The beginning of a new era

SX-IV
SSTO VEHICLE

Flexible Feasible Future
In the rapidly changing world, air mobility is vital in achieving the objective of getting people, equipment and supplies to any point on earth. Now Air Mobility has grown to a higher level. Commercialising transit to earth’s orbit was once man’s dream. Now evolved to level where Space Transit is a reality. More complex Science and fundamental understanding of concept isn’t enough to achieve all the needs of space travel. A new level of learning and understand is vital. It’s the flaming interest and passion of many that this is now possible. Space tourism, already looked into by many American and European countries is now possible in Asia. The industry is very young and crawling its way to Space Flight and Life in weightlessness.

Team AstroNuts has been given the task of conceptual designing a spacecraft for Low earth orbit flight at around 100-102km above sea level. Allowing for tourism, research and satellite launch and recovery. The booklet hosts scientifically proven methods, in most cases tested methods of technology and design applied to the aircraft. The team has been very enthusiastic and assertive about this project. In most cases juggling education and personal activities along with this competition. We strongly believe and are confident that our design is realistic and scientifically accurate in all cases possible. We take this competition as an opportunity to learn many new things which was an eye opener for even some of our friends whom were non-participants.

How this Book is organised ...

All the mission requirements have been colour coded above. When its being described, the title will host the color of the requirements or host a colored tag. All of these requirements follow the guidelines, mission background and mission specifications given to us by the competition host. The book will be based on the conceptual design of our team. No part is reproduced directly from any source. All diagrams and calculations were done by the team.

Contents
- Design Proposal
- Aircraft Full Structural Drawing
- Node Information
- Flight Profile
- Interiors
- Onboard Propulsion
- Life Support Systems
- Emergency Safety Systems
- Materials Technology
- Airframe profile
- Cost and Maintenance
- Airport Information and Procedures
- Satellite Launch and Repair System
- Dimensions and Performance Table
- Onboard Avionics
- A unique experience
- Changing World Greener alternatives
- Group Profile
- Project Planning
- Additional Deliverables

Environment Friendly Options will be marked with this leaf.

Additional Deliverables
Team AstroNuts wishes to provide the best presentation with minimal help from External sources such as school, clubs and friends. We have come up with a conceptual design in which case the meaning of conceptual is mere the stage whereby basic brainstorming is done on the plane. Thus not requiring detailed mathematical and scientific calculations. Our team has tried its best, using our self-attained knowledge from various resources such as documentaries, news articles, Internet, Books. We have come up with ...

1. Technical Reports File (Hardcopy)
2. Brochure (Hardcopy– Quality Print)
3. CADD Models (DISC 1)
4. Technical Reports & Documents Softcopy (DISC 2)
5. 3 Minutes Introductory Video (DISC 3)
6. Documentary Video (DISC 4)
7. Website (www.sgaviators.com/SX4)
8. 1: 16 Scale Fiber Glass Model (Plane Scratch Built by the team)
9. manufacturer’s Brochures (Attached to Technical Documents)

Software’s Used in this competition
- Solidworks
- Adobe Flash CS4
- Adobe After Effects CS4
- X-PLANE 9 by laminar Research
- Microsoft Office
- GIMP Image Editing
- Adobe Photoshop CS4
- Flight Simulator X
- Blender
- Google Sketch Up Professional
- Google Earth
- Windows Movie Maker
- Cyberlink Power Director
- Audacity
- Hypercam 2
- Orbiter Simulator
- Adobe Premiere
- 3DS Converter
**Alternative Use for the Aircraft**

The SX-4 is completely capable of flying normal subsonic flights. A SPS system shown below is designed for subsonic transport. The Spacecraft can also be converted to military capability by converting the type of engines and installing weapons systems. Moreover the SX-4 can also be upgraded with hooks to land on sea based landing zones like carriers or floating bays. This will increase functionality and transportability of the aircraft.

**Future Improvements**

**Canard**
Canard Control Surfaces can improve the maneuverability of the aircraft. This feature needs to be incorporated alongside the Chines this would require advanced engineering Design and analysis.

