# aero | astro ARCHITECTURE

~ the hybridizing frontier of emergent industries ~

by

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A thesis
presented to the University of Waterloo
in fulfilment of the
thesis requirement for the degree of
Master of Architecture

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# AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.



# **ABSTRACT**

Architectural designers often need to strike an uneasy balance between idealism and reality. Under most circumstances, architects are restricted by clients, budgets, and available technologies. However, divorced from traditional constraints, visionary concepts of new dwellings, new cities, and new "worlds" will spark greater forms of innovation and drive creativity for future generations. The exploration of new spatial boundaries and conceptual environments for design will irrevocably alter the human experience while adapting new challenging roles for future architects.

Architecture can be understood in part as the art of organizing spaces through the manipulation of materials and forms. Designed spaces are arranged to provide unique sensory reactions for their occupants while emotionally and physically orientating them on Earth. As a catalyst towards the awareness of one's surroundings, architecture has always had to contend with the many limiting factors imposed by the forces on Earth. These include, but are not limited to, gravity and climate. On Earth, structurally sound construction is limited by the forces of gravity as it influences design capabilities by standardizing forms, functions, and structural elements of architectural spaces. New design challenges and opportunities arrive when we look to create structures outside of Earth's boundaries.

This thesis proposes a futuristic model of an efficient and unique passenger transport system that connects Earth-based hybrid air/space ports with an *outer space orbital infrastructural hub*. This modern intervention will allow for new outer space industries, such as transit, tourism, and hospitality, which will provide unique opportunities for the future of humanity. Additionally, the thesis studies the positive architectural and experiential potentials for the future living occupancy of outer space. In recognizing the financial and logistical limitations of current space constructions, such as the International Space Station, the thesis looks beyond the limitations of current technologies and towards designs that are driven by the fulfillment of human experiences in space. Life in space, the thesis envisions, will spark new human experiences and rituals while necessitating new forms and designs in architecture. Weightlessness and its related spatial disorientations, in addition to the many other unique conditions in this unfamiliar territory, will inspire a new conceptual language for architecture and human cultures. The thesis will demonstrate that spaces designed for extraterrestrial experiences can be innovatively dynamic as they respond to new cultures and activities that evolve as a reaction to extreme conditions. Introducing humans to the environs of orbital space will be the initial stage in a long-term phasing tactic to colonize and commercialize beyond the expanse of Earth, eventually extending humanity to the remote neighbouring planets of the universe.



# ACKNOWLEDGEMENTS

This dissertation would not have been achievable without the assistance and guidance support of numerous individuals who in one way or another have contributed and extended their valuable innovative wisdom and vigor in the preparation and completion of this architectural thesis. I would like to sincerely thank and show my honorific appreciation by acknowledging these inspiringly supportive individuals who frankly paved every step of the way for my thesis from an imagination into a reality.

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Last but not least, I am gracefully indebted to the many colleagues who have conveyed interest and enthusiasm while accompanying me along the way throughout this majestic journey in completing my thesis research. To all my close companions and friends who believed and respected in my vision who have made my master's voyage full of hope, laughter, and happiness. Without this endless energy from these wonderful people, I would not have had the strength to carry on till the ultimate conclusion.

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Thank you all with love!

# **Jonathan Lim Yuen Fung**



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DEDICATION	In sincere dedication to the past, present, and future visionary designers who define and represent the emergent discipline of <i>Space Architecture</i> .



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#### [2.6.5] - By Author

Linear graph mapped to distinguish the chance of survival with respect to exposure time in a vacuum environment. Refer to [2.4.2], [2.4.3], and [2.4.4] for related details.

#### [2.6.6] - By Author

Infographic describing the varying energy levels throughout the 24 hour day in a 7 week cycle. All data are estimates and reflects a typical lifestyle of a person with a day job Monday through Friday from 9am to 6pm.

#### [2.6.7a] - By Author

Real-time orbital tracks (created by opensource GPredict satellite tracking software) of global positioning satellites in Geosynchronous Earth Orbits (GEO) and Lower Earth Orbits (LEO) on November 4, 2010 at 2:05am (local time of Cambridge, Ontario)

# [2.6.7b] - By Author

Real-time orbital tracks (created by opensource GPredict satellite tracking software) of Lower Earth Orbit (LEO) satellites on November 4, 2010 at 2:05am (local time of Cambridge, Ontario)

# [2.6.8a]

<http://www.imdb.com/media/rm931436800/tt0162222>

# [2.6.8b]

<http://www.imdb.com/media/rm2668728064/tt0362227>

# [2.6.8c]

<http://www.imdb.com/media/rm1309194496/tt0112384>

# [2.6.9]

<http://www.sengpielaudio.com/TableOfSoundPressureLevels.htm>

# [2.6.10]

<http://4.bp.blogspot.com/-NniDRKSxpJE/TpQ6HhxzS-I/AAAAAAAABrs/RuCAXnxLdA/s1600/LIPRRF-00004749-001.jpg>

#### [2.6.11]

<http://www.futuremorph.org/wp-content/uploads/2012/01/MP9004244271.jpg>

#### [3.0.1a]

<http://www.spaceflight.nasa.gov/gallery/images/station/crew-10/hires/iss010e13569.jpg>

# [3.0.1b]

<a href="http://www.nasa.gov/images/content/113083main\_jsc2005e08315hires.jpg">http://www.nasa.gov/images/content/113083main\_jsc2005e08315hires.jpg</a>

#### [3.0.1c] - By Author

Photograph of Alan Shepard's EVA life support spacesuit used on the Apollo 14 mission at Kennedy Space Center Visitor Complex's Apollo/Saturn V Center, Merritt Island, Florida, USA

#### [3.0.1d]

<http://25.media.tumblr.com/tumblr\_m8tebtlIzZ1qf71bqo1\_500.jpg>

#### [3.0.1e]

<a href="http://s3.amazonaws.com/estock/fspid10/23/01/82/7/fisheye-nikon-home-2301827-o.jpg">http://s3.amazonaws.com/estock/fspid10/23/01/82/7/fisheye-nikon-home-2301827-o.jpg</a>

#### [3.0.1f]

< http://www.techguru.com.br/wp-content/uploads/2011/10/Room-With-a-View-Window-on-the-World.jpg>

#### [3.0.1g] - By Author

Photograph of an iPhone display showing various downloaded social network apps

# [3.0.1h]

<http://www.openlettersmonthly.com/stevereads/wp-content/uploads/2011/09/enterprise-bridge.jpg>

# [3.0.1i]

<http://www.travelstaff.fi/custom/j0400552.jpg>

# [3.0.1j] - By Author

Rendered visualization of an early development for AERO | ASTRO's conceptual design.

# [3.1.1]

<http://mix.msfc.nasa.gov/IMAGES/HIGH/0005604.jpg>

# [3.1.2a]

<http://en.wikipedia.org/wiki/File:A7L\_plss.jpg>

# [3.1.2b]

<http://en.wikipedia.org/wiki/File:Apollo\_portable\_life\_support\_system.jpg>

#### [3.1.3] - By Author

A flowchart of many currently used outer space technological life support systems with the proposed future developments to close the loop with regenerative resources by creating an artificial biome condition in the space station.

#### [3.1.4]

<http://farm8.staticflickr.com/7178/6793661854\_bbf5885002\_z.jpg>

#### [3.1.5]

<http://www.inverca.es/web/images/stories/dsc03387.jpg>

#### [3.1.6]

Screen captured still from Hollywood film, "Sunshine" (2007) at 0:06:53

# [3.1.7]

<http://mix.msfc.nasa.gov/IMAGES/MEDIUM/7776898.jpg>

#### [3.1.8a]

<http://www.asc-csa.gc.ca/images/recherche/images/9efd8b45-2630-4db3-a010-0f152f51bbd3.jpg>

# [3.1.8b]

<a href="http://www.nasa.gov/centers/johnson/engineering/multimedia/LSS\_GalleryAsset9.html">http://www.nasa.gov/centers/johnson/engineering/multimedia/LSS\_GalleryAsset9.html</a>

#### [3.1.8c]

<a href="http://www.aviationspectator.com/files/images/Space-Shuttle-Endeavour-STS-126-084.preview.jpg">http://www.aviationspectator.com/files/images/Space-Shuttle-Endeavour-STS-126-084.preview.jpg</a>

# [3.2.1] - By Author

Cardinal directions viably diagramed for a Low Earth Orbit (LEO) parti in parallel with AERO | ASTRO's design intentions. Concept and terminology reference from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 153-167, 2009

# [3.2.2]

Configuration parti diagrams for revolving artificial gravity modules. Concept and terminology reference from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 153-167, 2009

# [3.2.3a] - By Author

A module section that denotes the basic concept of centrifugal designs describing the human relations with the station under artificial gravity conditions. The understanding of the artificial gravity concept references from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 133-152, 2009

#### [3.2.3b]

The physics of a particle hopping in artificial gravity. Concept and terminology reference from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 141, 2009

#### [3.2.3c]

The physics of a particle dropped in artificial gravity. Concept and terminology reference from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 140, 2009

#### [3.2.4a] - By Author

A variation of the Hill and Schnitzer 1962 rotational parameter's comfort chart used to calculate the appropriate sizes for modules that produces artificial gravity. The understanding of the artificial gravity concept references from "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 134-138, 2009

# [3.2.4b] to [3.2.4h]

Artificial gravity depicted at various points on the Hill and Schnitzer comfort zone chart. "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 142-144, 2009

# [3.2.4b]

The typical diagram showing the normal situation with Earth conditions.

# [3.2.4c]

Diagram showing conditions at "A" on chart.

# [3.2.4d]

Diagram showing conditions at "B" on chart.

# [3.2.4e]

Diagram showing conditions at "C" on chart.

# [3.2.4f]

Diagram showing conditions at "D" on chart.

# [3.2.4g]

Diagram showing conditions at "E" on chart.

# [3.2.4h]

Diagram integrating all options showing the extremes of the disparate conditions.

#### [3.2.5a]

Accessibility design to artificial gravity transferring from weightless conditions to an artificial gravity environment. Concept can also be conducted with mechanical systems such as elevators or escalators, but is denoted using a ladder for simplicity. "Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 146-150, 2009

#### [3.2.5b]

Screen captured still of an occupant entering the artificial gravity module using a ladder from the highly realistic film, "2001: A Space Odyssey" (1968) at 0:57:49

#### [3.2.5c]

Screen captured still of an occupant jogging in the artificial gravity module from the highly realistic film, "2001: A Space Odyssey" (1968) at 0:56:49

#### [3.2.6a], [3.2.6c], and [3.2.6d]

<a href="http://archinect.com/firms/project/6790084/astronauts-memorial/7024377">http://archinect.com/firms/project/6790084/astronauts-memorial/7024377</a>

#### [3.2.6b] - By Author

Photograph of the Dignity Memorial Plaque at Kennedy Space Center Visitor Complex, Merritt Island, Florida

# [3.2.7a]

<http://www.bundpic.com/upload/images/25/558ffc97ca682b60cee3899aa28fdeef.jpg>

# [3.2.7b]

<a href="http://es.wikipedia.org/wiki/Archivo:Columbia\_STS-107\_launch.jpg">http://es.wikipedia.org/wiki/Archivo:Columbia\_STS-107\_launch.jpg</a>

# [3.2.7c]

<http://livedoor.blogimg.jp/cat\_1970\_0624-kura/imgs/b/5/b5aadf57-s.jpg>

# [3.2.7d]

<http://clikhear.palmbeachpost.com/wp-content/uploads/2011/07/challengerexplode.jpg>

# [3.2.7e]

<http://0.tqn.com/d/history1900s/1/0/r/V/challenger10.jpg>

# [3.2.8] - By Author

Social health is important and one of the ways of modern times and most likely projected for the future is through digital social medias such as "Facebook" as denoted by the dense collage of profile pictures from a bunch of close friends and family in my (Jonathan Lim) account.

# [3.2.9]

<http://whatsfab.ca/wp-content/uploads/2012/03/230809549622222590\_Iit6Fhl9\_c.jpg>

#### [3.2.10] - By Author

Rendered visualization looking out the window of a suggested spacecraft or space station towards the planet Earth with a backdrop of the universe beyond.

#### [3.2.11a]

<http://www.canonrumors.com/forum/index.php?action=dlattach;topic=7691.0;attach=21776;ima
ge>

#### [3.2.11b]

<http://newsinphoto.ru/wp-content/uploads/2011/06/s134e009351.jpg4288%D0%93%E2%80%942848-700x464.jpg>

#### [3.2.11c]

<http://4.bp.blogspot.com/\_KE-1BxjdxA8/TPGDWwid-FI/
AAAAAAAAACqY/31d9zYX0m\_A/s1600/photog.jpg>

#### [3.2.11d]

<http://www.nasa.gov/images/content/245952main\_nyberg\_full.jpg>

#### [3.2.11e]

<chronowerx.files.wordpress.com/2010/02/ss-100204-issphoto-01-ss\_full.jpg>

#### [3.2.11f]

<http://en.wikipedia.org/wiki/File:Tracy\_Caldwell\_Dyson\_in\_Cupola\_ISS.jpg>

# [3.2.12a]

<http://dreamwall1.files.wordpress.com/2011/09/emphasis-10.jpg>

# [3.2.12b]

<http://dreamwall1.files.wordpress.com/2011/09/web-18.jpg>

# [3.2.12c]

<a href="http://www.dspusa.net/news/CEILING/files/attach/images/71/501/IMG\_7208.JPG">http://www.dspusa.net/news/CEILING/files/attach/images/71/501/IMG\_7208.JPG</a>

# [3.2.12d]

<http://dreamwall1.files.wordpress.com/2011/09/web-17.jpg>

# [3.2.12e]

<http://c1038.r38.cf3.rackcdn.com/group1/building5151/media/04\_Supreme188.jpg>

# [3.2.12f]

<a href="http://dreamwall1.files.wordpress.com/2011/09/web-2.jpg">http://dreamwall1.files.wordpress.com/2011/09/web-2.jpg</a>

# [3.2.12g]

<http://images.wisegeek.com/acoustic-foam-for-soundproofing.jpg>

#### [3.2.12h]

<http://image.made-in-china.com/2f0j00ivdEQmGJCHoT/Acoustic-Panel-28-4-4-.jpg>

# [3.2.12i]

<http://iconic3dpanel.com/images/En/En\_BG02.jpg>

#### [3.2.12j]

<a href="http://furnitursite.com/wp-content/uploads/2010/12/elegant-line-of-acoustic-wall-panels-3.jpg">http://furnitursite.com/wp-content/uploads/2010/12/elegant-line-of-acoustic-wall-panels-3.jpg</a>

#### [3.2.13]

<http://www.itdunya.com/attachments/225114d1273086147-aerial-view-cn-tower-toronto-canada.jpg>

#### [3.3.1a]

<a href="http://www.buyfloatationtank.com/wp-content/uploads/2011/07/Floatation-Open-Pool1.jpg">http://www.buyfloatationtank.com/wp-content/uploads/2011/07/Floatation-Open-Pool1.jpg</a>

#### [3.3.1b]

<http://www.floatshoppe.com/fs/wp-content/uploads/2012/05/Open-Float-Tank-Neil-04-noglare.jpg>

#### [3.3.1c]

<http://www.i-sopod.com/wp-content/gallery/studioshots/i-sopod-with-girl-floating.png>

#### [3.3.1d]

<http://www.float-spa.net/wp-content/uploads/2012/02/spa-setting-solo.jpg>

# [3.3.1e]

<http://farm5.staticflickr.com/4043/4362380611\_25bcd3dcc5\_z.jpg>

# [3.3.2a]

<http://www.alterg.com/wp-content/uploads/2012/11/Ivan\_SkyPT.jpg>

# [3.3.2b]

<a href="http://www.alterg.com/treadmill-training-rehab/wp-content/uploads/2010/04/091016\_AGp200\_BGSide\_A4\_F1\_Cack.jpg">http://www.alterg.com/treadmill-training-rehab/wp-content/uploads/2010/04/091016\_AGp200\_BGSide\_A4\_F1\_Cack.jpg</a>

# [3.3.2c]

<http://www.azinews.com/wp-content/uploads/2011/11/treadmill.jpg>

# [3.3.2d]

<a href="http://www.nasa.gov/images/content/648047main\_alterg\_2\_full.jpg">http://www.nasa.gov/images/content/648047main\_alterg\_2\_full.jpg</a>

# [3.3.3a]

<a href="http://www.runnersworld.com/sites/default/files/files/2012/08/LightSpeed.jpg">http://www.runnersworld.com/sites/default/files/files/2012/08/LightSpeed.jpg</a>

#### [3.3.3b]

<http://www.hengao.com.cn/uploadimg/contents/20100205102243303.jpg>

#### [3.3.3c]

<http://www.jneuroengrehab.com/content/4/1/1/figure/F1?highres=y>

#### [3.3.3d]

<http://www.hengao.com.cn/uploadimg/contents/20100205102132791.jpg>

#### [3.3.4a] - By Author

Modified patent drawings for resistance band training apparatus and tethering anchor points. Original base drawing source from <a href="http://www.strutpatent.com/patent/08002681/resistance-training-tool">http://www.strutpatent.com/patent/08002681/resistance-training-tool</a>

#### [3.3.4b]

<http://3.bp.blogspot.com/-yLLa\_Ekn65M/T0Mgm\_i9rgI/AAAAAAAAAHY/7\_QhMCo-1c8/s1600/bowflex-pr1000-cheap.jpg>

#### [3.3.4c]

<http://best-home-gyms-reviews.com/wp-content/uploads/2012/08/Bowflex-Xtreme-2-SE-Home-gym1.jpeg>

#### [3.3.4d]

<http://www.freestylernetwork.com/wp-content/uploads/weight-training-routines-for-women32.jpg>

# [3.3.5a]

<http://factspy.net/wp-content/uploads/2011/12/41\_Thagard\_Exercise.jpg>

# [3.3.5b]

<http://www.sciencer.ru/img/5686661134406902-0.jpeg>

# [3.3.5c]

<http://i.space.com/images/i/1377/iFF/h\_spaceislandgroup\_02.jpg?1292263870>

# [3.3.5d]

<a href="http://www.nasa.gov/images/content/235791main\_image\_1098\_946-710.jpg">http://www.nasa.gov/images/content/235791main\_image\_1098\_946-710.jpg</a>

# [3.3.5e]

<http://img.ffffound.com/static-data/assets/6/32efbbf1274af76238e3e86007c78fbc3f773fde\_m.jpg>

# [3.3.5f]

<http://ut-images.s3.amazonaws.com/wp-content/uploads/2010/02/131.jpg>

# [3.3.5g]

<a href="http://www.spacefuture.com/archive/images/zero\_gravity\_sports\_centers.3.jpg">http://www.spacefuture.com/archive/images/zero\_gravity\_sports\_centers.3.jpg</a>

#### [3.3.5h]

<a href="http://msnbcmedia2.msn.com/j/MSNBC/Components/Photo/\_new/120615-AstroPhoto-hmed-0130p\_files.grid-7x2.jpg">http://msnbcmedia2.msn.com/j/MSNBC/Components/Photo/\_new/120615-AstroPhoto-hmed-0130p\_files.grid-7x2.jpg</a>

#### [3.3.5i]

<http://www.universetoday.com/wp-content/uploads/2008/04/station\_golf.jpg>

#### [3.3.6a]

"The Playboy Club in Space" by A.J. Baime and Jason Harper, Playboy Magazine, page 72-73, March 2012

#### [3.3.6b]

"The Playboy Club in Space" by A.J. Baime and Jason Harper, Playboy Magazine, page 75, March 2012

### [3.3.6c]

<http://orbitaltechnologies.ru/en/images-of-the-commercial-space-station.html>

#### [3.3.6d]

<https://picasaweb.google.com/galacticsuiteresort>

# [3.3.6e]

"The Playboy Club in Space" by A.J. Baime and Jason Harper, Playboy Magazine, page 75, March 2012

# [3.3.6f]

<http://orbitaltechnologies.ru/en/images-of-the-commercial-space-station.html>

# [3.3.6g]

<https://picasaweb.google.com/galacticsuiteresort>

# [3.3.6h]

"The Playboy Club in Space" by A.J. Baime and Jason Harper, Playboy Magazine, page 74, March 2012

# [3.3.6i]

<http://orbitaltechnologies.ru/en/images-of-the-commercial-space-station.html>

# [3.3.6j]

<http://astrowright.files.wordpress.com/2010/11/spaceshiptwoastronaut.jpg?w=510>

# [3.4.1a]

<a href="http://www.nasa.gov/images/content/493648main\_sc2010e014044\_hires\_full.jpg">http://www.nasa.gov/images/content/493648main\_sc2010e014044\_hires\_full.jpg</a>

#### [3.4.1b]

<http://ucdavis.edu/local\_resources/images/hpbg/2012/july/robinson.jpg>

# [3.4.1c]

<http://www.nasa.gov/images/content/493648main\_sc2010e014044\_hires\_full.jpg>

#### [3.4.1d]

<http://www.spaceoffice.nl/blobs/persberichten/NSO09093001.jpg>

#### [4.0.1]

<http://gazou-navi.angry.jp/Photo/images/20080929184926.jpg>

#### [4.0.2] - By Author

Graph diagram indicating the ranges of average commuter transit times sourced from data collected by Central Intelligence Agency (CIA) World Factbook <a href="https://www.cia.gov/library/publications/the-world-factbook/">https://www.cia.gov/library/publications/the-world-factbook/</a>, United Nations (UN) Statistics Division <a href="https://www.norg/unstats.un.org/unstal/default.htm">https://unstats.un.org/unstal/default.htm</a>, Organisation for Economic Co-operation and Development (OECD) <a href="https://www.norg/">http://www.norg/</a>, and Nation Master Statistics Database <a href="https://www.nationmaster.com/">http://www.nationmaster.com/</a> \*not to scale represented as estimates.

#### [4.0.3] - By Author

Great circle flight route diagrams overlay onto a heat map of estimated travel times to major cities are generated to give several examples of the distance between cities (selection of Toronto as a consistent point of comparison) and identify the travel times required using various methods of travel. The base map is sourced at <a href="http://spatial-analyst.net/wiki/index.php?title=Image:Gaccessm.png">http://spatial-analyst.net/wiki/index.php?title=Image:Gaccessm.png</a> while great circle diagrams are generated with the integration of data collected from <a href="http://openflights.org/data.html">http://openflights.org/data.html</a> and basemaps from <a href="http://www.naturalearthdata.com/">http://www.naturalearthdata.com/</a> using ArcGIS mapper and Python scripts. The distance between the cities are estimates retrieved from <a href="http://www.timeanddate.com/">http://www.timeanddate.com/</a> worldclock/distance.html> while the times for travel are calculated according to the various distances with respect to the estimated velocities pertaining to each method of transit.

# [4.0.4] - By Author

Great circle flight route diagram generated to show the congestion in the air space. Great circle diagrams are generated with the integration of 58,541 data points collected by <http://openflights.org/data.html> and basemaps from <http://www.naturalearthdata.com/> using ArcGIS mapper and Python scripts.

# [4.0.5a]

<a href="http://en.wikipedia.org/wiki/File:Space\_Shuttle\_Columbia\_launching.jpg">http://en.wikipedia.org/wiki/File:Space\_Shuttle\_Columbia\_launching.jpg</a>

# [4.0.5b]

<nnw.bigfloridacountry.com/spaceshuttles/spaceshuttleendeavour/Space\_Shuttle\_Transit.jpg>

# [4.0.5c]

<a href="http://www.nasa.gov/centers/dryden/images/content/300901main\_ECN-6887\_full.jpg">http://www.nasa.gov/centers/dryden/images/content/300901main\_ECN-6887\_full.jpg</a>

# [4.0.5d]

<http://www.trbimg.com/img-1348264688000/turbine/la-look-up-m-001>

#### [4.0.6] - By Author

Original Space Shuttle and external fuel tank elevations traced over original 3D models provided at <a href="http://www.nasa.gov/multimedia/3d\_resources/models.html">http://www.nasa.gov/multimedia/3d\_resources/models.html</a> and scaled according to original Space Shuttle drawings from <a href="http://history.nasa.gov/SP-4225/diagrams/shuttle/shuttle-diagram.htm">http://history.nasa.gov/SP-4225/diagrams/shuttle/shuttle-diagram.htm</a>. External tank sections are original drawings basing from traced elements from the elevations and referencing from sources from NASA and diagrams such as <a href="http://en.wikipedia.org/wiki/File:Sts\_et\_cutaway.jpg">http://en.wikipedia.org/wiki/File:Sts\_et\_cutaway.jpg</a> and <a href="http://en.wikipedia.org/wiki/File:Sts\_et\_ecographic.jpg">http://en.wikipedia.org/wiki/File:Sts\_et\_ecographic.jpg</a>. The detachable concepts depicted by the external tank section are original as the proposed joints and details are conceived by the author.

#### [4.0.7a]

<http://up-ship.com/blog/wp-content/uploads/2009/11/alsv1.jpg>

#### [4.0.7b]

<http://www.buran.ru/images/jpg/maks15.jpg>

#### [4.0.7c]

<http://www.3dtotal.com/admin/new\_cropper/interview\_content\_images/28\_tid\_04.jpg>

#### [4.0.8a]

<http://s3images.coroflot.com/user\_files/individual\_files/original\_204062\_ HuGwH0t8t6AFlyPLOb6fW75Vt.jpg>

#### [4.0.8b]

<http://ianott.files.wordpress.com/2011/12/ss-091204-spaceshiptwo-07.jpg>

# [4.0.8c]

<http://www.architectureandvision.com/av/051.html>

# [4.1.1] - By Author

A flowchart diagram expressing current passenger experiences when taking air transit connecting through airports. It also incorporates statistics for elite status passenger travel trends (noted from "The Travel & Tourism Competitiveness Report 2011 - Beyond the Downturn" by Jennifer Blanke and Thea Chiesa, World Economic Forum, 2011) as well as the proposal of the future space transit experiences through the introduction of an elite spacefaring class to the current model.

# [4.1.2a]

GDP and premium passengers by country pairs

"The Travel & Tourism Competitiveness Report 2011 - Beyond the Downturn" by Jennifer Blanke and Thea Chiesa, World Economic Forum, page 54, 2011

#### [4.1.2b] - By Author

Manipulated graph showing premium passenger arrivals from selected countries. Original top50 graph is referenced from "The Travel & Tourism Competitiveness Report 2011 - Beyond the Downturn" by Jennifer Blanke and Thea Chiesa, World Economic Forum, page 54, 2011

#### [4.1.3]

<http://2.bp.blogspot.com/\_4mhfyNwc3bE/TPOINdkfy9I/AAAAAAAAAABo/rr-Vscr-67s/
s1600/Australian+aircraft+charters.jpg>

#### [4.1.4] - By Author

Population and growth with respect to national economic trends translated onto various world base maps using different mapping methods. Data sources collected from Central Intelligence Agency (CIA) World Factbook <a href="https://www.cia.gov/library/publications/the-world-factbook/">https://www.cia.gov/library/publications/the-world-factbook/</a>, United Nations (UN) Statistics Division <a href="http://unstats.un.org/unsd/default.htm">http://unsdats.un.org/unsd/default.htm</a>, Organisation for Economic Co-operation and Development (OECD) <a href="http://www.oecd.org/">http://www.oecd.org/</a>, and Nation Master Statistics Database <a href="http://www.nationmaster.com/">http://www.nationmaster.com/</a>. Base map sources from Natural Earth Vectors <a href="http://planet.openstreetmap.org/">http://planet.openstreetmap.org/</a>. Maps generated with the integration of data and base maps using ArcGIS mapper and Python scripts.

#### [4.1.4a] - By Author

Dot density map of integrated population and growth trends translated onto a Polyconic world base map.

# [4.1.4b] - By Author

Dot density choropleth map of population evaluations translated onto both Equirectangular and Robinson world base maps.

# [4.1.4c] - By Author

Dot density map of population growth trends translated onto both Equirectangular and Robinson world base maps.

# [4.1.4d] - By Author

Dot density choropleth map of gross national income evaluations translated onto both Equirectangular and Robinson world base maps.

# [4.1.4e] - By Author

Dot density map of financial infrastructure trends translated onto both Equirectangular and Robinson world base maps.

# [4.1.4f] - By Author

Dot density choropleth map of financial economic trends translated onto a Sinusoidal world base map.

#### [4.1.5] - By Author

Passenger and tourist arrival and departure trends translated onto various world base maps using different mapping methods. Data sources collected from Central Intelligence Agency (CIA) World Factbook <a href="https://www.cia.gov/library/publications/the-world-factbook">https://www.cia.gov/library/publications/the-world-factbook</a>, United Nations (UN) Statistics Division <a href="http://unstats.un.org/unsd/default.htm">http://unsdats.un.org/unsd/default.htm</a>, Organisation for Economic Co-operation and Development (OECD) <a href="http://www.oecd.org/">http://www.oecd.org/</a>, and Nation Master Statistics Database <a href="http://www.nationmaster.com/">http://www.nationmaster.com/</a>. Base map sources from Natural Earth Vectors <a href="http://planet.openstreetmap.org/">http://planet.openstreetmap.org/</a>. Maps generated with the integration of data and base maps using ArcGIS mapper and Python scripts.

#### [4.1.5a] - By Author

Dot density map of integrated local and foreign passenger arrival trends translated onto a Transverse Mercator world base map.

#### [4.1.5b] - By Author

Dot density map of local passenger arrivals translated onto both Equirectangular and Robinson world base maps.

# [4.1.5c] - By Author

Dot density map of foreign passenger arrivals translated onto both Equirectangular and Robinson world base maps.

#### [4.1.5d] - By Author

Dot density map of international tourist arrivals translated onto both Equirectangular and Robinson world base maps.

# [4.1.5e] - By Author

Dot density map of international tourist departures translated onto both Equirectangular and Robinson world base maps.

# [4.1.5f] - By Author

Dot density map of integrated international tourist arrival and departure trends translated onto a Mercator world base map.

# [4.1.6] - By Author

Great circle flight route diagrams generated to show the air traffic produced by the busiest airports in the world suggesting its importance as an international transit hub. The selection of these airports is a result of the analysis made by various versions of "World Airport Traffic Reports" by Airports Council International (ACI), Canada. Great circle diagrams are generated with the integration of 58,541 data points collected by <a href="http://openflights.org/data.html">http://openflights.org/data.html</a> and basemaps from <a href="http://www.naturalearthdata.com/">http://www.naturalearthdata.com/</a> using ArcGIS mapper and Python scripts.

#### [4.1.7] - By Author

A proposal diagram of selected countries with the potential capabilities to provide retrofit opportunities to support AERO | ASTRO's future launch capabilities. The points and lines are only suggestive to point at the selected countries and does not represent routing of any sorts. The translated overlay of an orbital track (an example of the International Space Station's coverage over Earth) suggests accessibility from these proposed airport hubs which makes it suitable for the selection.

#### [4.2.1] - By Author

Conceptual diagram that explains how an object is launched and stays in an Earth orbit using Sir Isaac Newton's hypothesis of shooting a cannonball out of a cannon. With excessive velocities, an object will generate enough counteracting force with respect to the gravitational pull of Earth, and therefore, the object will stay in an elliptical path of the orbital track.

#### [4.2.2]

<http://www.astrium.eads.net/media/image/metop\_sun-synchronous.jpg>

#### [4.2.3] - By Author

A transit phase diagram explaining the conceptual transit durations for commuting from point A on Earth to the transiting infrastructure in outer space (AERO | ASTRO).

#### [4.2.4a] - By Author

A suggestive diagram of the available orbital tracks that is currently present around Earth.

# [4.2.4b]

<http://upload.wikimedia.org/wikipedia/commons/thumb/b/b4/Comparison\_satellite\_navigation\_ orbits.svg/2000px-Comparison\_satellite\_navigation\_orbits.svg.png>

# [4.2.5] - By Author

The proposed transit system and its potential commute durations in accordance with [4.2.3]. The diagram proposes the commuter spacecraft to be launched from a point A on Earth to arrive shortly at a parking orbit until it reaches the docking of AERO | ASTRO's transit station. From there, passengers will transfer to another spacecraft (if they don't plan on staying to use the other facilities on AERO | ASTRO) and will depart the orbital infrastructure and return back to Earth to point B. All of this makes "going around the world in 80 days" into a new saying of "going around the world in 80 or so minutes".

# [4.3.1a]

<http://2.bp.blogspot.com/-G8jVqgYd6Vk/T-r7hI1xpUI/AAAAAAAHp0/IoOrR8aOj1w/
s1600/11.jpg>

# [4.3.1b]

<2.bp.blogspot.com/--mc1VFGLc\_Y/T-r5XACEKpI/AAAAAAAAHpg/fTb4islfitM/s1600/27.jpg>

#### [4.3.1c]

<3.bp.blogspot.com/-PyBnNkUvPDA/T-r7lHAxZHI/AAAAAAAAHqE/QpAUTvlXq10/ s1600/13.jpg>

#### [4.3.1d]

<http://tunnellingjournal.com/files/2012/06/TTC-TYSSEImage10-0800.jpg>

#### [4.3.1e]

<http://onlyhdwallpapers.com/wallpaper/trains\_subway\_tunnel\_train\_stations\_desktop\_2272x1704\_
wallpaper-115504.jpeg>

#### [4.3.1f]

<http://anthonyfavero.files.wordpress.com/2011/01/img\_2187e.jpg>

#### [4.3.2] - By Author

Conceptual diagrams of the original external fuel tank and its retrofit section in a sectional cut out perspective. These diagrams provide a foundation for the rest of the AERO | ASTRO designs in the following chapters.

#### [4.3.3] - By Author

Proposed kit-of-parts designed specifically for AERO | ASTRO.

#### [4.3.3a] - By Author

Type 1 modules are designed as typical primitives (majority of the components will be designed so similarly suit the fittings for these pieces).

# [4.3.3b] - By Author

Type 2 modules are designed as secondary primitives that are used for auxiliary circulations and module connections.

# [4.3.3c] - By Author

Type 3 modules are designed for the turning of corners encountered in the arrangement of AERO | ASTRO. These pieces are designed with a 60° angle corner to simulate an overall hexagonal shape, forming a "near circular" path for the internal circulation.

# [4.3.3d] - By Author

Type 4 modules are designed mainly to assist Type 2 [4.3.3b] connector modules in securing a perfect air tight bond. It also introduces another connecting adaptor that is used to connect the artificial gravity modules onto a revolving mechanism that generates the necessary centrifugal forces.

# [4.3.3e] - By Author

Type 5 modules are designed in a clover shaped section used only for the artificial gravity modules.

#### [4.3.3f] - By Author

Type 6 modules are designed specially for the amenity spaces that will host unique extraterrestrial activities such as sports (e.g. Astroball, gyms, etc.), observation modules on swivels, chapels, etc.

#### [4.3.3g] - By Author

Type 7 modules are designed as the living pods that are found throughout the residence block of AERO | ASTRO. These spherical shaped living units have a potential to also function doubly as escape pods (this concept will require further study on its technicalities).

#### [4.3.3h] - By Author

Type 8 modules are designed for the back of house programs and supportive systems. These include the power generation systems that operate with solar array structures.

#### [4.3.4] - By Author

Parti drawings of various archetypal interior configurations that are possibly fitted into the gutted external tanks as mentioned in [4.3.2]. This acts as a general concept in conjunction with the kit-of-parts from [4.3.3].

# [4.3.5] - By Author

A detailed representation of the archetypal interior configurations as mentioned in [4.3.4] with a detail sectional rendering displaying all the components of circulation and back of house spaces while developing a sense of scale to these volumes in a rendered visualization looking in from the center of the space.

# [4.3.6] - By Author

Detailed illustrations and drawings of two optional paneling types (as samples and are not limited to only these) proposed to be used throughout AERO | ASTRO.

# [4.4.-] - By Author

All drawings (details, plans, elevations, sections, etc.), diagrams (project phasing, program partis, etc.), and rendered still visualizations are designed and generated solely for the purpose of representing a sample variation of what the kit-of-parts mentioned earlier can produce. The spaces expressed in this section of Chapter 4.4 sets the stage for the following section in the descriptions on ritualistic experiences that are presented in a weightless culture of outer space.

# [4.4.1]

<http://www.slate.com/blogs/behold/2012/12/07/nasa\_s\_ames\_research\_center\_space\_colony\_
images\_from\_the\_1970s.html>

# [4.4.2]

<http://pbmo.files.wordpress.com/2011/02/torus-city.jpg>

#### [4.5.1] - By Author

A modified variation of the personal space diagrams introduced by Edward Twitchell Hall in 1966. This version reflects the two-dimensional qualities of one's personal space on Earth.

# [4.5.2] - By Author

A modified adaptation of the personal space diagrams introduced by Edward Twitchell Hall in 1966. This version reflects the three-dimensional aspects of one's personal space in outer space as a "personal bubble" surrounding oneself.

#### [4.5.3] - By Author

A heat mapped representation of the overlapping conditions of one's personal space boundaries in a space on Earth (the Milwaukee Art Museum). The base image was modified from <a href="http://3.bp.blogspot.com/-6C7HHAbCvak/UEIn4LCsDjI/AAAAAAAABxw/ebUtBqjTN-k/s1600/museum-crowd.jpg">http://3.bp.blogspot.com/-6C7HHAbCvak/UEIn4LCsDjI/AAAAAAAABxw/ebUtBqjTN-k/s1600/museum-crowd.jpg</a>

#### [4.5.4] - By Author

Diagram showing the general proximity/reach of one's personal space (typically within arm's reach).

#### [4.5.5] - By Author

A diagram showing the possible relationship of overlapped personal spaces on Earth.

#### [4.5.6] - By Author

Rendered diagram of the personal space bubble in outer space reflecting its relationship with others and the interior spaces as generated by the archetypal configurations for AERO | ASTRO.

# [4.5.7a]

<http://3.hp.blogspot.com/-fd6QfdJFmn0/T4j19--nwBI/AAAAAAAABgM/rgr\_7UspiZ0/
s1600/100\_0802.JPG>

# [4.5.7b]

<http://d6673sr63mbv7.cloudfront.net/archive/x1350020287/ g00000000000000000006afa488b57f1ad777633689b14a58aa89f4a8be5.jpg>

# [4.5.7c]

<a href="http://www.scottsaccess.co.uk/images/uploads/Gall027.jpg">http://www.scottsaccess.co.uk/images/uploads/Gall027.jpg</a>

# [4.5.7d]

<http://blog.therohogroup.com/wp-content/uploads/2011/12/Disabled-Sports-Bi-skier-Zach.jpg>

# [4.5.7e]

<http://blogs.gonomad.com/wake-and-wander/files/2012/06/Porta-Ledge-Bridge\_Panorama2111.</p>

#### [4.5.7f]

<a href="http://www.ketterersrescueproducts.com/Images/RescuePics/IceRescue2.jpg">http://www.ketterersrescueproducts.com/Images/RescuePics/IceRescue2.jpg</a>

# [4.5.8]

<http://www.sparqtraining.com/>

# [4.5.9] - By Author

Designed merchandise for AERO | ASTRO that doubles to function as the tethering apparatus used for the mobility and stability of the occupants in the space station.

# [4.5.10] - By Author

Designed fashion (spacesuits) that supports the various daily functions with various anchor points for tethering opportunities. All components are compliant with the handheld devices and industrial designed accessory merchandises.

#### [4.5.10a] - By Author

Pajama type spacesuit assists unfamiliar occupants to adapt to the sleeping conditions under weightlessness.

#### [4.5.10b] - By Author

Multipurpose type spacesuit assists occupants in activity specific functions as it provides additional padding support and several tethering opportunities using Velcro, magnetic, and typical anchor apparatuses.

# [4.5.10c] - By Author

Casual type spacesuits are the general outfits that allows flexible movements and simple tethering opportunities with shoulder anchor connectors.

# [4.5.11] - By Author

Rendered plans, sections, and perspectives of a conceptual apparatus, the AERO | ASTRO Bubble. It is designed as a furnishing for the space station that provides anchoring connectors for occupants to tether to and allows one to thrust off of to propel them throughout the interior volumes of the space station. The bubble also provides an opportunity for a point of interaction and resting as "seating" areas are supplied.

# [4.5.12a] - By Author

Traced Nolli map of Piazza del Campo. Original source was a screen capture of the area with "Google map".

# [4.5.12b] - By Author

A rendered interior perspective of the Piazza del Campo. The model of the piazza references the basic massing model of the piazza from "Google Earth".

#### [4.5.12c] - By Author

A rendered perspective section of the Piazza del Campo. The model of the piazza references the basic massing model of the piazza from "Google Earth".

#### [4.5.13] - By Author

A variation of the Nolli map represented for AERO | ASTRO illustrating the various public open and private enclosed spaces throughout the station.

#### [4.5.14a]

<http://wallpapersfor.me/wp-content/uploads/2012/06/prometheus-hologram-movie-ridley-scott-alien-science-fiction-2012.jpg>

#### [4.5.14b]

Screen captured still from promotional video by Corning Incorporated, "A Day Made of Glass 2 - Same Day, Expanded Vision" (2012) at 0:04:20

#### [4.5.14c]

Screen captured still from promotional video by Microsoft Office Labs, "Concept of How 2019 will Look Like" (2010) at 0:03:15

#### [4.5.15] - By Author

Rendered perspective of an interior space in the Nexus corridor of AERO ASTRO.

# [4.5.16] - By Author

Rendered perspective of an interior space looking towards the space piazza of AERO | ASTRO.

# [4.5.17a]

<http://www.hoteloceanasantamonica.com/uploads/backgrounds/home\_accomodation\_dining\_ocean-suite-bed\_1656\_1090x1095.jpg>

# [4.5.17b]

<http://dietcenterdenver.files.wordpress.com/2010/12/holiday-dinner1.jpg>

# [4.5.17c]

<http://steelcloset.com/wp-content/uploads/2008/10/poster-dinner-party.jpg>

# [4.5.17d]

<http://www.101loseweightfast.com/wp-content/uploads/2012/12/eat-less-to-lose-weight.jpg>

# [4.5.17e]

<http://www.lascasitasvillage.com/var/plain\_site/storage/images/media/images/internal-headerimages/dining/dining-image-1/2211-3-eng-US/Dining-Image-1\_home\_header\_image.jpg>

#### [4.5.17f]

<a href="http://aruba-daily.com/newspaper/wp-content/uploads/2011/06/La-Vista-Family-Dinner.jpg">http://aruba-daily.com/newspaper/wp-content/uploads/2011/06/La-Vista-Family-Dinner.jpg</a>

#### [4.5.18a]

Typical seating arrangement diagram as depicted by image <a href="http://digitaldaily.allthingsd.com/files/2011/02/obamaSV/dinner.jpg">http://digitaldaily.allthingsd.com/files/2011/02/obamaSV/dinner.jpg</a>

#### [4.5.18b]

Hierarchical seating arrangement diagram as depicted by image <a href="http://mojoguangzhou.files.wordpress.com/2010/11/erin11.jpg">http://mojoguangzhou.files.wordpress.com/2010/11/erin11.jpg</a>

#### [4.5.18c]

Informal (casual) scattered seating arrangement diagram as depicted by image <a href="http://4.bp.blogspot.com/-Mrtll]1sg]M/Tj7U2kmHLuI/AAAAAAAAAAPKU/Z4gG9oKKFOk/s1600/IMG\_+5471\_budson\_diner.jpg">http://4.bp.blogspot.com/-Mrtll]1sg]M/Tj7U2kmHLuI/AAAAAAAAAAPKU/Z4gG9oKKFOk/s1600/IMG\_+5471\_budson\_diner.jpg</a>

#### [4.5.19a]

<http://davidideas.com/images/uploads/11\_09\_DEwhaf-10.jpg>

#### [4.5.19b]

<http://blestphotography.com/wp-content/uploads/2011/03/fork.jpg>

#### [4.5.19c]

<http://glow-magazine-bce0cbed.s3.amazonaws.com/Images/FastFood.jpg>

# [4.5.19d]

<http://blestphotography.com/wp-content/uploads/2011/03/fork.jpg>

# [4.5.19e]

<a href="http://blestphotography.com/wp-content/uploads/2011/03/knife.jpg">http://blestphotography.com/wp-content/uploads/2011/03/knife.jpg</a>

# [4.5.19f]

<http://cdn2.reebonz.com/sites/all/files/TGFORKCHOPSUTENSILS\_1.jpg?d>

# [4.5.19g]

<http://blestphotography.com/wp-content/uploads/2011/03/knife.jpg>

# [4.5.19h]

 $<\!\!http://blestphotography.com/wp-content/uploads/2011/03/spoon.jpg\!\!>$ 

# [4.5.19i]

<http://2.bp.blogspot.com/\_Lu4mlxa1fyw/S\_rwRrlPa2I/AAAAAAAAAAAsg/Wz2ZXIW1Wag/ s1600/eco2.jpg>

#### [4.5.19]]

<http://blestphotography.com/wp-content/uploads/2011/03/spoon.jpg>

## [4.5.20] - By Author

Sectional drawings for the interior planning of the various dining space module types proposed for AERO | ASTRO.

#### [4.5.21a]

<http://2.bp.blogspot.com/\_eoa7aTS35vI/TKEUYAWIBuI/AAAAAAAAWU/fR2nJVpv\_
J8/s1600/PeggyFood.jpg>

#### [4.5.21b]

<http://ut-images.s3.amazonaws.com/wp-content/uploads/2012/02/Expedition\_20\_crew\_members\_
share\_a\_meal\_at\_a\_galley\_in\_the\_Unity\_node\_of\_the\_International\_Space\_Station\_-\_20090731.
jpg>

#### [4.5.21c]

<http://metronewsca.files.wordpress.com/2012/04/spacefood\_amber.jpg?w=618&h=408&crop=1>

#### [4.5.22]

Screen captured film sequence of a playful way of eating in outer space as depicted by Homer Simpson's ignorance and clumsiness. "The Simpsons - Season 5 Episode 15: Deep Space Homer" (1994) at 0:15:00 to 0:16:30

# [4.5.23] - By Author

Rendered exterior perspective of the residence block as seen on the approach from Earth to AERO}ASTRO's docking ports.

# [4.5.24] - By Author

3D models generated to remap the various individual and couple paired sleeping positions typically found on Earth. Data source and terminology from <a href="http://en.wikipedia.org/wiki/Sleeping\_positions">http://en.wikipedia.org/wiki/Sleeping\_positions</a> and <a href="http://news.bbc.co.uk/2/hi/health/3112170.stm">http://news.bbc.co.uk/2/hi/health/3112170.stm</a>

# [4.5.25] - By Author

Sleeping positions rendered in its variations found in outer space inside a proposed sleeping pod with unique "bedding" apparatuses.

# [4.5.26] - By Author

Sectional renderings of the living pod that hosts the basic functions for sleeping, toiletry, and living.

# [4.5.27a]

<http://www.audioadvice.com/wp-content/uploads/2012/06/1-Savant-Light.jpg>

#### [4.5.27b]

Screen captured still from promotional video by Corning Incorporated, "A Day Made of Glass 2 - Same Day, Expanded Vision" (2012) at 0:00:25

#### [4.5.27c]

<http://www.umbilicaldesign.se/>

# [4.5.28] - By Author

Rendered sectional perspective that describes the various quadrants found in the living pod.

#### [4.5.28a] - By Author

Rendered casing and sliding glass door for the sleeping pod used in a quadrant of the living pod.

### [4.5.28b] - By Author

Rendered inflatable room pocket that expands in the sleeping pod space to provide the many customizations available to suit the occupant's sleeping ritual needs.

#### [4.5.28c] - By Author

Rendered "bed" used in the sleeping pod with belt binding and anchor connectors for the option of grounding one's sleep position or attach their sleep cocoons to (sleeping bags).

#### [4.5.29] - By Author

Rendered perspective looking into the residential living pod towards the electro-chromic glazed windows that overlook Earth.

# [4.5.30] - By Author

Rendered perspective looking back at the entry hatch and main components of the residential living pod.

#### [5.0.1]

<http://explorationdayusa.org/wp-content/uploads/2012/08/moonboot.gif>

## [5.0.2]

<http://25.media.tumblr.com/tumblr\_m7l2i1u74c1qmjh2qo1\_1280.jpg>

#### [5.0.3]

<http://www.free-hdwallpapers.com/wallpapers/space/170404.jpg>





inception overview

On Earth, humans have always experienced the environment as consisting of two essential elements: the architecture surrounding us, and the sky above us. We have instinctively adopted a curious fascination with the potentials beyond our current proximity to the cosmos. This inclination to reach the unknown has radically revolutionized the human species. It has inspired us to explore unfamiliar realms and expand into uncharted territories, with the visionary objective of advancing human knowledge for the benefit of all while returning with technological innovations for practical, earthly applications.

Adventurous explorations have always been an instinctive motive for survival. Whether moving away from our origin points to broaden our scientific knowledge or to expand culturally in conquering greater boundaries of real estate, each one of us is ultimately a passenger on the Spaceship Earth. However, mankind is drawn to the heavens for the same reason we were once drawn into unknown lands and across the open sea. So let us [as homo sapiens] continue the journey² to fulfill our duty to future generations and their quest to ensure the survival of the human species. Through contemporary research and the development of extraterrestrial applications and sciences, visionary designs will motivate and support explorers to enter new realms, extending human experiences, cultures, and the species itself into uncharted territories. Additionally, inspired by this visionary research, future designers such as architects specialized in outer space applications will eventually be able to provide sound environments for the future occupation of the cosmos.

Buckminster Fuller, Operating Manual for the Spaceship Earth, 1969

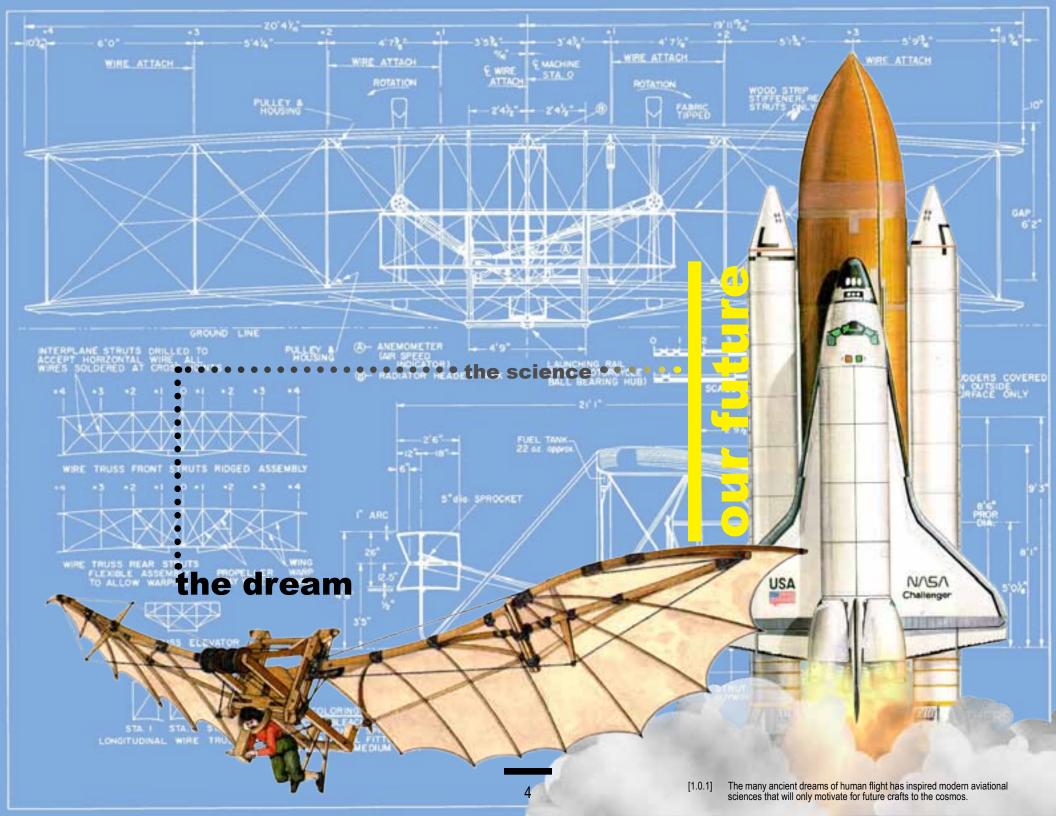
George W. Bush, speech at NASA Headquarters, January 14, 2004

<sup>3</sup> Edwin "Buzz" Aldrin, on the 37th Anniversary of the Apollo 11 Landing, July 2006

ght "The Art of Travel" by Alain de Botton, page 107, 2002

"Humboldt's early biographer, F.A. Schwarzenberg, subtitled his life of Humboldt 'What May be Accomplished in a Lifetime", and summarized the areas of his extraordinary curiosity: '1. The knowledge of the earth and its inhabitants. 2. The discovery of the higher laws of nature, which govern the universe, men, animals, plants, and minerals. 3. The discovery of new forms of life. 4. The discovery of territories hitherto but imperfectly known, and their various productions. 5. The acquaintance with new species of the human race—their manners, language and historical traces of their culture.' What may be accomplished in a lifetime—and seldom or never is."

"The Art of Travel" by Alain de Botton



In ancient times, explorers traveling by foot or on the backs of animals spent countless decades migrating through the vast landscapes of the Earth, far beyond the vicinity they called "home." It was only within the last few centuries that innovative solutions allowed humans to commute with comfort and efficiency from their familiar surroundings to new, desirable destinations. With the mid-18th century invention and early-20th century commercialization of a *self-propelled mechanical vehicle*, the automobile, people were for the first time able to travel far beyond their immediate environment quickly and safely. As well, such advancements directed scientists and engineers into the booming automotive industry, creating further opportunities for research and development. In the early 20th century, the brothers *Orville and Wilhur Wright* fabricated the first successfully operational aircraft, making the fantasy of manned flight a reality. As a result of this innovative breakthrough, the contemporary field of aeronautical design has grown into a multi-billion-dollar aerial transportation industry, making air travel a convenient way for modern people and businesses to travel globally.

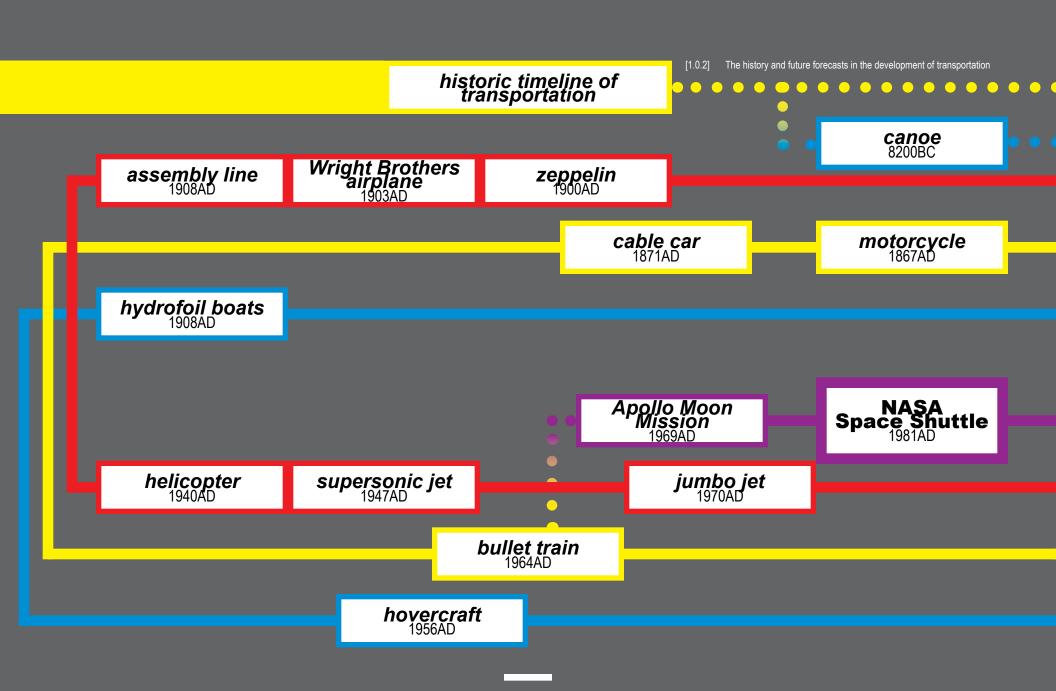
Finally, in the mid to late 20<sup>th</sup> century, the race to outer space was implemented into the homeland security agendas of two major global powerhouses of the time: the Union of Soviet Socialist Republics (USSR) and the United States of America (USA). It was this pursuit for technological and ideological supremacy, in conjunction with emerging new markets in the private sector that accelerated further advancements in human research and technological innovations.

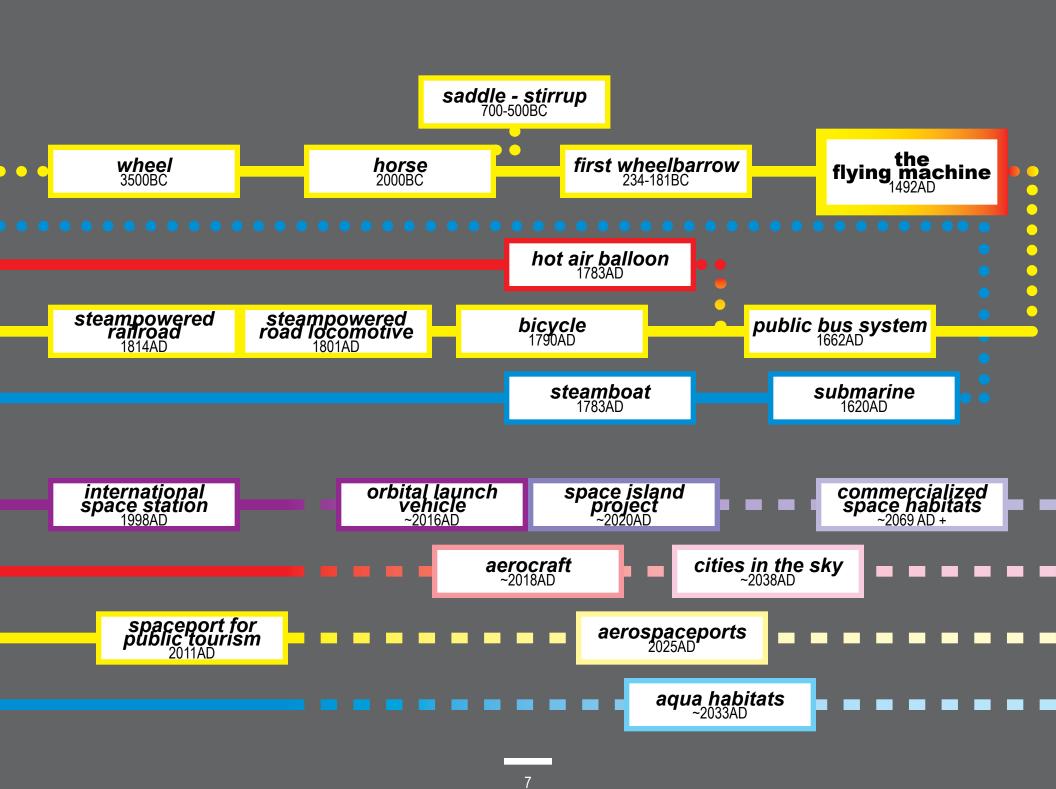
- The earliest successful invention of an automobile by French inventor, Nicolas-Joseph Cugnot in about 1769. This steam-powered tricycle was heavily disputed against Ferdinand Verbiest's design of a 65cm long scale model toy given to the Chinese Emperor during his 1672 Jesuit mission in China.
- 5 As described by the accompanying label description of the original Wright Flyer at the National Air and Space Museum:

"The original Wright brothers aeroplane. The world's first power-driven heavier-than-air machine in which man made free, controlled, and sustained flight. Invented and built by Wilbur and Orville Wright. Flown by them at Kitty Hawk, North Carolina December 17, 1903. By original scientific research the Wright brothers discovered the principles of human flight. As inventors, builders, and flyers they further developed the aeroplane, taught man to fly, and opened the era of aviation"

*left* [1.0.1] The designs of human flight

*next* [1.0.2] Timeline of transportation developments





Although the idea of reaching towards the heavens is an ancient concept, it is only recently that we have had the technology to potentially turn this flight of the imagination into an impending reality. Current migrating global trends indicate two significant factors for industry and market leaders to consider when forecasting high-profile investment strategies for serious developments such as space habitations: *the recognition and developments of emerging markets, and the ownership-taking of the modern consumer.*<sup>6</sup> For this reason, architectural practice structured only for the basic design build sectors of construction will not suffice as its own entity in the competitive market of integrative industries. The prevailing global architectural design leaders of the 21<sup>st</sup> century will need to strategically hybridize into specialized integrated sectors, such as the serious undertaking of space architecture, to initiate new models of architecture suitable for the amalgamation of various emerging markets.

This thesis proposes a futuristic model of an efficient and unique passenger transport experience that connects Earth-based hybrid air/space ports with an *outer space orbital infrastructure hub*. This modern intervention will allow for new outer space industries, such as transit, tourism, and hospitality, which will provide unique opportunities for the future of humanity. Introducing humans to the environs of orbital space will be the initial stage in a long-term phasing tactic to colonize and commercialize beyond the expanse of Earth, eventually extending humanity to the remote neighbouring planets of the universe. In the following sections, the migration of fundamental features of *Architecture, Aerospace, and Astronautics* will define the rudimentary language of an emergent specialization: *Space Architecture*.

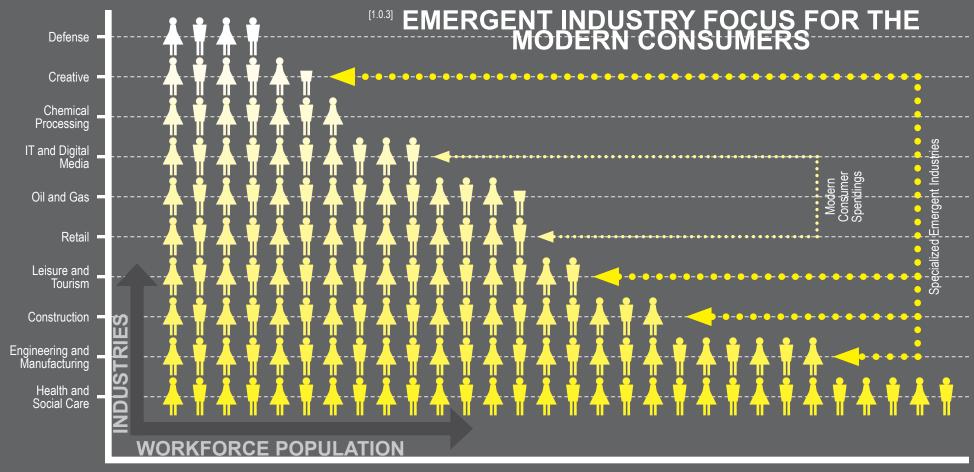
"Industry boundaries are blurring and so are those of the organizations that compete in them. Value spaces are increasingly being defined by consumers, not firms ... As boundaries blur and everything becomes mobile, players are increasingly interdependent, having to balance how they compete and cooperate with others, potentially fulfilling multiple roles in a network or across industries. This extends to interactions with society, where new forms of networks and smart partnerships are emerging, to deliver commercial and societal benefits simultaneously.

With more consumers globally with more wealth, choice and desire to get involved in co-creation, the fight is on to own the new consumer—a consumer that wants more involvement and personalization, that wants it all anywhere, anytime, and wants it to be cheap and chic as the climate of frugality bites ... As consumers increasingly demand experiences and solutions, this fight may evolve into new, creative forms of cooperation between firms and others."

"10 Key Trends to Watch" by Tracey Keys and Thomas Malnight, globaltrends, 2010

right [1.0.3] Infographic on emergent industry focus with respect to the total workforce

[1.0.4] Collage of industries offered to the global workforce



\* all data plotted is only an estimated representation of the relative comparison for each emergent industry







Architects tend to operate under the two opposing influences of reality and idealism. Under most realistic circumstances, Architects work within tight constrictions imposed by clients, budgets, market trends, municipal regulations, and available technologies. However, in the ideal realm of designers, visionary conceptions of new dwellings, new cities, and new worlds spark greater forms of innovation and creativity for future generations. Encounters with new boundaries and conceptualized environments will result in the evolution of human experience. To turn one's vision into a reality through the marriage of these two parallel universes is what an Architect lives and dreams for.

Originating as *vernacular constructions*<sup>7</sup> and tending towards the individualized needs of shelter and security, the practice of architecture has evolved from the trial-and-error method of building into a formalized craftsmanship and professional practice based upon cultural and technological advancements. In modern studios, the architectural practice is streamlined to develop through interdisciplinary design to construction workflow. The architect can be conceived as the maestro of a symphony, directing engineers, consultants, and designers (mechanical, electrical, and structural) to collaborate with their vision. Through this process, the schematic models of building designs and development strategies become a physical reality.

"Historically, people have always been modifying the internal environment in which they were living. Caves and other primitive types of dwellings were used in prehistoric times for protection from the external environment like rain, wind and earthquakes. These have developed later to simple artificial enclosures as civilization continued developing, and, in this way, different types and styles of identifiable dwellings started to appear around the world, depending on the climate, technologies and available local materials of the place. Therefore, the term vernacular architecture evolved, and is used to relate to these different styles of building around the world."

"Earthships as an Affordable, Sustainable Part of Vernacular Architecture" by Nikolaos Meintanis, University of Sussex, Earthzine - Fostering Earth Observation & Global Awareness, November 6, 2010

rignt

"10 Books on Architecture" by Vitruvius, translated by Morris Hicky Morgan, Book I: Chapter 1 - The Education of the Architect, 15BC

- "1. The architect should be equipped with knowledge of many branches of study and varied kinds of learning, for it is by his judgement that all work done by the other arts is put to test. This knowledge is the child of practice and theory. Practice is the continuous and regular exercise of employment where manual work is done with any necessary material according to the design of a drawing. Theory, on the other hand, is the ability to demonstrate and explain the productions of dexterity on the principles of proportion.
- 2. It follows, therefore, that architects who have aimed at acquiring manual skill without scholarship have never been able to reach a position of authority to correspond to their pains, while those who relied only upon theories and scholarship were obviously hunting the shadow, not the substance. But those who have a thorough knowledge of both, like men armed at all points, have the sooner attained their object and carried authority with them."

"10 Books on Architecture" by Vitruvius



Architecture<sup>8</sup> is fabricated by the coexistence of artistic acuity and scientific rationale within the diverse functions of our earthly resources. Spaces are designed to stimulate our senses while providing essential sheltering protection. Constructed areas provide for unique sensory reactions while orienting one in space. It is through architecture that one experience predefined lighting conditions and framed perspectives of Earth's visual landscapes. Artistically, designers envision forms and gestures that strive to captivate one's awareness with the manipulation of materials, textures, colours, and other elemental attributes. Through numerous scientific disciplines, these anticipated schematics of conceptualized space are assessed, developed, and represented as an erected installment within a manufactured landscape. Ultimately, architecture is an apparatus in which one lives and operates, where unique perceptions of physical surroundings are formed. Architecture is a catalyst for the expression of personal awareness of one's surroundings.

8 "All these [architecture] must be built with due reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry."

"10 Books on Architecture" by Vitruvius, translated by Morris Hicky Morgan, Book I: Chapter 3 - The Departments of Architecture, 15BC

[1.1.1] The various styles of architecture from different eras



flight and space expedition: aeronautics | astronautics

The allure of occupying and moving through aerial space, similar to those of the *avifauna specie*, is derived from an ancient aspiration that encouraged the promotion and evolution of aviation sciences. From myths and legends to primitive hypotheses of kites, balloons, and gliders, the inquisitiveness of humankind has pushed us off the ground. Over the last century, humans took flight for the first time in state-of-the-art machines that were developed and manufactured by pioneering aeronautical engineers. With these initial prototypes, the common ancestral objective of flight was accomplished. The emergence of a complex thriving industry in aeronautical engineering has enticed human curiosity to greater ambitions.

As the field of aeronautics grew, simultaneous developments were underway in the exploration of new frontiers for human advancements. It was not long before the novelty of flight slowly faded away as ambitious programs conducted in rocketry sciences sparked new human desires to reach further beyond the confines of the sky and into the universe. With this new target for the expansion of humanized territory, early space programs involving astronautics took inspiration from aeronautical progress to assist in the necessary advancement of scientific knowledge and understanding of humankind and the universe beyond Earth. Motivated by important milestones such as the first flight exceeding the speed of sound<sup>10</sup> and the Apollo missions to the moon,<sup>11</sup> the aeronautic and astronautic industries operating within the integrated field of aerospace design and engineering offer future generations the opportunity to explore beyond the native bounds of Earth and into foreign worlds of outer space.

9 The general scientific classifications of the most speciose class of tetrapod vertebrate animals, Birds [Aves]. These feathered bipedal creatures are equipped with wings which separates them from all other vertebrate classes of animals as they can uniquely mobilize through their primary means of locomotion of flight.

