The Future of Architecture in Space: Progressing the Human Dimension within machine driven Environments.

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"Imagination will often carry us to worlds that never were. But without it, we go nowhere."

-Carl Sagan

INTRODUCTION

We are fortunate to be living during a time when we will witness the progression of the new age of exploring the cosmos. "The sky is the limit", a saying that now couldn't be further from the truth in regards to our capabilities of scientific discovery. With that progression, there has never been a greater need for technology, greater minds for problem solving, and greater imaginations to consider the effectiveness of architectural design as something that must be beneficial. The age of space architecture is upon us, and it presents exciting possibilities addressing the challenges and constraints of these extreme environments. Often, the problem with designing for these harsh conditions is superseded by the need to ensure that these structures can weather the elements and protect the equipment and instrumentation effectively. Even as attention turns to designing places for humans to live in outer space, architects are not the first professionals called to help.[1] What can Architects contribute when designing for extreme conditions, and how can they add to the upfront design when considering the human's existence in this new reality?

There are many places on earth that could be considered "extreme" in nature, however most of these places would pale in comparison to challenges that are presented when considering a travel mission leaving our atmosphere and trying to sustain human life for long periods of time from the dangerous conditions that we can't find on earth. (micrometeoroids and (OD) orbital debris, (SPE) solar proton event, (GCR) galactic cosmic radiation, microgravity, artificial gravity, partial gravity, and then safely re-entering our atmosphere.)[2] Earth's most extreme environments only deal only with the typical problems of any extreme condition; access to oxygen, extreme temperature fluctuations, lack of light, long durations in small quarters with other humans; all of which are also dealt with when designing in space. Perhaps the most integral part of designing for extreme conditions is the necessity of habitat subsystems and infrastructure. These systems must be configured to meet limiting requirements for crew safety, performance, mass, power, volume, reliability, and

[1] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

[2] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

robustness.[3] The recycling and reuse of waste in space is a necessity, while on Earth it seems to be only an option of convenience. These technologies will eventually make their way back to earth as a source for future design capabilities; we have been benefitting from such NASA spin off technologies ever since the space race (1955–1972) which has helped usher in the expansion of technology in transportation systems, communications, food packing and sterilization, clothing, medical equipment, etc.[4] We owe most of our modern technological conveniences to space design; the evolution of design innovation thrives when pressed with extreme constraints.

Space architecture faces a multitude of challenges with design, especially as missions start to reach further away from planet Earth. As science and discovery trek into deep space for answers, the more we are pressed as designers to come up with solutions for humans who will be living in space or on these other worlds. As architects, we have a dual responsibility of both creating places that work and function, but also to create spaces for people to enjoy. Le Corbusier's famous quote, "A house is a machine for living in", embraces the technological advancements of the time and attempted to create an efficient approach to design by embracing purism.[5] There is an interesting relationship between the industrial age and the advancement of architectural theory. Can space architecture balance out its mechanical function and its need to provide for its inhabitant? Is space architecture just a machine that we live in, or can we use the machine as a tool to create an architecture that becomes alive?

[3] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

[4] "NASA Spinoff Homepage." *NASA Spinoff Homepage*. NASA, n.d. Web. 07 May 2014.

[5] Corbusier, Le, and Frederick Etchells. *Towards a New Architecture*. London: Architectural, 1946. Print.

METHODOLOGY

My responsibility in the future will be to design beneficial architecture, regardless of where that may be, and regardless of my experience within the field of science. I am approaching this specific challenge of design through an architectural lens, in hopes to better understand science and its application, and to explore what architecture can offer in return. Interviews are conducted with research scientists (Dr. Avi Mandell, NASA), space architect (Brent Sherwood, NASA), artists (Bryan Versteeg, Mars One), and Jason Bannister, Mechanimal Robotics) concerning specific project design constraints, and problem solving approaches [or strategies]. I examine the International Space Station and orbital architecture as a case study, to consider what works well, and what could be improved. Along with that, examine reviews and critiques of people who have been to the international space station and what they have experienced; delving into problems and ways architecture may be able to help. I consider current approaches and solutions to deep space habitats, Planetary Habitats, and Mobile research units.

Perhaps even more important than the actual application of science, is the understanding of the theory of architecture's capabilities, and its responsibility for the wellbeing of people. I will engage several literature reviews in hopes to strengthen, and give relevance to the issue of architectural responsibility. The International Space Station suffers from a variety of issues all of which can be addressed by theory and philosophy. First, I compare modernism and the Vienna Circle, as being parallels in time. One scientific; the other architectural. I examine modernism, and suggest that it may have resulted in the loss of the human dimension within architecture, by way of "the machine". Martin Pawley discusses the idea of the "machine" in relation to the modernist movement. Space architecture must function first and foremost (the machine), but also designing just a machine could potentially neglect the human element of design (architecture). Living in extremely close quarters with people is another issue that may

be overlooked within space design. Jean Paul Sartre, examines this through works of fiction that expresses his philosophical take on the issue of, "hell is people". Although the seclusion and isolation may at first seem like a problem in itself, it could be that it is the lack of self expression of the personal environment that makes seclusion such torture. Anne Cline discuses "the hut" as a means of creating a place of one's own, on the most basics levels of thinking. Creating a hut is like creating a tent or playhouse as a kid. That inherent need for design on the most primal of levels is something that relates directly to the human aspect of design, and is something that must be retained in space design.

Lastly, I consider the process by which I will explore approaching this challenge through a simulation of the industrial design and concept art pipeline. Designers and architects offer a fresh perspective on design, one that can harness the inspiration from nature and organisms into built forms and machines. By implementing the industrial design pipeline to approach design solutions, a large range of iterations can be explored, evolved, and developed in a very fast amount of time. Concurrently, there can be a wide range of input from other sources that can help accelerate the design process. Utilizing these skills of quickly exploring ideas, can directly influence the feasibility of actually influencing a design team.

To question in regards to the possible of designing in space is no longer relevant, it is a reality. As this paper is being written, there is a human living in lower earth orbit for the duration of a year, to test and probe at the needs of a human to survive a long duration missions in space.[6] Humans now live beyond This is an architectural question which deserves to be looked at from aspects of philosophy, history, psychology, and architectural theory.

[6] Spaleta, Steve. "Astronaut Scott Kelly: Merchant Marine To A Year In Space | Video | Space.com." N.p., n.d. Web. 07 May 2015.

CRITICAL EXAMINATION OF [ISS] AND PRINCIPLES OF ORBITAL DESIGN

In part 2 of "Out of This World - the New Field of Space Architecture", Brent Sherwood compares the orbital space architect's challenge to that of a submarine designer: ensure survivability, efficiency, and habitability in a lethal environment.[7] In many ways, the aesthetic quality of each space is very similar, despite one having internal structure and the other an outer structure. The (ISS) International Space Station has been in lower earth orbit since 1998. To this day, this is one of the only built environments that reside outside of earth's atmosphere. The sole purpose of the (ISS) is to be a mobile research laboratory where scientists can spend months conducting experiments in various different fields: human biology, physics, astronomy, etc.



Figure 1a - Image of submarine Figure

Request for living improvements are very common when reviewing feedback from recent inhabitants aboard the International Space Station. In 1999, there were very strict guidelines that address many of the problems with crew comfort, however due to significant cost growth and budgetary constraints, the ambitious concepts were reduced or eliminated all together. There has been vast research on the topic of human livability, and as Brent Sherwood identifies the need for a holistic approach that takes into consideration a

[7] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

multitude of design challenges for humans in a space environment; psychological, social, and physical.[8] A well rounded design approach would therefore consider crew interaction, privacy, proximity, lighting, sight lines, acoustics, temperature, circulation crew activities, schedules, etc.



Figure 1b - Image of International Space Station

THE MACHINE

When specifically examining the brief range of history from 1924 to 1936, there appears to be more than just a relationship between science and architecture; there seem to be intriguing parallels between the movement of the Vienna Circle, and the progression of modernism within architecture. With so much development in technology and discovery in science, the turn of the 20th century was a period of constant reinventions. The realm of science was ever expanding during this time; notable advancements such as Albert Einstein's theory of special relativity in 1905, Niels Bohr's model of the atom in 1913, Albert Einstein's theory of general relativity in 1915, and Georges Lemaitre's theory of the big bang in 1927. However, it was also closely related to the rapid advancement of technology. Concurrently, The Vienna Circle was formed as a diverse group of scientifically trained philosophers and other likeminded individuals who met under the leadership of Moritz Schlick. It was typical of the group to discuss the problems within the philosophy of science.[9] The Vienna Circle ultimately presented a theory of scientific knowledge which sought to renew empiricism by freeing it from metaphysical statements in exchange for a method of logical analysis. As science discarded any influence of metaphysics, modernism was also expressing its own stance on architectural standards and principles of the age. There was vast speculation as to which direction architecture needed to go. Around this same general time period, the modernist architectural movement was expanding as well. The Bauhaus school was established in Germany in 1919 and was in operation until 1933 under three different architect-directors. Walter Gropius, Haynes Meyer, and Ludwig Meis van der Rohe were arguably at the forefront of the modernist architectural movement.[10] Previously, there had been effort to fit in the ideas of metaphoric "hearths" or "lamps of sacrifice" into the modern architecture. Just as science purged metaphysics, modernism purged part of the human essence of architecture which led to a reductive, minimalist, pure, logical, architecture. It is a scientific conception; a logical analysis of architecture.

Similarly to that of the world of science and how metaphysics distorted the process of rational thought, the restrictive and limiting force of the traditional rules of architectural theory cluttered the path towards a new architecture. The work of The Vienna Circle may be only coincidently linked the phenomena of the modernist movement, but what we can deduce is that the 1900's were a time of architectural revolution where the artists and architects rebelled against every form of doctrine that was prevalently accepted by the masses. Can the loss of metaphysics within science be linked to this radical departure from the previously accepted forms of architecture? Perhaps, but what is for

[8] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

[9] *The Scientific Conception of the World: The Vienna Circle.* Dordrecht: Reidel, 1973. Print.

[10] "Heilbrunn Timeline of Art History." *The Bauhaus, 1919–1933*. N.p., n.d. Web. 14 Nov. 2013.

certain is that technology and science played a huge role in the development of modernism, and more importantly, applying rational and logical thought to practice. Martin Pawley discusses the relationship between science and architecture in his book, "Theory and design in the second machine age." Pawley examines the progression of both. "Unlike Science, which grows by the accumulation and cross-fertilization of a stochastic pattern of new discoveries, architecture comes out of actions and beliefs that have grown out of previous actions and beliefs".[11] It is only natural that the flaws of the International space station must be looked at as a foundation to build upon, rather than a negative attitude towards space architectural in general. The challenge of the [ISS], in Hegelian dialectic, would be to focus on the synthesis of art and science. Pawley identified the conflict between the two, especially the threat of infusing design by means of painstaking accumulation of factual data; the artistic identity is lost. Pawley states, "Before they died, the mutineers [early modernist] came to realize that their art was at the mercy of the machine, and not the other way around."[12]

The question directs itself to consider if current space architecture accommodates only the machine as capsule to survive in? Are we losing the human dimension within these machine driven environments?

ISOLATION, CLAUSTRAPHOBIA, PEOPLE

With companies like Sierra Nevada Corporation, Space X, Boeing, and mars Desert Research Station, a mission to Mars is inevitable, and the time when humans will be making the trek is fast approaching. Traveling to and from space, staying and researching in pods or stations, or living in mobile units on other planets or moons; one main concern that is raised is the isolation and seclusion for long periods of time. When averaging all past twelve mission trips to Mars that have occurred since 1964, the travel time would be approximately 225 days from Earth to Mars. There have been many studies and research done that evaluates the mental wellbeing of people who experience solitary confinement within the research laboratories, prisons, etc. Some prisoners talk about their ways of coping with isolation, some describe making up stories in their heads, or creating meticulous math games out everyday circumstances, even painstaking counting and collecting things. Medically speaking, such activities attempt to compensate for stimuli that are missing by creating stimuli of its own, that is, by increasing random activity within the brain. Whether these mental exercises preserve sanity or exacerbate it is unknown, however, it is clear that isolation has some effect on one's mental wellbeing. However, there seem to be instances where isolation is not only possible but intentionally desired. A hermit, as Ann Cline notes, "takes pleasure in his rustic tasks". Although the intention of the 18th century hermit did so for other reasons. Rather than placing himself above society, he set to distance himself from a place which categorizes men into different groups.[13] Seclusion allowed the hermit to eliminate the concerns of failure and success. Much like the prisoner though, rituals seem to be all that the hermit has that designates any manner of order. Ritual gives a sense of purpose.

Sometimes, the problems of seclusion is the exact opposite; some may argue even worse. When living in a space station or space craft, most often means being in a very compact, limited volume place, with no chance to "get away". Especially in research settings, individual responsibilities are important, and stress levels can escalate very quickly. Jean-Paul Sartre wrote a play called *Huis Clos*, or No Exit, which follows three characters as they are damned to Hell for eternity.[14] As the characters begin to get to know one another's past, they slowly begin to plot against one

[11] Pawley, Martin. *Theory and Design in the Second Machine Age*. Oxford, UK: B. Blackwell, 1990. Print.
[12] Pawley, Martin. *Theory and Design in the Second Machine Age*. Oxford, UK: B. Blackwell, 1990. Print.

[13] Cline, Ann. *A Hut of One's Own: Life outside the Circle of Architecture*. Cambridge, MA: MIT, 1997. Print.
[14] Sartre, Jean-Paul. "No Exit." *No Exit, and Three Other Plays*. New York: Vintage International, 1989. N. pag. Print.

another. Rather than finding the typical "Dante's Inferno" version of Hell, we find the conclusion that, "Hell is other people." This directly reinforces the idea that confinement and solitude, as well as living in close quarters for long periods of time with other people, are problems in which may not warrant enough thought when it comes to design. When assessing both isolation and claustrophobia with architectural language, it would seem that a delicate balance of both privacy and community space is required to have a functioning place for human activity to thrive.

ADAPTABILITY AND THE HUMAN DIMENSION OF DESIGN

Ann Cline quotes Thom Mayne in chapter 2 of "A Hut of One's Own" – Experimental Lives, where Mayne criticizes the Osaka Follies for their sculptural qualities, "To me the essence of architecture is to be found in its connection with daily life."[15] When applying that concept to the idea of a machine, one can make the same criticism. The International space station is not a place that is designed for "daily life". Therefore, if a place is not designed for daily life, how can it be called architecture? Ann Cline also talks about the primitive hut as somewhat of a deconstructive process, moving and changing things as one sees fit. She compares how children build forts, club houses, tents, and other structures of "primitive huts" as a form of mimicry of the architectural process. "Like designers, they obsess over details that seem meaningless to others."[16] As to the tent building children, we each have our own preferences with how we live, where we live, and what we live in. It becomes apparent to see that the concept of the machine can quickly suffocate any possibility of versatility or creative flexibility. Providing a crew member with a place of their own to personalize and to use for multiple functions as to whatever they would desire, could potentially eliminate the psychological strain of living in close proximity to others, or open up for interaction when desired. Even sleeping units could change and adapt. Some may prefer customizable volumes; others may favor a temporary sleep enclosure that could be harnessed at various places across the station.

In 1924 Mies van der Rohe wrote in a magazine regarding the future of building tectonics and practices. "I am convinced that the traditional methods of building will disappear", which was reinforced by Professor J.D. Bernal wrote in the "Social Function of Science: "It will soon be possible to break altogether with the tradition of putting stone on stone or brick on brick and move in the direction of rational fabrication."[17] In 1972, Italian designer Gianantonio Mari devised a modular support structure environment which addressed functional requirements but also allowed for personalization. He focused on studies of five categories: privacy, sleeping, dining, leisure, and sensory. The International Space Station was already designed based on a modular system, often referred to as a "kit of parts" including modules, nodes, docking adapters, and other attachments.[18] Naturally, using a "kit of parts" on a micro scale to design personal spaces would make the most sense. This allows for adaptation and evolution over time, as these places may be retrofitted in the future. Just as children experiment with the tents, playhouses, and forts, a kit of parts approach promotes that inherent need to self express, and to personalize.

[15] Cline, Ann. *A Hut of One's Own: Life outside the Circle of Architecture*. Cambridge, MA: MIT, 1997. Print.
[16] Cline, Ann. *A Hut of One's Own: Life outside the Circle of Architecture*. Cambridge, MA: MIT, 1997. Print.
[17] Pawley, Martin. *Theory and Design in the Second Machine Age*. Oxford, UK: B. Blackwell, 1990. Print.
[18] Howe, A. Scott., and Brent Sherwood. *Out of This World: The New Field of Space Architecture*. Reston, VA: American Institute of Aeronautics and Astronautics, 2009. Print.

ORIENTATION, DIRECTIONS, AND COSMOLOGICAL AXIS MUNDI

"Only in a hut of one's own can a person follow his or her own desires", Ann Cline states in the final chapter of her book, "here in a hut of one's own, a person may find one's very own self, the source of humanity's song."[19] The idea of finding one's self speaks to the idea of a person being grounded, or rooted to a place. In ancient mythology, the term Axis Mundi represented a connection from the earth to the heavens, a center of the world. Symbolically, the axis mundi represents a way to orient one's self in both a micro scale to a specific place, and also a macro scale relationship with the cosmos. Orientation to directions (up, down, north, south, east, west, etc), have always been an inherent need for humans.

Orbital architecture presents many new challenges of addressing means of orientation as well as unique opportunities to harness. Orbital architecture allows for new means of orienting to happen, locally up which is in relation to the pod/craft, and planetary orientation which orients above the planet or moon that would mimic the feeling of flying high above the source planet. The phenomena of vertigo would be exacerbated severely if orientation wasn't considered in space design where no direction is emphasized. The opportunity lies in considering multi-dimensional geometry that could be harnessed in space that otherwise would not be possible to use on planetary architecture. Three dimensional tartan grids could potentially allow for intelligent means of expanding and future growth. By introducing an intelligent parti, not only does the view and orientation benefit, but the functionality of the tectonics and infrastructure would as well.

Heidegger defines "Dwelling" as "the way in which we humans are on the Earth." He also calls what is between Earth and sky "the world", and says that "the world is the house where mortals dwell."[20] But what happens when humans begin to dwell in places beyond the limits of our own planet? Is there an overlap of considerations that are constant for human's to dwell on Earth and in outer space? Are these new environments rejected all together and masked with architecture that is "Earth like" for the sake of attempting to make these environments "like Earth"? Or do we embrace the conditions of outer space and other worlds as unique sites, in which unique solutions should be derived?

CURRENT SPACE ARCHITECTURE

Architecture finds itself imbedded in a new technologically driven epoch; one that relies heavily on digital design and digital fabrication, even here on earth. In 1924 Mies van der Rohe wrote in a magazine regarding the future of building tectonics and practices. "I am convinced that the traditional methods of building will disappear", which was reinforced by Professor J.D. Bernal who wrote in the "Social Function of Science". "It will soon be possible to break altogether with the tradition of putting stone on stone or brick on brick and move in the direction of rational fabrication."[21] However, this poses an interesting questions as to the level of "sacrifice", "truth", and "life" in which is imbued into the hands-on craftsmanship of the building. As John Ruskin said, " buildings should be made by human hands, so that the joy of masons and stone carvers is associated with the expressive freedom given them."[22] As science and technology progress, so does the lack or need for human hands to actually have any part in the overall crafting of structures.

Architecture is a constantly evolving art. Since the first rock became a shelter, and we constructed plazas for communal space,

[19] Cline, Ann. *A Hut of One's Own: Life outside the Circle of Architecture*. Cambridge, MA: MIT, 1997. Print.

[20] Norberg-Schulz, Christian. *Genius Loci: Towards a Phenomenology of Architecture*. New York: Rizzoli, 1980. Print.

[21] Pawley, Martin. *Theory and Design in the Second Machine Age*. Oxford, UK: B. Blackwell, 1990. Print.

[22] Ruskin, John. The Seven Lamps of Architecture. New York: Dover Publications, 1989. Print.

eventually erecting religious buildings to serve as monuments to the gods, ornament began to decorate our houses, and we eventually used mass production to create modules made from steel, wood, and stone in which to build with. We now design and build for people to dwell in lower earth orbit, construct capsules to support life for years of deep space flight, and have even begun to test habitats for other planets. From a cave shelter, to a digitally fabricated capsule floating around the edge of the earth; there must be some common link, some essence of the human dimension that can remain consistent in both.

Current concepts of space habitats focus on a few key things that attempt to reference Earth design. Bigelow Aerospace has already fabricated and deployed two subscale pathfinder spacecraft, Genesis I and Genesis II, which were launched in 2006 and 2007, respectively.[23] One thing to notice is the expandable habitat retaining a mechanical core with floor levels that self deploy after expansion. When considering these in relation to ideas like orientation, it is very clear that the implied direction references a local up and down. Floors are floors, and ceilings are ceilings. There would even be a local front and back in relation to where the birthing adapter would be located. Bigelow Aerospace's Space Station



Figure 2a - Image of Bigelow Aerospace's Hab Module.

Deep space living is only half the issue. What happens when humans arrive at a planet or moon and actually touch down on the surface for the first time? The mission to Mars is closest thing planned for human activity. The recent tests for the Orion crew module have been the first steps to the mission to Mars. Next steps will be testing hab modules and other mission components that will likely have humans on the red planet by 2015.[24] The Mars Desert Research Group has been testing habitable pods in southern Utah since the early 2000's.[25] The goal is to collect data and test strategies to survive the conditions of Mars. These environments have very typical layouts, often based off of a circle. The pods could be connected to multiple types of adapters and each other, however these concepts would likely be the same size and scale regardless of the specific function.

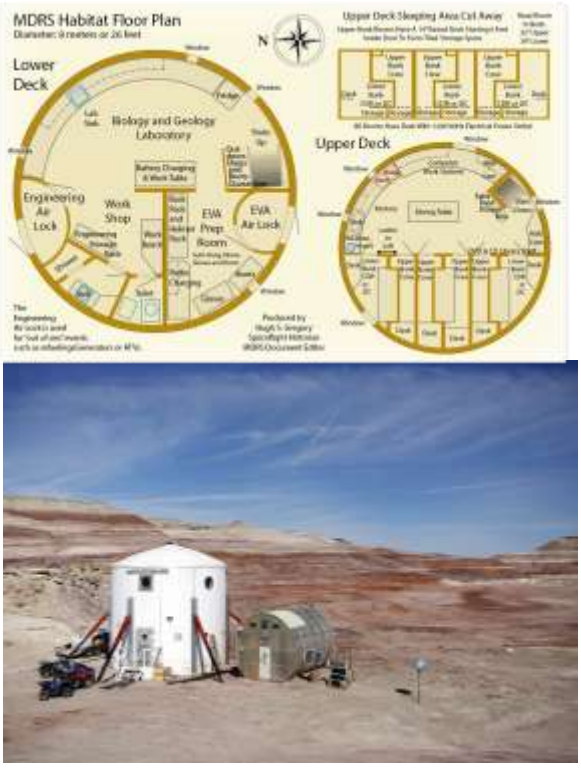

Figure 2b - Image of Mars Desert Research Group

[23] David, Leonard. "Bigelow Aerospaceu0027s Inflatable Habitat Ready for Space Station Trip | Space.com." N.p., n.d. Web. 08 May 2015.

[24] NASA. NASA, n.d. Web. 08 May 2015.

[25] "Mars Desert Research Station." Mars Desert Research Station. N.p., n.d. Web. 08 May 2015.

Have humans outgrown the need for certain primal needs like wind, water, earth, and fire? Have we developed a dependency on new needs; either technologically, sociologically, psychologically, or physiologically? How do we examine these in the context of a very different environment, one that is very "un-earthlike"? Designing for space with require the synthesis of both Atavistic human phenomena, as well as depending on the characteristics of extraterrestrial environments to provide new.

In contrast, I will consider theorists Michael Benedikt, Juhani Pallasmaa, Christian Norberg-Schulz, and Peter Zumthor as references to examine their written work. Does their writing hold weight when considering humans in space? What might they write about when considering designing outside of the Earth's boundaries? By summarizing key points, I can reflect on what they say in contrast to the conditions of space architecture, in hopes of finding traction in which to formulate a theory of architecture beyond Earth.

The (ISS) International Space Station has been in lower earth orbit since 1998. To this day, this is one of the only built environments that reside outside of earth's atmosphere. The sole purpose of the (ISS) is to be a mobile research laboratory where scientists can spend months conducting experiments in various different fields: human biology, physics, astronomy, etc. Currently, the reality of space architecture is driven by financial constraints, not lack of care. However, until substantial infrastructure in space is created which has a financial benefit to earth, such as asteroid mining, it will be difficult to reach past current launch constraints.

Regardless of the development of space technologies, or where they may be heading in the future. The reality is that there are people who live outside of Earth now, and often for months at a time. As the exploration into deep space continues, the need for space architects will be increasingly more vital.



Figure 3a - Image of International Space Station

PHENOMENA OF SPACE

In Benedikt's, "For an Architecture of Reality", he talks about a "direct esthetic experiences of the real."[26] He talks about the moments throughout life with which we build our most memorable experiences upon. Within these experiences we construct our own reality. He argues that this is what should be at the center of our concerns. The human should be put into contact with reality as it stands, and find beauty within that reality. He points to what architecture in its current form is lacking; a sense of reality.

In the context of space, we have no collective experiences. We have been dwelling outside of Earth for less than 30 years. That is a blink of an eye in regards to a cosmological timeline. This environment is a rather new experience for us as humans. Our perceived needs have been volume, space, light, nature, amongst other things that are specific to where we came from. It is a reality of Earth, not orbit, not deep space, not another planet. The new reality is weightlessness, views of other stars and planets, a more direct and unshielded connection with the sun, and a vast, surrounding emptiness of space. Our buildings are no longer brick, stone, or wood. The materials in space design are much more

[26] Benedikt, Michael. *For an Architecture of Reality.* New York, NY: Lumen Books, 1987. Print.

mechanical in nature. Until we can reach a truly earth like planet, a true space vernacular will be something that will be hard to attain.

Our direct esthetic experience will be the boundaries of these new environments and how the materials bridge the gap between the two. The new reality is metal, plastics, inflatable's, and foams. But our direct experiences can still read architectural language from earth; hierarchy of spaces, rhythm of structure, anthropomorphic relationships, light and shadow, sequences and circulation. The human should be put into contact with reality as it stands, not as re-creation of our reality on Earth.

METHODOLOGY OF DESIGN

Industrial design (ID) can be thought of as the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both the user and manufacturer. Often, industrial designers work within larger groups, and expresses concepts that embody all relevant design criteria determined by the group. This may include marketing, management, engineering, or manufacturing specialists. These concepts are often an accumulation of collected analysis and synthesis of data guided by the specific requirements of the client of manufacturer. Often designs are for humans, but mostly of smaller scale. Designs are executed by means of drawings, models, and verbal descriptions.

So what does the industrial designer offer? They are expected to be able to place emphasis of the aspects of products that relate directly to human characteristics. The concern for the user is at the forefront of the design process. This may even deal with psychological, physiological or sociological factors that may influence the design route or process, but is none the less an essential part of the industrial design pipeline. However this does not come without responsibility towards technical concerns or requirements. This involves having an intermediate understanding of the financial constraints, distribution and sales, servicing, processing, and manufacturing. An industrial designer must be able to harness technological advancements, materials, and tectonics to be an effective designer in the field.

Often, industrial designers are sought after for other types of work within the field, sometimes as consultants for a variety of design problems that deal with branding or a clients image. This could be things like product organization, planning and exhibit design, advertising, packaging, and other related design work. Industrial designers are professionals, and must have a wide range of awareness to fulfill contractual responsibilities to clients, protect the public safety and well being, and respecting the ethical business practice.

What is the difference between industrial design and concept art? There is wide speculation across the board in regards to what concept art actually is. Often, there is a public view of what concept art is, which seems to only be partially accurate in terms of what concept artist actually do. Although concept art is typically thought of as the finished product, which is what everyone sees, it is actually the accumulation and process of deriving the final solution. "Concept art is all the dirty work you have to do in order to establish the visuals to begin with."

A general definition states: Concept art is a form of illustration where the main goal is to convey a visual representation of a design, idea, and/or mood for use in films, video games, animation, or comic books before it is put into final product.[27] While not wrong, it is a little misleading in that these concepts don't just spring out of thin air. They are established after a long, and sometimes painstaking process of iteration and design. Only a fraction of what the concept artist actually creates gets used as a final image for a production.

[27]"Let's Get Real About Concept Art - Howtonotsuckatgamedesign.com." Howtonotsuckatgamedesigncom. N.p., 06 Feb. 2014. Web. 08 May 2015.

Concept art is something that follows a very distinct flow and methodology that is based in 3 stages of design. 1) Internal - which is focused around big ideas, exploration, and concepts. 2) For Partners - which is going to eliminate some of the weaker designs and highlight some potential ones that could be explored in greater detail requiring art direction, specific needs, function, branding, image, etc. 3) Public - which seeks to display a polished idea of the concept in a graphically presentable manner. For every finished product or model sheet, there is tons of exploration art, reference collections, thumbnail sketches, speed paints, variations, iterations, and rejected designs. Concept art relies first and foremost on an evolutionary process of design, which is further examined in greater detail.

INDUSTRIAL DESIGN / CONCEPT ART PIPELINE.

The pipeline or workflow that is most prevalent is a very common overlap between the fields of industrial design and concept art. Using the stage outline, it is apparent that there are some similarities between the two, and then ultimately compare them to the architectural design process to examine relationships, similarities, and differences.

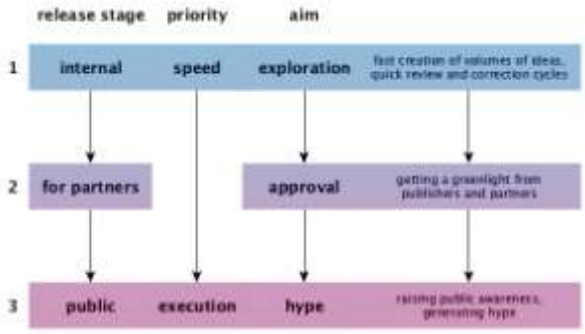

Figure 4a - Concept Art Design Pipeline

Stage one is big idea phase, and one that involves generating concepts and ideas that may seed into solutions or options of the overall design. Speed is more important than execution at this point because these ideas need to be generated quickly so that the team can eliminate ideas until only the strongest designs remain. "It's like mining - you have to eliminate rubble to get to the gold nuggets."[28] Spending a lot of time thinking into detail about an idea could be a real issue if the client wants designs and all the time and effort is focused on only one version. Generating ideas cannot take a lot of time, however this does not mean that the ideas are not thoroughly thought out and informed. This is not generic or random design. This is finding which designs don't work, and eliminating them from the workflow. Often there is a ratio of "design risk" which designates the risk involved with changing the original element by too much. If a designer retains 90% of the original component and changes 10%, this would constitute as a safe design. Likewise 70% would be a medium risk, and 50% and below would be very high risk because the original component is so drastically changed that people may not identify with it. This is important when considering concept art and industrial design, because this can sometimes make or break an idea.