**Tyson Bladeless Fan Engine**
Currently, in the design SX-4, we used the conventional type of turbofan engines used on Learjets. In our design process, we were thinking if we could use other methods of propulsion, something greener, energy-efficient, and less hazardous. We went onto the internet and searched for that concept in mind. During the process of research, we came across a new revolutionary table-top fan, which has no blades at all! We decided to venture more into it. Below are our summaries. Dyson Bladeless fan does not means no blades, but instead, the blades are concealed inside its cylindrical shaped body. It consists of one impeller which was powered by Dyson’s very own unique motor design.

View Technical report for more information.

**SX-4 Single Stage to Orbit Aircraft Design Proposal**

We propose to design and create a supersonic short-mid range single stage to orbit jet. It’s intended to have a cruise of 836km/h at FL40. Its main propulsion system will use Honeywell Aerospace TFE731-5BR Turbofan Engines, which has a sea-level thrust of 4400lb of thrust and 870lb of thrust at maximum altitude of FL40. Most common height limit for commercial engines are around Flight level 32000ft-40000ft. After which SX-4 will execute a stall maneuver while 2 Common Extensible Cryogenic Engines (CECE) are fired, a new deep-throttling, 30,000-pound thrust for the 2 engines is used to propel the aircraft into the low earth orbit. Mission tasks are carried out depending on mission types. Maximum total takeoff weight of the aircraft expected to be within 12500kg. With Non-expendable payload which includes 3 passengers including the pilot, life support systems and the engine. Our Design is a fully reusable SSTO Aircraft. With improved safety measures allowing for airliner-like operations.

**Aircraft Main Engines:** 811.93kg
**CECE Rocket Drynes:** 300kg
**Payload:** 200kg
**Passenger Payload+ Node Payload:** 470 (*3 PASSENGERS)
**Max Takeoff Weight:** 12500kg
**Max Turbofan Operation height:** 40000

The main structure will host estimated around 45-50% of the total weight. Basic Structural Design will include the Chines, front control canard, delta wing structure and payload bay. Use of composite materials will decrease the overall weight of the structure, meanwhile also containing suitable spaceflight properties.

The most important design factor on the SX-4 would be the Switchable payload system. (SPS). The SPS system allows various designs of payload to be loaded on the aircraft. These payloads vary on the types of mission profile. Our team mainly concentrates on 5 types of payload package. 1) Satellite Launch Payload. 2) Science Laboratory payload. 3) Passenger Transport Payload 4) Non-Space Flight payload 5) Orbit Cleaning Payload.
Changing World And Greener Alternatives

Being an unique species on earth and negatively contributing the ecosystem, its only us whom can solve our own problems. We have the knowledge to create and destroy mother earth. Though we cannot completely top all negative actions, we can adapt to greener technology which reduced the amount of impact on the environment. We have looked into the situation ourselves and came up with various ideas.

Super-Efficient Blade Less Fan Engine Technology

Tyson’s bladeless fan technology can be used on Future turbofan engines. The technology amplifies small amounts of air to a larger ratio creating wind, in our case exhaust. We hope to research more into this for our future projects. If successful it will be the most cleanest thrust producing engine.

Orbit Cleaning Payload (SPS SYSTEM)

Orbit Cleaning payload will ensure that the space Environment is maintained so that the safety of space-flight Can be idle. This means lesser orbital waste as time passes. This will adversely reduce the number of collisions on spacecrafts. The orbital cleaning payload can use different types of technology. 1. Robotic Orbital Cleaning, 2. Laser or 3. Cube Sails cleaning technology.

Chevrons Technology

The chevrons will reduce the noise produced by the engines. This means it will be much quieter as the aircraft takes off the airport in any location.