One of the earliest form of biomimicry or bioinspiration have been through the study of the avifauna specie of birds to enable the developments of human flight.

"Wilbur and Orville Wright weren't alone—nor were they the first—to dream, wonder, and debate about how humans could take flight. The earliest humans were born into a world already full of flyers. The world's first people undoubtedly watched with envy when birds, bees, and bats magically lifted themselves into the air. Written evidence of humanity's fascination with flying dates back many thousands of years ... Since before recorded history, watching birds has inspired people to wonder how we could join them in flight. Nearly every early pioneer of human flight—from Leonardo da Vinci to the Wright brothers—marveled at how our feathered friends made flying look so easy."

"The Wright Brothers for Kids: How They Invented the Airplane" by Mary Kay Carson, page 21-22, 2003

"Chuck Yeager, byname of Charles Elwood Yeager (born February 13, 1923, Myra, West Virginia, U.S.), American test pilot and U.S. Air Force officer who was the first man to exceed the speed of sound in flight...On October 14, 1947, over Rogers Dry Lake in southern California, he rode the X-1, attached to a B-29 mother ship, to an altitude of 25,000 feet (7,600 metres). The X-1 then rocketed separately to 40,000 feet (12,000 metres), and Yeager became the first man to break the sound barrier, which was approximately 662 miles (1,066 km) per hour at that altitude. The feat was not announced publicly until June 1948."

"Chuck Yeager" by Encyclopedia Britannica, 2012

"The Apollo program was designed to land humans on the Moon and bring them safely back to Earth. Six of the missions (Apollos 11, 12, 14, 15, 16, and 17) achieved this goal. Apollos 7 and 9 were Earth orbiting missions to test the Command and Lunar Modules, and did not return lunar data. Apollos 8 and 10 tested various components while orbiting the Moon, and returned photography of the lunar surface. Apollo 13 did not land on the Moon due to a malfunction, but also returned photographs. The six missions that landed on the Moon returned a wealth of scientific data and almost 400 kilograms of lunar samples."

"The Apollo Program (1963 - 1972)" by NASA, 2008

"Metamorphoses" by Ovid, translated by Rolfe Humphries, Book VIII: Line 183-235 - The Story of Daedalus and Icarus, 8AD

"... Daedalus said, 'surely the sky is open, and that's the way we'll go. Mino's dominion does not include the air.' He turned his thinking towards the unknown arts, changing the laws of nature ... He laid out feathers in order, first the smallest, a little larger next it, and so continued, the way that pan-pipes rise in gradual sequence. He fastened them with twine and wax, at middle, at bottom, so, and bent them, gently curving, so that they looked like wings of birds, most surely ... His cheeks were wet with tears, and his hands trembled. He kissed his son (Good-bye, if he had known it), rose on his wings, flew on ahead, as fearful as any bird launching the little nestlings out of high nest into thin air. Keep on, keep on, he signals, follow me! He guides him in flight—O fatal art!—and the wings move and the father looks back to see the son's wings moving ... And the boy thought 'This is wonderful!'"

"Metamorphoses" by Ovid



It is the mid-21<sup>st</sup> century. The aerospace industry is facing pressure from tourism, hospitality, and transportation industries to develop technologies that will move humankind into the cosmos. Emerging as the industry of the future, this diverse study has already evolved over the past half century from a privatized entity into an international public presence. As a global enterprise in the modern world, the ambitions of aerospace investments have been significantly altered. Over the past half century, space programs were initially deployed to support the race for national authority in a military arms race. The US versus USSR space race has given way to the current global joint ventures of futuristic infrastructures, operating as a collaborated transit hub hosting human research and development science laboratories. For future *market prospects*<sup>12</sup> and emerging lifestyle trends, the aerospace industry may be able to provide the general public with cost-effective and convenient methods of accessing the cosmos while ushering in a new era of commercialization in a versatile transitional zone of outer space. In due course, the potentials offered by the birth of the aerospace industry could generate many emergent industries that will individually be sustained by pioneering economies scattered throughout the planet and universe.

"Emerging markets represent an opportunity for the Canadian aerospace industry because domestic demand in emerging markets for aerospace products will outstrip domestic supply leaving a net opportunity for Canada if aggressive emerging market strategies are adopted. It is expected that developed countries will drive their future revenue growth from the differential between passenger growth and aircraft manufacturing growth in developing marketing. This gap represents an opportunity for the Canadian aerospace industry and a basis for shaping trade policies."

"The Strategic and Economic Impact of the Canadian Aerospace Industry" by Deloitte & Touche LLP, 4.7.3 Emerging markets will be an opportunity for Canada if the Canadian aerospace industry can reconfigure itself to capture this growth, 2010

[1.2.1] Future consumer lifestyle experience potentials as depicted by Galactic Resort



1.3

the onset of an emerging industry : space architecture

With the advent of an efficiently networked infrastructure, unique luxury experiences have become a booming global industry. However, to this date, the luxurious "out of this world" adventures into outer space have only been reserved for the small financially wealthy or intellectually wise population. It was only in the recent decades that opportunities involving emergent sectors of aerospace design and engineering began to work their way into the imaginations of other commonly known professional practices such as architecture and hospitality. With the future market trend of hybridized industries, space transit and residences will be popular subjects amongst a collaboration of worldwide innovative interests. With the launch of suborbital space tourism<sup>13</sup> programs developed by private investors in recent years, statistics show that the future of public space travel is very promising. Unfortunately, at its initial stages, space tourism opportunities are still only available for the wealthy, as the technology and infrastructural deployments required are promising to be extremely expensive. However, with the integration of ideas and concepts from an elite group of visionary architects and aerospace specialists under the emerging industry of Space Architecture, <sup>14</sup> future prospects for space travel have the potential to be highly efficient, feasible, and economical, not only for the very wealthy, but for members of the general public who carry similar evolutionary curiosities of inhabiting outer space.

"The description astronaut, cosmonaut, spationaut, and taikonaut are terms generally reserved for professional space travelers, trained by a human spaceflight program provided by a government space agency such as the Russian Federal Space Agency, NASA, or ESA, to serve as a crewmember of a spacecraft. Until the birth of the orbital space business in 2001, with the flight of Dennis Tito, professional space travelers were trained exclusively by government agencies, but Tito's flight created a new category of space traveler. Following his pioneering flight, Tito was described by the press as a commercial astronaut, a space tourist, a civilian astronaut, a pseudo-astronaut, a private space explorer, and a spaceflight participant... The attractiveness and exclusivity of traveling into space are two powerful driving forces that may, in the near future, turn space tourism into the multibillion dollar business predicted by several market research surveys...Space has always made an incredible impression on those who have ventured there and it is unlikely that this will ever change. The humbling awareness of the vastness of space will be a profound experience for everyone who has the opportunity to view Earth as a 'pale blue dot'. The first spaceflight participants will inevitably be those aforementioned adventure tourists, who often perceive themselves as being closer to explorers, usually traveling to places where little or no tourism infrastructure exists, as is the case with space tourism today. Eventually, however, the space tourism industry will evolve and the ranks of spaceflight participants will grow...space tourism will be operating as a fully fledged commercial industry capable of offering you any number of 'trips of a lifetime' and truly opening the frontier of space."

"Tourists in Space - a practical guide" by Erik Seedhouse, page 1-2, 305-306, 2008

This new field should present itself as a professional resource for humanity's future in space. The integration of technical responsibility and humanistic sensibility that is unique to architecture is essential for shaping a safe, productive, and ennobling physical human environment in outer space. Therefore, "Space Architecture is the theory and practice of designing and building inhabited environments in outer space."

"The Millenium Charter" by the World Space Congress Symposium of 46 professionals industrial designers, aerospace managers, researchers, 2002

"The Architecture of Happiness" by Alain de Botton, page 248-249, 2006

"The failure of architects to create congenial environments mirrors our inability to find happiness in other areas of our lives. Bad architecture is in the end as much a failure of psychology as of design. It is an example expressed through materials of the same tendency which in other domains will lead us to marry the wrong people, choose inappropriate jobs and book unsuccessful holidays: the tendency not to understand who we are and what will satisfy us...The places we call beautiful are, by contrast, the work of those rare architects with the humility to interrogate themselves adequately about their desires and the tenacity to translate their fleeting apprehensions of joy into logical plans—a combination that enables them to create environments that satisfy needs we never consciously knew we even had."

"The Architecture of Happiness" by Alain de Botton

TRADITIONAL ROLES terrestrial disciplines	ADDITIONAL ROLES subjects for space
ARCHITECTURE	
Human activity analysis and programming	Mission operations planning
Psychology and sociology	Psychology of remote isolation and sensory deprivation
Comparative historical analysis (precedents)	
Abstract and representational modeling	
Structural Engineering	Aerospace structures and mechanisms, including pressure containment and vacuum tribology
Materials development and testing	Aerospace materials and space environments
Environmental control engineering	Life support systems
Design for sustainability	
Site engineering	Planetology including alien engineering geology, weather, atmospheres, chemical environments, diurnal cycles, and gravity
Landscaping	
Construction engineering, safety, and quality inspection	
Interior design	
Color and lighting design	
Fire safety	
Power generation, management, and distribution	
Acoustic engineering	Vibrations and noise control
Environmental impact and wilderness management	
Furniture design	
Industrial design	
Art	
Economics and finance	
Negotiation and contracting	
Construction management	Aerospace project management
n/a	Astrodynamics; attitude control; and guidance, navigation, and control Propulsion, launch and docking Vacuum thermal management Command and data handling Autonomy Reliability, safety, and mission assurance



"Architects and engineers shape the human environment by building, and so they will shape our future on Earth and in space...Space architecture is a fascinating field, replete with high technology and limitless boundaries...Today's space architects are at the forefront of the evolutionary step where architecture breaks free of terrestrial limits to explore how humankind will settle space and other planets...Space architects are uniquely positioned to participate in the development of approaches for solving tough problems of human spaceflight, to integrate those solutions into comfortable, attractive, safe, and productive human environments for space missions, and then to see how those solutions can be adapted to benefit indigent populations and compromised environments on Earth...The

"Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 20, 404, 2009

architect's most fundamental motivation—to use good design to improve the world—has never been

needed more.'

[1.3.1] Table identifying the additional considerations and roles an architect must undertake when designing for outer space constructions.

"We can speculate that decades hence, perhaps in the second half of the 21st century, when large numbers of people are traveling, working, and living in space, architects might evolve to a more central role. By then, the technically challenging issues that dominate design and operation of habitable space systems today will have been largely solved and reduced to practice. As a result, and as spacefaring populations grow, more atavistic human needs will come to the fore. The discipline of aerospace engineering could then become subsumed into the panoply of subjects architects have historically coordinated."

"Out of this World - the new field of space architecture" by A. Scott Howe and Brent Sherwood, page 6, 2009

[1.3.2] The traditional architect's essential tools and fashion

[1.3.3] The modern futurist architect's fashionable apparatus

Architecture has always had to contend with the many limitations imposed by the forces on Earth. Gravity has always been a determining factor for design and construction processes. It defines what one is capable of sculpting on Earth, standardizing forms and the practical nature of architectural spaces. New challenges and flexibilities will arise when designing habitable spaces in an anti-gravitational environment such as outer space. Many architectural elements in terms of furnishings and system integrations will have to adapt to future lifestyles and comply with precautionary safety measures necessitated by this foreign environment.

Conceptualizing an architectural project in outer space will encounter many issues of economics, politics, and social ethics, as well as physiological and psychological challenges. For designers of the future who have engaged with the complicated task of exploring the relationships between architecture and human experience in outer space, these conflicting issues will have to be noted and resolved in order to successfully campaign humanity into the cosmos. However, this dissertation will focus on a rather idealistic approach in designing sound spaces that offer healthily amplified experiences, as opposed to the many variables pertaining to financial costs and social politics.

In order to ensure the healthy wellbeing of future space occupants, it is crucial that ample studies and research are conducted on the physiological and psychological impacts of extraterrestrial environments on the human body and mind. This knowledge will be crucial for space architects as they understand and prepare future thinking design solutions for spaces that will embrace and satisfy the physical and mental needs of their occupants. It is *the role of the space architect*<sup>15</sup> to envision concepts that go beyond the component systems established on Earth while visualizing solutions for the challenging issues posed by the extreme conditions of outer space.





individual explorations in a collective challenge

The complex mission of expanding human civilization and technologies beyond the boundaries of Earth presents many obstacles at both the micro and macro levels of society. Since the mid-20<sup>th</sup> century, contributing nations have begun to take initiative in abandoning their agendas of aggression and supremacy in favour of a collaborative mission to make space travel available to ordinary citizens. With this project-specific truce, a collaboration of resources, intelligence, and financial funding will safeguard a successful global endeavour for the prospering future of humanity and the pioneering spacefaring citizens of outer space colonies. Once this global alliance is assembled with a common interest in advancing human life, we can guarantee that the outer space frontier will be a single universal entity driven not by territorial states or military authority, but rather for the benefit of mankind in sustaining human evolution for future generations.

By defining a globally profitable market for the emerging space travel industry<sup>1</sup> through both public and private interests, research and development will diversify as innovation escalates throughout the world. Although this collaborative mission is cost and resource intensive, as a united directive between the individual and the collective it has the potential to facilitate cost-effective and sustainable prospects for such a complex investment. With the awareness of the global economy's capacity to sufficiently fund and practically produce such an ambitious enterprise, the academic mass can focus on inventing and developing product solutions for the many intricate system details introduced by the mission program in such extreme extraterrestrial site conditions.

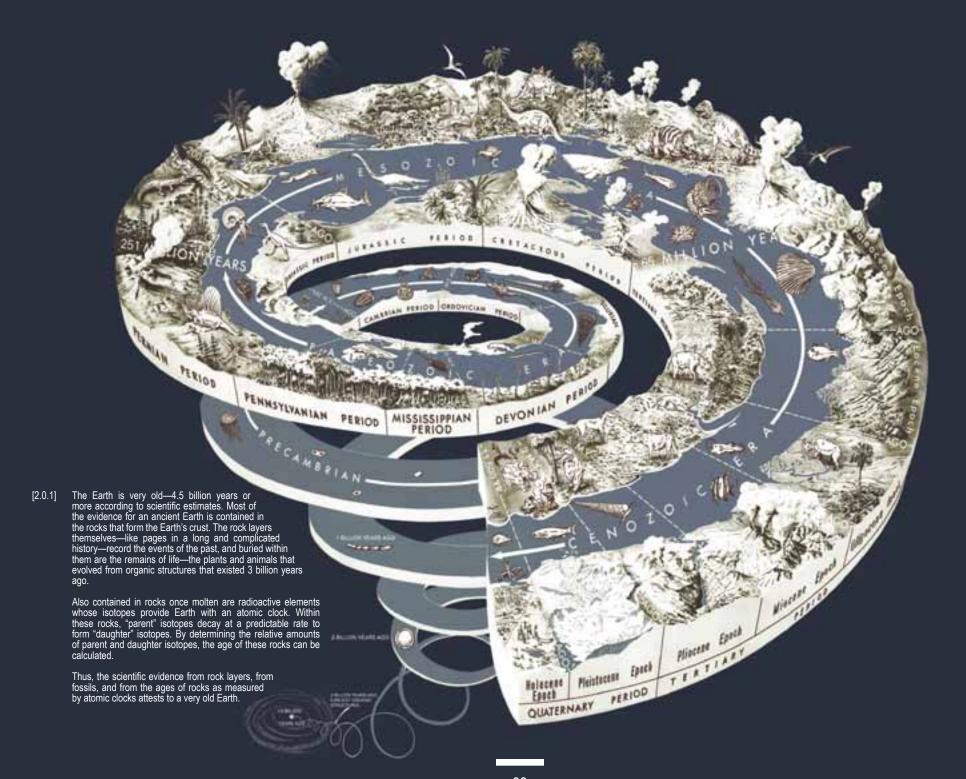
"With the growing importance of space activities in daily life also the number of launching sites and countries offering launching services is steadily rising. In addition, the emerging market for space tourism and space related services like space funerals fosters the idea of establishing commercial spaceports, particularly within the USA where two completely private spaceports already exist. Outside the USA several private and/or governmental spaceports are planned, often in collaboration with space travel agencies...At the moment sufficient returns on investment are not expected soon, but in a long term it is supposed that costs will fall and that launch services will be profit-making...Also the officials of (inter)governmental organisations like NASA and ESA meanwhile realised the economic potential of the launching business and that they must not shut their minds to this development by remaining hostile towards private initiatives... Altogether, the (inter)governmental organisations will feel impelled to ever more open up to private initiatives as well as expertise. Therefore, also the number of PPPs and other, very different kinds of collaboration agreements beteween (inter) governmental organisations and private actors will increase considerably in the future.

> Co-operation between the private and public sector is very varying as regards future projects. Many of them still are initiated by governmental organisations like NASA, ESA, Roskosmos, or JAXA, but inevitably private actors are involved...it can be said, that in space activities a general shift from the public to the private sector is noticeable... Privatisation and commercialisation of outer space are under way. The role of the private actors is growing whereas governments more and more withdraw from activities attractive for commercial use and confine themselves to tasks of strategic importance and to those securing the safety of space 'travel'. Altogether the future may resemble the development of the airline business in the 20th century...A general framework [legislation] would furnish the business with sufficient legal certainty and would accelerate the process of privitisation and commercialisation of outer space. This need for legislation becomes particularly obvious when talking about space tourism which together with industrial production is one of the main incentives for private activities in outer space. First space tourists and the existence of several companies specialised in space tourism prove that this new era has already

> "Recht Politik Wirtschaft Dynamische Perspektivenchapter: Space Transportation in the Future: Public Private Partnership" by Christian Brünner, page 78-79 and 84-85, 2008

ht "The Audacity of Hope: Thoughts on Reclaiming the American Dream" by Barack Obama, page i, 2006 "In response, I would usually smile and nod and say that I understood the skepticism, but that there was—and always had been—another tradition to politics, a tradition [of politics] that stretched from the days of the country's founding to the glory of the civil rights movement, a tradition based on the simple idea that we have a stake in one another, and that what binds us together is greater than what drives us apart, and that if enough people believe in the truth of that proposition and act on it, then we might not solve every problem, but we can get something meaningful done [for the people with whom we share this Earth]."

"The Audacity of Hope: Thoughts on Reclaiming the American Dream by the 44" President of the United States, Barack Obama



Multi-cellular organisms such as human beings have been through approximately one billion years of evolution since the Proterozoic era of the 4.5-billion-year-old Earth. Throughout this period of acclimatization, human evolution has passed along genes that determine the ways in which our bodies and minds naturally operate and adapt under the changing conditions of our Earth. This biological development has embedded in our minds a *geographical imagination*<sup>2</sup> of familiar landscapes and conditional behaviors in which our bodies feel genuinely comfortable and satisfied. However, as innovations and technologies push human existence beyond its natural threshold and into the celestial realm of outer space, travelers will be engaging with foreign and unorthodox conditions that will certainly be physiologically damaging and psychologically challenging to our bodies and minds. Therefore, it will be extremely important to develop technical knowledge of these harsh conditions in order to prepare the proper measures. Modified conditions must be sufficiently incorporated into extraterrestrial environment designs to ensure healthy conditions for the next generation of explorers who will inhabit outer space.

Inhabiting outer space has been the exclusive enterprise of very few skillfully prepared and talented individuals (mainly pilots, payload specialists, doctors, biologists, and engineers) who have been carefully selected by mission administrators and conditioned to become astronauts, *sailor[s] in space³*. Very few people have ever had an extraterrestrial experience. The majority of the human race would be ill prepared to travel to or exist in a space-based environment because their physiological and psychological systems are only attuned to an Earth-based scenario. The thesis thus looks to increase the level of academic knowledge about and solutions to cosmic conditions to better prepare for the future survival and expansion of our race when space colonization becomes a feasible reality for the general public.

2 "Another set of principles is brought into play - about the right of movement perhaps, or about how this planet, after all, belongs to all of us. And behind those other principles lies another, very different, equally particular, geographical imagination - this time of a world which is, essentially, without borders.

It is probably now well accepted, though it is still important to argue, that a lot of our 'geography' is in the mind. That is to say, we carry around with us mental images, of the world, of the country in which we live (all those images of the North/South divide), of the street next door. The New Yorker's mental map of the USA, Ronald Reagan's imagination of the world, became popular posters. All of us carry such images; they may sometimes be in conflict or even be the cause of conflict, and digging these things up and talking about them is one good way in to beginning to examine what it means to think 'geographically'...in this age of globalisation of course boundaries and borders must fall, is to imagine space as, first and foremost, a space of flows "

"Secondary Geographical Handbook" by David Balderstone, page 47-48, 2006

- 3 "Packing for Mars" by Mary Roach, page 165, 2010
- *left* [2.0.1] Earth's geological time spiral of the evolution of species

"The Geologic Time Spiral - A Path to the Past" by Joseph Graham, William Newman, and John Stacy, USGS - Science for a Changing World, 2008

By investigating the unique elements and factors that harsh outer space applications are required to reckon with, designers such as *space architects* can establish varied design opportunities by developing a dialect of original expression that harmonizes human issues with those presented by the absence of gravity and oxygen, as well as issues of monotony due to the inability to perceive time of day or time of year. Additionally, designers will have to focus on innovating human-friendly spaces, finishes, and cultural experiences that build on existing and future technologies as advised by consulting parties in specialized fields.

Designs and construction for complex infrastructures in outer space that will be networked to Earth-based centres cannot tolerate any mistakes, from conception to fabrication and into launch and operational stages. The space environment is completely unforgiving; unlike the Earth environment where buildings can perform "less well" and still be acceptable, any mistakes will ultimately conclude as a tragic fatality. {Remember the famous quote of Gene Kranz from the movie Apollo 13: "Failure is not an option!"?}<sup>4</sup> The industry of space architecture ought to belong to an elite category of hybridized fields of studies, enlisting a diversified intellectual group of individuals to resolve intricately complex problems regarding the wellbeing of humankind.

"As far as the expression 'Failure is not an option", you are correct that Kranz never used that term. In preparation for the movie, the script writers, Al Reinart and Bill Broyles, came down to Clear Lake to interview me on "What are the people in Mission Control really like?" One of their questions was "Weren't there times when everybody, or at least a few people, just panicked?" My answer was "No. when bad things happened, we just calmly laid out all the options, and failure was not one of them. We never panicked, and we never gave up on finding a solution." I immediately sensed that Bill Broyles wanted to leave and assumed that he was bored with the interview. Only months later did I learn that when they got in their car to leave, he started screaming, "That's it! That's the tag line for the whole movie, Failure is not an option. Now we just have to figure out who to have say it." Of course, they gave it to the Kranz character, and the rest is

Explanation by Jerry C. Bostick, Flight Dynamics Officer (FDO) of Apollo 13, www.spaceacts.com

"We've never lost an American in space and we're sure as hell not gonna lose one on my watch! Failure is not an option!"

Hollywood movie, "Apollo 13" screenplay of Eugene Francis Kranz, 1995

[2.0.2] Eugene (Gene) Francis Kranz at NASA headquarters





2.1

shaping of a transnational perspective

The ancient traditions of human exploration and expansion<sup>5</sup> are fueled by the need to assemble territories that generally follows increases in population and urban development. In the case of the "Scramble for Africa" during the New Imperialism period of the last quarter of the 19th century, European powers raced to colonize Africa in a process of invasion, occupation, and annexation. These invasions were in part a result of the global market declines stimulated by the Long Depression (1873-1896), as Africa was the last land untouched by informal imperialism and possessed many attractive human and economic resources. Similarly, a parallel interest can be seen in the launch of the space race in the mid to late 20th century. Initially an economic and military competition between nations, this period of the Cold War expanded rivalry tensions in global supremacy with the new trend of technological aggression that extended control beyond the boundaries of the Earth. All of these examples have been efforts by ancient social groups or contemporary nation-states. However, these individualized models will not suffice in the developments for outer space explorations as individual nations will not be able to afford the financial and resource demands of such ambitious programming. This collaborative need can be understood through the example of the design and construction process of the Cupula observatory module<sup>6</sup> that is found on the International Space Station (ISS) today. Although the ISS is already a joint venture between many nations globally, most function-specific modules are designed and constructed by individual nations. In the case of the Cupula project that was started by NASA (the National Aeronautics and Space Administration) and Boeing, it was eventually put to a halt as budget constraints and cuts made it impossible for the project to commence. However, in 1998, under a barter agreement between NASA and the European Space Association (ESA), development was able to recommence. Therefore, from previous experiences, space programs and initiatives of the modern era have slowly adapted to be worldwide collaborative ventures while the occupation of outer space environments by global space law settles for an international territory that contains no boundaries. With such distinctive universal governance, all of the predicaments concerning racism, discrimination, the fear of unknown projects conducted by aggressive nations, and other negative social dynamics can positively be disregarded amongst development team members and end user occupants for these outer space habitats.

"Historians may well be accused of adding a rather sombre note to a debate that takes the necessity (but not the inevitability) of space discovery and explorations for granted...Among historians of the early Atlantic world, such as myself - let alone anthropologists, ethnologists, and political scientists - discovery and exploration have recently become unfashionable, if not altogether disreputable, subjects of study among historians. Even the term "discovery" and its apparently more correct substitute, "encounter" have fallen into disgrace, because such terms allegedly give only a European point of view...This very sociological emphasis on the meeting of communities, as opposed to races, peoples, or nations, has now completely replaced the genres of national epic and even scientific reportage that had been the hallmark of discovery and exploration studies...Yet humankind, in the past, has proved to be able to survive, through sometimes at great costs, through adjustment, adaptation, and compromise. We trust that will happen again, when the time comes, although at what cost, no one is able to foresee."

> "Humans in Outer Space - Interdisciplinary Odysseys" by Luca Codignola and Kai-Uwe Schrogl, page 14-21, 2009

> "The origins of this shift from discovery and exploration to contact studies can be traced back to the late 1960s...The concepts of discovery and exploration should be applied only to places where no human being had ever set foot prior to the arrival of the discoverers and the explorers. This narrow definition leaves us with Antarctica, much of the Arctic region, previously inaccessible mountain and desert areas, and, finally, outer space."

"North American Discovery and Exploration Historiography, 1993-2001: From Old Fashioned Anniversaries to the Tall Order of Global History?" by Luca Codignola, page 185-206, 2002

"Components of the Cupola were initially fabricated in California, and the windows in New York in the late 1980s. But as budgets were cut, the Cupola was a favorite target. Several times it was fought back into the program only to be cut again as not technically required. More than once the responsibilities for fabrication were bartered to one international partner and then another in exchange for Shuttle launch services and resources that the US would provide on board the station in orbit. The Cupola made the rounds to Brazil and then finally wound up with ESA and the Italians in 1998, who did complete it back in 2003. Even then the launch of the Cupola was repeatedly delayed until it finally made it into orbit in February, 2010."

"Cupula (ISS module)" by contributers to wikipedia sources, 2012

ight "Humans in Outer Space - Interdisciplinary Odysseys" by Luca Codignola and Kai-Uwe Schrogl, page 171-174, 2009 "My name is **ποιμήν** (the shephard). I was born in Herakleion and I have never left Crete since ... There's not much grass, and it tends to be salty, but at ploughing time there's not much good grazing to be found anywhere else; even the sheep seem to know that and don't complain ... I'm constantly on the go with my flock. We have to cover a lot of ground to always be on a good pasture at the right season. In the trade we call that transhumance: here today, gone tomorrow. Our hero, for us pastoral shephards, is Ulysses: on the one hand, a ship to cross the seas and having exciting adventures; on the other, a wife waiting at home ... I reckon keeping watch over sheep is a lot easier than keeping watch over people ... And don't forget, we've always got one eye on the heavens, watching the Evening Star."

"Humans " in Outer Space - Interdisciplinary Schröd and Kal-Uwe









Metaprinciples for space explorations are recognized that international cooperation adds layers of complexity to the design and management of programmes, and also budget affects successful and schedule performance. Furthermore, states generally cooperate when it benefits their self interests and therefore. partners may be pursuing common programmatic goals, but for different reasons... In this context, since not all countries regard international cooperation equally and pursue collaborative endeavours for the same motives, enduring space exploration architectures require, as underlined by Correll and Peter, that metaprinciples for international exploration programmes be followed.

strategy The exploration therefore needs to be multifaceted and inspirational to involve a broad stakeholder community. Following the likelihood of the changing geopolitical future, any long term exploration programme will need to rely on international partnerships as no one has the means to do it alone. Therefore, international cooperation must become an anchor of any longterm strategy.

"The blending of high technology with a new forensic code of conduct on hitherto uncharted territory has brought to bear the need for the community of nations to formulate a sustainable legal theory that would ensure non-exploitation of space resources by individuals or States, while at the same time incorporating the element of responsibility and liability for individual and State conduct in outer space."

As mentioned earlier, the basic principle of space law is the 'common interest' (or common heritage) principle which emerged as a result of the first specific Resolution on space law of the United Nations General Assembly in 1958. The 'common interest' principle has since been incorporated in subsequent multilateral treaties, particularly the Outer Space Treaty of 1967, Article 1(1) which provides:

[T]he exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interest of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.

The transfer of technology and its symbiotic application, particularly in the sharing of technology among outer space faring nations of the world is critical to the progress of outer space activity. Therefore, as any other activity involving intellectual property rights, space law can attenuate for its basic principles the establishment of the World Intellectual Property Organization (WIPO) which was set up as a specialized agency of the United Nations in 1974."

"Space Security Law" by Ruwantissa Abeyratne, page 86-92, 2011

"The benefits of international cooperation are numerous and well documented. Among others, they include improving capability, sharing costs and building common interests and increasing the total level of available resources, eliminating the duplication of efforts, and improving international relationships. International cooperation in space activities allows rationalizing and optimizing resources and mounting missions that would otherwise not be possible. This expansion of resources made available through cooperation is not only just financial, but also scientific and technological."

"Humans in Outer Space - Interdisciplinary Odysseys" by Luca Codignola and Kai-Uwe Schrogl, page 114, 2009

[2.1.1] Stakeholders who have already made and has potential impacts on the future progress to the commercialization of outer space industries.

"Humans in Outer Space - Interdisciplinary Odysseys" by Luca Codignola and Kai-Uwe Schrogl, page 115, 2009

next [2.1.2] Statistical maps of R&D capable nations

left

Modern intellectual resources<sup>7</sup> regarding space developments have already been collectively pooled together through the many public service agencies of NASA, CSA (Canadian Space Agency), ESA, JAXA (Japan Aerospace Exploration Agency), ROSCOSMOS (Russian Federal Space Agency), AEB (Brazilian Space Agency), as well as other, smaller agencies. In addition to the global dynamics of these innovative nations, the gradual acceptance of the stipulation of merging public and private sectors in this specialized field to pool resources as a global partnership is an emerging intellectual and economic strategy.<sup>8</sup> This strategy has many important benefits, as such alliances can pool the resource diversity of intelligence, finances, and subvention essentials necessary for overcoming the many challenges pending in the mission to colonize outer space. Many non-government commissioned research scientists, designers, and developers from private corporate visionary agencies such as Richard Branson's Virgin Galactic, Elon Musk's Space X (Space Explorations Technologies Corporation), Eric Anderson's Space Adventures, Boeing, Lockheed Martin, and many others work to cross-reference the fast-growing stream of data and information in order to achieve maximum accuracy and efficiency in the development of such ambitious concepts.

In order to prepare for the celebratory milestone that will mark the beginning of a new era of space culture, visionary investors and national contributions must generously operate together as a whole in the construction of a transit infrastructure hub in outer space. This transnational connection of stakeholders in the private and public sector is more than just a social philosophy; rather, it is necessary for developing the singular common goal of developing a prospective space station for spacefaring citizens of the future. These citizens will be offered a socially healthy atmosphere in a revolutionary design inspired by the lessons learned from the International Space Station and other spacecrafts built to date.

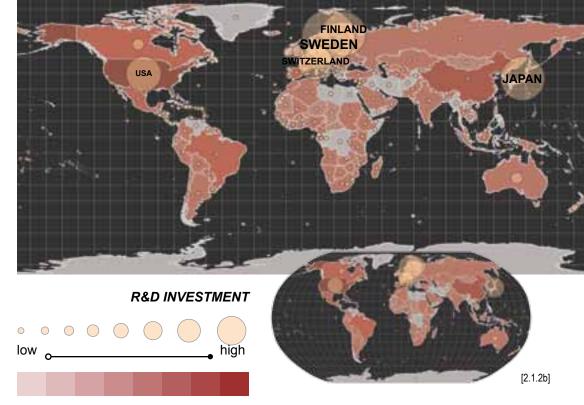


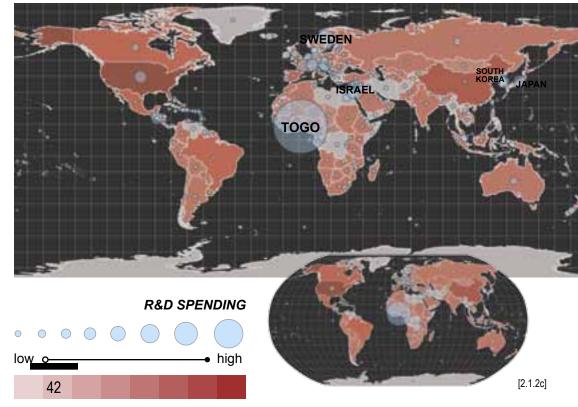
#### r&d investment

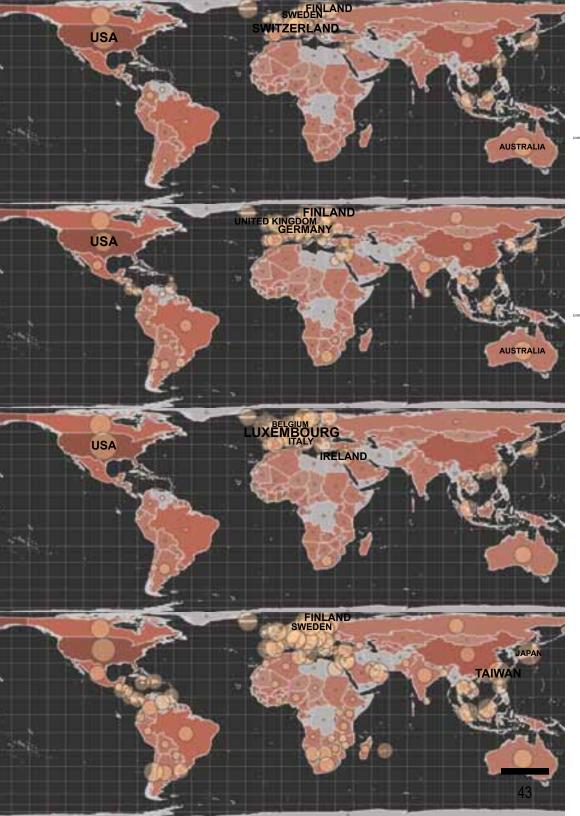
The amount of funding for creative work undertaken on a systematic basis to provide industries and companies with stock knowledge of man, culture, and society in order to develop new applications for the global population.

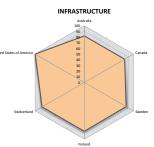
## r&d spending

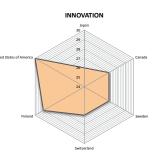
The relative amount of expenditure as a percentage of the gross domestic product in the research and developments of new innovations and technogies.

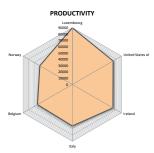


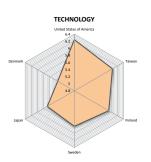












# *infrastructure*

Extent to which basic technological, scientific and human resources meet the needs of daily lifestyles and business operations.

# innovation

Extent to which inventive developments are being established in correspondance to the infrastructural basis and support of major business and research nations.

## productivity

Extent to which a nation is able to harness and efficiently allocate its human and physical resources to generate economic growth through the development of innovations and technologies.

# technology

Extent to which innovative ideas are produced through its original conceptions, developing new tools, techniques, systems, or methods of organizations to resolve specific problems and tasks.



feasibility of resource investments

The sophisticated progression of human advancement in an age of enhanced innovative technologies will not only require the affiliation of a globally unified organization of academic intellects. The success in such developments will also rely on the collective economic financing and resource availability for the associated members to manipulate. With the commercialization of outer space and its public tourist adventures counterpart in its matured state forecasted to become a multi-trillion-dollar sector, it is only logical that public and private investors grant generous budget allowances and resource support to the industry's research and development agencies. By supporting these agencies with the necessary funding for their design and manufacturing teams, prototyping timelines will be shortened and, most importantly, earlier public launch dates can be instigated for a sooner return on investment to all supportive stakeholders.

Unfortunately, objectives such as receiving appropriate and essential funding have met fierce resistance in the aerospace development industry, as people and organizations perceive extraterrestrial ventures with current technology to be high risk. Hence, investors have been reluctant to generously support early research into projects that are as new and ambitious as space travel requires. However, the concern of high-risk investing is slowly diminishing as stakeholding investors and the public are gradually realizing the opportunities that space travel has to offer to the world.

"...as services increase, technology improves and infrastructure develops (and prices drop like a meteor), Space Tourism may reach a multi-trillion dollar industry by 2030, with up to five million passenger rides annually...At the end of 2007, there were already 42 certified space travel agencies. Business, of course, won't stay in dry-dock: Imagine the UPS and FedEx's of the near-future delivering packages around the world - in just a few hours, or minutes. Imagine buzzing over to Tokyo for a power meeting; getting in a round of golf and being home that evening on the East Coast in time to catch your favorite programming on the boob-tube.

Like Nano and Bio, space tourism and space commerce will be chock full of careers catering to entertainment and lodging, vehicle design and lunar mining equipment, 'space history', trainers (welcome to zero-gravity), couriers, etc. Virgin Galactic, owned by the intrepid Richard Branson, has even hinted at a Galactic Idol program for aspiring astronauts (far out!). Naturally any endeavors in the great 'up there' will necessitate medical specialists, PR folks and product liability legal staff...and by the way, referring back to nanotechnology, imagine the world's skinniest 'straw' - a glorified elevator shaft or 'silo' extending miles into space for transporting people adn delivering supplies. Supposedly, the plans already exist...(flying cars, too, but that's another story).

What we do know is that there is sound scientific basis and development infrastructure already for many of these Jules Verne-like industries. And once more, young professionals in the decade from 2010 to 2020 will have unprecedented opportunities to 'get in on the ground floor' and create worlds we can barely imagine."

"10 Global Trends Impacting the Careers of the 21st Century" by Stephen Banick, page 19, 2009

t "The Long Tail of Tourism: Holiday Niches and their Impact on Mainstream Tourism" by Alexis Papathanassis, page 97, 2011

"In order to realise such revenues, it is most likely that the so-called skimming price strategy will be made use of (Goehlich, 2005) - a fairly straightforward pricing approach explained as follows: "...by sequentially lowering price over time, capturing incremental customers with every price drop, price skimming allows a company to charge each customer their reservation price" (Gebhardt, 2009). (The 'reservation price' refers to the highest price a customer is willing to spend on the product.) In the beginning, tickets will be sold to the very rich, who will have to contact a space travel agency and enquire about making a trip to space. Over time, the tickets will become cheaper and accessible for the mass market (Goehlich, 2005). It has been predicted that passenger numbers will climb to 1,000,000 per year when the ticket price is down to \$10,000 (Aldrin et al, 2002). According to market surveys, people from many countries are already prepared to go on space adventures now despite the high prices and physical risks."

"The Long Tail of Tourism: Holiday Niches and their Impact on Mainstream Tourism" by Alexis Papathanassis

[2.2.1] A prosperous field that faces a lack in political confidence and support in terms of budget distributions.

	NASA BUDGET			
YEAR	Nominal in	% of Federal	2007 Constant	
	\$-Millions	Budget	Million Dollars	
1958	89	0.1%	488	
1959	145	0.2%	1,841	
1960	401	0.5%	3,205	
1961	744	0.9%	6,360	
1962	1,257	1.18%	12,221	
1963	2,552	2.29%	24,342	
1964	4,171	3.52%	33,241	
1965	5,092	4.31%	33,514	
1966	5,933	4.41%	32,106	
1967	5,425	3.45%	29,696	
1968	4,722	2.65%	26,139	
1969	4,251	2.31%	21,376	
1970	3,752	1.92%	18,768	
1971	3,382	1.61%	15,717	
1972	3,423	1.48%	15,082	
1973	3,312	1.35%	14,303	
1974	3,255	1.21%	11,494	
1975	3,269	0.98%	11,131	
1976	3,671	0.99%	11,640	
1977	4,002	0.98%	11,658	
1978	4,164	0.91%	11,411	
1979	4,380	0.87%	11,404	
1980	4,959	0.84%	11,668	
1981	5,537	0.82%	11,248	
1982	6,155	0.83%	11,766	
1983	6,853	0.85%	13,051	
1984	7,055	0.83%	13,561	
1985	7,251	0.77%	13,218	
1986	7,403	0.75%	13,421	
1987	7,591	0.76%	13,735	

	NASA BUDGET		
YEAR	Nominal in	% of Federal	2007 Constant
	\$-Millions	Budget	Million Dollars
1988	9,092	0.85%	14,454
1989	11,036	0.96%	16,734
1990	12,429	0.99%	18,019
1991	13,878	1.05%	19,686
1992	13,961	1.01%	15,310
1993	14,305	1.01%	18,582
1994	13,695	0.94%	18,053
1995	13,378	0.88%	16,915
1996	13,881	0.89%	16,457
1997	14,360	0.90%	15,943
1998	14,194	0.86%	15,521
1999	13,636	0.80%	15,357
2000	13,428	0.75%	14,926
2001	14,095	0.76%	15,427
2002	14,405	0.72%	15,831
2003	14,610	0.68%	16,021
2004	15,152	0.66%	15,559
2005	15,602	0.63%	16,016
2006	15,125	0.57%	16,085
2007	15,861	0.58%	15,861
2008	17,318	0.60%	17,138
2009	17,782	0.57%	17,186
2010	18,724	0.52%	17,804
2011	18,448	0.53%	<b>7</b> 17,005
2012 (estimate)	17,770	0.48%	16,014
2013 (projection)	17,711	N/A	N/A

NASA's budget peaked in the period 1964-1966, during the height of construction efforts leading up to the first moon landing under Project Apollo.

"The economic benefits of NASA's programs are greater than generally realized. The main beneficiaries (the American public) may not even realize the source of their good fortune...

10

"Nature (355) - International Weekly Journal of Science" by Roger H. Bezdek and Robert M. Wendling, Article: "Sharing out NASA's spoils", page 105-106, January 1992

"Chase Econometric Associates conducted a second econometric investigation of the relationship between NASA expenditures and the U.S. economy. The first phase of the Chase study employed the 185 interindustry input-output model developed at the University of Maryland to analyze the shortrun economic impact of NASA R&D expenditures. Simulations of the input-output model were undertaken assuming that \$1 billion of federal expenditure was transferred (proportionately) from other nondefense programs to NASA with no change in the size of the federal budget. Chase estimated that the \$1 billion transfer would increase manufacturing output in 1975 by 0.1 percent, or \$153 billion (measured in 1971 dollars), and would increase 1975 manufacturing employment by 20,000 workers...The second phase of the Chase study considered the long-run effects of NASA R&D expenditures. Using a production function which related NASA R&D expenditures to the productivity growth rate in the U.S. economy from 1960 to 1974, Chase concluded that society's rate of return on NASA R&D expenditures was 43 percent (MRI's estimated social rate of return was 33 percent). The Chase second phase also estimated the effects of changes in NASA R&D expenditures on economic growth and stability. Overall, these long-term estimates confirmed the significant positive effects of NASA R&D expenditures on national productivity and employment levels.

What is the economic value of NASA's technical "acceleration effect?" Drawing on four case studies (gas turbines, cryogenic multilayer insulation, computer simulation, and integrated circuits), Mathematica, Inc. concluded that the economic benefits that result from NASA's acceleration of technology are very large. The value of a speedup in technology in those four fields was estimated to be between \$2.3 billion and \$7.6 billion in 1974 dollars. Mathematica's "most probable" estimate is that the four case studies alone produced savings egual to 6 percent of all NASA R&D expenditures since 1958 (on a discounted value basis)"

"The Economic Impacts of the U.S. Space Program" by Jerome Schnee, 1983

[2.2.1] Table hilighting the peak extremes of NASA's

Appreciative of the complexities involved in developing applications for outer space, the public's perception of the national budgeting for space developments has been overestimated<sup>10</sup> at an exceedingly high average of about 20 percent of a national account's federal budget. On the contrary, ever since the beginning of galactic research, the confidentially formed government agencies of NASA, ROSCOSMOS, JAXA, and CSA have been vitally disregarded, with an inappropriate split of the pie from their respective federal budgets that is much lower than the perceived percentage.

The annual budgets from the most substantially funded and currently largest government space agency, NASA (USA), have been fluctuating for over half a century. Yet every year their budgets have been proportionally held below the mid-20th-century average of approximately 1.15 percent of the USA's annual federal budgets. This average value was so great due to the initial six to eight years of competitive developments during the Cold War's space race, when government spending provided a generous but temporary dedication towards space directives and missions. It is evident that over the years, significant events such as the Cold War and the space race that proceeded have been responsible for sudden escalations and declines in federal funding for these national space agencies. The national devotion to global supremacy in space explorations led NASA to their peaking budget in 1966 at approximately 4.41 percent of the federal budget. However, it has been proven through national records that with its diversity of expertise, the aerospace production industry pertaining to research and development has kept national economies from deteriorating during economic downturns or global recessions. Developing NASA technologies has benefited national economies with decently funded job opportunities while providing innovative products for the general public's consumption in other industries.

From an economic standpoint, research breakthroughs and innovative technologies by space agencies also benefit and support other industries. For example, experiments conducted to determine the influence of outer space conditions on the human body and mind provide scientists on Earth with new medical knowledge and hypotheses. Also, the innovative principles in design and building materials for spacecrafts and station modules ultimately provide designers on Earth with an insight on efficient planning and sustainability in managing resources. In most cases, the sustainable resources used for space applications are unique variations of those on Earth, but the specialized developments of these new forms of materials, systems, and treatments can be transferred to contemporary architecture in the promotion of "green" sustainable design.

Clearly, a project like the outer space transit infrastructural hub could be a feasible endeavour as a function of diversified contributions of resources. Financially, investment in this development will be beneficial for the economy, as employment will be steady throughout the duration of the mission's life. In addition, the greater the early investments, the earlier the return on investments will be through public use of the proposed system. Taking precedent from previous spaceflight research and developments that triggered subsector startup industries in telecommunications, satellites, nanotechnologies, microelectronics, regenerative materials, sustainability modeling and so on, innovative technologies will ultimately be a natural by-product of such an ambitious and complex project. These technologies will not only support the projects initiated for its outer space purpose, but *Earth-based applications will also receive beneficial breakthronghs*<sup>11</sup> as efficient building strategies and original exploitation of materials will assist designers with sustainable designs for contemporary terrestrial architecture.

"Space missions have become increasingly ambitious, calling for ever-more rigorous technologies to ensure functionality, survival and safety. The necessity for highly accurate, reliable and advanced technologies in space science and manned spaceflight has resulted in impressive advances in imaging, new materials and computer technologies. These advances have in turn been spun-off for application in medicine, a field that similarly demands highly precise, durable equipment...Meanwhile, the need to understand human adaptation and physiological response in the harsh space environment has spawned an immense pool of research on the subject, the knowledge of which has also been applied towards understanding disease processes, treatments and management strategies on Earth...Special attention is given to telemedicine and its spinoffs, owing to its potential to address issues of healthcare accessibility and global developments...Ultimately, space technologies are shown to be highly relevant and beneficial in day-today medicine on Earth, and continue to advance the limits of accuracy, efficiency and survival on Earth.

Medical technologies have come a longway in the twenty-first century, due in no small part to advances in other areas of science, from laser technology to materials engineering: automatic insulin pumps, portable x-ray devices, ataract surgery tools, high-tech imagers, implantable heart aids - they've all come from space."

"Space Technologies for the Benefit of Human Society and Earth" by Phillip Olla, page 123-128, 2009

right [2.2.2] Various everyday materials and technologies that humans use on Earth that was influenced or developed due to the developments in human spaceflight

"NASA news release 10-81AR" by Ruth Dasso Marlaire, September 2010

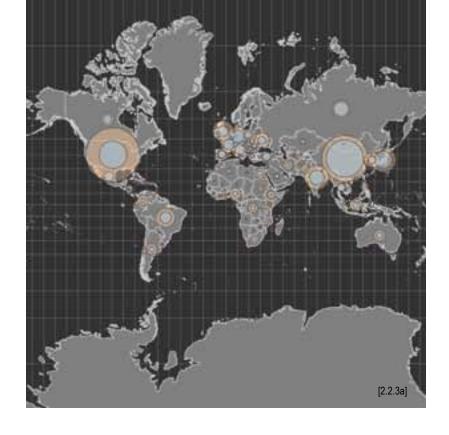
next [2.2.3] Statistical maps of global leading telecom providers and services

[2.2.4] Statistical maps of national public/private contributions to technological investments

[2.2.5] Statistical maps of worldwide end users of invested technologies

NASA's Sustainability Base, a candidate for the Leadership in Energy and Environmental Design platinum certified office building being constructed at NASA's Ames Research Center is the winner of this year's U.S. General Services Administration Real Property Award in the category of Green Sustainability Innovation... Base will use NASA developed software systems that have been repurposed into a building environment. These NASA technologies were originally developed for everything from aircraft control systems to mission planning for the Mars rovers, Opportunity and Spirit... Temperature, humidity, carbon dioxide, light levels, noise levels, energy consumption, production, energy and the building's system and subsystem health status will be monitored and evaluated to continuously balance occupant comfort and energy efficiency... This new building will be zero net energy consuming and will use 90 percent less potable water than a conventional building of equivalent size... To reduce water consumption, NASA will repurpose its water recovery system, originally designed as a sustainable, closed loop system on long term space missions... Finally, the energy efficiency features in Sustainability Base can be widely replicated.



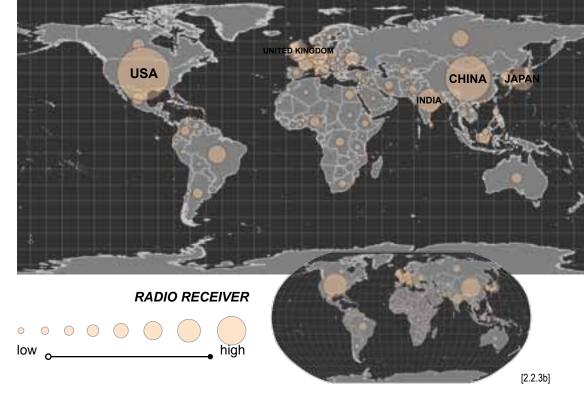


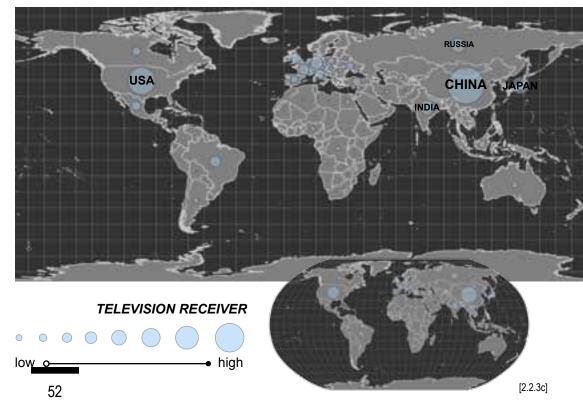
#### radio receiver

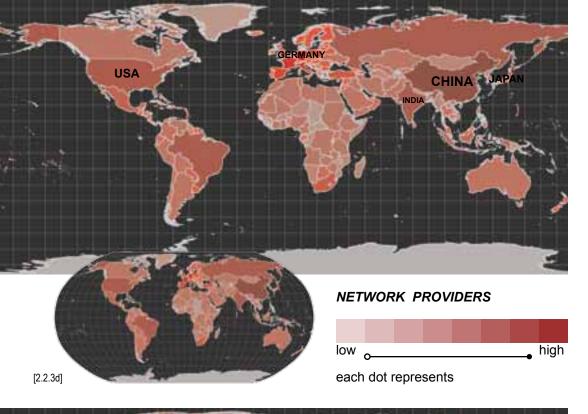
Total amount of electronic circuit receivers including: consumer audio receivers (high fidelity/AV), communication receivers, satellite TV and communication receivers, and other measuring and scanning electromagnetic receivers. Of these, telecommunication services also use and require radio receivers for daily operations.

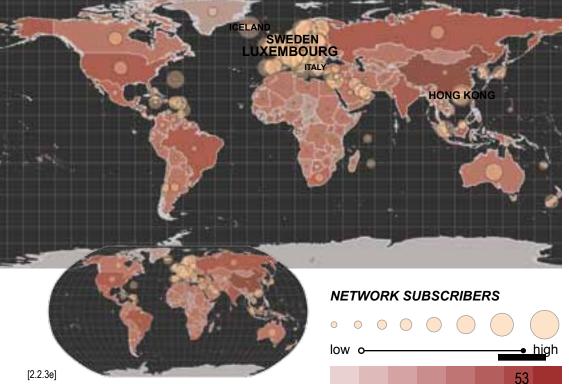
#### television receiver

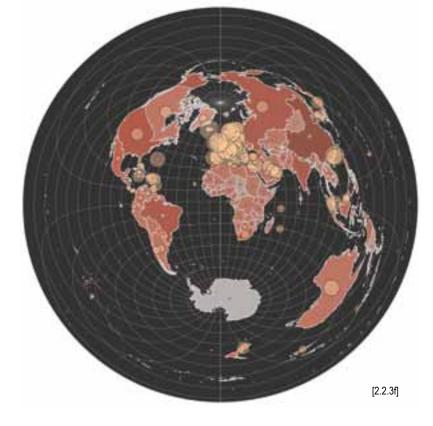
The total amount of television receivers for consumer and surveillance needs. These include radio frequency (F connector) tuners, digital tuners, HDMI and other wave frequency receivers.









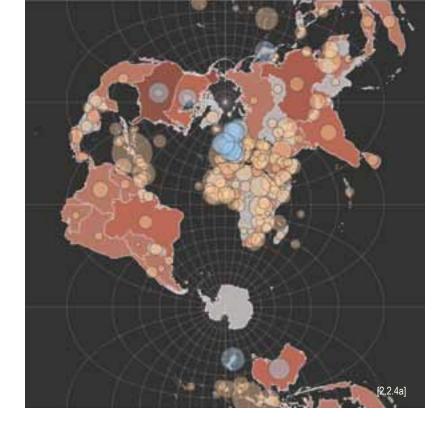


## network provider

Information and communication technology providers for personal and industry operations. These include services for information technology consultation, computer and systems integrations, web hosting, data processing and storage services, voice and data communication services, wired/wireless telecommunication networks, and the Internet.

#### network subscriber

Total population of subscribers to personal entertainment/ communication and other business, educational, and surveillance research/communications networks. The majority of these are internet and mobile network connections.

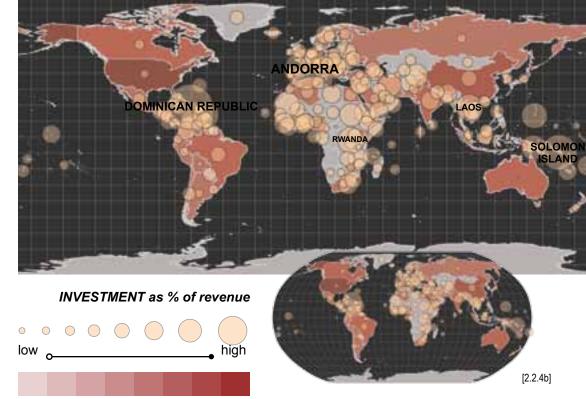


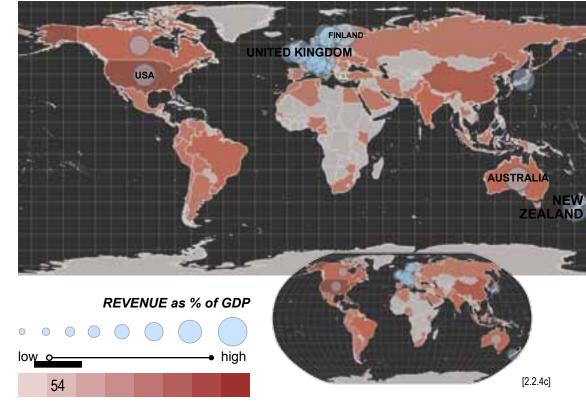
#### telecom investment

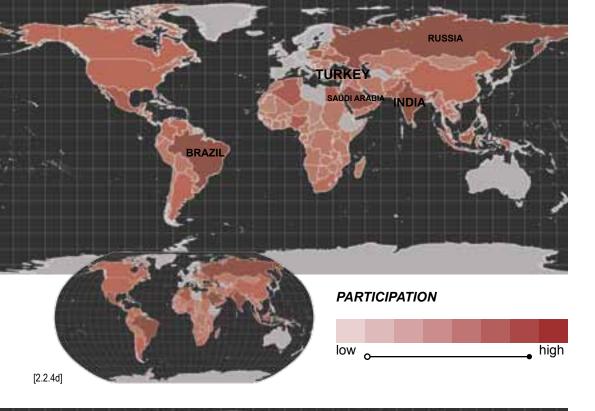
Telecommunications investment refers to the expenditure associated with acquiring the ownership of telecommunication equipment infrastructure (including supporting land, space, and buildings and intellectual and non-tangible property such as computer software). These include expenditure on initial installations and on additions to existing installations.

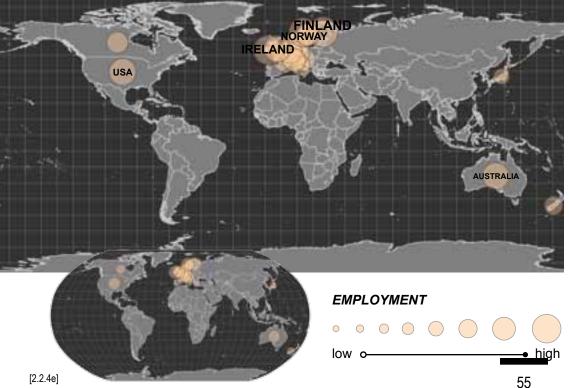
#### telecom revenue

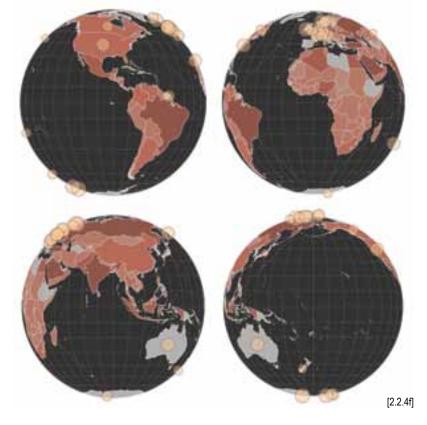
The overall income received by telecom enterprises for setting up infrastructure and providing services for the general population of the world. The values analyzed refers to the gross profit as a percentage of the GDP.









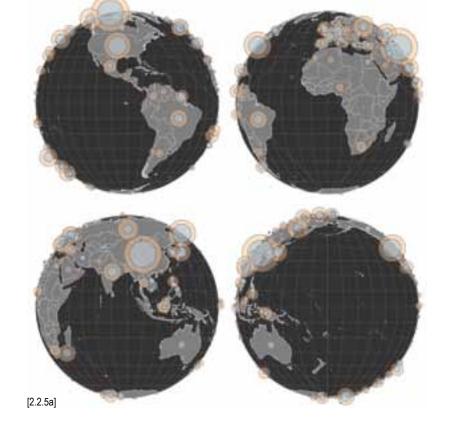


## private participation

Investment in telecom projects with private participation covers infrastructure projects in telecommunications that have reached financial closure and directly or indirectly serve the public. These commitments are the sum of investments in facilities and investments in government assets. The types of projects included are operations and management contracts, operations and management contracts with major capital expenditure, greenfield projects, and divestitures.

## telecom employment

Employment rates as a share percentage of the national employment rate of those employed in telecom services.

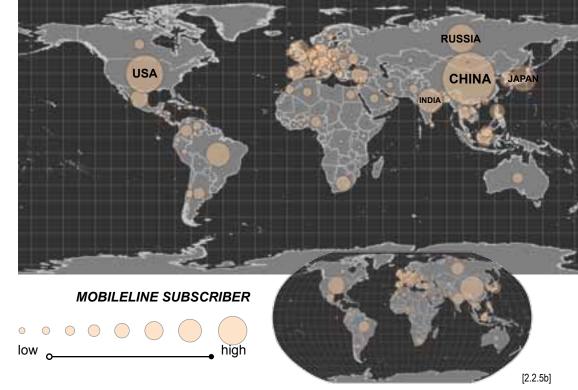


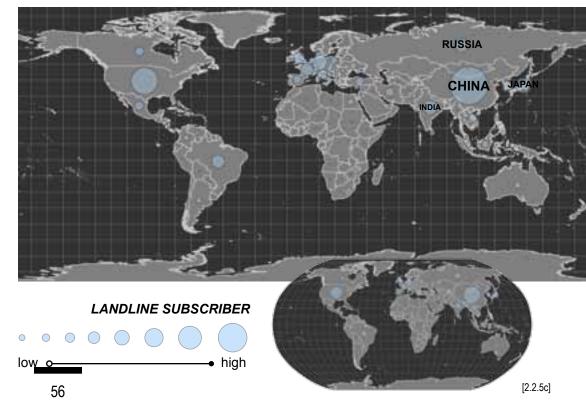
#### mobile users

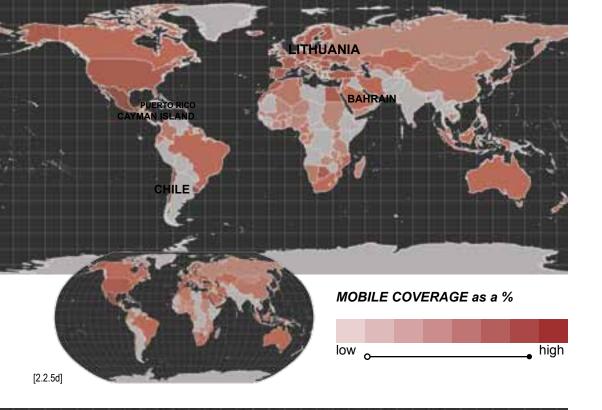
Mobile phone subscribers refer to users of portable telephones subscribing to an automatic public mobile telephone service using cellular technology that provides access to the public switched telephone network.

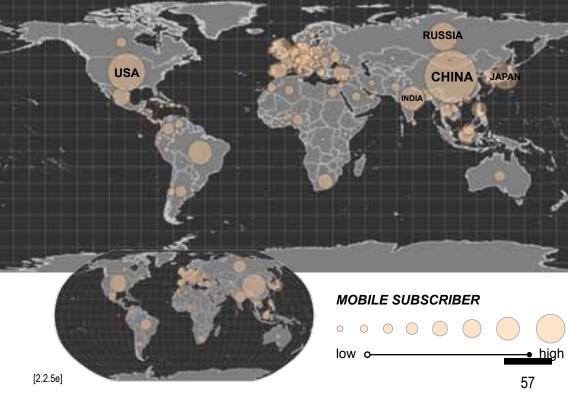
### landline users

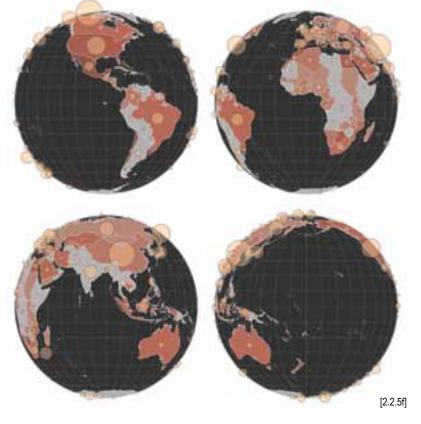
Fixed lines are telephone mainlines connecting a customer's equipment to the public switched telephone network. These networks are integrated into all developed infrastructures of urban and suburban communities along with other telecommunication services provided by the networking hubs around town.











## mobile coverage

The population covered by mobile telephony is the percentage of people within the range of a mobile cellular signal regardless of whether they are subscribers. It is typical to find major financial cities to host the greatest coverage of this service.

#### mobile subscribers

Mobile phone subscribers refer to users of portable telephones subscribing to an automatic public mobile telephone services. People and businesses operating within districts of economic power and developed cities are usually subscribed to mobile services which nowadays include teleconferencing, vocal/video communications, and text messaging capabilities.



2.3

terrestrial familiarities

Throughout many generations of adaptation, the human body and mind have evolved to become accustomed to many unique conditions within the bounds of Earth. This basic tie to the immediate environment has ingrained *many fundamental desires and necessities that are compulsory for sustenance*<sup>12</sup> in the vast body of the planet. As a living organism with an apparent standard of living, humans rely on many resources uniquely originated on Earth. The longevity of humanity relies immensely on natural resources provided by the planet over artificial supplements that are only becoming available as technology develops to adapt to the increasing needs of a resource-demanding world.

"There is no simple definition that encapsulates the essence of what it means to say that something is alive. We know at the very least that life is tenacious, and on Earth it thrives, or at least can survive, in any environment where liquid water exists. This includes places where the temperature ranges from freezing point of water to its boiling point and incorporates locations from the highest mountaintops to the claustrophobic depths of the deepest mines and the oppressive darkness of the abyssal sea. Certainly, life as we know it on Earth is a series of aqueous chemical reactions, and accordingly we take something to be alive if it satisfies the following list of criteria:

1 It is chemical in essence.

2 It exploits thermodynamic disequilibrium.

3 It takes advantage of the covalent boding properties of carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur.

4 It is able to reproduce.

5 It undergoes Darwinian evolution.

All life on Earth is derived from a (last) common ancestor that first appeared some 3.8 billion years ago...The cyanobacteria are one of the oldest life forms on Earth, and they generate their energy by photosynthesis, releasing oxygen into the atmosphere in the process. It was the appearance of such oxygen-producing organisms that caused Earth's original atmosphere to slowly change from a reducing one to an oxidizing one. This dramatic change in the Earth's atmospheric composition took place between 3 and 2.5 billion years ago."

"Terraforming: The Creating of Habitable Worlds" by Martin Beech, page 37-39, 2009

"Space Enterprise: Living and Working Offworld in the 21st Century" by Philip Robert Harris, page 407, 2009

"Although the human species required over three and a half billion years to evolve, George Robinson, a space philosopher and attorney, observed that in the past 50 years we have moved beyond Earth to penetrate near space, deep space, and other planets. In the process of transforming our perceptions of humanity, space law scholars speculate that Homo spatialis or spacekind will develop as a new species altered in time from Homo sapiens, physically, psychologically, and socially. In contemplating the human occupation of outer space, issues related to its industrialization and settlement may be viewed as problems or challenges. Preferring the latter approach, there are indeed numerous multidimensional challenges: the first are technological, biological, and financial."

"Space Enterprise: Living and Working Offworld in the 21st Century" by Philip Robert Harris



The atmosphere surrounding the Earth hosts many layers of important gases retained by Earth's gravitational pull. These layers in the atmosphere protect life from the sun's direct ultraviolet radiation, the greenhouse gas effect, and the significant reduction of temperature extremes throughout daily cyclical conditions. Aside from this, Earth's atmosphere provides aerobic organisms such as humans with the essential resource of air, necessary in one's primary respiratory system. It is through the process of photosynthesis that we have the fresh air that we breathe in our lungs. Without this, humans and other *aerobes*<sup>13</sup> would cease to exist. Among the essential gases captured within Earth's atmosphere, in two parts hydrogen and one part oxygen, is water, the second most valuable resource for living organisms on Earth. This chemical substance, sometimes referred to as *the fuel of life*, carries out important functions as vital nourishment for all forms of life. Water covers 70.9 percent of Planet Earth's surface while it circulates at approximately an equivalent percentage throughout our bodies. Distributed globally by the hydrological cycle, fresh purified water is still a rare commodity as it only accounts for 2.5 percent of the world's water resources. In addition to providing sustenance, water is relied upon for personal hygiene, wellbeing, refreshment, as well as particular meditative cravings.

For human beings to stay healthy, the cultivation of edible products is vital. Food is the major nutritional support for our bodies as it provides the essential nutrients necessary to produce energy and to maintain the healthy conditioning of one's life. Therefore, human culture and colonization efforts have been principally connected with arable land suitable to provide agricultural opportunities for the people. Not only do plants contain the nutritional values for sustenance, but they also have the ability to cleanse and freshen systems in the environment and within one's bodies. For example, plants can break down into various aspects as edible food products for energy consumption, provide air generation through photosynthesis, and provide desirable aromatic scents to enhance emotional and sensory levels in a terrestrial life support system.