Before a design can proceed to stage 2, there are some approvals that need to be procured:

- Creative directors or investors, who want to see their vision represented.
- 3D animators, animators, manufacturers, engineers concerned with budget constraints.
- Clients with specific needs and expectations or constraints.

Stage two is more about presentation while still retaining the approved concepts moving forward from stage one. Select ideas and presentations are now pitched to the partners of the team. At this point, the industrial designer/concept artist have already gotten the team convinced and it is time to start executing the design. However, this is more of a balancing act, because during this detail phase, it is important that things aren't super polished. There cannot be a whole lot of hours

[28] "Industrial." University of Cincinnati. N.p., n.d. Web. 08 May 2015.

put into an image only to have one of the partners thrash it with other demands and requirements. It is a balance of both speed and quality. The key thing to take away from stage two, is that is a rather easy jump from stage one into stage two. All of the hard work, research, thumb nailing, sketching and brainstorming is done. It should be very seamless to turn concept into production as you already have the team convinced.

Before a design can proceed to stage 3, there are some approvals that need to be procured:

- Manufacturer budgetary constraints.
- Marketers want to see brand represented well, but also ensure that new creation will have its own identity.
- Funding and financial team members will want to ensure desired financial results.

Stage 3, Finally, some of the art/design gets approved for final publication or production. The final stage is to wow the public or audience with flashy, very tight, rendered images. It is no longer about the process, because the process isn't what will sell the design, the finished creation is what is viewed as the finished product. However, this is still somewhat of a misconception. Both industrial design, and concept art, are only the beginning. Unlike art, which is the final product to be viewed, interacted with, and experienced by the audience, concept art and industrial design production images are only the first step into making that into a game, movie, or reality. Often the final boards and production images are the only thing that the public sees. They do not see the gritty drawings, scratch sketches, speed paintings, or all of the research behind it all. This often leads to a skewed view as to what concept art/ industrial design is. This also paints a distorted vision of what design is all about.

ARCHITECTURAL PROCESS

There is no question that the architectural design process is not quite as cut and dry as the industrial design pipeline. The typical architectural pipeline can be laid out in roughly 5 steps:

- initial discussion / client input
- information gathering and research (precedent study)
- schematic design and feasibility
- design development
- construction drawings / construction

It is not to say that each architect does each of these 5 things in the same manor, but ultimately, they must pass each step with adequate completion before moving forward to the next process. In comparison, the processes are similar. They all have a client or person who has input on the new creation. They all gather information and data regarding the design subject. Often though, if there is a big idea phase, it is quite short in terms of duration in relation to the larger scope of the project. Sometimes there is no big idea phase where ideas are generated. Often schematic design, although sometimes thought of as a concept phase really isn't. The precedent study, often mixed with the client input already dictates a preconceived idea of what this thing is going to look like. Granted, there are changes and customizing things specifically for the client, yet there is still no dirty, messy, big idea, concept that could send the project in a new direction.

Another thing that makes for a crucial difference is the concept of time. More times than not, schematic phase is rushed to be able to get to something substantial. There are some successful firms or designers actually are in big idea land for a longer duration, however for the sake of this paper, I am targeting the typical practice. Obviously, time is money and there are phases where it is better to be fast and generate many ideas, rather than to be

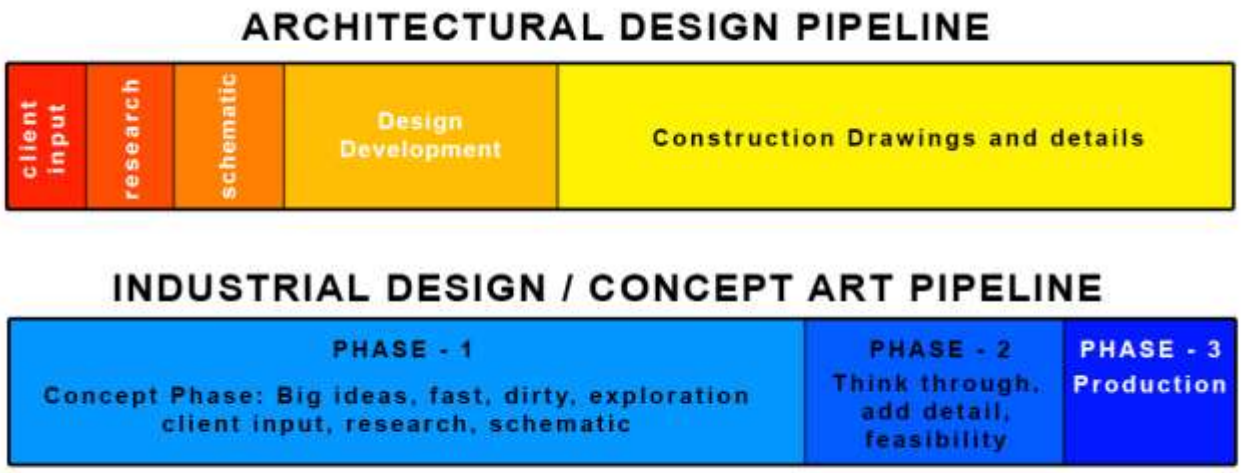

Figure 5a - Pipeline comparison

tight and precise with only one idea. This comes down to outcome. Both methodologies are inevitably seeking a final design that comes to fruition, however it seems that in both the industrial design pipeline, and concept art workflow the focus is on the early stage of big ideas and how to allow them to inform the final production.

There are two important ideas to take away from this. 1) both the industrial design and concept art methodology, and the architectural process have very similar components and a very similar method about going from phase to phase. 2) The time designated to each section of these phases is often severely skewed and disproportionate when compared. It is clear that a look at how much time is spent in each area is nearly inverse. The architectural design pipeline has a small amount of the client input, research, and schematic making up less that 25% of the total process, where as the (ID) and (CA) accumulates nearly 70% of the total process time. So to clarify, the components are the same in each, yet the time is drastically different between the two. Why? What stops the architecture field from adopting this front loaded design process. Why is the majority practicing this very back loaded process? Are there advantages to doing one compared to the other?

Take the idea of a charette for example. Why do these quick crash course designs often turn out a better "idea" when compared to project that might have more time put into it? A charette actually involves more of the big idea, fast, dirty, concept stuff. Architecture may short change itself but cutting the big idea phase into such a small chunk of the overall design solution. There is a reason that concept art and industrial design relies heavily on the upfront concept stage. In their industry, mediocrity or un-evolved solutions just don't cut it. If the new iPhone designers do not come up with something better they are in trouble. If the new Gears of War game doesn't out-do the last, it is in big trouble. What happens when the quality of architecture drops? Nothing. We accept it as part of the process, and often other architects find great dissatisfaction with the acceptance of mediocrity within the realm of architecture.

Space design would benefit greatly from a more mutative concept art approach of design for a few reasons. It offers an approach that seeks to purge any accumulation of "Earth Architecture" related thinking. In doing so, would better accept the reality of the conditions in these alien worlds for what they are, which would allow the designer to strive towards an architecture of reality in space. Secondly, the quick generations of concepts could inspire scientists and engineers throughout the design process. The concept of constant progression that the (ID) and (CA) pipelines offer would lend that same approach when considering specific problems with space designs. Architecture will have to branch out and begin to consider these new realms and what role the architect now plays in space design.

In the future, design will require a new breed of architects versed both in the traditions of building for human activity and the new subjects unique to space technologies and constraints. Humans has trekked beyond the extents of the Earth, where theory about "Earth architecture" can only go so far. The more we search for the "recipe" of what to do for humans, the less truth there is within what we create. It becomes nearly impossible to make rational statements about what we are doing and have it still hold any truth.

CONCLUSION

Architecture in space will likely not concern itself with labels, or categories. We will no longer have Classical, Roman, Victorian, Modern, Usonian, International Style, Post Modern, Deconstructive, etc. All we will have are the lessons from which they taught us. In space, there will be three crucial elements: 1) protecting human life, 2) extracting the abstract concepts of earth architecture, and 3) relaying the composition with new materials and new environments. A critical "cosmological" regionalism. As designers and Architects, we must begin to accept the reality of these new environments for what they are, rather than to just transplant the needs we have on Earth. The machine can be used as a tool to work with, not design against.

There is no question that there is a direct relationship between the progression of science, and the progression of architecture. However architecture's history is constantly reinterpreted based off the architectural present. As our understanding of the cosmos expands, and architects become more involved with the process of space design, architecture will eventually reach further into our solar system and eventually other planetary systems. Scientific exploration into the cosmos will continue, regardless of the condition of our planet. What becomes clearer is the need to remember the human's value of design in this new age of the machine. Designing for new worlds will require the embracing of technology and science, but most importantly, harnessing architecture's responsibility of the inhabitant's needs both physically and psychologically. Architecture must function, provide a human relationship to the built environment, and must do both beneficially, and appropriately. The opportunities of orbital architecture are as exciting as they are challenging. Orbital design presents ways to rethink the values of design based on psychological needs, means of creating a dynamic environment, and ways to orient the inhabitants to both a local reference and on a cosmological scale. Architecture is for people; therefore both science and art should play a role when conceptualizing design.

As architects begin to take responsibility for designing beneficial architecture, working within the constraints of extreme conditions, paired with the phenomenological approach to human consideration, we can begin to synthesize the two into a more complete, and rich approach to beneficial design for any environment. As designers, we must conclude that architecture is not only a mechanism of resilience and adaptation, but a prominent display of art and beauty which must be carried over into the realm of space architecture. We must strive to ensure the human dimension is not lost in the process of embracing "the machine".

Ralph Waldo Emerson once said, "Do not go where a path may lead, go instead where there is no path, and make a trail".[29] It is time to rethink design.

[29] Ralph, Emerson W. "A Quote by Ralph Waldo Emerson." *Goodreads*. N.p., n.d. Web. 10 Sept. 2014.

List of Figures

Fig 1a- "The inside of the Midget Submarine HMS X24 - Picture of Royal Navy Submarine Museum, Gosport." - TripAdvisor. N.p., n.d. Web. 08 May 2015.
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Fig 2a- David, Leonard. "Bigelow Aerospaceu0027s Inflatable Habitat Ready for Space Station Trip | Space.com." N.p., n.d. Web. 08 May 2015.
Fig 2b- "Mars Desert Research Station." Mars Desert Research Station. N.p., n.d. Web. 08 May 2015.
Fig 3a- NASA. NASA, n.d. Web. 08 May 2015.
Fig 4a- "Let's Get Real About Concept Art - Howtonotsuckatgamedesign.com." Howtonotsuckatgamedesigncom. N.p., 06 Feb. 2014. Web. 08 May 2015.
Fig 5a- Image by author

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[17] Pawley, Martin. *Theory and Design in the Second Machine Age*. Oxford, UK: B. Blackwell, 1990. Print.

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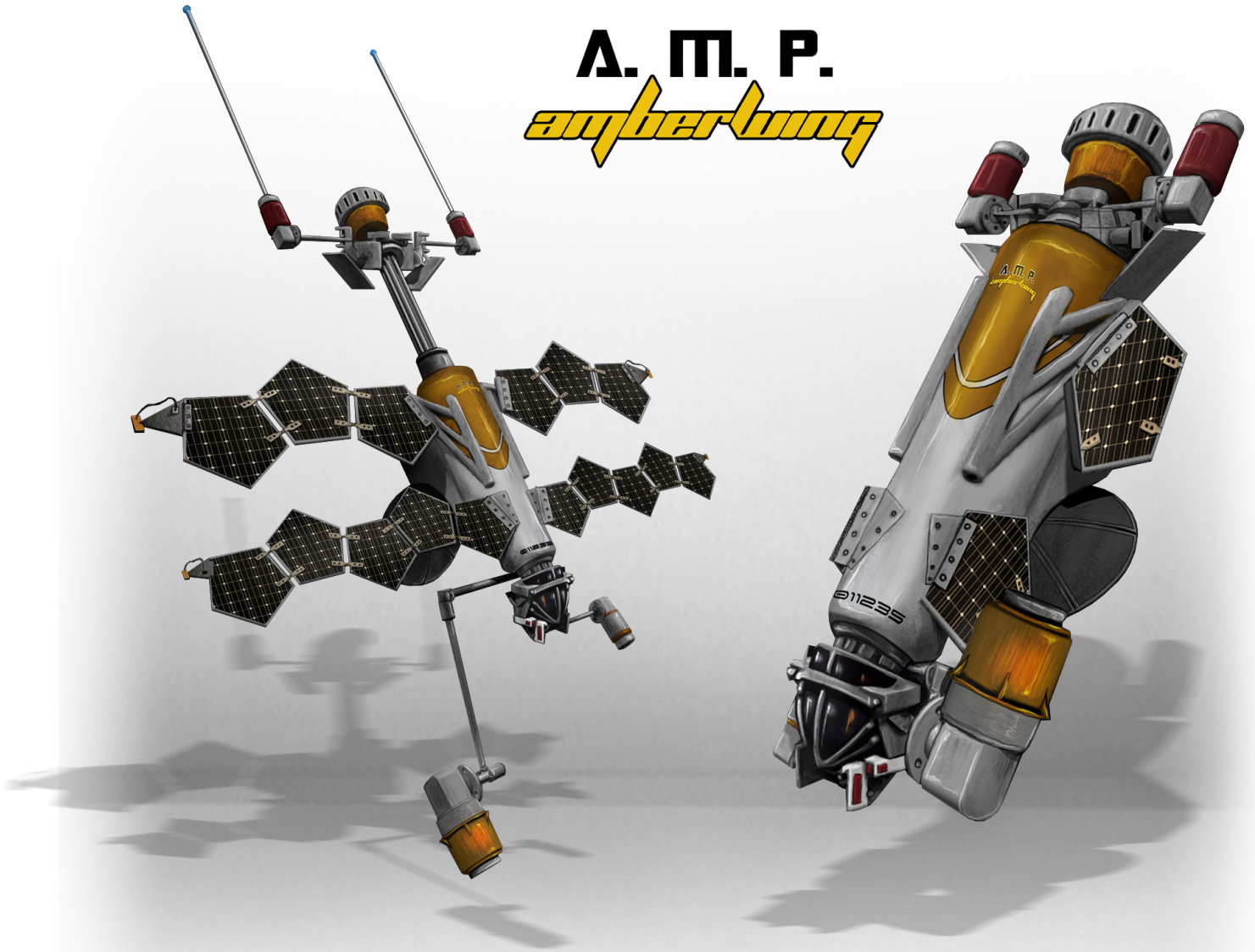
01

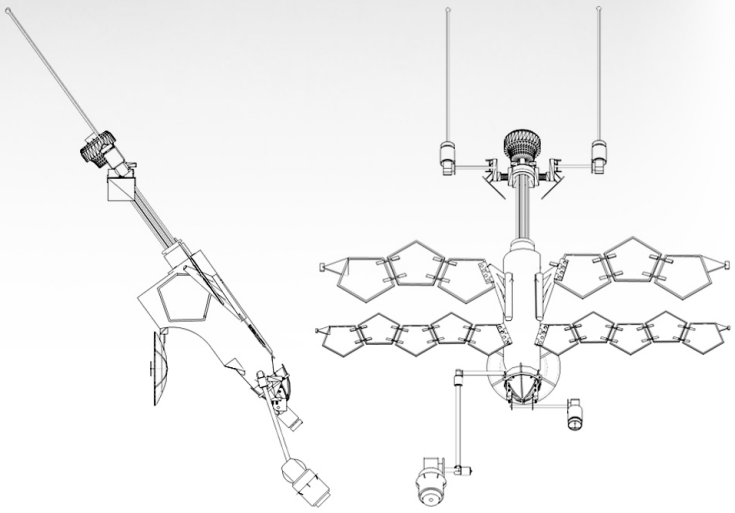
[A.M.P] ATMOSPHERIC MONITORING PROBE



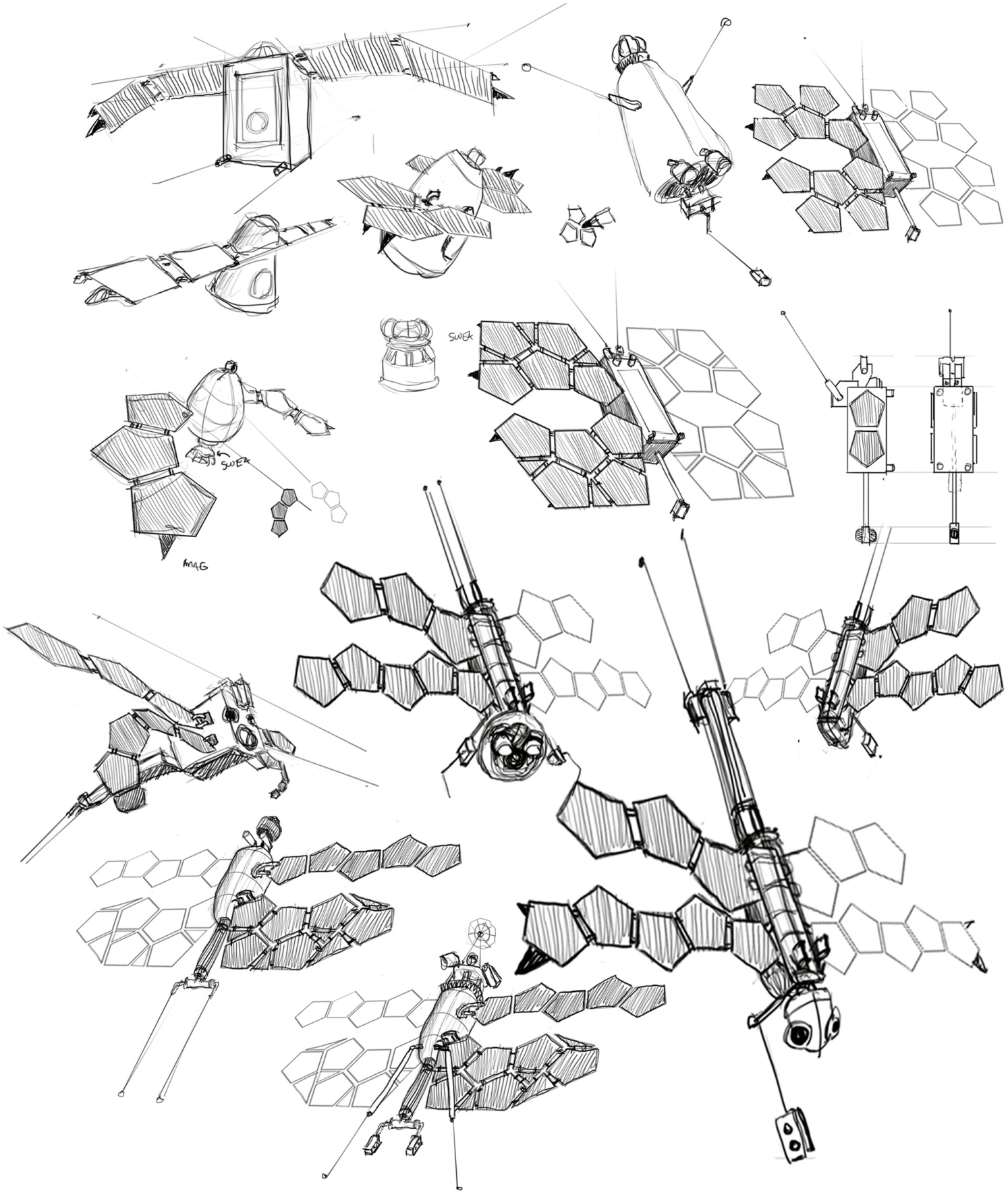
MISSION TYPE: EXPLORATORY - SEEKING SIGNS OF LIFE
MISSION GOALS:
DETERMINE THE ROLE THAT LOSS OF VOLATILES TO SPACE FROM THE CERIAN ATMOSPHERE HAS PLAYED THROUGH TIME.
DETERMINE THE CURRENT STATE OF THE UPPER ATMOSPHERE, IONOSPHERE, AND INTERACTIONS WITH THE SOLAR WIND.
DETERMINE THE CURRENT RATES OF ESCAPE OF NEUTRAL GASES AND IONS TO SPACE AND THE PROCESSES CONTROLLING THEM.
DETERMINE THE RATIOS OF STABLE ISOTOPES IN THE CERIAN ATMOSPHERE.

LAUNCH MASS 2,454 KG (5,410 LB)
DRY MASS 809 KG (1,784 LB)
PAYLOAD MASS 65 KG (143 LB)
POWER 1,135 WATTS

MAJOR COMPONENTS:
SOLAR WIND ELECTRON ANALYZER
LANGMUIR PROBE AND WAVES ANTENNAS
SOLAR WIND ION ANALYZER
SOLAR ENERGETIC PARTICLES (X2)
MAGNETOMETER (X2)
SUPRATHERMAL AND THERMAL ION COMPOSITION

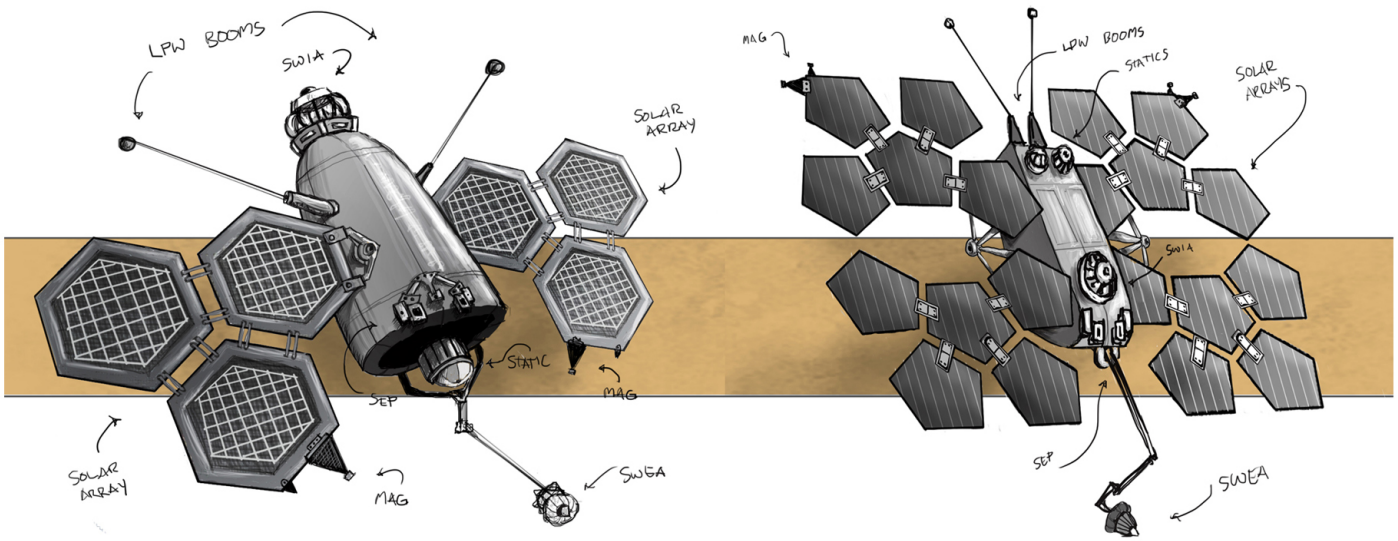


ATMOSPHERIC MONITORING PROBE (A.M.P)



01

[A.M.P] ATMOSPHERIC MONITORING PROBE



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ATMOSPHERIC MONITORING PROBE

PROTO TYPE
AMP BUTTERFLY
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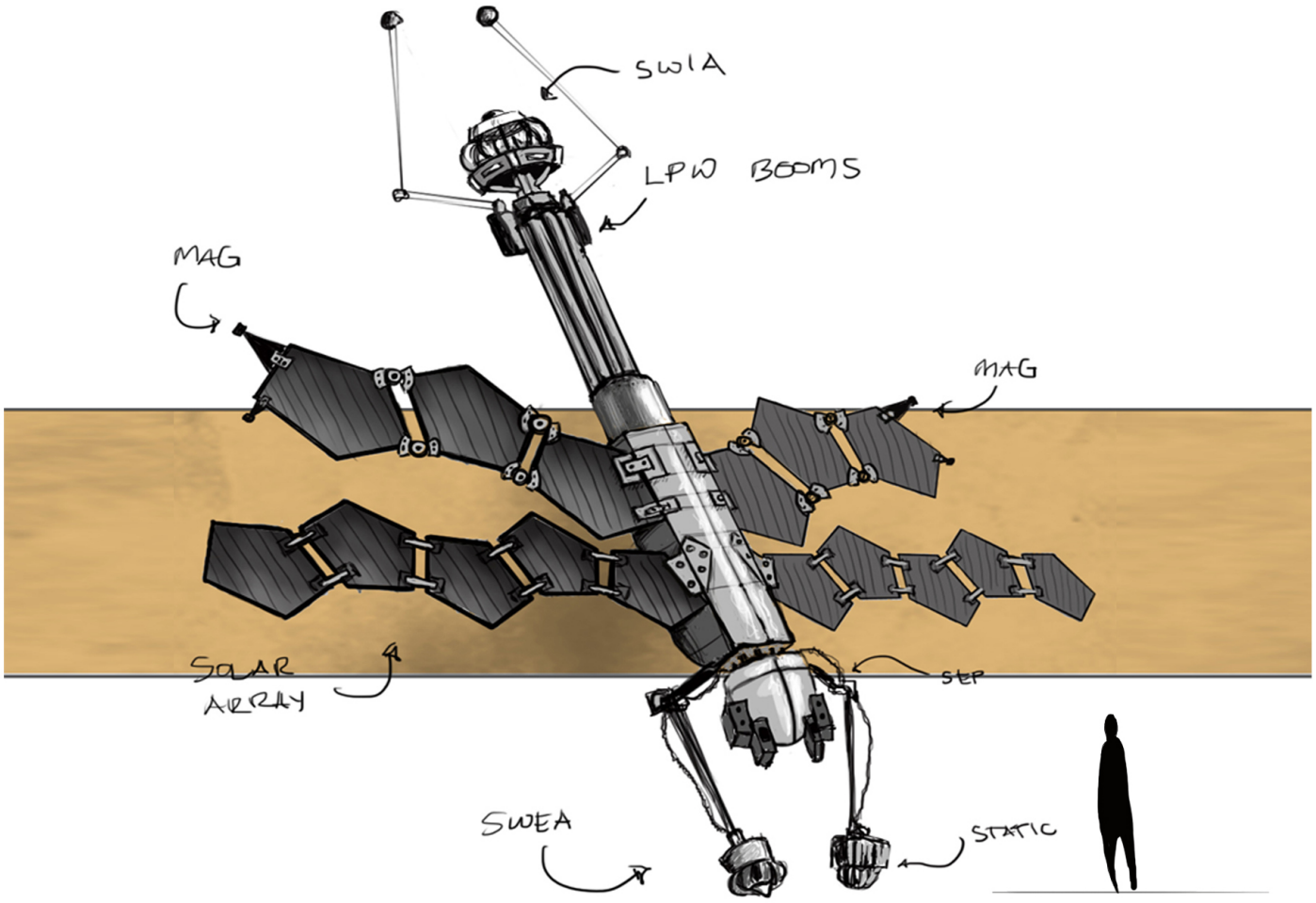

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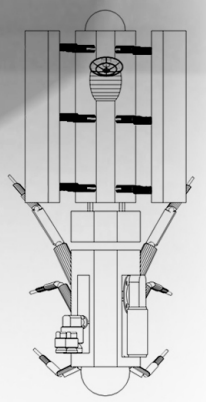
KENNY LEVICK XL

[A.P.D] ASTEROID PROSPECTING DRONE

A.P.D.
SIPHONAPTERA
stinger







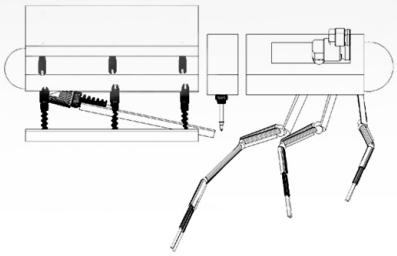
MISSION TYPE: EXPLORATORY - SEEKING ELEMENTAL PROPERTIES OF ASTEROIDS FOR HARVESTING.