Bio Fuels

Algae/jatropha oil-derived biofuel have been proven successful as aviation biofuels. As the petrochemical industry grows, more new fuel sources will be discovered we expect that space flight will become more green. Moreover our CECE rocketdrynes use methane or hydrogen as rocket fuel. Both of these fuels are not Perishable and are readily obtainable.
Cost and Maintenance

Cost
Incurred by research, development, test, evaluation (RDT&E) phase. The cost of research and development is amortized over and initial fixed number of production aircraft used to distribute this cost increases. The purchase Cost per Aircraft decreases. The decision on the total number of the aircraft is therefore an important factor in establishing the purchase price. Thus Estimates given below is only solely based on estimates on materials in the current market and costs incurred by major components.

But our team has come up with a cost estimate of the aircraft derived from data of current day space vehicles, and commercial vehicles. A single prototype would cost US$15-25 Million. This figure is without avionics, systems, R&D costs.

Maintenance
Singapore has sufficient resources to maintain this plane.
Our industry has already been strong in MRO. While being able to maintain various types of engines. The Honeywell will be as easy to maintain like any other turbofan engine. However is best to Create a special team for the SX-4. Thus able to monitor the aircraft’s Condition more in-depth. This will ensure engineers will be at the optimum capability for this workload. This will ensure the engines on the SX-4 will receive full attention. Our FAA will work to FAA Standards.

For Detailed information, Please Refer to Technical Report.
The Satellite Launch Payload
This payload will include a three seater cabin compartment with a satellite launch and repair system. Thus equipped with a robotic arm as well as a Payload Dispense System (PDS). This system is equipped with the latest technology to automate satellite launch procedure. The PDS module will allow pilots and engineers to conduct space repair works. Possibility of allowing spacewalks is being further researched.

Science Laboratory Payload
This payload will include scientific equipments required for research. The economical thing about this is that R&D companies can invest in 0g labs to develop new technology and reach new frontiers. This payload would include a toilet and storage facilities. Earth observation and study is also vital.

Passenger Transport Payload
This payload will incorporate as much life support as possible for Space tourism, and Future passenger transportation for space stations. This passenger transport system can be altered according to the types of passengers and their requirements.

Non-Space Flight Payload
This module could serve as a high speed transport system in the atmosphere. This feature can be used by military for combat reconnaissance, private/commercial transport or for High Speed Medical Support.

Orbit Cleaning Payload
We like to have this as a additional feature in our design. It’s still in the research phase. New concepts will allow orbit cleaning in future. The aircraft should be able to detect, destroy or collect space debris which moves at high velocity.

For detailed description of the SPS modules refer to technical specifications booklet.
**SK-4 METEOR**

All data given below is of the best of our knowledge at the time of printing. Certain data, only can be derived by prototyping wind tunnel testing. The SX-4 has been tested on a FAA certified X-PLANE software by Laminar Research®. It is constantly being improved after every flight. While our team is very confident with the outcome.

**SPS SYSTEM DIMENSIONS**

- **Aircraft Length**: 16M
- **Wing Span**: 15.8-16M
- **Thrust to Weight**: 0.63144
- **Wing Area**: 54.829m²
- **Wing Loading**: 227.98m²
- **Aspect Ratio**: 9.339
- **Taper Ratio**: 7.25

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**AIRFOIL MORPHING INFORMATION**

**SUPERCROSIC AIRFOIL**  
NACA: 63A012  

**SUBSONIC FLOW**

**SUPERSIC AIRFOIL**  
NACA: 65-h06  

**SUBSONIC FLOW**

**Flight Profile**

- **Low Earth Orbit**: 100-102km above Sea Level  
  40 Minutes to reach orbit

**Civilian Airport**  
Runway > 8000ft  

**Flight Level**  
40000FT  
Supersonic Flight  
CECE engines fire.
**Interior Design**

**Windows**

The SX-4 windows afford an excellent view, and they block out harmful Ultraviolet (UV) rays from the Sun, survive the heat from reentry, and withstand the pressure and temperature differentials throughout the flight. The XP windows and doors are a “plug” design with layers of high temperature glass and Lexan. Special coatings on the windows keep out harmful UV rays. They provide redundant protection from both the heat of reentry, and double-walled containment for the internal pressure.