"An aerobic organism or aerobe is an organism that can survive and grow in an oxygenated environment. Facultative anaerobes grow and survive in an oxygenated environment and so do aerotolerant anaerobes."

Obligate aerobes require oxygen for aerobic cellular respiration. In a process known as cellular respiration, these organisms use oxygen to oxidize substrates (for example sugars and fats) in order to obtain energy.

Facultative anaerobes can use oxygen, but also have anaerobic methods of energy production.

*Microaerophiles* are organisms that may use oxygen, but only at low concentrations.

Aerotolerant organisms can survive in the presence of oxygen, but they are anaerobic because they do not use it as a terminal electron acceptor."

"Aerobic Organisms" by wikipedia author, http://en.wikipedia.org/wiki/Aerobic\_organism

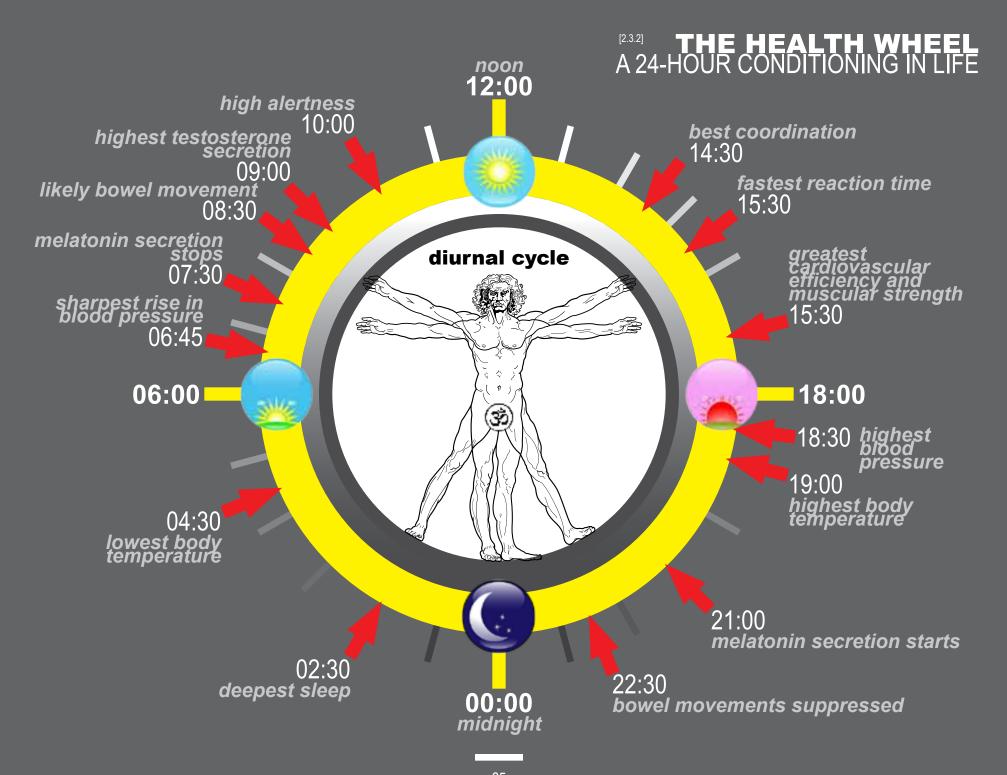
[2.3.1] Basic necessities for sustenance includes plants used in photosynthesis, water to hydrate oneself, and cultivatable resources for nutritional ingestion The only known environment in the solar system that can provide air, water, and food, critical for human survival, is Earth. Humans must also undergo daily rhythmic cycles of conscious and unconscious states of mind according to *the circadian cycle*. <sup>14</sup> We are active during the day when the sun is out, and we rest and rejuvenate at night when it is dark. During these cycle changeovers, physiological rejuvenation takes place as many organic systems harness the latter unconscious period of the daily cycles to cleanse and build up personal immunities in the system.

Human body compositions have developed in such a way that they function best within the Earth's gravitational field. Body functions become more difficult when humans experience a dramatic increase or decrease in gravitational strength in comparison to the standard average of  $g = 9.81 \text{m/s}^2$  on Earth. Under prolonged exposure to these new conditions, physiological problems with circulation, digestion, and muscle development will ultimately arise. This gravitational pull is very important for orientation on Earth as it delineates the basic point of reference of up and down, directing the vestibular system with vital information for balancing the body relative to the ground plane. Aside from this notion of grounding oneself, physical muscular buildup and customary Earth-based activities require this resisting force of gravity for basic conventional functioning needs.

"For the first 2 decades of human spaceflight, issues of sleep and circadian rhythms in space did not get much attention...the effects of the space environment on the circadian system of humans and processes of sleep regulation remained largely unexplored. However, this situation has changed. It has become recognized that sleep disturbances and fatigue, as well as alterations of circadian rhythms in astronauts, are among the most important factors contributing to impaired wellbeing, alertness, and performance during space missions...Optimizing the work-rest schedules of astronauts, as well as monitoring them for fatigue, are viewed as important factors in maintaining behavioral health and performance efficiency in space [Flynn, 2005; Mallis and DeRoshia, 2005]."

"Space Psychology and Psychiatry" by Nick Kanas and Dietrich Manzey, page 27, 2008

[2.3.2] The Vitruvian Man transposed into a generalized circadian rhythm wheel





extraterrestrial disparities

Space environments pose significant challenges to human existence, being devoid of air, water, and food, as well as the area and materials necessary to generate these resources. Space travel to this date has shown that humans have a limited ability to adjust to life in space. Even if provided with a breathable environment and engineered supply of food, the lack of gravity places severe stress on all human systems. Under these circumstances, physiological and psychological human behaviours will have to adjust to various contradicting emotional and sensory reactions as one's body and mind are estranged from the conventional patterns that are naturally tendered for Earth-like environments. It is necessary to acknowledge the major symptoms and consequences in order to propose *countermeasure systems*<sup>15</sup> in artificial innovations of life support that will relieve these physiological and psychological stressors. Finally, aspects of architectural design will be greatly important for maintaining one's physiological and psychological soundness under these extraneous conditions. It is felt that the development of space station and spacecraft architecture to date has not gone far enough in addressing the human condition in space, beyond survival for restricted periods of time. Therefore, the focus of the thesis design in the later chapters will look to making human experience in space more pleasurable by focusing on issues that are typically encountered in the daily routines of living.

"Faced with the necessity to maintain astronauts' health during periods of exposure to microgravity and other extreme conditions of spaceflight, NASA has pursued the development of preventive and counteracting measures to guard against or reverse potential patho-physiological effects of space travel. A variety of countermeasures have been used in longer-duration spaceflights (Mikhailove et al., 1984; Bungo et al., 1985; Greenleaf et al., 1989; Fortney, 1991; Arbeille et al., 1992; Cavanagh et al., 1992; Charles and Lathers, 1994; Hargens, 1994; Convertino, 1996b)...Some examples of countermeasures that had been developed as of 2000 include subcutaneous injections of erythropoietin to prevent decreases in erythrocyte mass and vigorous in-flight exercise regimens to reduce loss of bone mineral density.

NASA's general approach to development of countermeasures was presented to the IOM committee at the Johnson Space Center (Paloski, 2000; Sawin, 2000). The rationale outlined a number of steps that have been incorporated into NASA's Countermeasure Evaluation and Validation Project, which can be summarized as follows:

- conduct research to understand the basic nature of the physiological problem,
- 2. formulate a countermeasure strategy based upon that phyisiological understanding,
- 3. test the countermeasure and demonstrate its efficacy on the ground, and
- 4 validate the countermeasure in space."

"Safe Passage - Astronaut Care for Exploration Missions" by John R. Ball and Charles H. Evans Jr., page 40-41, 2001

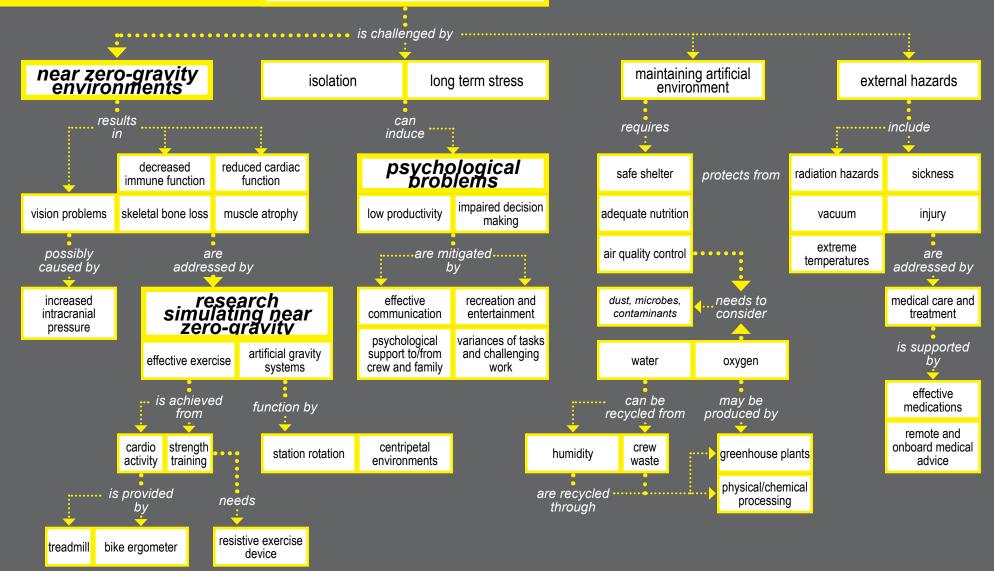
f "Humanizing Outer Space: Architecture, Habitability, and Behavioral Health" by Albert A. Harrison, Acta Astronautica, page 890-891, 2009

"Psychologists and architects are natural allies, joined by their search to support people in their varied endeavors. To be sure, there are some differences, in that psychologists characteristically emphasize picking the right people for the environment while architects mold environments to fit their occupants. But these distinctions are somewhat arbitrary because many psychologists share architects' interest in environment design and architects seek to understand a structure's future occupants and their activities before undertaking a preliminary design...Human factors, architecture, habitability, and behavioral health are highly interrelated. Human factors and ergonomics are roughly equivalent terms...Narrow views of human factors limit to anatomy, physiology, biomechanics, perception and cognition are giving way to enlarged views that include emotions, attitudes, personality, interpersonal relations, group and organizational dynamics and culture. Also, contemporary human factors extend beyond work to self-maintenance (sleeping, eating, personal hygiene) and leisure time activities...A broad view of human factors is essential to protect spacefarers from an accumulation of stresses that could lead to performance lapses, interpersonal strife, and possible psychiatric breakdowns."

"Humanizing Habitability," and Benavoral Health" by Albert A. Harrison



## human health and performance in space



Based on primitive knowledge of the universe, most people perceive outer space as an alien place that one does not belong to, but also a place that one needs to explore to improve and expand knowledge beyond the fringes of Earth. The experience in an extraterrestrial environment is generally viewed as a graceful space where one can float freely in the absence of gravity while being able to hear the most pleasant sounds of silence. Hence, we can categorize our occupancy of outer space in terms of "being out in space confined by the universe" or "being within space confined by the architecture." It is important to acknowledge this key difference in orienting oneself in outer space as they both conform to a similar setting, but both psychologically address humans in unique and differing ways. The effects of weightlessness, lack of atmosphere, and cyclical disorientation are considered *psycho-physiological stressors*, while symptoms pertaining to proprioception in sensory mechanisms and kinaesthetics are *psycho-environmental stressors*. Although many of the psycho-physiological stressors are inevitable due to the fact that our selected destination is outer space, *we as architects and future space architects can eliminate other psycho-environmental stressors by exploring the deeper messages that these symptoms are offering, and designing healthier spaces that acknowledge these psychological issues to minimize the overall psychical effects.<sup>16</sup>* 

16 "The failure of architects to create congenial environments mirrors our inability to find happiness in other areas of our lives. Bad architecture is in the end as much a failure of psychology as of design. It is an example expressed through materials of the same tendency which in other domains will lead us to marry the wrong people, choose inappropriate jobs and book unsuccessful holidays: the tendency not to understand who we are and what will satisfy us...The places we call beautiful are, by contrast, the work of those rare architects with the humility to interrogate themselves adequately about their desires and the tenacity to translate their fleeting apprehensions of joy into logical plans—a combination that enables them to create environments that satisfy needs we never consciously knew we even had."

"The Architecture of Happiness" by Alain de Botton, page 248-249, 2006

[2.4.1] Flowchart of factors and symptoms affecting the physical and psychological performance of an astronaut

Unlike the highly habitable environment on Earth, outer space is a vacuum, which by definition is a volume empty of matter where atmospheric pressures and frictions do not exist. The environment of outer space is in such perfect vacuum that the direct exposure by an astronaut in this empty void will be fatal due to depressurization and harmful levels of radiation from the unfiltered sun. Humans cannot survive when exposed to a vacuum environment as they would lose consciousness in a matter of seconds and eventually die of hypoxia, a pathological condition in which the body (generalized hypoxia) or a region of the body (tissue hypoxia) is deprived of adequate amounts of oxygen. In addition, there is no water or oxygen within the void of the celestial space. Even if outer space could provide us with oxygen, without water, the second most important source for life, no living organism will be able to exist in the unprotected emptiness of the outer space environment. Not only is water crucial for hydration, other hygienic concerns will arise, especially for extended occupancies in this extremely hostile environment. Furthermore, the cosmic barrenness does not have any potential for cultivating food products.

"Human beings can survive quite a wide range of natural terrestrial environmental conditions. Their optimal conditions for well being, comfort, and safe, efficient, work, however, form a more limited range. Conditions inside a spacecraft are largely manmade, and control over most aspects is technically feasible. There are generally two ranges applicable for any environmental condition. The wider range is that in which a human being can survive; the narrower range is that in which a human being is comfortable and can work well.

Optimizing the human factors of a spacecraft consists of matching what the human needs from an environment with what the spacecraft provides. The spacecraft must protect the human from the extremes of vacuum, heat, cold, and radiation that characterize the natural space environment. On top of that, the spacecraft must not expose human to excessive levels of noise, vibration, and acceleration which result from the spacecraft's activities and mission. And with increasingly longer missions, spacecraft must ensure that the human being is in a comfortable social and psychological environment. Weightlessness, the factor that is most obvious in space flight, is an issue but should not be given excessive importance—certainly not at the expense of the other factors mentioned above.

"The Standard Handbook for Aeronautical and Astronautical Engineers" by Mark Davies, section 15, part 7 - Human Factors, sub 15.33 - Health Care, page 1527, 2003

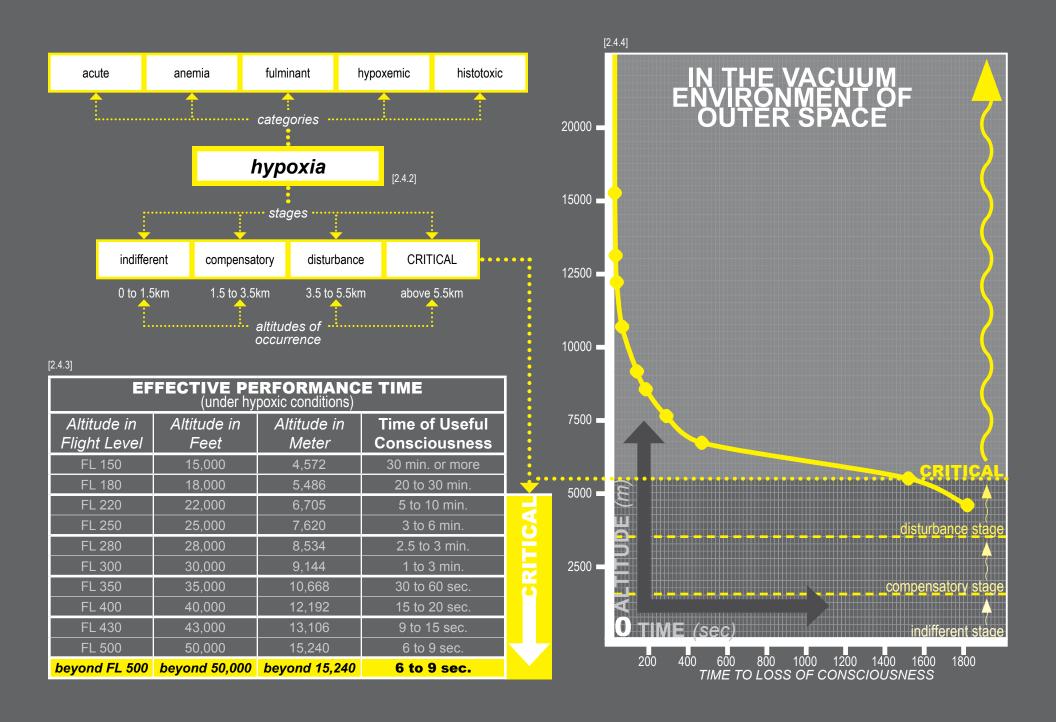
right [2.4.2] Categorizing hypoxia according to altitude variances

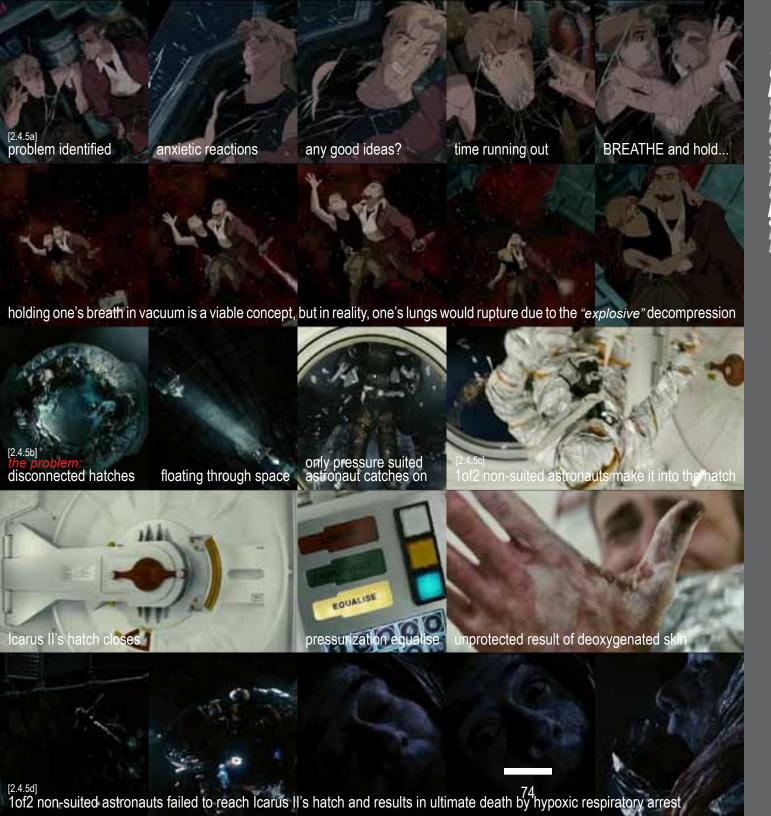
[2.4.3] Table of the effective performance time, a period of consciousness under hypoxic conditions prior to blacking out

[2.4.4] Graph visually indicates critical altitudes near vacuum environments

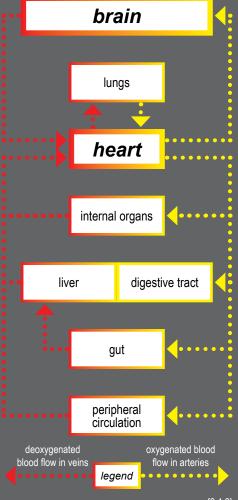
ext [2.4.5] The means of surviving in a vacuum environment and depressurization scenarios as depicted in flim

[2.4.6] Diagram of the oxygenation process of blood flow in a body





The partial pressure of O in the lungs and in the palmonary vessels in the arterial and venous bloodstream (PaO and PvO respectively) are equal to 96 and 40 hPa, such that O will flow from the lungs to the blood cells. Upon rapid decompression, PaO plummets so drastically and so quickly that it becomes lower than PvO<sub>2</sub>.



Dr. David (astronaut) Bowman prepares depressurization launch maneuver to get him from an EVA pod into the pressureless air-lock of a space station in 2001: A Space Odyssey.

Depressurization activated as the hatch of the EVA pod blasts open, launching Dr. Bowman towards the open air-lock. Exposed to the vacuum space environment, the countdown for the time of useful consciousness hearins **begins.** exposure <10 sec. @ 4 sec.

With the short opening for survival, Dr. Bowman scrambles to reorient himself and locate the emergency hatch closure handle (quick reflexes of the fictional astronaut reacts and activates mechanism in a quick 4 activates mechanism in a quick 4 seconds.)

exposure < 10 sec. @ 8 sec.

Holding on to his life, Dr. Bovman reaches the humanly limit and begins to lose consciousness as the hatch closes of the humanly limit of the humanly limit of the human l physiological peaking limit of the body in vacuum exposure is around 9-11sec.)

exposure >10 sec. @ 12 sec.

Air-lock hatch closes in due time, repressurizing the module to 100% as Dr. Bowman luckily regains consciousness as he reoxygenates under the pressurized environment any longer in the vacuum space environment would have been fatal)





18 "Humans don't belong in space. Everything about us evolved for life on Earth. Weightlessness is an exhilarating novelty, but floaters soon begin to dream of walking. Earlier Laveikin told us, "Only in space do you understand what incredible happiness it is just to walk. To walk on Earth."...EVA [extravehicular activity] height vertigo is not a phobia, but a normal response to the novel and terrifying cognitive reality of falling through space at 17,500 miles per hour... Zero gravity presents a uniquely perplexing sensory conflict. On Earth, when you're upright, gravity brings your otoliths to rest on the hair cells along the bottom of the inner ear. When you lie down on your side, they come to rest on the hairs on that side. During weightlessness, the otiliths, in both situations, just float around in the middle. Now if you suddenly turn your head, they are free to richochet back and forth off the walls. "So your inner ear says you just laid down and stood up and laid down and stood up," says Cowings. Until your brain learns to reinterpret the signals, the contradictions can be sick-making... Astronauts have to deal with the mother of all sensory conflicts: the visual reorientation illusion. This is where up, without warning, becomes down... It happens most readily in spaces with no obvious visual clues as to which is the floor and which the ceiling or wall."

"Packing for Mars" by Mary Roach, page 58, 71 and 112-114, 2010

"At night, the airport emerged as a home of nomadic spirits, types who could not commit to any one country, who shied from tradition and were suspicious of settled community, and who were therefore nowhere more comfortable than in the intermediate zones of the modern world, landscapes gashed by kerosene storage tanks, business parks and airport hotels. Because the arrival of night typically pulls us back towards the hearth, there seemed something especially brave about travellers who were preparing to entrust themselves to the darkness, to be carried in a craft navigated by instruments alone and to surrender to sleep, finally, only over Azerbaijan or the Kalahari Desert.

"A Week at the Airport" by Alain de Botton, page 83, 2009

[2.4.7] Stephen Hawkings under weightlessness on a parabolic flight conducted by Zero-G

left

Without the three primary resources that human beings rely on for survival (air, water, and food), it is obvious that the creation of habitation in outer space will raise colossal challenges for designers and developers. Besides this, other features of this environment tend to drive negative human performance and functions. In outer space, the absence of gravity<sup>18</sup> may be experientially unique and conceptually amusing, but this weightless reality establishes many disconcerting problems that hinder the way the human body maneuvers while performing simple tasks. In addition, due to the lack of physical grounding and gravitational resistances, deficiencies in exteroceptivity of one's perception and orientations towards the outside world and interoceptivity of one's perception of inner pains and cravings will gradually escalate into unhealthy dysfunctions. These dysfunctional symptoms may cause stress overloads amongst inexperienced occupants, while spawning health issues that pose difficulty for recovery upon returning to Earth.

Therefore, as the thesis commences to propose an initial development phase of a publicly hospitable destination in outer space, it is crucial the designs thoroughly investigate the novelty of weightlessness and its negative effects to occupants under prolonged exposure. In doing so, the design should encompass programmed spaces and activities that ensure a pleasurable and entertaining environment, exploiting these unique conditions while also having pockets of decompressive zones where one can escape when this lifestyle novelty becomes overwhelming. Additionally, other aspects such as orbital track selections will be crucial to providing a healthy setting for the occupants and a sound foundation for the station. For convenience of resupplying and maintenance by terrestrial support, it will be mandatory that the station is situated within the proximity of the lower Earth orbits. Given that orbital periods are usually less than the typical 24 hours of the Earth-based diurnal cycle, inhabitants of the space station will have to adjust their *rhythmic patterns*<sup>19</sup> to suit their new sense of the passage of time. Phases beyond this particular establishment within Earth's proximity will face even greater challenges as projects stretch deeper into the universe and away from Earth's orbits. In these projects, an absence of natural cycles will occur as endless exposures will be present without the protecting shade of a planet's mass.



2.5

physical disruptions of the human body

When the human body is exposed to unfamiliar conditions, instinctively, one's physiological conditions gradually adjust to synchronize their personal physique with the necessary performance factors within these extraneous settings. New muscle adaptations will be essential due to the inaugural stresses introduced under regular extraterrestrial operations, while other parts of the body will inevitably atrophy through lack of use. One of the major concerns for current astronauts is the ability to maintain a healthy, strong physical build within the weightless abyss of outer space. On top of this, it is of high priority to prevent any physical deterioration for spacefaring passengers who transit through outer space, as it is crucial that routine bodily functioning remains regular upon return to the surface of the Earth.

Of the seemingly exotic attractions of space, weightlessness poses the most dramatic challenges for human physiology. Weightlessness is defined as the condition that exists on an object or person when they experience little or no acceleration that defines their inertial trajectory or the trajectory of pure free-fall. In other words, this can be considered the zero-gravity-like (zero-g) effect on an object or person mingling in the environment of outer space. Without gravity, there is no sense of grounding oneself as one floats in space. No longer is one compressed by gravity and, therefore, one's physical form will elongate. This stretching of one's physical form also straightens and extends internal components such as spinal nerve roots and tendons which can at length generate back pains and other *musculo-skeletal dysfunctions*.<sup>20</sup>

20 "The third system that is significantly affected by the loss of gravitational force in space is the system involving muscles and bones. During evolution, this system has been shaped to support the weight of humans induced by gravity, as well as to allow for an upright posture and movement against the mechanical impact of the gravitational force. In fact, more than half of all muscles in the human body are involved in dealing with gravity. In particular, this holds for most skeletal muscles in the legs and lower back. Similarly, the main weight-bearing bones of the legs and the lower spine are mostly loaded by gravitational force.

During spaceflight, microgravity progressively leads to a significant decrease of muscle volume and strength (i.e., muscle atrophy), as well as a reduction of fatigue resistance, particularly in those muscles that are required to oppose gravity [Jaweed, 1994]. In addition, hypoactivity due to confinement in a comparatively small living environment contributes to these effects. Muscle atrophy can be observed after the first few days in space. If no appropriate countermeasures are applied (see Section 2.2.4), astronauts can lose up to 20% of muscle mass during short-term missions and up to 50% during long-term missions.

The similarity of bone demineralization in space to the aging processes and to osteoporosis has made this effect of microgravity an interesting topic for physiological and medical research. However, not all of this research needs to be conducted during actual space missions. Instead, so called "bed rest" studies can be used to study these effects on Earth. During bed rest studies, individuals are kept in a horizontal position for several days or even weeks or months, usually combined with a 6° head-down bed tilt. This leads to physiological effects that resemble those of microgravity (e.g., hypoactivity, decreased mechanical force on weight-bearing muscles and bones, absence of a hydostatic pressure gradient along the head-foot axis). Accordingly, this approach not only has been used to study effects analogous to those in space on muscles and bones, but also on the cardiovascular system in an Earth-bound setting.

"Space Psychology and Psychiatry" by Nick Kanas and Dietrich Manzey, page 23-24, 2008

f "Architectural Design Vol 70 No 2 - Space Architecture" by Maggie Toy and Rachel Armstrong, page 51-52, March 2000

"On Earth the relationship between the body and the environment is dominated by gravity, which is tracked by both proprioceptive and vestibular sensing. The relationship between the sensations and the movements of the body allow for the understanding of the conditions that are inhabited. Humberto Maturana and Francisco Varela describe the organism as an essentially closed system that brings forth an understanding of both itself and of its media by means of a structural coupling with the media. The covariance of the dynamics of sensor states in relation to the dynamics of effector states forms the foundation for this distinction. The drastic reduction of gravity removes much of this correlation and results in a kind of motion sickness, which is the result of the decoupling... Once an adjustment to the absence of gravity has been made, a process that takes several weeks, the remaining sense of spatial organisation is dependent upon visual cues in relation to the body...'It turns out that you carry with you your own body-oriented world, independent of anything else, in which up is over your head, down is below your feet, right is this way and left is that way; and you take this world around with you everywhere you go.' - cited from Henry Cooper's 'A House in Space"

"Architectural Designe Yol 70 No. 2 Armstrong



21 "The 'fight or flight response' is our body's primitive, automatic, inborn response that prepares the body to 'fight' or 'flee' from perceived attack, harm or threat to our survival.

By its very design, the fight or flight response leads us to fight or to flee—both creating immense amounts of muscle movement and physical exertion. This physical activity effectively metabolizes the stress hormones released as a result of the activation of our fight or flight response. Once the fighting is over, and the threat—which triggered the response—has been eliminated, our body and mind return to a state of calm."

"The Body/Soul Connection - Health and Healing for the Mind, Body & Spirit" by Dr. Neil F. Neimark, www.thebodysoulconnection.com, 2010

left [2.5.1] Muscular atrophic patient

[2.5.2] Operations under the weightless condition allows tedious operations to be done at ease

next [2.5.3] Flowchart of things that trigger the fight-orflight response

"To produce the fight-or-flight response, the hypothalamus activates two systems: the sympathetic nervous system and the adrenal-cortical system. The sympathetic nervous system uses nerve pathways to initiate reactions in the body, and the adrenal-cortical system uses the bloodstream. The combined effects of these two systems are the fight-or-flight response.

When the hypothalamus tells the sympathetic nervous system to kick into gear, the overall effect is that the body speeds up, tenses up and becomes generally very alert. If there's a burglar at the door, you're going to have to take action—and fast. The sympathetic nervous system sends out impulses to glands and smooth muscles and tells the adrenal medulla to release epinephrine (adrenaline) and norepinephrine (noradrenaline) into the bloodstream. These "stress hormones" cause several changes in the body, including an increase in heart rate and blood pressure.

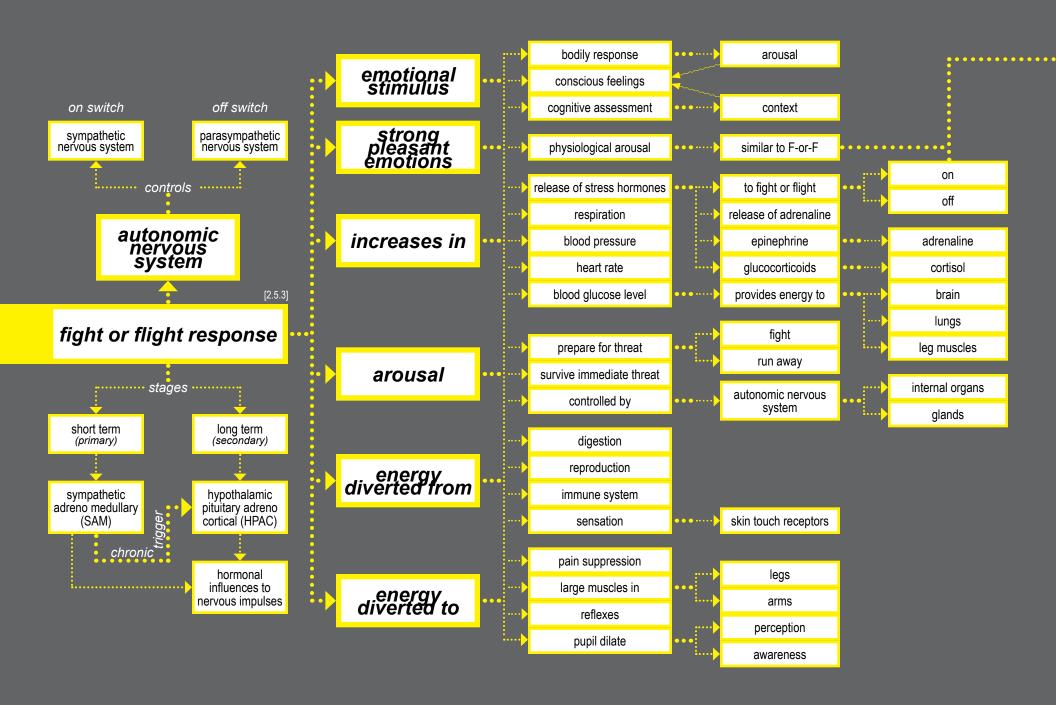
At the same time, the hypothalamus releases corticotropin-releasing factor (CRF) into the pituitary gland, activating the adrenal-cortical system. The pituitary gland (a major endocrine gland) secretes the hormone ACTH (adrenocorticotropic hormone). ACTH moves through the bloodstream and ultimately arrives at the adrenal cortex, where it activates the release of approximately 30 different hormones that get the body prepared to deal with a threat."

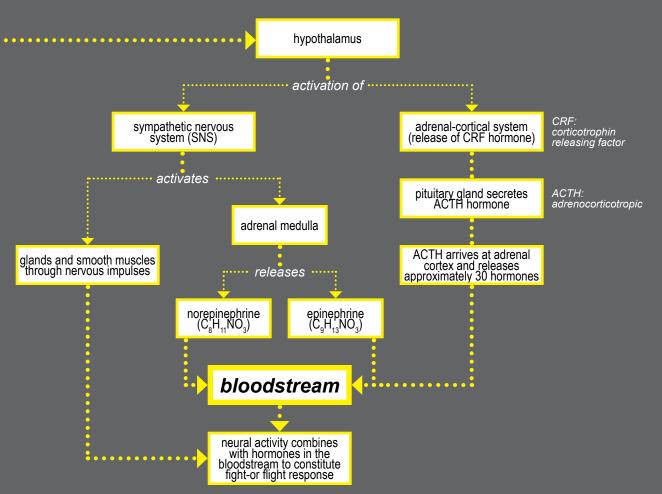
"How Fear Works" by Julia Layton, science.howstuffworks.com, 1998-2012

[2.5.4] Typical rresponse of a headache/migraine under stress of the fight-or-flight response

Cardiovascular variances will occur upon liftoff, arrival, and the duration of stay in outer space; anxiety and other cerebral reactions to weightlessness and the foreign environment will increase one's heart rate and blood pressure. Later, when the body establishes an acquaintance with the living environments under weightlessness, one's heart rate, blood pressure, and the variability of the two tend to decrease as one is relieved from the stresses of conventional resilient forces. Therefore, an overall decrease will be evident in the activity of the sympathetic fight-or-flight response nervous system,<sup>21</sup> an important bodily response system responsible for the up and down regulating of many homeostatic mechanisms in living organisms that mediate and prime the body for reactionary decisions and actions in response to threats and hazards.

Additionally, as a result of the zero-gravity-like experience, tasks that are tedious on Earth due to muscular strength limitations can be performed simply in the weightless environment of outer space. The lack of pressure on one's joints and muscles alleviates one from the many strict postures required on Earth, and one may move freely without having to cope with natural resistances. However, over time, this effortlessness of corporal functions will eventually weaken muscles and potentially disable typical buildup of general muscular mass. This progressive weakening of muscular strength is an indicator of partial or complete muscle atrophy, which will ultimately affect one's ability to exert necessary force under natural or artificial resistances. As a health concern, one's quality of life will suffer immensely from the failure to perform certain basic errands while worsening accidental risk factors when performing straightforward tasks such as walking and lifting heavy objects. Muscular atrophy increases the risk of falling in conditions such as inclusion body myositis and, in some cases, bodily deformations will transpire as weakened portions of the body shrink. This physiological breakdown process will be problematic as occupants under these muscular atrophic circumstances will not be suited to return into the normal terrestrial conditions that host many pressures of natural resistances.





The sudden flood of epinephrine, norepinephrine, and dozens of other hormones causes changes in the body that include:

heart rate and blood pressure increase, pupils dilate to receive as much light as possible, veins in skin constrict to send more blood to major muscle groups, blood-glucose level increase, muscular tension energized by adrenaline and glucose, smooth muscle relaxes in order to allow more oxygen into the lungs, nonessential systems (digestion/immune) shut down to allow more energy for emergency functions, and troubled focus on simple tasks.



The many physiological problems posed by outer space occupancy will have serious health consequences. One's initial response *upon returning to Earth's gravitational conditions will be awkward and difficult.*<sup>22</sup> Coordinating one's movements will be difficult due to diminished peripheral vascular capabilities. This extended immobility causes the human brain to forget how to activate the sympathetic nervous system as a response to the forces of gravity and hypotension, which will cause many sudden health impediments. Upon return to Earth, spacefarers will have learned many new ways of doing things. This would include going around corners without the reliance of a pivotal contact with the ground, or catching things that do not have the tendency to fall, or even new defining perceptions for the orientations of up and down. This new adapted sense of extraterrestrial awareness will typically cause lack of coordination on Earth while impairing motor control and abnormal baroreflexes.

22 "The sum of these stressors renders the current extraterrestrial experience potentially overwhelming to the human psyche. The psychological imbalances and dysfunctions that manifest themselves in humans during spaceflight include boredom, lack of motivation, loneliness, withdrawal, depression, and paranoia. These negative psychological effects lead to interpersonal conflicts as well as impaired judgement and decision-making, all of which jeopardizes the safety of the crew, the success of the mission and the validity of any research that is conducted during the mission.

The extraterrestrial experience is so challenging and exhausting that upon their return from a space mission, all astronauts and cosmonauts are provided a protracted absence from their normal duties in order to recover. Dr. Albert W. Holland, the Chief Psychologist at NASA, stated that after postflight debriefing and depending on the individual's needs, all astronauts are given about 1 week for rest, emotional recovery and physical rehabilitation for every month in orbit. The RASA provide even more time off for its cosmonauts. Depending on the mission's rigors and the particular circumstances of the individual, some astronauts remain emotionally drained for several months more and take some time off after all the post-flight medical tests, experiment data collection and media events are done, before returning to office duties or flight status.

Significant progress has been made to improve the live/work condition in outer space, but it has been a slow process due to budget restrictions and cutbacks. Clearly, much more needs to be done to improve the situation in light of the increasingly longer space missions that humans face in the years ahead."

"Acta Astronautica 56" by Angel Marie Seguin, page 982, 2005

right

[2.5.5] The team Expedition 31 of NASA astronaut Don Pettit of NASA, ESA astronaut André Kuipers, and RSA Astronaut Oleg Kononenko landed safely near Zhezkazgan, Kazakhstan at 08:14 GMT after 193 days in space. As a result of such long duration in space, the astronauts are all physically inadapt to the Earthly conditions such as the pressures of gravitational forces on their bodies.







psychological dysfunctions of the human mind

"The Right Stuff" has been the dominant archetype for astronaut selections for many years, since the initiation of the space race and the beginnings of major space programs. The media and general public considered it folly to conduct any psychological analysis of astronauts and their reactions to outer space, as they were imagined to be more than just typical human beings. Instead, astronauts were selected as brave, strong, and perfect men who had the uncritical willingness to face danger—those who, in short, had the right stuff. For this reason of *negative publicity*, <sup>24</sup> research on human spaceflight psychology and behavioural factors have been held back about twenty to thirty years in comparison to other fields of sciences that mandate for a successfully engineered and fabricated module for astronauts and test subjects (e.g. monkeys, test pilots/astronauts themselves, etc.) prior to entrance into the cosmos.

"As to just what this ineffable quality was...well it obviously involved bravery. But it wasn't bravery in its simplest sense of being willing to risk your life. The idea seemed to be that any fool could do that, if that was all that was required, just as any fool could throw away his life in the process. No... the idea here (in the all-enclosing fraternity) seemed to be that a man should have the ability to go up in a hurtling piece of machinery and put his hide on the line and then have the moxie, the reflexes, the experience, the coolness, to pull it back in the last yawning moment-and then go up again the next day, and the next day, and every next day, even if the series should prove infinite—and, ultimately, in its best expression, do so in a cause that means something to thousands, to a people, a nation, to humanity, to God...to prove at every foot of the way up the pyramid that you were one of the elected and anointed ones who had the right stuff and could move higher and higher and even—ultimately, God willing, one day-that you might be able to join that special few at the very top, that elite who had the capacity to bring tears to men's eyes, the very Brotherhood of the Right Stuff itself."

"The Right Stuff" by Tom Wolfe, page 17-298, 1979

"...for this period of minimal involvement in the space program suggest that the "right stuff" image worked against the field until the mid-1990s, when space station expeditions brought the challenges of long-duration missions into focus...Since there were practically no studies of astronauts, researchers relied heavily on studies conducted in Antarctica, submarines, and research submersibles, and simulators...Today, NASA has shown increased recognition of shared perspectives, privacy, leisuretime activity, family separation and reunification, cultural awareness, the satisfying properties of windows and view ports, and many other topics that were formerly overlooked if not seen as irrelevant or frivolous. From NASA's perspective, the significance of these factors is less in the fact that they can help people "feel good" rather than leaving potential impact on risk and performance of their missions...For decades, expanding the role of psychology in the US space program was an uphill battle with psychologists' pleas generally falling on deaf ears. The socialogist Charles Perrow has discussed how resistance to human factors within complex organizations has strong structural and cultural underpinnings and is not overcome easily... at least in memory, heroes did not disappoint. Psychological research or, worse yet, the faintest possibility that a mission would be comprised by psychological factors could be a public relations nightmare...For astronauts, the stereotype of the right stuff helps maintain flight status. After all, part of the heroic myth is that under the greatest of adversities, people with the right stuff can still get the job done!"

> "Psychology of Space Exploration: Contemporary Research in Historical Perspective" by Douglas A. Vakoch, page 17-24, 2011

"Footprints on Clouds" by K.O. Eckland, 1976

"Within all of us is a varying amount of space lint and star dust, the residue from our creation. Most are too busy to notice it, and it is stronger in some than others. It is strongest in those of us who fly and is responsible for an unconscious, subtle desire to slip into some wings and try for the elusive boundaries of our origin."

"Footprint on Clouds" by K.O. Eckland



"Our leap into space was a significant accomplishment of the past 30 years and the ergonomic findings that helped bring it about have enriched our profession in countless ways... Generally, NASA has limited the access to astronauts by social science researchers, even by its own psychiatrists and psychologists; the agency has failed to capitalize on the data it collected that could improve spaceflight and living for others to follow...For years, she wrote, psychology played a minimal role in astronaut selection, and because the assessment of individual astronaut performance was prohibited, it was not possible to collect normative data for test validation and other purposes...those disciplines that are rooted in biology, engineering, and experimental psychology have found greater acceptance within the space program than disciplines rooted in personality, social, and organizational psychology.

> "Psychology of Space Exploration: Contemporary Research in Historical Perspective" by Douglas A. Vakoch, page 5-7, 2011

26

""The 1998 Committee's recommendations included studying the effects of the physical and psychosocial environment of spacecraft on cognitive, psychophysiological, and affective measures of behavior and performance; the development and evaluation of countermeasures for mitigating adverse effects of the physical and social environments on individual and group performance; in-flight studies of the characteristics of sleep during long-duration missions; groundbased studies of change and stability in individual psychophysiological patterns in response to psychosocial and environmental stressors; the effects of individual differences on cognitive, psychophysiological, and affective measures of behavior and performance; improved methods for assessing interpersonal relations and crew compatibility; and improved training [didactic and experiential] in psychological and social adaptation to space. The Committee also urged exploring the effects of crew composition on crew tension, cohesion, and performance; factors affecting ground-crew communication and interactions; and conditions that affect the distribution of authority, decision-making, and task assignments between space crews and ground control."

"Psychology of Space Exploration: Contemporary Research in Historical Perspective" by Douglas A. Vakoch, page 5-7, 2011

[2.6.1] Scene from 1983 film, "The Right Stuff" depicting the brave rare men who are conceived to be the only ones capable in surviving the extraterrestrial missions in the new territory of human spaceflight

As the pioneering establishment to human spaceflight, minimal precedents were available in terms of psychology and physiology on astronauts during the original administration of the space program. It was not until a collective effort by physicians and psychologists who came together to form in collaboration a Committee on Space Biology and Medicine that indications of significant importance began to surface in this academic field for spaceflight commissions. The earliest initiations were notably the interests in the 1930s regarding the effects of high altitude flight on the mind and body, which soon evolved into the dedicated field of space and aviation medicine in the 1940s. However, it was not until the 1980s that the severity of psychological impacts and behaviours on those who linger for long durations in outer space were realized. In the mid-1990s, it finally became apparent the "right stuff" image had been conspicuously working against the developments of healthy spaceflight programs.<sup>25</sup> As missions began to expand and commissions for longer durations were introduced with the help of space stations and space laboratories, it was understood that more research was required. By 1998, the whole perspective of the space program had shifted to address heightened research requirements with the announcement of a proposed Mars program for near future missions involving long hauls of astronautic space travel. At the start of the new millennium, topics such as habitability, physical and psychological confinement, deprivations (sensory, sexual, sleep, etc.), cumulative fatigue from a confused circadian cycle, isolation, loneliness, disorientation, radiation, weightlessness, microgravity, and biological dysfunctions under the pressures of the extreme conditions that are natural in outer space but foreign in human nature, are all topics that cannot be ignored in the development of modernday space sciences.26

Psycho-physiological stressors are the most common type of stressors in our lifestyles, and are major influencing factors in causing psychosomatic illnesses. The major stimulants of such stresses in outer space are derived from the three unique conditions of the extreme environment that are exotic for our bodies and minds to adapt to: 1. the body in weightlessness at a constant free-fall; 2. the vacuum of space with the absence of an atmosphere; 3. cyclical disorientation with a non-synchronized circadian rhythm. *Feeling detached and separated from our roots on Earth, one's sense of belonging re-justifies*<sup>27</sup> over prolonged exposure to such exotic surroundings as psycho-physiological stressor symptoms emerge.

As a major distress indication to psycho-physiological stressors, the *novelty of weightlessness in outer space* has huge impacts upon both our minds and bodies.<sup>28</sup> While in the absence of gravity, bodily fluids are directed to the upper portions of the body, causing a metamorphosis to the physical appearance. In addition, the redistribution of bodily fluids and transmutations can obstruct one's performance in routine functions. This will also have an effect on the senses of smell and taste. Finally, as one floats around in space, one loses track of up and down. This sense of disorientation may eventually cause other sensory dysfunctions that lead to perceptive malfunctioning as the sense of sight becomes obscured.

""Everything one takes for granted on Earth must be rethought, relearned, rehearsed...People can't anticipate how much they'll miss the natural world until they are deprived of it. Separation from the earth with all of its unconscious symbolic significance for man...might in theory at least be expected...to produce—even in a well-selected and trained pilot—something akin to the panic of schizophrenia...The breakaway effect appears to have been repackaged as "earth-out-of-view phenomenon": In the history of human beings, no one has ever been in a situation when Mother Earth, and all of her associated nurturing and comforting aspects...has been reduced to insignificance in the sky...It seems possible that it will induce some state of internal uncoupling from the Earth. Such a state might be associated with a broad range of individual maladaptive responses, including anxiety and depressive reactions, suicidal intentions, or even psychotic symptoms such as hallucinations or delusions. In addition, a partial or complete loss of commitment to the usual (Earth-bound) system of values and behavioral norms may occur."

"Packing for Mars" by Mary Roach, page 16, 57, 66 and 72, 2010

"Humans don't belong in space. Everything about us evolved for life on Earth. Weightlessness is an exhilarating novelty, but floaters soon begin to dream of walking. Earlier Laveikin told us, "Only in space do you understand what incredible happiness it is just to walk. To walk on Earth."...EVA [extravehicular activity] height vertigo is not a phobia, but a normal response to the novel and terrifying cognitive reality of falling through space at 17,500 miles per hour... Zero gravity presents a uniquely perplexing sensory conflict. On Earth, when you're upright, gravity brings your otoliths to rest on the hair cells along the bottom of the inner ear. When you lie down on your side, they come to rest on the hairs on that side. During weightlessness, the otiliths, in both situations, just float around in the middle. Now if you suddenly turn your head, they are free to richochet back and forth off the walls. "So your inner ear says you just laid down and stood up and laid down and stood up," says Cowings. Until your brain learns to reinterpret the signals, the contradictions can be sick-making... Astronauts have to deal with the mother of all sensory conflicts: the visual reorientation illusion. This is where up, without warning, becomes down... It happens most readily in spaces with no obvious visual clues as to which is the floor and which the ceiling or wall."

"Packing for Mars" by Mary Roach, page 58, 71 and 112-114, 2010

right [2.6.2] Everyday ritualistic tasks and routines will be altered under the weightless environment of outer space

[2.6.3] The sense of up and down will be disoriented as there will be no grounding forces for one to reference off of in outer space. Similarly the concept of disorientation is depicted in the film, "Inception".





29 "Only someone who has drifted free in the unlimited stretch of the universe could understand that burial in space, like the sailor's burial at sea, holds not disrespect, but honor...To prove that a suit was safe for a man, we were going to test it on a chimp, but to prove the suit was safe for a chimp, we had to test it on a man. U.S. Spacesuits coauthor Joe McMann said in an email. That was a mind boggler."

"Packing for Mars" by Mary Roach, page 19 and 156, 2010

"Within the lungs the alveola provide the interface between air and blood. The blood which is returned from the body tissue into the alveolae has given away most of its oxygen so that the oxygen partial pressure in the lungs is higher than in the arriving blood. A process of diffusion then drives oxygen through the thin alveolar wall into the blood.

The most important parameters for the oxygen diffusion process are the oxygen percentage and barometric ambient pressure. Changing these parameters changes immediately the oxygen saturation level in blood and with it the oxygen supply to the body tissue. Unfortunately, there is no significant storage of oxygen in the human body, unlike many other chemical substances necessary to maintain life. The blood is the only storehouse for oxygen, and its capacity is very limited. Hence, the human body lives only a hand-to-mouth existence with its oxygen supply.

As the pressure of air in the atmosphere decreases with increasing altitude, the partial pressure of oxygen in the air reduces and with it the diffusion of oxygen into the body. Reduction of oxygen availability in the body results in loss of functions ranging from slight impairment up to death. It is the nervous system, in particular in the higher centres of the brain, and the eyes which have a high metabolism with no oxygen reserve. These are most sensitive to oxygen depletion and therefore are the first to be affected by a reduced oxygen supply.

The effects of reduced oxygen supply to the body (hypoxia) vary between persons, depending on health, physical fitness, age, activity level and statistical scatter with the population. Pilots and flight attendants usually require more oxygen during an emergency than healthy, seated passengers and might therefore suffer earlier from hypoxia effects."

"FAST 38 - Airbus Technical Magazine" by Kenneth Johnson, page 21, July 2006

31 "CBS Interview of Gus Grissom" by Nelson Benton of CBS, December 1966

Ieft [2.6.4] One of the world's largest vacuum chambers at NASA

[2.6.5] Graph illustrating the survival rate dependent on the duration of vacuum exposure

A vacuum, by definition, is a volume or a space that is empty of matter in which atmospheric pressures and friction do not exist. The environment of outer space is in a perfect vacuum with no atmosphere; hence, direct exposure by an astronaut in space results in harm due to depressurization and radiation from the unfiltered sun. Humans cannot survive when exposed to a vacuum environment<sup>29</sup> as they will lose consciousness in a matter of seconds and eventually die of hypoxia, 30 a condition where the body is deprived of adequate amounts of oxygen. Although spacesuits and pressurized module vessels are available for astronauts, a more challenging problem persists: the fear of death that arises in this situation, where the instinctual "what if" question persists. What if the life support system on board the space station or my spacesuit fails and depressurization occurs? This suspicion of technical failure is naturally embedded in the minds of extraterrestrial travelers. Space architecture is a man-made product, and these are historically known to be fraught with defects as human error is inevitable. In addition, the structures deployed into space consist of millions of components, making the potential of error substantial. Therefore, astronauts have always been selected as daredevils and have been trained with the mental preparations for potential failures. Virgil I. "Gus" Grissom expressed his safety concerns at an interview in December of 1966, only one month prior to his death during a ground test as the commanding pilot of the catastrophic Apollo 1 mission (AS-204): "You sort of have to put that [accidents] out of your mind. There's always a possibility that you can have a catastrophic failure, of course; this can happen on any flight; it can happen on the last one as well as the first one. So, you just plan as best you can to take care of all these eventualities, and you get a well-trained crew and you go fly."31

Rhythm, in regards to the human psyche, refers to a synchronized lifestyle commonly embedded in the evolved being that undergoes cyclical patterns and schedules throughout the day. This circadian rhythm, regulated by the planet's rotations, is the approximate 24-hour rejuvenation cycle for the biochemical, physiological, and behavioural processes involved in a person's sleeping (unconscious) and waking (conscious) states of awareness. Dependent on the orbit or trajectory of the architecture that one resides in within outer space, this rhythm will be altered according to the number of sunrise and sunset occurrences within a 24-hour period. For example, the International Space Station in Low Earth Orbit (LEO) orbits the Earth approximately sixteen times in a 24-hour day cycle. In a situation like this, one will eventually lose track of time and enter into a free cycle, which will disorder many immune functions within the human body. These symptoms will include a dysfunctional sleep schedule, depriving the necessary sleep patterns<sup>32</sup> that help with one's metabolism, hormone productions, and other mental alerting systems. The reduced performance and receptive levels of astronauts, if not treated, will result in psychological disorders. Therefore, it is a challenge in architectural design under these conditions of irregular patterns to integrate visual cues of shading and lighting system treatments that will create an illusion of familiar patterns of the passage of time. "The human organism is built for tension and relaxation, work and sleep. The principle of life is rhythm."

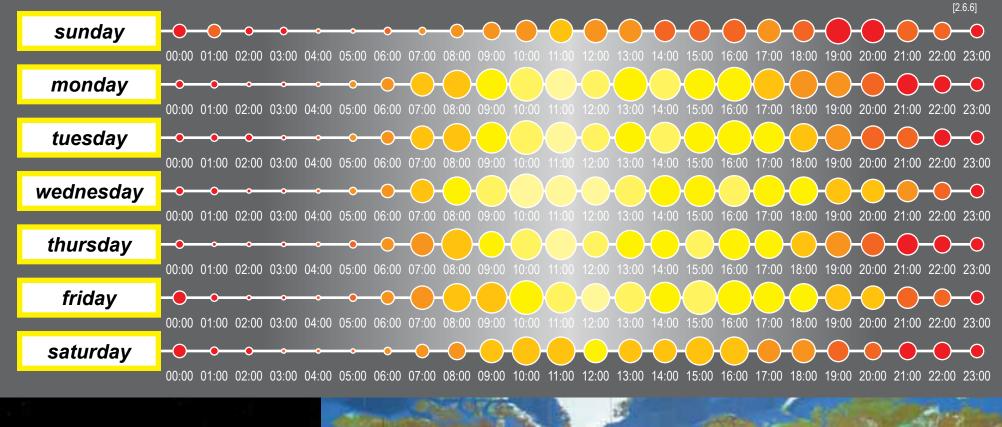
"At night, the airport emerged as a home of nomadic spirits, types who could not commit to any one country, who shied from tradition and were suspicious of settled community, and who were therefore nowhere more comfortable than in the intermediate zones of the modern world, landscapes gashed by kerosene storage tanks, business parks and airport hotels. Because the arrival of night typically pulls us back towards the hearth, there seemed something especially brave about travellers who were preparing to entrust themselves to the darkness, to be carried in a craft navigated by instruments alone and to surrender to sleep, finally, only over Azerbaijan or the Kalahari Desert."

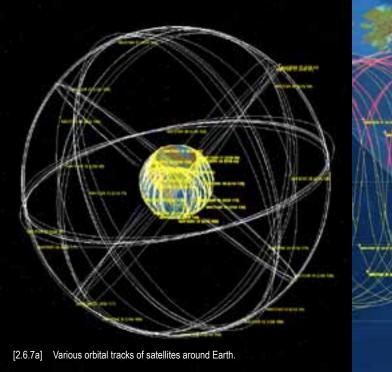
"A Week at the Airport" by Alain de Botton, page 83, 2009

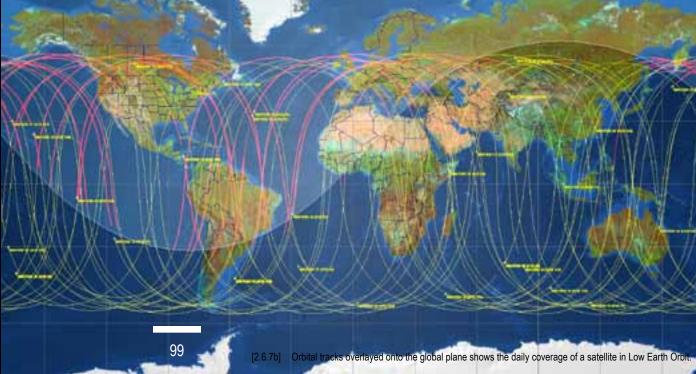
33 "Packing for Mars" by Mary Roach, page 75-76, 2010

right [2.6.6] Infographic of a weekly rhythm of one's sense of alertless throughout their daily 24 hour circadian cycles

[2.6.7] Various orbital tracks on LEO that circles the Earth multiple times in 24 hours, generating irregular rhythmic cycles for the foreign traveler









"I was spurred on by an uncertain longing to be transported from a boring daily life to a marvellous world...There is an almost quaint correlation between what is in front of our eyes and the thoughts we are able to have in our heads: large thoughts at times requiring large views, new thoughts new places..."When I consider...the small space I occupy and which I see swallowed up in the infinite immensity of spaces of which I know nothing and which know nothing of me ["linfinite immensite des espaces que j"ignore et qui m'ignorent"], I take fright and am amazed to see myself here rather than there: there is no reason for me to be here rather than there, now rather than then. Who put me here?"—Pascal, Penseé. 68"

"The Art of Travel" by Alain de Botton, page 57, 159 and 253, 2002

"On entering a new space, our sensitivity is directed towards a number of elements, which we gradually reduct in line with the function we find for the space...I forced myself to obey a peculiar kind of mental command: to look around me as though I had never been in this place before. And slowly, my travels began to fruit...the pleasure we derive from journeys is perhaps dependent more on the mindset with which we travel than on the destination we travel to...Receptivity might be said to be its chief characteristic. We approach new places with humility. We carry with us no rigid ideas about what is interesting. We irritate locals because we stand on traffic islands and in narrow streets and admire what they take to be strange small details."

"The Art of Travel" by Alain de Botton, page 246-251, 2002

"A few astronauts have described some of the behavioral challenges that they encountered in space: maintaining high performance in the face of extreme danger, loneliness, and minor conflicts with other crewmembers. On the debit side of the balance sheet, members of isolated and confined groups frequently report sleep disturbances, somatic complaints (aches, pains, and a constellation of flulike symptoms sometimes known as the "space crud"), heart palpitations, anxiety, mood swings including mild depression, inconsistent motivation, and performance decrements. Cremembers sometimes withdraw from one another, get into conflicts with each other, or get into disputes with Mission Control...Soyuz 21 (1976), Soyuz T-14 (1985), and Soyuz TM-2 (1987) were shortened because of mood, performance, and interpersonal issues."

> "Psychology of Space Exploration: Contemporary Research in Historical Perspective" by Douglas A. Vakoch, page 26, 2011

[2.6.8] Tom Hanks in "Cast Away", "The Terminal", and "Apollo 13", depicts various roles under different forms of confinement

Psycho-environmental stressors can cause dysfunction of one's psyche through sensory deprivation and dissatisfaction. Space environments, as they seem to be currently designed with the limitations of realistic budgets, payloads, and construction constraints, do not properly address the human psyche, inevitably causing psychological disorders and mental illnesses. Major symptoms include: 1. the sense of confinement; 2. sensory deprivations and overloads; 3. social tedium of crews. *Some of these symptoms are a result of poorly planned and designed interiors of modern-age space stations, as they provide astronauts with a small, confining, and bland environment to operate in with very minimal private space.*<sup>34</sup> Because of such dullness, astronauts lose the motivation to function at a high capacity.

Confinement, similar to imprisonment, is a feeling that one has in small, enclosed, and cramped spaces as they lack freedom of movement. Humans strive for a sense of freedom<sup>35</sup> and desire to choose environments that are suitable to their varying states of mind and emotions. For example, depending on one's emotional state, one may want to be in privacy for personal reflection, while in other situations; one may reach for public spaces to socially connect with the energies of others. For long durations in secluded isolation within confined spaces, dysfunctional psychological states will develop<sup>36</sup>, with experiences of cabin fever and other mood disorders of anxiety, depression, and withdrawal. Therefore, for a serious proposition as conducted in this thesis, these issues regarding program dynamics must be addressed accordingly in a generous reflection to the mission's funding.

Deprivation is a process of attenuation to the state of mind in which there is an absence of normal conditions that are essential for both the physiological and psychological wellbeing of an individual's nervous system. Aside from the deprivations of cyclic rhythms which in time evolve into sleep deprivation, other monotonous symptoms of boredom and amnesia may appear as sensory deprivations that can lead to serious instabilities in the human psyche. On Earth, chronic sleep loss has shown cognitive impairment after a 17-hour duration of wakefulness. Through actigraphy and self-reporting by current astronauts to flight surgeons, it has been determined that *most astronauts sleep only an average of 5.6 hours for each 24-hour cycle onboard in space, compared to the typical 7.9 hours on Earth.* This reduction in the quantity of sleep eventually affects the quality, and this can ultimately lead to reduced reaction times and erratic performances. Other symptoms that occur include short-term memory loss and the assumption of a multiple personality. The extreme form of sensory deprivation can be so incapacitating and destructive within the unconscious that this has been used as a torturing technique in federal and military interrogations for secret information under the process of solitary confinements. The extreme form of sensory deprivation can be so incapacitous for secret information under the process of solitary confinements.

Overloads are instances when excessive and repetitive conditions act upon the human senses over an extended period of time. Although it is logical to believe that these overloads are counteracting factors to sensory deprivation, these two sensory effects do not balance out. In addition, sensory and mission objective overloads add to the psychological stresses<sup>39</sup> that already affect the occupant in the extreme environment. The major source for this sensory overload is typically the constant rumbling noises and vibrations that travel throughout a space station in the vacuum environment, as the mechanical systems and onboard equipment generate high levels of residual sounds. This eventually causes fatigue in the occupants as they are constantly kept awake. The instinctual "what if" and claustrophobic effects can also be increased through constant contemplation of the potential failure of mechanical devices, thus stimulating psycho-reactive responses to such acoustical provocations.

- 37 "Human Health and Performance Risks of Space Exploration Missions" by NASA Human Research Program, page 85-116, 2012
- "Solitary confinement is the confinement of "a prisoner alone in a cell for all, or nearly all, of a day with minimal stimulation and minimal opportunity for social interaction." It has "long been known that severe restriction of environmental and social stimulation has a profound deleterious effect on mental functioning" (Grassian, 2006)...The effects of solitary confinement on the mental faculties of detainée José Padilla offers an excellent case study into sensory deprivation, psychology, and the law...as court filings indicate, Padilla was allegedly subjected to sleep deprivation, stress positions and extreme temperatures. Worse, he was held without human contact, without a clock or even natural light with no way to know how quickly or slowly time was passing...Psychologists have long reported that extreme sensory deprivation is one of the quickest ways to drive people mad and make them willing to confess to anything...Sleep deprivation, physiological stress, and repeated questioning only exacerbate the traumatic nature of the experience. Mr. Padilla believed he was going to die on a number of occasions during his detention...Dr. Hegarty is candid and in her professional judgment concludes that Padilla "was not the same man he was in 2002 and whatever happened to him during his solitary confinement has radically changed him" (Richey,

"Bad Bad Juju - Sensory Deprivation and Solitary Confinement" by Gary I. Wilson, March 2009

"Along with the considerable stress of confinement, sleep deprivation, language and cultural gaps, and lack of privacy, more subtle torments plagued the crew... You're sleep deprived, and you have to perform perfectly or else you don't fly anymore. As soon as you're done with something, ground control is telling you something else to do. The bathroom stinks, and you have noise all the time. You can't open a window. You can't go home, you can't be with your family, you can't relax. And you're not well paid. Can you get a worse job than that?... The researchers soon began to realize that sensory deprivation was a poor approximation of spaceflight. Space is black, but there's plenty of sunlight, and the capsules would be lighted. Radio contact would be possible much of the time. Claustrophobia and solitude were the more salient concerns, especially on a longer mission."

"Packing for Mars" by Mary Roach, page 48, 53 and 62, 2010

right [2.6.9] Table of various sound levels and the acceptable tolerances

[2.6.10] Loud undesirable noises are irritating physically and mentally

SOUND LEVELS (L) (loudness)					
Source of Sound	Sound Pressure Level (Lp) or (dB SPL)	Sound Pres- sure (p) N/m² = Pa sound field quantity	Sound Intensity (I) W/m² sound energy quantity		
jet aircraft @ 50m away	140	200	100		
THRESHOLD OF PAIN	130	63.2	10		
THRESHOLD OF DISCOMFORT	120	20	1		
chainsaw @ 1m distance	110	6.3	0.1		
disco @ 1m from speakers	100	2	0.01		
diesel truck @ 10m away	90	0.63	0.001		
curbside of busy intersection @ 5m	80	0.2	0.0001		
vacuum cleaner @ 1m	70	0.063	0.00001		
conversational speech @ 1m	60	0.02	0.000001		
average home	50	0.0063	0.0000001		
quiet library	40	0.002	0.00000001		
quiet bedroom at night	30	0.00063	0.00000001		
background noise in TV studio	20	0.0002	0.0000000001		
rustling of leaves in the distance	10	0.000063	0.00000000001		
THRESHOLD OF HEARING	0	0.00002	0.000000000001		

THRESHOL	D OF PAIN	PERMISSIBLE EXPOSURE TIME		
Sound Pressure Level	Sound Pressure	Sound Pressure Level	Sound Pressure	Permissible Exposure Time
140 dB SPL	200 Pa	115 dB	11.2 Pa	30 sec
137.5 dB SPL	150 Pa	112 dB	7.96 Pa	1 min
134 dB SPL	100 Pa	109 dB	5.64 Pa	2 min
130 dB SPL	63 Pa	106 dB	3.99 Pa	4 min
120 dB SPL	20 Pa	103 dB	2.83 Pa	7.5 min
		100 dB	2.00 Pa	15 min
		94 dB	1.42 Pa	30 min
		94 dB	1.00 Pa	1 hr
		91 dB	0.71 Pa	2 hr
		88 dB	0.50 Pa	4 hr





Social tedium, in its most basic definition, is interaction with a limited society in confined conditions. Being in such high social densities on a continuous basis can cause a heightened sense of awareness, which ultimately migrates into fatigue and other mental frustrations. This condition causes wear and tear on a person's psychological state, which eventually becomes a psychic dysfunction as one becomes withdrawn from interpersonal engagements. It is a crucial prerequisite for life as much as for the people engaging in extreme environments to have an open social mindset bonding one another<sup>40</sup> to create a positive atmosphere within the limited confines of the livable environments in outer space. Additionally, from an architectural perspective, spatial diversity can aid with this chaotic condition as people tend to need some variety of experiences or else they will become stressed and claustrophobic. Therefore, strategically programmed designs can offer a variety of activities in public interactive volumes while also providing private escape zones where one can decompress.

"Astronauts have to be people who play well with others. NASA's recommended astronaut attribute list includes an Ability to Relate to Others with Sensitivity, Regard, and Empathy. Adaptability, Flexibility, Fairness. Sense of Humor. An Ability to Form Stable and Quality Interpersonal Relationships...Suppressing one's feelings too tightly for too long takes a toll. You either explode or implode...'Boris, there are people who are your relatives due to blood connection. But there are also people who are your relatives due to things you do together. Now you are closer to me than your brother or sister. We landed. We are alive. The prize is life."

"Packing for Mars" by Mary Roach, page 32-33 and 76, 2010

[2.6.11] Healthy social interactions require one to have a sense of inclusion amongst their peers and not to be felt left out secluded of place in awkwardness





integration of unique systems

The apparent preconditions of an extreme extraterrestrial setting require designers to source and specify complex and innovative technologies to create environments and spaces that provide a basic similarity to prerequisites for life as found on Earth.¹ System failures in materials and design will be perilous to occupants, as it would be impossible for a human being to survive in outer space without the aid of these highly specialized systems. Therefore, it is critical that extraterrestrial designs include innovative sustainable life support systems and secondary backup procedures in the event of emergency situations and system failures. Additionally, design intentions have to simultaneously innovate, provide for supporting systems, and pay heed to potential physiological and psychological dysfunctions.