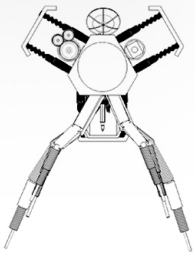
THE INSTRUMENTS ARE DESIGNED TO:

MEASURE THE ELEMENTAL, MOLECULAR, MINERALOGICAL, AND ISOTOPIC COMPOSITION OF THE COMET'S SURFACE AND SUBSURFACE MATERIAL
MEASURE CHARACTERISTICS OF THE NUCLEUS SUCH AS NEAR-SURFACE STRENGTH, DENSITY, TEXTURE, POROSITY, ICE PHASES AND THERMAL PROPERTIES; TEXTURE MEASUREMENTS WILL INCLUDE MICROSCOPIC STUDIES OF INDIVIDUAL GRAINS

LAUNCH MASS 100 KG (220 LB)
PAYLOAD MASS 21 KG (46 LB)
DIMENSIONS 1 × 1 × 0.8 M (3.3 × 3.3 × 2.6 FT)
POWER 32 WATTS AT 3 AU

MAJOR COMPONENTS:
- APXS - ALPHA-P-X-RAY SPECTROMETER
- CIVA - PANORAMIC AND MICROSCOPIC IMAGING SYSTEM
- CONSERT - RADIO SOUNDING, NUCLEUS TOMOGRAPHY
- MUPUS - MEASUREMENTS OF SURFACE AND SUBSURFACE PROPERTIES
- ROLIS - IMAGING
- SD2 - DRILLING AND SAMPLE RETRIEVAL







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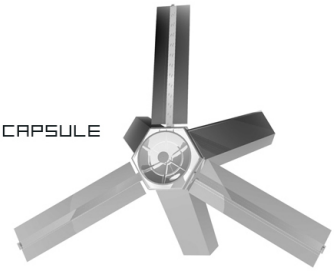
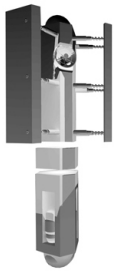


IRIS CAPSULE

UN-PACKED



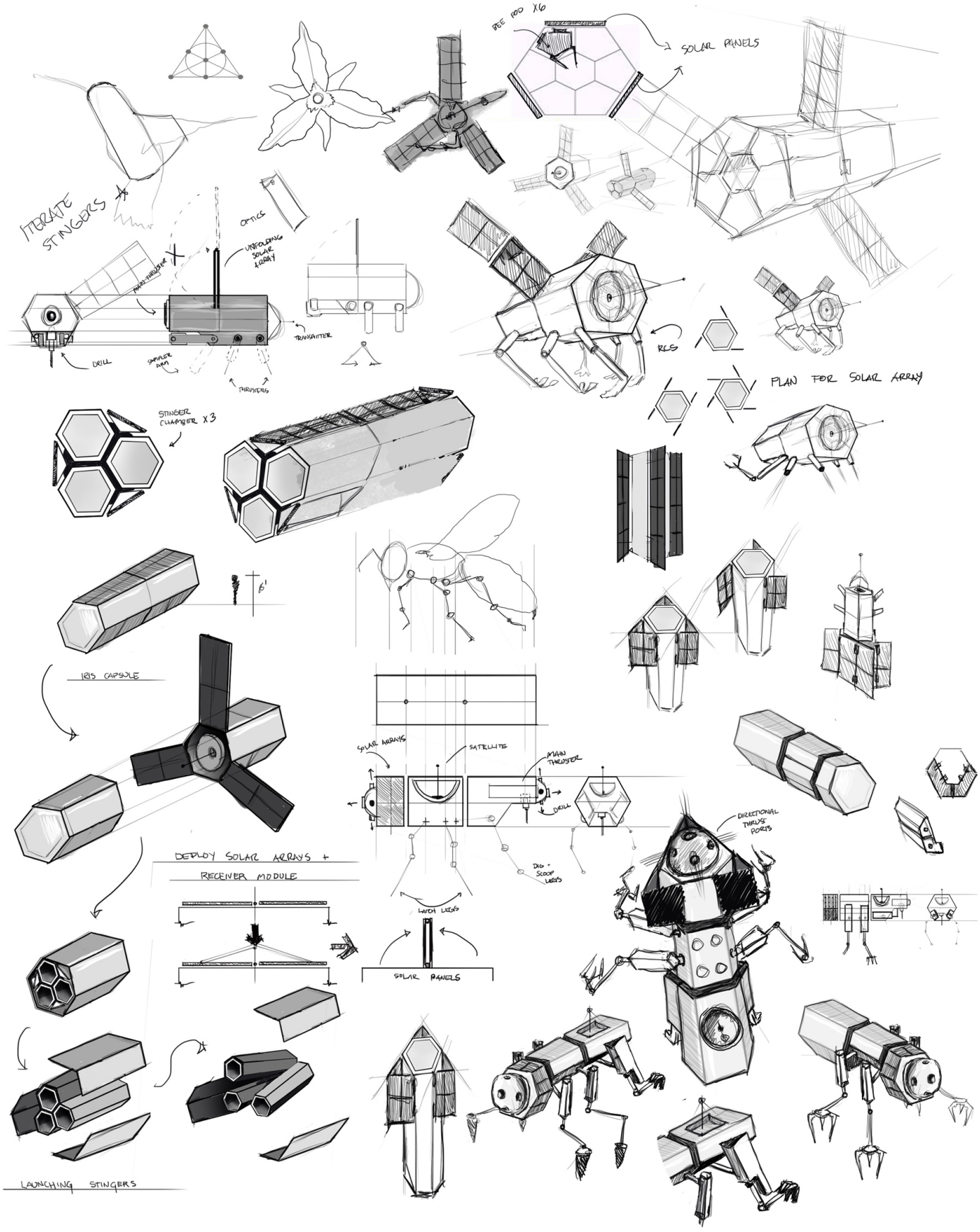
STINGER CARTRIDGE



STINGER HIBERNATION



STINGER LATCHED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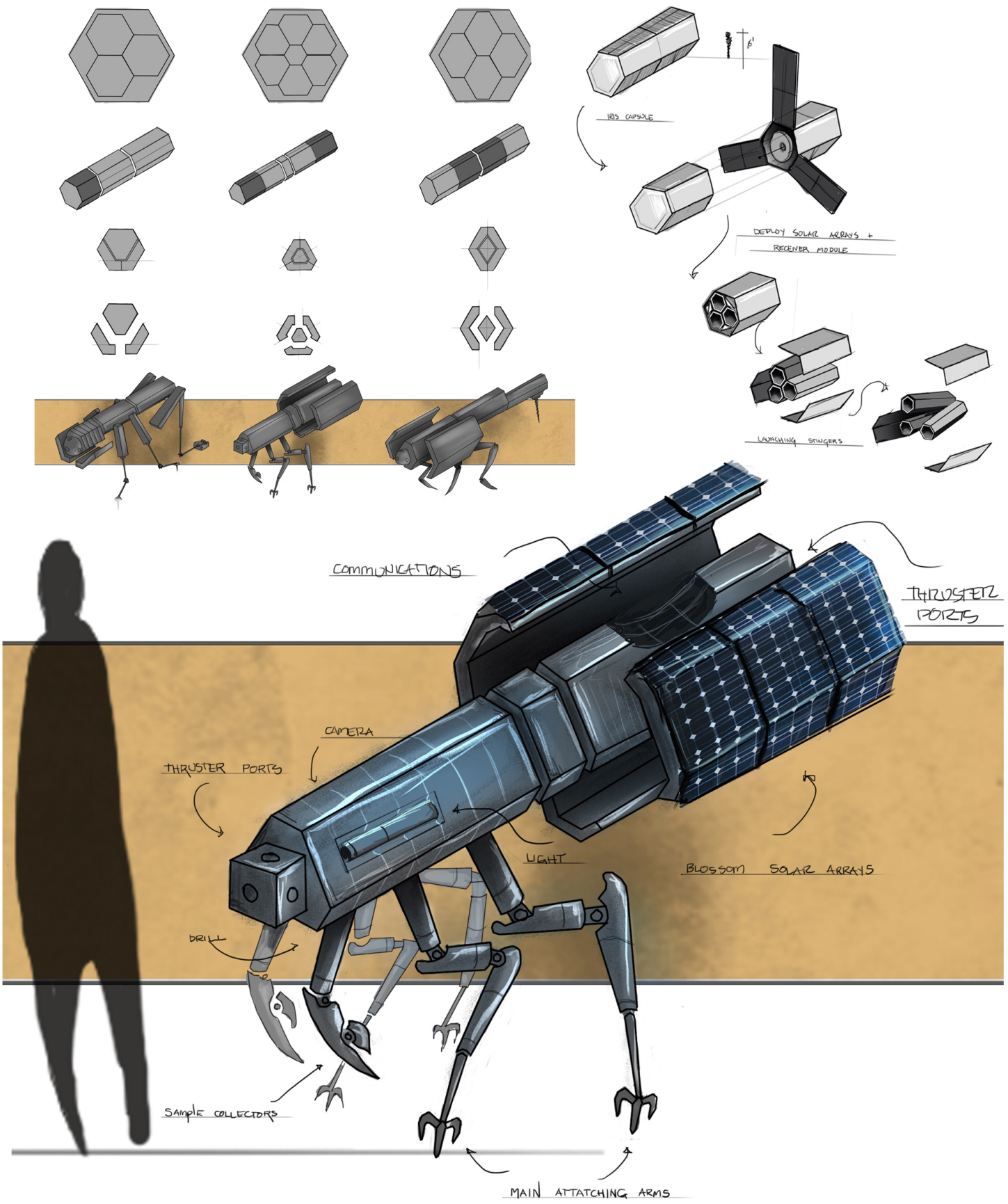
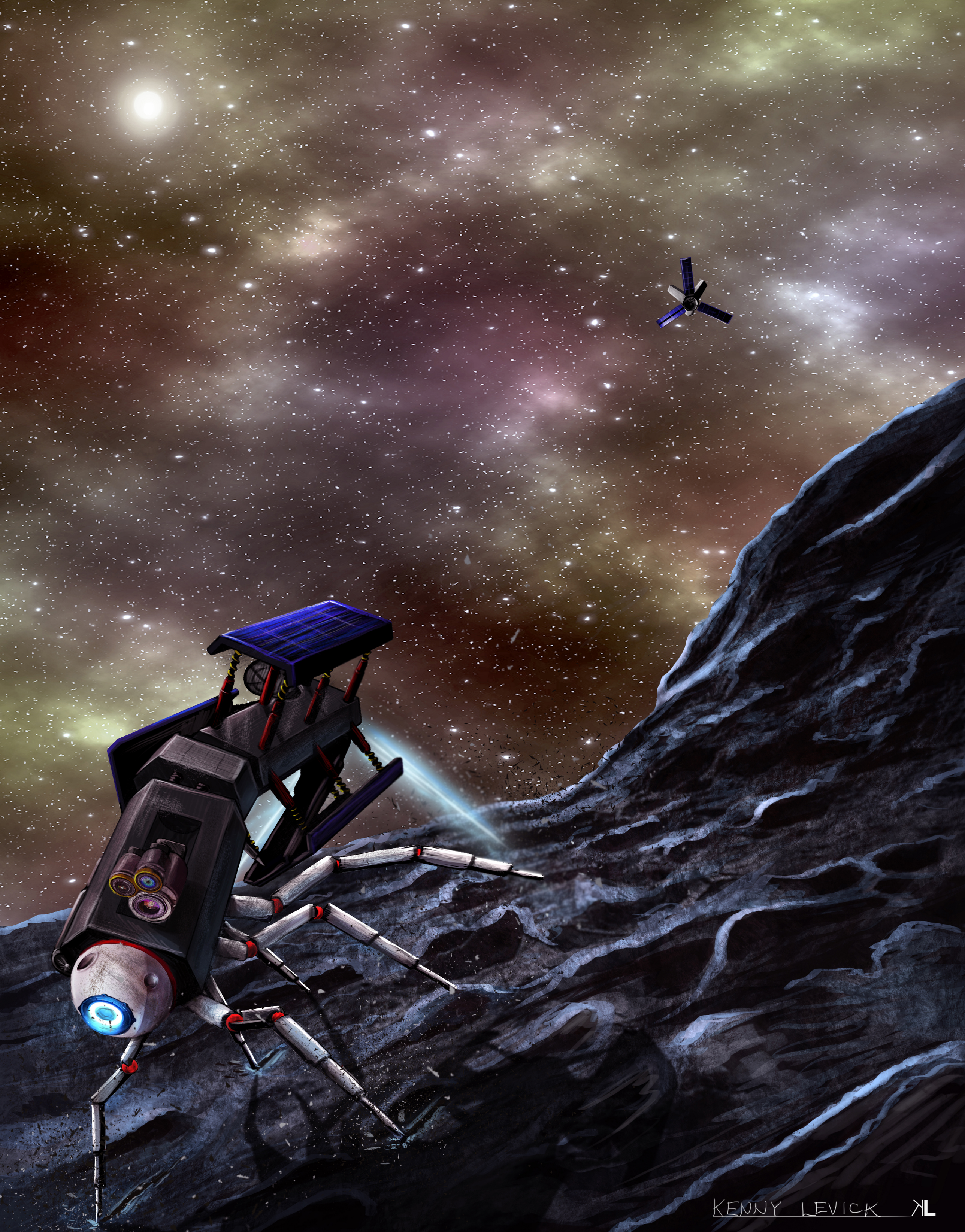
ITERATE STINGERS
OPTICS
UNFOLDING SOLAR ARRAY
MAIN THRUSTER
DRILL
SAMPLER ARM
THRUSTERS
TRANSMITTER
RCS
PLAN FOR SOLAR ARRAY
STINGER CHAMBER X3
IRIS CAPSULE
SOLAR ARRAYS
SATELLITE
MAIN THRUSTER
DRILL
DIG + SCOOP LEGS
DIRECTIONAL THRUST PORTS
DEPLOY SOLAR ARRAYS + RECEIVER MODULE
LATCH LEGS
SOLAR PANELS
LAUNCHING STINGERS

02

[A.P.O] ASTEROID PROSPECTING DRONE

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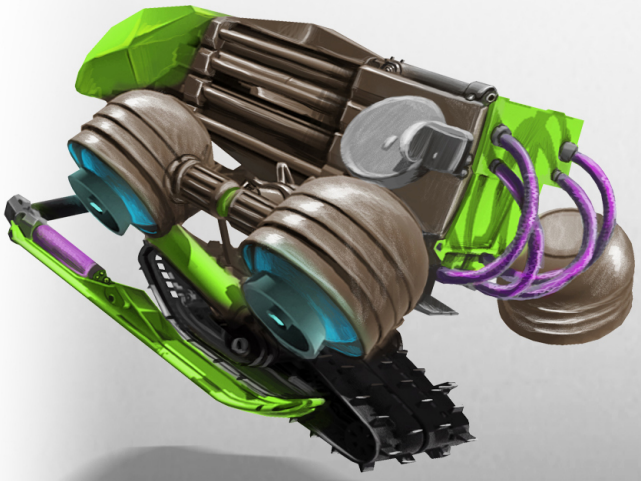


S.O.R.
SEPTAPOD

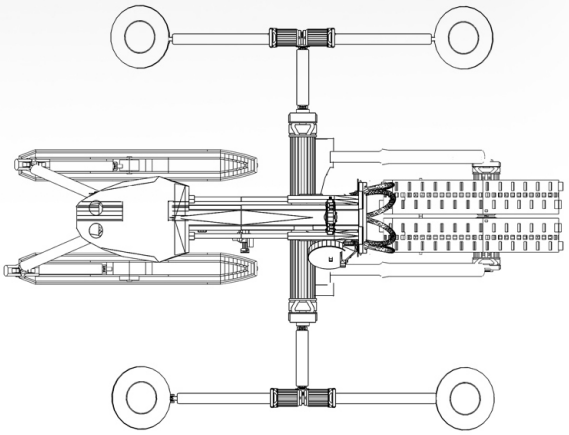


MISSION TYPE: EXPLORATORY - SEEKING LIFE AND GEOLOGICAL INFORMATION WITHIN THE ICE AND ROCK OF CERES.

THE INSTRUMENTS ARE DESIGNED TO:

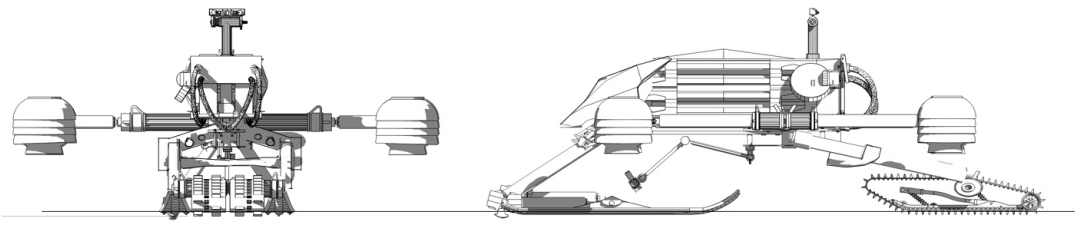
DETERMINE THE NATURE AND INVENTORY OF ORGANIC CARBON COMPOUNDS
INVESTIGATE THE CHEMICAL BUILDING BLOCKS OF LIFE (CARBON, HYDROGEN, NITROGEN, OXYGEN, PHOSPHORUS, AND SULFUR)
INVESTIGATE THE CHEMICAL, ISOTOPIC, AND MINERALOGICAL COMPOSITION OF THE CERIAN SURFACE AND NEAR-SURFACE GEOLOGICAL MATERIALS
DETERMINE PRESENT STATE, DISTRIBUTION, AND CYCLING OF WATER AND CARBON DIOXIDE

LAUNCH MASS 900 KILOGRAMS (2,000 LB)
80 KG (180 LB) OF SCIENTIFIC INSTRUMENTS
DIMENSION IS (9.5 FT) LONG BY (8.9 FT) WIDE BY (7.2 FT) IN HEIGHT
POWER - RTG (NO SOLAR PANELS)
MULTI-DIRECTIONAL (40) ION DRIVE THRUSTERS



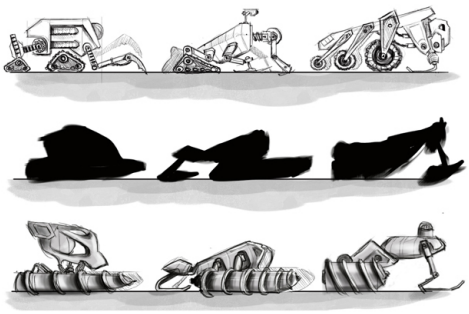
MAJOR COMPONENTS:
- RTG - RADIOISOTOPE THERMOELECTRIC GENERATOR
- HRS - HEAT REJECTION SYSTEM
- RCE - ROVER COMPUTER ELEMENT
- X BAND TRANSMITTER AND RECEIVER

- MAST CAM - MULTI DIRECTIONAL FULL COLOR LENSES
- CHEM CAM - LASER INDUCED BREAKDOWN SPECTROSCOPY
- HAZ CAMS - MONITOR HAZARDS
- ROBOTIC ARM - DRILLING, SCOOPING, SLEVING, AND PORTIONING SAMPLES
- DAN - DYNAMIC ALBEDO OF NEUTRONS - MEASURES ICE CONTENT



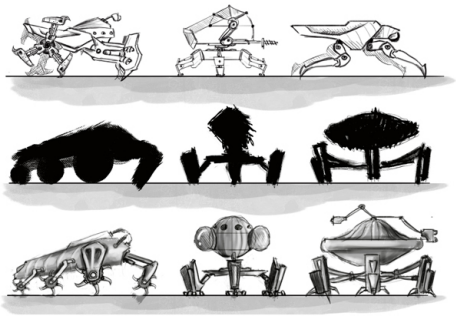
LOW RISK DESIGN
LOW BENEFIT

ROLLER / TRACKS



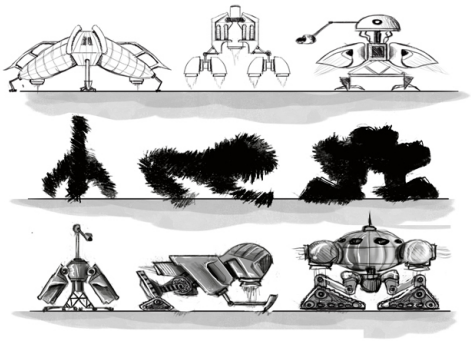
MEDIUM RISK DESIGN
MEDIUM BENEFIT

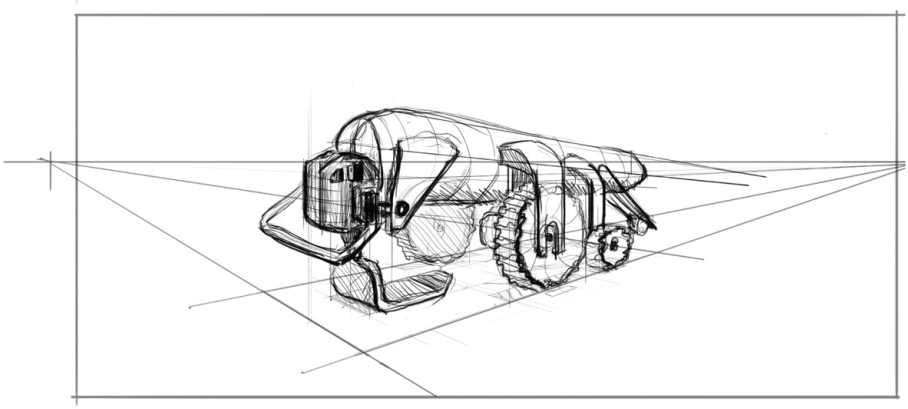
CRAWLING / LATCHING

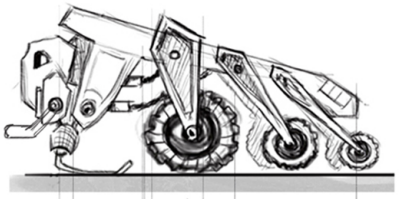


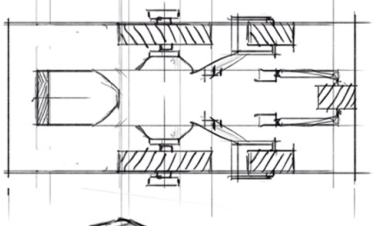
HIGH RISK DESIGN
HIGH BENEFIT

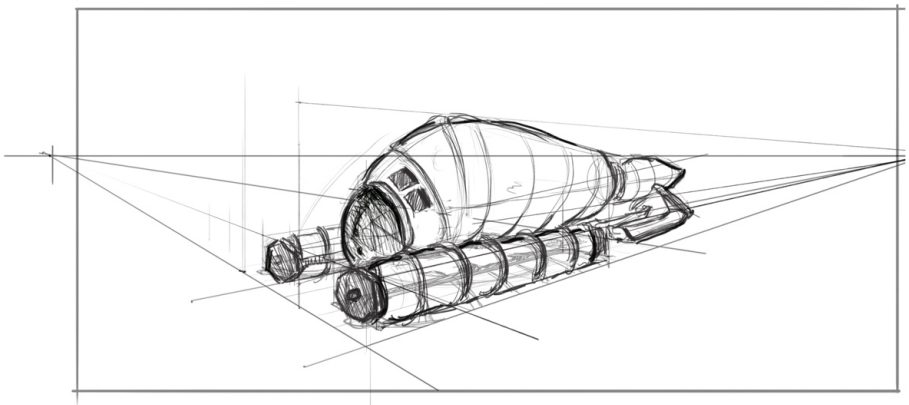
PROPULSION

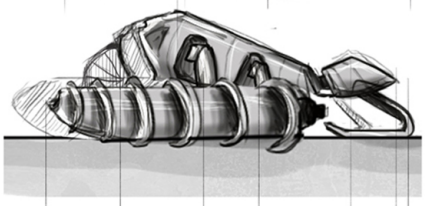


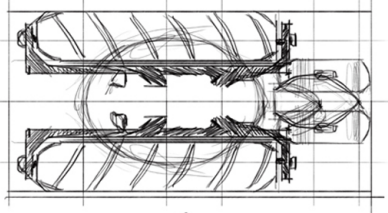


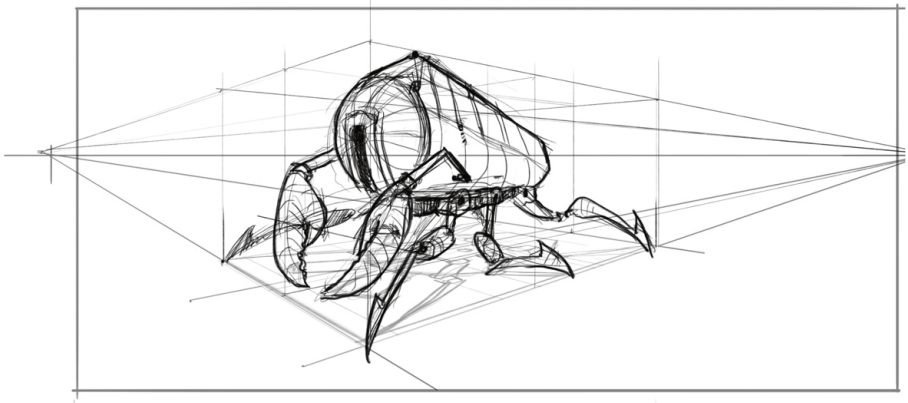


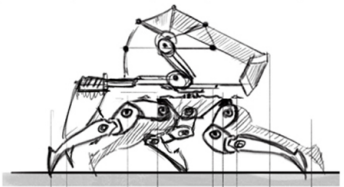


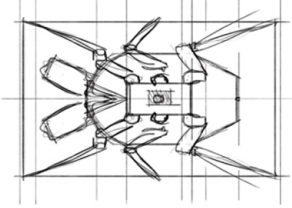






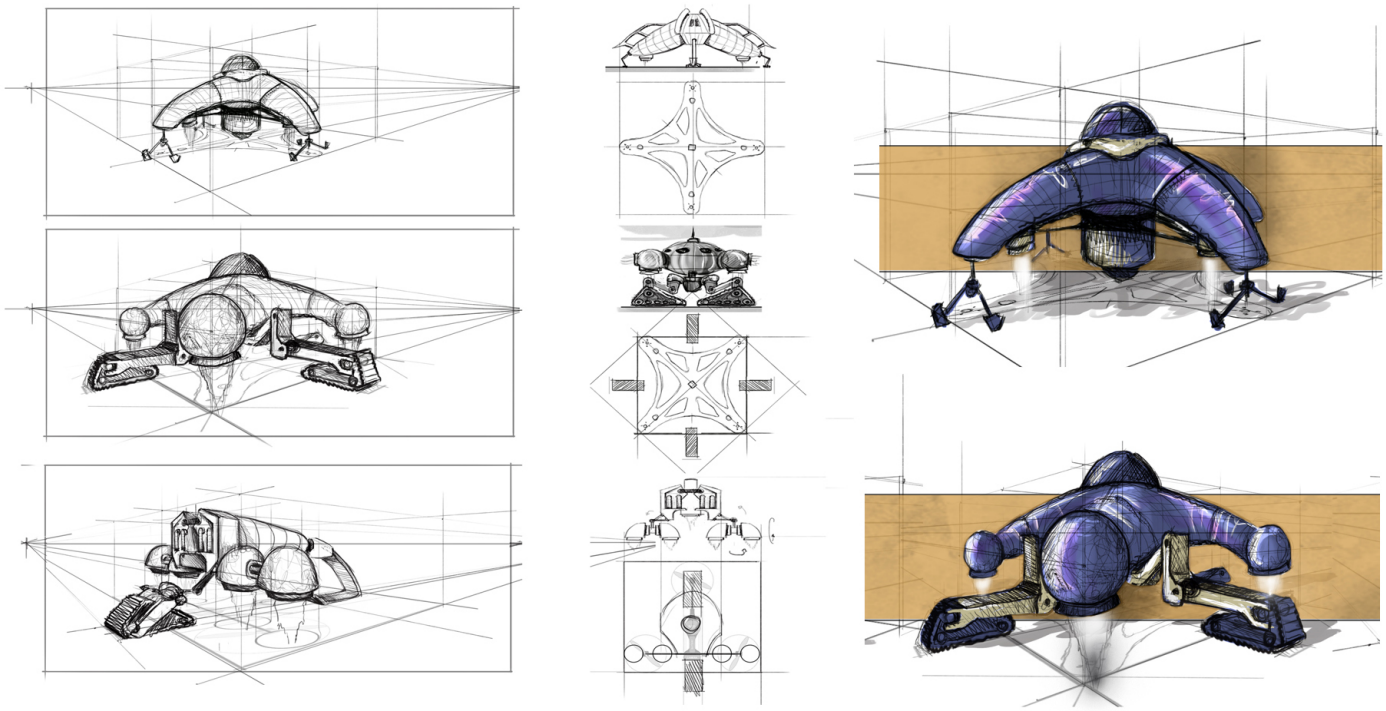


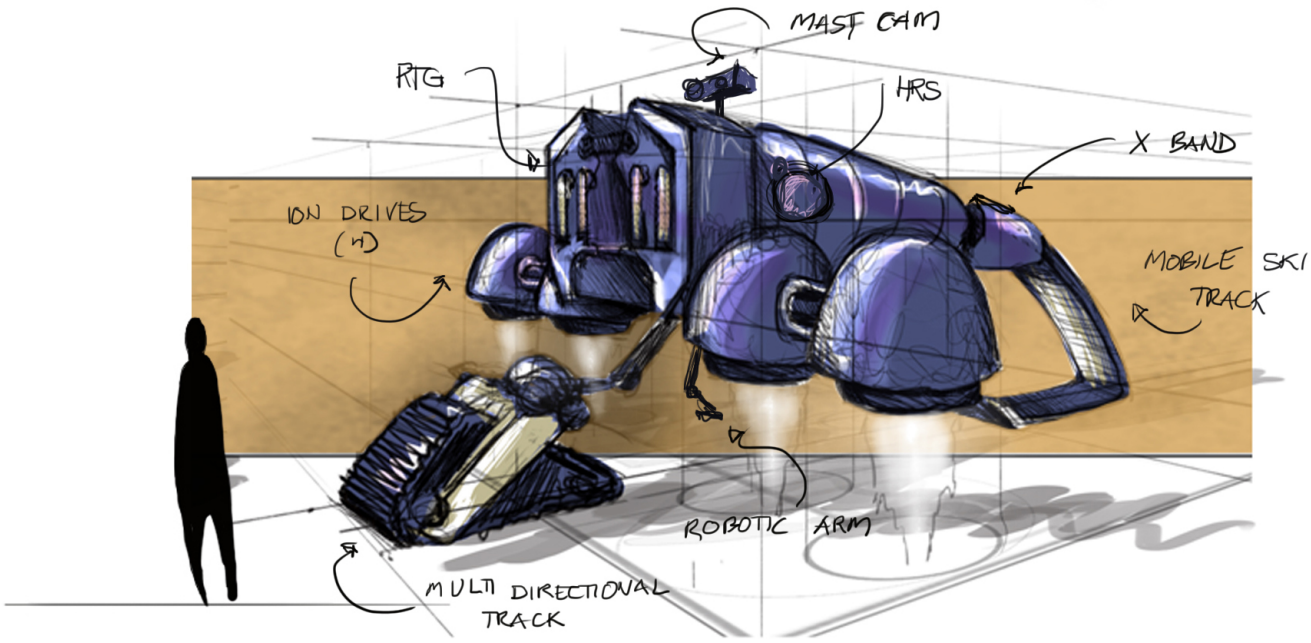


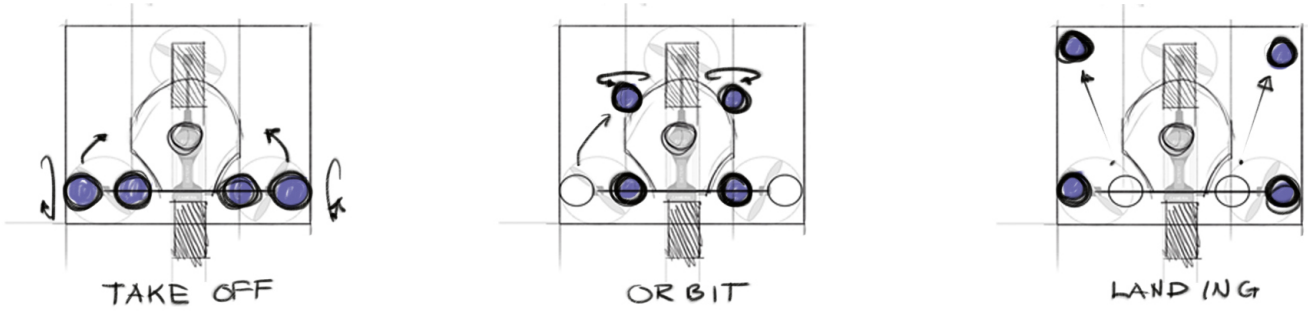


03

[S.O.R] CERES SPECIFIC ORBITING ROVER

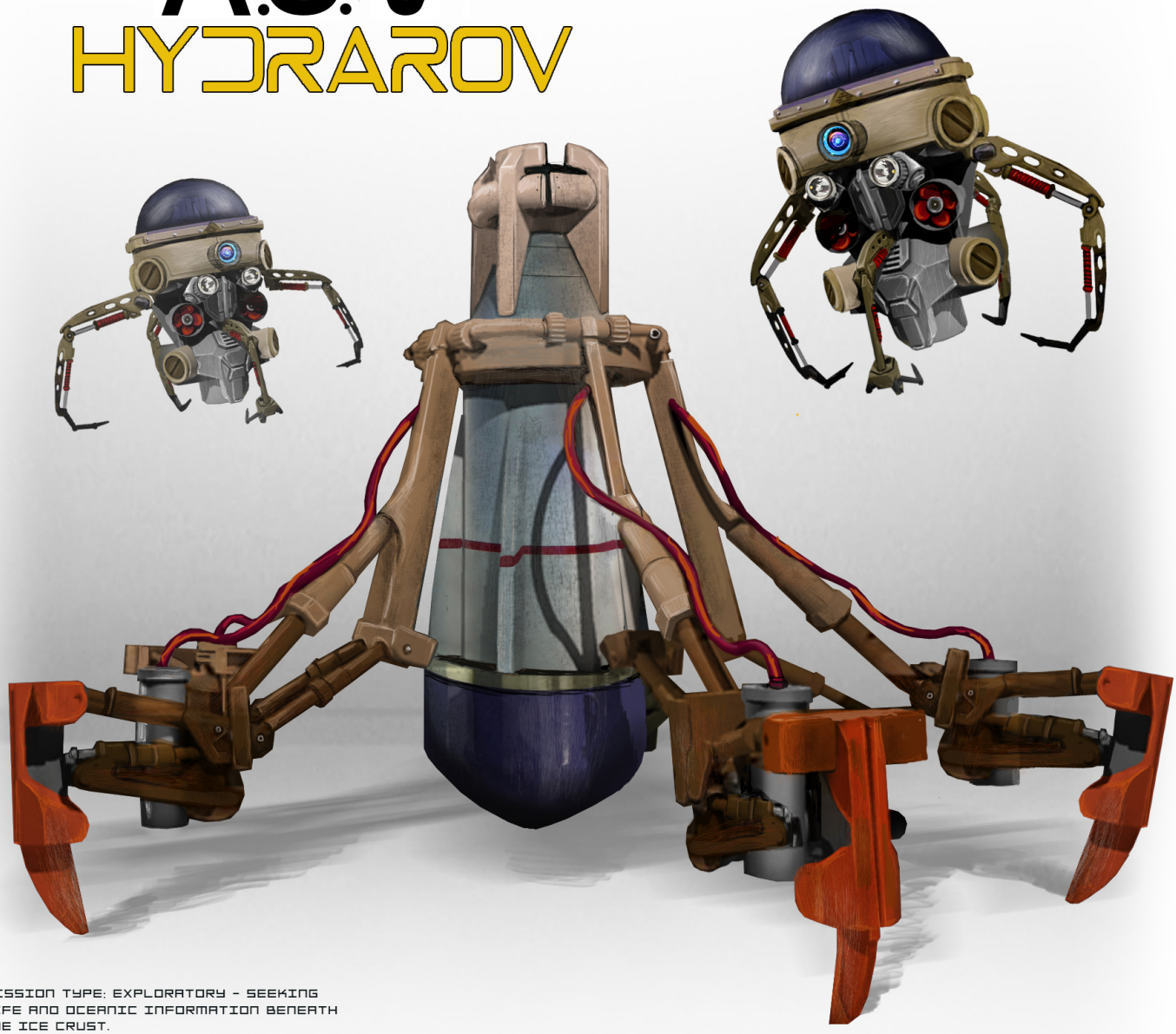






KENNY LEVICK KL

A.U.V
HYDRAROV



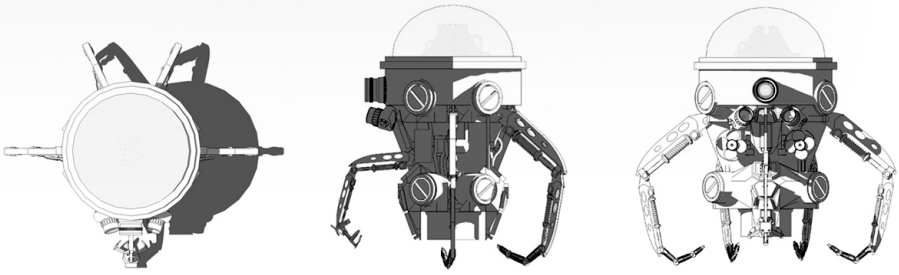
MISSION TYPE: EXPLORATORY - SEEKING LIFE AND OCEANIC INFORMATION BENEATH THE ICE CRUST.