**Seating**

The chairs in the SX-4 will ensure maximum comfort and safety for the passengers. The Astronuts team have considered all ergonomics and anthropometrics while designing the seat. The seat is powered by pneumatics to extend and retract so as to allow more space while in low earth orbit experience. It also has suspension to absorb rough flight conditions if any were to happen. The chair collects biological data and provides this to the pilot. The pilot will take necessary actions to ensure the passengers safety.

**Ergonomics**

The Ergonomics on the SX-4 will be sufficient for both long and short term space flight. Handles, hand rests etc using body anthropometrics have been considered during all three scenarios whereby passengers will sit, stand and float. The spacecraft can host different class of standards for different groups of people. The first class cabin payload will have better interior furnishing compared to economy class. However all Class payloads will host wall cushioning around the interiors so that the risk for injuries is minimal due to the irregular environment which can be difficult to adapt for the passengers.

**Airport Information**

**Ratellite Launch and Repair**

The SX-4 SSTO vehicle can take off from over 60 known airports in south east Asia. With takeoff distance being 8000ft , the aircraft is more suitable for airliner like operations from various countries. This allows the SX-4 to choose more airports to land at after earth re-entry. While allowing refuel and flying back home. The aircraft is suitable for other runways all around the globe. The aircraft will be able to adhere to almost all the FAA rules during low altitude flight. While following FAA regulations for noise control, the SSTO is able to operate without disturbing the environment or the people in the country or city.

For details on the different airports available for landing, refer to technical specifications booklet.

The Satellite launch will be done by the SX-4 with 3 passengers on board or they can choose to only send a autopilot SX-4 , unmanned into space. This way the launch procedure need not require unnecessary risk taking by anyone. Moreover lesser fuel would be needed to burn the aircraft into Low earth orbit. The payload bay doors and the elevator ejection system will take over automatically after reaching a preferred height in the outer space.

Though the SX-4 can be set for autopilot for satellite launch, it cannot fix satellites on its own yet. It will take some years before such programming technology is implemented into space robots . Meanwhile Humans will still carry out the repair and servicing while in orbit.
The avionics in the cockpit are of top notch technology. They can be easily altered to specific conditions of the flight. Some of these instruments include, Synthetic vision module, Display System windowing. Advanced Human Machine Interface. The glass cockpit technology used on STS-101 Atlantis space shuttle will replace gauges and electromechanical displays. A new full color, flat panel multifunction Electronic Display Subsystem will allow easy-to-read graphical statistics and flight indicators.

Other systems include, the autopilot system which is able to fly the aircraft completely unmanned. It will be able to deploy satellites and do missions which do not require manned operations that would be risky. State of the art communication technology is implemented in the SX-4. Joystick controls will allow the pilot to maneuver the aircraft more precisely. While also allowing control for the orbital thrusters. Other controls such as primary ejection system is located across the aircraft. Cockpit windows are designed to withstand orbital debris impact. While also allowing excellent pilot vision.

Piping and tubing need to withstand variable pressures, heat, radiation and microgravity flow. Special pipe connections need to be used. Metal Woven Pipes are sometimes used. Stainless Steel and Inconel 625 nickel-iron and Monel 400 nickel-copper alloy tubing is common for space applications. Thus also used on the SX-4.

1. (Breathing Air) OXYGEN/NITROGEN Supply : 3400PSI
2. (Cooling System) Thermal Control System
Two phase anhydrous ammonia :377PSI
3. Propellant Based Tubing
4. Electrical Wiring

Please Read Technical Specifications On Piping and Tubing Technology

Under contract to NASA, PWR is developing the Common Extensible Cryogenic Engine (CECE), a new deep-throttling, 15,000-pound thrust-class cryogenic rocket demonstrator engine, to validate technologies that support a wide range of lunar and in-space mission applications, such as crew exploration, lunar landing and transfer vehicles.
Onboard Oxygen Generating Systems
Similar to the elektron, the Russian oxygen and the NASA’s Oxygen Generating System. Generators used on board the International Space Station (ISS). Water/ Distilled water stored on board undergoes a process called electrolysis which splits water molecules into oxygen and hydrogen. Oxygen produced will be vented into the cabin. While on the other hand, hydrogen produced will be stored as compressed gas for the use of “Cold Gas” boosters.