"Extreme environments can only be made habitable by implementing technologies that mitigate the hostile physical conditions. Historically, exploration has extended the range of environments in which habitation is possible and has led to technical innovation. The aerospace and defence industries are currently developing a range of technologies that attempt to instill biological capabilities into synthetic material systems by integrating sensing actuation and control strategies into the structure of the craft.

The objective of research into intelligent material systems and structures is commonly and explicitly biomimetic. This approach seeks to duplicate the functioning of biological materials and living systems in sythetic artefacts. There is a growing recognition that the standard engineering practice of optimising the use of materials or systems of stable characteristics does not allow for the interdynamics that often occur in complex systems. In addition, designing for 'worst case' contingencies in an effort to accommodate the unforeseen (an obvious contradiction) results in inefficiencies in material, use and economy and limits the capacities of the systems in question.

The technological systems that will be implemented in extreme environments will encompass a full range of intelligent media and material systems. According to NASA: Future Space missions will employ extensive automation as well as extensive on-line resources. Automation systems may include rovers, robots, tele-operators of control, piloting and fault management systems. Information systems may include image, video and audio databases, medical databases, video monitoring systems, piloting systems, and electronic documentation for troubleshooting, repair, maintenance and training. Ensuring flexible intuitive safe interfaces to information and automation for both flight and ground crew is a fundamental challenge of Space Human Factors."

"Architectural Design Vol 70 No 2 - Space Architecture" by Maggie Toy and Rachel Armstrong, page 50-51, March 2000

"There is No North Arrow in Outer Space" by Sara Hart, page 153, 2002 "While conceding that space architecture is a rarefied specialty within the profession, the work under way at this moment should prompt earthbound architects to think outside the ozone in several areas:

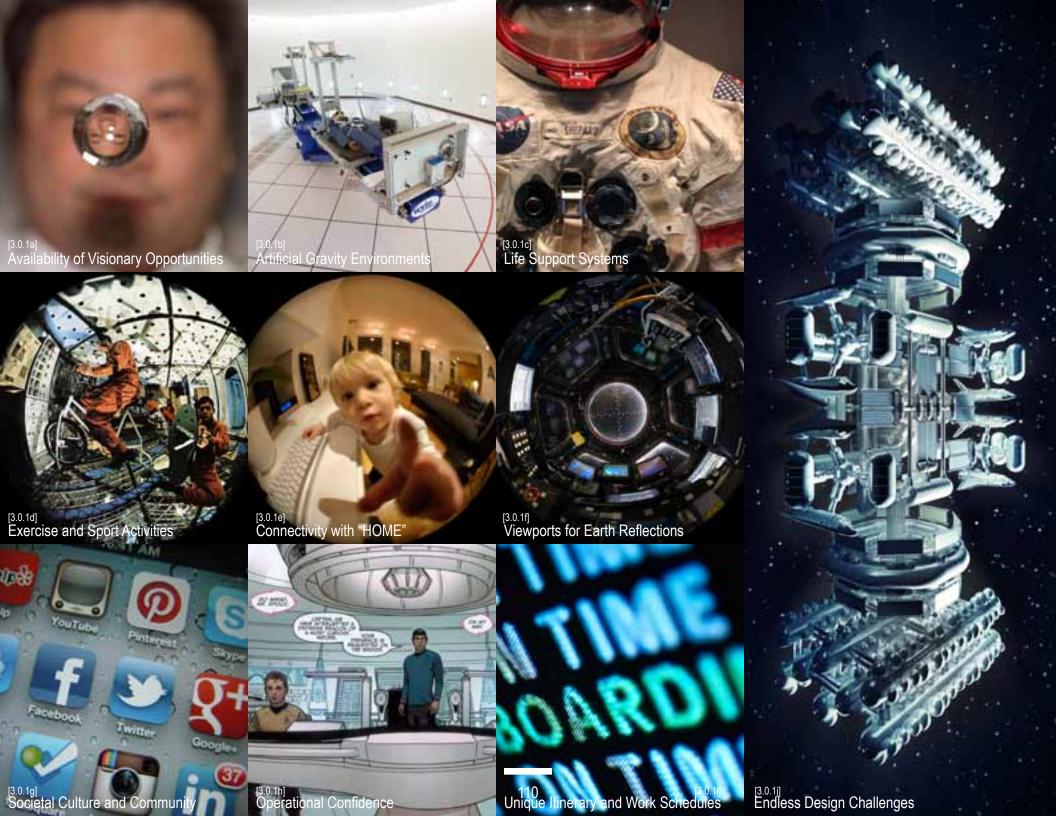
Sustainability - In space, obsolete structures will be disassembled and their components reused. On Earth, buildings are typically demolished and dispatched to landfills.

Cost - In space, the lighter and more portable the load, the more economical the launch and deployment. On Earth, lighter is more economical, but portability, whether in the form of manufactured components or prefabricated systems, remains a fledgling industry.

Life safety - In space, life safety literally means survival. Egress to the outside to escape fire or smoke is not an option. On Earth, life safety translates, in most building codes, to acceptable risk determined by a rating system for materials and assemblages.

Life cycle - In space, because even routine maintenance can be logistically problematic, lifecycle issues are a major part of the design process. On Earth, besides attention to surface finishes and access to equipment, postoccupancy mitigation, as required, is the norm."

"There is No North Arrow in Outer Space" by Sara



"On two occasions, I have had the privilege of being a crewmember on an HST servicing mission (SM-1 and SM-3A). The perfect combination of remote control from the ground (for normal scientific operations) and human interventions on orbit (for repair, servicing and/or improvements) ensured the extremely successful completion of the programme. Shuttle-based servicing missions have allowed the correction, in two instances, of the loss of essential telescope capabilities (optical resolution in 1993, attitude control in 1999). Automatic and robotic functions alone would never have achieved what has been done thus far with HST, and this is an important lesson for the future. Not that it always will be possible to afford the luxury of human spacecraftbased servicing, but, whenever it is feasible, this approach will provide us with a lot of options, flexibility, and the capability for correction or even recovery from critical failures.

> It is well known that views of the Earth and of the starry nights are very spectacular from a Low Earth Orbit. Although more a background than a subject of close attention during busy times on-orbit involving robotics and/or spacewalks, the Earthis surface and atmospheric phenomena receive a lot of attention and recordings on digital cameras during quiet times on the Shuttle and the ISS. Most impressive are the large-scale geological features like the Sahara desert, the Himalaya mountain range and the Andes. The rapid succession of day and night, the beautiful lighting at every transition, the amazing spread of thunderstorm areas in the equatorial regions, the auroras, zodiacal light and the Milky Way, are unforgettable and are a substantial addition to the dimension of each expedition to Low Earth Orbit."

> "Humans in Outer Space - Interdisciplinary Odysseys" by Luca Codignola and Kai-Uwe Schrogl, page 125-126, 2009

> [3.0.1] Factors to consider in standardizing basic prerequisites to an infinite dimension of challenges

With an understanding of the many impending symptomatic challenges for spacefaring occupants as previously mentioned, the planning and programming stages for the networked framework of infrastructural modules will be highly important for the physiological maintenance and sociological conditioning of their occupants. Via intricate program-specific spatial planning, unique social interactions and familiar forms can be designed as preventative measures against prospective physio-psycho health dysfunctions caused by prolonged exposure in an extraterrestrial environment. The creation of both public social spaces and private solitary spaces can encourage a healthier emotional status for the people on board.

Onboard operators and staff with extensively committed schedules will be the ones mostly affected by space habitation. Short-duration exposures in artificial outer space atmospheres, as experienced by future travelers, do not engender as much damage physiologically and psychologically as those rendered through longer periods of time. Therefore, creating balanced schedules and activity plans will be crucial for ensuring a healthy workplace environment for those personnel. Not only does the operational staff require detailed itineraries for their routine cycles, but passengers traveling on the infrastructure will also require a thoroughly outlined schedule so that their short visit will be full of unique activities and experiences while not endangering their health. In addition, it is imperative that there are ample opportunities for all astronautic occupants to communicate and visually refer to Earth and their loved ones in order to provide an intimate existence and a sense of inner life throughout one's journey in space.<sup>2</sup>



3.1

operations and maintenance

As discussed in the previous chapter, human sustenance relies upon several fundamental factors that are uniquely supplied on Earth and that constrain the general creative approaches in the design and operation of outer space applications. Systems for life support and architectural maintenance on Earth rely practically upon standard mechanical heating, ventilation, and air conditioning (HVAC) devices. However, these systems are technically insufficient in space. Therefore, the Environmental Control and Life Support Systems (ECLSS) aboard space station modules include the integration of many innovative mechanical devices, such as atmospheric control systems, water source and reclamation systems, agricultural supply and cultivation facilities, temperature synchronization controllers, sanitation and hygienic apparatuses, and failure detection and suppression devices and strategies.<sup>3</sup>

Atmospheric pressurization is a major item to be considered and implemented in the designs for a site located in a total vacuum environment. Without pressurization and an ample air supply, habitats designed in the extreme conditions of outer space will not be a livable environment for human beings. Therefore, life support systems for an air-locked vessel generally maintain Earth-like atmospheric compositions of the minimum prerequisites of oxygen, water vapour, and carbon dioxide to provide a breathable environment for the crew and visitors. With the partial pressures of these components, an appropriate and safe nominal interior barometric pressure of approximately 101.3kPa or 14.7psi should be artificially distributed\* throughout the vessel modules. The International Space Station already utilizes these sophisticated models of ECLSS and the proposal suggested by this thesis is assuming a technically similar system.

"During space missions, temperature variations can run to extremes, even in Earth orbit, with the spacecraft enduring sixteen sunrises and sunsets in a given 'day', and the consequent exposure to heat and cold, unchecked by atmospheric protection. In such situations, the hardware is pressed to maintain suitable living conditions.

If the air-conditioning on the Shuttle breaks down, the craft becomes extremely hot - like August in Houston. On Mir, however, if solar lock was lost it could become extremely cold. Keeping the temperature under control is important for crew health and comfort and their ability to work. When Apollo 13 suffered its systems failures as a result of an explosion, the crew soon had to contend with extreme cold and dirty air.

With all the equipment running, and exposure to direct sunlight, the internal volume will become warm, and so the crew will utilise some of the heat. Some of it could be recycled, and the rest emitted into space. Equally, the spacecraft has to be kept cool, and so a balance must be maintained.

Humans exhale carbon dioxide - which, although not poisonous, is suffocating, as it prevents oxygen inhalation. It therefore has to be removed (scrubbed) from the air in the spacecraft. Lithium hydroxide has so far been successfully used as a scrubber on every human space mission, but its disadvantage is that many canisters have to be carried. In Earth orbit, space stations can be resupplied by Progress ferry or the Shuttle...In some systems, carbon dioxide is removed with zeolites - tubs or containers coated with a particular type of chemical which does not use any consumables. These can be connected to a vacuum and heated to dump all the carbon dioxide overboard, and can be used indefinitely."

"Marswalk One - First Steps on a New Planet" by David J. Shayler, Andrew Salmon and Michael D. Shayler, page 200-205, 2005

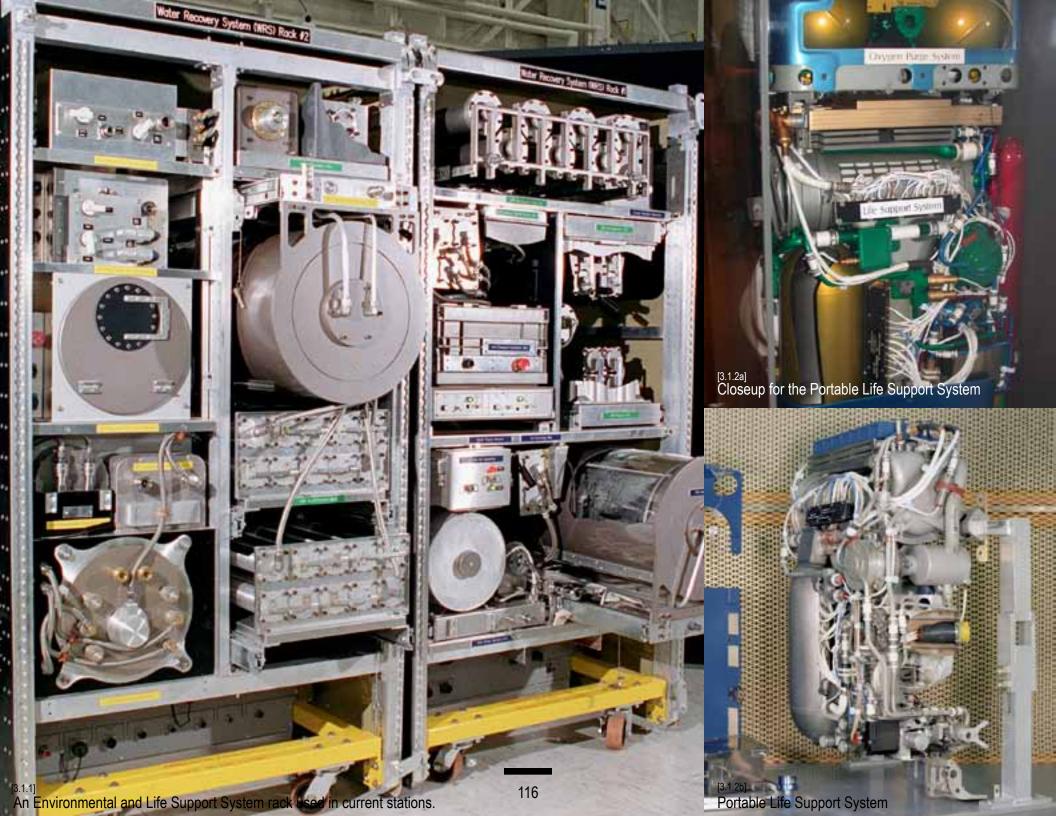
4 "The life-support system needs to be able to provide the following functions in any configuration in response to metabolic consumption and loss of cabin atmosphere to space:...Capability to maintain cabin total pressure at greater than 14.1psi. This maintenance of cabin pressure shall not cause nitrogen partial pressure to exceed 11.6 psia, or cabin total pressure to exceed 14.9psi (or equivalent in the metric system 97.2kPa and 102.7kPa respectively).

"Space Safety Regulations and Standards" by Joseph N. Pelton and Ram S. Jakhu, page 437, 2010

"Standard Handbook for Aeronautical and Astronautical Engineers" by Mark Davies, page 1544, 2003

"Any spacecraft that is intended to contain living matter, from the simplest experimental biological material to a human crew, requires a life support system. The complexity of the system will depend on what has to be supported and the duration and destination of the mission. There are broadly two kinds of life support system. Environmental control and life support systems (ECLSS) are open or partly closed loop and based generally on regenerative physico-chemical processes. Biological life support systems (BLSS) are similar but, as the name implies, based on biological processes. A special subcategory of BLSS is the closed or controlled ecological life support system (CELSS), which, again as the name implies, is closed loop. All currently operational life support systems are of the ECLSS kind, although some promising subsystems based on biological processes now exist which could ultimately be integrated into an otherwise physico-chemical ECLSS."

"Standard Handbook for Aeronautical and Astronautical Engineers" by Mark Davies



5 "The Oxygen Generation System produces oxygen for breathing air for the crew and laboratory animals, as well as for replacement of oxygen lost due to experiment use, airlock depressurization, module leakage, and carbon dioxide venting. The system consists mainly of the Oxygen Generation Assembly (OGA) and a Power Supply Module.

The heart of the Oxygen Generation Assembly is the cell stack, which electrolyzes, or breaks apart, water provided by the Water Recovery System, yielding oxygen and hydrogen as byproducts. The oxygen is delivered to the cabin atmosphere while the hydrogen is vented overboard. The Power Supply Module provides the power needed by the Oxygen Generation Assembly to electrolyze the water.

The Oxygen Generation System is designed to generate oxygen at a selectable rate and is capable of operating both continuously and cyclically. It provides from 5 to 20 pounds (2.3 to 9 kg) of oxygen per day during continuous operation and a normal rate of 12 pounds (5.4 kg) of oxygen per day during cyclic operation.

The Oxygen Generation System will accommodate the testing of an experimental Carbon Dioxide Reduction Assembly (CReA). Once deployed, the reduction assembly will cause hydrogen produced by the Oxygen Generation Assembly to react with carbon dioxide removed from the cabin atmosphere to produce water and methane. This water will be available for processing and reuse, thereby further reducing the amount of water to be resupplied to the Space Station from the ground."

"International Space Station - Environmental Control and Life Support System" by NASA Marshall Space Flight Center, page 3, May 2008

6 "Each molecule of water contains two hydrogen atoms and one oxygen atom. Running a current through water causes these atoms to separate and recombine as gaseous hydrogen H, and oxygen O<sub>2</sub>.

The oxygen that people breathe on Earth also comes from the splitting of water, but it's not a mechanical process. Plants, algae, cyanobacteria and phytoplankton all split water molecules as part of photosynthesis—the process that converts sunlight, carbon dioxide and water into sugars for food. The hydrogen is used for making sugars, and the oxygen is released into the atmosphere."

"Breathing Easy on the Space Station" by Patrick L. Barry, Science@NASA, November 2000

[3.1.1] ECLSS hardware rack of regenerative systems for water recovery and oxygen generation

[3.1.2] Portable life support subsystems used by astronauts in extra-vehicular activities and emergency depressurization situations

The ECLSS is a multi-faceted system that assimilates a variety of onboard systems necessary to provide for the essentials of life. A triple redundancy program for the generation of oxygen supply is one of the main features of this system; the Oxygen Generation System (OGS)<sup>5</sup> acts as the primary source of chemically reacted supply, while secondary backup oxygen generation utilizes Solid Fuel Oxygen Generators (SFOG) and canisters of stored oxygen. The OGS is an enhanced reproduction of the Russian Space Agency's model of the Elektron oxygen generator, which is designed to generate oxygen through the chemical splitting process of electrolysis in water molecules  $[2 \text{ H2O}(l) \rightarrow 2 \text{ H2}(g) + O2(g)]$ .<sup>6</sup> In such processing, the oxygen is released through a separate vent to either the onboard oxygen storage or throughout the station to maintain comfortable oxygen supply levels while the hydrogen is vented off separately to its own storage for future backup energy generation or the reproduction of water supply. With this method, an initial supply of water can infinitely supply oxygen and reproduce water through the Water Recovery devices. As there are bound to be malfunctions and failures, as in any strategy for artificial life support, secondary backups will be necessary. Secondary systems such as an oxygen purge system will act as a temporary life support while maintenance crews can work to restore the primary devices to full capacity.

Since the major source of air is highly reliant on the abundance of water supply, and since water is one of the core resources for the existence of life, the storage and treatment of water is crucial in the overall mechanical network of systems. As mentioned above, current oxygen generation is through a reaction that utilizes a *Water Recovery System (WRS)*. This system is required to perform multiple tasks, such as the collection of water vapour from the artificial atmosphere to be reused in the production of oxygen, the purification of waste water from sinks, toilets, showers, and other systems on board, and a vacuum distillation procedure to separate liquids and gases as exercised in the Oxygen Generation System. It is crucial that water reserves are kept uncontaminated and an adequate level is maintained considering the many functions it provides both for the crew members and the generation of energy onboard.

By generating an artificial atmosphere and a recycle and reuse system for water, two of the major components necessary for life can be mechanically accounted for. However, nutritional support for life in the extraterrestrial environment is still an ongoing obstacle. As of today, there has not been any effective deployment of operational agricultural and cultivation programs for outer space operations. There have, however, been many successful efforts and experiments that have proven the feasibility of agricultural production within the laboratories of the International Space Station. Therefore, it is reasonable to envision the prospects for future artificial biomes to be manipulated and executed into bio-laboratories and hydroponic cultivation facilities onboard space infrastructures. With this elaborately integrated ECLSS system of water, oxygen, and cultivated products, a closed-loop system will endlessly supply regenerative and recycled materials for the life support system necessary to ensure longevity for its occupants in space.<sup>8</sup> But until this is resolved, residents of the infrastructural modules of outer space will have to cope with the currently available space food of edible microwaveable products that are vacuum-packed for extraterrestrial use.

7 "The WRS provides clean water by reclaiming wastewater (including water from crewmember urine, hand wash, and oral hygiene waters); cabin humidity condensate; and extravehicular activity (EVA) wastes. The recovered water must meet stringent standards before it can be used to support crew, EVA, and payload activities.

The WRS is designed to recycle crewmember urine and wastewater for reuse as clean water. By doing so, the system reduces the net mass of water and consumables that would need to be launched from Earth to support six crewmembers by 2,760 kg (6,000 lbs) per year.

The WRS consists of a Urine Processor Assembly (UPA) and a Water Processor Assembly (WPA). A low-pressure vacuum distillation process is used to recover water from urine. The entire process occurs within a rotating distillation assembly that compensates for the absence of gravity and therefore aids in the separation of liquids and gases in space. Product water from the UPA is combined with other wastewaters and delivered to the WPA for treatment. The WPA removes free gas and solid materials (hair, lint, etc.) from the water before it goes through a series of multifiltration beds for further purification. Any remaining organic contaminants and microorganisms are removed by a high-temperature catalytic reactor assembly. The purity of product water is checked by electrical conductivity sensors (the conductivity of water is increased by the presence of typical contaminants). Unacceptable water is reprocessed, and clean water is sent to a storage tank, ready for use by the crew

"NASA Engineering Design Challenges -Environmental Control and Life Support Systems Water Filtration Challenge" by NASA Marshall Space Flight Center, page 2, September 2008

8 "The oxygen that humans and animals breathe on Earth is produced by plants and other photosynthetic organisms such as algae..."Eventually, it would be great if we could use plants to (produce oxygen) for us," said Monsi Roman, chief microbiologist for the ECLSS project at MSFC. "The byproduct of plants doing this for us is food."..."We're looking to close the loop completely, where everything will be (re) used," Roman said."

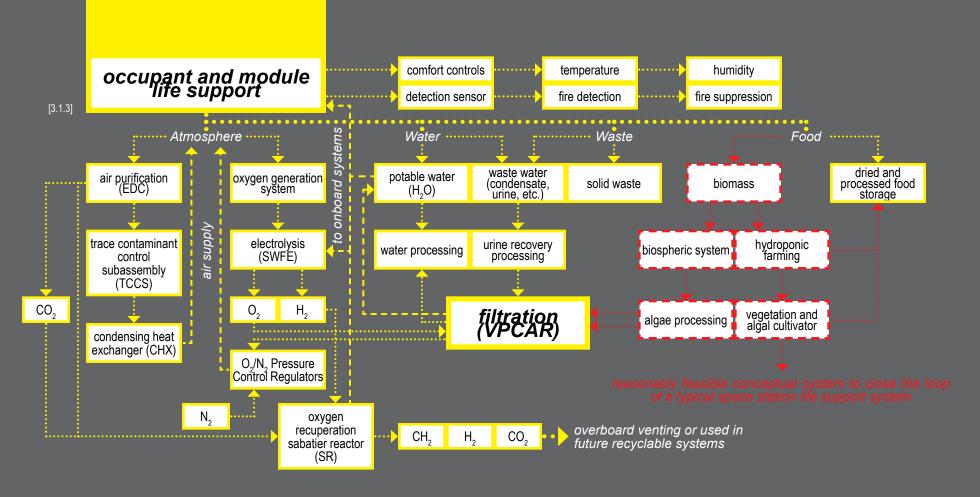
"Breathing Easy on the Space Station" by Patrick L. Barry, Science@NASA, November 2000

[3.1.3] Flowchart of the regenerative life support components in the ECLSS and its processes

[3.1.4] Hydroponic farming laboratory

[3.1.5] Hydroponic farming greenhouse

[3.1.6] Artificial biome utilizing hydroponic techniques depicted in the film, "Sunshine"







## 9 "§ 460.11 ECLSS:

- (a) An operator must provide atmospheric conditions adequate to sustain life and consciousness for all inhabited areas within a vehicle. The operator or flight crew must monitor and control the following atmospheric conditions in the inhabited areas or demonstrate through the license or permit process that an alternate means provides an equivalent level of safety—
- (1) Composition of the atmosphere, which includes oxygen and carbon dioxide, and any revitalization;
- (2) Pressure, temperature and humidity, (3) Contaminants that include particulates and any harmful or hazardous concentrations of gases, or vapors; and
- (4) Ventilation and circulation.
- (b) An operator must provide an adequate redundant or secondary oxygen supply for the flight crew.
- (c) An operator must:
- (1) Provide a redundant means of preventing cabin depressurization; or
- (2) Prevent incapacitation of any of the flight crew in the event of loss of cabin pressure.

Monitoring provides insight into atmospheric conditions so that adjustments can be made to maintain a nominal, safe atmospheric condition to sustain life and consciousness. The measured values may either be continuously refreshed or periodically updated, depending on the hazard that an unmonitored atmospheric condition would present to the vehicle occupants. Monitoring may be primarily the responsibility of the on-board crew, an on-board computer system, or of a ground-based remote operator who can alert the on-board crew of an unsafe condition. In some cases, control may be achieved using open-loop systems. These options may be used to assist designers or developers with their design solutions in an effort to comply with the requirements of 14 CFR § 460.11(a).

"Environmental Control and Life Support Systems for Flight Crew and Space Flight Participants in Suborbital Space Flight—Version 1" by Federal Aviation Administration, page 5-6, April 2010

left [3.1.7] Construction of the double hull external tank structure

[3.1.8] Complex control panels and maintenance protocols being practiced by astronaut crews on Earth

A thorough temperature synchronization system that manages the temperature and humidity of modules and spaces according to programmed activities will be particularly important to ensure extraordinary hygienic levels within the space station. Aside from the hygienic necessity of temperature variances, differing temperatures in spaces with a variety of programs can influence different emotional moods and conditions. Under Federal Aviation Administration (FAA) standards and aerospace operational regulations, it will be very important for operational personnel to have adequate knowledge of the thermal controls and synchronizations for temperatures throughout the programmed station areas. With this knowledge, and the availability of elaborate thermal controllers, crew operators and onboard engineers will be able to see any potential system malfunctions and provide for the immediate maintenance care necessary to resolve these problematic failures.

In any mechanized vehicle, malfunctions are inevitable, especially during the later portions of its operational life. However, system malfunctions onboard an infrastructural network away from the terrestrial bounds of Earth will pose many challenges and potential catastrophes. It is important that for every singular intervention of design, there is at the very least a secondary resolution or backup procedure that can be automatically activated in response to potential failures. Architecturally, the structural shell of a space station must be designed in a double hull construction such that, if failure occurs upon the external surfaces of the space station, a secondary layer will provide a supportive backing and prevention against depressurization until the breach is repaired. In order to be warned in advance of system malfunctions or any failures both inside and outside the station, many monitoring devices are required throughout the entire construction of the space station to track the condition of these systems and materials. From detection devices managing the larger issues, such as internal hull pressurization breaches of air-locked spaces, to the more personal level of detection devices for odour intensities for hygienic measures, the overall management of the system is required to prevent and react to failures.



3.2

sensory rehabilitation amenities and programs

Based on information gathered by observing previous accounts in spaceflight history, we have discovered a set of psychological dysfunctions and symptoms that must be considered within the more visionary, occupant-experiential design ideals of the space program proposed by this thesis. By analyzing these common effects and symptoms, we can begin to understand how the conditions in space cause our subconscious mind to transmit messages to our body in the form of health problems. According to this knowledge, we can *generate basic countermeasures in terms of architecture and aesthetics to prevent hazardous consequences that would result in harming the occupants' sense of belonging while inhabiting the structures of outer space.* Having defined these remedies, space architects can design in a more responsive way, with a synchronized mentality that every aspect of a space is essentially stimulating a part of one's psyche.

One of the major issues that require much attention in research in order to understand human adaptability to extreme extraterrestrial environments is weightlessness. As one's body physically undergoes a metamorphosis in this situation, the unconscious system is also signaling warnings to the conscious mind of a performance dysfunction due to certain differing circumstances than one has been accustomed to on Earth. Space is a bottomless abyss<sup>11</sup> with an infinite surrounding void of gravitational forces. One will be perceptively disoriented and never feel grounded in these circumstances. It is this sensation of being grounded on Earth that enables a connection with our ancestry as well as with a positive and healthy sense of belonging and purpose in life.<sup>12</sup> Therefore, it is imperative that the concept of gravity and perceptive orientation cues are reinforced in architectural solutions so that occupants can physically operate in a normal manner while improving mobility and senses. Additionally, in order to reduce instinctive judgements that activate the sense of disorientation, archetypal spatial arrangements defined by round tubular sections lacking ceilings and floors will be an effective architectural gesture. This unique design language without a ceiling or a floor and, in most cases, with angular walls (wall edges should be softened to a round profile to compliment the reduction of disorienting cues while acting as a safety precaution for people and objects that has the chance to bump into it), will assist the psyche of the occupants while allowing them to determine their frame of reference.

"The house is...a universal symbol. The house can symbolize the state of the whole psyche, while the rooms that appear in a dream are parts of yourself that make up the whole of the psyche...The house in your dream will symbolize the way you are living your life. In a dream, going home indicates that you are reconnecting with yourself...We are engaged in a busy exchange of keeping, acquiring, storing, displaying, and discarding. The word "belonging" says it best. There are things that we develop strong attachments to and there are things we are no longer tied to. We have a sense that things not only belong to us, they have acquired a capacity to connect us to a place. They are part of why we feel we belong. Objects help us to belong because they carry an aspect of our emotional lives; they lift the space out of the realm of utility and help us to cross over some subtle threshold that divides utility from warmth. The architect Le Corbusier's famous statement that a house is a machine for living in, while perhaps directed at technology and issues of production, became a powerful voice in the making of the modern idea of home."

"The Inner Studio" by Andrew Levitt, page 86-88, 2007

"When I saw that star and realised that space is a bottomless abyss, the first thought that occurred to me was that it would take thousands of years to get to that star - and that's not the end of our world. One can travel further and further and there is no limit to that journey. I was so shocked by this thought that I felt something crawling up my spine."

Quoted by Vitaly Mikhaylovich Zholobov, Flight Engineer of Soyuz 21 (49 day mission in Salyut 5), 1976

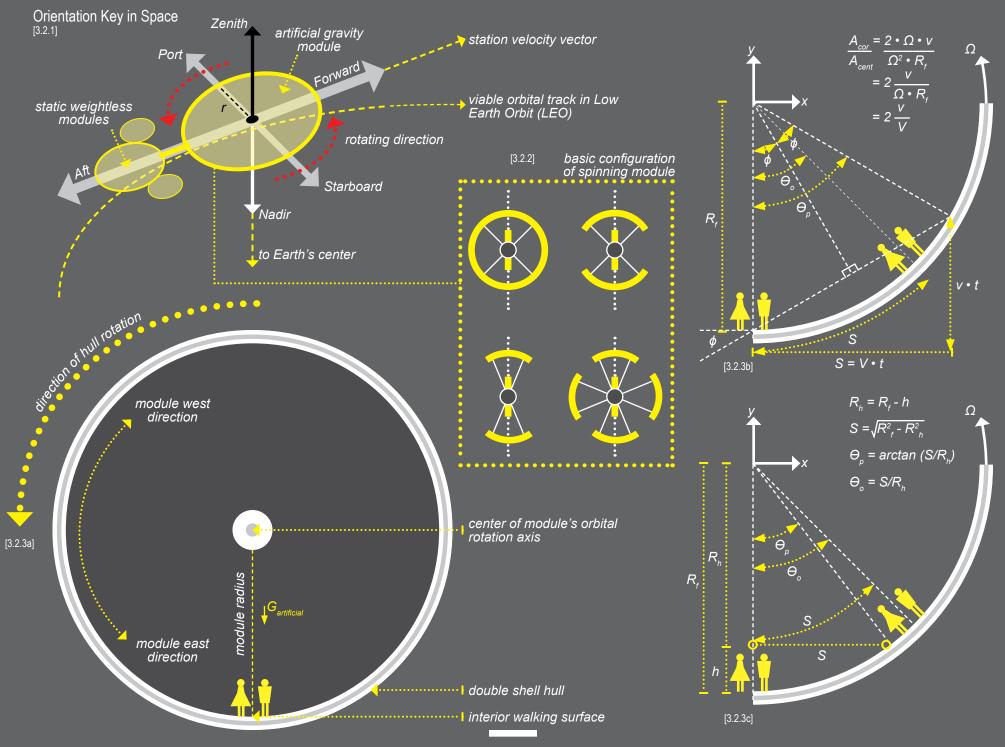
"There is a gravity, or what passes as gravity, in this physical world of poetry. You go from feeling like a body in a space to a body full of space...All the holes, all the emptiness, all the openings in the work are strangely familiar and this intimacy confers upon our own inner gravity a sense of acceptance. It resonates with something I feel inside myself, something not perfect, finished yet not complete, slowly developed, fragile, not everlasting. Inside us, the gravity of the physical world feels like a sorrow and hope...The Jungian analyst James Hollis says the test for soul is found in three things: luminosity, depth, and resonance. I want to add another quality that I found in this studio: the voices of ancestors. The voices of the ones who have come before were strong."

"The Inner Studio" by Andrew Levitt, page 68-69, 2007

ght "A Week at the Airport" by Alain de Botton, page 41-42 and 100-101, 2009

"Our capacity to derive pleasure from aesthetic or material goods seems critically dependent on our first satisfying a more important range of emotional and psychological needs, among them those for understanding, compassion and respect...At beginning of human history, as we struggled to light fires and to chisel fallen trees into rudimentary canoes, who could have predicted that long after we had managed to send men to the moon and aeroplanes to Australia, we would still have such a trouble knowing how to tolerate ourselves, forgive our loved ones and apologise for our tantrums?...We may spend the better part of our professional lives projecting strength and toughness. but we are all in the end creatures of appalling fragility and vulnerability. Out of the millions of people we live among, most of whom we habitually ignore and are ignored by in turn, there are always a few who hold hostage our capacity for happiness, whom we could recognise by their smell alone and whom we would rather die than be without."

"A Week at the Airport" by Alain de Botton



"In an artificial gravity environment, the direction of rotation should be visually obvious throughout the design, to establish connection between visual and vestibular cues to rotation so that crew can orient their movements advantageously with regard to Coriolis accelerations. Floors that are wide with respect to the rotational radius should not be flat; they should be cylindrical arcs so that centripetal acceleration remains perpendicular to the surface. thus avoiding unwanted apparent slopes. Circular plans without obvious orientation to the habitat's rotation should be avoided...Color and pattern can further distinguish east (prograde) from west (antigrade). This can help keep inhabitants visually oriented with respect to the rotation, so that they can anticipate the directions of Coriolis accelerations that will accompany various actions such as standing up and sitting down."

> "Out of this World – The New Field of Space Architecture" by A. Scott Howe and Brent Sherwood, page 152, 2009

"The question of where up or down is becomes relative; the only absolute is the situated human body and its capacity to constitute a coherent space...The primordial form of spatiality is a 'horizon of all our experiences, but it is a horizon which cannot be in principle ever reached and thematized in our express perception.'...There is no ultimate origin or ground of space, for the same reason that there is no ultimate ground of the world...the nature of space depends on the continuity of reference to deeper [spatial] structures in terms of topology (closely linked with the topology of being), about the continuity of references in terms of orientation, and about the explicit manifestation of spatiality in terms of physiognomy. The topology, orientation, and physiognomy of space constitute a unity: the visible aspects of space, its physiognomy, depend on orientation; and orientation in turn depends on the topological character of the surrounding world. Such manifestations can be made especially obvious in space of zero gravity..."I had no way of determining up from down, I had no visual reference in the dark. I had to turn on the light, but I just did not know what direction to put my hand in. So I had to feel things to orient myself..." The astronauts used similar language in stressing the importance of natural primary orientation: "You tend to orient yourself when you are in a room even though you are in zero gravity, and when you orient yourself you should find everything is the same. You don't like something up and something under. You like things to be orderly like they always are on Earth."

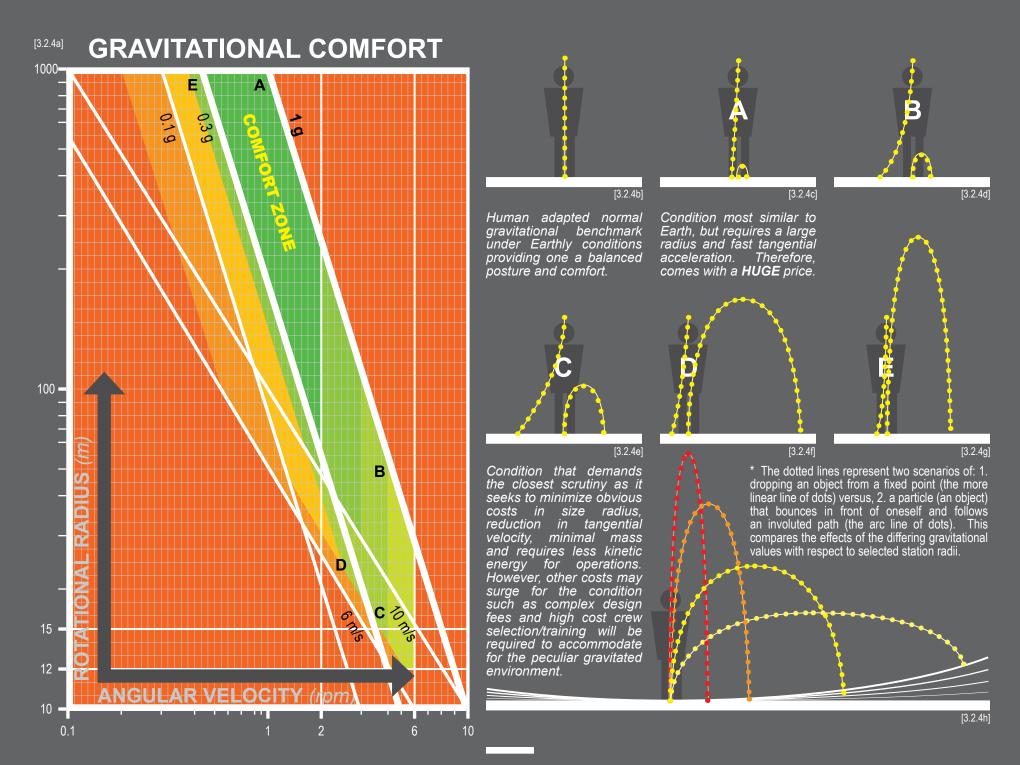
"Architecture in the Age of Divided Represntation" by Dalibor Vesely, page 48-55, 2004

[3.2.1] Standardized diagrammatic orientation key denoting the axial assignments in outer space

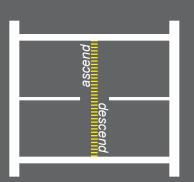
[3.2.2] Design parti arrangements of revolving modules to simulate artificial gravity

[3.2.3] Diagrams of the science behind artificial gravity

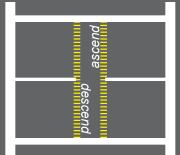
It is important to create the perception of an environment with artificial gravity<sup>13</sup> within the structural hulls of the modular space stations. The preferred method is to use centrifugal forces generated by the steady rotation of the inhabited structure about an axis in which the occupants are kept at constant acceleration. However, this source of gravity is a directionally dependent force according to the axis of rotation, and therefore, one may encounter a fluctuation in magnitude variances of the gravitational pull. As one moves against the rotational axis, one will experience a greater gravitational force as compared to what is experienced when they move away from the rotational axis. This variance in gravitational forces poses an additional problem because, as the occupants change direction (rotate around from a pivot and change their displacement headings), they will experience an awkward moment of motion sickness as they get either shot away with the lack of gravity or pulled in as if a heavy load were added upon them. This can be psychologically lethal for the unprepared body and mind as one's visual perceptions will conflict with their kinaesthetic sense causing the experience of Coriolis (motion) sickness. The architecture and aesthetics of the interiors can play a major role to reduce such dysfunctional occurrences.<sup>14</sup> Architecture can be designed in various forms, shapes, and sizes to provide helpful visual directional cues. Architecture can give an indication of the direction of motion relative to the rotational axis of the environment. The use of colours on surfaces and other informative signage to indicate the changes in direction will also be successful tools to unconsciously remind occupants of their directed motion and subconsciously eliminate any kinaesthetic-visual anomalies that may materialize. This will form a very advanced method of architectural wayfinding to move the occupants in directions and along paths that will cause the least physical discomfort.



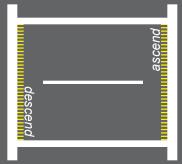
## LADDER ARRANGEMENT [3.2.5a]



tangential velocity



tangential velocity







To this date, public perception of space travel has been predominantly influenced by portrayals in science fiction films and television shows with a positive portrayal of the environments presented. The believable environments depicted in films such as 2001: A Space Odyssey (1968) and Moon (2009) have presented realistic ideas of what living in space would be like. Unfortunately, negative publicity through news coverage of actual space disasters, such as the Soyuz 11's decompression incident (1971), Space Shuttle Challenger's tragic launch (1986), and Space Shuttle Columbia's disintegration during re-entry (2003) does very little to instill the public with a sense of confidence in adventures to outer space. The Space Shuttle boosters of Atlantis consist of 2.5 million moving components, which hundreds of scientists and engineers control back at the mission command facilities on Earth. The tiniest malfunctioning detail on board poses the risk of major failure or disaster (e.g. a loose screw or valve somewhere which from one aspect of the failure will ultimately lead to another). It is inevitable that astronauts will tend to worry about the artificial atmospheric conditions in the vacuum of outer space and the life support systems that are provided for their supposed safety. This instinct to fear and lack trust in others' abilities to fully perform their responsible tasks with perfection has been an evolutionary shadow that can be traced back to the beginnings of humankind.<sup>15</sup>

It is important to look into these issues regarding the lack of trust in others, as the alien pressures in space can potentially form a psychological blockade between one's mind and the world. Whereas professional astronauts have been prepared for travel in space, the thesis proposal is targeted at the more adventurous traveler who will not necessarily have had the benefit of exhaustive preparative training. The only solution to this is for space architects to confidently plan out space stations with ample resources for both private and public exposures. In addition, precautionary services are to be provided for ease of access, as well as idiot-proof networks of communication panels that are system engineered to connect the occupants in outer space with both the ground crews on Earth and the people close to the astronaut (e.g., friends, relatives and loved ones, etc.). <sup>16</sup> These people in close relationships can monitor the occupants' conditions while offering spiritual support and providing the astronauts with a sense of community.

"This is usually the moment when we start to feel afraid of failing—"I'm doomed" "This project is doomed" "I shouldn't be an architect"...The despair isn't helpful because judgment is the opposite of creation. Everything gets worse because imagination cannot function when judgment is present and we lose the relaxation that is so necessary for creative work...The experience of "letting go" is often the quickest way of learning from obstacles and difficulties...Letting go connects us with the present moment and this kind of attention always brings creativity and wisdom. Giving up has the feel of resignation, of being unable to move forward, of being the victim of circumstances...Let go, set free, and do not judge is the mantra to recall when difficulty strikes. As Jung once said, "In the hour of reconciliation, great marvels appear.""

"The Inner Studio" by Andrew Levitt, page 151-152, 2007

"The newly emerging discipline of space psychology involves the application of psychological and behavioral principles to the support of crew health and well-being before, during, and after space flights...The experience of Russia and the US in long duration spaceflight has revealed the need for psychological countermeasures to support human crews in space and facilitate their resistance to the stressors of spaceflight. Accordingly, countermeasures are being developed, validated, and implemented, which aim to lessen the impact of these stressors on crews and subsequently increase mission safety and success while lowering risk. Psychological countermeasures involve astronaut selection, training, and in-flight support.

In-flight psychological support involves: 1) groundbased monitoring of the psychological, cognitive, and emotional state of crewmembers by flight psychologists and psychiatrists, 2) the provision of entertainment (e.g. videos, books, games, special items), leisure activities, and opportunities to communicate with the ground (i.e. with family and loved ones), and 3) care of the families of astronauts on the ground to help compensate for the effects of a missing spouse or parent created by the astronaut's absence. For example, long duration spaceflight crews during the Mir Phase I flights have been known to comment that the care packages sent to them on-orbit were extremely uplifting.

"McGill Journal of Medicine Vol.6 No. 1— Psychological and Human Factors in Long Duration Spaceflight" by M. Ephimia Morphew, page 77, 2001

ight [3.2.6] Astronaut memorial for those who lost their lives in fatal accidents of the most minute of errors

prev [3.2.4] Gravitational comfort levels in relation to artificial module's centrifugal radius

[3.2.5] Ladder concept to access artificial gravity spaces depicted in film, "2001: A Space Odyssey"

ext [3.2.7] Tragedy of Space Shuttle Columbia in 2003

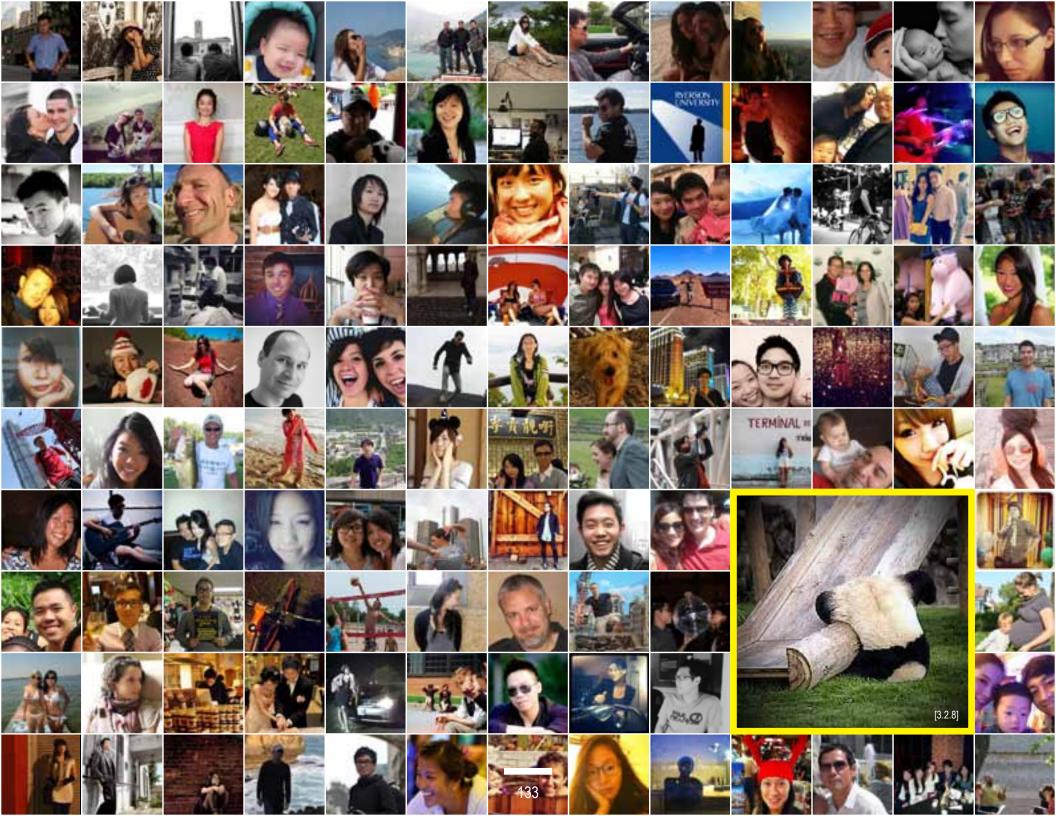












"People deprived of sleep for long periods appear less attractive and more unhealthy than those who are well rested, say researchers. Volunteers were photographed after eight hours sleep and again after being kept awake for 31 hours. Observers scored the sleep-deprived participants as less healthy and less attractive, the BMJ reports. The concept of beauty sleep is well known. But, according to researchers at the Karolinska Institute in Stockholm, it has lacked scientific support. The team asked untrained observers to rate the faces of 23 young men and women who had been photographed after a normal night's sleep and then after a night of sleep deprivation. The photographs were standardised so that people were the same distance from the camera, wore no make-up and used the same expression. The authors wrote in their paper published in the British Medical Journal: "Sleep deprived people are perceived as less attractive, less healthy and more tired compared with when they are well rested."" "Beauty sleep concept is not a myth, says study" by Helen Briggs, BBC News, December 14, 2010

17 "Sleep and circadian rhythmicity exert an influence over a spectrum of physiological functions such as body temperature, cardiovascular activity, immune responses, hormonal functions, behavioral functions, and cognitive functions such as fatigue, alertness, and memory. No astronaut, no matter how well prepared and regardless of the environmental protection provided, is immune from the daily control of physiology and performance by the homeostatic drive for sleep and the endogenous circadian timing system...While the cause of sleep disruption is still unknown, it has been suggested that such disturbances may be caused by exogenous factors such as space motion sickness, perception of light flashes when high-energy protons hit the retina, emotional stress, thermal discomfort, noise, muscle pain, or even an unsuitable sleeping bag. Anxiety may also be a factor as some astronauts have lost sleep due to worrying about how thin the walls of the spacecraft were. Another contributing factor is the absence of a natural 24-hour light/dark cycle in an orbiting spacecraft, which means that your circadian system will be unable to synchronize effectively. A combination of the afforementioned factors will cause you to experience differences in your sleep architecture in space compared with sleep on

"Tourists in Space - A Practical Guide" by Erik Seedhouse, page 117, 2008

18 "When you feel tired, rest. When you are tired, put the heavy load down. This sounds too simple, yet fatigue and lack of time have become very common obstacles during a creative project...I have often thought that Mediterranean cultures hold so many of the Western world's treasures because these cultures practice the afternoon nap or siesta. This enables these cultures to dream twice a day. increasing the chance for the wisdom of the psyche to come through...Dreaming is ancient. A recollected dream can deeply affect our sense of self and time. giving the present an unforeseen depth, relating us both to distant ancestors and to new possibilities. A recollected dream can bring us a sense of wonder or dread and reminds us that we belong to something beyond our normal experience of the world...The dream always tells us where our life energy wants to go. Its unscripted content is the key to its value and its recollection by our ego is an act of psychic wholeness that represents a victory for the psyche even before the dream is understood.

"The Inner Studio" by Andrew Levitt, page 61-62 and 72-73, 2007

Ieft [3.2.9] The sleeping state is a meditative enlightment of pure relaxation from the stressors received throughout one's daily lives

prev [3.2.8] Collage portraying the use of social media such as facebook, twitter, blogs, etc. to communicate and share personal experiences on board a space station Day and night cycles that regulate sleeping patterns are very important for human growth, both physically and psychologically. <sup>17</sup>On Earth, people can experience irregular patterns as they travel rapidly through long distances over several time zones along the transmeridian plane (east-west or west-east directions). This shift in one's cyclical pattern is typically referred to as "jet lag" or desynchronosis, where travelers experience fatigue, headaches, and a disruption to their functional maneuverability. In outer space, irregular cyclic patterns will be inevitably difficult to control, as the station's orientation towards the sun will not allow for the 24-hour circadian cycle that we are accustomed to on Earth. Depending on where the occupied infrastructure takes place in space and whether in a Geosynchronous Earth Orbit (GEO), a Polar Earth Orbit (PEO), a Low Earth Orbit (LEO) [refer to 4.2.4], or even en route to a distant star or planet like Mars, the number of sunrises and sunsets will vary and fall out of synchronization with our usual 24-hour body clock. This "free cycling" in space will stimulate sleep deprivation, causing symptoms of muscle and bone atrophy, fatigue, and restlessness. Aside from these symptoms, sleep deprivation will mean fewer opportunities for dreams. It is through dreaming that we are capable of mentally rejuvenating from daily stressors and understand through our innate signals our current states of mind. <sup>18</sup> Fewer opportunities to dream will result in a lack of unconscious communication from our minds to our bodies, which can potentially lead to false judgment in operations and other task performance failures.

There are several ways designers can team up with engineers to resolve such cyclic disorientation for extraterrestrial habitats. To condition an artificial 24-hour cycle will be the simplest solution for this situation, while a strategically deployed trajectory can also help simplify the adaptation process to slightly altered cyclic rhythms. For an artificial cycle, windows will need to be specifically placed and specially oriented along the outer face of the space station so that visually, the sun and other sleep-disrupting factors can be controlled. Also, windows must be equipped with mechanically programmed shutters so that a regulation of the day and night cycle can be automatically synchronized to the occupants' schedules. All in all, the passage of time will be automated and controlled when necessary by ground crew and commanding officers on board.

Inside the man-made structures in outer space, there are restricted volumes and areas that astronauts can occupy, causing physiological and psychological problems. Confined within such minimal spaces with a high-density population, living in *space is frustrating due to the unforgiving environment in which you are trapped. If* you're trapped long enough, frustration metastasizes to anger. There is only so much one can presently do within these spaces given the current state of design. Therefore, resultant boredom quickly takes its toll on the minds of astronauts. 20

Architecturally, outer space modules should be planned and designed to host more spatial variations of volumes and areas for occupants to move through. Allowing for this freedom in movement and choices in destinations, occupants will be able to focus their mental strengths on other tasks, creating experiential variety and thus alleviating boredom. A fair balance between public and private spaces will be recommended. As well, the implementation of auxiliary programs such as amenity and recreational spaces will give more options for occupants to keep busy. Viewports designed to overlook Earth have also proven helpful in previous space ventures as they have had an uplifting mental affect on the occupant/astronaut.<sup>21</sup> It has been recommended by NASA psychologists to have astronauts dictate and schedule personal photography sessions of different aspects of the Earth as a meditative yet therapeutic solution for confinement and boredom. This could also become a vital research-related activity for occupants of the type of space structure proposed by this thesis.

- "Packing for Mars" by Mary Roach, page 54, 2010
- 20 "It's important to listen to boredom. Becoming aware of feeling bored is the beginning of reconnecting to your creative instincts...Public places that graciously draw us out of our separateness offer us the setting we need to gather in peace and watch life unfold...Human settlement has always included public space. Places to gather, to celebrate military victory, exchange goods, share religious beliefs, or spontaneously meet friends are a part of our collective civic inheritance and have been evolving for centuries...Space is for being in. Space is for occupying. It's message from the humanist space age. The piazza is a great classroom—it teaches us how to hold our ground in the world...Great cities are designed for being in, not moving through...but rarely are you encouraged to move along a path. All points seem equal, as though it is more important to be present than to get somewhere...To be in the middle of things is to be centered in your own body and mind...one goal of any successful architectural project, beyond its capacity to support practical and safe functioning, is to satisfy needs that are less easily expressed, such as comfort and an emotional sense of belonging—perhaps even the capacity to inspire hope and creativity."

"The Inner Studio" by Andrew Levitt, page 17, 25, 54-55, 83, 103 and 153, 2007

"John Glenn, the first U.S. astronaut in orbit, talked NASA into letting him carry a camera on Friendship 7 on 20 February 1962. On reaching orbit, Glenn told capsule communicator Alan Shepard over the radio, "Oh, that view is tremendous."...A number of the astronauts who have followed have verbally recounted emotional experiences related to seeing and photographing Earth, and several astronauts have documented in written form their responses to views of Earth linked to their photography activities while in space. Space Shuttle astronaut Kathryn D. Sullivan wrote in an article documented with her Earth photography, "It's hard to explain how amazing and magical this experience is. First of all, there's the astounding beauty and diversity of the planet itself, scrolling across your view at what appears to be a smooth, stately pace...I'm happy to report that no amount of prior study or training can fully prepare anybody for the awe and wonder this inspires." Observations of familiar places on Earth can also have strong emotional connections. NASA-Mir astronaut Jerry Linenger recorded photographing his hometown in Michigan in his crew notebook, "Great View-Michigan + Great Lakes cloud-freeready to go home, now!""

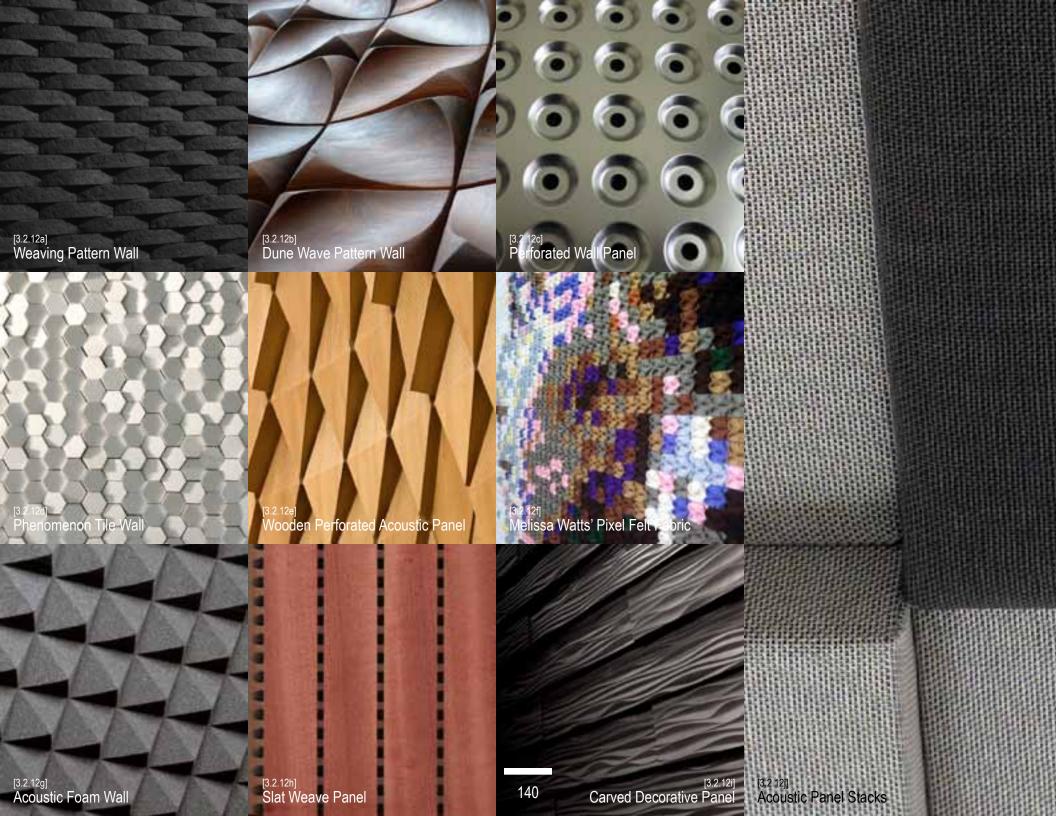
"Psychology of Space Exploration" by Douglas A. Vakoch, page 81, 2011

- right [3.2.10] The alluring vistas of Earth as observed out a porthole on a spacecraft
- [3.2.11] Photography sessions in space is a captivating past time in personal subconscious rehabilitations









"Self-regulation as a theoretical construct has the potential to integrate several phenomena related to place preferences. First, the cognitive and affective structures forming place identity (cf. Feldman, 1990; Proshansky, Fabian, & Kaminoff, 1983) can be seen as results of an active self-regulation process (Korpela, 1989, 1992)...the concepts of place identity on the cognitive level, place attachment on the emotional level, and behavioral processes such as territoriality, personalization, and privacy become integrated in the environmental self-regulation point of view...The observation that people use particular places for self and emotion regulation is common to research on place identity, place attachment, and restorative environments. Place identity is fundamentally formed by the experiences and cognitions in places that have a role in a person's emotion and self-regulation. Thus, place attachment is implicit in place identity (Korpela, 1989). Attachments are formed to places that fulfill people's emotional needs and enable them to develop and maintain their identities (Kaiser & Fuhrer, 1996). The developmental tasks of forming a self-identity and peer-group relations may be reflected in place preferences...These integrating or stabilizing principles are referred to in the description of the functions of place identity cognitions, which are to (1) recognize environments, (2) construct the meaning of the environment, (3) match the preferences of the person and the necessary requirements of the environment, (4) mediate change, and (5) serve as anxiety and defense mechanisms. The functions appear in the thoughts, behavior, and experience of the individual and meet the need for some level of integration of the individual's self-identity.

"Handbook of Environmental Psychology" by Robert B. Bechtel and Arza Churchman, page 368-370,

"Our heart's desire has the power to transform what begins in the mind into something that can help and inspire others...When a number of people visit the same place there are always multiple stories to tell... The mind/body imbalance is a hallmark of modern life and is visible around us...an environment that can provide a refuge for our nervous systems or a place where our minds are free to roam...The body has a great capacity to signal our preferences. The mind can be included through its ability to learn from the responses of the body, its ability to focus into the field of responses that arise in our bodies...our bodies are always in space and have memories of every kind of space."

"The Inner Studio" by Andrew Levitt, page 31, 56 and 58, 2007

[3.2.12] Samples of acoustic materials to reduce distractive cross program ambiences interuptions

left

In space, conditions are distorted such that most of our typical sensory feedbacks become divorced from what we were used to on Earth. In order to maintain a sense of belonging and reduce monotonous symptoms such as boredom and memory loss (of who we are as homo sapiens), aesthetic arrangements of private spaces and transitional vestibules outside personal quarters should be a personal design task of the occupants themselves.<sup>22</sup> Everyone who is assigned a dwelling compartment in outer space should have the freedom to personalize it with affectionate reminders from Earth (from aromatic scents to images projected throughout the interiors that reflect and stimulate one's memory and identity back home). Therefore, a selection of recyclable space bubbles containing sensory items such as scents and a database of imagery and video collections should be accessible for the occupants to select from so that they are free to transform their personal spaces. This self-learning process should be a mandatory exercise for all occupants onboard.<sup>23</sup>

On the other hand, sensory overloads can occur in these cramped space stations, as the mass turbines and other mechanical equipment on board that generate immense noise and vibrations disrupt the occupants from their cycles. It is recommended that passengers have recordable music devices of their likings on board that can play music they favour as this will soothe and calm the occupants. The architecture of the inner hull and interiors of the space stations should be sheathed with acoustical reduction surfaces such as fabric or foam that can help deflect and absorb ambient sounds. In addition, through the planning process in the conceptual phase of spacefaring designs, space architects will need to strategically organize program groupings to minimize adverse acoustical disruptions between individual programs in order to reduce and avoid convoluted auditory conditions.

As human beings, our capacity to exchange and interact with others is variable according to one's social personality. However, social interaction with others is inevitable. Under normal circumstances, when there is ample opportunity to escape and decompress if matters escalate to an altercation, social interaction is usually a peaceful feat. But in the confines of a space station, it would be difficult for one to escape these situations due to the minimal availabilities for decompressive spaces. In these situations, a buildup of irritation and anger emerges if the unwanted interaction is prolonged. Intelligent programming and arrangements of space station amenities will be crucial to help keep situations calm and friendly with the many different kinds of people on board.<sup>24</sup> Guaranteeing an abundance of public and amenity spaces in the proposed design will also allow for a more social and friendly atmosphere amongst the crowded densities of people while ensuring decompressive opportunities in personal pockets of private spaces, such as one's residence.

Also, in order to accommodate the varying social and privacy needs for the many passengers coming from various cultural backgrounds, a diversity of spaces can encourage friendliness amongst these occupants. As indicated in the official "outer space law," the outer space environment is real estate that is owned by all of mankind. No one race or culture shall take dominance over another as a sign of aggression in outer space. Because space belongs to all of mankind, it should be clearly understood upon entry into the cosmos that one belongs to a new cultural race of Spacemen.<sup>25</sup> With this model, new space cultures can take precedent from the various matured communities on Earth, such as "the global village" of Toronto, that already exercise this simple principle of diverse cultural acceptance.

"We can already see that the busy built world has title regard for nature, the body of the earth. We feel guilty when we put our own needs for health ahead of the task we have been given; we feel we should be able to complete the project without taking a break. We think we should be able to solve every problem. If we pause, we risk losing the respect of some colleague or peer or parent. These notions lead to stress and reflect the shadow that may influence the design process...Good design is like a good deed—it travels to the ends of the earth... Cities are great not only because of their economy and culture, but because they are where so many lives lived...Amenity, the idea that an artifact, space, or place can be capable of an act of good will, is a vastly underappreciated resource of design. Arcades, canopies, generous thresholds, porches, and urban-scaled stairways can all be designed to perform a service beyond their original use. The accumulation of these acts of kindness and generosity are like medicine to the urban soul.'

"The Inner Studio" by Andrew Levitt, page 62, 84 and 176, 2007  $\,$ 

"Outer space and celestial bodies can be used for the common heritage of mankind but are res extra commercium like the high seas. However, here the distinction ends, in that unlike the high seas, which can be appropriated in certain circumstances, such as through acquiescence by one State of appropriation of an area of the high seas by another, outer space or celestial bodies cannot be appropriated under any circumstances...A fortiori, outer space has been identified as one composite area which cannot be appropriated by one particular State to the exclusion of others by Treaty provision.

Freedom of outer space, which lays the foundation for conduct of persons in outer space, is enshrined in Article 1 of the Outer Space Treaty of 1967, which stipulates that the exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind. The provision also requires outer space to be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law. Finally, the provision grants free access to all States in relation to all areas of celestial bodies."

"Space Security Law" by Ruwantissa Abeyratne, page 45-46, 2011

right [3.2.13] Aerial photograph of the multiethnic city of Toronto

Excerpts from an artistic documentary of Toronto, "TOin24" by Dale Hildebrand





## 3.3

preparing for physical and psychological symptoms

Overloads from the many stressors upon the body and mind are highly likely while humans adapt to the new environmental situations presented by an extraterrestrial setting. Under a great deal of stress from sensory deprivations and the perception of isolation while in outer space, it is crucial to have many unique activities provided onboard the space station to actively exercise reactive sensory associations in order to ease the passage of time. It is also important to plan for a balance in public and private spaces in order to regulate the degree of social interaction while providing for personal meditative needs.

As a holistic approach of sensory neurorehabilitation, the self-regulating practice of meditation is considered to be one of the most successful ways to harmonize any emotional dispossessions through a self-induced exercise in balancing the body and mind. The National Institutes of Health and the National Center for Complementary and Alternative Medicine have proven that the practice of meditation has remarkable merit in physical relaxation while improving psychological balance that can enhance the wellbeing and health of oneself. Similarly, restricted environmental stimulation therapies (REST) can be conducted to relieve anxiety, hallucinations, and depressions caused by long-term sensory deprivations, which are common psycho-symptomatic outcomes for untrained occupants in outer space.

"Complementary therapies are often termed holistic. What we mean by holistic therapies and holistic health is that the totality of a person is often incorporates four areas of need and function: the physical (traditionally the body and movement), the intellectual (the brain and mind functions), the emotional (feelings and needs), and the spiritual (the eternal questions that help us organize meaning - What am I to do?) How these four areas function while interrelating in the world refers to the social aspect of need and function. This social aspect becomes the fifth area to consider.

In general, complementary and alternative therapies can be termed holistic and focus on using to advantage the inextricable link between mind and body. These therapies are administered in an effort to help a person regain health and stay healthy by facilitating the flow of that person's human energy or ch'i. Holistic theory posits that when human energy is balanced and flowing freely, it contributes to overall homeostasis, but when blocked, it interferes with health and renders the body and mind together vulnerable to pathogens and/or biochemical imbalance. The natural state of the human is to be in balance, to be healthy.

Conplementary and alternative therapies are nontraditional interventions that can be administered either as a substitute to (alternative to) traditional allopathic therapies or in conjunction with (complementary with) traditional therapies. They can be classified as systems, approaches, or techniques within approaches. health care systems include chiropractic, Ayurveda, traditional Chinese medicine, homeopathy, and naturopathy. Within systems are found approaches such as acupuncture, acupressure, and herbal therapies in traditional Chinese medicine. Even more basic is a technique within an approach, such as auricular acupuncture, found within the system of traditional Chinese medicine, and transcendental meditation and sesame oil massage, both found within the system of Ayurveda.

Mind-Body Interventions include: Psychotherapy, support groups, meditation, imagery, hypnosis, biofeedback, dance and music therapies, art therapy, prayer, mental healing, yoga, Ta'i chi, Qi gong, etc."

"Neurorehabilitation for the Physical Therapist Assistant" by Darcy Umphred and Connie Carlson, page 218, 2006

"Journal of Allied Health, Spring 2012, Vol 41, No1" by Kimberly A. Vogel, page 37-39, 2012

"The neuroplasticity literature suggests that active participation is better than passive. Attention to a task at hand will yield greater neuroplastic changes than passive participation. Resting attention is marked by cortical midline activity. When attention is directed to the present moment through mindfulness meditation (a form of attentional control training), there is a reduction in midline network activity. Meditation practice is suggested to result in cortical thickening of the right insula, somatosensory, and inferior parietal lobule cortices. This demonstrates cortical activation changes when a person is attentive versus inattentive...A primary goal of neurorehabilitation is to guide recovery of functional skills after injury through evidencebased interventions that operate to manipulate the sensorimotor environment of the client. Integrating conceptual elements of engagement such as attention, motivation, the use of enriched environments, and mental practice may further enhance neuroplasticity."

"Journal of Allied Health, Spring 2012, Vol 41, No



"Short-term sessions of sensory deprivation are described as relaxing and conducive to meditation; however, extended or forced sensory deprivation can result in extreme anxiety, hallucinations, bizarre thoughts, and depression. Therefore, therapeutic sessions of sensory deprivations provide the human psyche with positive meditative gains for one's neuro-functionings. There are two basic methods of restricted environmental stimulation therapy (REST): chamber REST and flotation REST.