INSTRUMENT SPECIFICATIONS:

DEPTH RATING 3,000M
DIMENSIONS 1700MM (L) 800MM (H) 1300MM (W)
INSPECTION SENSORS 3D FORWARD LOOKING SONAR
COLOUR INSPECTION CLASS VIDEO CAMERA
PROFILING SONAR & DOWNWARD LOOK CAMERA
- COMMUNICATIONS ACOUSTIC, WI-FI, SATELLITE
- NAVIGATION:

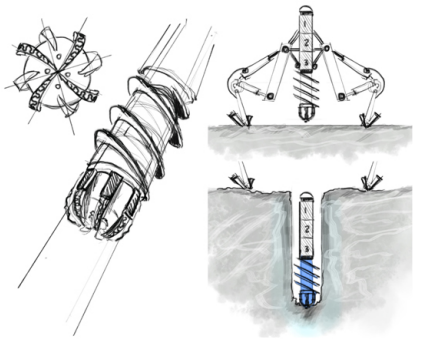
GENERAL DEAD RECKONING (1% DISTANCE TRAVELLED) AIDING SENSOR

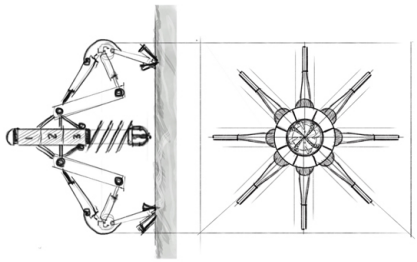
YAW, PITCH, AND ROLL THRUSTING
3D SCANNER AND TRANSMISSION
SAMPLE COLLECTOR
ON BOARD MICROSCOPE

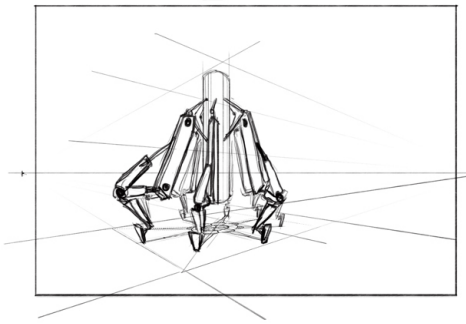


DIAMOND BIT CORE DRILL - ICE REMOVING DRILL SHAFT

LOW RISK DESIGN
LOW BENEFIT

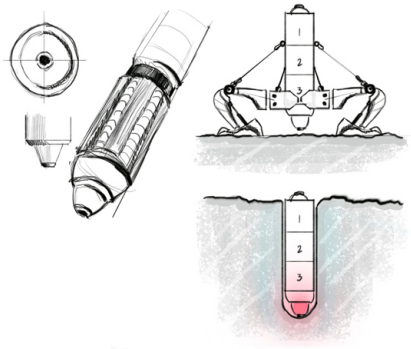


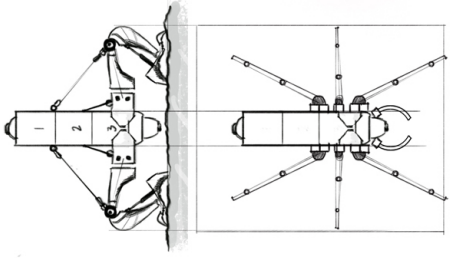


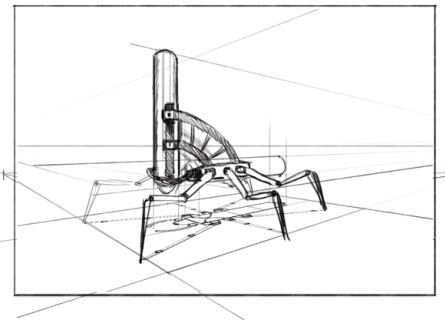


MELT PROBE - NUCLEAR HEATED TORPEDO

MEDIUM RISK DESIGN
MEDIUM BENEFIT

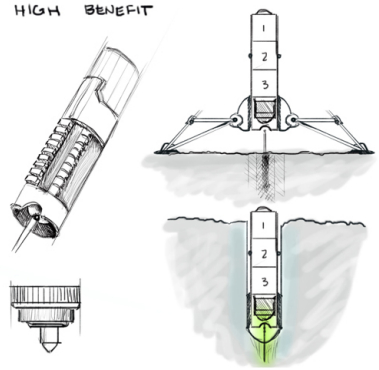


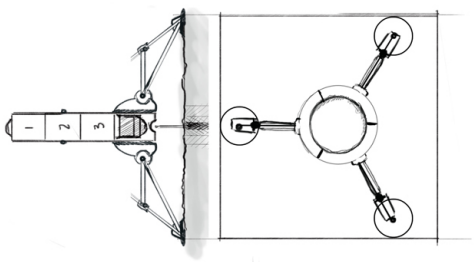


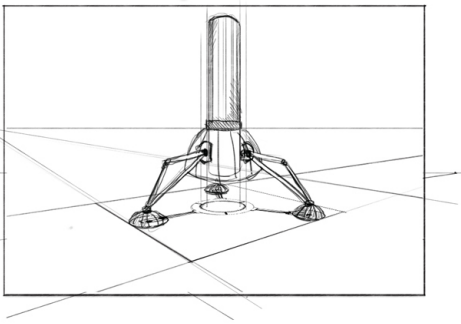


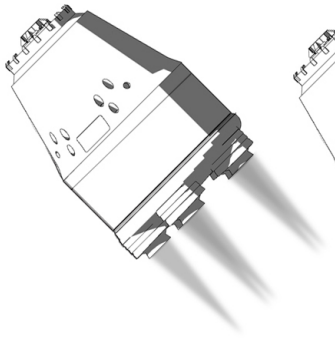
PLASMA ACCELERATED LASER - ION HEATED TORPEDO

HIGH RISK DESIGN
HIGH BENEFIT

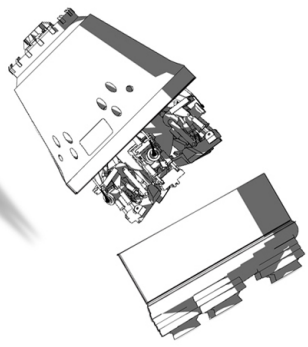




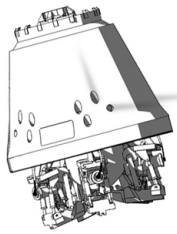




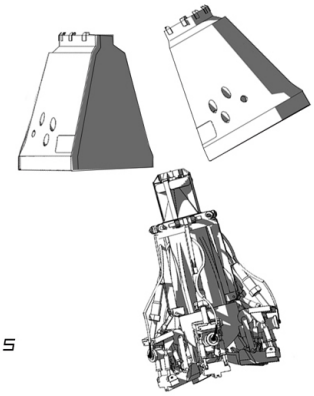
STAGE 1 -
BURN RETROGRADE



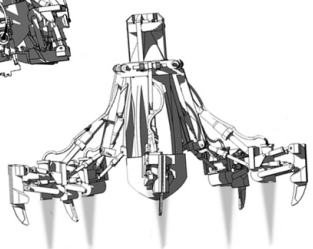
DISENGAGE FRONT SHELL



STAGE 2 -
ON BOARD CONTROLS



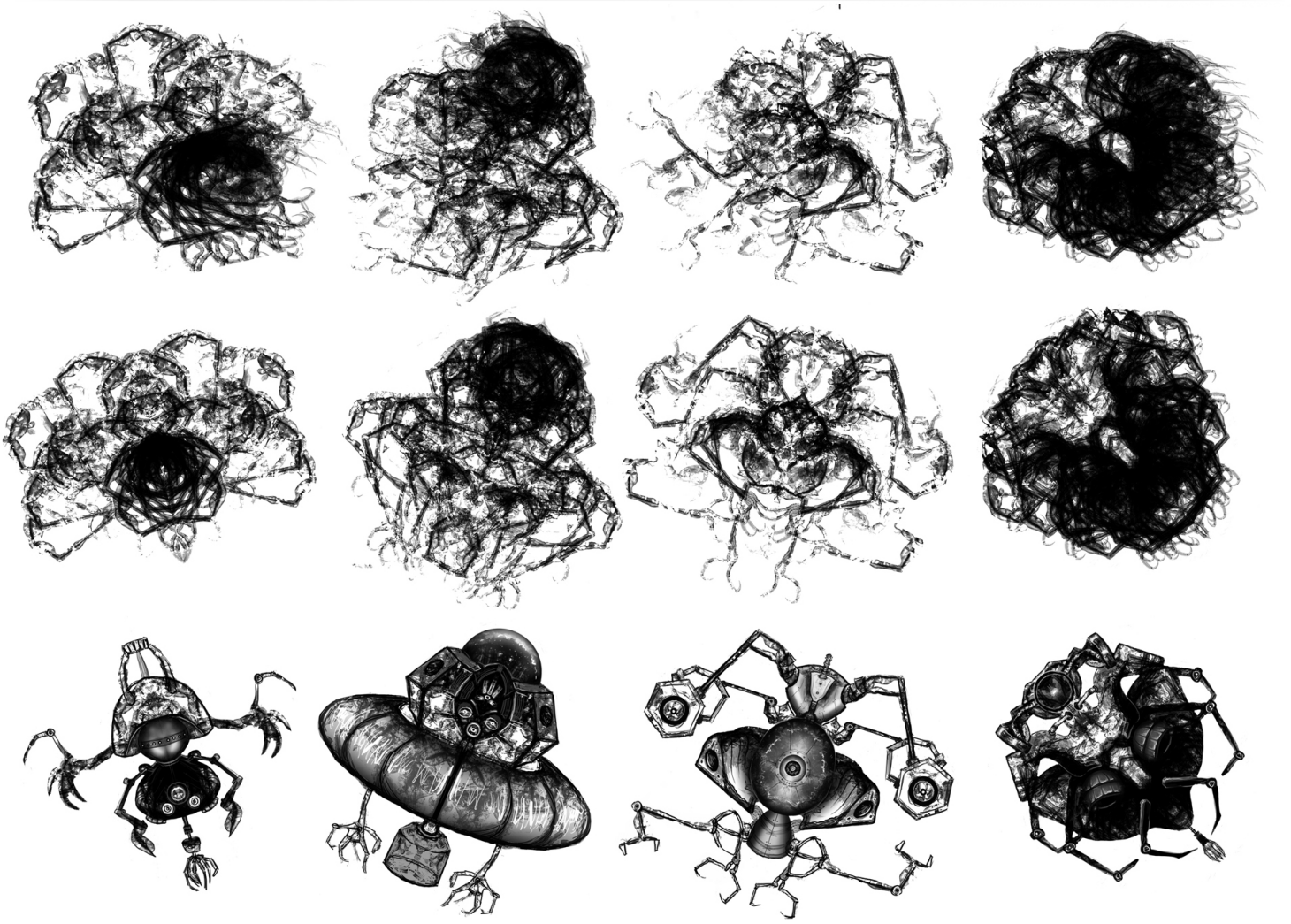
DISENGAGE BACK SHELL

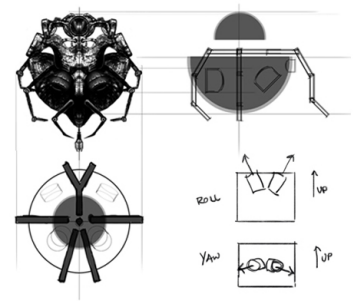


EXPAND LANDING GEAR
POWERED DESCENT

04

[A.U.V] AUTONOMOUS UNDERWATER VEHICLE



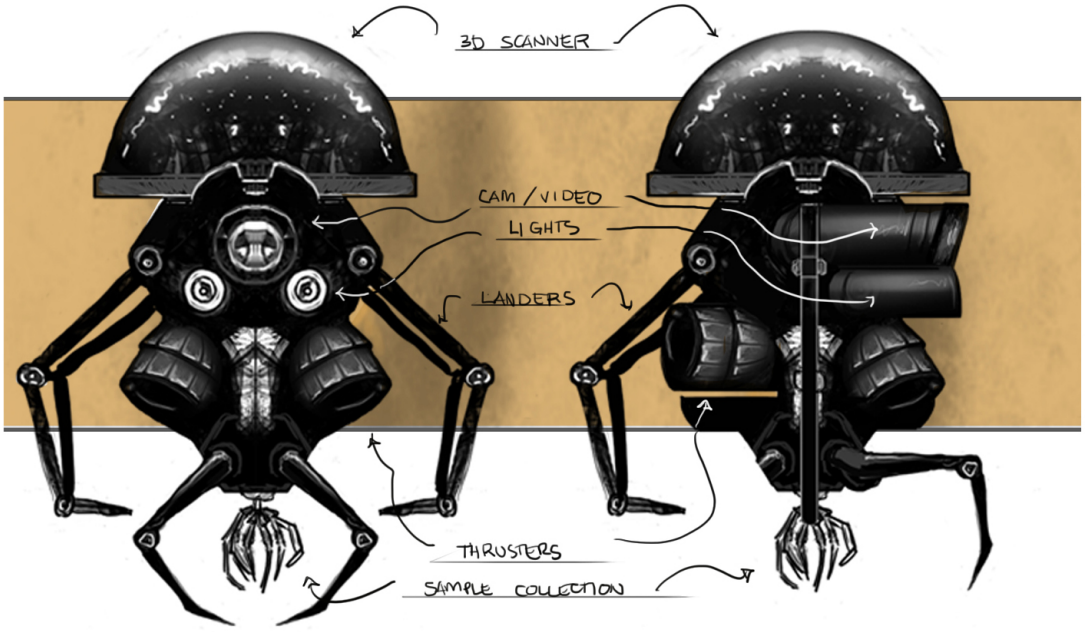


MAIN TRANSMITTER (LAND)

CENTRAL RECEIVER
- 3D SCAN
- 3D IMAGE / PHOTO
- SURFACE TRANSMISSION

2x ROVERS
- LIGHTS FRONT / BACK
- CAMERAS FRONT / BACK
- MAIN X-AXIS THRUST
- TWO LATERAL AND VERTICAL PROPULSION
- TWO FORWARD / BACKWARD YAW PROPULSION
- TWO ROBOTIC ARMS
  - WATER
  - MINERALS
  - LIFE

} COLLECTION

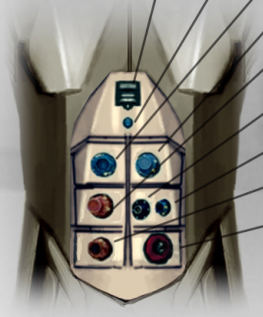



KENNY LEVICK
KL

M.E.V
VIPERPACK

CENTRAL JET PACK







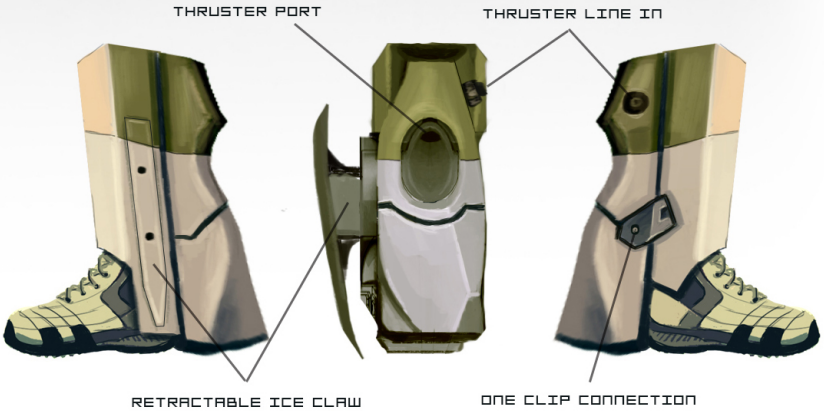
MISSION TYPE: PRE-INTEGRATION - BASIC LIFE SUPPORT SUIT DESIGNED TO EXPLORE THE CERIAN TERRAIN AND ORBIT.

INSTRUMENT SPECIFICATIONS:

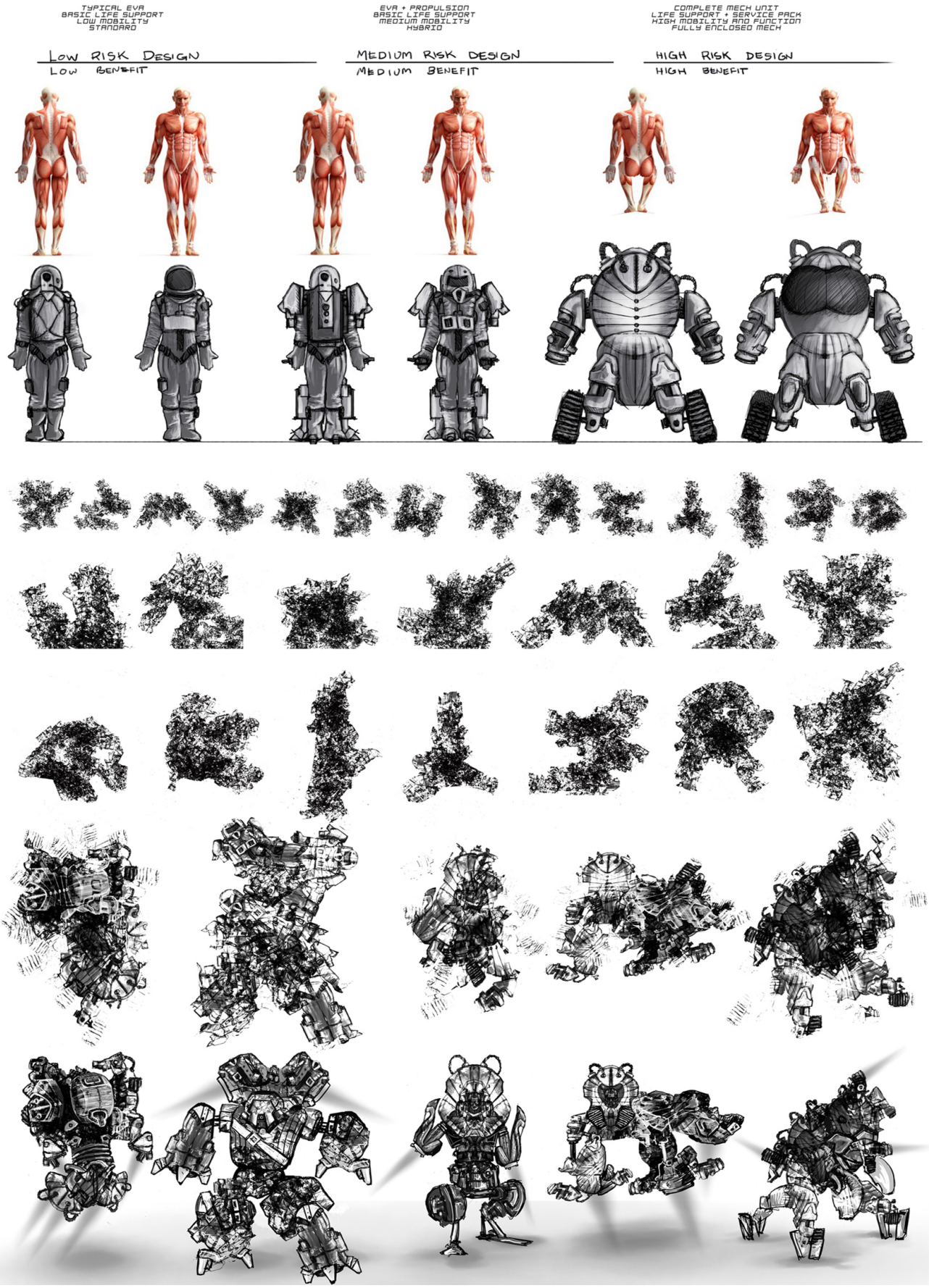
LIGHT WEIGHT FORM FITTING UNDERSUIT
GORTEK
CORE LIFE SUPPORT SYSTEM
COMPONENT ADDITIONS:
- CENTRAL JETPACK
- LEG JET PACKS
- WRIST CONTROLS

HELMET OPTIONS:
- DUAL LIGHT SOURCES
- NECK CAMERA / VIDEO
- ON BOARD USER INTERFACE DISPLAY

BOOT ATTACHMENTS:
- RETRACTABLE ICE CLAWS

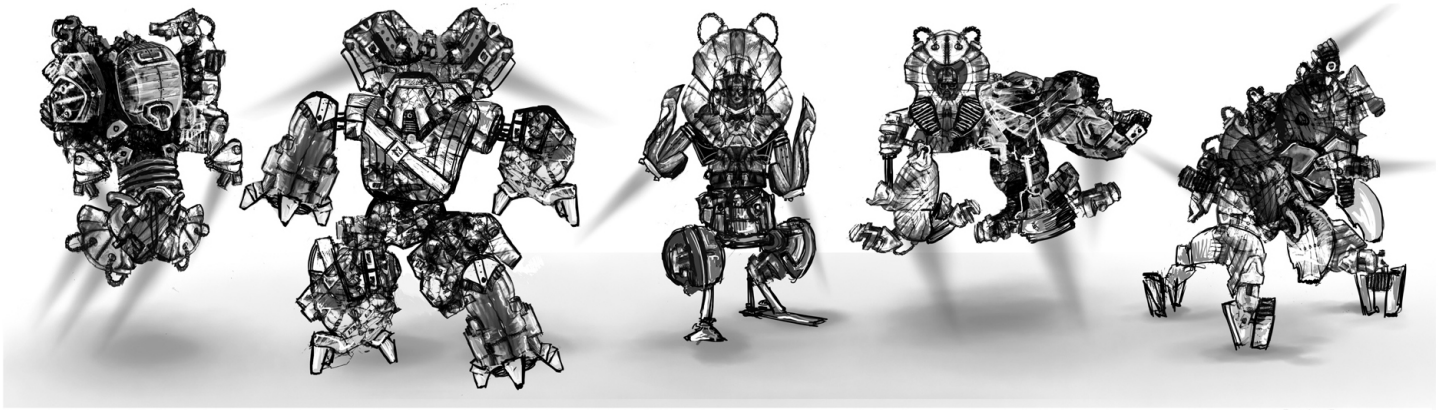


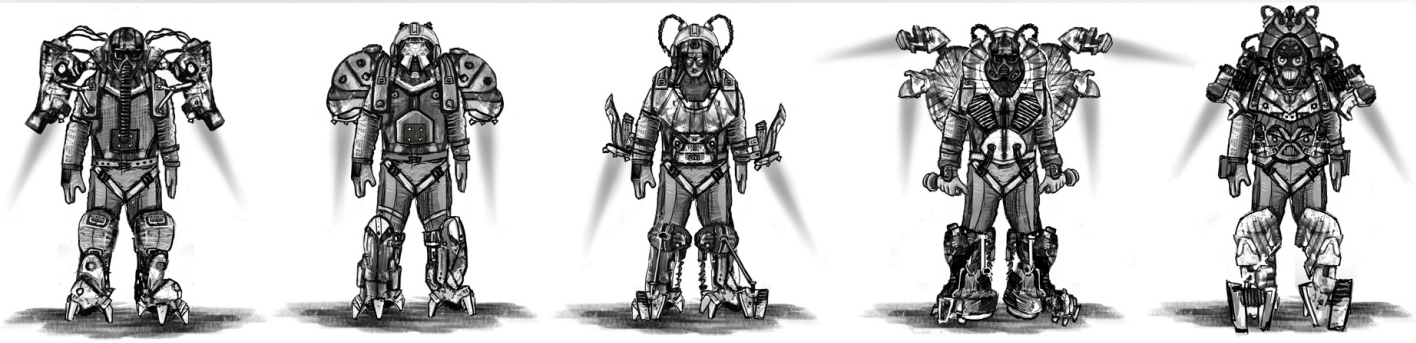
MECHANICAL EXTRA-VEHICULAR SUIT [M.E.V]

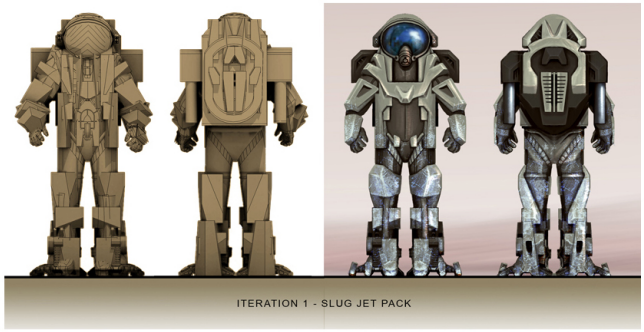


05

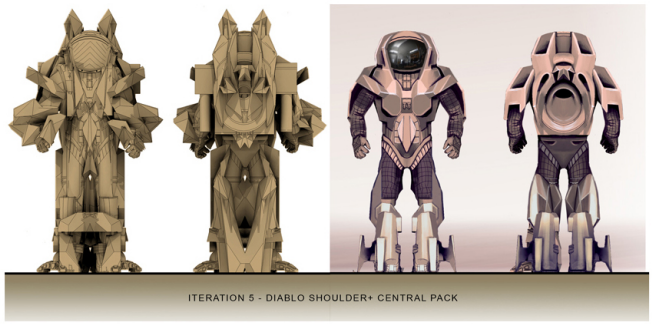
[M.E.V] MECHANICAL EXTRA-VEHICULAR SUIT







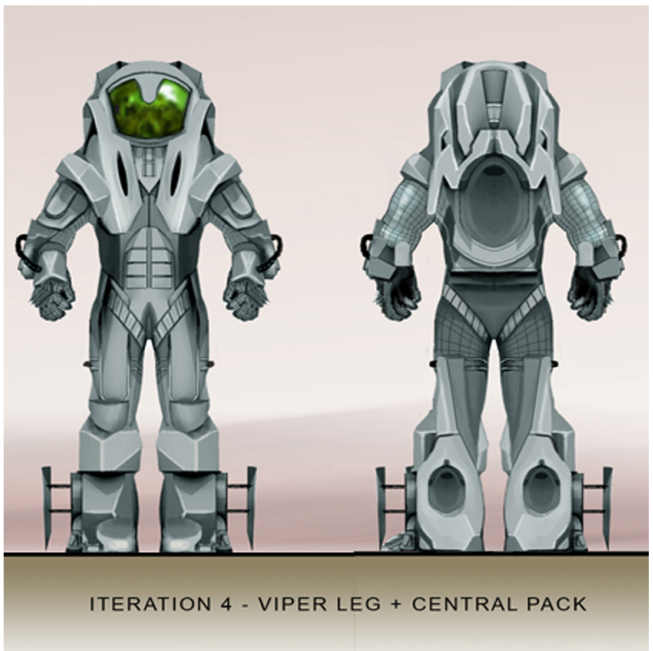
ITERATION 1 - SLUG JET PACK



ITERATION 5 - DIABLO SHOULDER+ CENTRAL PACK



ITERATION 3 - ANGEL JET+CENTRAL PACK



ITERATION 4 - VIPER LEG + CENTRAL PACK



ITERATION 2 - SCORPION ARM+CENTRAL PACK

KENNY LEVICK KL

STV AMPHIPOD

MISSION TYPE: PRE-INTEGRATION - PROPULSIVE CRAFT FOR NAVIGATION OF CERES TERRAIN AND ORBITAL CAPABILITIES.

