it describes the company's plan for providing the product, and explains why the customer can be confident that the company has a superior design and will produce it according to the customer's requirements and within the described cost and schedule

rectenna: receiving antenna, converts directed microwave energy (e.g., from an SPS) to electric power

Glossary Page 4

Request for Proposal (RFP): document prepared by a customer, which describes features of a product they want a contractor to produce

requirements: features a customer requests to be included in the design of a desired product

returnweight: amount of payload weight carried by a vehicle to Earth's vicinity inbound from another location in the solar system

Reusable Launch Vehicle (RLV): launch vehicle that returns from its missions intact, and is designed to be maintained after flight and fly repeated missions

satellite: any object in orbit around another object; usually refers to human-made devices in orbit around large natural bodies (i.e., planets, moons, stars)

shirtsleeve: environment in a vehicle or habitat enabling humans to operate without protective gear

Single Stage to Orbit (SSTO): launch vehicle that ascends from ground to orbit without staging, or shedding of components during ascent; such vehicles contain all fuels and oxidizer they require in tanks inside their structures, and return to the ground with tanks intact (the amount of oxidizer onboard can be reduced through use of air-breathing engines during flight in the atmosphere)

solar panel: device that converts sunlight into electrical power

Solar Power Satellite (SPS): a satellite, usually very large, consisting mostly of large arrays of solar panels producing electrical power that can be converted (usually to microwave energy) and transmitted to users in other locations

solar sail: a surface, usually very large and lightweight, that makes use of pressure due to light or solar wind for propulsion

spacer: of or referring to people who live in space

spacesuit: garment providing pressure, breathing air, fluids and nutrients, waste removal, and protection from the space environment, enabling a human to move and operate on EVA

station-keeping: use of small rockets, solar sails, or other propulsion to prevent satellites from drifting out of their desired orbital locations

Glossary Page 5

station-keeping: use of small rockets, solar sails, or other propulsion to prevent satellites from drifting out of their desired orbital locations

terraforming: process of making a planet more Earth-like, i.e., habitable by humans

upweight: amount of payload weight carried by a launch vehicle to orbit

Van Allen radiation belts: bands of radiation trapped in Earth's magnetic field, which both absorb ambient deep-space radiation and provide protection for Earth's surface, and are a hazard for satellites and humans operating within them

zero-g: see "micro-g"

Space Science And Education Foundation

The UK Space Settlement Design Challenge is organised and funded by the Space Science & Engineering Foundation (registered charity number 1170548) with generosity of our sponsors and supporters.

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Galactic Challenge

The **Galactic Challenge** holds space design competitions for students aged nine to fourteen. Students are placed in teams and spend the day producing designs before presenting to an audience including their peers, their parents, and a panel of judges.

Our regional events are tailored for local primary and secondary schools. We also provide resources for groups to run their own events. If you would like to host your own Galactic Challenge, please get in touch!

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The Space Science Engineering Foundation (SSEF) was set up to foster and extend students' interest in space, and to use space as a vehicle for learning about science, technology, engineering and mathematics, the STEM subjects of the National Curriculum, and importantly, leadership, psychology, management, design and business. It does this through the UK, EU and Middle East Africa (MEA) Space Design Competition (SDC) and the Galactic Challenge (GC), all industry simulations. Formulated to give students an insight into the real world of business and industry it addresses the long-standing complaint from employers that students leave school and college without the general attributes that would make them useful employees. The SSEF's programmes show students how important it is to be able to work in a team, solve problems, work to deadlines, keep within budgets and communicate effectively.

The students bear testament to the success of our programmes in achieving all these goals, and it has been interesting to note that there are several other advantageous personal results. These include increased confidence, awareness of their own strengths, a breadth of understanding of other people, a feeling of capability and responsibility for the consequences of their actions. Above all, there is a sense of enjoyment and achievement. How does all this happen in the space of a few short hours?

The (fictional) Foundation Society, based in the future, requests a design proposal (RFP) with specific parameters for a settlement in space or on a planetary body. Students then form companies that they run through their own management and engineering team. Each company is made up of an elected president, vice president of marketing, and heads of engineering in four areas: Operations, Human, Structural and Automation. Professional engineers and scientists assist the students, however, the running of the company and the designs are the student's own work. Companies have a day to come up with a detailed design, in the form of a slide show which they present to a panel of judges who include experts in the field and representatives of the UK Space Agency.

For the SDC finals, usually held in mid-March each year. the students have two days to address the RFP. Selected students presenting winning designs go to NASA's Kennedy Space Center for the International Finals.

The Space Design Competitions are organised and funded by the Space Science Engineering Foundation (registered charity number 1170548), along with generous support from other sponsors.

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Sponsoring an appeal will create memories and knowledge that the students will never forget. You can help students in a variety if ways: by sponsoring food at regional events, the UK finals, travel to local events, scholarships, travel to Kennedy Space Centre, sponsoring an award to a student.

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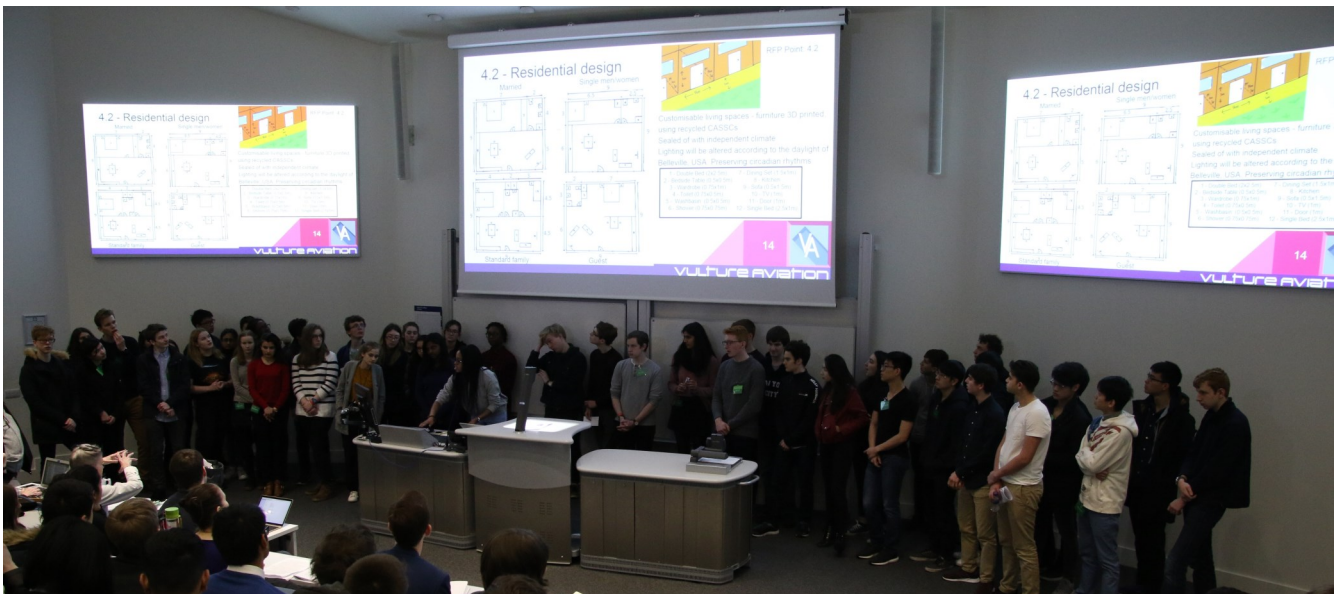

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