In chamber REST, subjects lie on a bed in a completely dark and sound reducing (on average, 80 dB) room for up to 24 hours. Their movement is restricted by the experimental instructions, but not by any mechanical restraints. Food, drink and toilet facilities are provided in the room and are at the discretion of the tester. Subjects are allowed to leave the room before the 24 hours are complete, however fewer than 10% actually do.

In flotation REST, the room contains a tank or pool. The flotation medium consists of a skin-temperature solution of water and Epsom salts at a specific gravity that allows for the patient to float supine without worry of safety. In fact, to turn over while in the solution requires "major deliberate effort." Fewer than 5% of the subjects tested leave before the session duration ends, which is usually around an hour for flotation REST.

Flotation therapy has been academically studied in the USA and in Sweden with published results showing reduction of both pain and stress. The relaxed state also involves lowered blood pressure and maximal blood flow."

"Secondary Geographical Handbook" by David Balderstone, page 47-48, 2006

[3.3.1] Various flotation chamber REST therapies utilizing different apparatuses to achieve absolute meditative tranquility

To facilitate for REST programs in space, amenity modules must be provided with essential space for the meditative treatments. The two varying REST treatments available on Earth are Chamber REST and Flotation REST, which both rely upon varying spatial situations. In Chamber REST, patients are engaged in a prolonged meditative experience under simple spatial conditions with minimal distracting elements for sensory recuperations, whereas in Flotation REST, patients are submerged in a pool of liquid to simulate the effects of reduced gravitational resistance so that joints and muscles are soothed as the mind calms into a contemplative state.<sup>27</sup> Therefore, modules containing isolated meditation chambers and personalized graphical projection theatre pods could offer the basic meditative experience for private episodes in outer space. To mimic the REST treatments on Earth, special programmed modules could provide integrative spaces with the minimal setting as in a REST chamber or an i-sopod flotation chamber. These spaces have reduced acoustics while providing options to manually alter temperatures and gravitational pulls with artificial gravity to emulate flotation REST treatments.

Aside from the specific private programming of meditation modules, privately separated sectors for residences are crucial to the dwelling needs of long-duration occupants in outer space. Typically, these residences should be customized to the occupants' needs and desires such that optimal comfort can be attained in their solitary and quiescent moments during their stay. A distinct separation of the residential dwelling modules from all other amenities and programs will be advantageous to the overall quality of personal rehabilitation during resting and contemplating activities, as a reduction in distracting ambiences and visualizations from contiguous neighbours will provide a more reposed environment. This tends to be somewhat similar to the contemporary hotels on Earth that separate quiet residential rooms from the more publicly shared amenities that tend to be noisier. It will be much easier to separate functions on the basis of noise and traffic rather than to create physical noise barriers for disparate functions in close proximity.

When planning programs for amenities and entertainment, designers can use the unique conditions that outer space offers to enhance the exercises designed for the many physical and psychotherapeutic needs of the occupant. Facilities pertaining to exercise and rehabilitation will be very important for both the passenger occupants and operational staff in order to prevent physical health degenerations while residing in the extraterrestrial environment. Therefore, exercise modules should be made available throughout the space station's network with distinctive characteristics allowing for a unique training experience.

In the absence of gravity, muscular workouts will differ from those on Earth. Devices and apparatuses on Earth have been designed to be appropriate for muscle building based upon the resistance that gravity exerts on bodies in upright activities.<sup>28</sup> These are not suitable for space. [See illustration 3.2.4] Variations offered in outer space, such as anchored elastic resistance training, can provide similar results as weight lifting on Earth. In addition, within the floating environment of space, familiar cardiovascular training on Earth such as jogging and aerobics will be difficult. In order to comply with the cardiovascular health fitness needs, differential air pressure systems such as an AlterG Anti Gravity Treadmilf<sup>29</sup> or artificial gravitational modules will be required to provide the similar experience in the microgravity environment of outer space. On top of these specifications, the use of robotics in rehabilitation therapies such as Hocoma technology's Lokomat (a robotically guided treadmill) or other patented safety-harnessing mechanisms will be highly recommended for use on treadmills and other motion devices, as accidents in reduced gravity will be catastrophic if one were catapulted off of the fitness machinery. In order to prevent accidents and severe injuries, finishes within such active zones should be padded with cushioning materials and spatial designs must prohibit the use of sharp-edged forms.

28 "On Earth, gravity can cause a lot of stress to a person's bones and muscles, whether the stress is caused by running a marathon or simply climbing a staircase. However, in space, the lack of gravity can also cause problems for astronauts' bodies.

[Robert] Whalen developed the hypothesis that musculoskeletal maintenance in space requires Earth-equivalent functional loading (or weighting), which is loading bones and muscles with activities and force levels in space similar to daily activity on Earth. In space, most bone loss and muscle atrophy occur in the lower body. Whalen explains, "On Earth, our most significant musculoskeletal loading—particularly of the lower body—occurs during normal upright activities, such as standing, walking, and stepping off a curb." These various activities impart different levels of musculoskeletal loading, which keep our leg muscles able to support our weight.

Astronauts do not have these types of functional activities in space and must replace them with treadmill exercise using a loading harness to hold the astronaut in place on the treadmill. Whalen suggested using air pressure as an effective way of applying a high force, equal to body weight, to astronauts during treadmill exercise to replace the harness system."

"NASA Spinoff" by Publications and Graphics Department NASA Center for AeroSpace Information (CASI), page 40, 2009

"Originally conceived by Dr. Robert Whalen to design effective exercise regimens for NASA's astronauts, Differential Air Pressure (DAP) technology has been adapted by AlterG for use in training and rehabilitation. Cleared by the FDA in 2008, the AlterG Anti-Gravity Treadmill is a medical device that can be used for: 1) Rehabilitation of lower extremity injuries 2) Treatment of neurological conditions 3) Weight reduction 4) Aerobic conditioning 5) General training to combat the diseases of aging... The G-Trainer creates a powerful lifting force known as Air Pressure Differential that allows ultra-low impact training. Your body is surrounded by an airtight enclosure which becomes pressurized. You can adjust the amount of body weight on your legs and feet by controlling the amount of lifting force..."AlterG has allowed us to advance our rehab and conditioning of our players. We have been able to have players that are recovering from injuries start to run at least a week and sometimes up to a month before they would have been able to normally. The AlterG is a great progression back to the field with minimal risk." quoted Bill Tillson, Head Athletic Trainer of AC Milan"

"Alter G" - http://www.alterg.com

ight [3.3.2] Anti-Gravity treadmills used for rehabilitations

ct [3.3.3] Tethered harnesses and robotic guidance supports to aid physical rehabilitation exercises

[3.3.4] Patented elastic resistance band training as introduced by BowFlex gym products













Astronauts, by necessity, work hard in space, but during their precious time off aboard the International Space Station (ISS), some spaceflyers are picking their brains to come up with the future of space sports... The Space Olympics!

Astronaut Alan Shepard, one of the first seven NASA astronauts. played golf on the moon in 1971 during the Apollo 14 mission. His first swing was a bust, but he hit home on the second try with his ball going for "miles and miles," as he radioed Mission Control at the time. Thirty-five years later, Russian cosmonaut Mikhail Tyurin whacked a golf ball off the International Space Station as part of a publicity stunt for a Canadian golf club "We'll have manufacturer. opened a golf course in space," David Sindall, co-founder of the Toronto based Element 21..."It's the smallest clubhouse definitely, but with the largest real estate, infinite real estate, and the longest fairway."

In addition, space station astronauts have come up with their own zero-gravity sports. One involves tossing hefty bags of water around like medicine balls, then jumping on them while they move to see how far they could ride in weightlessness.

"Like other sports, water sports also will be possible in weightlessness, and they seem likely to be popular because of the entertaining novelty that will be introduced by the new environment of "zero-G". Most people know that blobs of water float in the air inside orbiting spacecraft (many astronauts have demonstrated this phenomenon) and it is interesting to imagine how to swim in a large spherical mass of water in orbit. Hazama Corporation began to consider zero-G swimming in 1992. Despite the lack of buoyancy in water in weightlessness, body movements are effective in moving through water by creating a reaction against the water, and so it will be possible to move in any direction, and to hold swimming races in a large body of water."

"Proceedings of Space 98—Artificial Gravity Swimming Pool" by Patrick Collins, Sunao Kuwahara, Tsuyoshi Nishimura, and Takashi Fukuoka, page 744-751, 1998

"One reason for expecting space tourism to become popular, and to grow rapidly once it has started is because of the wide range of unique and entertaining activities that are possible in "zero gravity or "zero-G", as the micro-gravity environment in side orbiting spacecraft is popularly known. This is a very attractive world which many people are keen to experience at least once in their lives. Both relaxing activities such as viewing the Earth, space and heavenly bodies, and energetic activities involving moving around in zero-G, have been greatly enjoyed by those who have visited space.

One field of such activities that seems likely to become popular is that of "zero-G sports", perhaps played initially by athletes selected through competition. Such sports would seem to have good potential to earn profits from commercial broadcasting world-wide, as championship professional boxing, F-1 Grand Prix and other sports do today.

Trying to imagine 3-dimensional American football or 3-dimensional soccer is an interesting test for the imagination...One team sport that is likely to become popular is a zero-gravity variant of rugby and/or football. One interesting aspect of such games is the range of new tactics possible in zero-G. The fundamental basis of movement in this new world is different from that on Earth; it might be called an "action & reaction world", or a "kinetic energy world". That is, moving does not require continuing effort, as on a sports-field on Earth, but depends on pushing-off from a wall or another person."

"Proceedings of Space 94—Zero-Gravity Sports Centers" by Patrick Collins, Tsuyoshi Nishimura, and Takashi Fukuoka, page 504-513, 1994

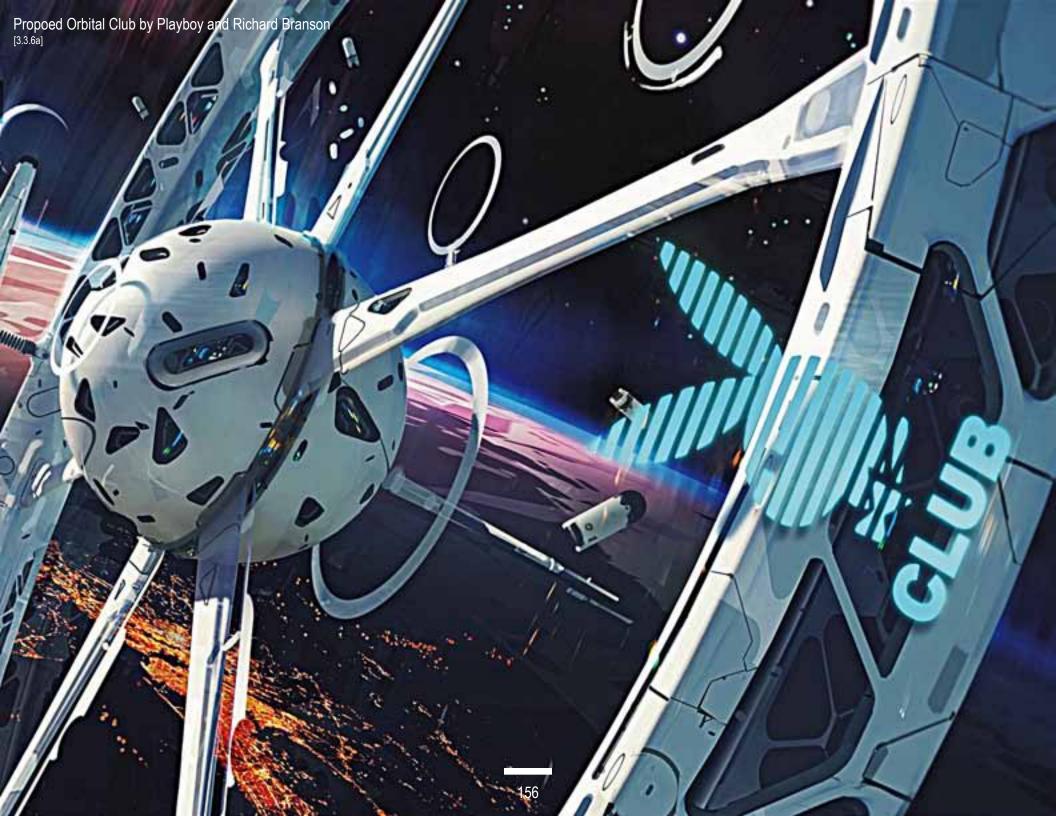
left [3.3.5] Athletics and adventurous activities that exploit the unique conditions of outer space

next

[3.3.6] Various amenity concepts for hospitable opportunities in outer space developed by visionary investors of Playboy, Virgin Galactic, and Orbital Technologies

Other unique outer space sports facilities can be additionally considered as an expansion to a primarily settled transit station. These facilities can service *individualized pools for outer space swimming*, <sup>30</sup> a unique public or private experience that uses the special materialized formation of water in space, a free-floating blob (a phenomenon of fluid physics in microgravity in which water molecules are attracted through surface tension into spherical blobs due to the lack of gravitation in space). Many other alterations of sports can be made available which handle the unique condition of microgravity in space environments, such as handball and ultimate Frisbee. Revolutionary sports facilities can be dedicated to futuristic playgrounds and other sports activities designed specifically to suit the conditions of the extraterrestrial environment. With such facilities available in the future and many innovative sports being advertised under these extraterrestrial conditions, major business opportunities will arise with endorsements commercialized to promote the new age of professional outer space sports and leagues.<sup>31</sup>

Finally, it is a fascinating curiosity to most people who express interest in space travel to experience firsthand a privately guided spacewalk under safe and secured conditions. Facilities and equipment pertaining to spacewalk activities can be designed and programmed alongside other amenity modules to allow for a diverse selection of excursions for spacefaring passengers. To ensure the safety of all spacewalking passengers in these facilities, innovative technological support and training will be necessary to securely service such alluring experiences.



Welcome to the Heaven in your exclusive ticket to a party that's out of this world. Imagine the wildest party on Earth. Now imagine that party just blasted off of it.

At the beginning of the first space race, in the early 1960s, Hugh Hefner started opening Playboy Clubs and publishing the magazine's iconic "pad" features. So at the dawn of the new space race, as corporations rather than governments vie to be the first to launch pleasureseeking civilians into the heavens, we [Hugh Hefner's Playboy and Richard Branson's Virgin Galactic] created the first renderings of a new celestial mecca. With the help of futurists and rocket scientists, including Virgin Galactic's head designer, Adam Wells, a Playboy Club is imagined in space. The Playboy club in space will be on a station in orbit, like a cruiseship. Orbiting Earth is one idea, but it could also travel around other celestial bodies. "You could literally swing around the dark side of the moon," says Virgin Galactic's Wells. The ship will consist of a stationary and thus zerogravity superstructure, along with an outer ring that spins centrifugally, creating artificial gravity. Humans will get to the club by rocket, but cargo will likely arrive by machine gun. Naturally, windows will abound to provide views of the heavens.





life support and systems management

As previously mentioned, the rhythmic differences within orbital conditions of outer space can disrupt the daily patterns that one is accustomed to back on Earth. These sporadic cyclic challenges to one's living patterns stimulate the biological altering of one's physiological and psychological states. By closely monitoring the daily operations of occupants through the development of a balanced program of activities, chances of dysfunctional buildup will be minimized.

For short-term passengers and commuters utilizing the transit facility of the space infrastructure, stress- and pressure-relieving services should be made available to ensure for a pleasing experience. Due to the briefness of the visit, the long-term rhythmic challenges will seldom affect these passengers as their exposure to abnormal timings of daily cycles can be neglected for the few hours of transit in space. However, ample opportunities to look back towards the Earth should be provided in all transit corridors and modules used as waiting areas to provide a sense of appreciative belonging to the place that humans call home.<sup>32</sup> Instead of a retail-oriented concourse area, educational opportunities should be provided with descriptions and artifacts presented along the way through the transferring corridors. Space restaurants and lounges should also be made available to provide for a gratifying time during the brief waiting periods upon departure. This is particularly important as eating and drinking under extraterrestrial conditions will pose unique challenges, even as it stimulates a sense of amusement for occupants learning this new ritual.

32 "All of the astronauts and cosmonauts speak about being able to look out a window at the Earth and stars. Taking pictures through a window is one of the most enjoyable tasks. Thus, a visual connection to the outer world is a necessity for a habitable environment."

"Handbook of Environmental Psychology" by Robert B. Bechtel and Arza Churchman, page 684, 2002

"Windows to the World, Doors to Space: The Psychology of Space Architecture" by Andreas Vogler and Jesper Jorgensen, page 391-394, 2006

"The many layers of space involved in planning space habitats include four main ones: (1) physiological space: the spatial environment we need to survive physically; (2) perceptible space: how our senses interact with space; (3) psychological space: how we project and reflect our inner selves to the outside space; and (4) sociological space: how we define zones of privacy and community. All layers overlap and find their expression in the eventual built environment and the way it is to be inhabited...In our everyday life we experience not solid and immediate facts but stereotypes of meaning. We are aware of much more than what we have ourselves experienced, and our experience itself is always indirect and always guided. The first rule for understanding the human condition is that men live in secondhand worlds. The consciousness of men does not determine their existence; nor does their existence determine their consciousness. Between the human consciousness and material existence stand communications and designs, patterns and values which influence decisively such consciousness as they have."

"Windows to the World, Doors to Space: The Psychology of Space Architecture" by Andreas Vogier and Jesper Jorgensen



"Crews who are on orbit and the ground teams who support them face not only the likelihood of recurrent sleep loss but also the risk of circadian desynchronization. Circadian rhythms regulate subjective alertness, cognitive functions, and sleep propensity as well as core body temperature, hormone secretion (including melatonin), and the nocturnal secretion of growth hormone. A misalignment of circadian rhythms results in disturbed sleep and impaired performance and alertness... Crews who are on orbit and the ground teams who support them face not only the likelihood of recurrent sleep loss but also the risk of circadian desynchronization. Circadian rhythms regulate subjective alertness, cognitive functions, and sleep propensity as well as core body temperature, hormone secretion (including melatonin), and the nocturnal secretion of growth hormone. A misalignment of circadian rhythms results in disturbed sleep and impaired performance and alertness...Work overload also poses a risk to the behavioral health of space flight crews. NASA management currently sets limits, which are known as "Fitness for Duty Standards," for the planned number of hours in which astronauts are to complete tasks and events. The planned nominal number of work hours for space crews is 6.5 hours per day; it is recommended that crew members not exceed a 48hour total work week. NASA researchers have found that maintaining nominal work hours and workload is especially important during critical operations. The NASA definition of a critical overload workload for a space flight crew is 10-hour work days that are undertaken for more than 3 days per week, or more than 60 hours per week. Not only is the duration of the workday important, but so, too, is the intensity of the workloads for space flight crews. Astronauts who have taken part in high-tempo missions, from the historic Apollo to the current space shuttle missions, have accomplished complex tasks in the most dangerous surroundings while enduring hours of intense concentration. Anecdotal reports from veteran astronauts indicate that at times of high intensity, workload can result in mental and physical fatigue. Field studies from the medical and aviation industries show that increased and intense workloads, particularly in conjunction with disturbed sleep and fatigue, can lead to significant health issues and performance errors, which, in turn, can cause increased incidents of injuries, accidents, or

"Human Health and Performance Risks of Space Exploration Missions" by NASA Human Research Program, page 88, 2012

[3.4.1] The endless variety of personal leisure activities conducted in outer space

Although the majority of the spacefaring facilities are geared towards short-term transiting commuters, it is primarily up to the long-term operating staff to maintain order and safety during the operational life of the space infrastructural transit hub. Therefore, spatial designs and amenities should be planned for these longer-term onboard personnel to ensure their physiological and psychological wellbeing. In addition, the scheduling of staff operations should deliberately allow for a rhythmically balanced daily cycle of routines and personal time to ensure that time is properly spent on maintaining their physical and mental health. Therefore, similar to the typical working schedules on Earth, personnel should be required to operate under four- to eight-hour shift cycles so that within a simulated twenty-four-hour daily cycle, one can reasonably engage in about six to eight hours of private personal exploration time and eight to ten hours of sufficient resting periods. Currently, NASA has implemented nominal limits (about six and a half hours per day and forty-eight-hour maximum work weeks) to the amount of time an astronaut is allowed to work within its "Fitness for Duty Standards." 33

Within the scheduled shift hours of operations, personnel are to be given a variety of tasks and responsibilities such that they are able to employ various mental and physical functions throughout their term in space. For example, an employee can be responsible for customer relations in assisting commuters with their transit during the initial portion of their shift, and attend to module maintenance procedures during the latter portions of their scheduled period on duty. On any given day, errands accomplished on the previous day should not be repeated. Therefore, during this new day, this employee will be given tasks to manage within a new post elsewhere within the infrastructural network, such as supervision of specific amenities or inventory inspection and maintenance. By arranging a mixture of contractual obligations for each employee, a diversified experience can reduce stressors caused by boredom, anxiety, and depression. This also trains personnel with expertise in a number of areas such that in the event of an emergency or sickness, it will be easy for people to assist and fill in where needed.





design intervention: AERO | ASTRO

Given increased globalization and pace of future businesses, it will likely be necessary to increase travel efficiencies and reduce travel times. The time required for tasks and communications has become a critical factor in achieving maximum economic superiority in global industries. Such efficiency reduces the time spent on tedious tasks, leaving more time to spend on pleasure and entertainment activities. An example of this fast-paced lifestyle can be observed in the financial districts of *Hong Kong¹*, where economic growth is consistently skyrocketing parallel to the annual increase in operational efficiency in businesses through the use of innovative technologies and business solutions.

Over the recent decades, many frontiers in human transit and exploration developments have been broken. We are currently at an age where high-speed land and air vehicles provide ample opportunities for people to conveniently travel and see the world while businesses are shaped and structured globally, ultimately boosting worldwide economies. However, as the lifestyle tempo continues to increase for future generations of human beings, these current modes of transit support will be insufficient to cope with the gradually shifting pace in society. Additionally, with the long hours of daily work, it is only logical that these fast-paced citizens will seek solitary opportunities for personalized moments of decompression when possible, rather than spending countless hours within the confines of an encapsulated vehicle.

1 "Hong Kong is a bustling, modern and cosmopolitan city. On July 1, 1997 Hong Kong became a Special Administrative Region (SAR) of China after 150 years of British colonial rule...Famous for being fast-paced and efficient, time is money in Hong Kong. Punctuality is therefore considered a must in business. It is therefore very important for one to allow for sufficient travel time. Hong Kong has a very efficient public transportation system. While taking a taxi might sometimes be really handy - both in terms of speed and accuracy, traffic congestion at the peak hours (8 am to 10 am and 5 pm to 7 pm) in the central districts and other areas could make it a poor choice. Taking the Mass Transit Railway (MTR) which covers most main areas in both Hong Kong Island and Kowloon could confer certain advantages. Maps and information of the MTR system are readily available in tourist information centres. Other public transportation systems include very efficient bus services as well as tram services (on Hong Kong Island only).

> "Hong Kong: Culture" by globalEDGE of Michigan State University, http://globaledge.msu.edu/, 1994-2012

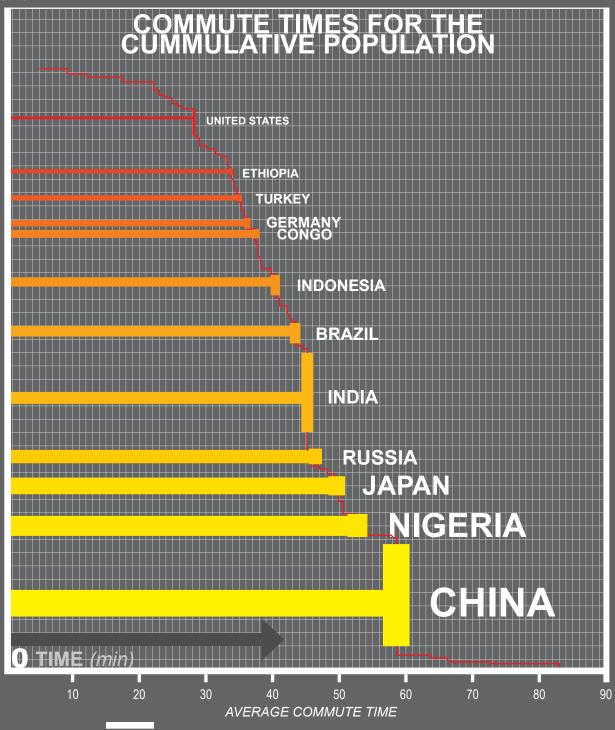
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[4.0.1] Clustered city traffic due to inadequate infrastructure support

[4.0.2] Graph illustrating average worldwide commute time data







CHICAGO

**ATLANTA** 

# O THE WORL D'S VERY CONTINENT

### 703km 1,180km 3,503km 6,017km 6,052km 6,153km @ $5 \text{km/hr} \approx 1,204 \text{ hrs}$ @ 5km/hr ≈ 141 hrs @ 5km/hr ≈ 236 hrs @ 5km/hr ≈ 701 hrs @ $5 \text{km/hr} \approx 1,211 \text{ hrs}$ @ $5 \text{km/hr} \approx 1,230 \text{ hrs}$ @100km/hr $\approx 7$ hrs @100km/hr ≈ 12 hrs @100km/hr $\approx$ 35 hrs @100km/hr $\approx$ 60 hrs @100km/hr ≈ 61 hrs @100km/hr ≈ 62 hrs @750km/hr ≈ 8 hrs 750km/hr ≈ 8.1 hrs @750km/hr $\approx 8.2 \text{ hrs}$ @750km/hr ≈ 0.9 hrs @750km/hr $\approx 1.6 \text{ hrs}$ @750km/hr $\approx 4.7 \text{ hrs}$ **RIO DE BUENOS** ROME **CAIRO TOKYO JANEIRO SANTIAGO AIRES** 7,100km 8,582km 8,924km 9,229km 10,615km 8,251km @ 5km/hr $\approx 1,717$ hrs @ $5 \text{km/hr} \approx 1,420 \text{ hrs}$ @ $5 \text{km/hr} \approx 1,650 \text{ hrs}$ @ $5 \text{km/hr} \approx 1,785 \text{ hrs}$ @ $5 \text{km/hr} \approx 1,846 \text{ hrs}$ @ 5km/hr $\approx 2,075$ hrs (a) 100km/hr ≈ 71 hrs @100km/hr ≈ 83 hrs @100km/hr ≈ 86 hrs @100km/hr $\approx$ 89 hrs (a) 100km/hr ≈ 92 hrs @100km/hr ≈ 104 hrs @750km/hr $\approx 9.5 \text{ hrs}$ @750km/hr ≈ 11 hrs @750km/hr $\approx 11.4 \text{ hrs}$ @750km/hr ≈ 11.9 hrs $760 \text{ m/hr} \approx 12.3 \text{ hrs}$ @750km/hr ≈ 13.8 hrs **HONG KONG ADELAIDE BEIJING DUBAI** SYDNEY **MELBOURNE** 16,638km 10,615km 11,087km 12,571km 15,564km 16,265km @ $5 \text{km/hr} \approx 2,123 \text{ hrs}$ @ $5 \text{km/hr} \approx 2,218 \text{ hrs}$ @ $5 \text{km/hr} \approx 2,514 \text{ hrs}$ @ $5 \text{km/hr} \approx 3,113 \text{ hrs}$ @ $5 \text{km/hr} \approx 3,253 \text{ hrs}$ @ 5km/hr $\approx$ 3,328 hrs @100km/hr ≈ 106 hrs @100km/hr ≈ 111 hrs @100km/hr $\approx$ 126 hrs @100km/hr ≈ 156 hrs @100km/hr ≈ 163 hrs @100km/hr ≈ 166 hrs $750 \text{ km/hr} \approx 14.2 \text{ hrs}$ $750 \text{ km/hr} \approx 14.8 \text{ hrs}$ @750km/hr $\approx$ 16.8 hrs $750 \text{ km/hr} \approx 20.8 \text{ hrs}$ 7 @750km/hr $\approx$ 21.7 hrs $750 \text{km/hr} \approx 22.2 \text{ hrs}$

**LOS ANGELES** 

**PARIS** 

**MADRID** 

**CASABLANCA** 

Surveys indicate that the world average commuting time is approximately 40 minutes one-way under moderate traffic, which equates to about 80 minutes (1.3 hours) per day, 400 minutes (6.6 hours) per 5-day working week, 1600 minutes (26.6 hours or 1.1 day) per month, and 20,800 minutes (346.6 hours or 14.4 days) per year. These average values do not account for traffic stoppages, public transportation delays, transfer wait times, and other factors that may affect the overall duration of the commute. A 50% contingency can be added to this average commute time to more accurately comprehend this data, making one's total daily commute an average of about two hours. With this more realistic value, a working citizen in their local proximity will spend a total of about 21½ days a year inside a vehicle only to get from home to work. As one's role within society or an organization matures, more responsibilities may arise, including an increased expectation to travel out of town for business contracts. This effectively adds to one's overall commute times as they branch further outside their local boundaries and into international grounds for business meetings and other project inspections.

left [4.0.3] Dataset and great circle maps from Toronto's Pearson International Airport (YYZ) to the world's busiest city hubs. An example displaying the various additional commute distances and times spent traveling through various means of current Modern consumers investing in the transit and tourism sectors have been seeking exclusive prospects that provide unique experiential opportunities and high-end, exceptional services. These futuristic ventures are only recently beginning to evolve and range from land-based theme resorts to cruise-type expeditions. The more adventurous prospects include higher-risk ventures such as arctic adventures, heli-skiing, balloon excursions, parabolic flights, long range sailing, wilderness excursions, caving, and mountain climbing. Finally, the more "out of this world" experiences, which some have already signed up for, include the limited spaces on commercial weightless spaceflight ventures that bring passengers over the *Armstrong limit*<sup>2</sup> and onto the edge of the Earth. Some of these commercial aerospace ventures are seen as pioneers in a new age of space travel, one that will also include space tourism and hospitable prospects.

Technologically speaking, there are still many improvements necessary to make this modern space agenda a reality, but we are at a time when technologies are able to satisfy the advanced requirements of spacecraft manufacturing and sustainable space station construction. With the initiation of a contemporary transit system in extraterrestrial domains, consumers and frequent international commuters could be given an option to avoid the long hours of transit in the chaotic air space while having the opportunity to become part of an elite class of modern spacefaring astronauts. In addition, with this infrastructure in place, further expansions can be marketed to initiate a commercialization movement for extraterrestrial tourism and hospitality.

2 "The Armstrong limit, often called Armstrong's line, is the altitude that produces an atmospheric pressure so low (0.0618 atmosphere or 6.3 kPa (1.9 inHg)) that water boils at the normal temperature of the human body: 37°C (98.6°F). It is named after Harry George Armstrong, who founded the U.S. Air Force's Department of Space Medicine in 1947 at Randolph Field, Texas."

"Armstrong Limit" by contributors to Wikipedia, 2012

[4.0.4] Congested air traffic great circle vector map of 58,541 destination/arrival data points





The thesis proposal is the architectural concept design of an infrastructure hub within orbital space (a space station) that is programmed to provide a transition zone for future spacefaring transit commuters as well as groundwork for other hospitality functions in the age of space tourism, such as a themed destination resort or hotel, a multipurpose conference center, and an educational science research facility. Initially, the program of the orbital infrastructure hub will be similar to an airport as a transit zone situated in outer space close to Earth. This port destination will host new-age space commuter crafts and systems targeted for elite spacefarers to dock and go, while establishing itself as a payload delivery camp during constructional phases of the project. The latter phases of the station's evolution will come through the expansion of the transit station into a tourist destination with various hospitality functions.

The project will showcase only an architectural vision of the prospective spaceport in the near future. Any mention of technical materials and systems is only included for reference and based on either current technical achievements or the supposition of some future innovations. Conceptually, the project will reference the successful Space Shuttle program, the Space Transportation System (STS), which was formally retired on August 31, 2011, with its last mission flight by STS-135 Atlantis (July 8-21, 2011). The thesis design concept focuses mainly on an idea of a retrofitted version of the Space Shuttle and its External Fuel Tanks. With a contemporary engineered system of rocketry, the thesis proposes that the new external tank rig will become a recyclable element that will stay in orbit, unlike the previous versions that return to Earth. As proposed, this new system retrofitted to the new reusable space transporting vehicle will "kill two birds with one stone," as it will supply the spacecraft with sufficient fuel and chemicals to rocket propel the spacecraft to its orbital destination in outer space, while the leftover materials from the external tanks will become the root foundations of the contemporary commercial space station.

left [4.0.5] Tethered Space Shuttle and inaugural launch of Space Shuttle Columbia

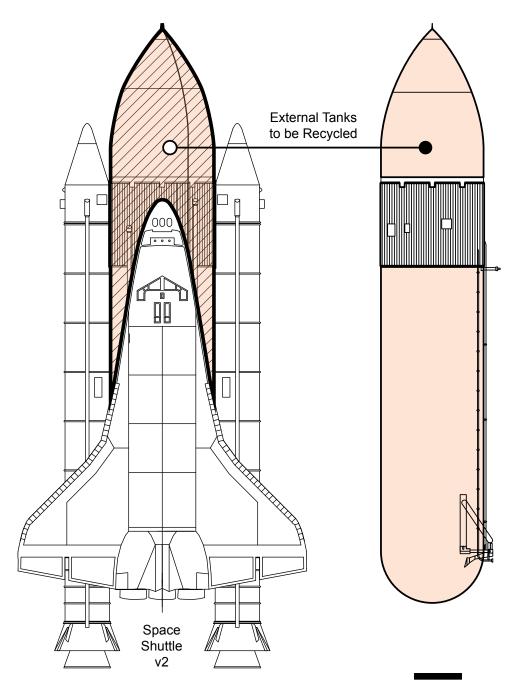
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[4.0.6] Concept of detachable components for future external tanks that are programmed to be launched into orbit for the foundations of AERO|ASTRO's design intentions

[4.0.7] Concept of launchpad and tethered launch

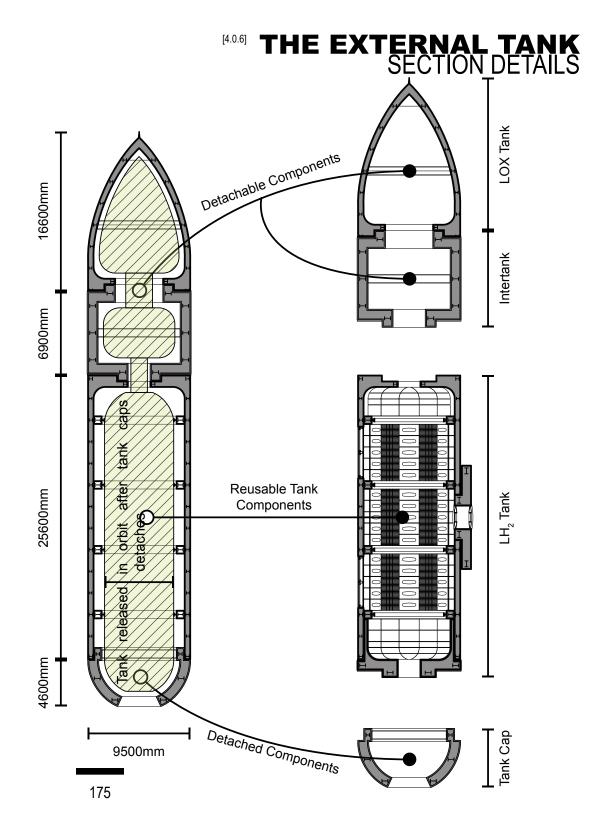
[4.0.8] Interior concepts of future spacecraft and hospitable modules for the commercial use of space tourism

# THE EXTERNAL TANK [4.0.6] ELEVATION DETAILS











terrestrial domain selection for air | space port retrofit

In the transitional stage between the current availability of transit systems to the age of spacefaring commutes, various terrestrial infrastructural upgrades will be necessary to support the demand for construction payloads for the AERO | ASTRO space station. Additionally, terrestrial hubs will need to be retrofitted to support the size and technical needs of future spacecrafts that will be using the facility. As the facility is expected to be transnational in ownership and use, many factors need to be taken into account when selecting the suitable "site" for these renovations to occur.

In the site assessment, we will explore several criteria relative to a worldwide census in order to propose several options for the air/space port infrastructure. These criteria are:

- 1. *premium seat demands:* to identify the growing need to provide elite services to travelers.
- 2. *population growth:* to identify nations with the need for infrastructural upgrades to support the large incoming population with efficient means of transit.
- 3. *national finances:* to identify nations with the necessary financial and resource backings to contribute to this expensive project.
- 4. *tourism hotspots:* to identify the prospects of drawing in connecting tourists with this unique destination adventure.
- 5. *airport identity and traffic*: to identify the experience and suitability of an airport center to host initial connections to the proposed space station. For example, an airport that might only need minimal retrofit to accommodate the space vehicles and that is also centrally located for Earthbased access.

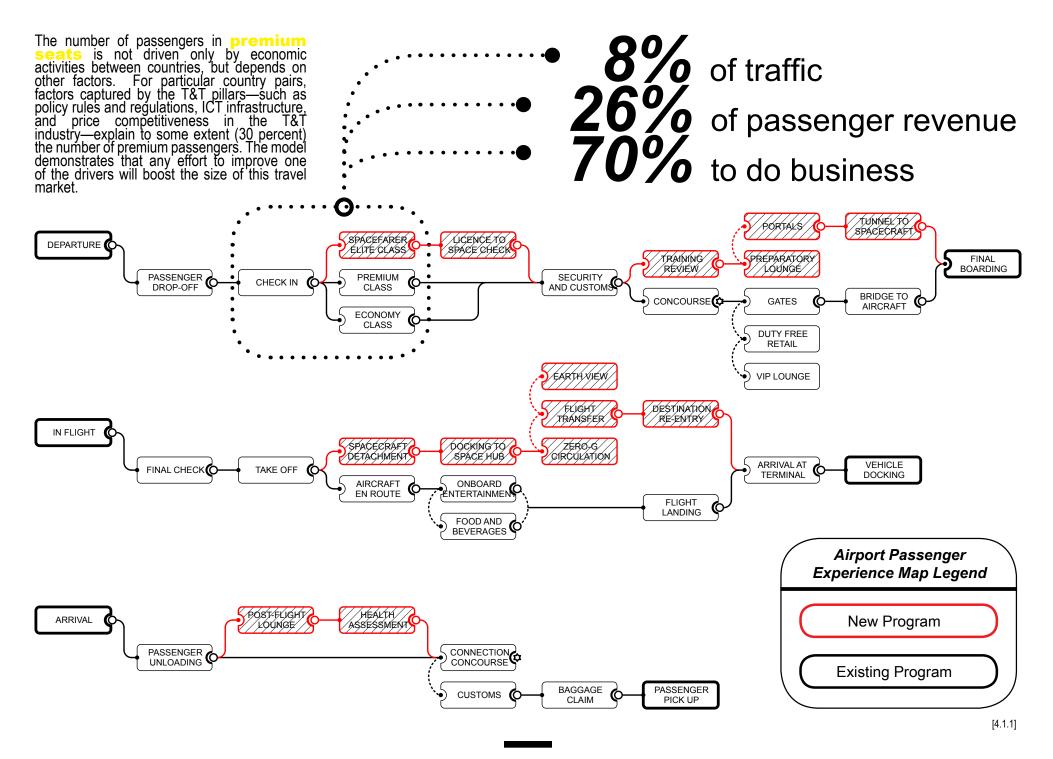
right "The Travel and Tourism Competitiveness Report 2011: Beyond the Downturn" by Jennifer Blanke and Thea Chiesa, World Economic Forum, page 69-75,

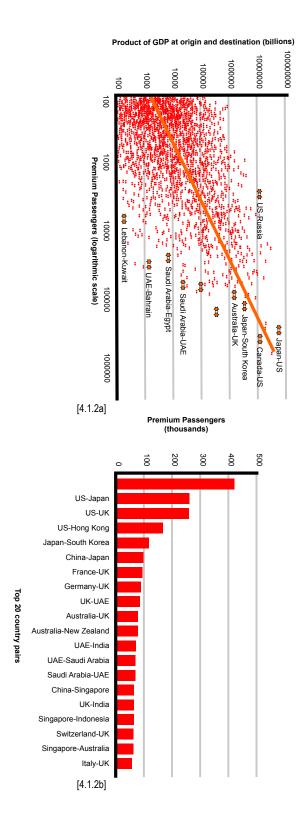
[4.1.1] Conceptual spacefaring experience flowchart of passenger flow through future airports with interventive program retrofits to support the connective infrastructure in orbital space

- [4.1.2] Statistical graphs of emergent trends in premium travel potentials
- [4.1.3] Elite status travelers enjoying a flight in a private jet service
- [4.1.4] Statistical maps of national population with respect to its economic aptitude
- [4.1.5] Statistical maps of tourist arrivals/departures suggesting popular travel trends
- [4.1.6] Flight density map of the top 10 transit hubs according to passenger and cargo traffic

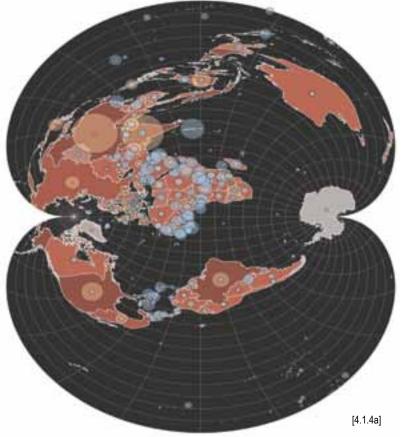
"Investment in T&T [travel and tourism] products and infrastructure is not only essential for destinations to maintain and expand capacity, but it also allows for and encourages improvements in quality, competitiveness, and productivity. Historical data and our joint research over the past decade confirm that both new capital projects and major refurbishments—both of which are classified as investment—are integral to current and future destination performance. Proposed capital projects may remain constrained by limited access to finance, however, even in locations where demand is growing strongly. In contrast, there is also evidence of overinvestment in some destinations despite the clear upturn in industry performance, now that the global economy has emerged from recession. Nevertheless, even in destinations where existing T&T infrastructure is sufficient for the current volume of demand, and even where there is excess capacity, the industry's capacity is not necessarily directly aligned to evolving consumer preferences. Visitors from emerging source markets often distinctly prefer more mature destinations, and all markets tend to be unpredictable: their tastes evolve over time in line with their individual definitions of both basic home comforts and luxury goods. This means that T&T investment remains important at every stage of the global business cycle."

"Investment: A Key Indicator of Competitiveness in Goodger Tourism" by Nancy Cockerell and David







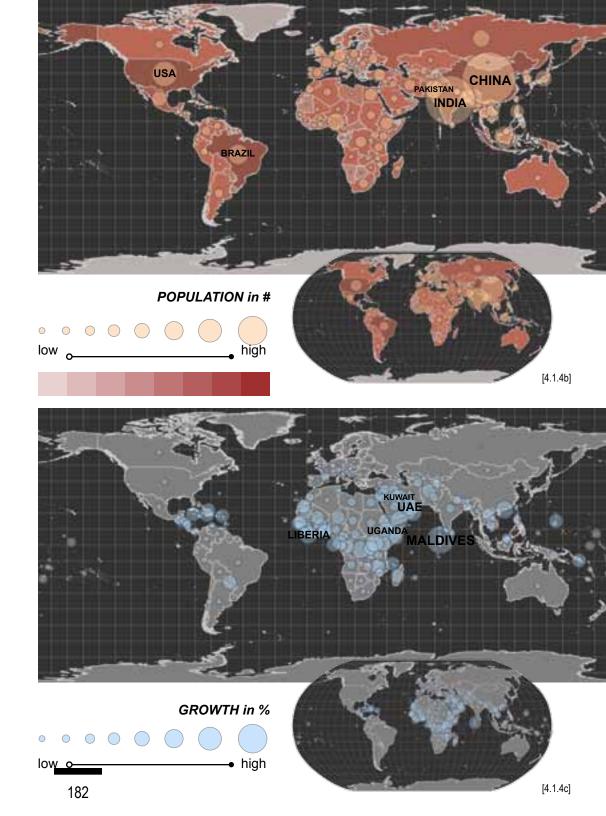


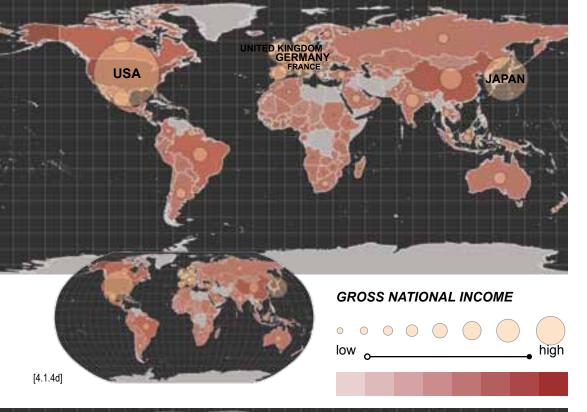
## population

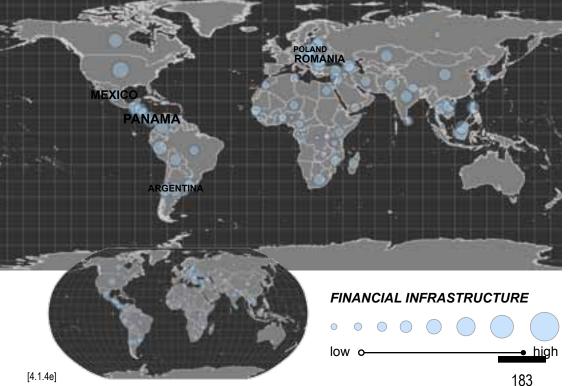
Total population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship—except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of their country of origin.

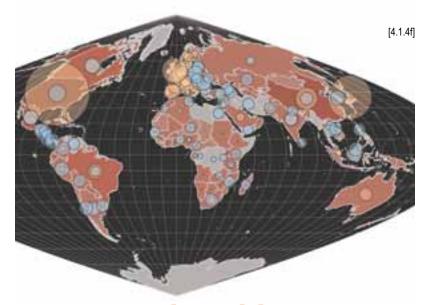
### growth

The average annual percent change in the population, resulting from a surplus (or deficit) of births over deaths and the balance of migrants entering and leaving a country. Rapid population growth can be seen as threatening by neighboring countries.







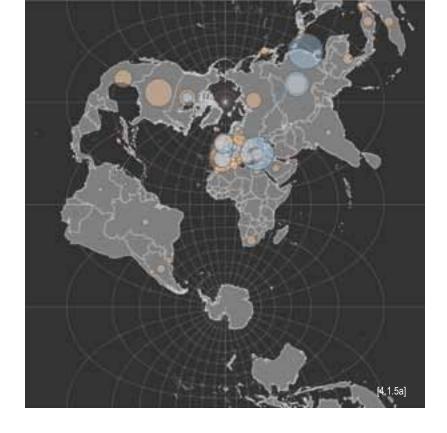


### gross national income

Gross national income (GNI) comprises the total value produced within a country (i.e. its gross domestic product), together with its income received from other countries (notably interest and dividends), less similar payments made to other countries. The GNI consists of: the personal consumption expenditures, the gross private investment, the government consumption expenditures, the net income from assets abroad, and the gross exports of goods and services.

### financial infrastructure

Financial infrastructure index is based on 10 measures, 6 covering the scope, quality, and availability of credit reporting data (in private and public registries) and the existence of a basic legal framework for credit reporting. The remaining 4 cover the availability of public registry data for collateral (fixed and moveable) and corporate registries and court records.

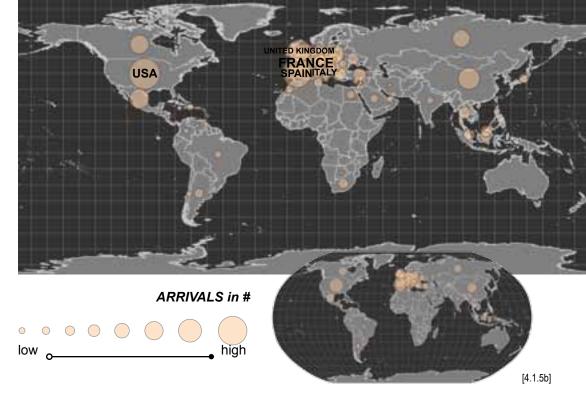


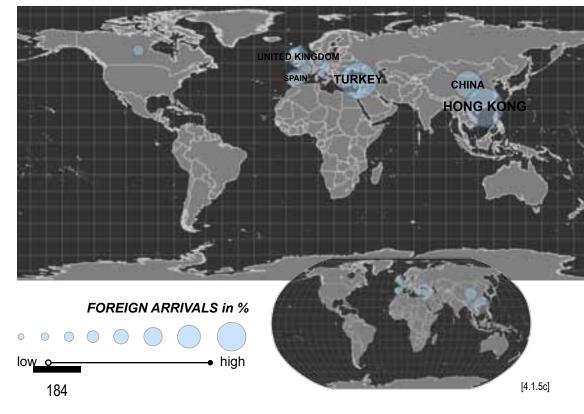
### arrivals

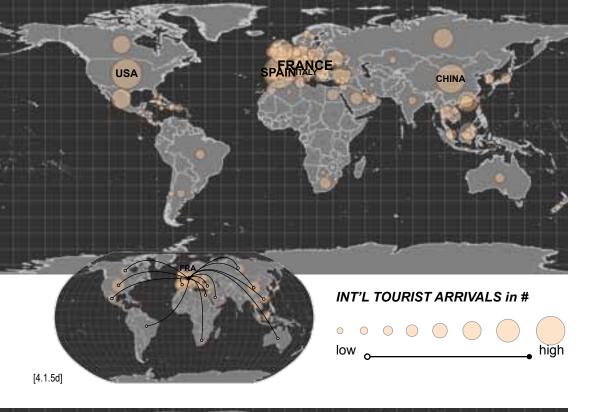
The total number of people, no matter local or foreigners, landing at a specific location by any means of travel: air (airplane/helicopter), water (boats/cruiser), or land (car/bus/railway).

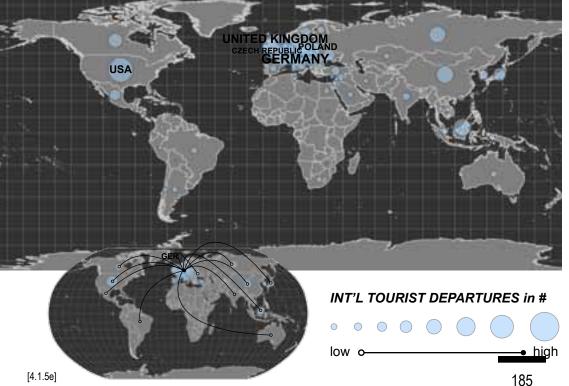
### foreign arrivals

The total number in the population of arrivals who are denoted as a foreigner at the point of destination. In other words, foreign, the total non-citizens that cross the borders, landing at a foreign country for travels, tourism, education, or even businesses.









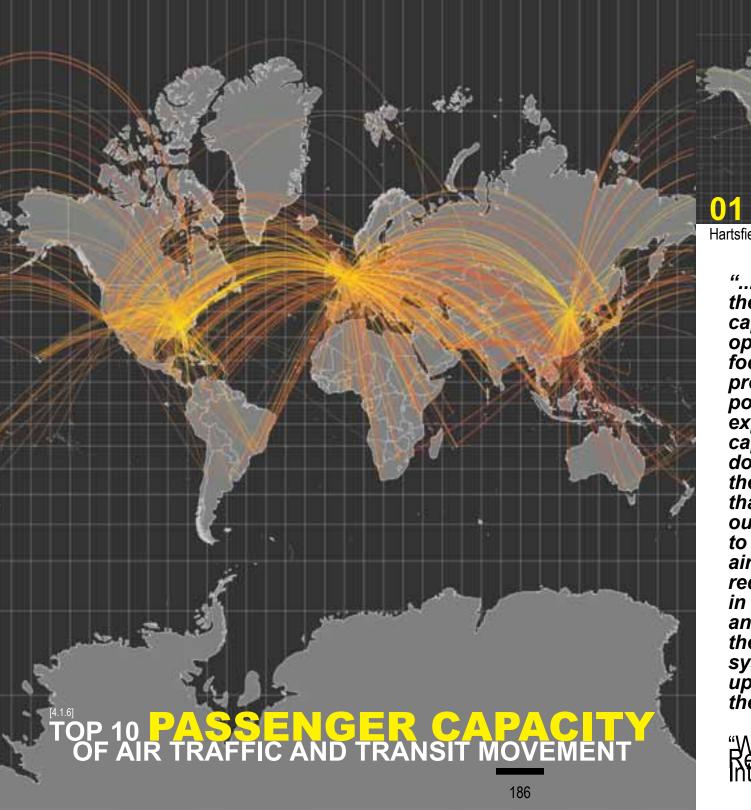


#### int'l tourist arrivals

International inbound tourists (overnight visitors) are the number of tourists who travel to a country other than that in which they have their usual residence, but outside their usual environment, for a period not exceeding 12 months and whose main purpose in visiting is other than an activity remunerated from within the country visited.

### int' tourist departures

International outbound tourists are the number of departures that people make from their country of usual residence to any other country for any purpose other than a remunerated activity in the country visited.



Total Passengers: 92,365,860

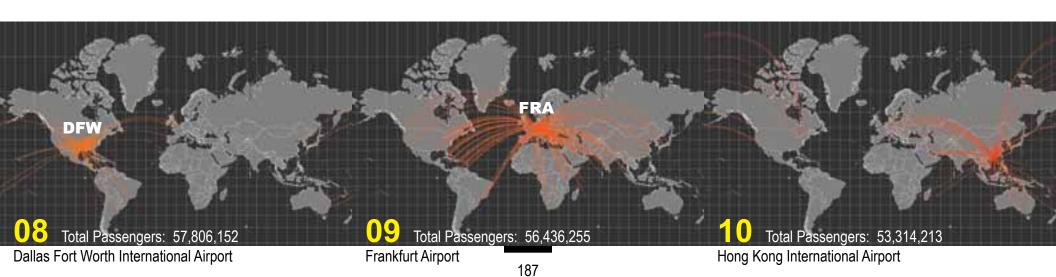
Hartsfield-Jackson Atlanta International Airport

"...these numbers underscore the urgency of the airport capacity challenge. Airport worldwide operators focusing on the need to provide the passenger a positive, seamless travel experience, and planning new capacity to meet the expected doubling of passengers in the next 15 to 20 years. More than ever, governments and our airline partners will need to work closely with our airports to ensure that the required capacity is added in a safe, secure, efficient and sustainable manner. At the same time, air navigation systems will need to be upgraded to keep pace with the growth curve."

World, Airport Traffic Report, by Airports Council International Goodger







Nationwide space agencies such as NASA, ESA, CNES, JAXA, ROSCOSMOS, CNSA, CSA, and so on have expressed an urgent need for a magnitude of national support while stressing that the global economic trends have had a direct effect on the progress in their research and development goals throughout the industry's history. By selecting specific data points from a collection of analytical records assembled by the United Nations Statistics Division and the Central Intelligence Agency's World Factbooks, one can determine who the frontrunners are in major emergent developments such as new-age outer space industries as well as the modern trending necessities within a society.

As the previous chapters have strongly suggested, this infrastructure in outer space is not and cannot be achieved by a single entity. The analyzed data explore the forecasted potentials of emergent nations through the relationships made by their trending growth in finance and technologies. It takes more than one person or nation to build up an empire; hence, building a new industry and infrastructural system of high degree in innovations and technologies will need many stakeholders and contributors. Therefore, for the development of AERO | ASTRO, it is proposed that Earth-based transit hubs (typically but not limiting to an airport with linear planning qualities)<sup>3</sup> are to be retrofitted to support the inevitable evolution of travel initiated at various hubs over the planet. This spread of accessibility over several continents will encourage the multinational support goals set out earlier while persuading design creations to provide ample variety of public and private spaces suitable for the fusion of ethnic functions.

"...most international airports, which would generally have the ability to service larger jets, have many site constraints since they're usually built as close to the downtown core as possible (especially in Europe). Expansion is always difficult and you usually can't accomplish it without completely retrofitting the entire airport. Many international airports today are old and in desperate need of renovation or even reconstruction.

"Modular" airports have inherent footprint expansion capabilities built into them. An example of this is Stansted (though I think they botched their strategy by adding some very standard satellite concourses near the main terminal). In theory, terminals designed modularly (in plan and section) can expand in 5 directions if need be.

Linear (with or without satellites) terminals also make a lot more sense in terms of lateral expansion. This includes Kansai, Shanghai Pudong's terminals, Madrid-Barajas T4, Heathrow's T5, both of Munich's terminals, etc.

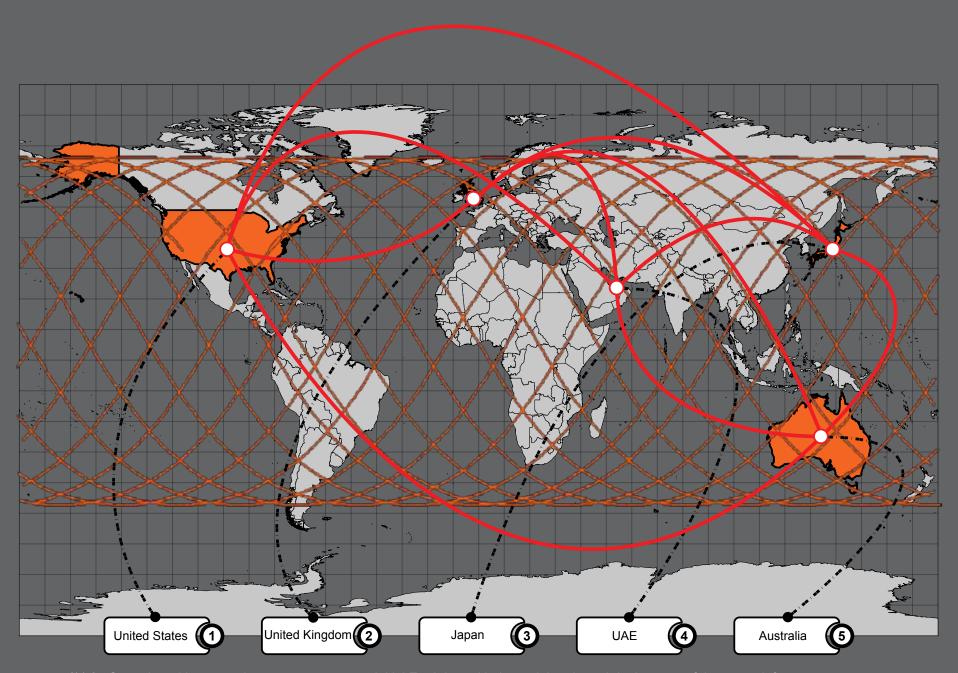
Beijing's T3 is enormous, but unfortunately has a static footprint. However, because it's so massive, it will definitely have ample runway length to service future iets.

This is the conundrum: most "hub" airports like Beijing or Chicago O'Hare (because of their enormity) have extensive lengths of runway and a multitude of hangar types on site, but they are generally locked-in in terms of being able to expand later on. When building massive, impressive airports, I've noticed that architects tend to concentrate a lot more on form (obviously), which has a detrimental effect on expansion capacity.

But, with that being said, the linear terminals I've mentioned, though not necessarily the largest in size or capacity, would suit the needs for future retrofits better in every respect (all being international airports)."

"Tomorrow's Airport Today - A Holistic Approach to Modern Terminal Design" by Andrea Larisa Nagy, conversational dialogue, September 10, 2012

ht [4.1.7] Mapping of five potent countries (financially sound, technologically capable, and high traffic demands) to adapt the future model of integrated air-space commuter transit



[4.1.7] Countries with economic prospect to support initial Earth based hubs and the phased deployment of the space infrasstructure.



4,2

extraterrestrial site selection for infrastructural transit hub

An orbit, by definition, is the curved path, usually elliptical, followed by a planet, satellite, comet, or other object in its motion around another celestial body under the influence of gravitation. As illustrated on the next page, for an object satellite such as a space station to stay up in orbit, it has to be strafing (moving sideways) relative to the barycentre of the evaluated entities. This can be simply understood as the constant freefall of an object that keeps on missing the surface body of the "stationary" object (e.g. the Earth).

When visualizing an object under constant orbital freefall towards the Earth [see illustration 4.2.2], one can imagine the sideways motion of the object as a velocity vector directed tangentially perpendicular to the gravitational acceleration vector directed towards the centre of the planetary object. Under the effects of inertia, the object has the tendency to maintain motion infinitely in a straight line within the near frictionless vacuum of space as a horizontal force is applied to it, but due to the force of gravity acting on the object, it is eventually steered to re-enter Earth's atmosphere to land on its surface. In order for the object to stay in orbit, a large enough lateral force must be applied to the object. If this criterion is met, then the constantly falling object that is being hauled towards the centre of the Earth's mass would as appear to be laterally moving away, such that the curvature of the Earth at the same time "falls away" as quickly as it falls towards its centre. Therefore, the object is always falling while never actually getting closer to the Earth.

In *Sir Isaac Newton's hypothesis*<sup>4</sup> of a similar phenomenon, he envisions a cannonball fired out of a cannon. With a small charge of gunpowder, the cannonball does not fire very high or far as it only provides a minimal thrust, giving it a very slow speed. As the charge increases, the cannonball is launched farther until, theoretically, there is enough charge to give the cannonball sufficient velocity to break the proportions to the curvature of the Earth. At this velocity, the cannonball will achieve orbit as the ground surface of the Earth curves away faster than the cannonball is falling. Hence, the cannonball is illustrated to be plummeting towards Earth in perpetual freefall, but always missing the Earth as it revolves around the orbital track.

"In many situations relativistic effects can be neglected, and Newton's laws give a highly accurate description of the motion. The acceleration of each body is equal to the sum of the gravitational forces on it, divided by its mass, and the gravitational force between each pair of bodies is proportional to the product of their masses and decreases inversely with the square of the distance between them. To this Newtonian approximation, for a system of two point masses or spherical bodies, only influenced by their mutual gravitation (the two-body problem), the orbits can be exactly calculated. If the heavier body is much more massive than the smaller, as for a satellite or small moon orbiting a planet or for the Earth orbiting the Sun, it is accurate and convenient to describe the motion in a coordinate system that is centered on the heavier body, and we say that the lighter body is in orbit around the heavier. For the case where the masses of two bodies are comparable, an exact Newtonian solution is still available, and qualitatively similar to the case of dissimilar masses, by centering the coordinate system on the center of mass of the two.

With two bodies, an orbit is a conic section. The orbit can be open (so the object never returns) or closed (returning), depending on the total energy (kinetic + potential energy) of the system. In the case of an open orbit, the speed at any position of the orbit is at least the escape velocity for that position, in the case of a closed orbit, always less. Since the kinetic energy is never negative, if the common convention is adopted of taking the potential energy as zero at infinite separation, the bound orbits have negative total energy, parabolic trajectories have zero total energy, and hyperbolic orbits have positive total energy."

"Orbit" by contributors to Wikipedia, 2012

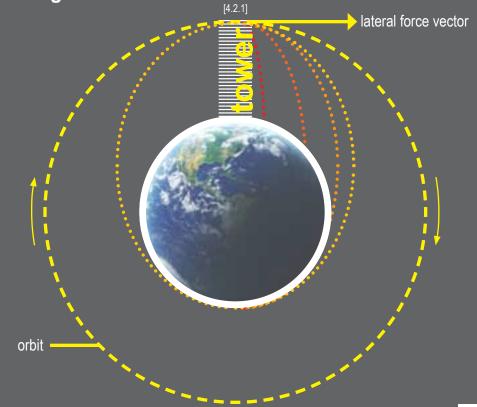
right

[4.2.1] Diagram illustrating the conceptual physics to an object placed in a specific orbit around Earth

nex

- [4.2.2] Variation of unique orbital tracks of an object in a sun synchronous orbit in order to stay consistently oriented to the sun
- [4.2.3] Proposed timing of a transit system reaching the orbital infrastructure in a LEO orbital proximity
- [4.2.4] Map of typical Earth proximate orbits
- [4.2.5] Visual map of proposed timing structure of air-space commuter transit system where the proposed infrastructure station is located on a sun synchronous track

Consider a tower-block 1000 km high, protruding above the Earth's atmosphere. Imagine that you are dropping something off the top of this tower. If you just drop it (ignoring the rotation of the Earth), it will fall straight down, burning up in the atmosphere near the base of the tower. But now, give it a sideways push as you drop it. As it falls, it will continue to move sideways, until it burns up. The harder you push it, the further away from the base of the tower it will land. If you push it hard enough, it will miss the Earth altogether – by the time it's fallen 1000 km, it will have moved so far sideways that the Earth is no longer below it. If you're clever, you can get it moving in a circle around the Earth – perpetually falling but never hitting the bottom.



#### **TYPICAL GEOCENTRIC ORBITS**

#### Low Earth Orbit (LEO) ~ 160 to 2,000km

At 160km above the mean sea level and situated between Earth's atmosphere and below the inner portions of the Van Allen radiation belt, an object can revolve around the planetary mass in about 90minutes at a circular orbital speed of about 8,000m/s. A subcategory of LEO is its equatorial variation that offers rapid revisiting times due to its low inclination to the Equator of the Earth. All of human spaceflight to this date (except for the Apollo lunar and Hubble Space Telescope repair missions) have taken place in a Low Earth Orbit.

#### Medium Earth Orbit (MEO) ~ 2,000 to 36,000km

Also known as an Intermediate Circular Orbit (ICO), an object situated at this range from Earth may begin to experience electronic failures as charge accumulations and radiation levels intensify, fostering interferences to communication signals and other circuitry malfunctions. However, certain ranges of MEO are appropriate for global positioning and telecommunication application satellites as it can yield consistent 12 hours orbital periods or other intervals between 2 to almost 24 hours in range.

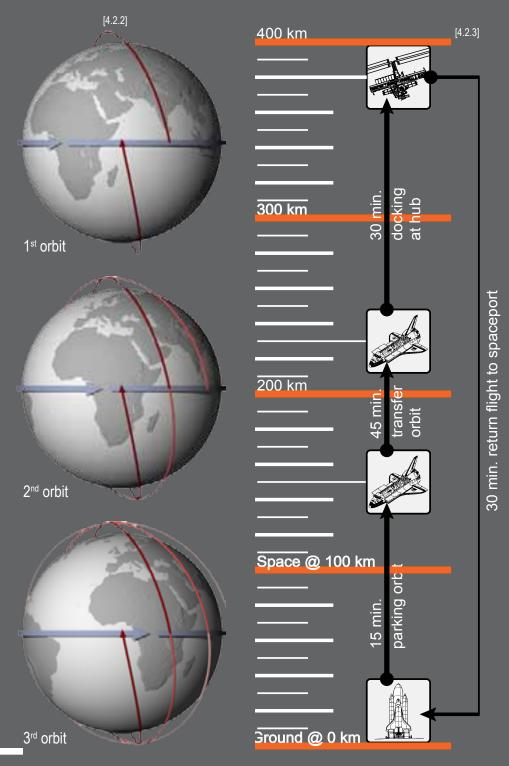
#### Geosynchronous Earth Orbit (GEO) ~ 36,000km

An object situated in this orbital range is characterized to correspond and maintain the same position with one singular point on Earth as its orbital period coincides with the sidereal rotational period of Earth (~24 hours). A subset of this orbit is the Geostationary Orbit which is located directly above the Equator and highly appropriate for the use by communication satellites. Hence, this is sometimes called the Clarke Orbit where a belt of broadcast satellites would be found. In addition, just a few hundred kilometers above GEO is the "graveyard" orbit where retired satellites are moved into to prevent close to Earth space debris.