THE SPACE CRAFT IS DESIGNED TO:

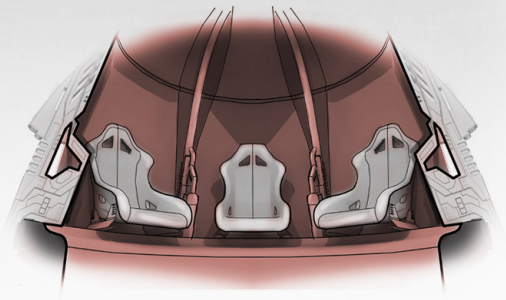
BE PILOTED BY ONE ENGINEER, WHICH CONTROLS BOTH FLIGHT AND LANDING.

STORE AND TRANSPORT MATERIALS, INSTRUMENTS, AND CARGO.

TRANSPORT AND HARNESS 3 CREW MEMBERS TO EITHER ORBIT, SPECIFIC DESTINATION, OR MOBILE RESEARCH LABORATORY.

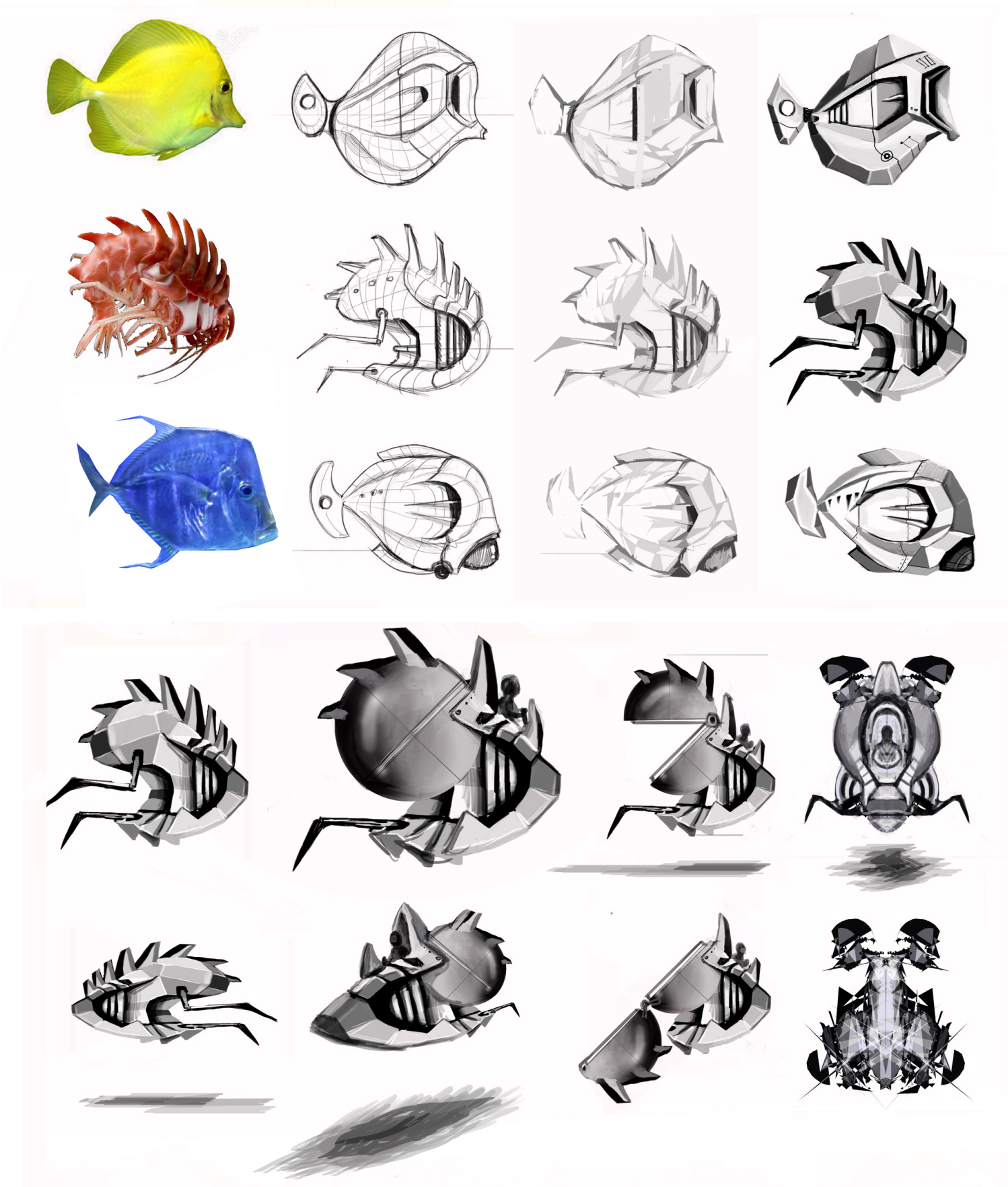
USES 3 DRACO PROPULSIVE ENGINES.



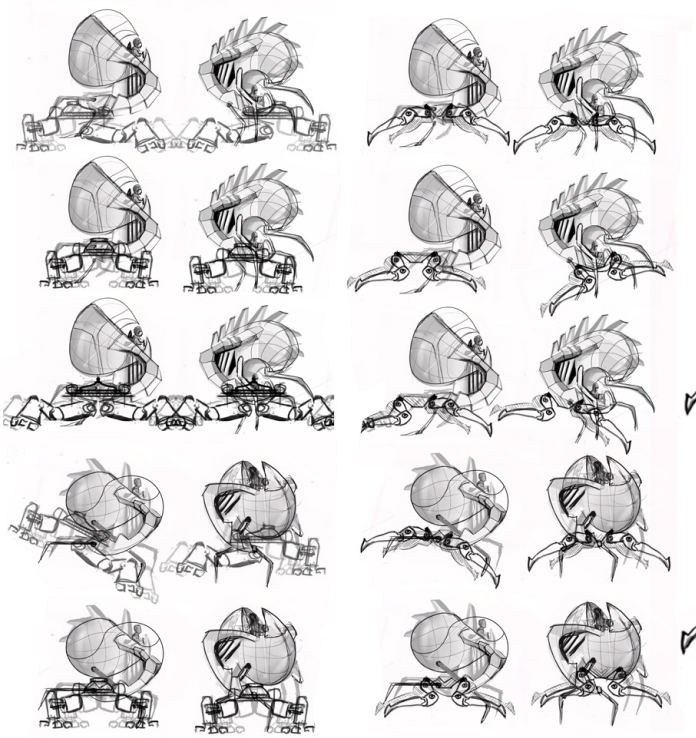


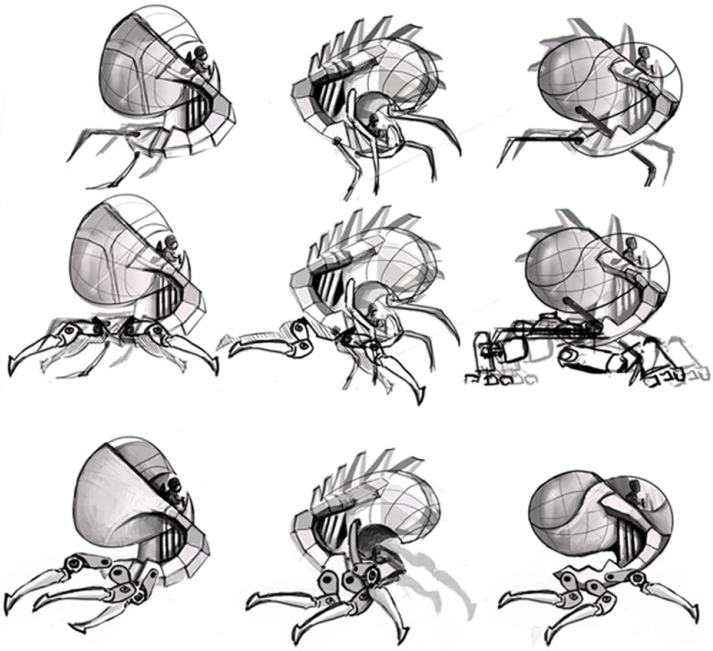
3 PERSON CREW HATCH

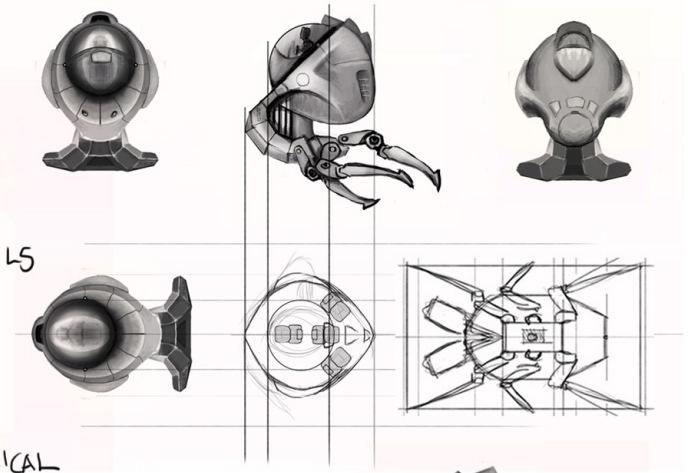




[S.T.V] SPECIALIZED TRANSPORT VEHICLE

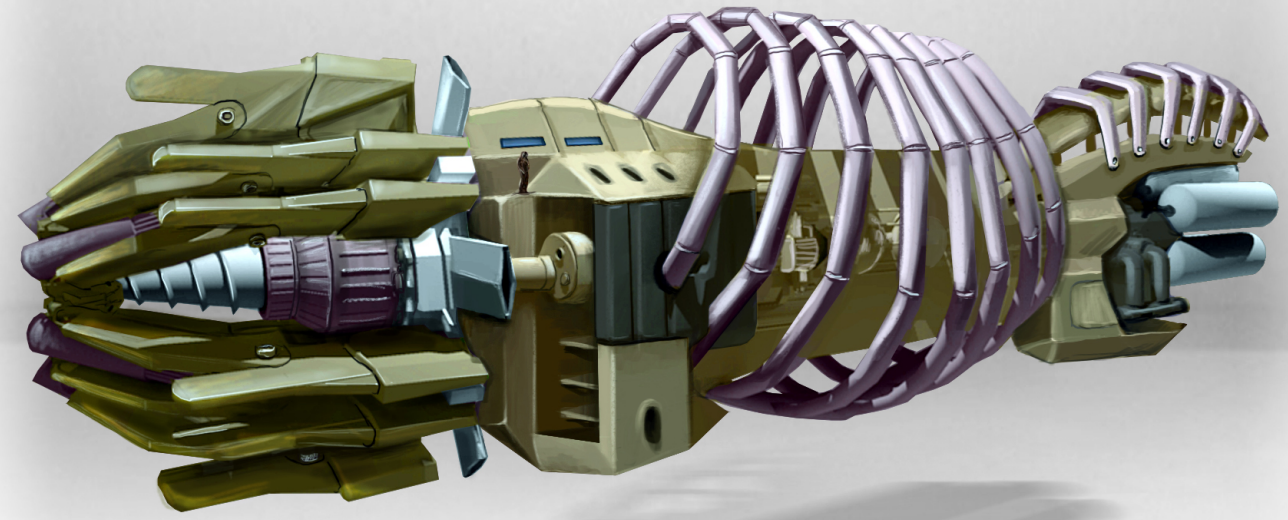







KENNY LEVICK KL

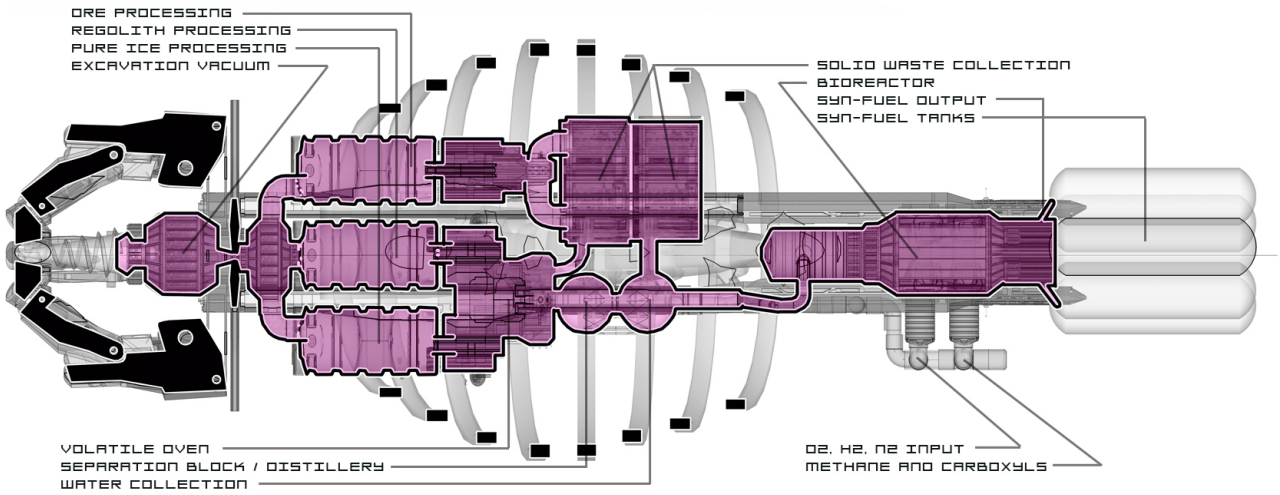
ACT RAPTOR

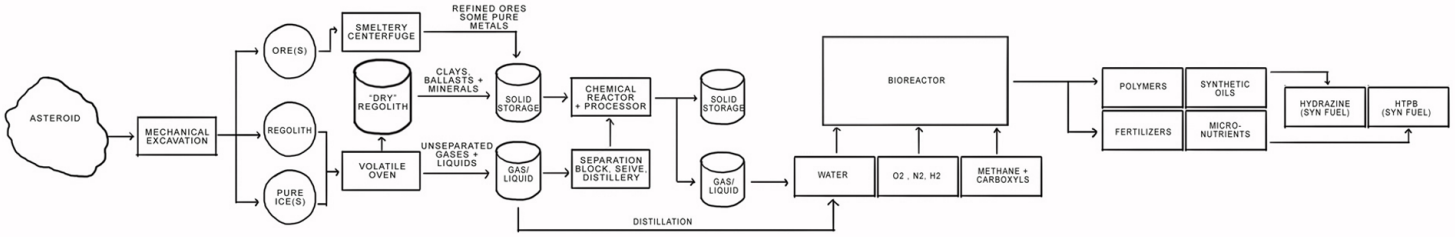


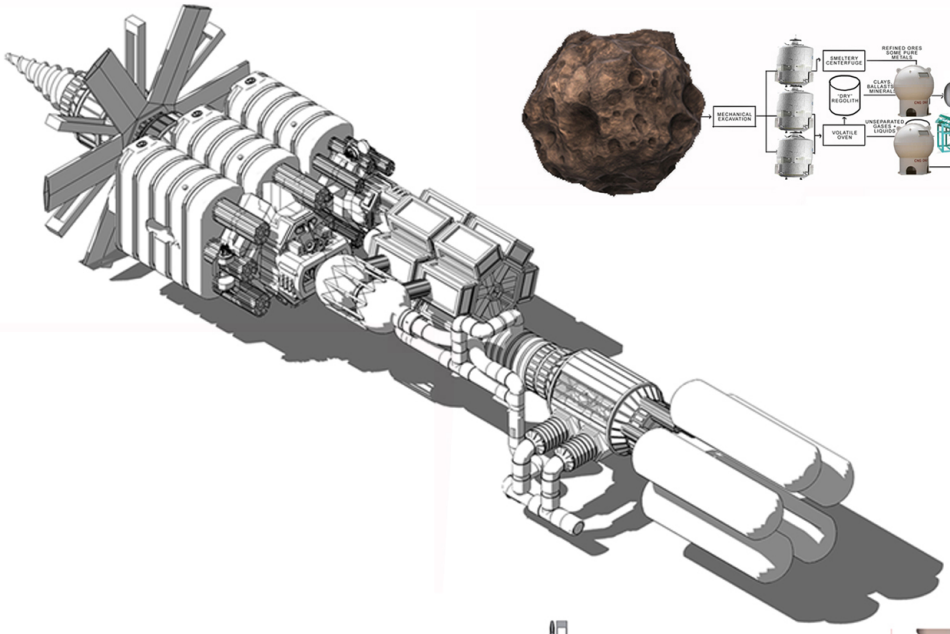
MISSION TYPE: INTEGRATED DESIGN - DEEP SPACE BARGE USED TO LATCH ASTEROIDS AND PROCESS THEM INTO USABLE ROCKET FUEL.

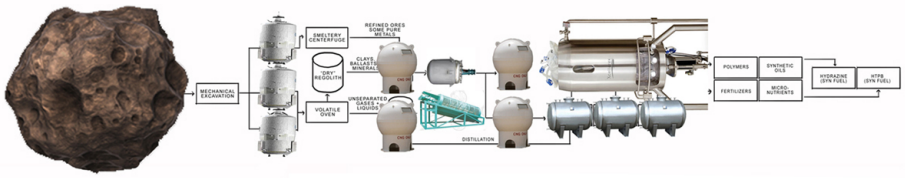
MAJOR COMPONENTS:
- LIGHT WEIGHT COMPOSITE BONE-LIKE SPACE FRAME
- CARBON FIBER AND STEEL RIGID FRAMING
- MULTI-DIRECTIONAL DRILLING CLAW
- FULLY FUNCTIONING PROCESSING SYSTEM

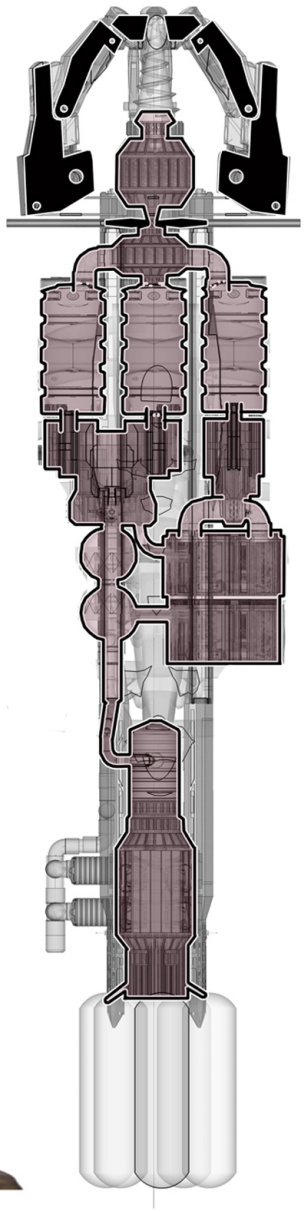
- ORE, REGOLITH, AND PURE ICE PROCESSING
- SMELTERY FOUNDERY TO PROCESS ORE
- VOLATILE OVEN TO PROCESS WATER
- SOLID STORAGE FOR WASTE
- TANKS FOR LIQUID COLLECTION
- BIOREACTOR TO SEPARATE ICE INTO SYN-FUEL