One disadvantage will be the bulky and weight of the device. Another alternative will be bottled oxygen or Solid Fuel Oxygen Generation canisters. If we can replicate the similar technology to a smaller device for a specified volume. It will be more feasible for long stay in orbit.

Environmental Control and Life Support
The SX-4, Environmental Control and Life Support System (ECLSS) provides or controls atmospheric pressure, fire detection and suppression, oxygen levels, waste management and water supply. The highest priority for the ECLSS is the SX-4’s atmosphere, but the system also collects, processes, and stores waste and water produced and used by the crew—a process that recycles fluid from the sink, shower, toilet, and condensation from the air. The Electrolysis system aboard the SX-4 will generate oxygen aboard the station. The crew has a backup option in the form of bottled oxygen and Solid Oxygen Generation (SFOG) canisters. Carbon dioxide is removed from the air by the Vozdukh system. Other by-products of human metabolism, such as methane from the intestines and ammonia from sweat, are removed by activated charcoal filters. The atmosphere on board the SX-4 is similar to the Earth’s. Normal air pressure on the SX-4 is 101.3 kPa the same as at sea level on Earth. An Earth-like atmosphere offers benefits for crew comfort, and is much safer than the alternative, a pure oxygen atmosphere.

Thermal Protection System
When the SX-4 reenents Earth’s atmosphere the leading edges of the wings, tail, flight control surfaces, and nosecone will experience temperatures in excess of 600-700 degrees Fahrenheit. These surfaces are made of titanium which is not only very temperature resistant but light as well. The rest of the vehicle is covered in a special ceramic paint that emits over 93% of the energy it receives. In select areas such as near the rocket engine, ceramic blankets will be used to protect the fuselage from not only the heat of reentry, but also the heat produced by the rocket engine.

Onboard Life Support Systems
When the SX-4 reenters Earth’s atmosphere the leading edges of the wings, tail, flight control surfaces, and nosecone will experience temperatures in excess of 600-700 degrees Fahrenheit. These surfaces are made of titanium which is not only very temperature resistant but light as well. The rest of the vehicle is covered in a special ceramic paint that emits over 93% of the energy it receives. In select areas such as near the rocket engine, ceramic blankets will be used to protect the fuselage from not only the heat of reentry, but also the heat produced by the rocket engine.

Chines
Sharp edges leading aft on either side of the nose and along the sides of the fuselage. The aerodynamicists discovered that the Chines generated powerful vortices around themselves, generating much additional lift near the front of the aircraft, leading to surprising improvements in aerodynamic performance. The angle of incidence of the delta wings could then be reduced, allowing for greater stability and less high-speed drag, and more weight (fuel) could be carried, allowing for greater range. Landing speeds were also reduced, since the Chines’ vortices created turbulent flow over the wings at high angles of attack, making it harder for the wings to stall.

Jouster/Aero spike
A drag-reducing aero spike is a device used to reduce the fore body pressure drag of blunt bodies at supersonic speeds. The aero spike creates a detached shock ahead of the body. Between the shock and the fore body a zone of re-circulating flow occurs which acts like a more streamlined fore body profile, reducing the drag.

Ruddervator-Winglets
The rudder on this aircraft is situated at the winglets. It’s a proven method of using rudders. This means overall weight of the aircraft will be reduced, also less drag is created. The winglets can be set at different angles according to the type of flight. During supersonic flight. The Rudder-Winglets will straighten parallel to the wing. While returning for subsonic flight, it will position at a certain angle.