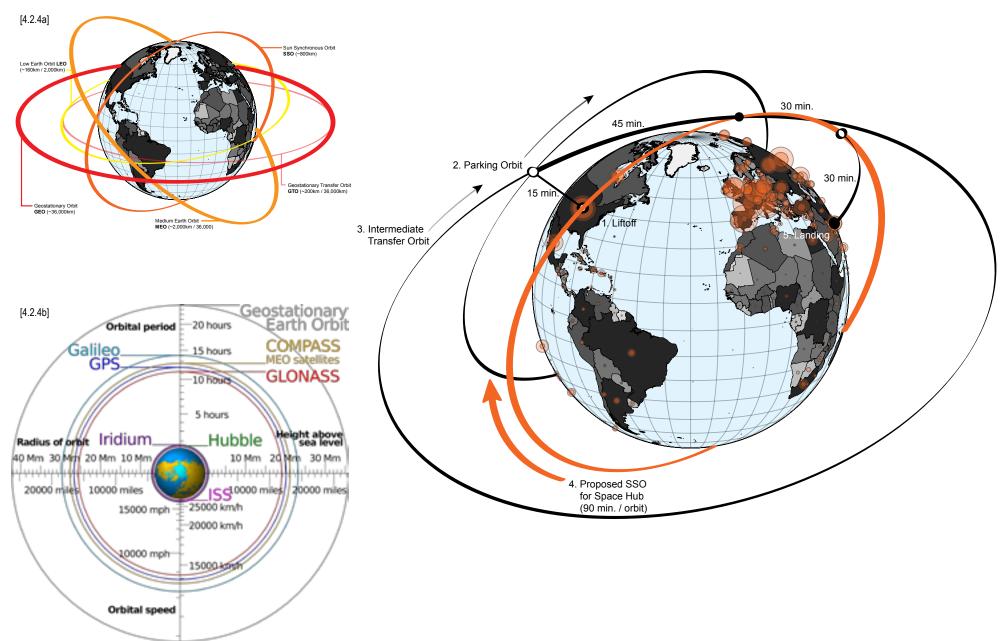
#### **SUN-SYNCHRONOUS ORBIT (SSO)**

Sometimes referred to as a heliosynchronous orbit, SSO is a special variation of a geocentric orbit near Earth (typically 600-1000km above sea level with orbital periods of about 90-100min) that travels along the polar tracking around the Earth rather than the usual equatorial tracks of commonly used satellite orbits. It is considered a special type of orbit because it carries the unique attribute of always orienting with the same consistent illumination angle to the sun. As a polar orbit synchronized with the sun, objects in an SSO will have each of its successive orbits occurring at a constant local time on Earth. This means that in each orbital pass, a satellite will pass through the equatorial longitudes at a different latitude, but coincidently, the local time on Earth will be the same.

These aspects of a sun-synchronous orbit are the important key factors in considering the orbital path selection for AERO ASTRO. Provided that the sun is constantly hovering at the zenith [refer to 3.2.1] of the station while the Earth at the nadir [refer to 3.2.1] side, the configuration of programs and the planning for visual vistas can simply be predefined with the back of house and ECLSS/regenerative components located at the zenith side while residences and windows located in the direction of the nadir side of the station. This key orientation of the functional program helps minimize the use of unique systems of shading devices and eliminates the need for mechanical systems to constantly orient the power generating solar arrays to the sun at an on going 24 hour basis. With these reductions, it will save overall design and built payload deployment costs while reducing the energy consumptions of unnecessary mechanical devices during operations. Finally similar to LEO, SSO is within a reasonably commutable distance to Earth and with its consistent timings passing various locations worldwide, it provides a consistent array of launch and arrival times at terrestrial hubs along similar longitudinal planes around the globe.



station's orbital tracking on a Sun Synchronous Orbit (SS0) and its implication on a modern, conceptual, space transit system





# 4.3

the kit-of-parts to the modern grapheme of space architecture

Many lessons can be learned from patented building blocks, from standard parts toy kits by Kiddicraft, Lego, K'nex, and Tinkertoy, to the more sophisticated scaled erector construction sets by AC Gilbert Company and Meccano, to the professional use of 80/20 aluminum alloy framing system and prefabrications in "final line" constructions on Earth. Architecture conceived for outer space must comply with two basic principles: flexibility and retrofitting. By satisfying these two principles, high efficiencies in terms of sustainability can be achieved while reducing overall operational and life cycle costs in future upgrades and expansions.

On Earth, post-occupancy mitigations typically include upgrades for HVAC equipment and aesthetic surface finish maintenances, and superseded assemblies are generally dispatched to landfills after demolition. However, in outer space, these customary terrestrial actions are not feasible as materials cannot afford to be wasted in graveyard orbits. Financially there is much capital invested in the materials that are brought into space, and to reuse and recycle can be looked at for sustainability and economic savings. Therefore, it is necessary through the design process to include a strategy that will allow for an accommodating system of parts and arrangements that will seldom become obsolete and that will be responsive to future retrofits of new systems and materials.

As a compliant part to complex devices, Apple Inc.'s patented MagSafe dock connector (a simple multi-oriented five palindromic pinned power connection that is attached and held together by magnetism) can be considered as a miniature scale precedent to the kit-of-parts strategy. With this patented male connector and female socket, a platform of cross-generation products were created where one could upgrade to newer versions of Apple's products while still making good use of the old components that they already owned. This also set certain standards in future retrofits of the company's product as the MagSafe connectors could be applicable in the design process for new products as a standard component in a large kit-of-parts, saving time and money on research and developments for specific elements. Having a kit-of-parts set up will minimize both costs and time in design upgrades and manufacturing. In addition, design and development focuses can be geared towards more important innovative disciplines, rather than revisiting past accounts for unnecessary upgrades.

5 "The 323 Apple patents that list Steven P. Jobs among the group of inventors offer a glimpse at his legendary say over the minute details of the company's products — from the company's iconic computer cases to the glass staircases that are featured in many Apple stores.

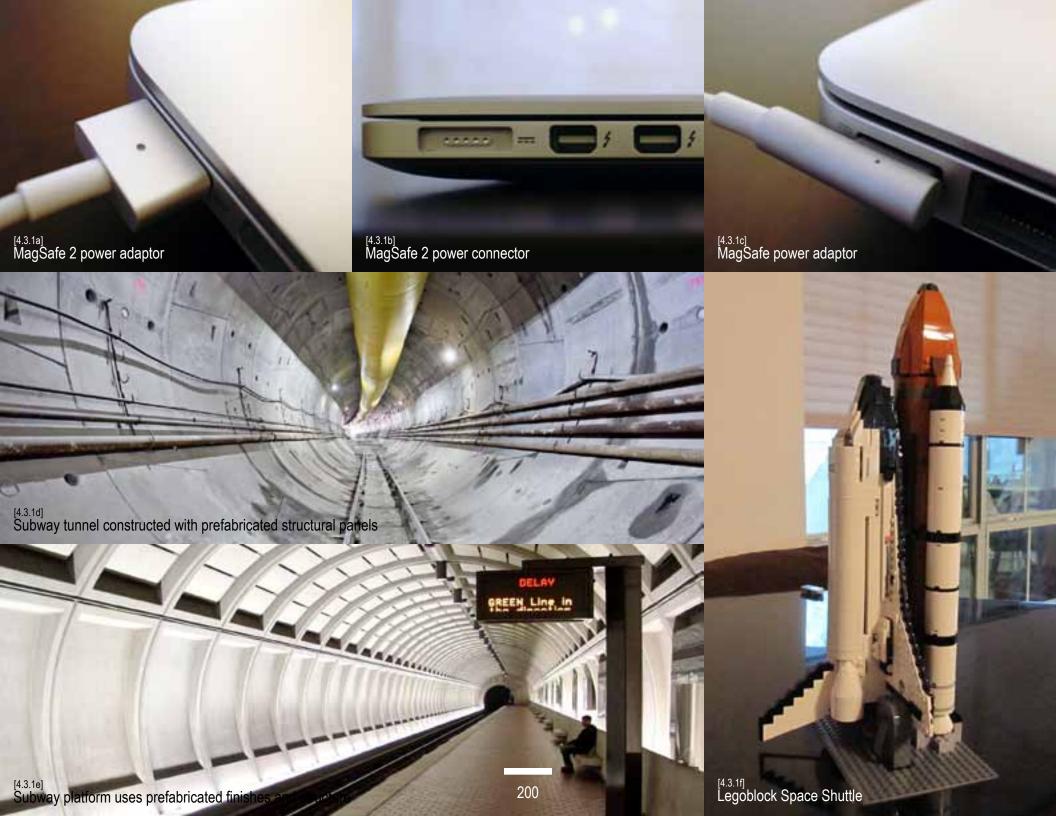
> When people in the technology industry speak of Steven P. Jobs's knack for design, they often have Apple's iconic products in mind: the early all-in-one Macintosh computers, the first iMacs with their brightly colored and translucent cases, and more recently, the various iPods, iPhones and iPads. But what about the striking glass staircases in many of Apple's stores? Mr. Jobs led their design — and has his name on two patents Apple received for that design. The white plastic power adapters in newermodel Macintosh computers? Mr. Jobs helped to design them too, according to patent filings. And he also had a hand in the final look of a startling number of products, including the seemingly insignificant and those that have proved central to Apple's success: the lanyard for some iPod headsets, the plastic clasps that hold cords in place, the cardboard packaging for scores of iPods, and model after model of desktop and laptop computers, monitors, mice, keyboards, mobile devices and media players. Mr. Jobs's say over the minute details of Apple's products is legendary in Silicon Valley. The patents that carry his name, for these products and others, offer a glimpse into the range of his influence at Apple. And they paint a picture of a roll-up-your-sleeves chief executive whose design choices reached into every corner of the company."

> "Steve Job's Patents - A Chief Executive's Attention to Detail, Noted in 313 Patents" by Miguel Helft, The New York Times, August 25, 2011

"Out of this World: the new field of space architecture" by A. Scott Howe, page 61, 2009

"Extended space missions beg for a flexible environment with outfitting that can reconfigured for cleaning and maintenance and for accommodating changing crew composition, preferences, and activities. Flexibility can be achieved via a group of objects that can be configured to achieve different functions by a system that supports a family of objects, each possessing a unique function, or by arriving at a reduced collection of elements whose functions are fused...Retrofitting provides an existing machine or structure already in use — such as a jet, computer, space station, or rack volume — with parts, devices, or equipment that did not exist, or were not available, at the time of the original design or manufacture."

"Out of this World: the new field of space architecture by A. Scott Howe



In order to develop and construct in orbital space with absolute flexibility and efficiency, a kit-of-parts methodology must be implemented in the conceptual and schematic design processes. With this kit, designers and contractors will be at ease in selecting and connecting the appropriate components for a highly complex modulated structure in outer space. This next generation of prefabricated construction will differ from the way terrestrial pipelines function, as components will not be bonded by permanent connectors as on Earth; rather, they will be designed to be adaptable to conjoining members through mediating elements such as air-sealed hatches. As a measure of its flexibility, these standardized module assemblies will need to demonstrate a high capacity to demount, disassemble, and be reused in various new applications while achieving maximum opportunities in a variety of modulated arrangements. Finally, all of the parts within the kit must be manufactured and retrofitted within an appropriate size range in accordance with payload shipping and other constraints in handling both on Earth and in orbit.

The kit-of-parts theory has been used in many precedent applications on Earth in various industries, including children's toys and infrastructural engineering. This functional model has been used by astronautic designers since the beginning of the ambitious space program. However, it is only in recent decades that there has been a movement, led by architect Scott Howe, to retrofit and develop contemporary modulated components to improve living conditions while upgrading the current parts with up-to-date technology. In Scott Howe's approach, the architect is to create a distinctive library that will spell out in its own grapheme (the smallest possible unit of language), a series of configurations including every major assembly of parts (modules, nodes, joint systems and hatches, docking support adaptors, trusses, solar arrays, payload attachments, etc.), and also many of the minor detailing components and apparatuses used onboard the space station (storage racks, interior paneling, anchors and holds, motion handles, tethering nodes, sensors and actuators, etc.). By adapting to this philosophy in construction with a kit-of-parts, a modulated space station will become an organism in itself as it dynamically evolves architecturally and internally with the endless variations of expansion opportunities.

[4.3.1] Kit-of-parts precedent reference includes the Magsafe connectors by Apple, Lego building blocks, and the sectional prefabricated construction of underground subway tunnels (both structural and finishings)

With the sustainable aspiration of resourcefully maximizing material use and its reusability, the design intervention of AERO | ASTRO will create its own version of the kit-of-parts theory as previously mentioned. These new symbols will abstractly introduce a flexible language for the station's major architectural assembly elements, while recycling external tanks used for deploying space shuttles into orbit as a foundation to these modulated assembly elements. In addition, a common design pattern of linear and faceted circular (typically hexagonal and decagonal) passages practically and formally suggest a basic configuration, allowing endless interior circulation flow while offering the ability to evolve and expand the space station in an assortment of directions. Finally, similar to the developments by Scott Howe and his colleagues, the notion of AERO | ASTRO's standardized kit-of-parts is strictly a conceptual vision in accordance to the final proposed design intervention. In order for these components to be considered deployable, further technical improvements in research and development are needed to satisfy the continually evolving automation of construction techniques, tools, and detailing employed in outer space.

As previously mentioned, the design concept of AERO | ASTRO will concentrate on the idea of reemploying a retrofitted version of the Space Shuttle's External Fuel Tanks. In doing so, it standardizes, for the most part, the "tubular" foundations when generating the modulated language for the station. Based on this model [see 4.3.2] the station's ultimate sectional radius of about 4,750 millimetres, the maximum barrel wall length of about 3,200 millimetres, the double hull structural construction details, and other existing components from the referenced External Fuel Tanks will regulate the workable design boundaries for space architects. Not only will these standardized base structures create a consistent architectural language in tubular space construction, these foundations will also identify volumetric constraints that designers have to follow in order to achieve maximal efficiencies satisfying payload limits and sustainable benchmarks. By following this formulated set of sizes and shapes, the generation of the kit-of-parts used in the assembly for AERO | ASTRO is exhibited in the following diagrams that reflect a variation of this precedent technology.

right

[4.3.2] Concept diagram of the extracted portions of an external fuel tank as a foundation to the module developments in the kit-of-parts for AEROJASTRO

next

[4.3.3] Primitive set of AERO|ASTRO kit-of-parts grapheme categorized from A.1 to S:

Module TYPE 1 (A to D): A to C are the standard base modules of various lengths used throughout the station. They act as the general boundaries for the interior retrofits for major public/private corridors while serving for most other activity spaces. The hemispherical cap (D) is used to shut off dead ends (temporarily and permanently) and is the detachable seal to the overall air-tight system in the station. It is detailed to flexibly detach and reassemble during expansions of the station as an efficient method of construction while maintaining operational status during non-constructional phases.

Module TYPE 2 (E): These pieces are adaptors that act as secondary passages (an alleyway to corridors and programmed activity spaces). They are typically used to connect TYPE 1 modules but, in special cases, they act as a hatched capping, connecting with spacecraft docking equipment at the port. The openings to these alleyways range from 1,250mm to 2,000mm in radius, such that the size distinction can indicate the transition of programmatic variances while bottlenecking traffic within the circulation flow. This also regulates the occupancy loading and movement speeds that transition between connected activity spaces.

Module TYPE 3 (F to G): Corner pieces denoted by (F) modules connect the linear TYPE 1 modules to direct passage into a simulated circular flow throughout the station. It turns specifically at a 60° angle to create this simulation in a hexagonal configuration.

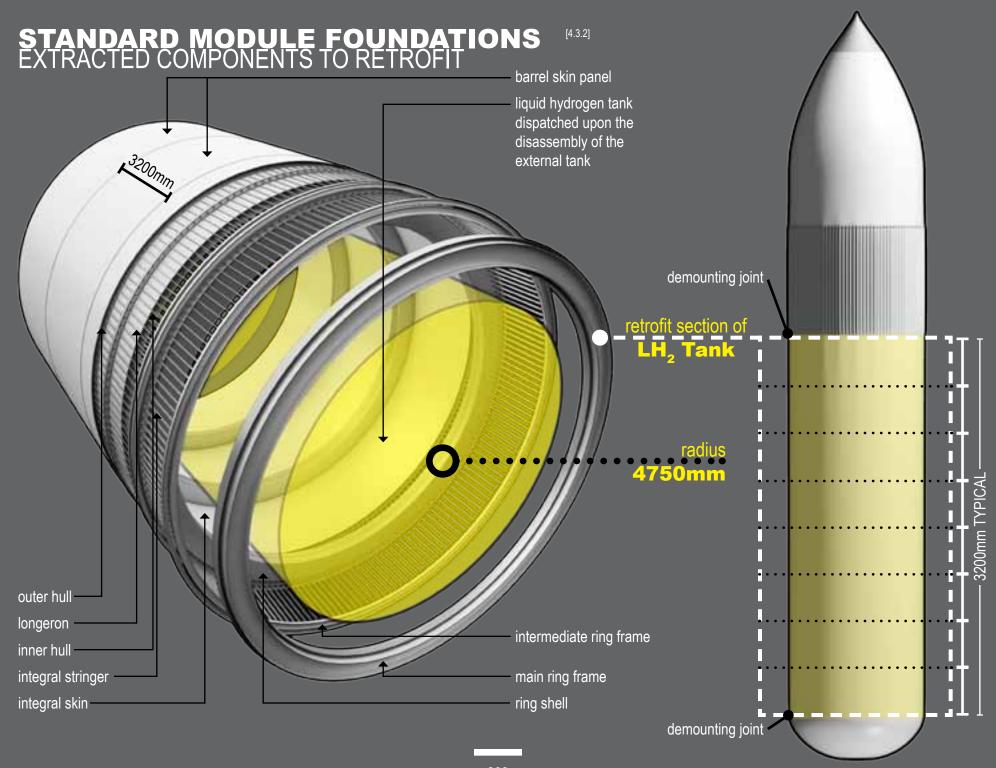
Module TYPE 4 (H to I): Connector pieces (H) offer a soft padding to TYPE 1+2 joints while suctioning the joined modules to an air-tight seal. (I) is a special connector with a motoring mechanism that generates the centripetal spinning of the revolving artificial gravity amenity modules.

Module TYPE 5 (J to K): A clover-shaped modular section that uses four sliced segments of TYPE 1 modules in forming the four-leaf configuration. These modules are used for the multi-storey programs of the artificial gravity areas as well as the unique revolving swimming pool.

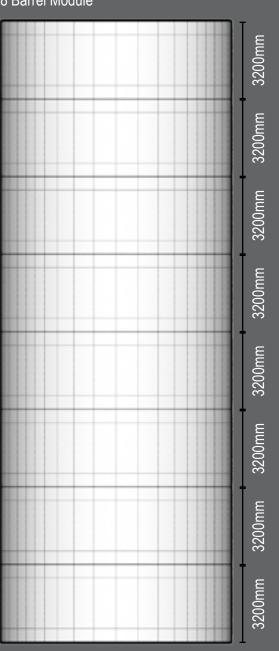
Module TYPE 6 (L to Q): Various unique amenity modules derived in the basis of spherical forms reduce disorienting cues for its occupants as it lacks the conventions of a ceiling (up) and a floor (down).

Module TYPE 7 (R): Living pod modules; see [4.5.24] to [4.5.28] for details.

Module TYPE 8 (S): Technical modules necessary for power generation, HVAC/ECLSS, and other unique mechanical systems.

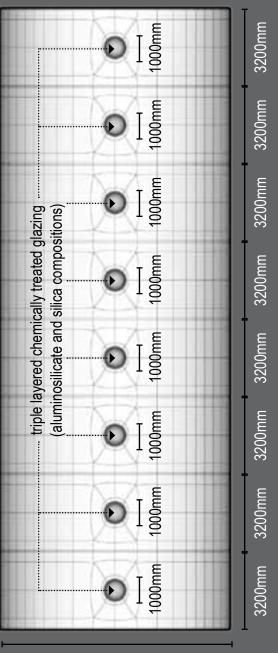




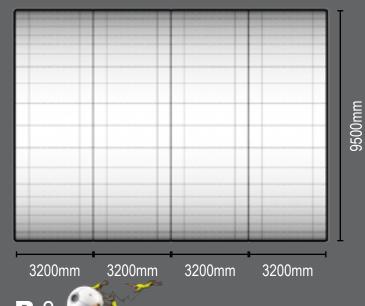


9500mm

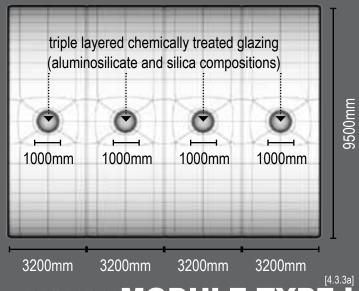
A.2 8 Barrel Module with Windows

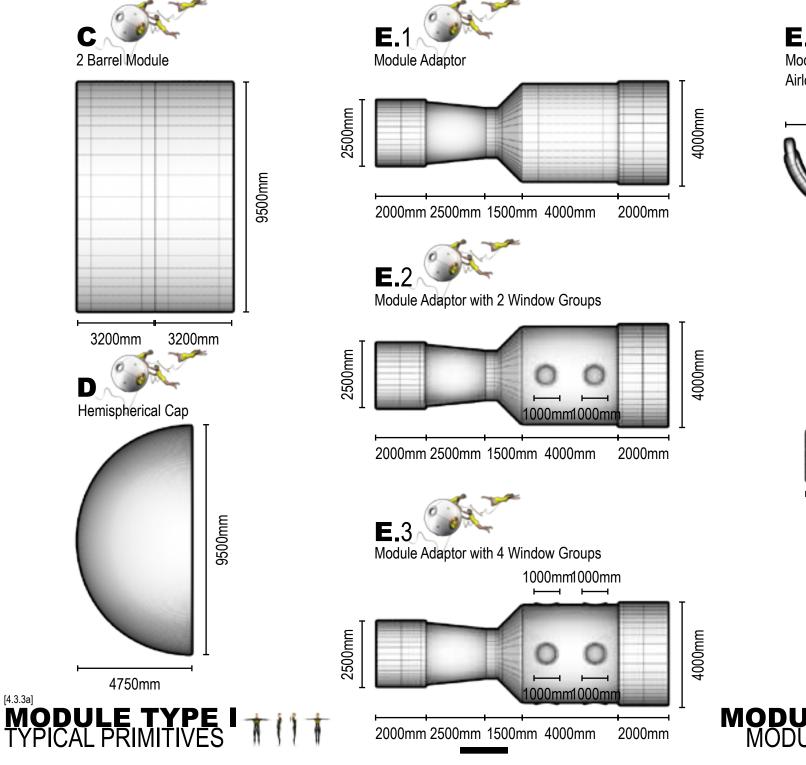


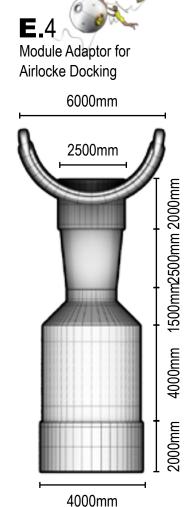
B.1 4 Barrel Module



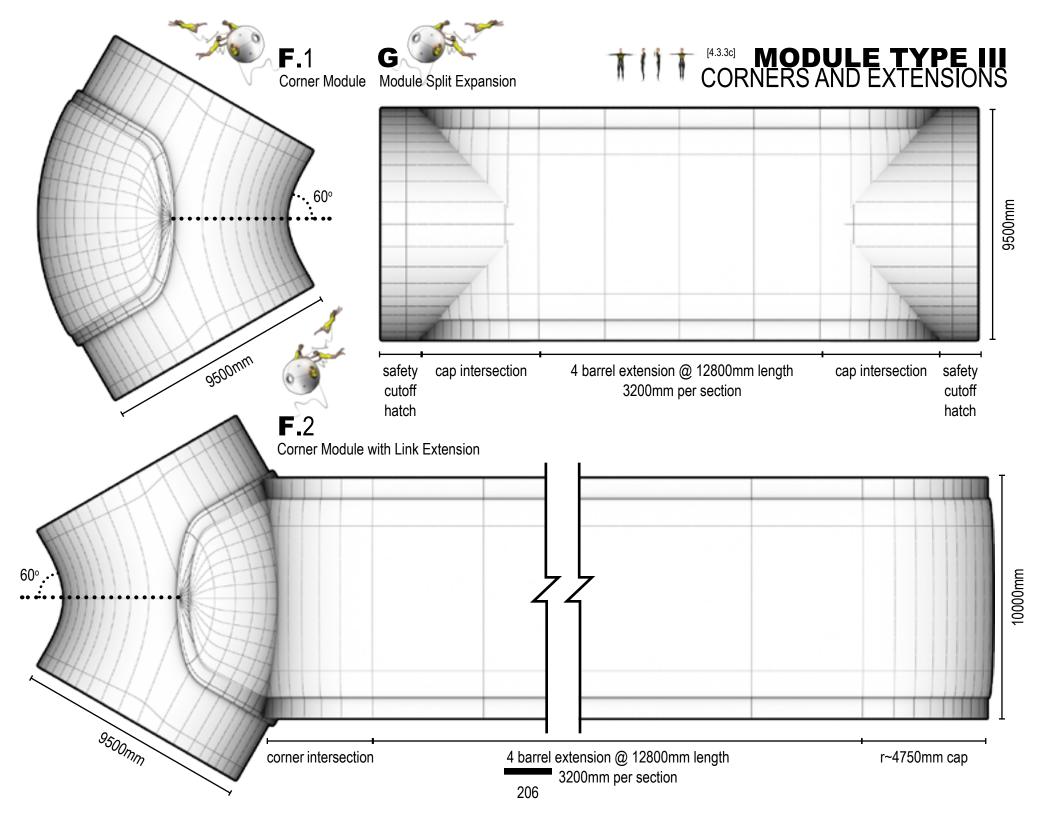
4 Barrel Module with Windows

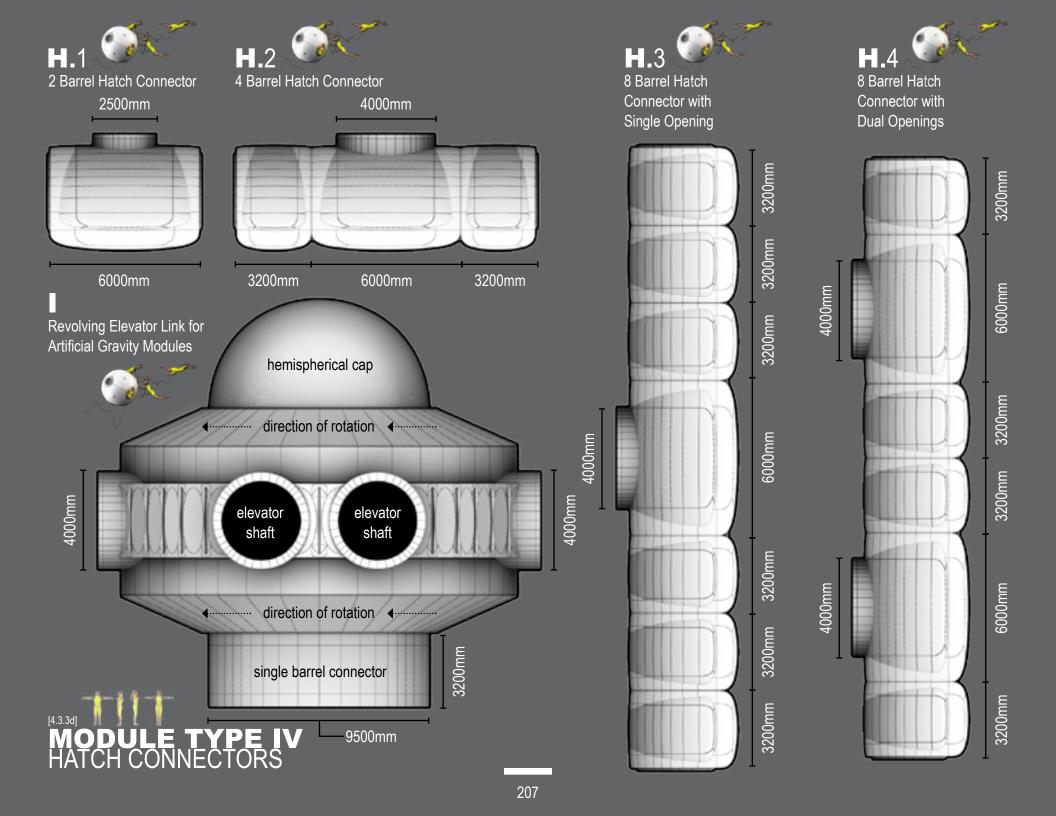






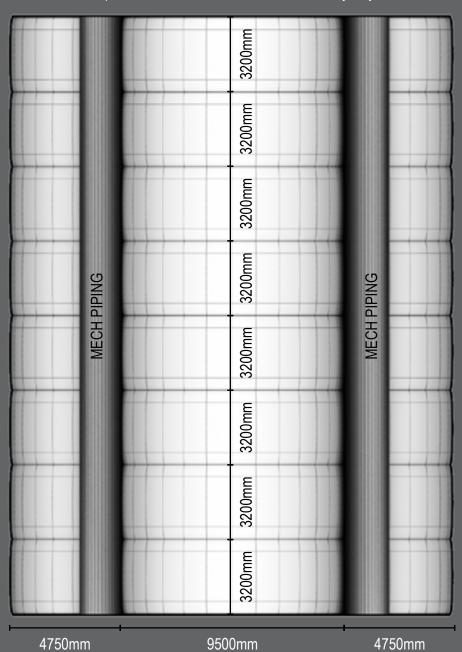


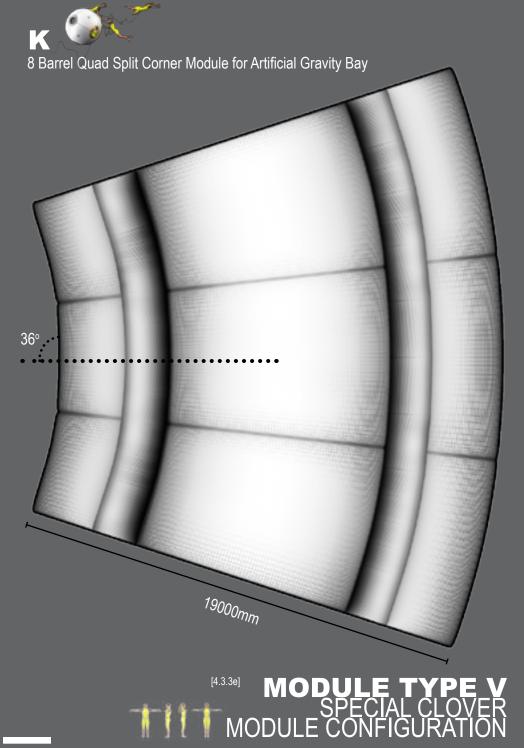


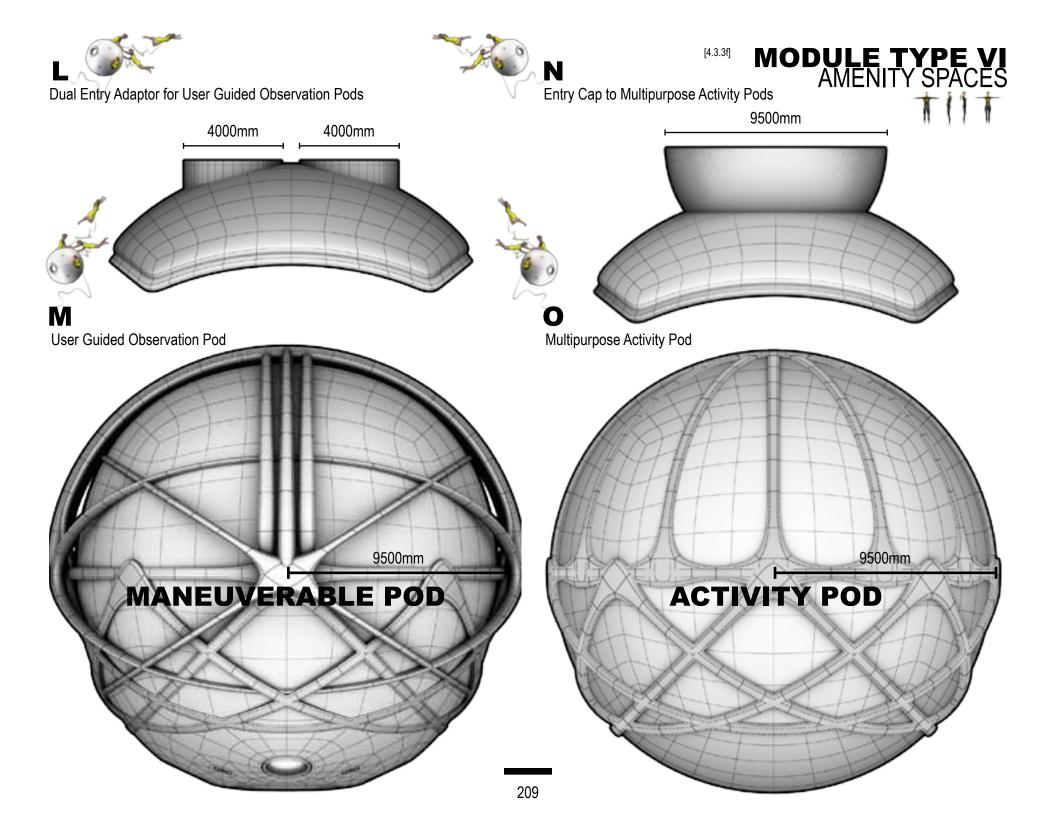




8 Barrel Quad Split Connected Module for Artificial Gravity Bay



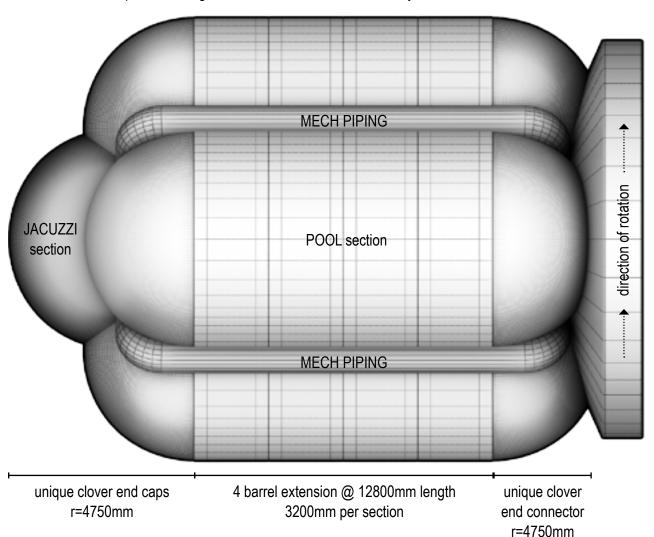




### **SWIMMING POOL** REVOLVING

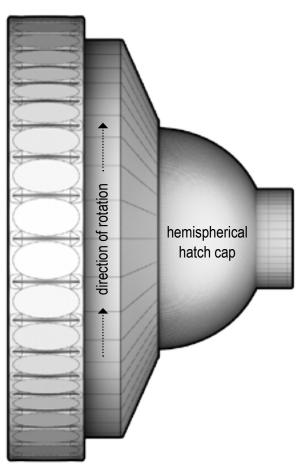


4 Barrel Quad Split Swimming Pool Module under Artificial Gravity

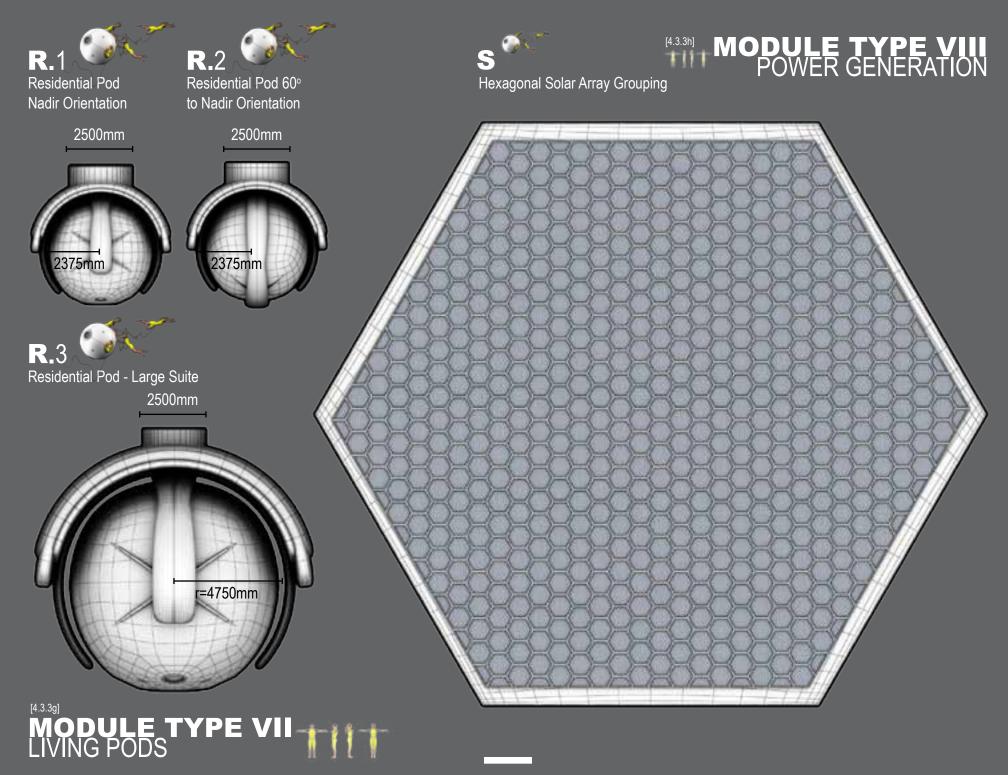


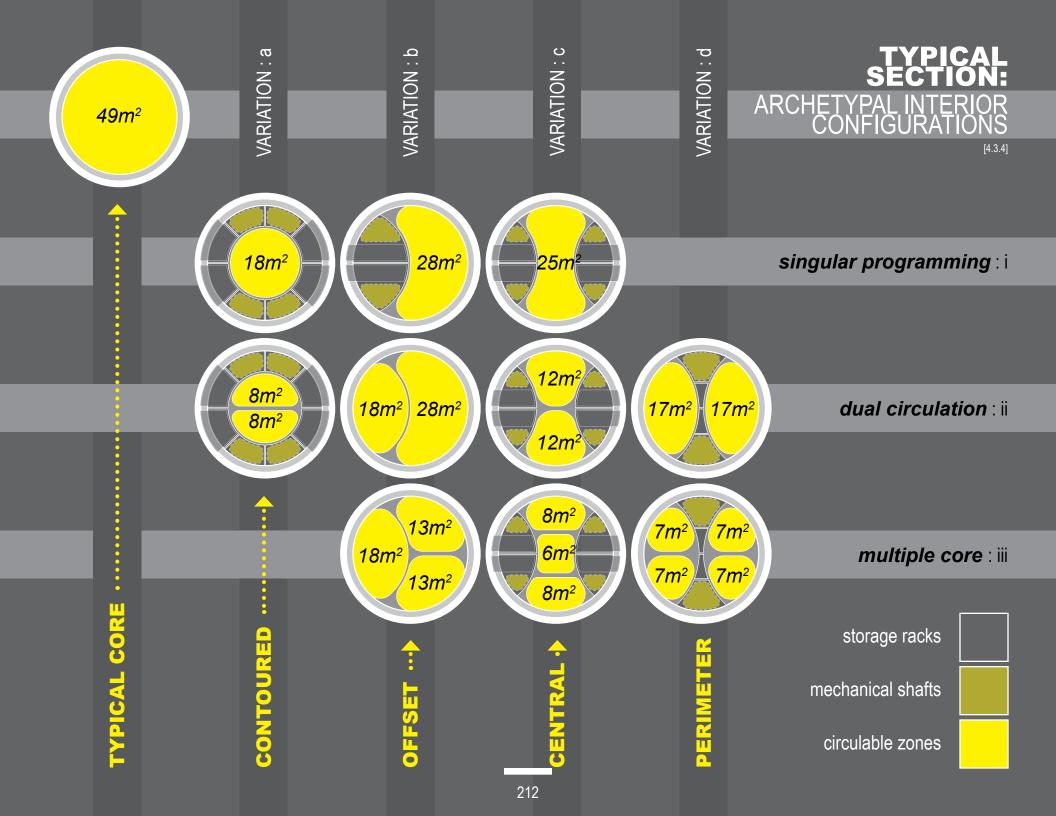


Revolving Mechanism for Swimming Pool Module









As suggested by the kit-of-parts in the preceding diagrams, the general foundations (external shells) proposed for this thesis revolves around the functional boundaries identified within the liquid hydrogen section of an external fuel tank. Based on the referenced measurements for the interior sections of this functional boundary, designers are given approximately 49 square metres of sectional area to work with after accounting for the necessary cavities and structural thicknesses required for the double hull and other mechanical/electrical systems. This equates to approximately 156.8 cubic metres of spatial volume per barrel length (3.2 metres) to be accounted for in the proposed design. The workable volume is an important parameter as it regulates the overall density that is capable of populating within the barrel section. It is also important to ensure that there are plenty of open spaces both within and between occupants and their surroundings.

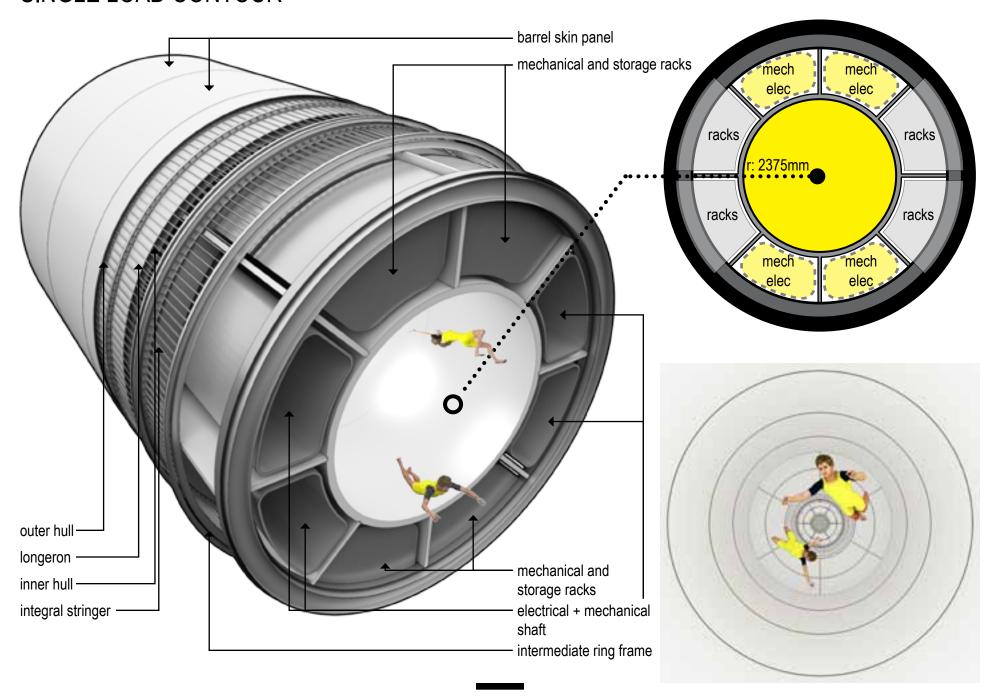
In dividing programmed spaces for human occupancy, perceptual discriminators involving one's response to forms, proportions, and scales should be considered. In other words, schematically designing the retrofitted areas of the extracted external tank will involve a variety of spatial volumes and shapes, and also a variance in pathway options for moving around. For a general rule of thumb, spaces that have been designed for human occupancy should never contain sharp edges to prevent foreign space travelers from bumping into them and hurting themselves. Therefore, spaces with softened edges and rounded corners will denote circulatory arrangements while the negative spaces in the forms of cavities with a mix of sharp and soft edges will be used mainly for mechanical systems and accessible storage. To determine the acceptable sectional scale (a value that can equate to barrel section volumes) when sorting out archetypal options for comfortable interior space arrangements, the designs in this thesis consider the minimal and maximal distances of comfort required for one's personal space bubble [refer to 4.5.2]. Deriving from this, the minimal sectional area of comfort is approximately 4.5 square metres according to the social theory of personal space (a point about 1.2 metres from one's centre). Therefore, given an additional 10 percent on top of this for contingent flexibility, sectional areas of spatial boundaries for singular flow occupancy should not be below the benchmark of approximately 4.95 square metres while spaces designed for free-flowing occupancy should allow for at least a two-way flow of 9.9 square metres in sectional areas.

*left* [4.3.4] Archetypal parti configurations of individual module interior sections

[4.3.5] Archetypal configurations a.i to d.iii in detail with a rendered representation of the space generated

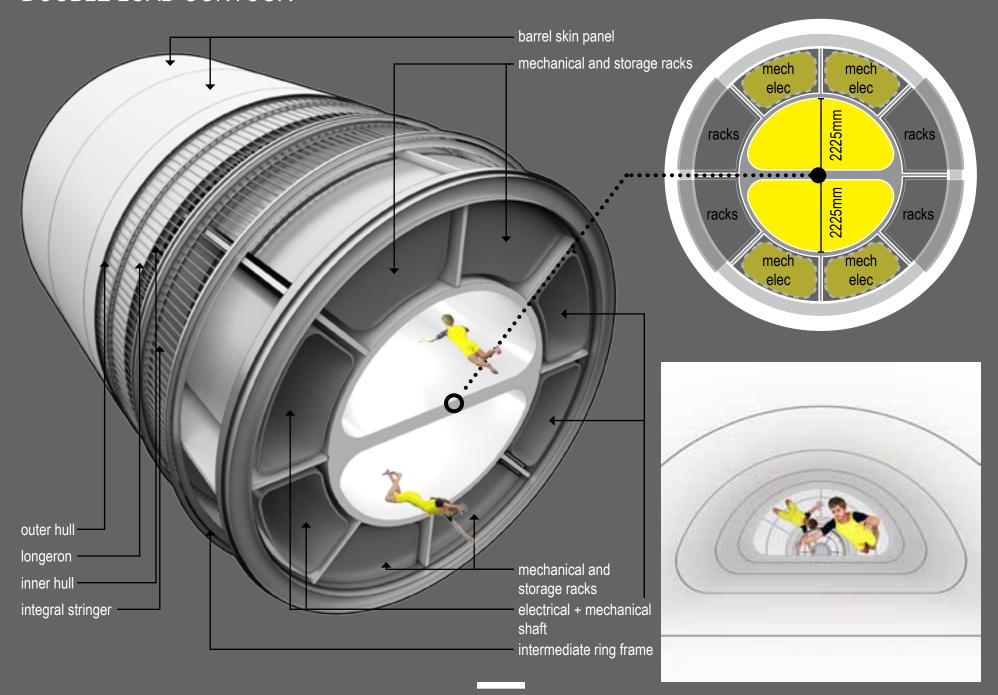
### INTERIOR TYPE a.i SINGLE LOAD CONTOUR

[4.3.5a]

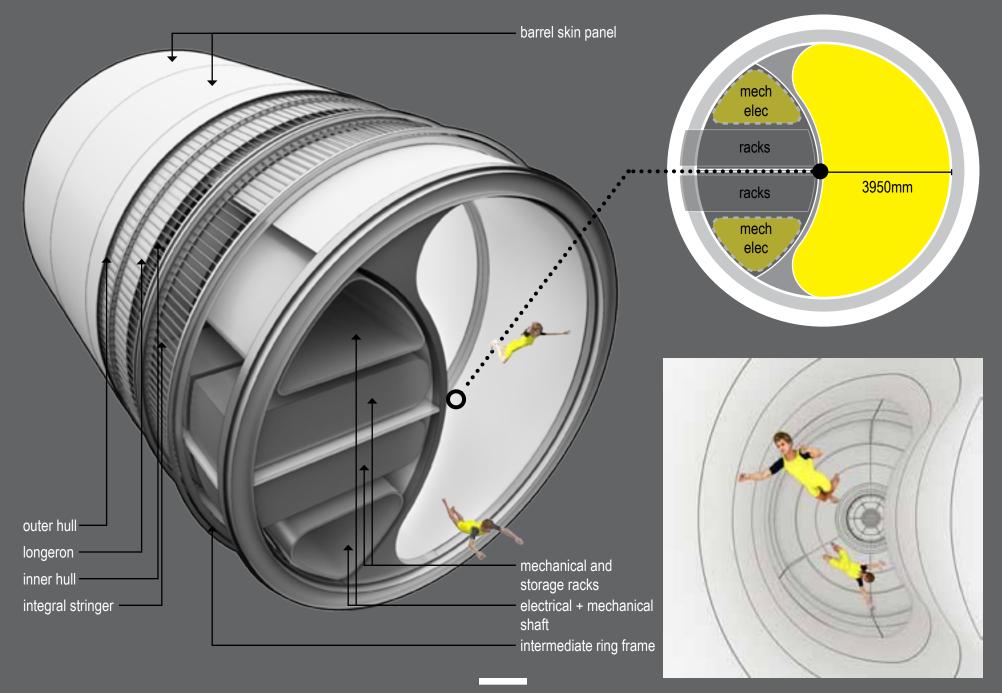


### INTERIOR TYPE a.ii DOUBLE LOAD CONTOUR

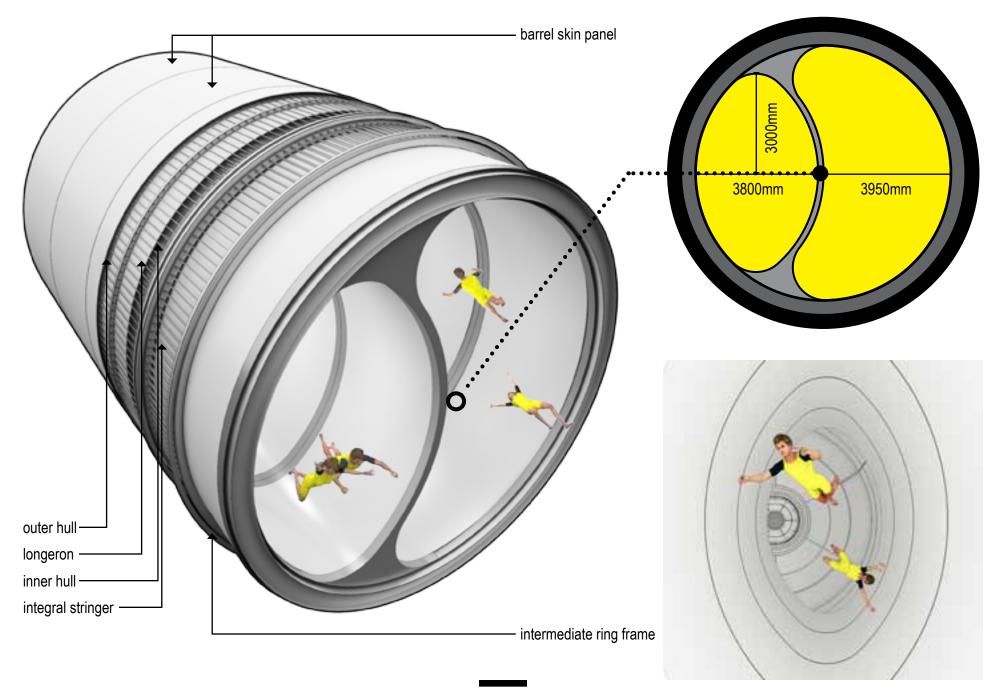
[4.3.5b]



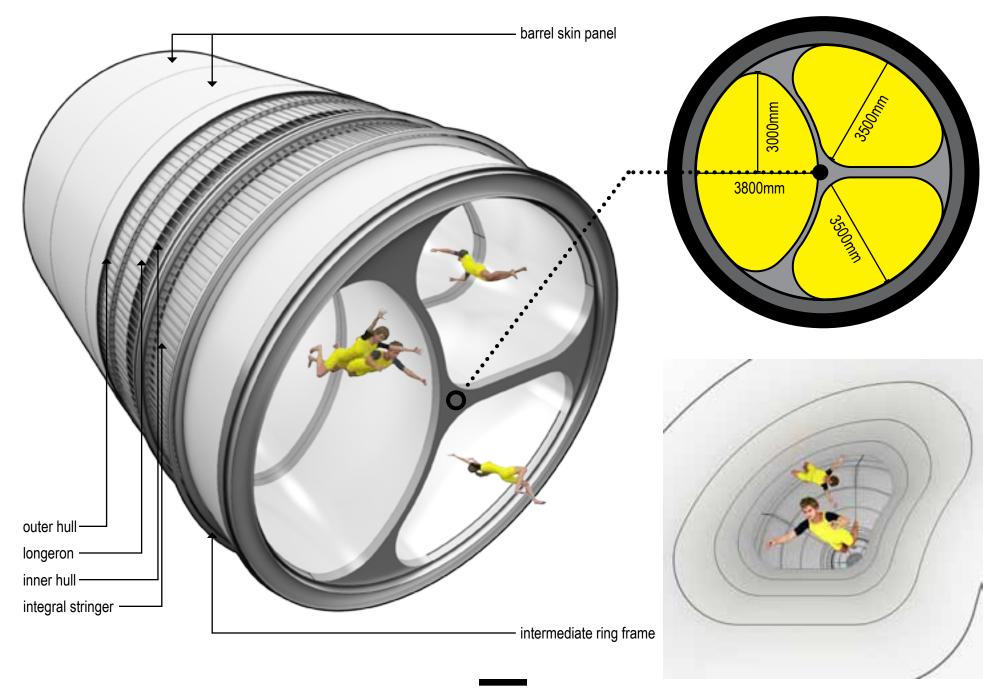
# INTERIOR TYPE b.i [4.3.5c] SINGLE LOAD OFFSET



## INTERIOR TYPE b.ii [4.3.5d] DOUBLE LOAD OFFSET

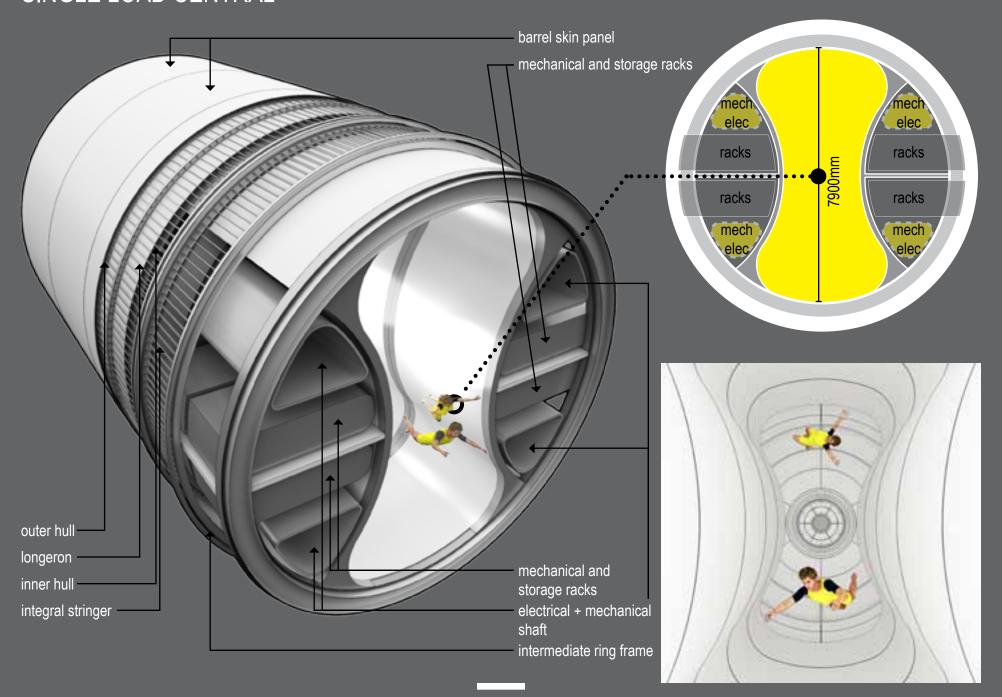


## **INTERIOR TYPE b.iii** [4.3.5e] TRIPLE LOAD OFFSET

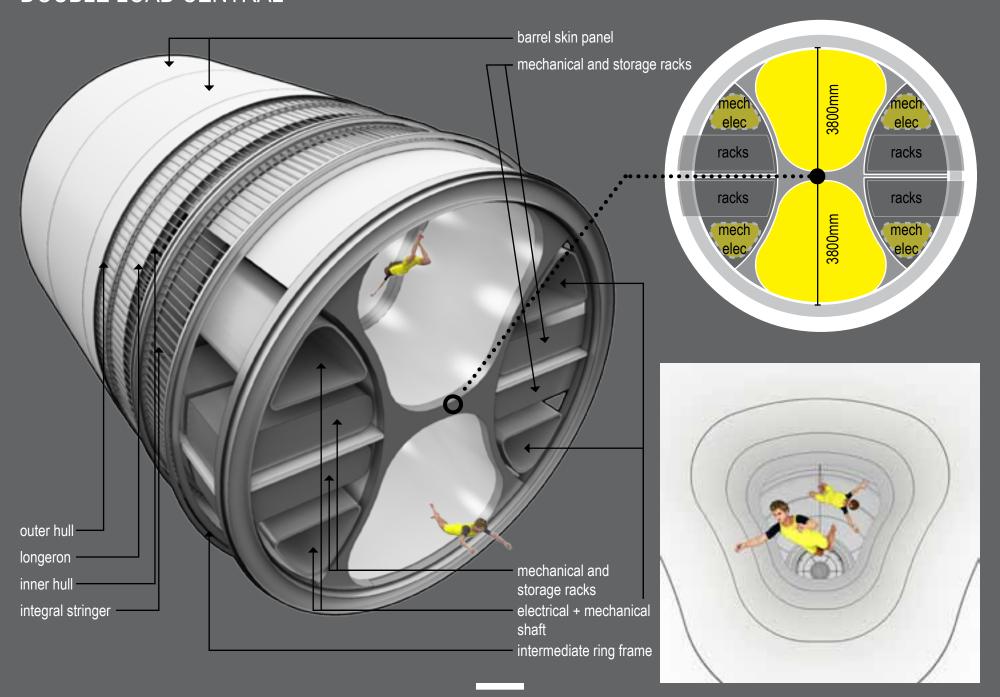


#### INTERIOR TYPE c.i SINGLE LOAD CENTRAL

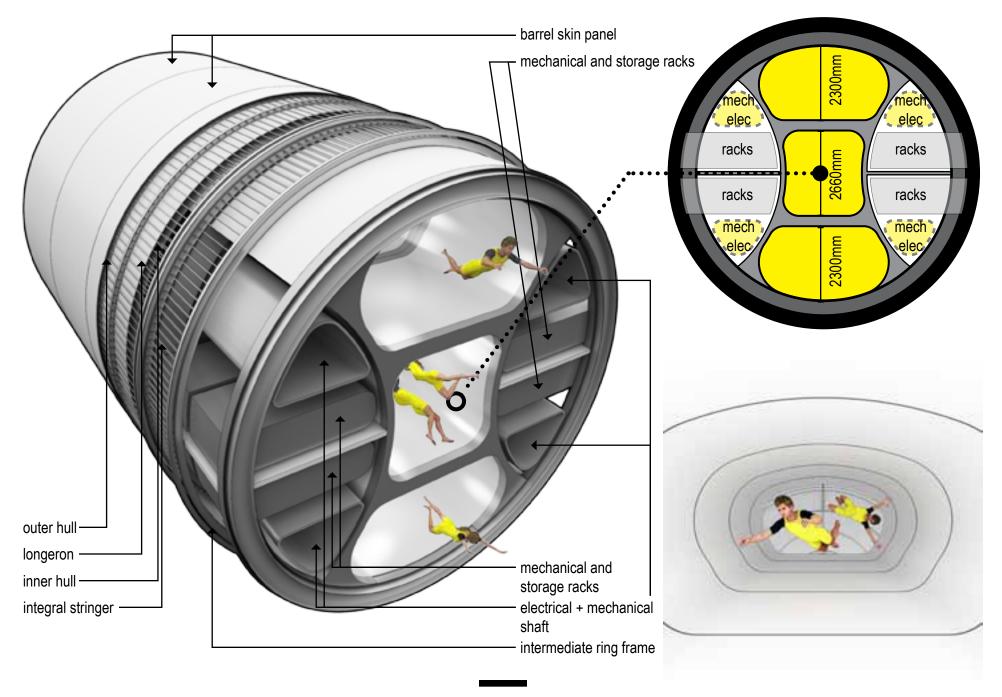
[4.3.5f]



### INTERIOR TYPE c.ii [4.3.59] DOUBLE LOAD CENTRAL

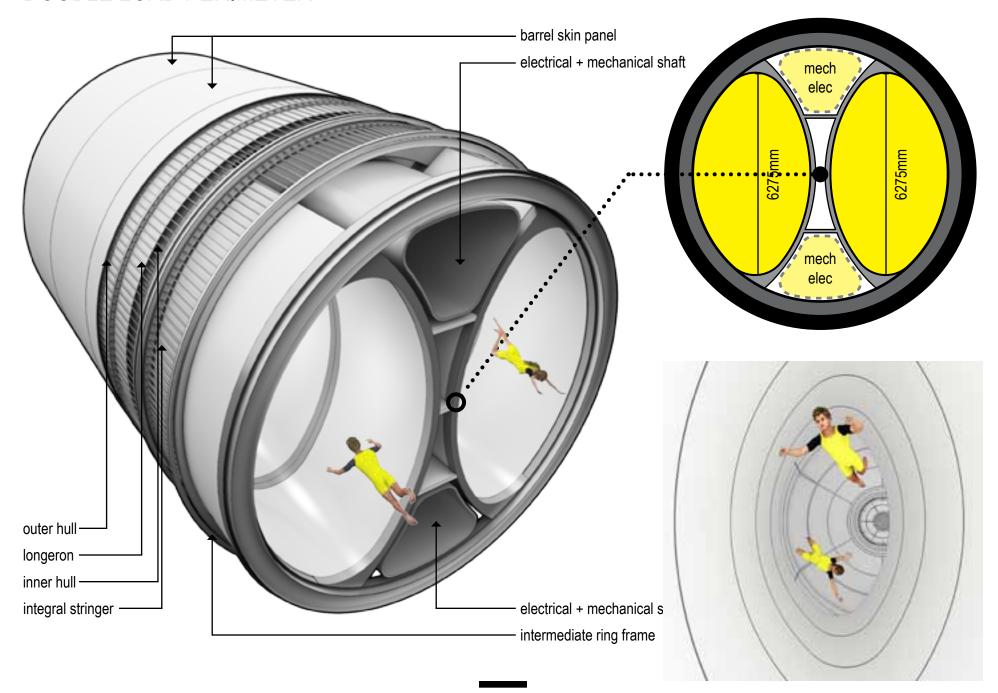


## INTERIOR TYPE c.iii [4.3.5h] TRIPLE LOAD CENTRAL

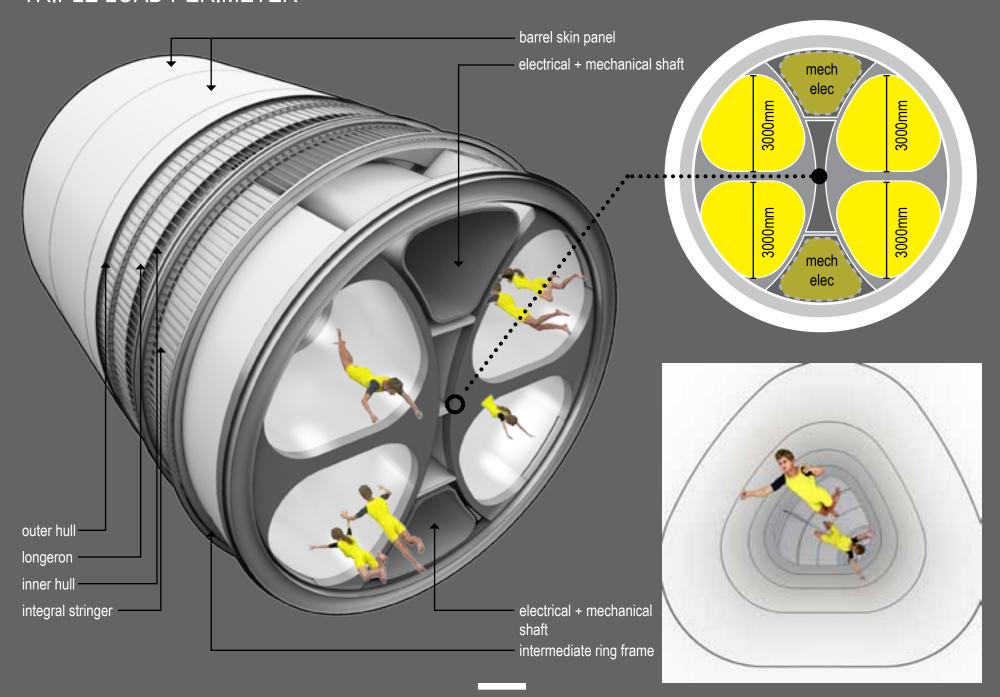


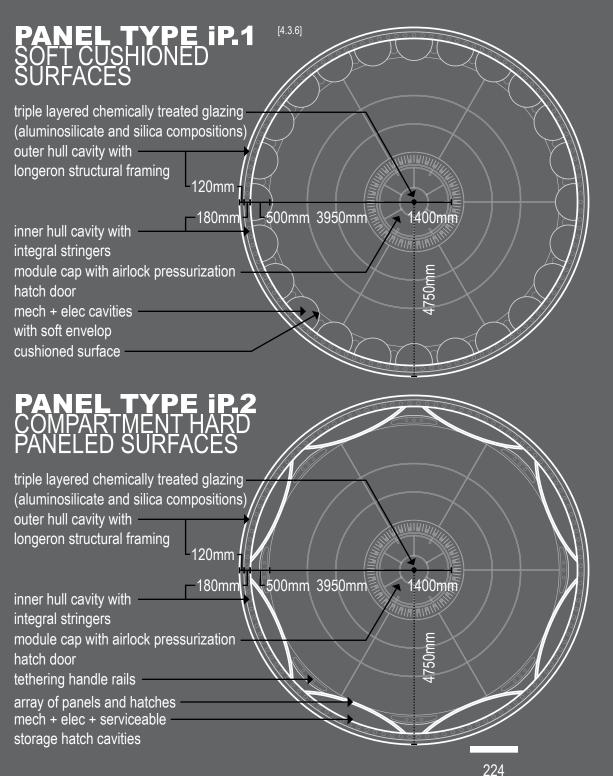
#### [4.3.5i]

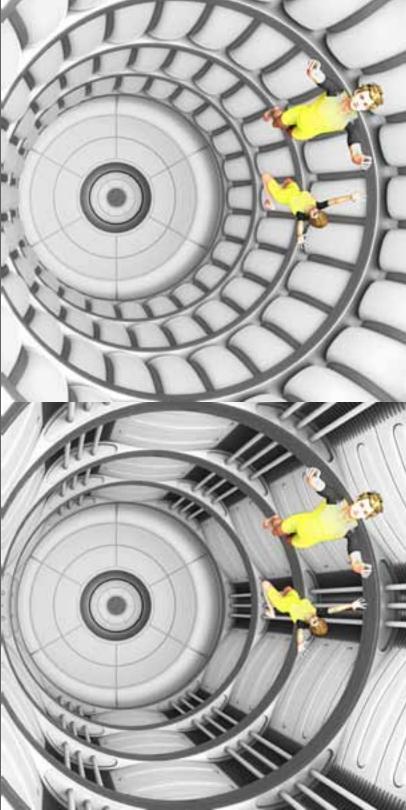
#### INTERIOR TYPE d.ii DOUBLE LOAD PERIMETER



# INTERIOR TYPE d.iii [4.3.5] TRIPLE LOAD PERIMETER







When furnishing the interior volumes of the retrofitted external tanks, designers need to pay great attention to the selection of the finishes, as this can critically affect issues of physical safety. For the most part, finishes are designed as prefabricated panels of soft pillows or hard surface hatches that are delivered with considerations of the maximum spacecraft payload capacities.