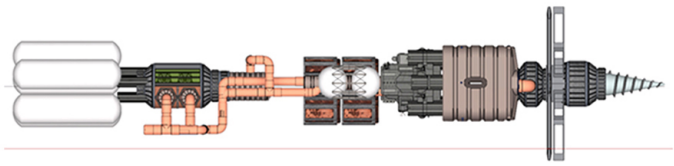


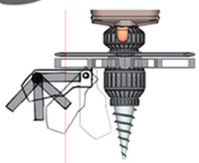




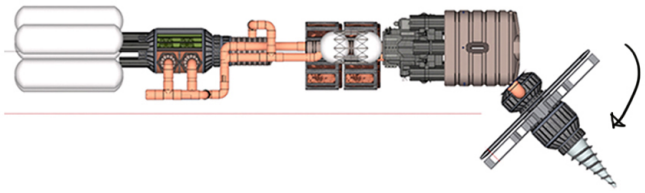


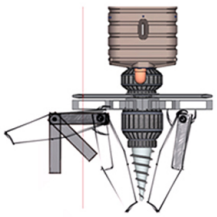




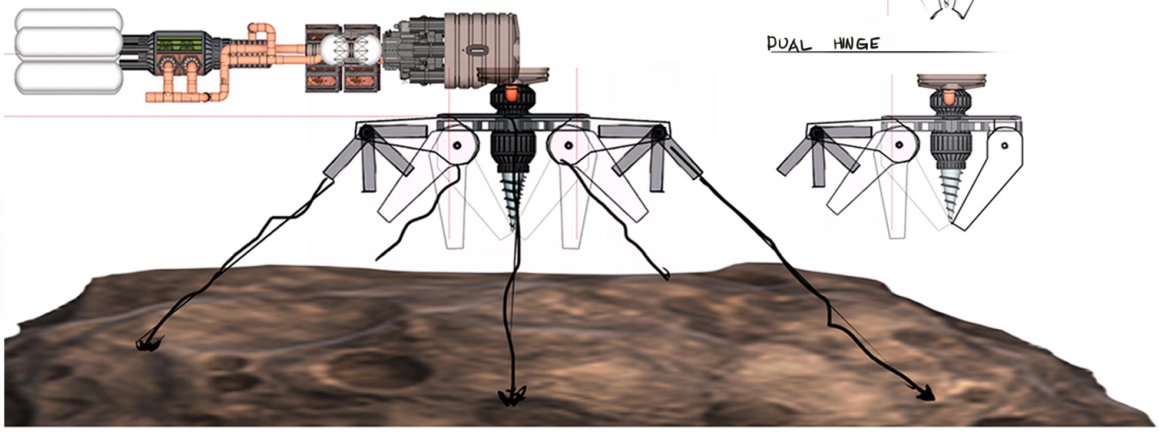


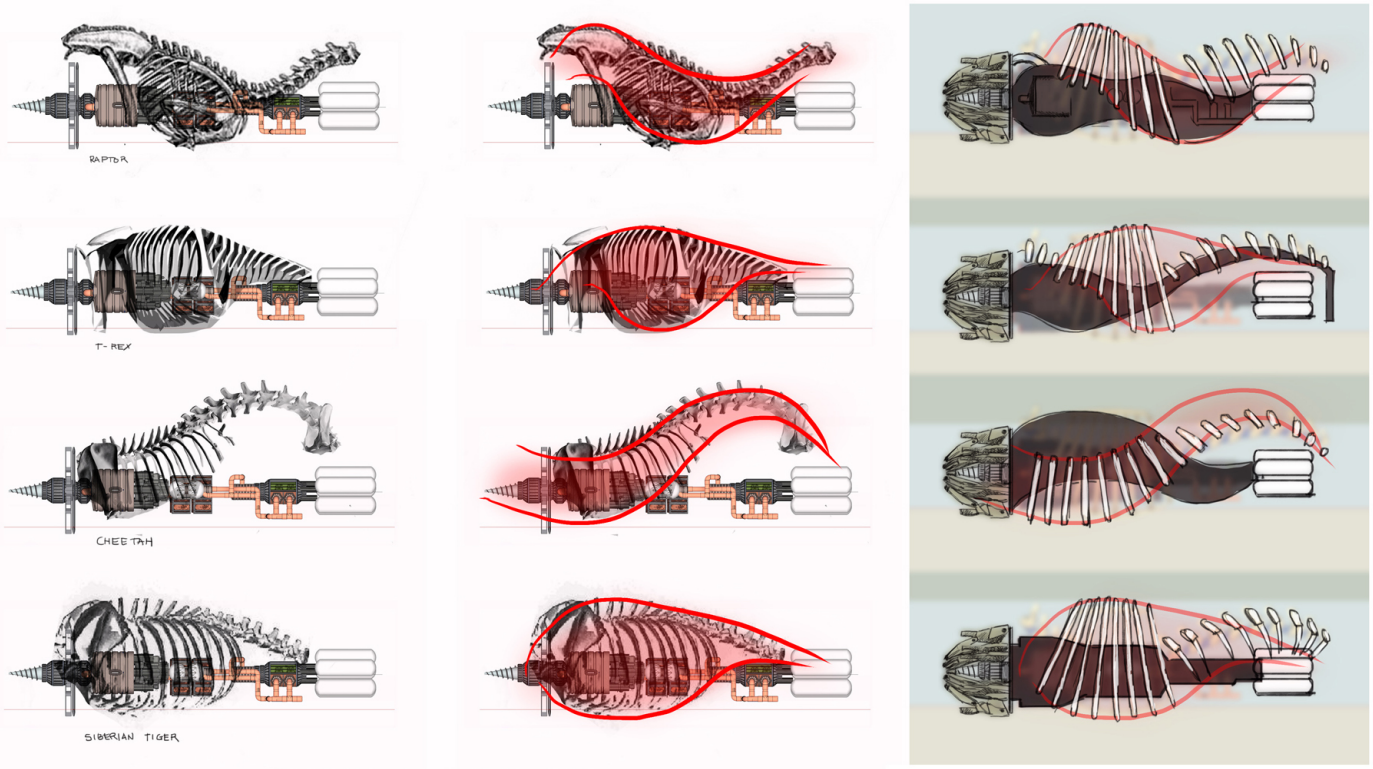
SINGLE HINGE

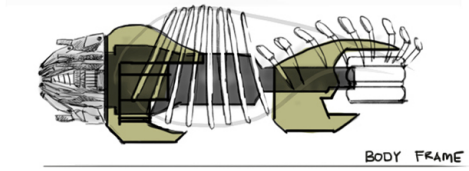




DUAL HINGE




RAPTOR
T-REX
CHEETAH
SIBERIAN TIGER


BODY FRAME

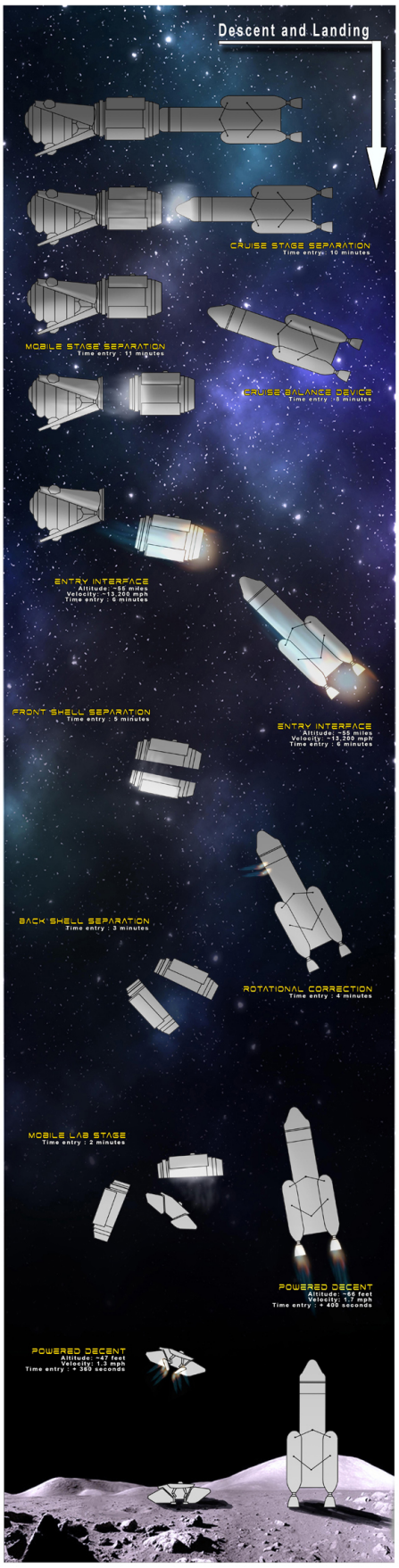

STRUCTURE

SECTION / ELEVATION
HARPOONS


KENNY LEVICK
KL

PRELUDE LAUNCH AND LANDING SEQUENCE











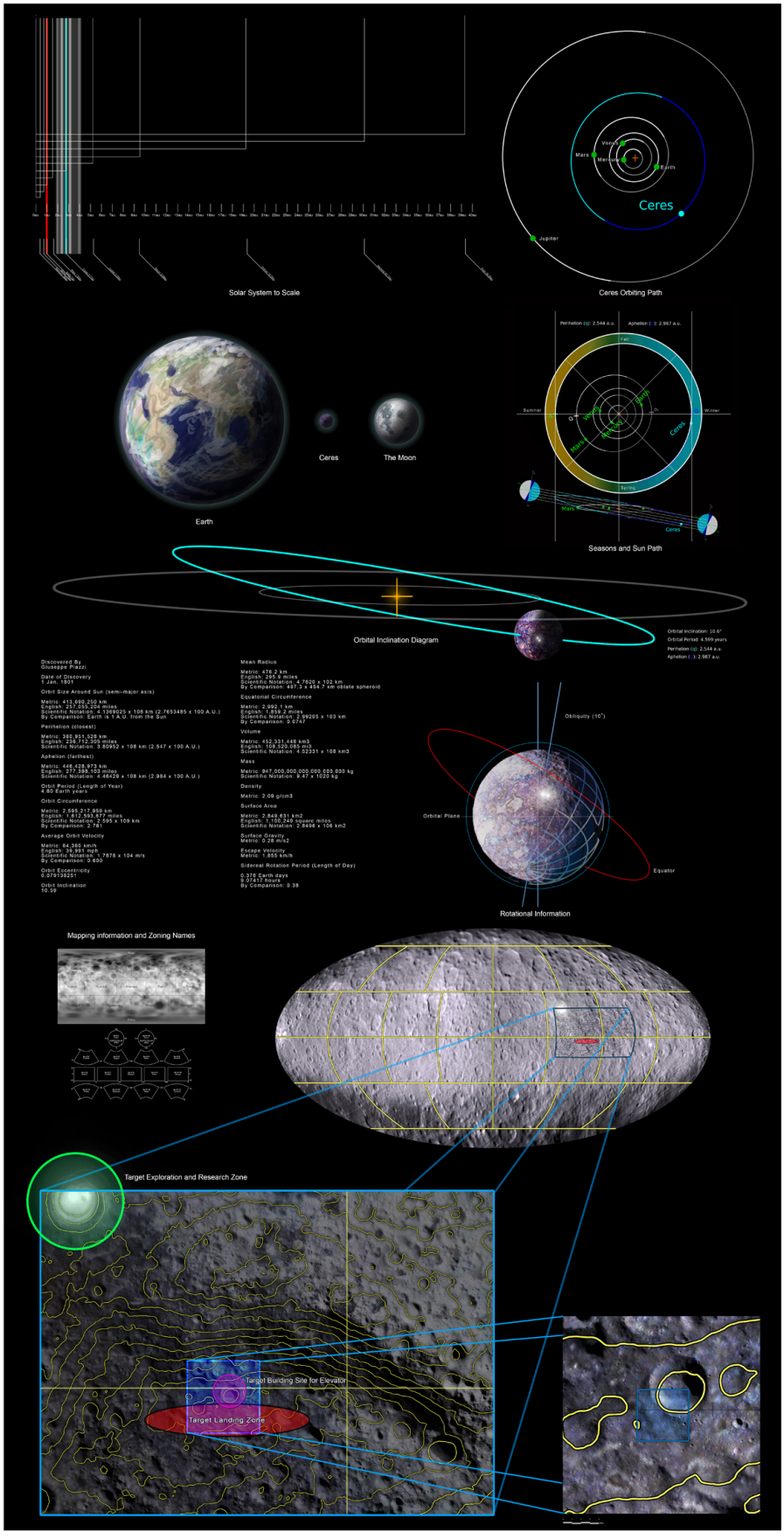


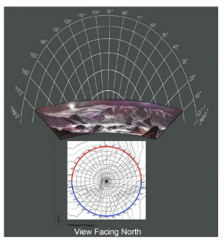


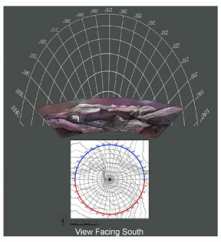


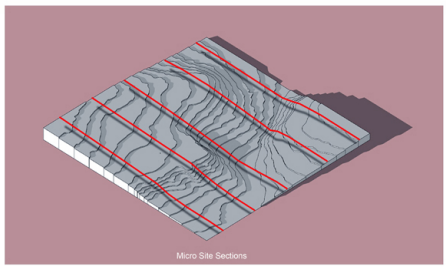


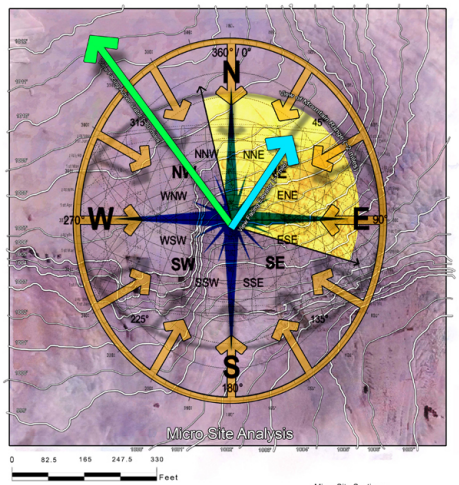


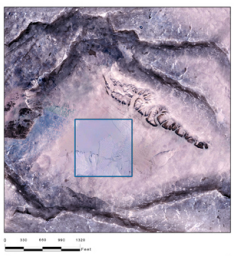

Solar System to Scale
Mercury
Venus
Earth
Mars
Jupiter
Ceres
Ceres Orbiting Path
Earth
Ceres
The Moon
Perihelion (q): 2.544 a.u.
Aphelion (-): 2.987 a.u.
Spring
Summer
Autumn
Winter
Seasons and Sun Path
Orbital Inclination Diagram
Orbital Inclination: 10.6°
Orbital Period: 4.599 years
Perihelion (q): 2.544 a.u.
Aphelion (-): 2.987 a.u.
Discovered By
Giuseppe Piazzi
Date of Discovery
1 Jan. 1801
Orbit Size Around Sun (semi-major axis)
Metric: 413,690,250 km
English: 257,030,284 miles
Scientific Notation: 4.1389025 x 108 km (2.7653485 x 100 A.U.)
By Comparison: Earth is 1 A.U. from the Sun
Perihelion (closest)
Metric: 380,851,028 km
English: 238,712,305 miles
Scientific Notation: 3.80952 x 108 km (2.547 x 100 A.U.)
Aphelion (farthest)
Metric: 446,428,973 km
English: 277,388,103 miles
Scientific Notation: 4.46429 x 108 km (2.984 x 100 A.U.)
Orbit Period (Length of Year)
4.60 Earth years
Orbit Circumference
Metric: 2,595,217,959 km
English: 1,612,593,577 miles
Scientific Notation: 2.595 x 109 km
By Comparison: 2.761
Average Orbit Velocity
Metric: 64,360 km/h
English: 39,991 mph
Scientific Notation: 1.7878 x 104 m/s
By Comparison: 0.600
Orbit Eccentricity
0.07913521
Orbit Inclination
10.59
Mean Radius
Metric: 476.2 km
English: 295.9 miles
Scientific Notation: 4.7620 x 102 km
By Comparison: 487.3 x 454.7 km oblate spheroid
Equatorial Circumference
Metric: 2,992.1 km
English: 1,859.2 miles
Scientific Notation: 2.99205 x 103 km
By Comparison: 0.0747
Volume
Metric: 452,331,448 km3
English: 108,520,085 mi3
Scientific Notation: 4.52331 x 108 km3
Mass
Metric: 947,000,000,000,000,000,000 kg
Scientific Notation: 9.47 x 1020 kg
Density
Metric: 2.09 g/cm3
Surface Area
Metric: 2,849,631 km2
English: 1,100,249 square miles
Scientific Notation: 2.8496 x 108 km2
Surface Gravity
Metric: 0.28 m/s2
Escape Velocity
Metric: 1,855 km/h
Sidereal Rotation Period (Length of Day)
0.378 Earth days
9.07417 hours
By Comparison: 0.38
Obliquity (10°)
Orbital Plane
Equator
Rotational Information
Mapping information and Zoning Names
Target Exploration and Research Zone
Target Building Site for Elevator
Target Landing Zone

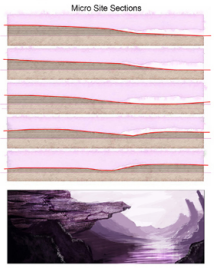

View Facing North

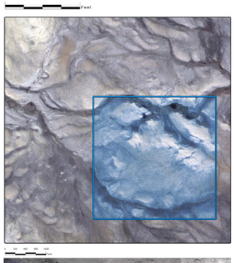

View Facing South

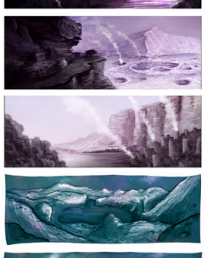

Micro Site Sections

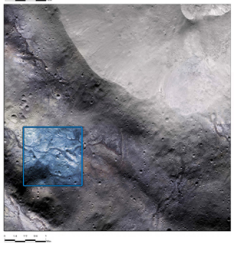

360° / 0°
45°
90°
135°
180°
225°
270°
315°
N
NNE
NE
ENE
E
ESE
SE
SSE
S
SSW
SW
WSW
W
WNW
NW
NNW
Micro Site Analysis
0
82.5
165
247.5
330
Feet

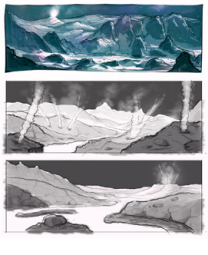



Micro Site Sections









PRELUDE
MISSION TO CERES

MANIFESTO

ARCHITECTURAL CONTEXT

HUMAN DIMENSION

AS HUMANS EXPLORE THE COSMOS, PEOPLE WILL INEVITABLY BE **LIVING** IN DEEP SPACE, ON SPACE STATIONS, OR ON OTHER PLANETS. AS HUMAN'S RETAIN THEIR **NEED TO CREATE** THEIR OWN **SENSE OF PLACE**, AN ELEMENT OF **HUMAN TOUCH** IN DESIGN MUST FOLLOW.

PSYCHOLOGICAL NEED

DESIGNING FOR **HARSH CONDITIONS** IS A CHALLENGE ARCHITECTURALLY. LIVING IN **ISOLATED** CONDITIONS, OR IN TIGHT QUARTERS WITH OTHERS PRESENTS A NEW CHALLENGE, AND ONE THAT SUGGESTS A NEW WAY OF APPROACHING **ADAPTABLE** ENVIRONMENTS.

FORM AND FUNCTION

THE TIME FOR CONSIDERING LIVING CONDITIONS IN SPACE AS **PURELY FUNCTIONING** MACHINES IS OVER. A **SYNTHESIS** NEEDS TO TAKE PLACE, ONE THAT **HARMONIZES** BOTH **ENGINEERING** AND **ART** TOGETHER.

PROCESS OF DESIGN

CONCEPT TRANSLATION

DESIGNERS AND ARCHITECTS OFFER A **FRESH PERSPECTIVE** ON DESIGN, ONE THAT CAN HARNESS THE **INSPIRATION** FROM NATURE'S ENGINEERING AND **ORGANISMS** INTO BUILT FORMS AND FUNCTIONING MACHINES.

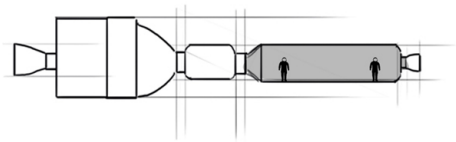
SPEED / QUANTITY

THE **INDUSTRIAL DESIGN** PIPELINE APPROACH TO SOLUTIONS OFFERS A LARGE RANGE OF **ITERATIONS** THAT CAN BE EXPLORED, EVOLVED, AND DEVELOPED VERY **QUICKLY**. CONCURRENTLY, THERE CAN BE A WIDE RANGE OF INPUT FROM OTHER SOURCES THAT CAN **ACCELERATE** THE PROCESS.

DESIGN COLABORATION

THE UTILIZATION OF THIS PIPELINE AND METHOD OF CONVEYING **BIG IDEAS**, CAN DIRECTLY **IMPACT** AND **CONTRIBUTE** TO THE SUCCESS OF A PROJECT; WORKING DIRECTLY WITH THE SCIENTIST AND ENGINEERS.

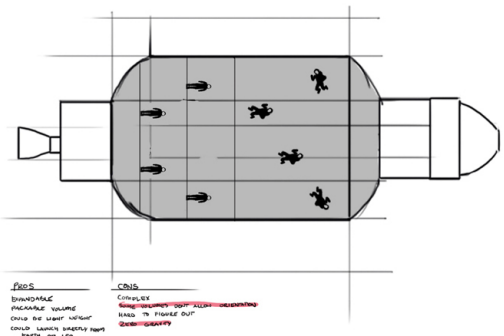
LOW RISK DESIGN
LOW BENEFIT



PROS
STANDARD
UP / DOWN
CURRENT LEVEL TECH.
FEASIBLE

CONS
SMALL BECAUSE OF LAUNCH
ARCHITECT HAS LESS CONTROL
REQUIRES MORE OF WORKING AROUND
THE MINIMUM
ZERO GRAVITY

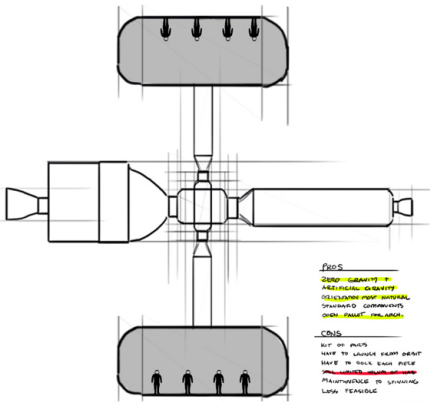
MEDIUM RISK DESIGN
MEDIUM BENEFIT



PROS
EXPANDABLE
PACKABLE VOLUME
COULD BE LIGHT WEIGHT
COULD LAUNCH DIRECTLY FROM
EARTH OR LEO
VERSATILE
MAXIMIZE INTERIOR VOLUME

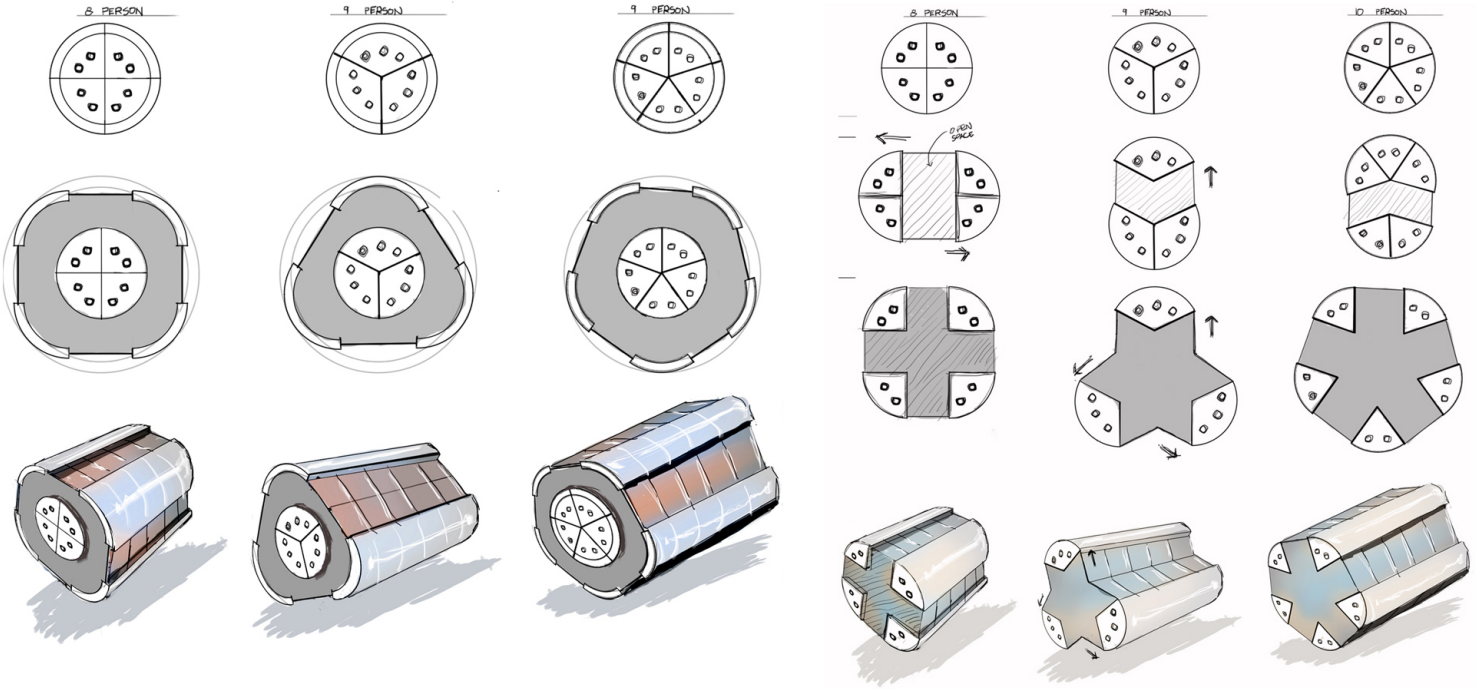
CONS
COMPLEX
SOME SYSTEMS DON'T ALLOW ORIENTATION
HARD TO FIGURE OUT
ZERO GRAVITY

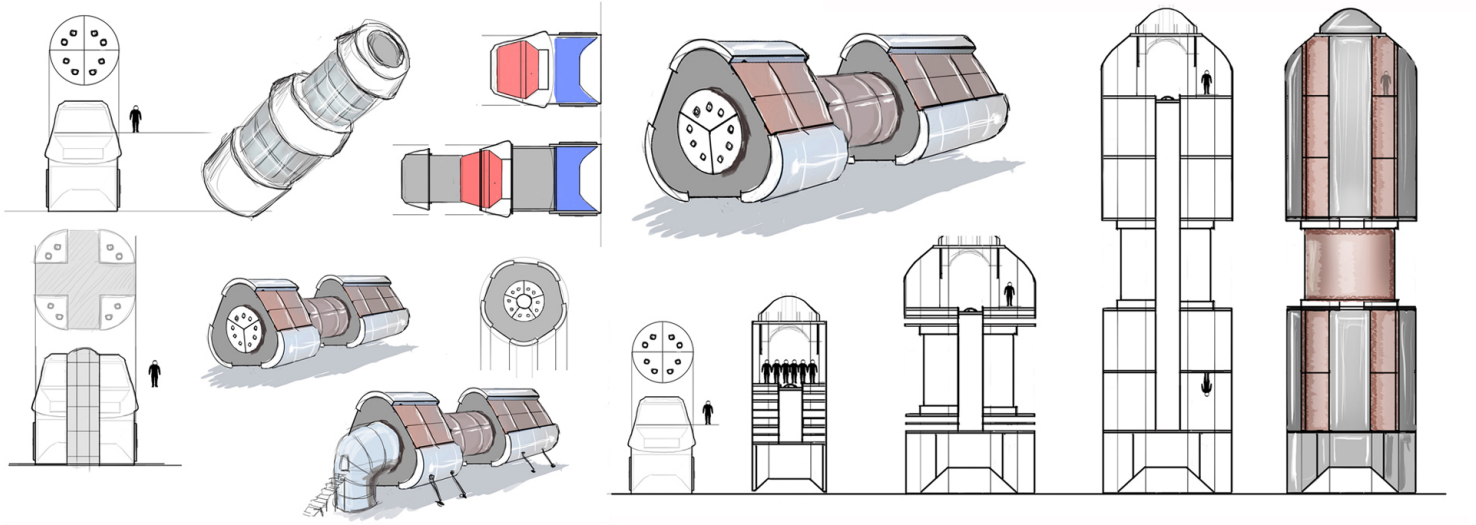
HIGH RISK DESIGN
HIGH BENEFIT



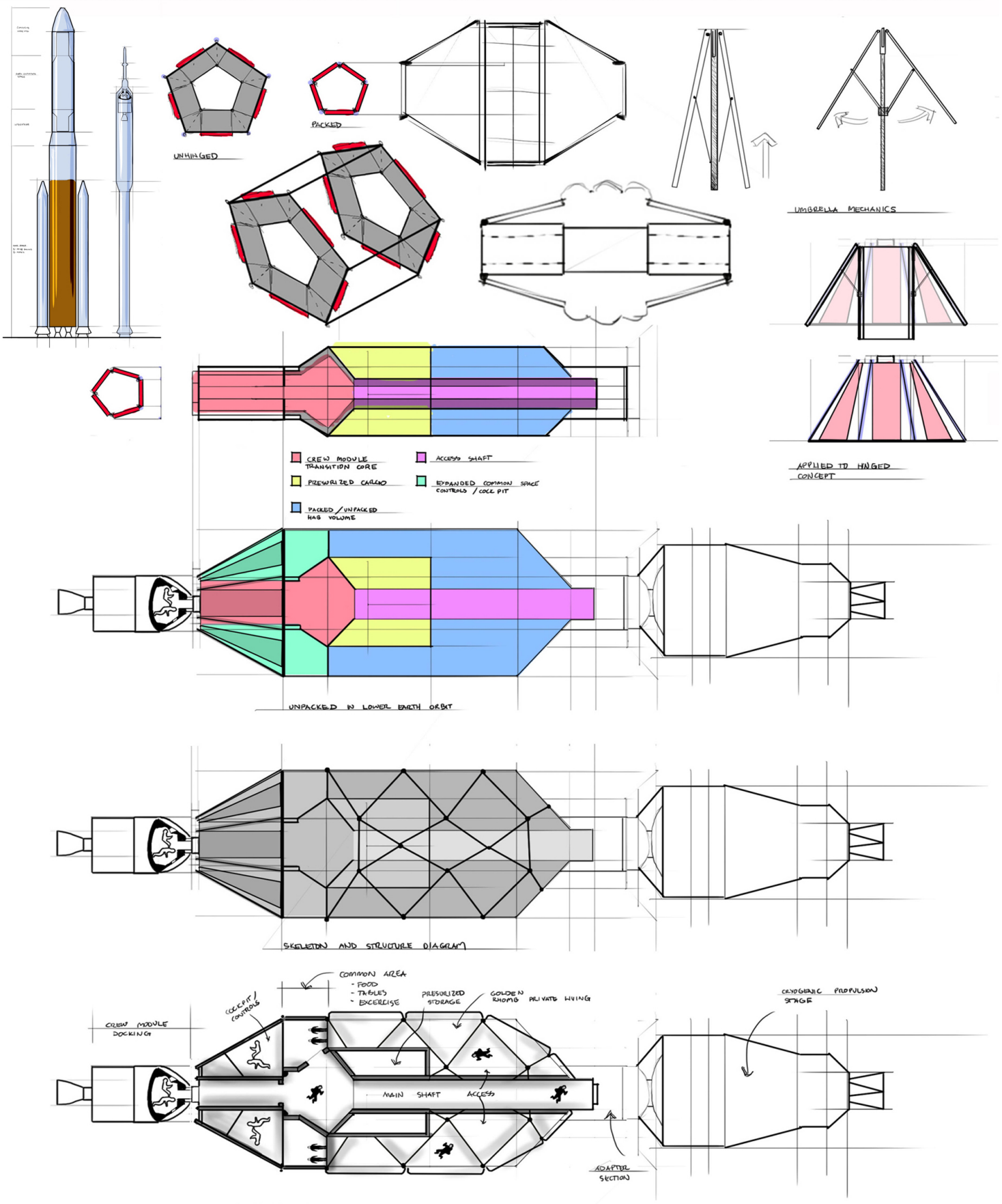
PROS
ZERO GRAVITY +
ARTIFICIAL GRAVITY
UTILIZATION FROM NATURAL
STANDARD COMPONENTS
OWN PAINT JOB ARCH.

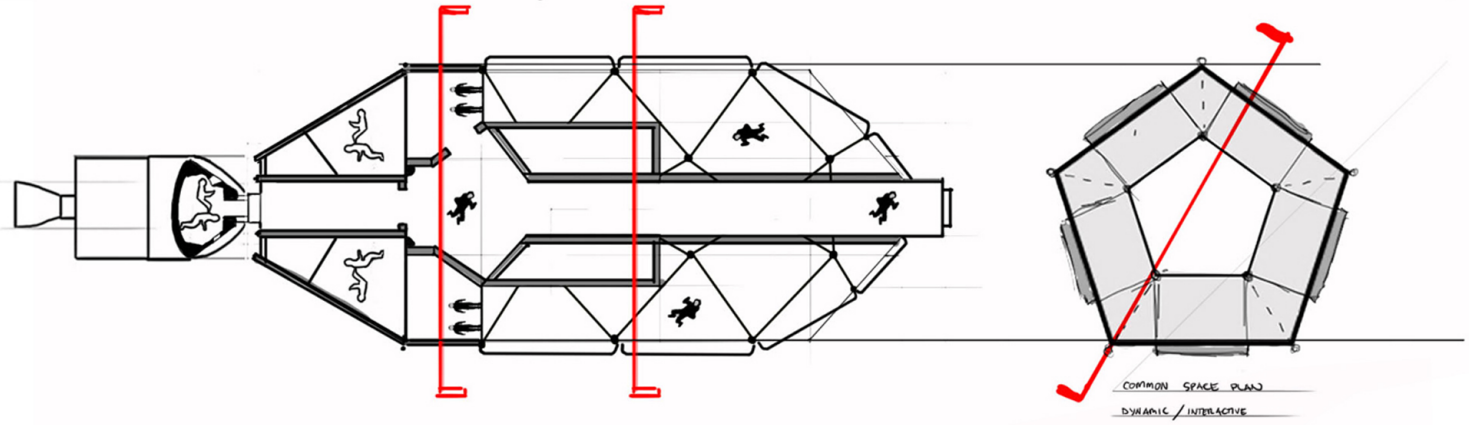
CONS
KIT OF PARTS
HAVE TO LAUNCH FROM EARTH
HAVE TO TOUCH EACH PIECE
MAINTENANCE TO SUSTAINING
LOOK FEASIBLE