Meso-Flaps
Approaching supersonic speeds, the boundary layer interaction between the plane surface and the airflow begin exerting great forces on the airframe. This results in increased drag and flow separation and inhibits the full aerodynamic efficiency of conventional supersonic aircrafts. This system will get rid of the costly, complex and heavy bleed systems of the current supersonic aircrafts. Use of Aero elastics such as (NiTinol) will eventually adjust itself to optimize its effects on re-

Blended Design
The Blended Design learnt from X-48 would allow significant payload advantages in strategic airlift/air freight. Moreover fuel efficiency will increase. Though the method is not applied throughout the aircraft. We had to currently only apply this technique to certain areas only. The design also reduced drag compared to conventional designs. Also the blended wing design would increase the overall lift of the aircraft.

Airfoil Morphing Lifters
Powered by either hydraulics or pneumatics. By using compressed air from the turbine engines (at subsonic speeds) and diverting them in to these bladders, the airfoil, increases surface area, camber, and ultimately, lift. The same ability could be diverted to the leading edges to ‘dull’ the leading edge, decreasing stall speed.

For more information refer to technical report.
The materials involved in space flight are complex. It will be impossible to explain all the materials exactly. View SX-4 Technical Documents which comes along with this booklet, it will explain in much detail.

Following the study of the shuttle orbiter aircraft. The materials technology to our SSTO Aircraft is very similar to its design. Thus we decided study the materials found on the orbiter spacecraft very closely. Materials used for fabrication must withstand operational temperature requirements, loads, contamination, life expectancy and natural space environments. Properties to be considered include mechanical properties, fracture toughness, flammability, corrosion, stress corrosion, thermal and mechanical fatigue properties. Materials shall be selected to ensure maximum life and minimum maintenance. Materials which are not expected to meet design life requirements but must be used for functional reasons shall be identified as limited-life items requiring maintainability. We are presuming that by the time this aircraft is in production, there should be more lighter and stronger options of materials.

LOW EARTH ORBIT ENVIRONMENT SURVIVABILITY
Materials exposed in the Low Earth Orbit (LEO) environments shall be selected to perform in that environment for their intended life cycle exposure. The critical properties of the material shall survive exposure to LEO environments of atomic oxygen, solar ultra violet radiation, ionizing radiation, plasma, Vacuum, thermal cycling and contamination. Meteoroids and orbital debris shall also be considered.

Here’s a list of materials considered for our aircraft:

- Reinforced Carbon-Carbon
- Silica tiles
- Nomex Felt Coating
- Titanium
- Aluminum
- Fused Silica and borosilicate glass (windows)
- Steel
- Magnesium
- Beryllium
- Cadmium
- Mercury
- Refractory Metals
- Super-Alloys (NICKEL/COBALT BASED)
- Elastomeric Materials
- Polyvinylchloride
- Fiber Reinforced Plastics
- Glues and Sealants
- Super-Alloys (NICKEL/COBALT BASED)
- Laser safety
- Crew training safety
- Meteoroid and debris protection
- Noise control design
- Materials safety
- Software systems safety
- Containment of hazardous materials
- The Caution and Warning System

When the SX-4, experiences emergency situations whereby it’s confirmed that all options of safe craft re-entry is not possible. The SPS System will go through a ejection and orbit re-entry process. While deploying parachutes at a safe height to reduce speed and safe landing. The whole SPS module will eject out of the aircraft using pneumatics or hydraulics. The module will have 1 emergency foldable chair for the pilot to enter the module and safely strap in. The system will still keep the capsule pressurized with all vital information is displayed on a screen inside the SPS Control Panel.

Other than the SPS System, there are also various other systems in place which ensures the passengers safety.

- Life support systems safety
- Collision Avoidance systems
- Robotics systems safety
- Oxygen systems safety
- Avionics safety
- Battery safety
- Mechanical systems safety
- Propellant systems safety
- An integrated process fire safety
- Safety considerations for the ground environment
- Extravehicular activity safety
- Pyrotechnic safety

Please refer technical Report for more information.