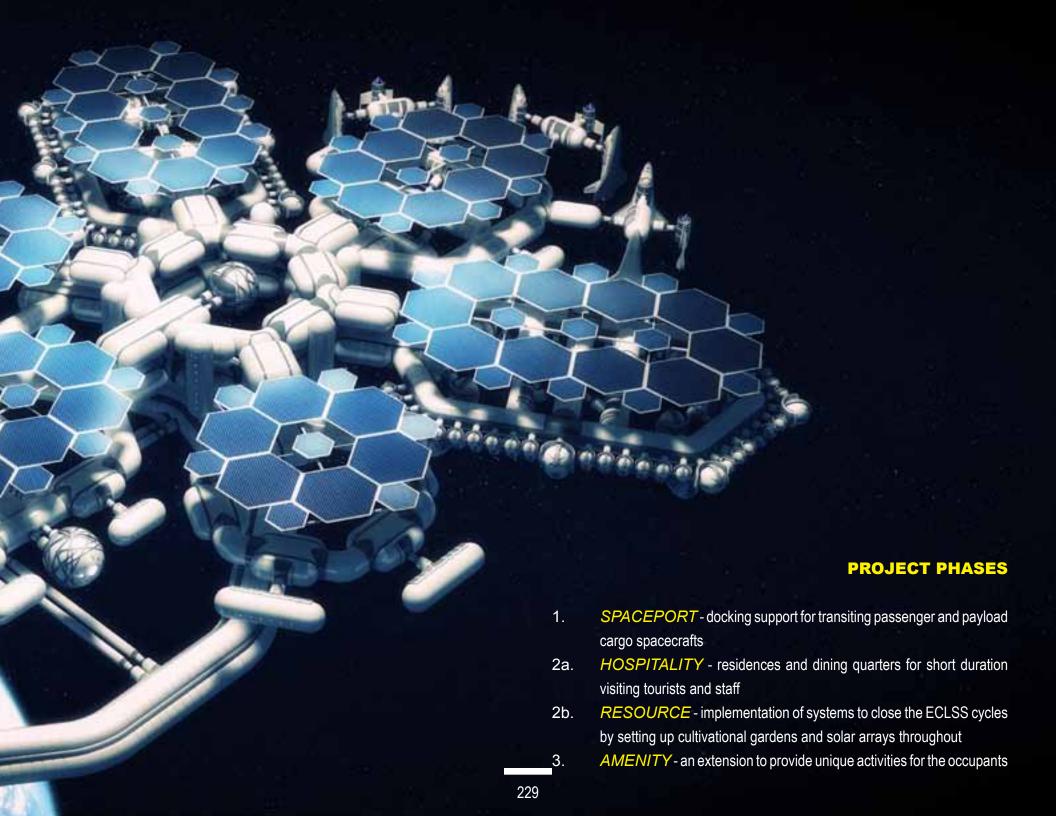
Generally, soft material surfaces, usually cushioned by a layer of padded gel, foam, or inflatable materials sheathed with soft fabrics would be recommended for most spaces. This goes especially for those areas designed for a high density of occupants, such as public spaces that are used for high-impact and motional activities. It is also recommended that in areas of initial exposure to the novelty of weightlessness (i.e. the docking ports), designers should pay extra attention in carefully selecting an extra-soft finish for these spaces to allow first-time space travelers to experiment with and adapt to the new forms of maneuvering in outer space. Hard surfaces can sometimes be handy when spaces require accessible storage and options to maintain mechanical and electrical systems in the cavity zones of the module sections. It is recommended that these finishes are only considered for lower-density zones or in functional spaces for specific activities that require minimal movement (e.g. reading in a library, doing experiments in a laboratory, etc.).



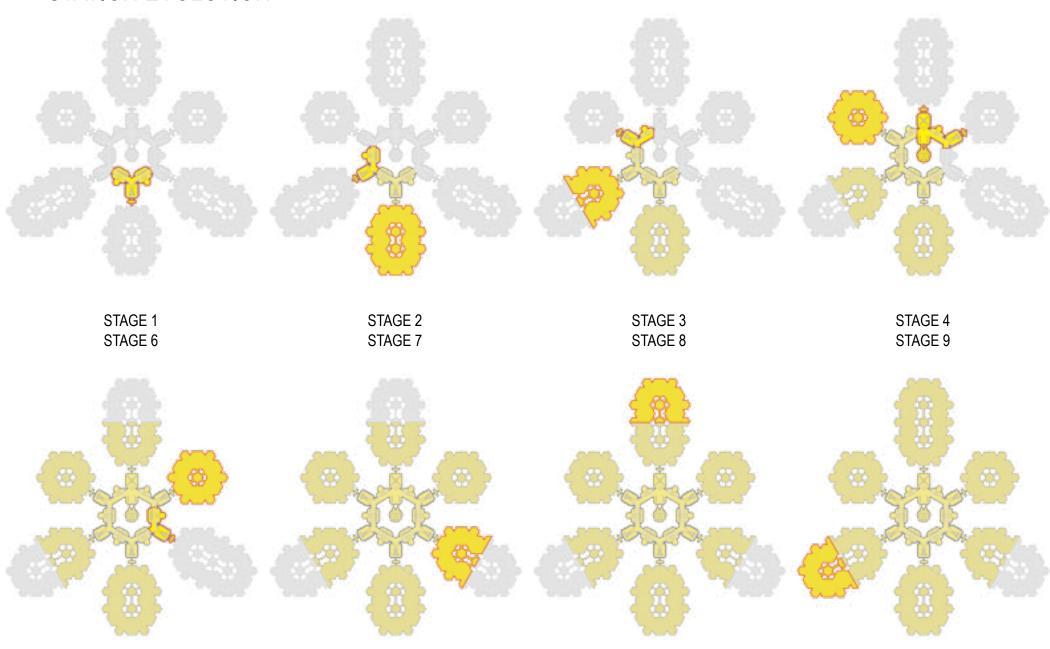


# AERO ASTRO

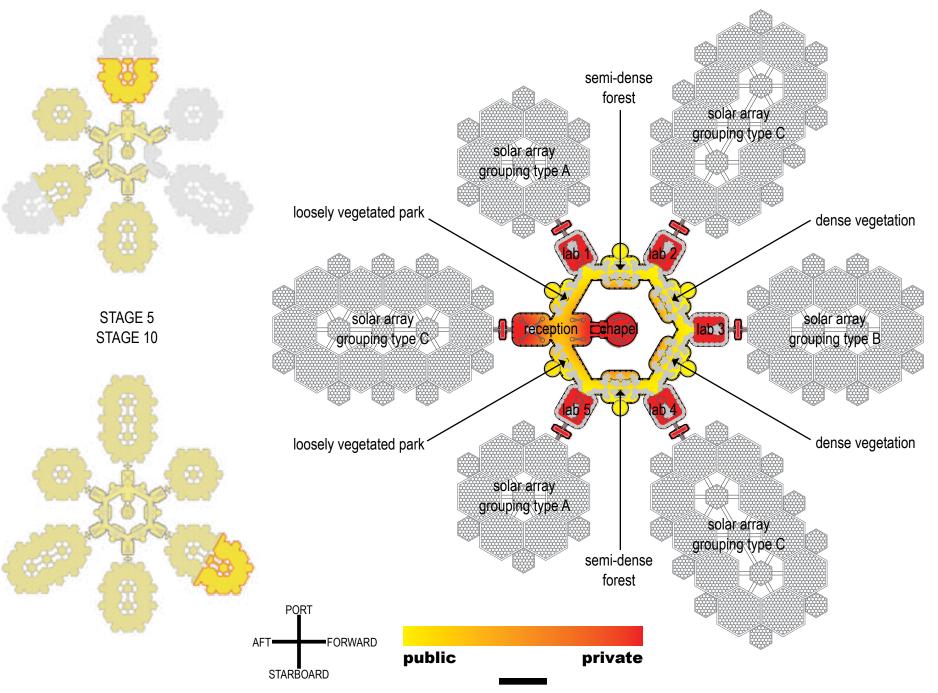


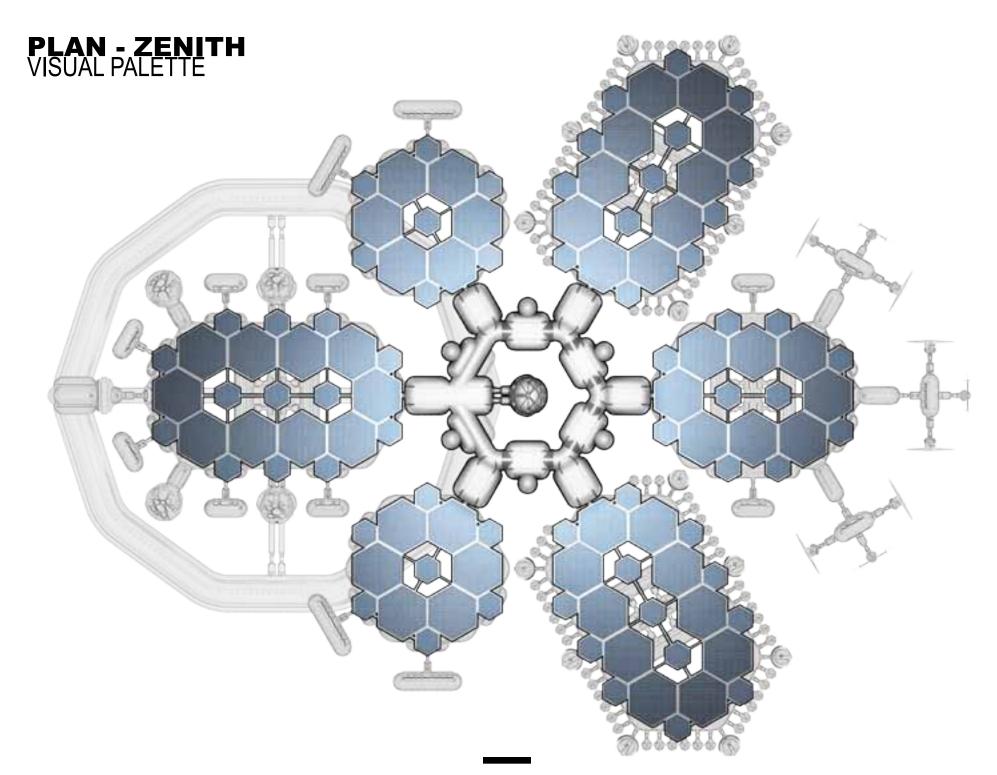


## **PHASING** STATION EVOLUTION

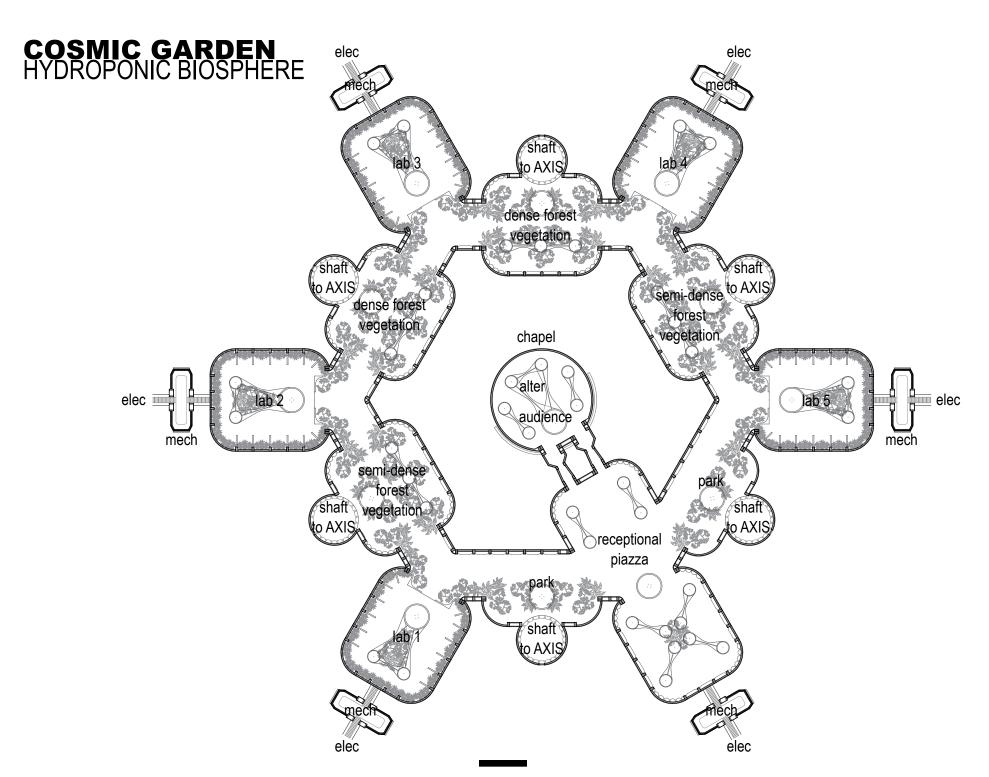


### PLAN - ZENITH CIRCULATION

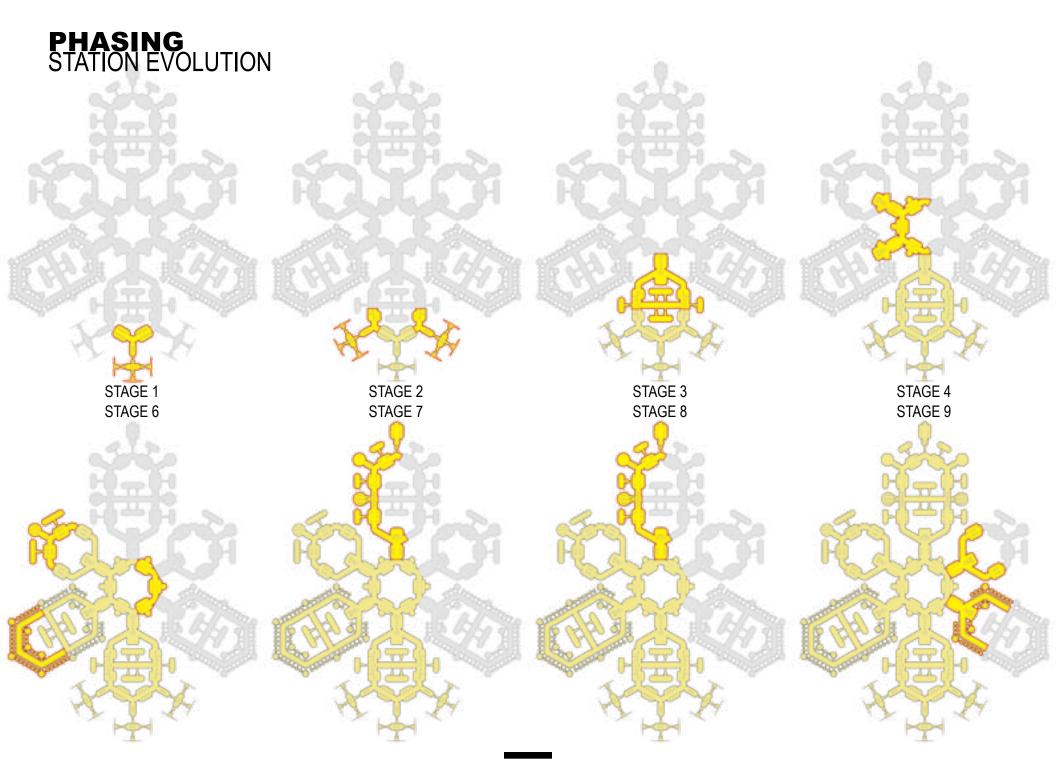




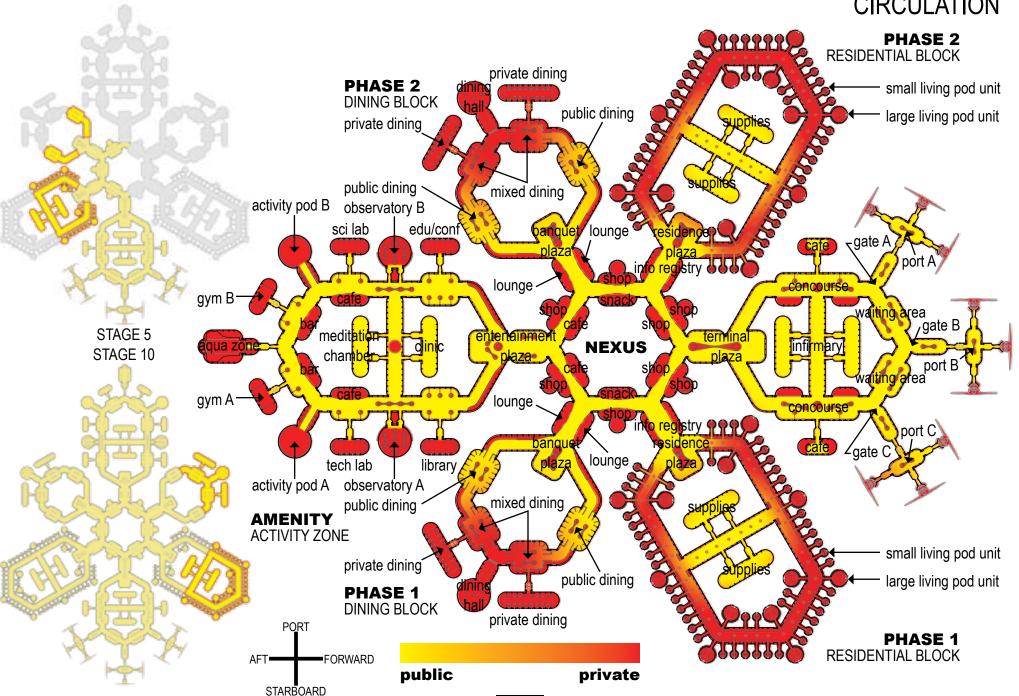


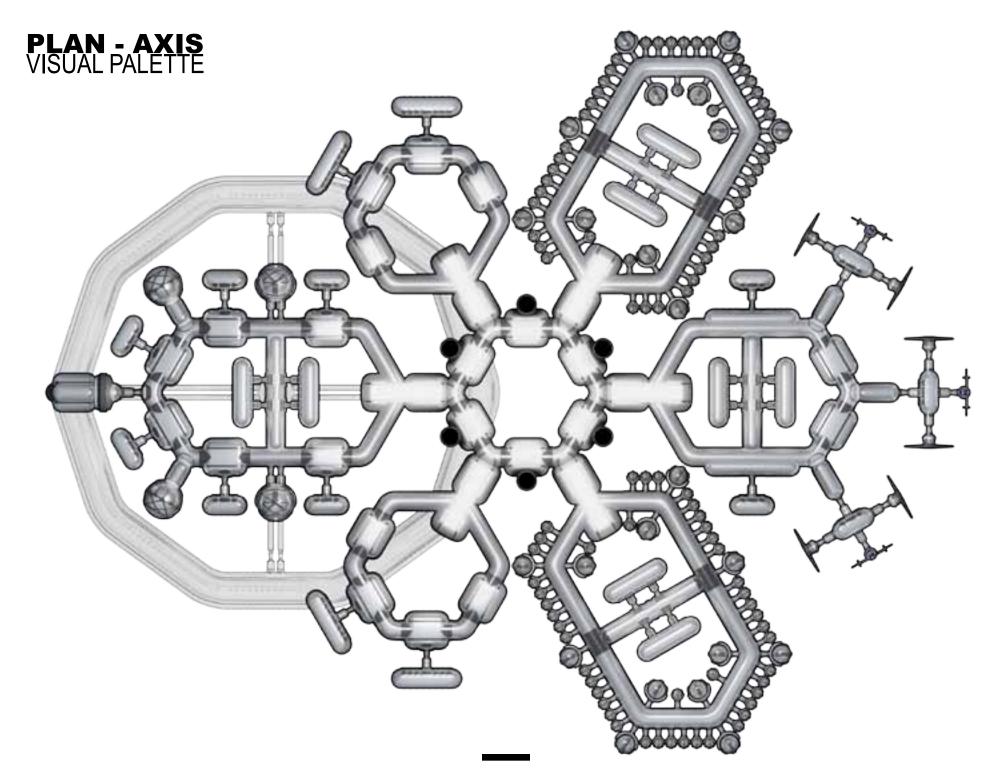


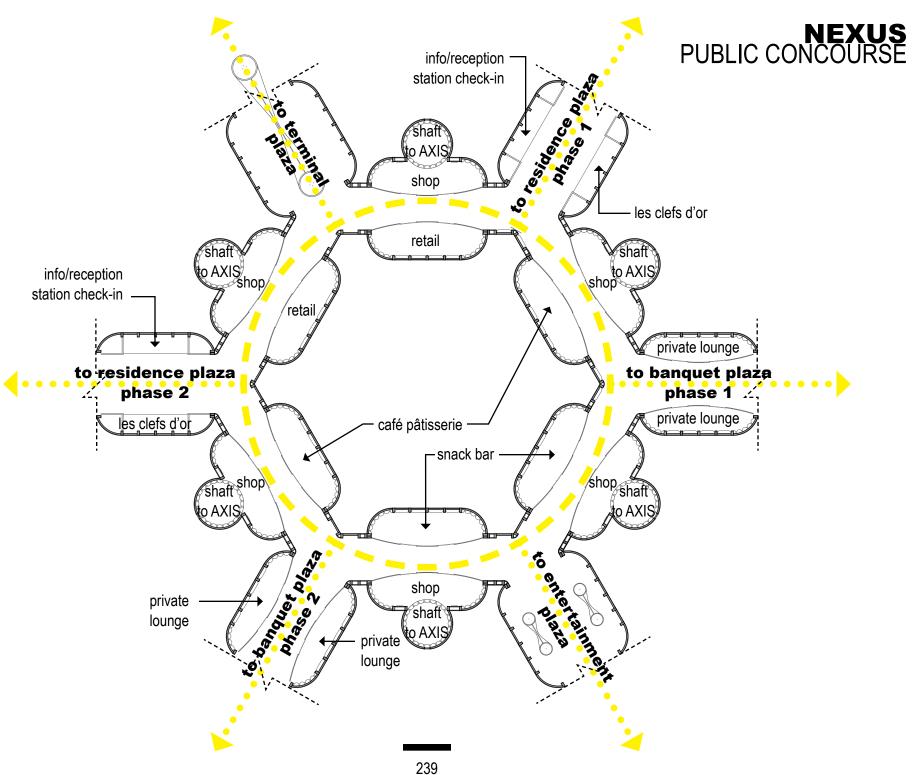


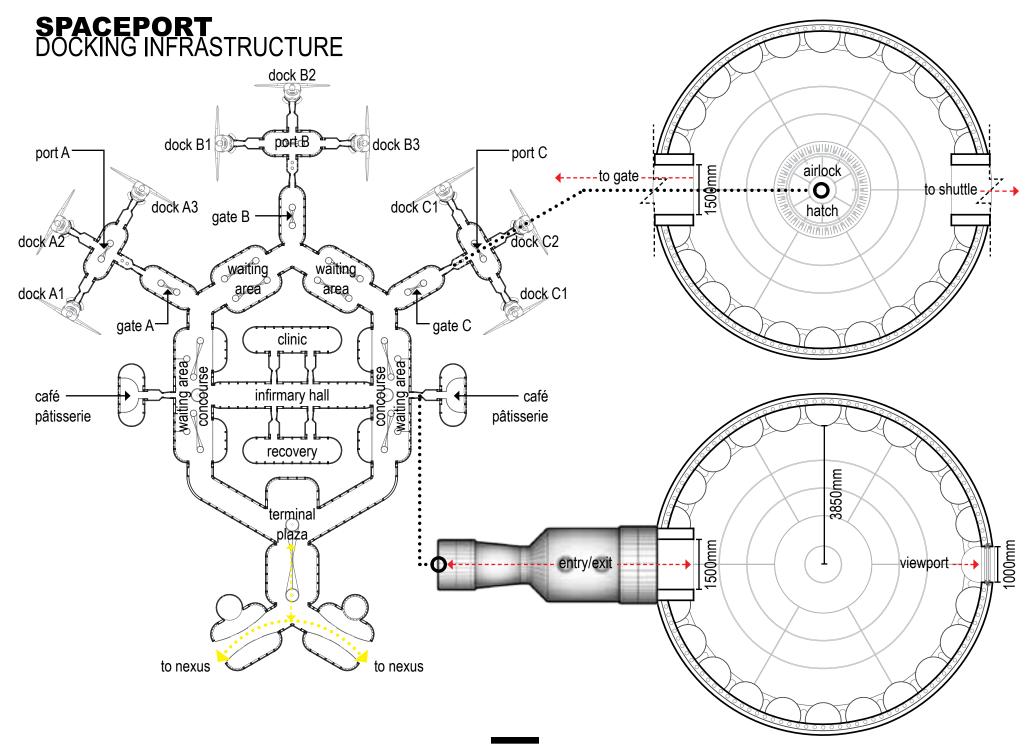


#### PLAN - AXIS CIRCULATION

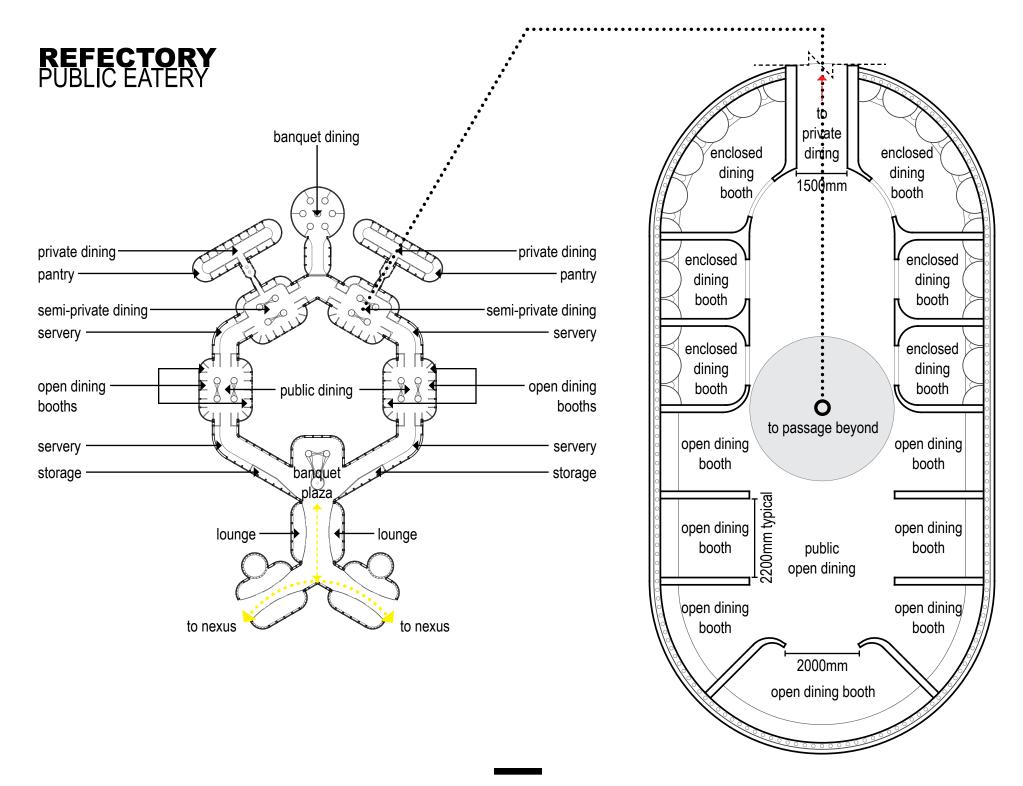


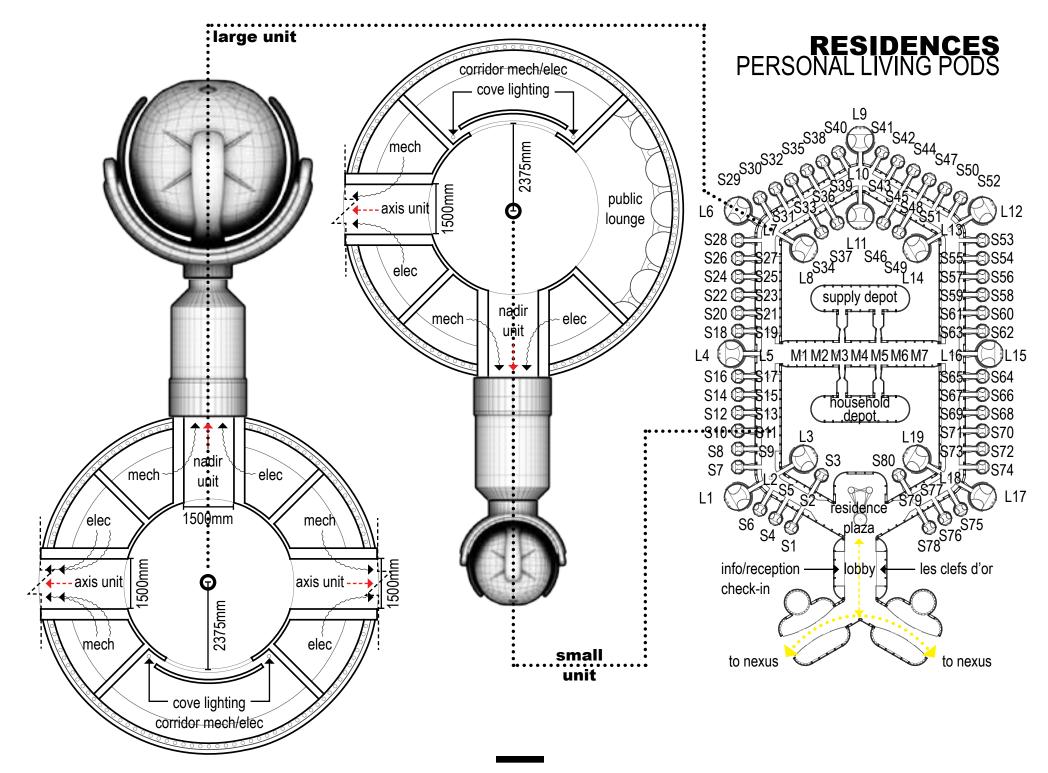






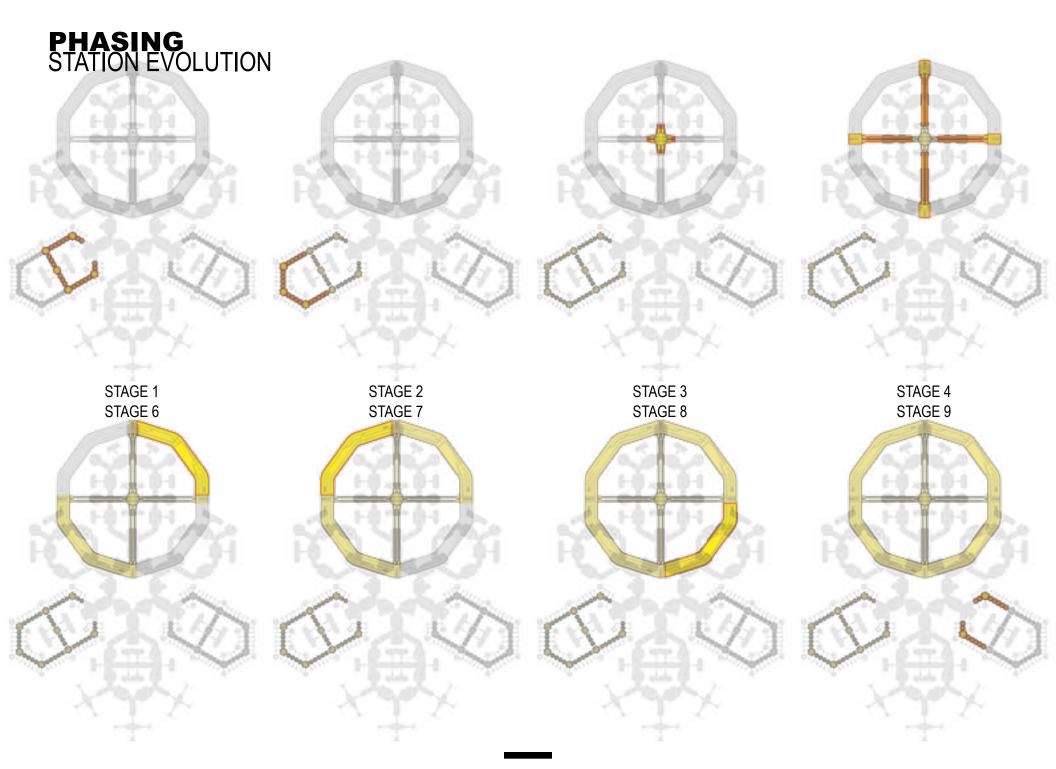




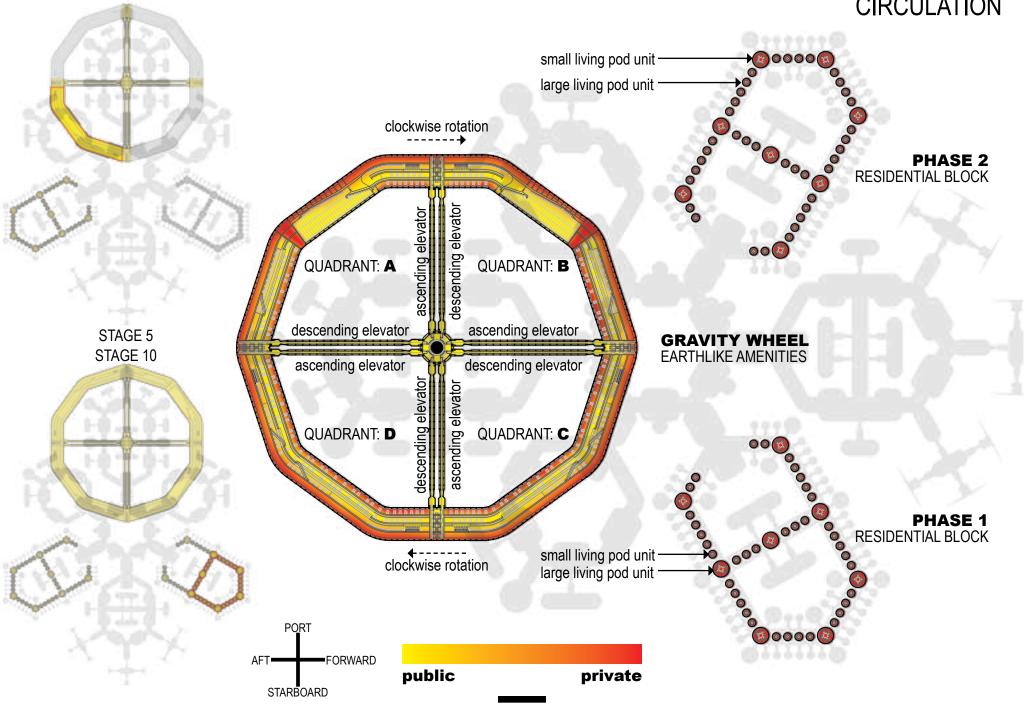


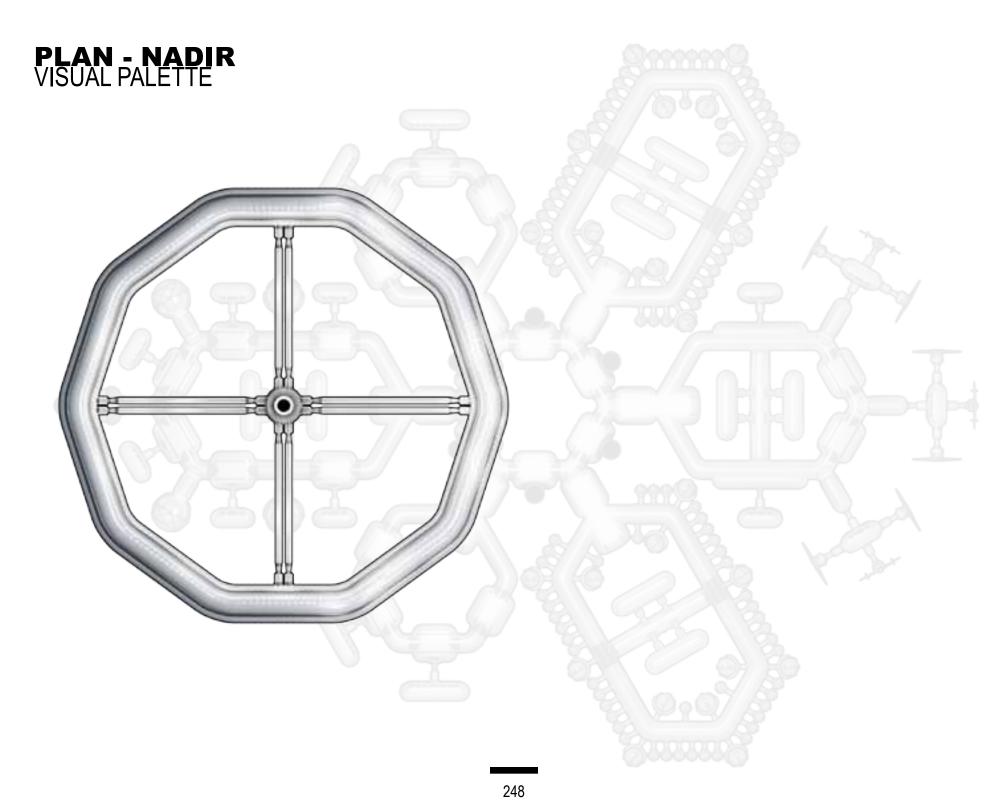
#### **ENTERTAINMENT**DOCKING INFRASTRUCTURE jacuzzi jacuzzi seating deck dry stations 6900mm gym B - resistance gym A - cardio pool pool 4750mm activity activity pod B pod A 18500mm pool café pâtisserie tech lab science lab meditation chamber mech + mech + filtration filtration to gravity module observatory observatory system system 1250mm rehabilitation center library education center platform deck entertainment \_plaza female male change change dry dry station station to nexus to nexus





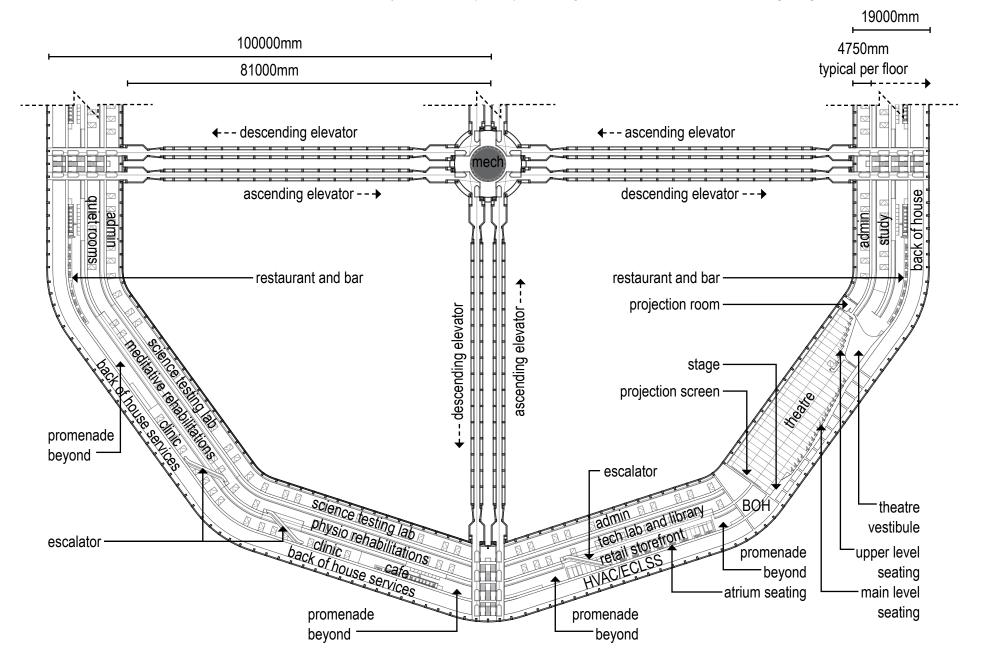
#### PLAN - NADIR CIRCULATION

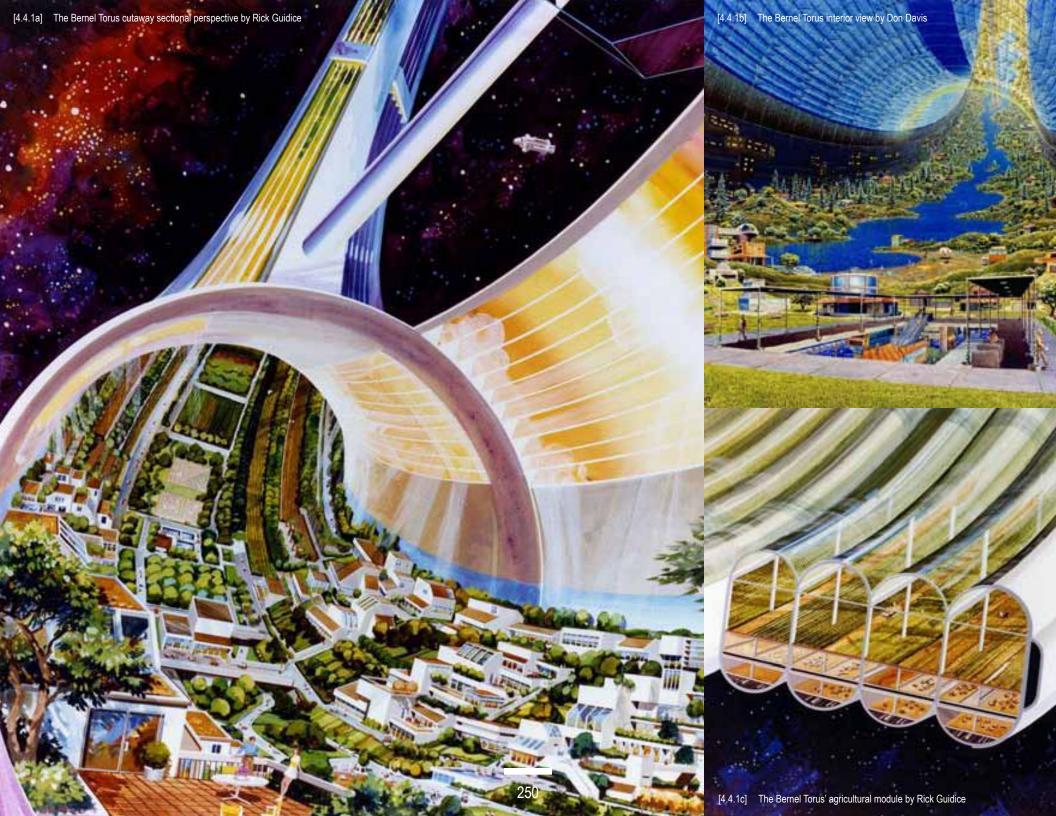




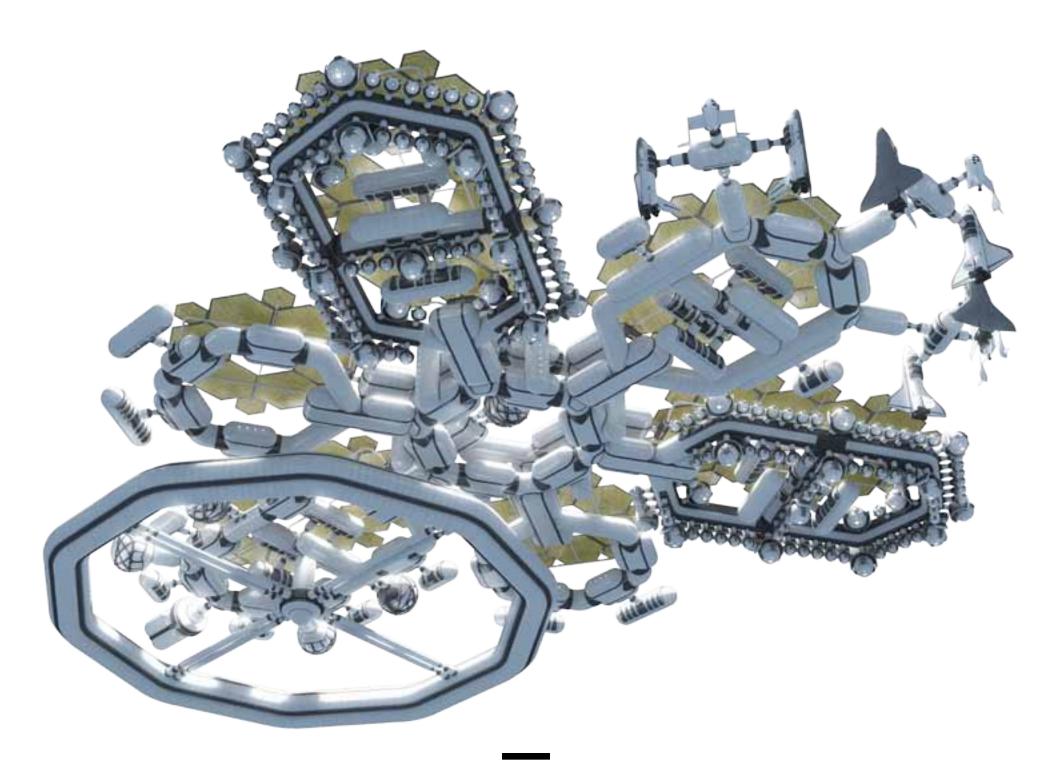
## **GRAVITATY WHEEL** PUBLIC AMENITIES

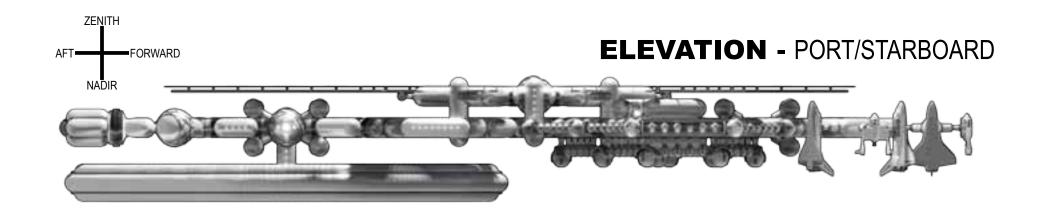
\* concept of artificial gravity module reflects the 1970 idea of the Bernel Torus while adjusted in size (radius) according to the comfort chart described in [3.2.4]

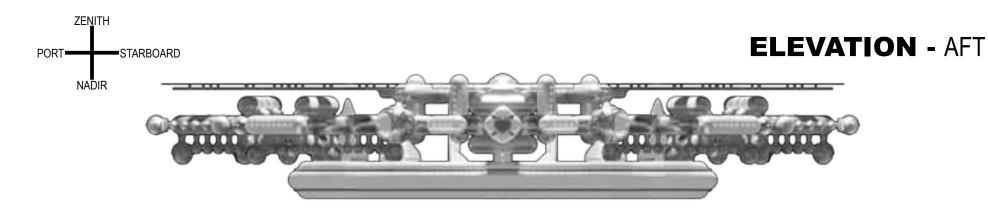


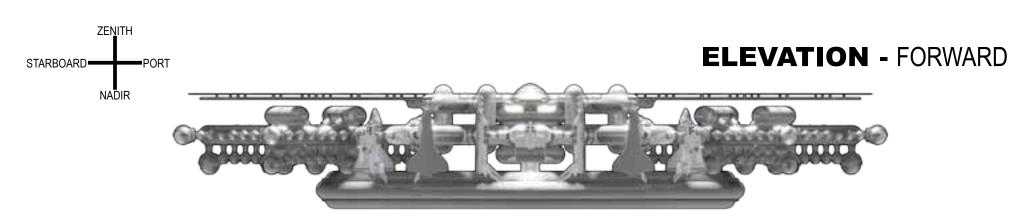




















living in space: the experience of unique daily rituals

The daily rituals to which people have become accustomed on Earth are directly connected to both culture and an environment influenced by gravity. Many actions and routines that were learned during infancy and early childhood have become entirely instinctual. These include rituals that maintain one's physiological and psychological health, such as eating and sleeping, while typical movements such as walking and running are also important transmigrated functions that one fluidly performs on a regular basis under earthly conditions. As one enters the unfamiliar settings of outer space (this would include the weightless environment and the lack of breathable air), one's quality of life and instinctual judgments will literally be turned upside down. Carrying out even the most mundane of activities will require a significant adjustment. In addition to daily personal rituals related to health and hygiene, rituals affected will also include social interactions amongst peers when under disoriented perspectives. For example, the new problems encountered in dining without the ability to stabilize eating utensils and food; sleeping without the provisions of a source for grounding oneself due to lack of gravity; and even the simple act of passing another passenger in a corridor without unwanted close interaction due to the inability to control movement and travel directions.

In the subsequent sections, a proposal for conceptually addressing these space-centric issues will be explored in relation to the developments for the AERO | ASTRO space station. For instance, the ritual of interpersonal communication has always taken place within preferred comfort zones as derived by various distances offset from one's personal space. It is important to note that personal space on Earth is typically depicted by a two-dimensional plane centered to oneself as it extends radially to the person of interaction. However, in outer space, with one's lack of orientation and the ability to float about within an environment, one's personal space will have to be altered from the conventional area model to a volumetric zone depicted as a three-dimensional bubble that surrounds oneself. By exploring the volumetric scales of these personal bubbles, designers can create and arrange public and private environments that avoid the unwanted overlaps to its occupants' personal spaces. In addition, special apparatuses can be designed to control the separation between the people who are in dynamic motion with those under static postures.

right "The Origin of Species" by Charles Darwin, page 114-115, 1859

ext [4.5.1] Personal space bubbles as understood in 2D for terrestrial applications and in 3D as a bubble in space

[4.5.2] A variation of the personal space bubble diagram introduced by Edward Twitchell Hall in 1966

[4.5.3] Spatial rendering of personal spaces interacting within an architectural setting (Milwaukee Art Museum) on Earth

"Journal of Applied Social Psychology - Volume 34, Issue 4" by Catherine MJ Beaulieu, page 794-805, April 2004

[4.5.4] Personal space proximity analysis

[4.5.5] Personal space overlap relationship diagram

[4.5.6] Overlap relationships of personal space in archetypal sections of AERO|ASTRO modules

"...the mere existence of individual variability and of some few well-marked varieties, though necessary as the foundation for the work, helps us but little in understanding how species arise in nature. How have all those exquisite adaptations of one part of the organisation to another part, and to the conditions of life, and of one distinct organic being to another being, been perfected?...Owing to this [the] struggle for life, any variation, however slight and from whatever cause proceeding, if it be in any degree profitable to an individual of any species, in its infinitely complex relations to other organic beings and to external nature, will tend to the preservation of that individual, and will generally be inherited by its offspring. The offspring, also, will thus have a better chance of surviving, for, of the many individuals of any species which are periodically born, but a small number can survive. I have called this principle, by which each slight variation, if useful, is preserved, by the term of Natural Selection, in order to mark its relation to man's power of selection. We have seen that man by selection can certainly produce great results, and can adapt organic beings to his own uses, through the accumulation of slight but useful variations, given to him by the hand of Nature."

"The Origin of Species" by Charles Darwin

# personal space bubble for infinite approach points within disoriented environment of outer space sampled subject subject's personal space boundaries as on Earth [4.5.1a] [4.5.2a] personal space bubble for infinite approach points within disoriented environment of outer space sampled subject intruding subject subject's personal space boundaries as on Earth [4.5.1b] [4.5.2b] 260

### PERSONAL SPACE GENERAL BOUNDARIES

Amongst the most sacrosanct rules in social behavior, the tolerance of permissible entry into a neighbor's personal space bubble is a highly variable topic in which it is dependable on one's cultural and personal upbringing throughout the individual's life. Therefore, only indicative figures are used for the diameters and a suggestive rule of thumb for cross cultural interactions: stay one step back from your own comfortable boundary.

## PERICUTANEOUS INTIMATE SPACE

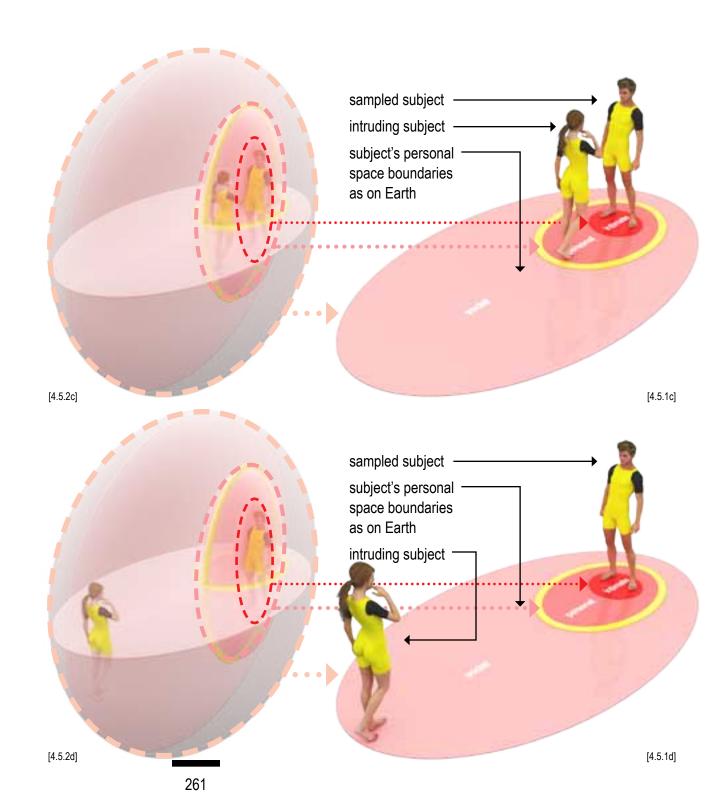
The intimate space is a reserved space for private and close relationships between people as it occurs within an individual's reach capacity of about 0.45m apart. Therefore, typically only lovers, children, and close family members will be able to breach this proximity without a confrontation, but not to mention, close friends and animal pets are sometimes made exceptional to this parameter.

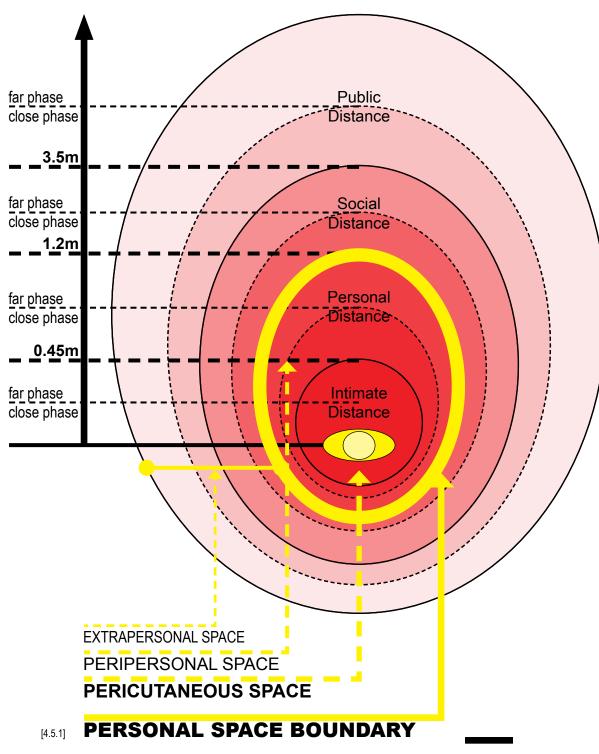
# PERIPERSONAL PERSONAL SPACE

Beginning from the edge of the intimate range, the personal space is typically within the reach of any limb on an individual. This boundary ranging from about 0.45m to 1.2m is a comfortable zone in which social interactions are generally initiated between individuals. Within conversational range, an individual is loose with minimal security issues in the amygdala of their brain and will provide confident eye contact in the exchange.

# **EXTRAPERSONAL** SOCIAL SPACE

Visual tactile perceptive fields overlap within the processing of those entering this space. It is an instinctual realm just out of touch by one's body but still within the proximity between parties. This space is about 2.4m to 3.5m away from the body and is usually set aside for acknowledged strangers and newly developed acquaintances who are just within one's associated social group while the general public lies beyond.

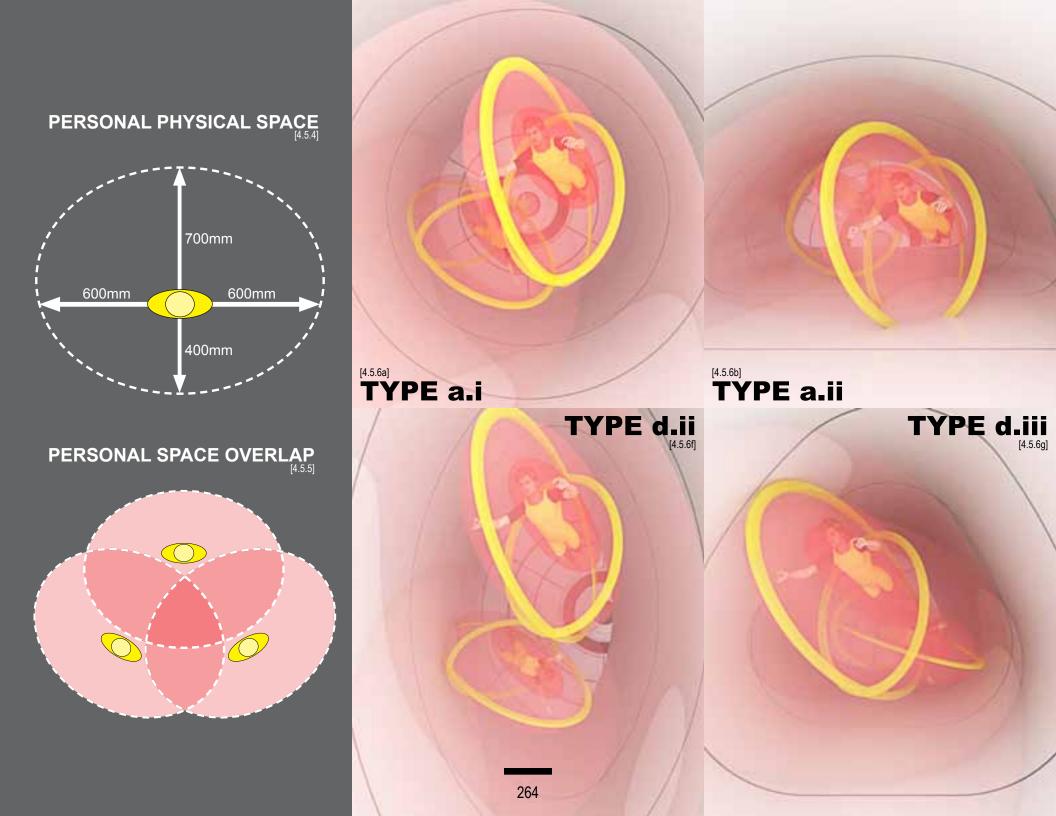


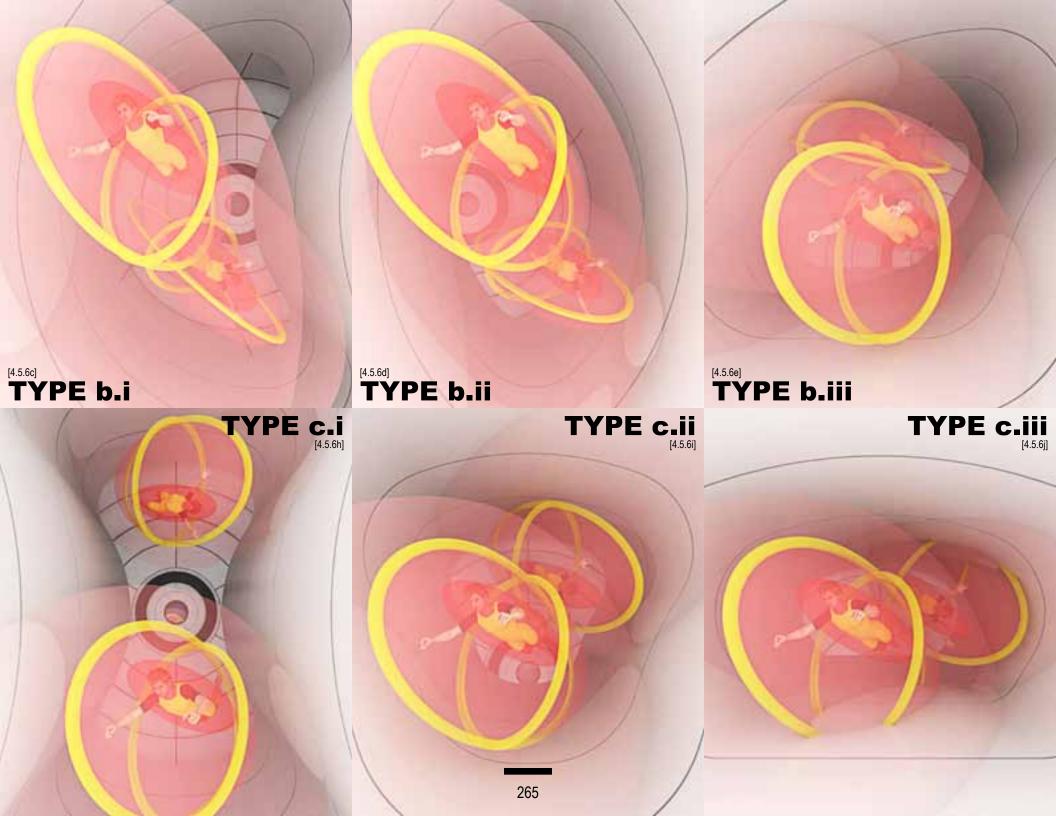


The measurements for these zones of comfortable distances will vary dependent on different cultures. On AERO ASTRO, multinational space station, it will be inevitable will that conflicts arise between the various ethnic groups when their comfortable zones clash. Therefore, as a general thumb. as rule Earth, occupants should generally keep an area around their body that is around an arm's length to another occupant to stay approximately outside proximity of one's The intimate distance. development of apparatus and interior spaces should also comply with this rule allowing enough space for maneuvering for the occupants to stay at least within this short distance of an arm's length.

"This invisible three-dimensional zone that we call personal space can be envisioned as a bubble around a person. Difficult to measure, the invisible zone exists around a person, is fluctuating, and is a part of a communication style. Most of the time, a person becomes aware of his or her personal space by the feeling of irritation or malaise when another person invades the space...personal space is a mediating, cognitive construct, which allows the human organism to operate at acceptable stress levels. On the other hand, in the growth process, all humans beings are shaped by the environment and learn spatial cues that tell them how to behave and regulate interpersonal interactions. Thus, personal space is acquired and varies according to culture... The personal space between people depends on the amount of space available in the room (Freedman 1975) and is determined by age group, gender, affiliation, role, activity, setting, social class, region, and culture. The distance between two persons also varies from interpersonal emotion response reflecting on their relationship."

"Intercultural Study of Personal Space: A Case Study by Catherine MJ Beaulieu





Lack of gravity in outer space causes severe loss of coordination and orientation for the inhabitants of the space station. Without counteracting forces such as gravity on Earth, people and objects in the frictionless vacuum will never find themselves grounded and normal resting positions will be in floatation. These conditions will become major obstacles for simple movement through the proposed space station while provoking very complicated interactive experiences.

In order to assist occupants in their navigation through the space station, anchor points and handlebars will be designed and located to allow one to thrust themselves into any direction towards their anticipated destinations. Selective areas throughout the station will also host a labyrinth of multifunctional tether support bubbles [see 4.5.11] that will act as localization points of interests in public spaces while also allowing parties of people to connect onto and congregate with ease in a new space ritual of socialization. Rather than the conventional handshake or friendly hug, touring astronauts will develop new greeting rituals which may take the form of, for instance, sharing personalized tether rods to connect to one another.

To fully optimize this communal space ritual, discretionary outfits and gadgets will be made available for the occupants to ensure for a safe and fluid voyage on board the space station. A series of "spacesuits" will be provided to support the various activities available on the station, with each alternative designed to enhance the experiential qualities of its targeted activity. These sets of clothing and accessories (belts, wristbands, bandheld devices, etc.) [refer to 4.5.8, 4.5.9, and 4.5.10] will act as harnesses and come in various fashionable styles, while maintaining compliance to the kit of tethering attachment components (retractable wiring connectors, magnetic anchors, Velcro strippings, etc.) used throughout the station. These types of tethering attachments and methods will be based on existing precedents such as Baby Buddy toddler tethers, portaledge tethers, safety harness tethers used by the construction and rescue workforce, and many others. [see 4.5.7]

right

[4.5.7] Precedents for tethering apparatuses used in various situations on Earth

next

[4.5.8] Portable handheld tethering tool concept by NIKE SPARQ

[4.5.9] AERO|ASTRO specific fashion accessories for containing tether cords while acting as a portable tether anchor point

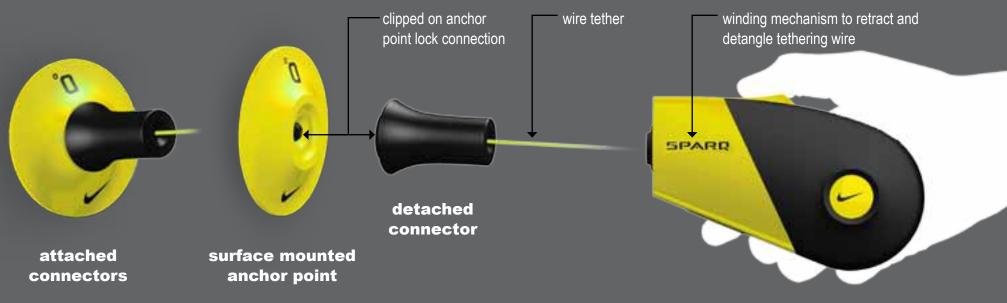
[4.5.10] AERO|ASTRO activity specific spacesuit fashion

[4.5.11] AERO|ASTRO Bubble, a public multifunctional tether point for general social needs throughout the station



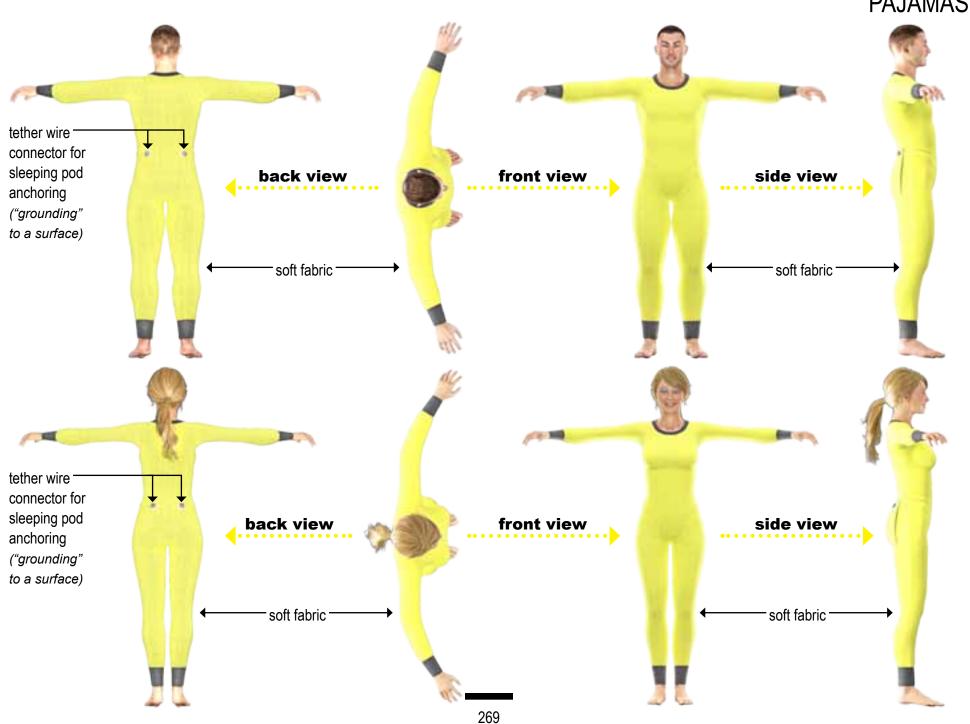


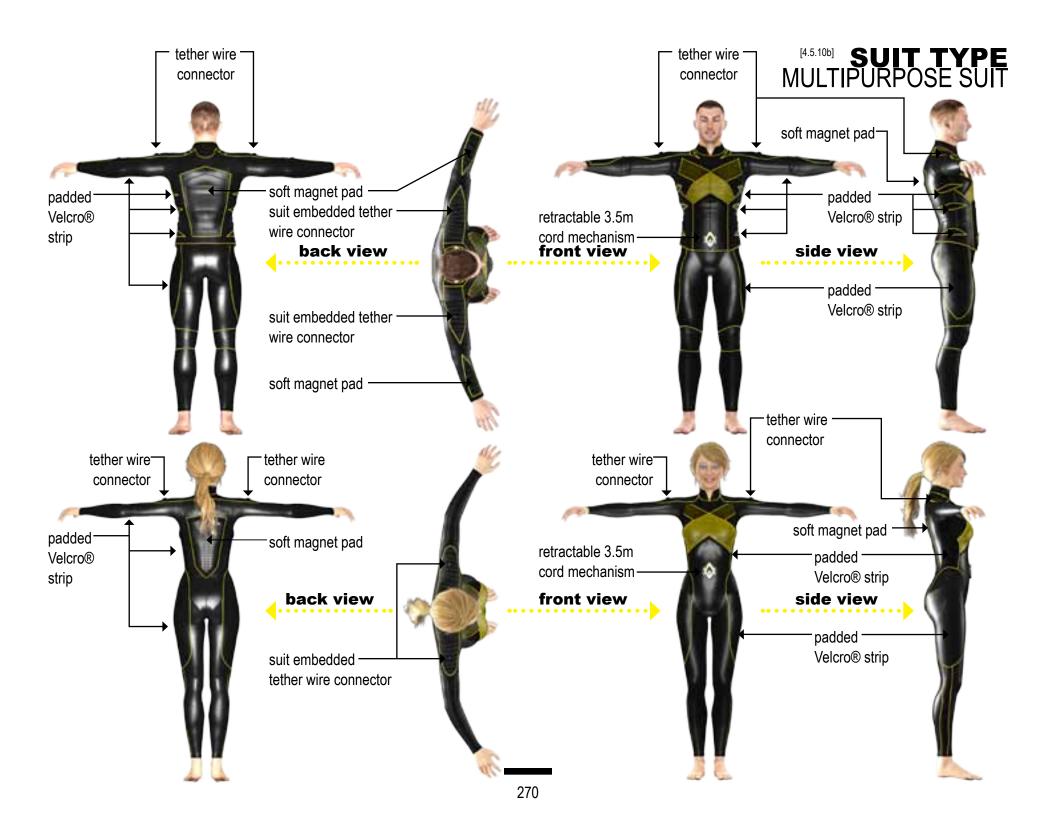
\* Precedent concept of NIKE SPARQ Viz Kit Eyeline Tool as a portable tethering device (pocket handheld apparatus)

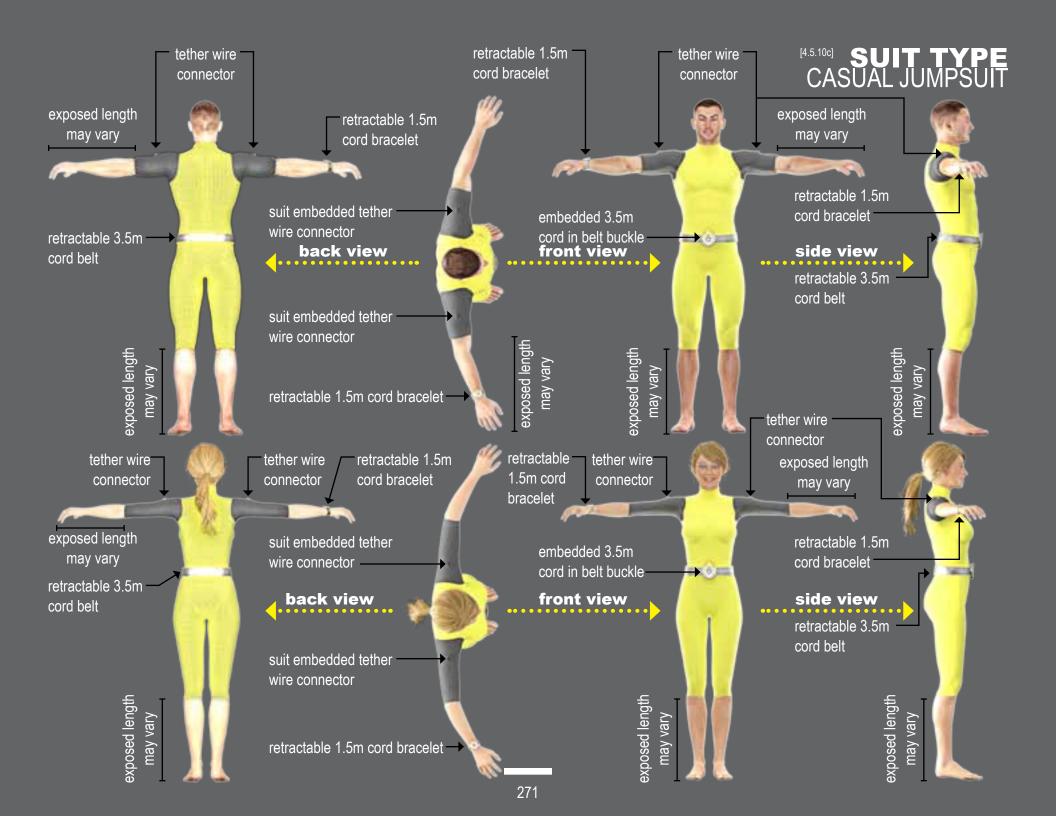


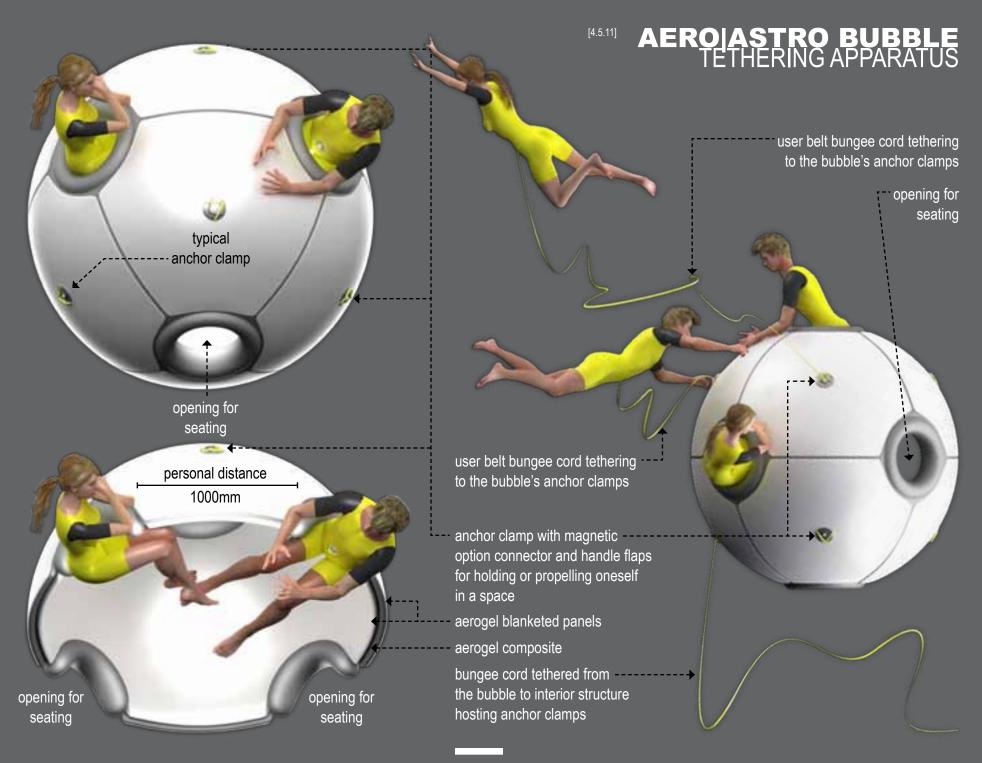


# [4.5.10a] **SUIT TYPE** PAJAMAS











Aside from having the essential apparatuses to assist one's mobility in space, the spatial planning of the station will build upon urban morphologies to create a "city-like" place. New cultural artifacts and space types will be created that respond to and build upon the person-to-person interactions as described in the preceding pages, as well as to other amenities that are provided, such as swimming or sports and activity facilities that have been designed to exploit the exciting potential of the zero-gravity-like environment. This guidance through architectural arrangements and interior elements will instigate new ritualistic values for the way one lives and operates in outer space. In addition, these strategies are essential to the continuity and preservation of an urban fabric's identity, time, and space, as it advocates the sense of permanence with its cultural artifacts and typologies shared throughout history and future generations.