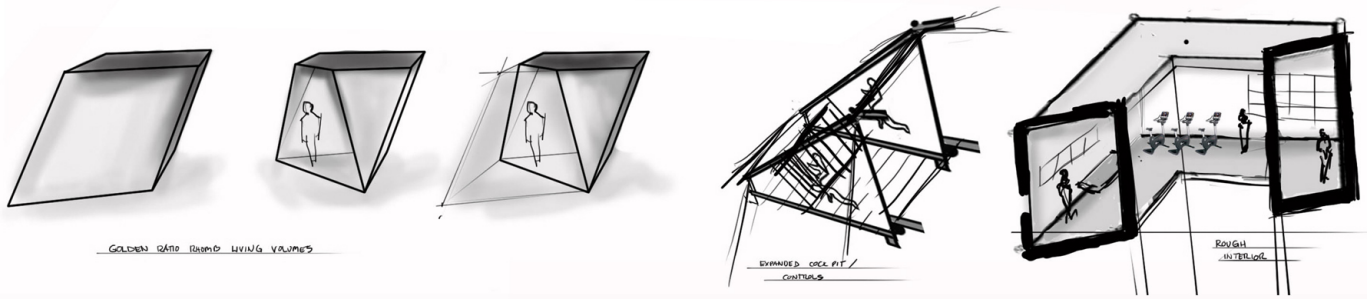


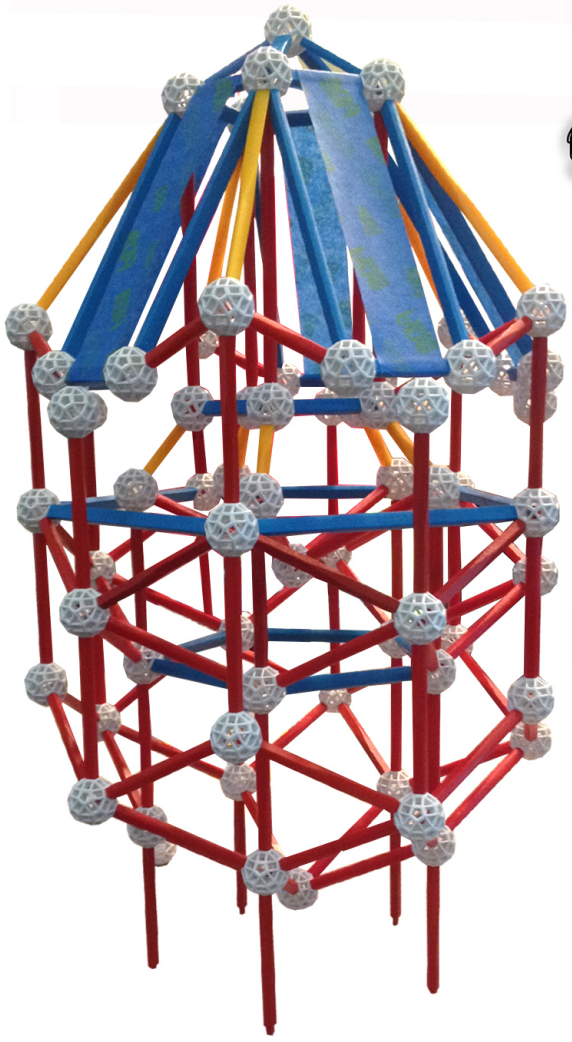


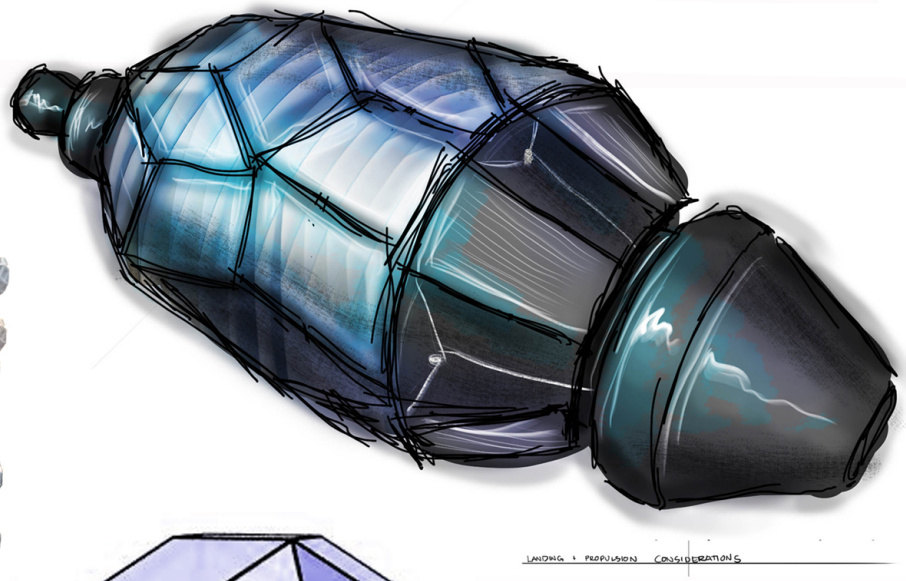
[OS.H.M] CLASS 1 DEEP SPACE HAB MODULE

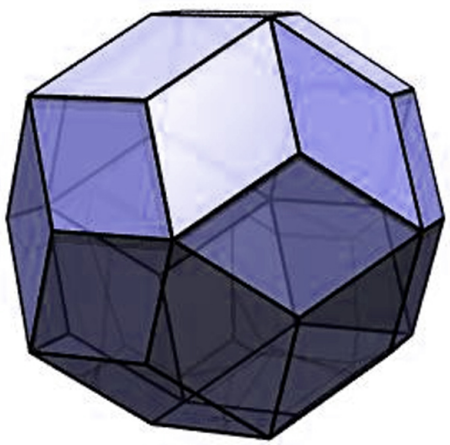


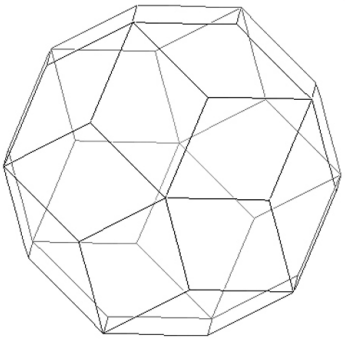

COMMON SPACE PLAN
DYNAMIC / INTERACTIVE

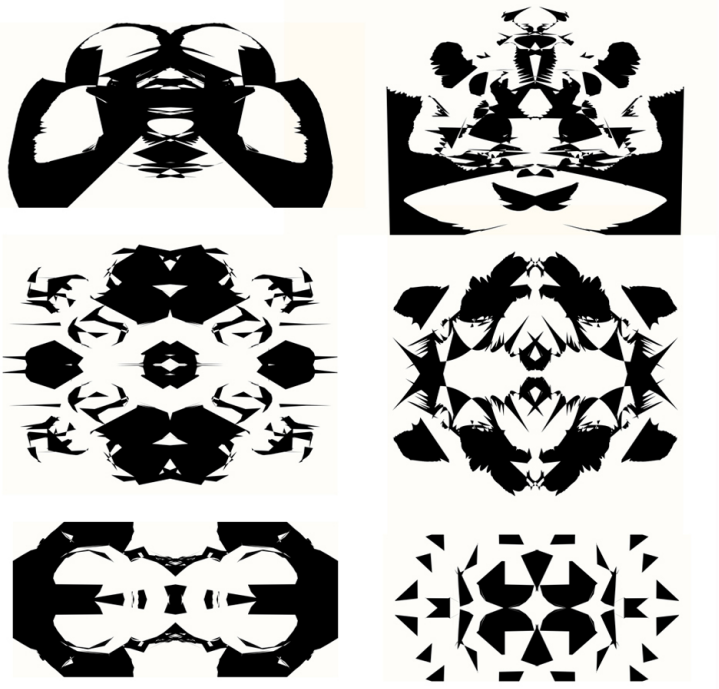

GOLDEN RATIO RHOMB LIVING VOLUMES
EXPANDED COCKPIT / CONTROLS
ROUGH INTERIOR

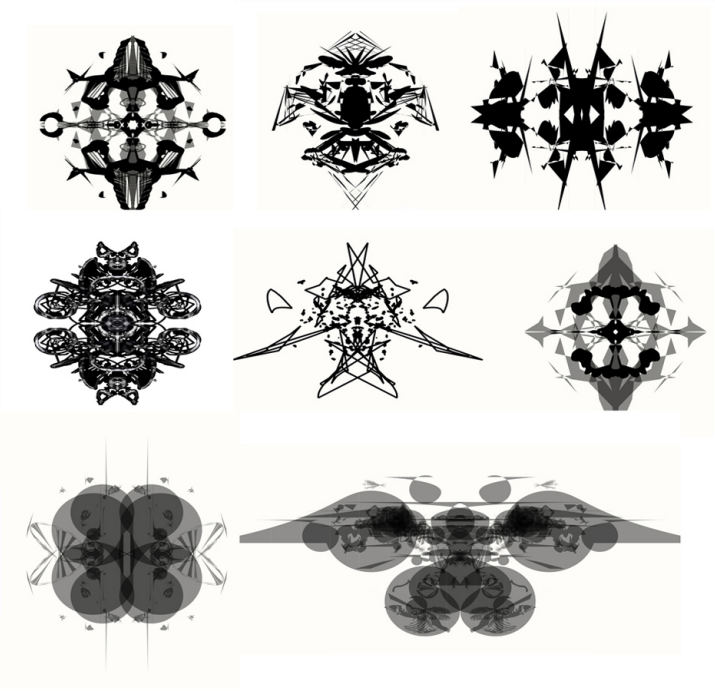



LANDING + PROPULSION CONSIDERATIONS

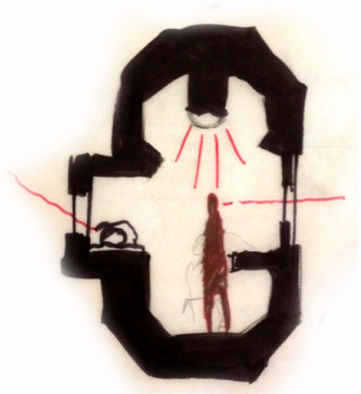


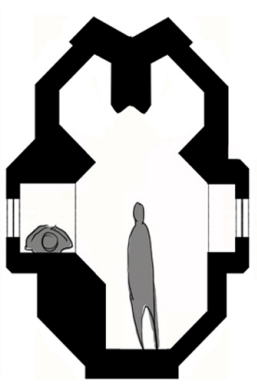


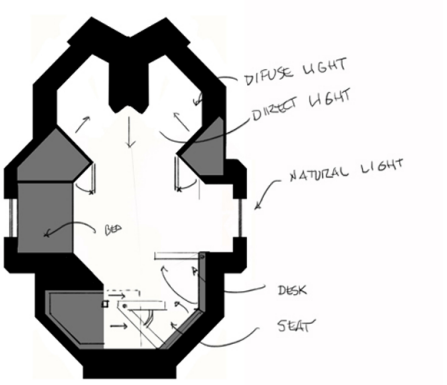


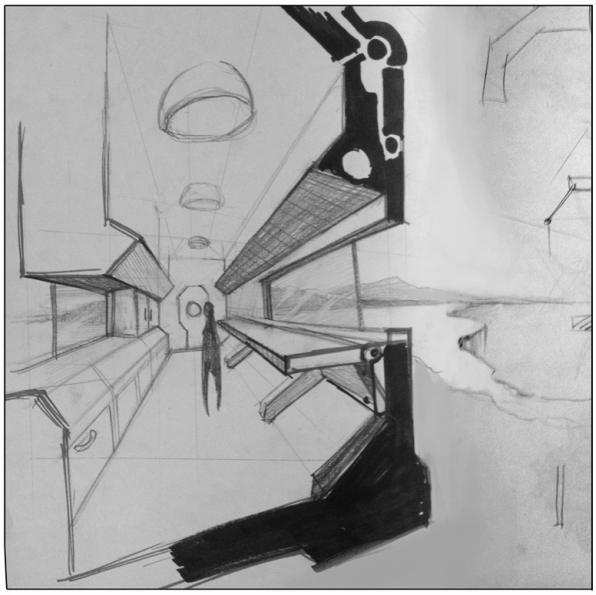


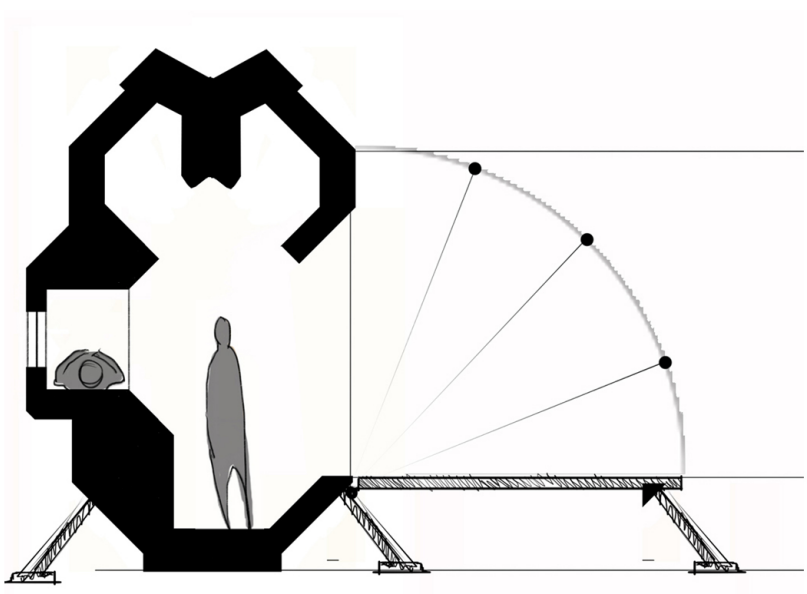


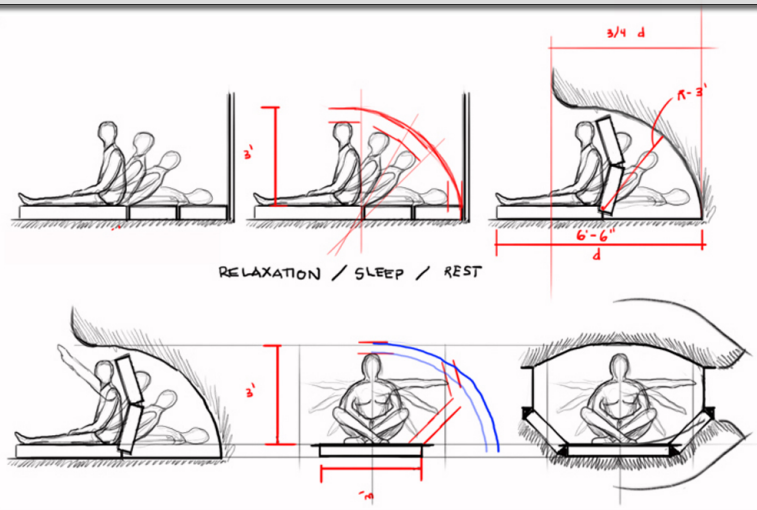


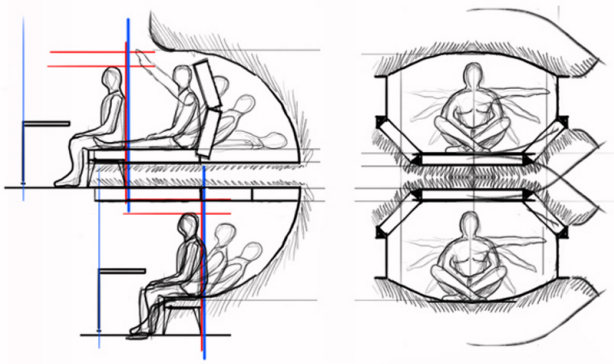


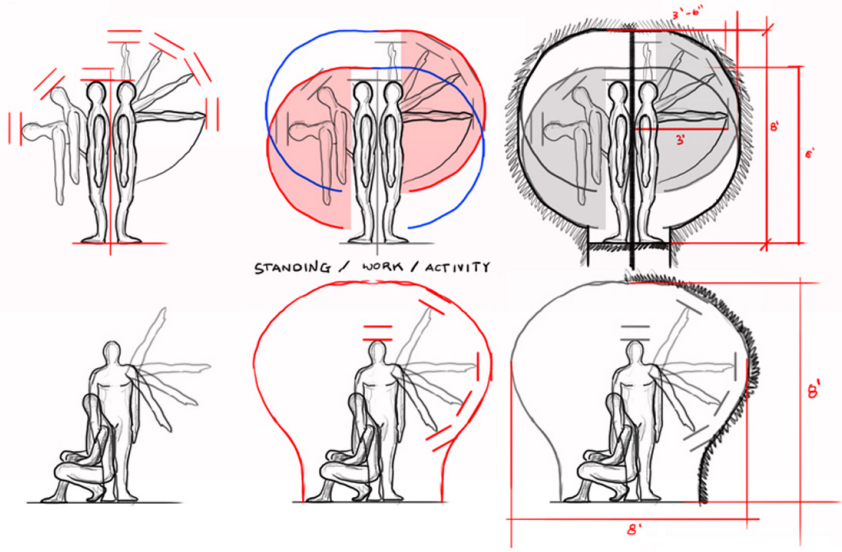

DIFUSE LIGHT
DIRECT LIGHT
NATURAL LIGHT
BED
DESK
SEAT

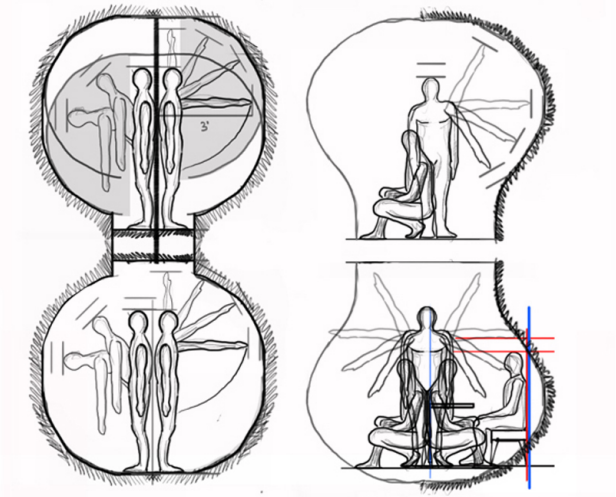


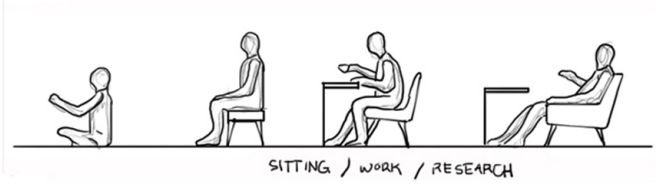


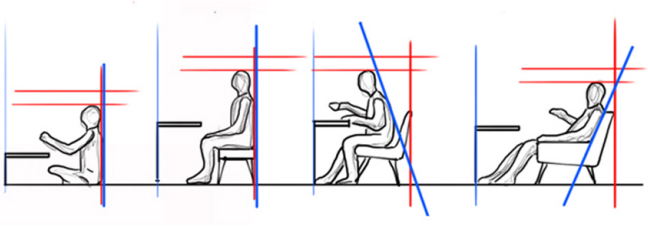

3/4 d
3'
6'-6"
d
RELAXATION / SLEEP / REST
3'

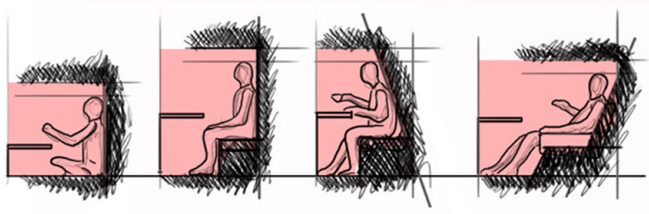


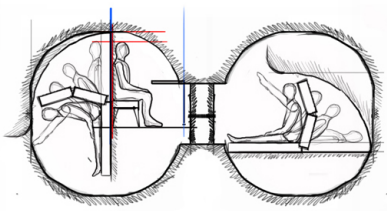

3'-8"
3'
8'
STANDING / WORK / ACTIVITY
8'

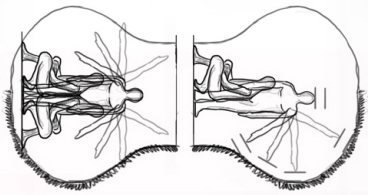


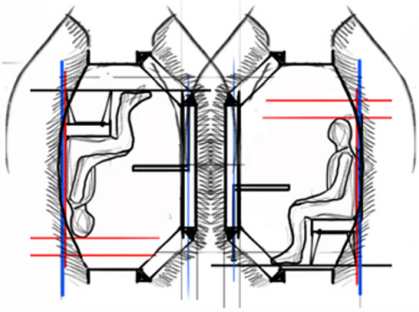

SITTING / WORK / RESEARCH

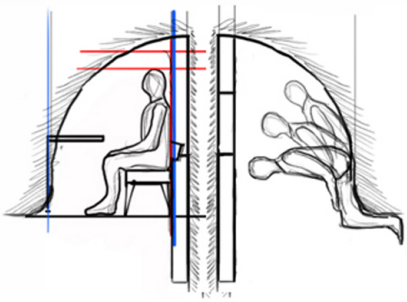






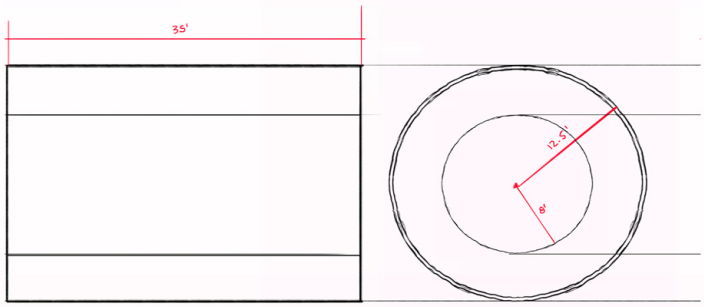


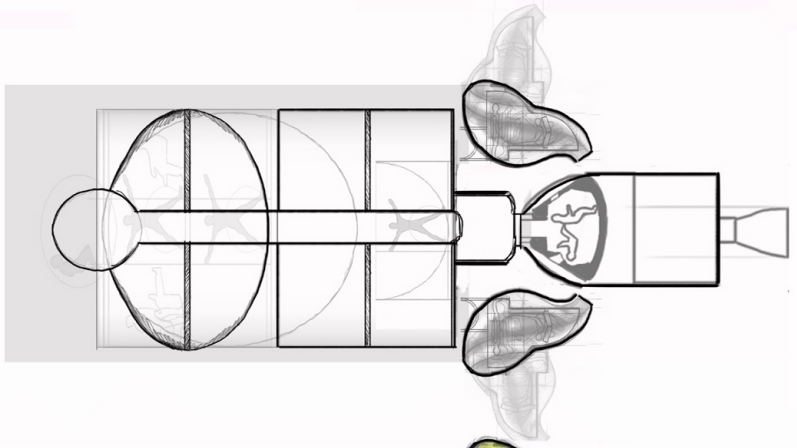


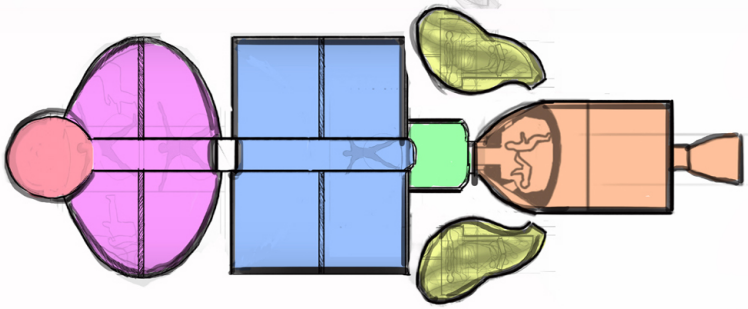


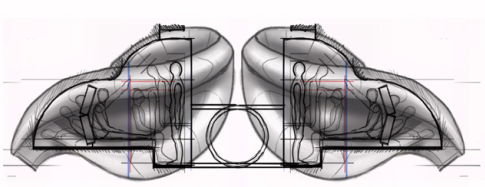
09

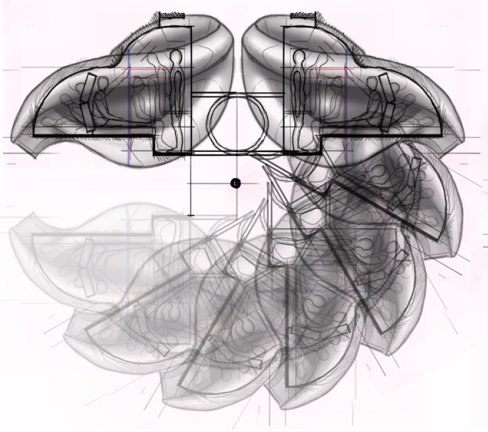
[OS.H.M] CLASS 1 DEEP SPACE HAB MODULE

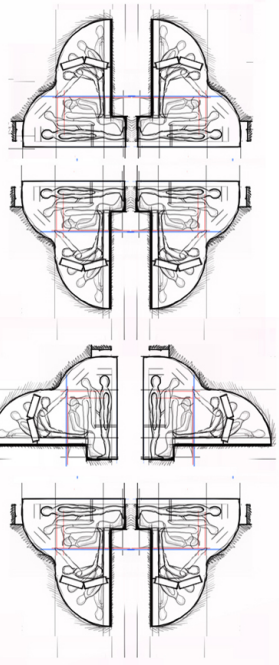


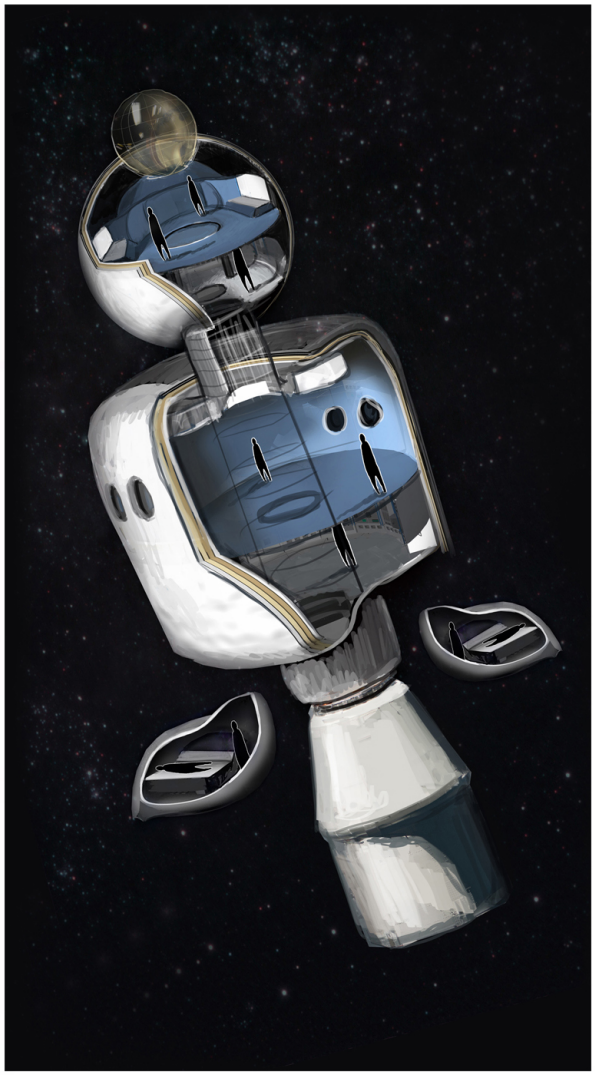




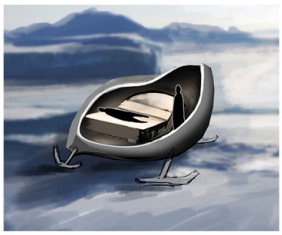




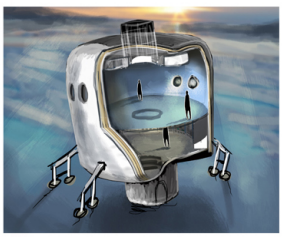


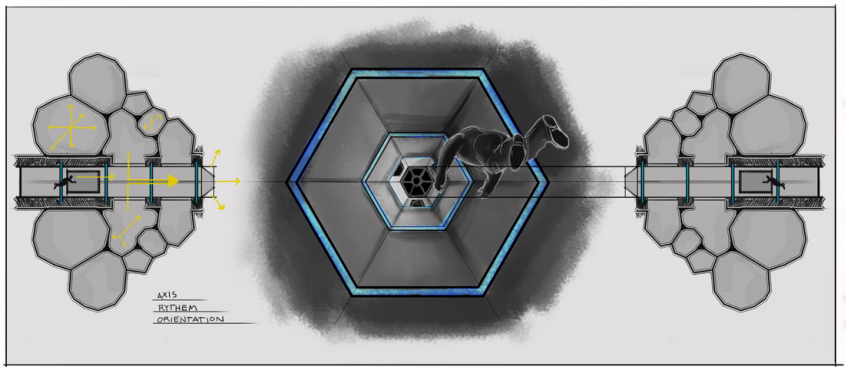






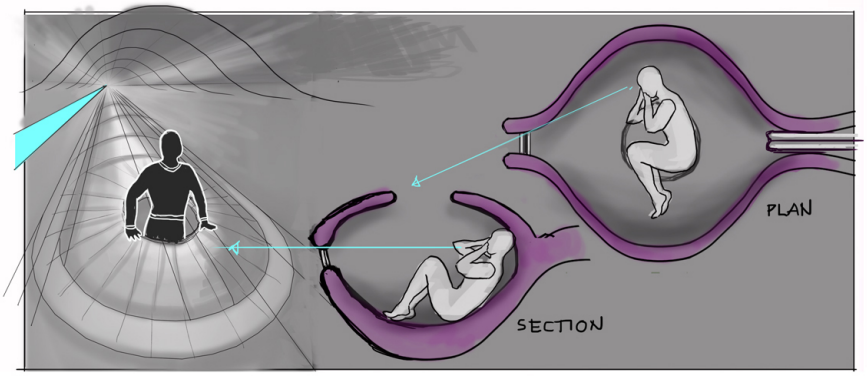






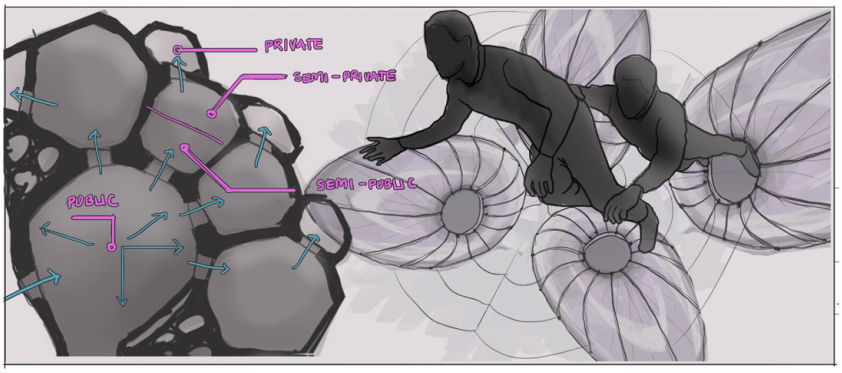
AXIS, RHYTHM, ORIENTATION.

Embracing the reality and conditions of deep space, there will be a range of conditions. Some like earth, using axis and rhythm as a means to orient one's self. There will be a balance of these moments throughout that intentionally orient the inhabitant, and then intentionally disorient the inhabitant.



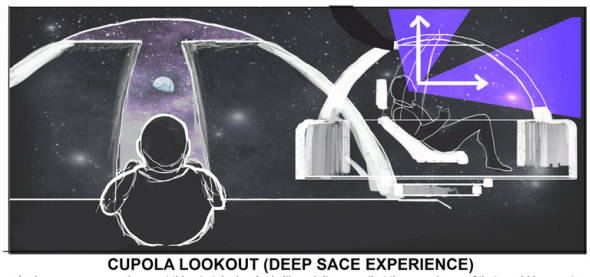
SLEEPING (WOMB PODS)

Beds on Earth work well, but consider for a moment all the other times we may sleep, either on a couch, or in a hammock, or in a sleeping bag. Humans actually have many sleeping habits, none the same as the next. In space, offering a variety of ways to sleep will allow to establish one's own nook in which to sleep. The spaces may change, there may be different volumes, some normal, some odd, but all versatile to whatever people may want and need.



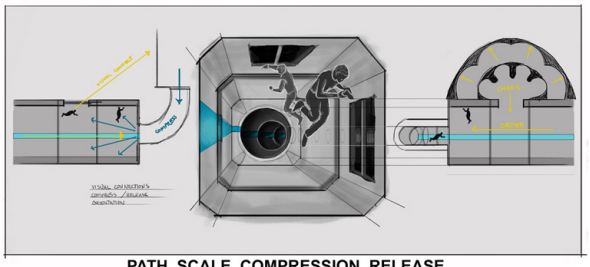
LIVING TRANSITIONING SPACES

Floors don't make sense in zero gravity. In deep space travel, thinking in 3 dimensions is critical. Designing in section becomes the plan and section all at the same time. This allows for a very dynamic arrangement of spaces that become rich, complex networks of pods. These pods may transition from public to semi public, to semi private, to private. Each space scaling down to a more personal relationship with the inhabitant.



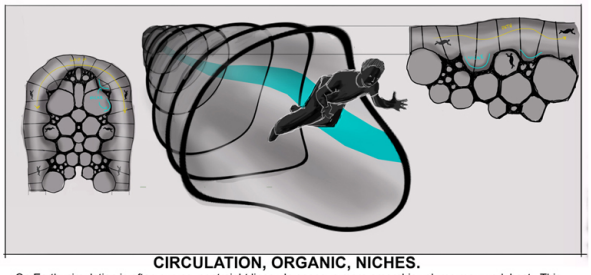
CUPOLA LOOKOUT (DEEP SACE EXPERIENCE)

In deep space, space is a vast thing to take in. And although it seems that the experience of that would be great, the reality is, that agoraphobia is a real problem. This robotic cupola allows the user to direct views in 360 degrees of rotation. The slit frames a view that can target earth to give a sense of place, or even Ceres to target where they are going. A self orienting machine, completely user controlled.



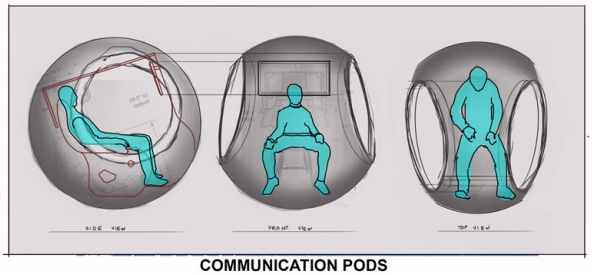
PATH, SCALE, COMPRESSION, RELEASE.

Much like on Earth, things that make us feel compressed or confined often heighten the experience of entering a large space, even if the space isn't that large. By visually identifying spaces you want to get to, along with a compression through a tube like corridor, this may create a more experiential path for one to navigate through on a daily basis.



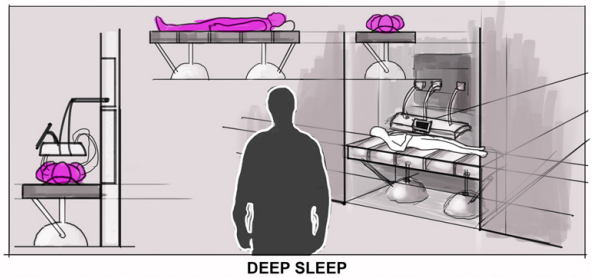
CIRCULATION, ORGANIC, NICHES.

On Earth, circulation is often curves, or straight lines. In space, a more amorphic volume may work best. This blobby circulation relays on shaping itself off of the volumes around it. If things just out, there is a bump in the path, if things cut in, there is a niche that forms. Traveling too and from, the experience may be quite different each way.



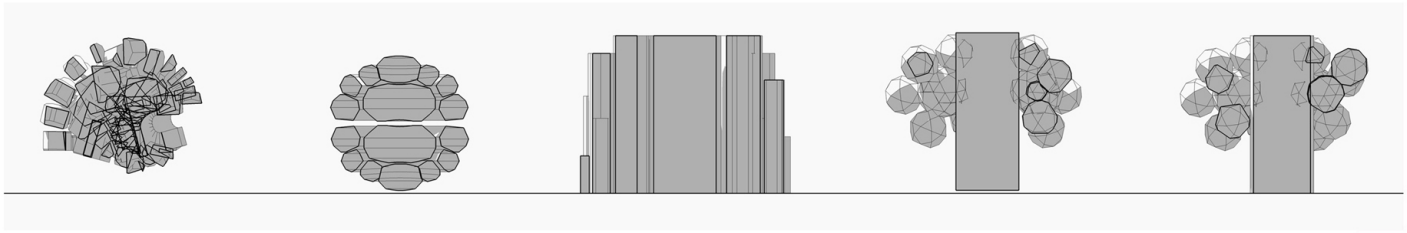
COMMUNICATION PODS

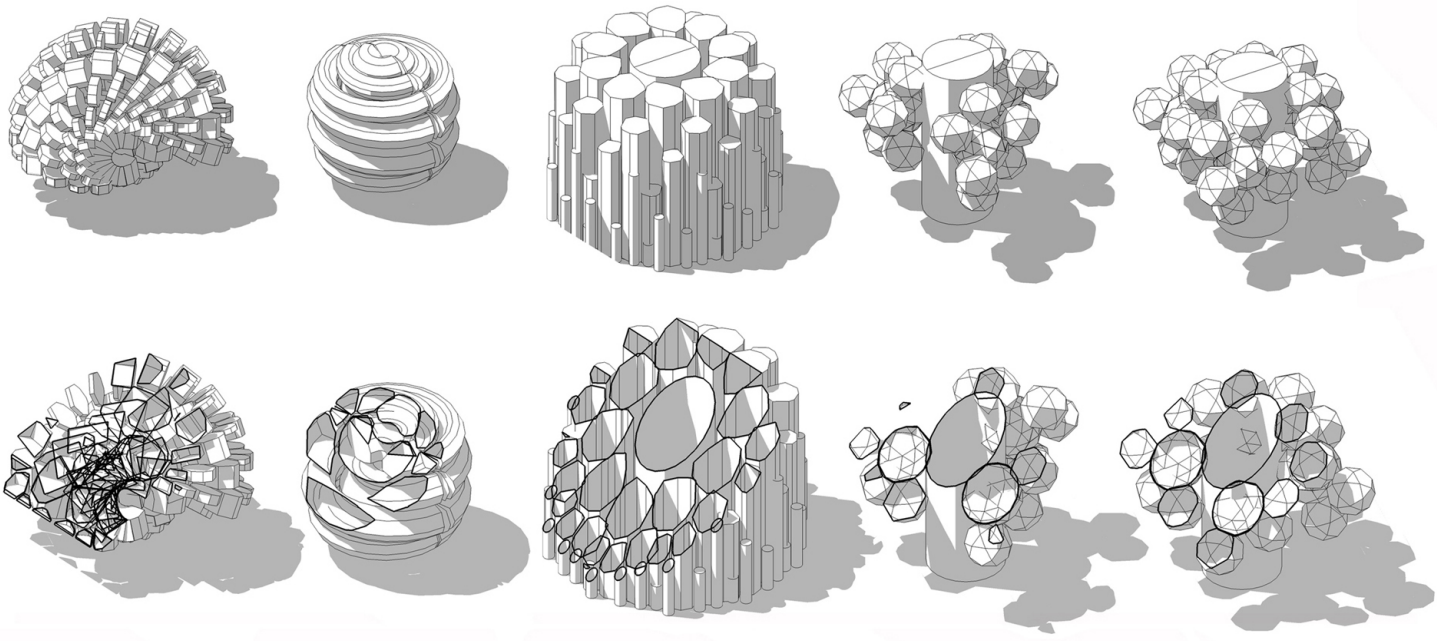
Once on the planet, it would be typical for the workers to be outside often doing maintenance or setting up other construction projects. And airlock acts as both an elemental barrier, providing a place that shelters from the outside, and acts as a transitional machine to enter the habitat space.