On Earth, the public piazza (a pocket of public gathering space centralized within the core locations of a city) is considered a well-established place of interaction that offers foreigners an opportunity to engage and interact with the locals. This cultural experience is conducted by following a network of interconnected passages that migrate into an open congregational zone of the piazza. Usually surrounded by three- to five-storey buildings with an artistic monument centered to an architectural artifact, one is framed within the axial orientations of the piazza. As foreigners observe and begin to adapt to the rituals performed at the living stage, they in turn influence more newcomers who observe and adapt to their behaviours.

6 "A piazza (equivalent to the Spanish Plaza) is commonly found at the meeting of two or more streets. Most Italian cities have several piazzas with streets radiating from the center. Shops and other small businesses are found on piazzas as it is an ideal place to set up a business. Many metro stations and bus stops are found on piazzas as they are key point in a city.

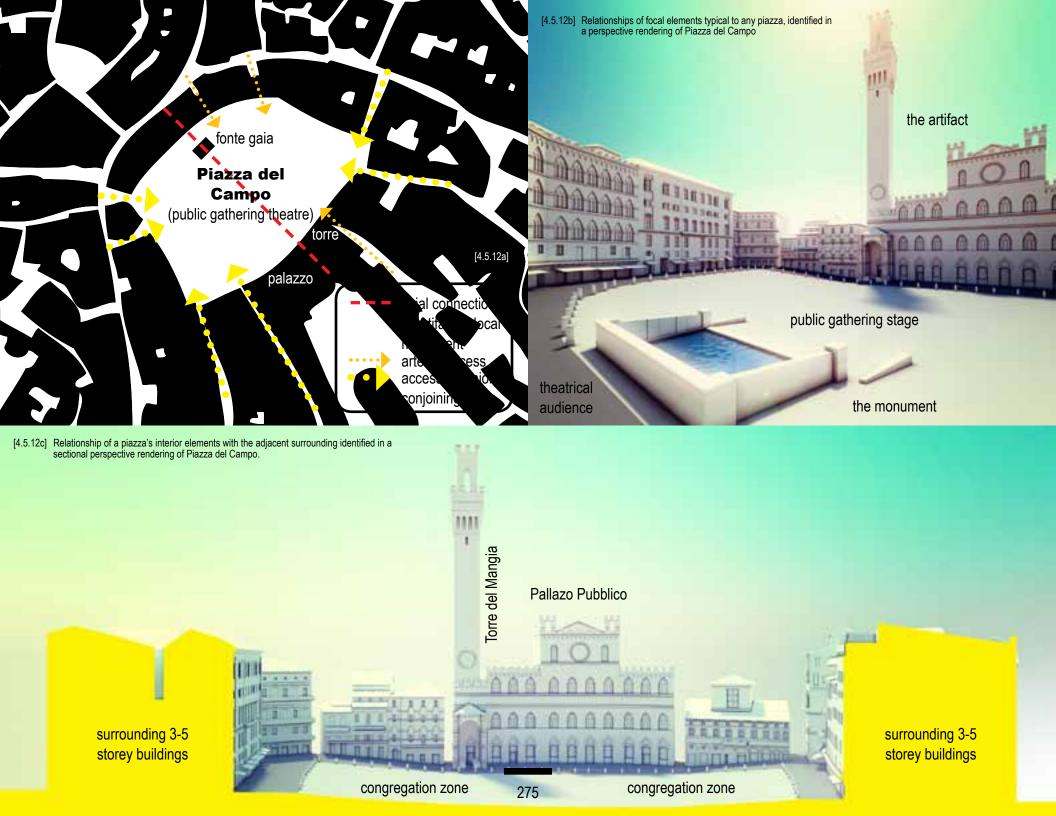
A plaza is a Spanish word related to "field" which describes an open urban public space, such as a city square. All through Spanish America and the Spanish East Indies, the plaza mayor of each center of administration held three closely related institutions: the cathedral, the cabildo or administrative center, which might be incorporated in a wing of a governor's palace, and the audiencia or law court. The plaza might be large enough to serve as a military parade ground. At times of crisis or fiesta, it was the space where a large crowd might gather. Like the Italian piazza, the plaza remains a center of community life that is only equaled by the market-place."

"Piazza/Plaza" contributors of Wikipedia, 2012

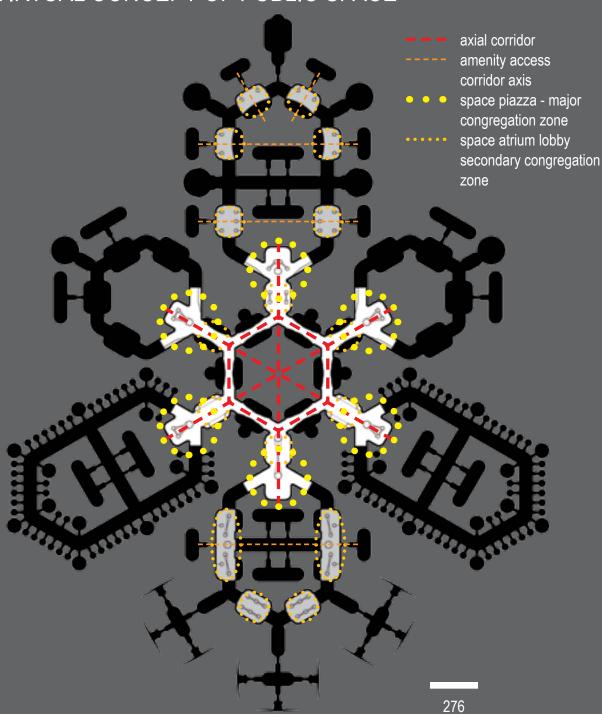
rignt

[4.5.12] The piazza typology on Earth depicted by a labelled Nolli map, rendered section and perspective of Piazza del Campo, Siena, Italy

[4.5.12a] Nolli map to identify spatial relationships of the circulations connecting to a piazza.



# AEROJASTRO PIAZZA [4.5.13] A VIRTUAL CONCEPT OF PUBLIC SPACE





In outer space, there are many complex variables and technicalities that limit designers in proposing socially hospitable concepts. However, building on the spatial morphologies and urban strategies from developments on Earth, space architects can derive new typologies specific to outer space applications that will generate a new sociable culture in space. By referencing iconographic principles from significant terrestrial precedents while integrating technological systems to the new outer space models, innovative lifestyle experiences can emerge as space dwellers adapt to the unique but responsive man-made environments.

Public places in space stations are very important for providing communal opportunities for experiential interchange and social interactions. Learning from piazzas and other public domains on Earth, space architects can create new typological principles when designing socially interactive spaces for spacefaring occupants. Piazzas in outer space are limited in scale and will not be able to directly correlate with the sectional scale of a piazza on Earth. However, key features such as axial orientations, converging circulation paths, and the identification of the monument/artifact can be used to inform the new space variation of this urban typology.

In AERO | ASTRO, the major piazzas operate as buffer zones to activity spaces transitioning from the central circulation loop of the Nexus to an interstitial zone of the lobby (the artifact) dependent on the activity zonings. Finally, from the lobby, one enters the piazza at the open congregational area that hosts a unique hi-tech centrepiece (the monument) that acts as a tether point of interest where the social actors mingle. As one floats about this specific tether point, they are also given the opportunity to learn from each other and the centrepiece (conceptually an animated holographic artwork) about how certain rituals are performed in space. Additionally, with the integration of control and automation software applications of handheld devices (developed by Microsoft, Savant, etc.) to impending glass optical fiber architectural wall displays (by Corning, etc.), one will have the opportunity to manipulate the appearance of their surrounding environments. Rather than having cultural continuity through intergenerational demonstrations, space piazzas will evolve to adapt to constant generational changes in a dynamically virtual world.

left [4.5.13] Nolli map of AERO|ASTRO locating the public space piazza and lobbies throughout the space station

[4.5.14] Precedent systems and technologies used throughout AERO|ASTRO includes holographic models projected into a space, the use of electronically manipulated glass and software applications in support of the multifunctional material finishings

next [4.5.15] Rendered perspective looking out of intermediate lobby space into the Nexus corridor

[4.5.16] Rendered perspective looking into lobby towards holographic projection displays in a typical space piazza







Dining is a recurring event that is typically exercised as a daily cycle of three meals (breakfast, lunch, and dinner) within the circadian 24-hour day interval with a snack or two in between meals. Some specialists and trainers may also suggest five to six meals a day according to a two- to three-hour consumption interval that can help keep energy levels high while maintaining a consistent metabolism. Whether one is accustomed to three or six meals a day, dining is one of our significant daily rituals.

As human beings, our metabolism and healthy conditioning depend on a well-balanced daily diet that includes sufficient nourishment. This includes the balanced ingestion of solid and liquid foods that come from various nutritional groups (varying according to cultures and on the basis of allergies and dietary preferences). Over the generations, the method in which one consumes their cultivated harvests has uniquely evolved within different cultures. This is due to technological advances in apparatuses, materials, and understandings in nutritional sciences, while the method of eating has also become an indicator of cultural mannerism and etiquette.

As dining is culturally and socially significant, it will be essential in the space environment to support the act of dining in a space that offers all the fundamental requisites necessary for dining rituals. As mentioned before, cultural differences and dining customs and etiquettes may involve various spatial settings and utensil requirements, but ultimately, the typical milieu involves private groupings of individuals (family, friends, etc.) who are usually seated and oriented in an arrangement around a table for optimal interaction.

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[4.5.17] Precedents on dining as a ritual in various settings and preferences

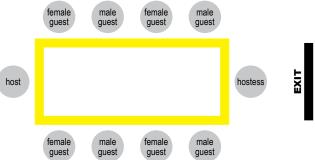
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[4.5.18] The etiquette of dining in terms of formal and informal arrangements of participants around a dining table

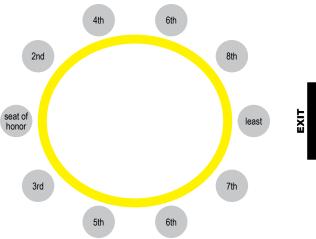
[4.5.19] Utensils used in dining rituals as a multiethnical and cultural point of view



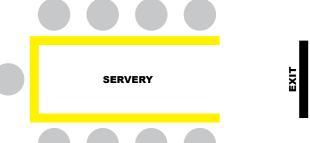
typical seating arrangement [4.5.18a]



hierarchical seating etiquette [4.5.18b]

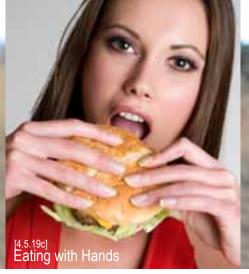


informal scattered seating [4.5.18c]















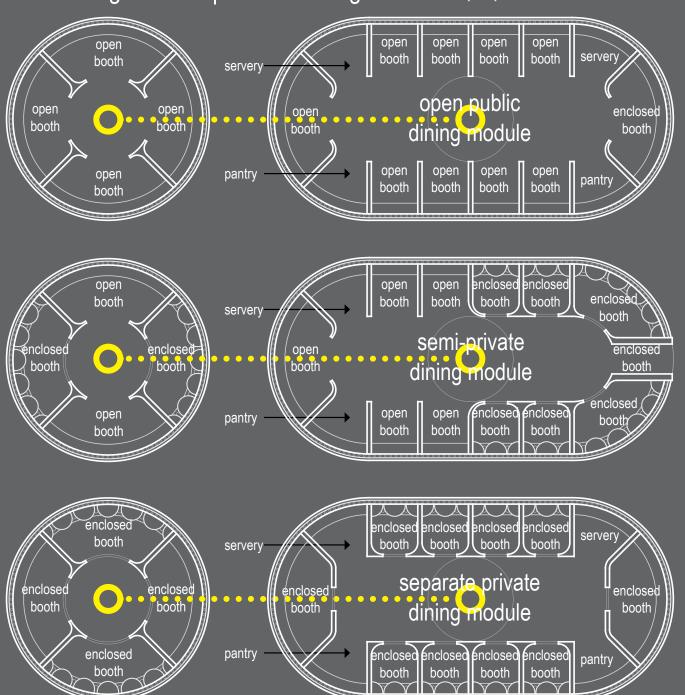








# Planning of AERO | ASTRO Dining Modules [4.5.20]





When living in outer space, many unfamiliar aspects under weightlessness may lead to drastic loss of appetite and other sickening symptoms. However, travelers eventually regain their appetite and emotional stability as they adapt to all the anomalies encountered in the new environment. As this happens, there will be plenty of new confusing challenges to the first-time astronauts where dining rituals and etiquettes are concerned. For example, food, like all other objects in space, will be floating, which inevitably will be a difficult aspect to deal with for first-time space travelers. It is important that spacefaring occupants become adept in the daily dining rituals with or without ill symptoms, as it is essential for them to stay healthy and also provides for congregational opportunities in sharing daily experiences amongst their peers. Fortunately, the act of swallowing will not be impaired by weightlessness, as John Glenn explains during his inaugural orbital flight in 1962. It was determined afterwards that swallowing is enabled by the *peristalsis (a radially symmetrical contraction and relaxation of muscles which propagates in a wave down the muscular tube)*<sup>7</sup> of the esophagus and not gravitational conditions. Therefore, from the many conflicting challenges that occupants go through, this fictional aspect of ingestion will not pose additional worries for the first time space travelers.

Architecturally, various dining-space typologies should provide for, including cross-interactive dining experiences in open public environments, personal and intimate dining experiences in privately enclosed environments, and a conjunction of the two for those who seek the intermediate jurisdiction of a semi-private environment for dining. In addition to the surrounding space, basic occupant arrangements and orientations within the space will have their own unique characteristics in these dining spaces. Unlike on Earth, maintaining a formal organizational structure in terms of anchoring (the equivalent of seating orders on Earth) will be difficult as everyone will be floating about. Therefore, it is recommended to disregard the formal hierarchical assembly around the usual dinner table, instead adapting to a new tradition of informal dining arrangements where occupants can playfully float amongst one another in various orientations while still maintaining the social interactive contact through direct visual eye contact.

"Peristalsis is a radially symmetrical contraction and relaxation of muscles which propagates in a wave down the muscular tube, in an anterograde fashion. In humans, peristalsis is found in the contraction of smooth muscles to propel contents through the digestive tract. In much of the gastrointestinal tract, smooth muscles contract in sequence to produce a peristaltic wave which forces a ball of food (called a bolus while in the esophagus and gastrointestinal tract and chyme in the stomach) along the gastrointestinal tract. Peristaltic movement is initiated by circular smooth muscles contracting behind the chewed material to prevent it from moving back into the mouth, followed by a contraction of longitudinal smooth muscles which pushes the digested food forward. Catastalsis is a related intestinal muscle process."

"Peristalsis" by contributors of Wikipedia, 2012

[4.5.20] Sectional diagrams of dining module types proposed for AERO|ASTRO

[4.5.21] The current dining conditions of astronauts on the International Space Station.

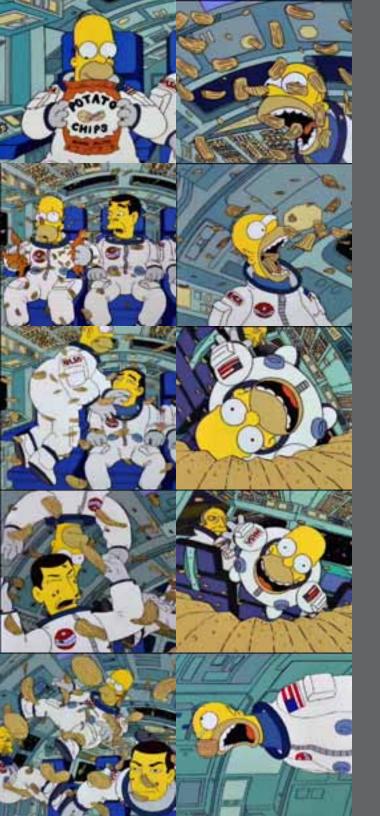
Once settled into a comfortable arrangement within the dining spaces, further chaos will arise as drinks and food are served to the party. Without gravity, there is no way of setting these materials down. Therefore, with retractable surfaces along the periphery of individual dining booths hosting pre-mounted magnetic cloisters, Velcro strips, and anchor points, food containers and other eating utensils can be held conveniently in place. Bungee tethers, handrails, and foothold anchors will also be available to provide further stability for the occupants within dining spaces. As everyone is finally accustomed to the equipment and the spatial set-up, the most important aspect of dining arises: what do we eat? In precedents such as the ISS, astronauts have been fed a variety of over one hundred selections of freeze-dried, low-moisture, or thermostabilized airtight packaged foods because of the need to conserve space and weight for payload deliveries and storage. However, because AERO | ASTRO's intent is to attract tourists, it is proposed that ample storage space is planned throughout the station (even though this is an economical waste in real estate and functionality) to store a variety of food styles (e.g. fine dining, fast food, cafe, patisserie, pub, etc.). Additionally, "Urban Cultivators" and other hydroponic cultivation labs will be located throughout the cosmic garden sector and the banquet serveries to supply fresh produce for dining menus.

Summing up this ritual of dining in outer space, with the intention of a casual and free-dining culture, various terrestrial table manners can be omitted as the environment of outer space necessitates certain creativity when dining. Therefore, the etiquette of "not playing with one's food" will surely be ignored as initial first-time astronauts will already have many other coordination challenges to deal with. It will also be a trial-and-error process to see how one manages one's food while being tempted to exploit the special condition of weightlessness in space. Whether to dine at the expense of an individual's will or be fed by a peer with a supply of floating food, the overall experience of dining in space will be a playful and enjoyable ritual. Finally, as a vacation destination, these dining opportunities will be considered of extra importance and, therefore, material variety for food products (i.e. different cuisine styles, textures of foods in various grouping categories, unique "space-type" food products, etc.) must be made available with the exceptional services performed by the crew personnel.

rıght

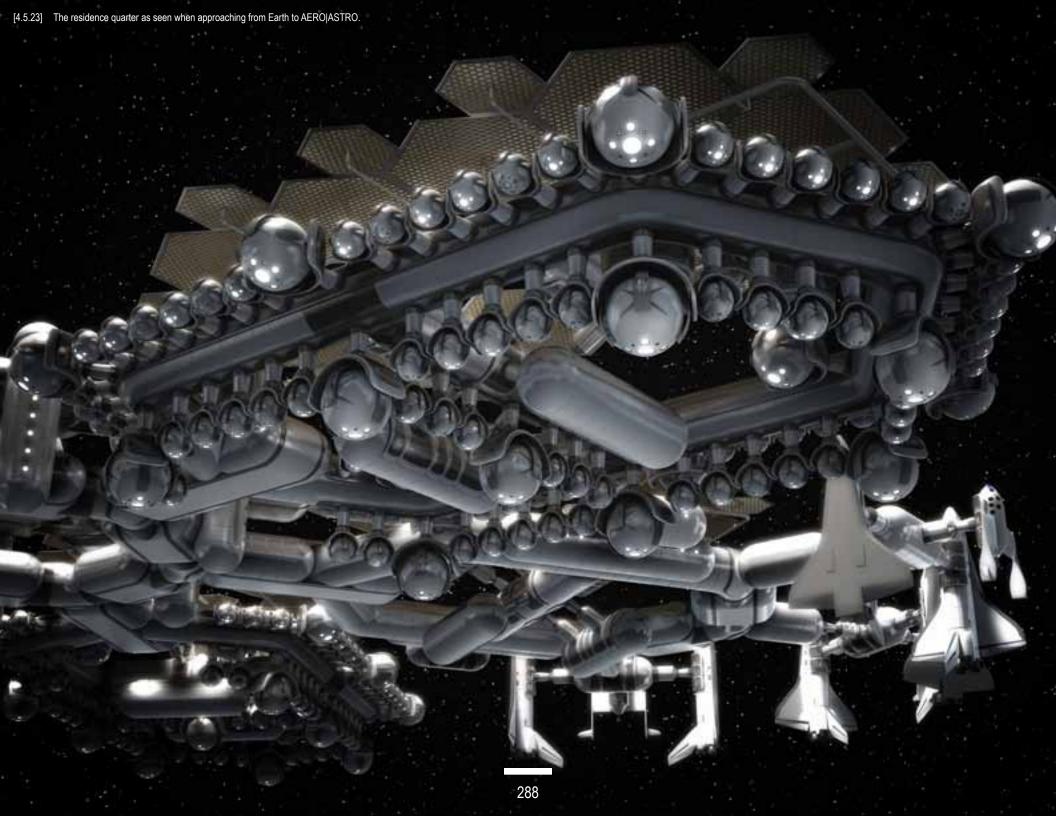
[4.5.22] Excerpts from the animated series, "The Simpsons - Season 5, Episode 15, Deep Space Homer", Homer Simpson converts a catastrophic situation into a fun and creative dining experience in the famous "Space Chips" scene

"Michelin Stars for Space Station" by Allan Hall, The Telegraph, January 11 2010



"German Harald Wohlfahrt has binned the freezedried tubes of nourishment which taste like "cat food" and replaced them with delicacies such as braised veal cheeks with wild mushrooms, white bean purées, Swabian potato soup and plum compote. Recognised as one of the greatest chefs in Europe – his restaurant in the Black Forest is a magnet for celebrities the world over – the ISS has taken delivery of his first culinary offerings which still have a shelf life of two years. The chef who has cooked for Bill Clinton, Angela Merkel and Sophia Loren, had to take into account many factors when drawing up menus for astronauts floating nearly 250 miles above the earth. Salt accelerates bone loss while extra Vitamin D is needed due to lack of sunlight. A human's sense of taste is altered in space too so the food gets more pepper and other seasonings than it would in his kitchen on earth. The sauces he serves up at the Schwarzwaldstube in Hotel Traube Tonbach are also strictly off the menu...Although the food has to be packed in tins, it was so good it fooled critics in a blind tasting who thought it had come straight from Herr Wohlfahrt's restaurant. The tins are heated to 195 degrees C in ovens on board the ISS. The chef added; "We canvassed the astronauts and they said they missed "rustic" cooking from home, so that is what I try to give them."..." am told good food motivates astronauts," he added. "I hope they enjoy it.""

"Michelin Stars for Space Station" by Allan Hall



On Earth, after a long day, the body becomes tired and will instinctively signal a need for sleep. In contrast, in outer space, one does not endure the same physical stress buildup as on Earth, because there is no gravity to force the muscles to counteract these forces. Rather, one is most likely exposed to other stresses on their mind and body as they struggle to move through the weightless environment of outer space in a floating posture. Therefore, sleeping quarters designed for space stations will need to offer sufficient space for one to float in without crashing into things, and optional anchorage opportunities for those who need a sense of grounding support to sleep. Sleep positions will vary according to one's preference while generally categorized as either untethered (floating) or tethered postures. An in-between variation can be considered through the use of unique apparatuses such as a sleeping cocoon, where one is wrapped in a free-floating sleeping bag that is tethered to the bedding pad, or one is strapped onto the bedding pad with flexible braces to restrict excessive movements while grounding oneself to a surface. In addition, customizations for various levels of light, sound, and smell should be made available throughout the residence and on handheld devices so that these intensities can be adjusted at any time to desired levels. As well, inflatable room pockets that host various sensual stimulants should be made available and be deployed into the sleeping pods as a personal blanket of preferences to filter specifically desirable interactive visual and aromatic stimulants while hygienically providing a disposable environment for the continuous exchanges in occupants.

left

[4.5.23] Exterior perspective as seen on approach from the Earth of the array of living pods at AEROIASTRO's residential quarters

next

[4.5.24] Terrestrial sleeping positions on a bed

[4.5.25] Extraterrestrial sleeping options under weightless conditions of outer space

[4.5.26] Residential living pod cross sections

[4.5.27] Precedents on materials and systems that are used in a living pod to service maximal comfort to its occupants

[4.5.28] Residential living pod section and sleeping quarter details

[4.5.29] Perspective view of the living space of the residential pod coming in from the entry hatch

[4.5.30] Perspective view of the main components in the residential pod looking back towards the entry batch



common exercise: 5%

common exercise: 41%





common exercise: 8%

common exercise: 41%





common exercise: 20%

common exercise: 4%





common exercise: 4%

common exercise: 4%





common exercise: 13%

common exercise: 7%





common exercise: 13%

common exercise: 7%



# [4.5.25a]





### **UNTETHERED OPTION**

The free floating position is the most basic method of sleeping inside the personal sleeping pods in the residential units of the station. Although this condition allows one to freely occupy the volumetric space of the pod, it also comes with a drawback that one will bump randomly around the pod as there's no friction stopping one's motion in the pod. This can become extremely distracting to one's sleep states and can potentially affect one's spirit the following day with fatigue and other symptoms lacking of quality sleep.







### **TETHERED OPTION**

While connected to a surface with an adjustable tether cord, this method in sleeping allows one to have the freedom of customizing the distance that they can float to. Hence, it can prevent one from bumping into objects within the sleeping pod to disrupt their quality of sleep. However, as one is tethered via a cord connected on them and a surface, it is inevitable some tugging may occur when one reaches the limited distance allowed by the cord. In this case, the tugging will become a distractive factor that may reduce the quality in sleep to the occupant.

#### **BRACED OPTION**

Similar to having seat belts on a car, the occupant is fastened to the bedding pad with their arms held in place, locking their position from floating off. Additional toe anchor holds will be availble for additional grounding to the surface. Although this method resolves many of the floatation problems that involves distractions of bumping into other objects within the space, it may be uncomfortable to some people who are used to having the freedom on Earth to roll around in bed, and therefore, the quality of sleep would be disrupted.







#### **COCOON OPTION**

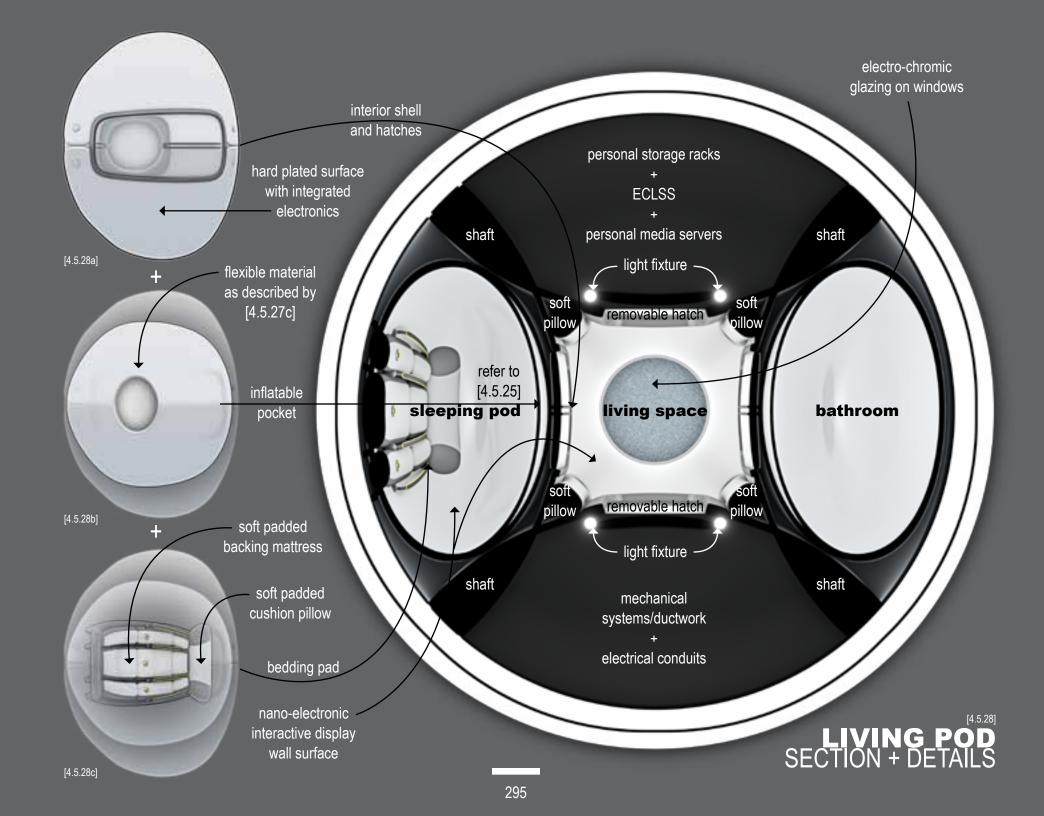
As an intermediate between the tethered and untethered options, the cocoon variation in sleeping utilizes a sleeping bag apparatus (available for the individual or a couple scale) to soften one's collisions with objects and walls of the living space. In addition, the "cocoon" is tethered to the bedding pad and gives off the sense of being grounded to the occupants. These sleeping bags can be a personal item brought on board and therefore, one doesn't have to worry about the cleanliness of their sleeping environments while the pods will be cleaner for the exchange of occupants.



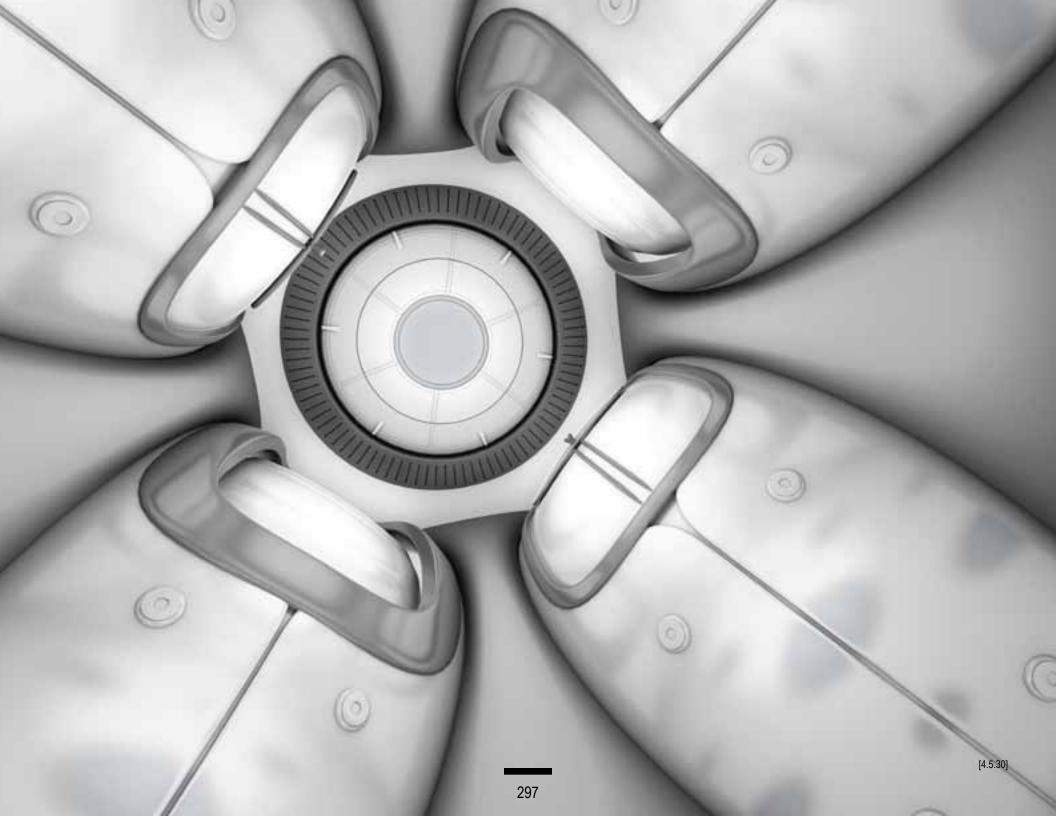














4.6

experiential reflections on AERO | ASTRO

I was woken up this morning by the alarm on my personal handheld device that played a faint rock-steady reggae beat that I picked out last night, "Wake Up and Live" by the legend Bob Marley (one of my favorite songs/artists!) As I opened my eyes, regaining consciousness from my epic dream last night (I slightly remember it as being something about a highly classified mission that I was involved with, to explore the universe at ludicrous speeds, hopping from one AERO | ASTRO port to another in search of an answer to life. And, as usual, I sadly woke up right about the point where the answer was about to be revealed...sigh!), I begin to feel a fresh breeze of this Woody, lemony fragrance that was injected into my sleeping pod through the diffusers of the pod's air purifier. In addition to these freshening scents that are pumped into my pod by the computerized scent delivery system, I began to notice through my blurry vision that the darkness was gradually fading away as the electro-chromic windows outside my sleeping pod were slowly changing from opaque to transparent states, giving ambient lighting to my living unit again. I dragged myself out of my sleeping cocoon and glided over to look out these windows, and the view was absolutely shocking!! As beautiful as the landscapes can get on Earth, nothing seems to speak the same pristine language as what was before my eyes: an infinite abyss with the planet I had recently left behind in the distance spinning in front of me.

Stuck in that awe-inspiring moment, I lost track of time until I finally realized through the reflections on the window that the space around me had started transforming with many informative pop-up notes and graphics all over the walls. Now marveling at the new unique setting of my personal virtual space, which is driven by the informative and personal data retrieved from my handheld device, the nano-electronic interactive displays built into the walls reminded me that I had to start work very very soon! Getting myself back together, I rushed to the bathroom compartment in my living pod and quickly went through the usual daily cleansing routines (brushing, toiletry, shower, etc.), which was CHAOTIC! Although I've been up here for several days already, I'm still having some difficulties with certain tasks such as showering and using the toilet, but I'd rather not get into details at the moment. So, after putting on my fancy uniform — a cross between a spacesuit and a typical office outfit (it's a bit difficult to explain) — my day begins.



I quickly maneuvered through the central corridor loop of the Nexus and made my way swiftly to the dining hall for a quick breakfast. As quickly as I wanted to eat, it probably still took longer than it would have on Earth, as I still **struggle** with my hand-to-eye coordination and, when your food is flying all over the place, it gets quite difficult. But I am definitely doing much better than two days ago when I made the crazy mess in the dining pod with food splattered all over the place and myself. I guess the blame for this partially belongs to my inner child instinct to have fun around a group of other playful first-time crewmates; we all experimented with helping each other to eat. At one point, a few crewmates began squirting liquid blobs from their drinking packs all over the open dining space and made a game out of it as they raced to see who could be the quickest to capture all the blobs in their mouths. **Just imagine** the chaos we made! Clean-up crews would've had a tough time clearing out the mess if it weren't for the specially engineered vacuums that are stored under the hatch compartments of the dining hall. These vacuums are our lifesavers as crews because they basically suction 90% of the mess into the station's materials filtration and restoration systems.

Anyways, getting away from all these techie details those were taught to us at the One month crew training camp back at AERO|ASTRO headquarters in Florida, my morning shift began. As crewmembers, in addition all the techie knowledge that we were tested on, we were also trained in almost all services throughout the station so that our daily routines are always unique with different guest servicing roles for every three- to four-hour shift. I guess this a good way to exercise and keep our brains moving at various paces, as we have to solve all types of problems throughout our shifts and, at the same time, it makes it fair for all crewmembers to have the chance to do both pleasurable and less amusing tasks. Fortunately for me today, the program agenda that was sent to my handheld device, put together by the schedule coordination team back at headquarters, seems to be filled with very entertaining responsibilities!

So taking note of my responsibilities for the first shift of the day, I projected my way through the Nexus until I reached the **Activity Zone**, where I found lots of people already awake and mingling about with each other in the Activity Zone's Space Piazza. I projected myself towards the piazza through the entertainment lounge lobby area, where I bumped into another crewmate who had just finished her shift. She asked if I wanted to **tether up** with her and have a little chat around the maze of many floating tether bubbles, but I sadly had to decline. Moving on, I maneuvered through the crowds at the piazza and went by the library and tech labs, finally getting to Activity Pod A. Here, I signed in with another crewmate who was getting off as I replaced him of his duties. As you may notice by now, there really isn't a job position hierarchy here in AEROJASTRO, as we all are still learning as we go in this pioneering service industry. We have to always think on our toes to ensure the passengers arriving from Earth have a safe and delightful experience on board. I think it's a great model implemented in this workplace, giving us all equal opportunities to learn while making it politics-free amongst crewmembers. I always hated all the office politics when I interned at these architectural firms back home on Earth! So before I let the other crewmate leave, I consulted him about issues that might have come up during his shift that I should take note of to understand better how to serve the occupants in their activities in Activity Pod A (a space similar to a high school gym, but spherical in shape and surrounded by a soft bubbly finish).

It turns out I was only required to make sure the occupants of the space have a good time playing this newly invented sport (Astroball) specifically designed for AERO ASTRO. In my opinion, this sport is actually very fascinating, as it seems to be a blend of dodgeball and basketball in a disorienting environment of floating rings and ricocheting sponge balls. If I'm not wrong, the inventors of this sport must've been huge fans of the Harry Potter series, because if only everyone had a flying broomstick and a Hogwarts' robe, I'd have mistaken this to be Quidditch!! So, in a blink of an eye, a few smooth hours passed doing demonstrations and umpiring Astroball matches. It was actually pretty fun, since I was in the midst of a lot of the action in the games, and it isn't as painful as sports on Earth 'cause all the maneuvering through the obstacles in space requires little effort, only a soft tap off the spongy walls or someone else.

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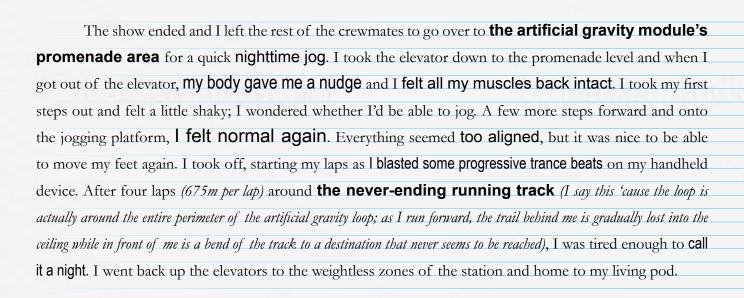
After I gave some words of wisdom to the next crewmate who took over my duties, I went over to the Tech Lab to transmit some videos I took today of the Astroball games to show my family and friends on my blog. It was free time now, and I had four or five hours to kill. As crewmembers, we're allowed to use the facility as if we're a passenger on board during our off time, so I tried to pick what I want to do today. There are so many activities to select from that it's actually quite difficult to choose what to do because they all sound so fun and interesting! I've heard many positive responses for some of the facilities and activities from touring families when I worked at the customer feedback desk yesterday. A majority of them complimented the wild experience they had at the Aqua Zone. The revolving pool and Jacuzzi seem to be a major spectacle here and I'm dying to have a try myself. But I wasn't up for getting soaked with water this early afternoon, so instead, I went to grab a quick bite at the dining hall and then went over to the observatory for a personalized tour of the universe. Here at the observatory, the software application in my handheld device connected itself with the observatory module itself and allowed me to Swivel the module around to change the orientation of the module to the universe. This freedom to pilot the viewport is quite nice as I can perceive specific details of the universe at my own pace.

Finishing with my session at the observatory, **I felt very relaxed** and wanted to go clean myself up, since I hadn't been able to during this morning's rush to get out of my living pod. So, I went back to the living pod for a more thorough cleansing session while **taking a break from the crowd of people** throughout the station. I took out my handheld device and ran some tunes while I took some more photos of Earth to post on my blog. I relaxed a little and my second shift of the day creeped up on me. One thing I realized since I got here on **AERO | ASTRO** is that **the air seems fresher**, but this could be **my imagination**, just like **my feeling of time passing by extra quickly** every day. Now that I was refreshed, I put on a new uniform, as I was scheduled to help out over at the **transit centre** over at the **Terminal Plaza**. There, I will be responsible for assisting arriving passengers by helping them through their adaptive process in the new floating conditions. Most first-time travelers will encounter problems with their mobility upon arrival. I will also be able to guide them with some information about their stay and activities while directing them to the registrations counters at **the Station's check-in zone** if they're staying with us for longer durations in their layover.

After I was ready, I took off to meet **the arrival greeting crew** to get more information to begin my service at the gate and waiting areas. When I had confirmed my duties, I went to **the concourse area**, where I was to be stationed to help guests who were having a difficult time moving through the concourse. It was quite interesting to see some of these first-time travelers flopping around in weightlessness, as it reminded me of **my first "steps"** out of the spacecraft and onto the station. All I can say was that **it was very rough times!** I remember bumping into everything possible that was in the airlocked port, **even other arriving passengers!** Oops! I felt so bad, but another crewmate who was stationed at the gates at the time helped encourage and guide me through the basics for moving through the space station. It didn't take too long for me to begin **zipping through** the concourse area, and once I was ready, I was guided to my designated living pod by the friendliest concierge crews you could ever find.

I really enjoyed this second shift today as I was able to help so many passengers on their way to their first vacation here at AERO | ASTRO. It was very satisfying seeing their confused faces turn to delight when they began to get the hang of floating around rather than of walking. Again, this shift quickly came to an end as I was preoccupied with helping so many people, and my six- to eight-hour daily shift was soon over. I went back to my living pod and washed up, changing into a more casual spacesuit, one that resembles a mid-sleeved jumpsuit, as I was going to meet a few crewmates for dinner and a show at the theatre. The show was very fascinating. Cirque du Soleil produced yet another exciting and adventurous story exploiting the many unique conditions offered here in AERO|ASTRO. In addition to the usual acrobatics by well-trained actors, there were many compelling interactive moments where new technologies of holograms and other artificial intelligent systems brought the audience to life with a unique engagement. The acrobatics were wild with many remarkable stunts that could not have been imagined on Earth.

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Back at my living pod, I cleaned up and played around with some of the interesting features on my handheld device. I sent several message transmittals to my family back on Earth, updated my blog (we've been asked to write detailed descriptions of our days here, to help us process all the new experiences we're having and to give people back on Earth an idea of what life here is like), checked out other blog entries from other passengers/crews (according to a crewmate who heard from the programming group at headquarters, there will be a convention for science fiction enthusiasts next week, and we are going to decorate the station with this theme in mind. I seriously can't wait to meet all the people dressed up Jedi Knights and Captain Picards arriving next week!), downloaded my new itinerary for tomorrow, adjusted my alarm according to my new schedule, changed the aromatic controls to blast a jasmine scent into my sleeping pod to wipe out that woody, lemony smell from this morning (I usually sleep better with this compared to other scents), and just cuddled into my sleep cocoon, all ready to fall asleep in preparation of another exciting day ahead.

~END

I woke up full of excitement this morning as the light shined extra bright into my room. I've been waiting for this day for a long time now, ever since I received my medical clearance that approved my certification to take the charity trip to AERO|ASTRO. I'm seventeen years old and the bottom half of my body has been paralyzed for the past two years now due to a tragic accident at a junior high school hockey game, where I sustained an injury to my spine when I fell from a heavy body check. Life has never really been the same since. But when the doctors told me that new medical technologies on board AERO |ASTRO, a space station that opened a couple months ago, had the potential technologies to cure my disability, my life was flipped right-side-up again, giving me a new hope. This trip doesn't come cheap, but fortunately, with the help of the medical group watching over my rehabilitation, they were able to convince AERO|ASTRO to donate a charity medical trip for me to vacation in space and undergoing these new treatments while giving me an Out-of-this-world opportunity to get my mind off of things. My mother also booked a ticket to come up and support me, but unfortunately, my father has to keep working in order to cover these medical bills and other financials for my family, which includes my little sister as well.

So, my mother came into my room to help me out of bed and prepared me to go to London's Heathrow Airport, Terminal 5, to catch our flight. Since the flight was an early bird, my father was able to drop us off at the terminal. There, we were fortunate to bypass the long lineups at the check-in counters, as we had our own "Spacefarer Elite Members" line. We went through some quick documents and showed the reception crews the space travel permit that I got with the medical clearance, and were then guided to a security and customs area where we also dropped off our small luggage and provided all our identifications, as we would during a normal flight to the customs officers. Once we were signaled to move on into the concourse, we were led by AERO ASTRO staff to the spacefarer lounge area, which was an extended level retrofitted above the original concourse area for aircraft passengers. At the lounge, we were given a review on several safety procedures that we already know about because we took the training course prior to the spacefaring license exams. But it was nice to be refreshed about some of these things as I had already forgotten a few of these procedures. After the debriefing, we moved forward into another lounge where we were changed into the transiting spacesuits and had a few refreshments. Here, we could see our spacecraft tethered over the jumbo jet that is on course for Sydney, Australia. It wasn't long until we heard over the announcement system that we would be boarding, so my mother and I went over to the portals (the bridge that connects to the spacecraft doors) and boarded the spacecraft.

Inside the spacecraft, **I had mixed feelings** and could see that my mother was pretty nervous, knowing that she's not too fond of heights. But in my case, I'm very happy to be going into space for the first time because it's been a rarity for normal people like me to go into space without any academic reasons. On the other hand, I was a little nervous about leaving Earth, but knowing the opportunity of having my medical condition fixed up on this trip **boosts my courage**.

I looked out the window, and the ground crews are signaling the jumbo jet to taxi onto the runway. As we made the final turn onto the runway, the pilot of the spacecraft came by to ensure all passengers were fastened to their seats and then swiftly fastened himself over at the cockpit seat. The airplane moved faster and faster and began to lift off from the ground. So far, our flight had gone smoothly and it felt like every other flight I'd had so far when I went on vacations. Suddenly, the pilot signaled us to hold on as we were about to detach from the jumbo jet and ignite the rocket boosters to go supersonic into space. I held on tightly to handlebars next to my seat and looked at my mom, who at this moment looked slightly scared, but I put my hand on hers to assure her everything would be fine. Just as I replaced my hand to my own handlebar, I felt the spacecraft jerk suddenly (knowing it's now not tethered to the airplane), a loud boom sounded from behind, and a force pinned me down into my seat. Suddenly a huge crack sounded and the pilot assured us everything was all right; we had just broken the sound barrier, which caused the sonic boom. I looked out the window and everything was getting smaller and smaller below us and I had a strange feeling in my body as if I was about to throw up. Luckily I didn't, and very soon we were seeing the horizon of Earth morph into a marvelous arch and above us was the darkest dark I've ever seen leading to the many stars infinitely scattered beyond in the universe.

We were on the flight for about an hour and a half to two hours, with everyone staring out their windows in awe at the beautiful planet that we'd left behind, when the pilot announced that we were approaching AERO | ASTRO and would dock shortly. I looked up to see the massive space station above us. We were passing by an array of bubbly-looking structures (I later realized these were the living pods we stayed in) and the dock was clearly in sight ahead of us. Like the pilot said, we docked very shortly after the announcement and already I felt different. There were no pressures pulling me down, but instead, once we took the seatbelts off, we immediately floated around in the volume of the spacecraft. The pilot worked with the station's crew to ensure a pressurized connection was made and invited us to enter into AERO|ASTRO. Everyone seemed to have problems finding their way through the tunnel into the port. My mother led me through the tube and into the port as I turned around, watching my mother come through in confusion.



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Seeing the confusion of everyone in the port area, I noticed that my paralyzed bottom half wasn't really much of a disability anymore. Psychologically, I didn't seem out of place as everyone seemed to have weird dysfunctions at this point and our mobility is all the same, CHAOTIC! We were directed by one of the welcoming crewmembers to the waiting area next to the gates, where we were greeted by another crew, who guided us with some pointers in moving around in the weightless environment. It was very hilarious to watch my mother tumble roll all over the place, bumping into almost everything in sight. I guess that's why everything in the space station seems to be padded by a soft material with lots of round bubbly corners to prevent us from hurting ourselves. But after some demonstrations and help from the crew on board, we were both freely moving around in no time. As I've mentioned before, my mobility wasn't obstructed by my disability, and in fact, I find that I sometimes move through the spaces quicker than most others who can move normally on Earth.

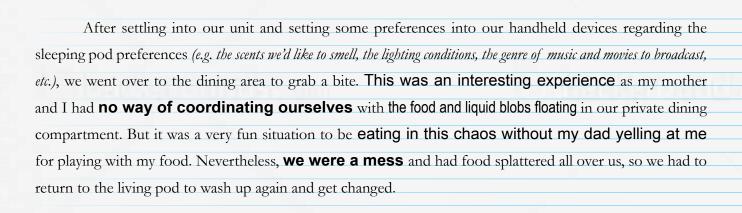
Once my mother and I were settled with our sense of mobility, the crewmember gave us our own personalized handheld devices. She told us that this handheld device is **personalized to many of our desired presets** that we've programmed on Earth while at the training before our trip. We were able to adjust and do almost anything with the touch of a button. I pressed a button on my device and suddenly my father's face popped up. Apparently, the device is tracked with a positioning system and it can direct the transitioning of onboard video feeds pointed at me (my handheld device) back to other display devices on Earth. So my father told me that although he's not in space with me right now, he'll be with my mother and I digitally throughout this rehabilitation journey. I was so happy to see him and had so many things to tell him about our trip so far, but the crew told us to save that until a little later as we had to register and receive our living pod units.

When we got into our living pods, I quickly thrust myself over to the many windows that overlooked the universe and the planet Earth. I rushed my mother over to check out the view. She and I stared out and were dazed at the beautiful sight in front of us. I saw a sudden tear drop from the corner of my mother's eye and I thought she must've missed home, but instead, she was actually so overjoyed by the sight and this life-adjusting opportunity given to me that she broke down in tears. Suddenly, in the reflections of the windows, I saw the walls behind us begin to change. My doctor appeared as if the walls around us were virtual display panels. The doctor told us not to be afraid; he had been signaled by the positioning system on our handheld devices that we'd safely arrived and found our way into our living unit. During this time, he told us to just settle in and explained the schedule of treatments to come in the next few days.

From what I understand, my treatments here on AERO | ASTRO will take place in weightless conditions, where adjustments to my spine will be made with state-of-the-art technologies through a remote surgery system operated by my specialist on Earth. I will then be sent over to the artificial gravity modules where I will attend physiotherapy and be assessed under gravitated conditions to determine whether the treatment was successful or not. If not, we will go through this process several times until I have feeling in my lower body again. My mother and I were both extremely happy in hearing the confidence coming from our specialist, and were encouraged that this charitable trip will be worthwhile even if, upon return, my mother will have to work even harder to help my father repay the medical debts piled up over the last few years. Before the doctor logged off from the video conference on our walls, he told the two of us that during non-therapeutic times, we should enjoy our stay with all the activities and amenities as if we were on vacation. Apparently up here in space, I'm as normal as everyone else and will be able to do pretty much everything that is offered under the weightless conditions. The only areas I won't be able to go alone or without assistance are activities that function in artificial gravity modules (e.g. the pool that I've heard so many interesting remarks about, and other gravitated amenities). I was very happy to hear this. I am finally normal again! And shortly after this trip, I will be a normal seventeen-year-old on Earth again!



## continued...



We explored the station for the remainder of our first day here, trying to adapt to this new atmosphere where everyone is floating in different orientations. My mother picked up some information about some of the activities we can do, and she also booked a massage at the meditation spa near my rehabilitation infirmary. She will be having her own treatments while the medical staff takes care of me for my first therapy session tomorrow. After a few trips around the station, we were tired and went back to our living pods, where we broadcasted a video call to my father on that large display wall. We also sent home some photos of our view outside the window and my father was pretty jealous of our experience so far, but is grateful that we're enjoying ourselves on this life-changing opportunity. After the call, we took to "bed," which was in a sleeping bag that they call "the sleeping cocoon." With a touch of a button on my handheld device, everything turned dark (including the windows outside, blocking out all the ambient lights into our living pod). I closed my eyes with the biggest smile on my face, a smile of hope and a new start to a new life ahead.

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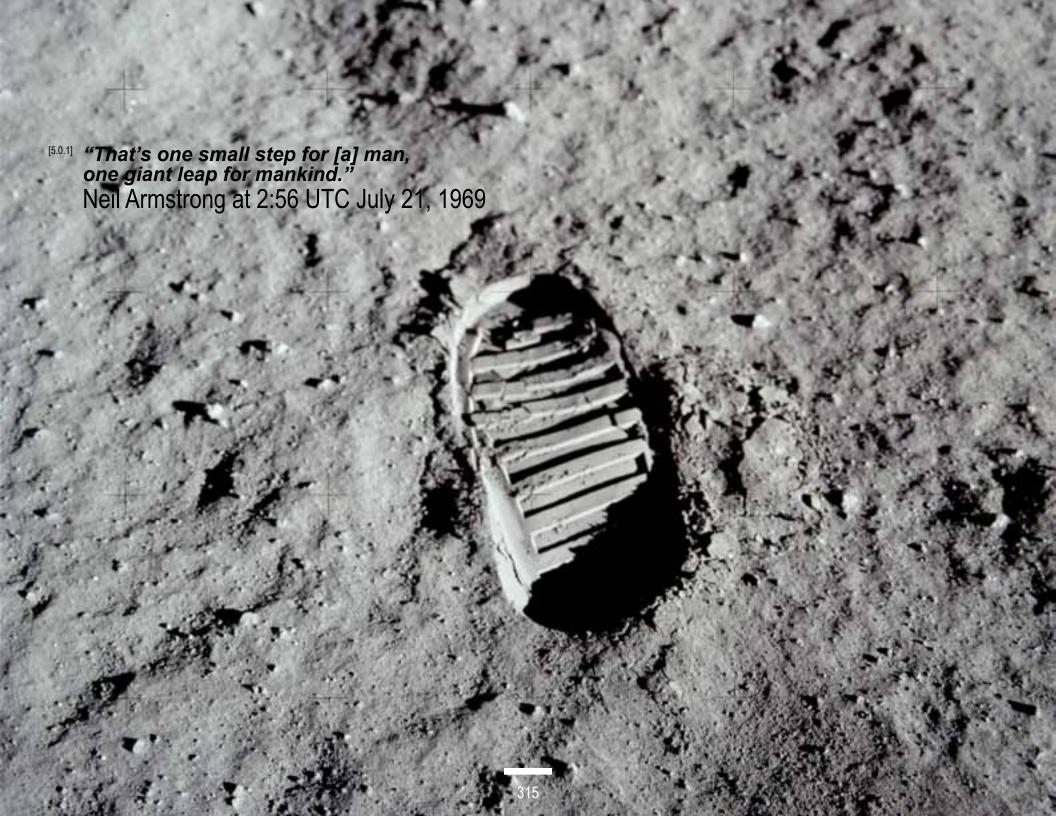
epilogue

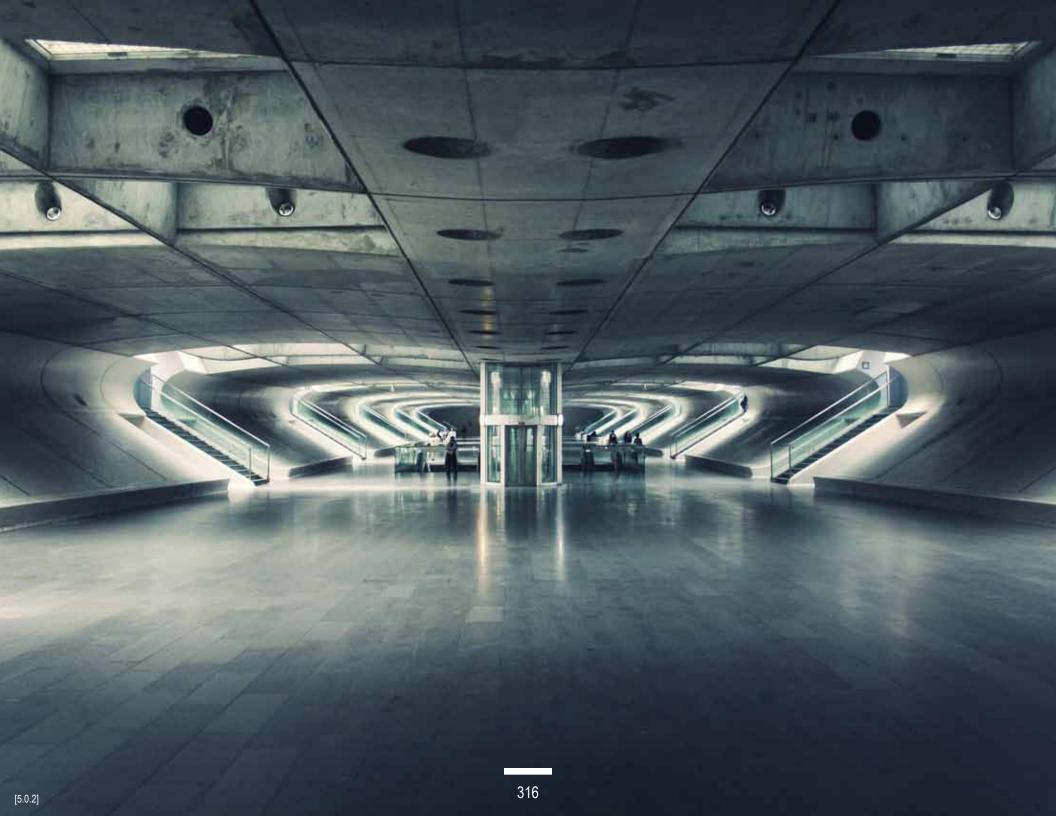
Inspired by fiction, film, and speculative science, the classical idea of living in space has always revolved around conceivable philosophies of Utopian ideals. These principles have generated fantasized cultural aspirations regarding the science, technologies, and human relationships that free new space communities from the histories and legacies of the world they left behind. It was only through the influence of competition for global political and economic supremacy during the mid- to late-20th century that realistic human spaceflight agendas began to emerge. However, it is also because of the continually shifting nature of these national ambitions that the progress of these advancements has fluctuated throughout this period.

With rapid technological progress from the early 21st century to current times, private investors have new confidence in emergent outer space developments of prospective industries (e.g. hospitality and tourism). These new extraterrestrial ambitions to provide cutting-edge solutions in servicing the inexperienced public, rather than only well-trained astronauts, have uncovered many humanizing factors that will affect outer space habitat developments. In addition, the predominantly technical workflows for these innovative enterprises will change, as privatized endeavours will stipulate new standards that are directed at a new genre of specialized designers who are trained to conceive of and prioritize innovative spatial qualities that enhance occupant experiences in terms of comfort and safety.

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[5.0.1] The first step on the moon by a human being made by Neil Armstrong during the Apollo 11 spaceflight mission. This mission marks the end of an era for the Space Race and has fulfilled national goals that were proposed in 1961 by U.S. President, John F. Kennedy: "First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth. No single space project in this period will be more impressive to mankind, or more important for the long-range exploration of space; and none will be so difficult or expensive to accomplish." - John F. Kennedy May 25 1961





Architects are professionally trained to position themselves within the marriage of both technical and experiential aspects in designs, and are therefore the appropriate candidates for this new specialized design role. Although architects have been involved as consultants to engineers throughout the developing history of human spaceflight, it will be through these new opportunities formed by private space tourism and hospitality industries that will expose architects to significant roles in these new, highly technical environments. On Earth, architects have been educated with a spatial sense and trained proficiency to shape the essence of forms and functions into integrated work. They are familiar, through the diverse integrative practices of architecture, with various disciplines regarding the harmonizing connections between the poetics of habitable spaces and their occupants. As well, over their careers, architects possess a library of design languages, experiences, and philosophies pertaining to human social factors that will be invaluable when creating sensible design solutions to the many humanizing challenges featured in the new extraterrestrial environment. In particular, what is best in architecture has always addressed what is most important to the human wellbeing.

For outer space projects, these new space architects can consider transitioning their terrestrial knowledge of effective design elements and strategies into their proposed concepts for extraterrestrial conditions. These may include, but are not limited to: 1. the planning of circulation flow and connections of public and private functions; 2. the use of windows/doors and axial/visual orientations to create portals within a space to direct a bonding link for an occupant to a specific focal point; 3. the instinctual inclusion of cavity spaces in a design to flexibly account for mechanical ductwork, electrical conduits, and future life support systems; 4. the exploitation of modulated designs using repetitive and prefabricated elements to create flexibility in expansion and ease in construction; 5. the clever use of regenerative materials and spatial orientations to maintain sustainable objectives; and 6. via unique designs for architecture to influence a positive sense of belonging for its occupants.

[5.0.2] The inner gallery of Gare do Oriente (Lisbon Orient Station) in Lisbon, Portugal designed by Santiago Calatrava.

Architecture designed and constructed on Earth have the tendency to induce creative influence for the designs conceived for outer space. The ability to balance forms and functions, architects have valuable skills that they can offer to the engineer dominated workflows in the aerospace industry to collaborate for sound and aesthetical extraterrestrial designs.

AERO | ASTRO was proposed as a tourist destination expanded from an orbital infrastructural transit hub set in the near future to demonstrate both the freedoms and constraints that space architects will be confronted with when conceiving unique designs that provide a healthy quality of life for its occupants. Also, the design addresses new stylistic languages to the overlapping issues and concerns for many complex topics established by the outer space environment. These may include, but are not limited to: 1. the planning of flexible parameters for the arrangements of spaces and programs; 2. identifying efficient methods for construction and retrofit strategies; 3. the use of unique architectural languages and elements to assist in the adjustments to physiological and psychological alterations in the foreign environment; 4. the generation of unique activity spaces to enhance and stimulate new rituals in space culture by exploiting the many opportunities that microgravity offers; and 5. the assistance in human mobility and "grounding" from microgravity with industrial designed furnishings and apparatuses found both within the architectural spaces and on the fashioning concepts of special spacesuits.

Space architects should certainly be incorporated into spaceflight design, offering valuable assistance to technical engineering teams in developing habitable designs for emergent space industries. The impact of this new architectural role in space habitat design will inevitably resolve the many physiological and psychological challenges that would affect the inexperienced spacefaring occupants. However, securing this significant role within an engineer-dominated field will not be easy. It will be the responsibility of the emerging community of space architects to educate, promote, and market their expertise to convince high-risk investors of their credible value. This thesis offers designers a foundation to build from when developing plausible, innovative solutions in the advocation of emergent industries as space travel begins to be normalized. In the end, these hybridized industries will encourage investors and the general public with an efficient and profitable phase in outer space commercialization.

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It has become the new visionary goal of investors and emergent industries to provide services that will allow the general public feasible access outer space.

"We hope to create thousands of astronauts over the next few years and bring alive their dream of seeing the majestic beauty of our planet from above, the stars in all their glory and the amazing sensations of weightlessness and space flight."

"adAstra Interview" quoting Richard Branson, Fall 2006

With these new ambitions, new roles and challenges will arise, and it will be up to the hybridization of industries to provide sound solutions to these problems. The initiation of the space architect role amalgamating engineers and architects will be a major step in the commercialization of outer space as many of these new challenges will require the knowledge in both technical and humanizing aspects of design.

"More important than the material issue...the opening of a new, high frontier will challenge the best that is in us...the new lands waiting to be built in space will give us new freedom to search for better governments, social systems, and ways of life."

"The High Frontier" by Gerard K. O'Neill, 1976





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