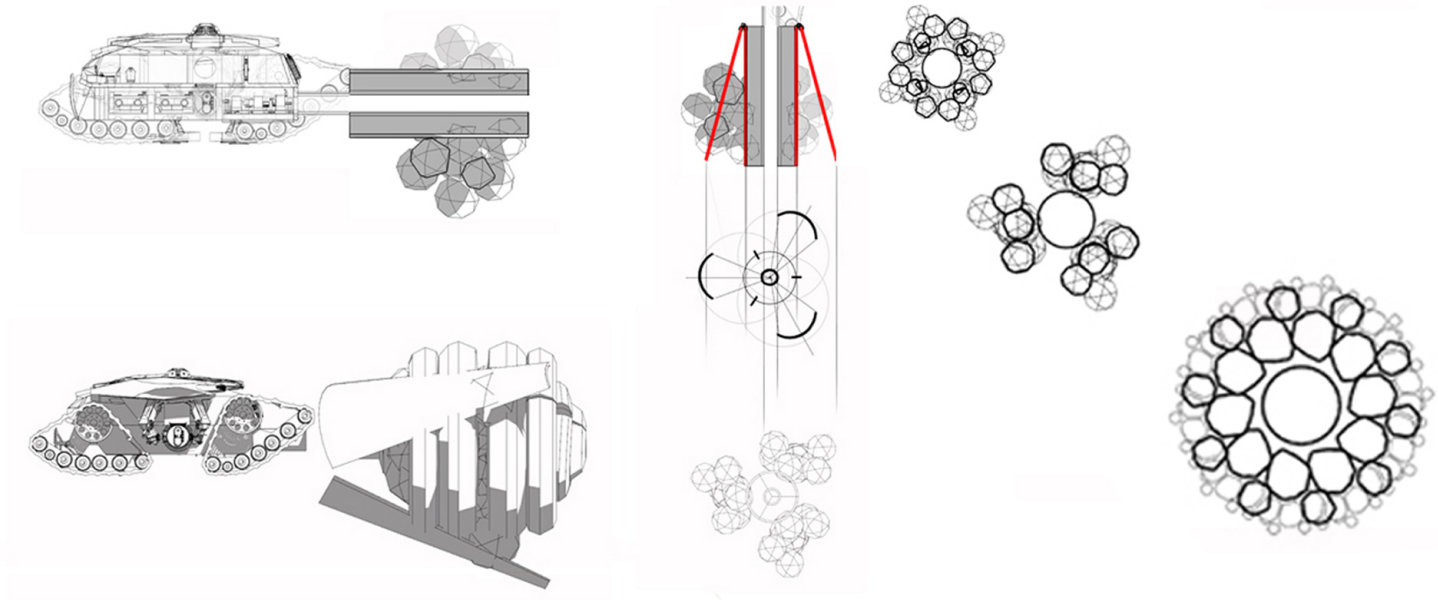


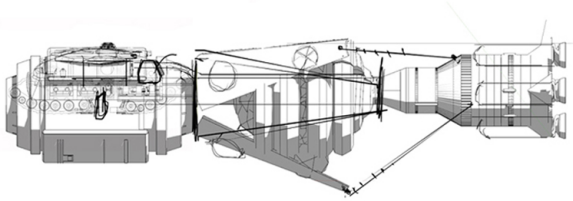
DEEP SLEEP

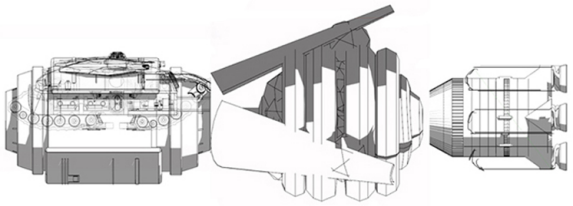
Testing has already begun for long term deep sleep, and there are many benefits so far. Deep sleep would require constant medical examination where I would imagine these detachable interfaces that could plug right into the human, feed them, monitor them, etc. There might even be a diagnostic monitor that allows the medical staff to quickly monitor brain activity, heart rates, etc.

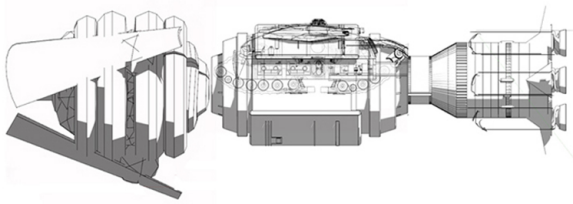


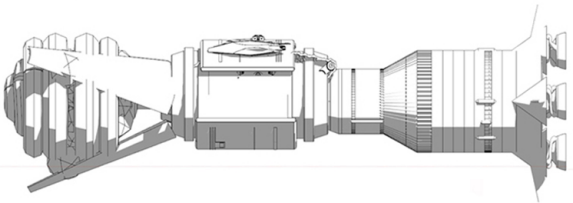


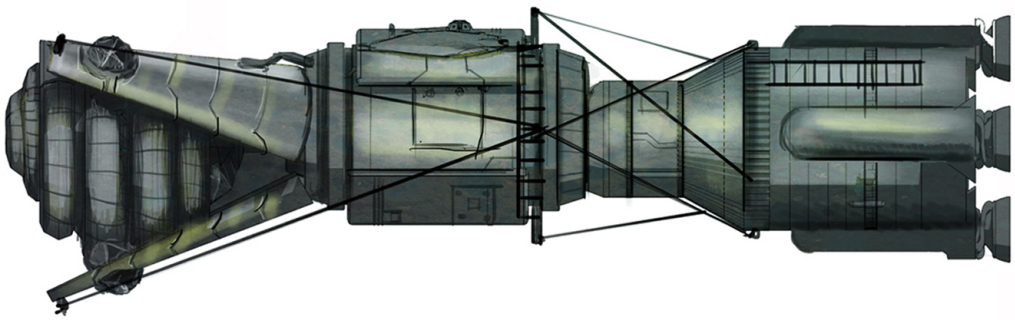


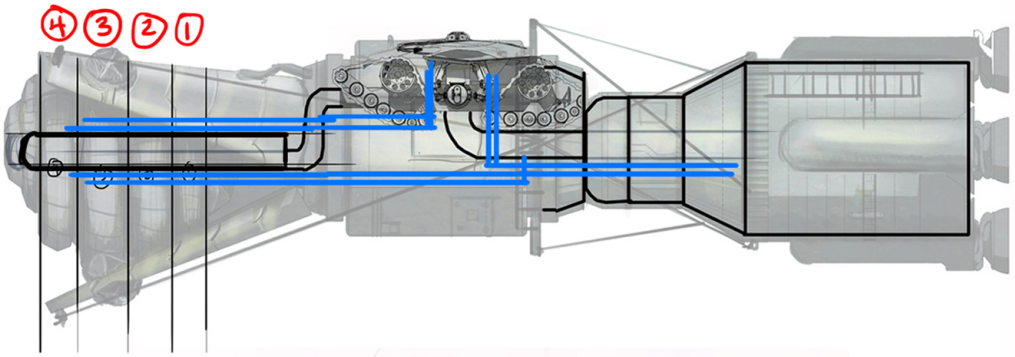








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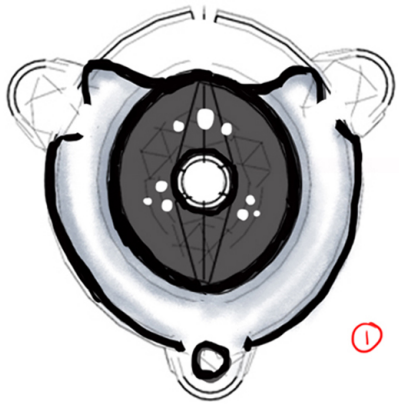
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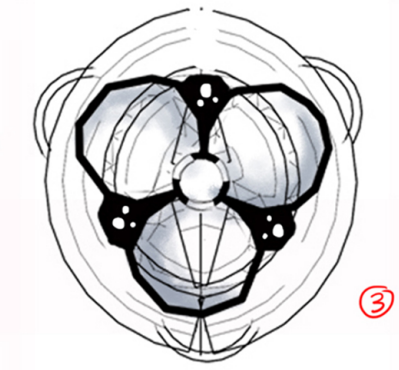
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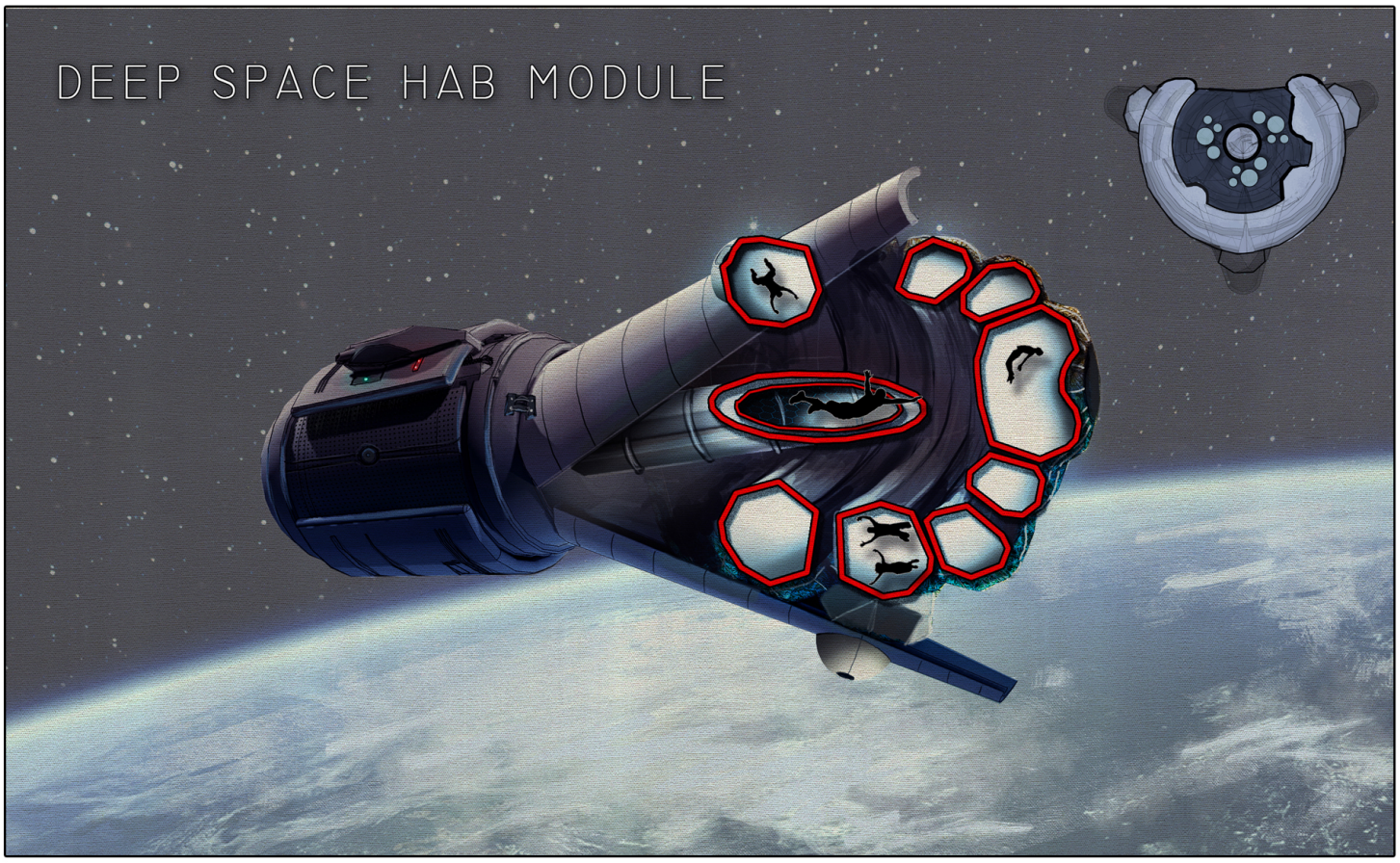
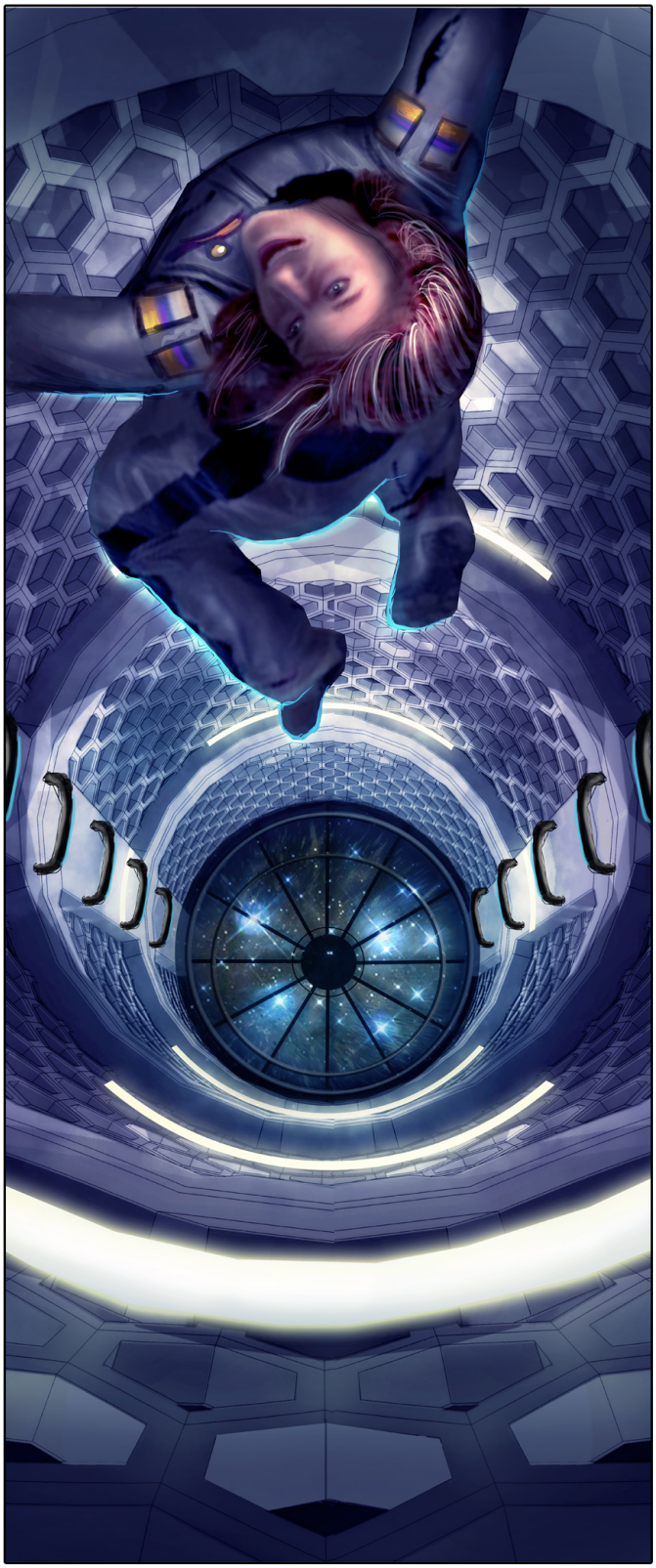
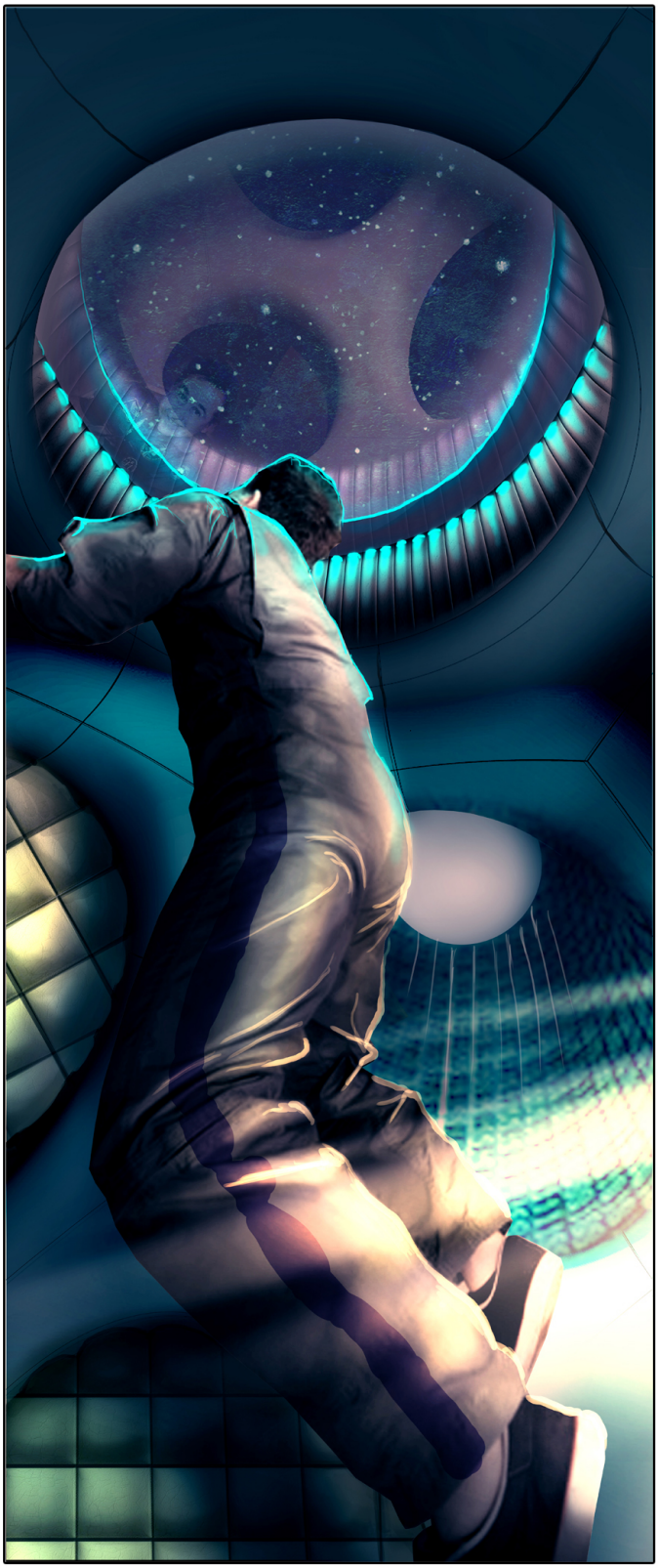
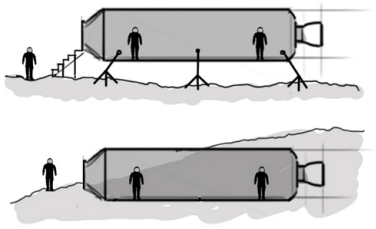

DEEP SPACE HAB MODULE







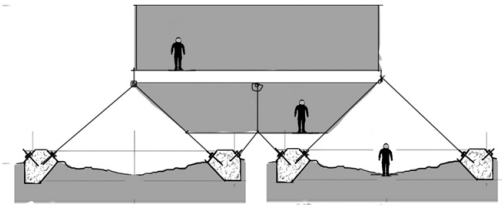
LOW RISK DESIGN
LOW BENEFIT



PROS
PRE BUILT
CURRENT FEASIBILITY

CONS
MINIMUM VOLUME
ARCHITECT HAS LOW INPUT
NOT ADAPTIVE
STATIC

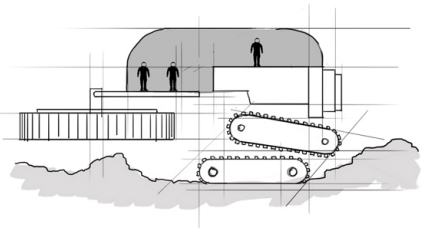
MEDIUM RISK DESIGN
MEDIUM BENEFIT



PROS
INFRASTRUCTURE IN PLACE
KIT OF PARTS
MODULAR
LARGE VOLUME

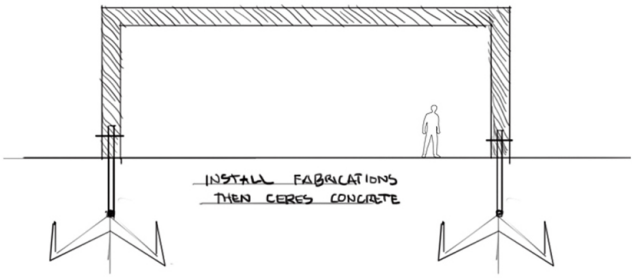
CONS
INVOLVES A LOT OF CONSTRUCTION
MATERIALS LOCAL TO CERES
RELIES ON ROBOTS FOR CONSTRUCTION
STATIC

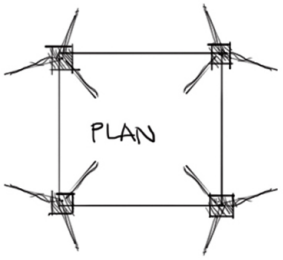
HIGH RISK DESIGN
HIGH BENEFIT

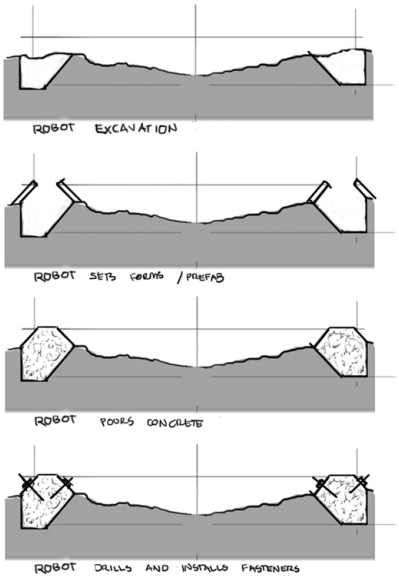


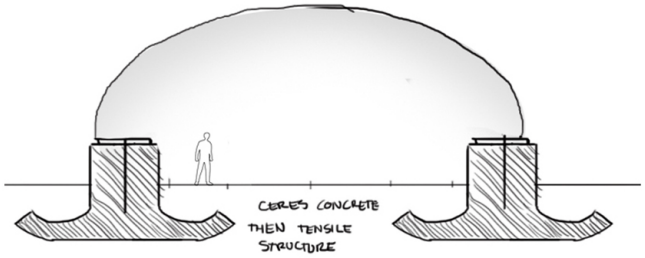
PROS
MOBILE
ADAPTIVE
DYNAMIC
KIT OF PARTS ?

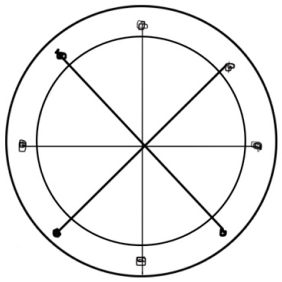
CONS
ASSEMBLY
MASS
COMPLEX
KIT OF PARTS ?

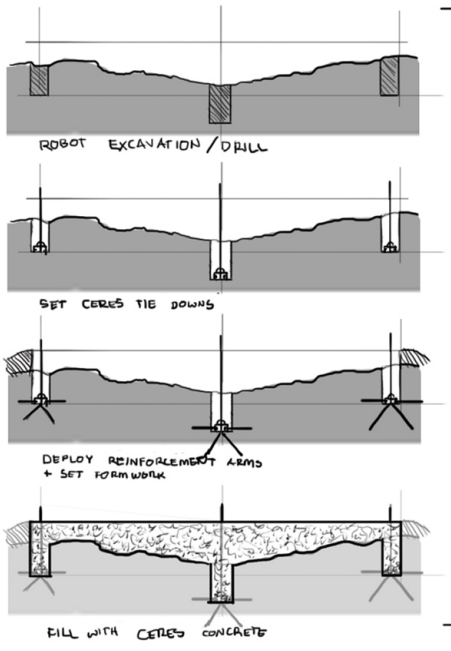


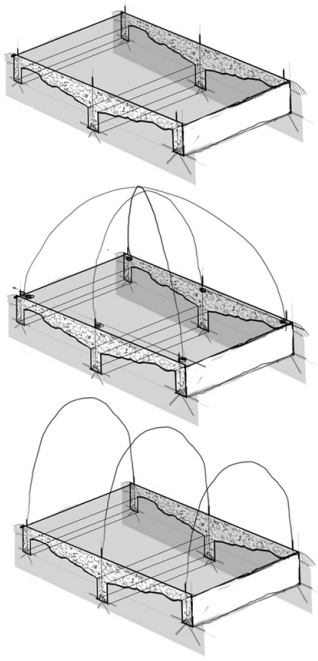


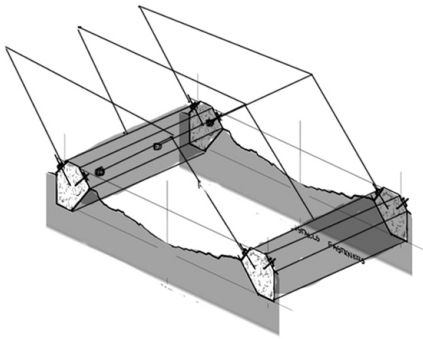


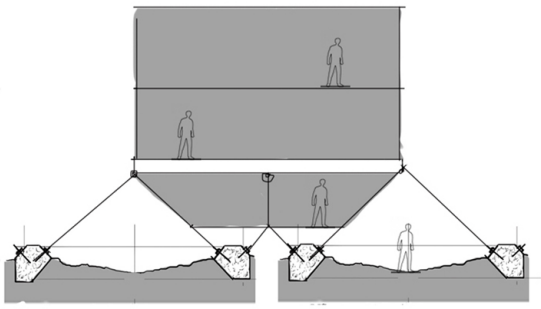


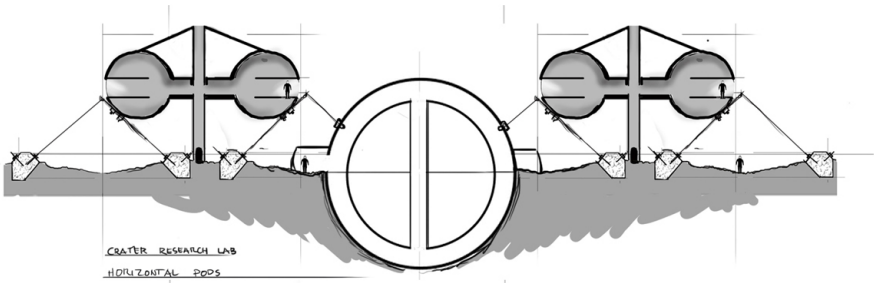




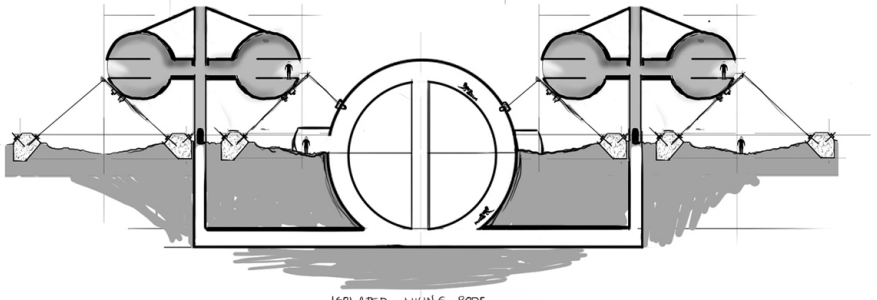




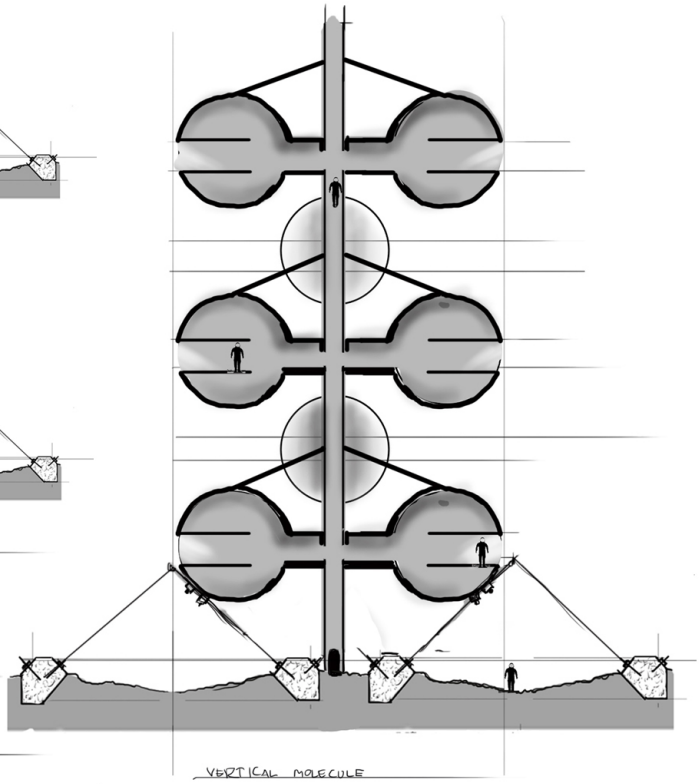




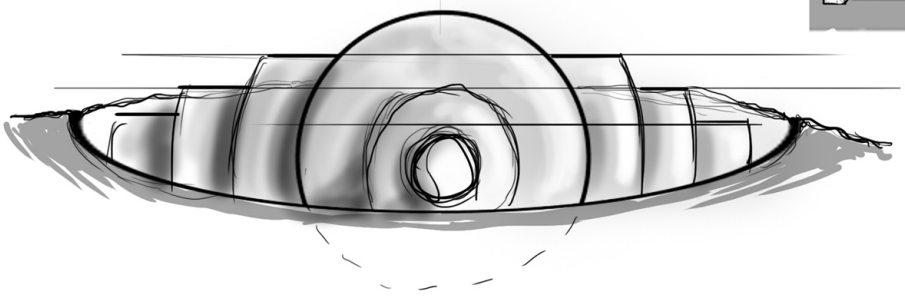
CRATER RESEARCH LAB
HORIZONTAL PODS



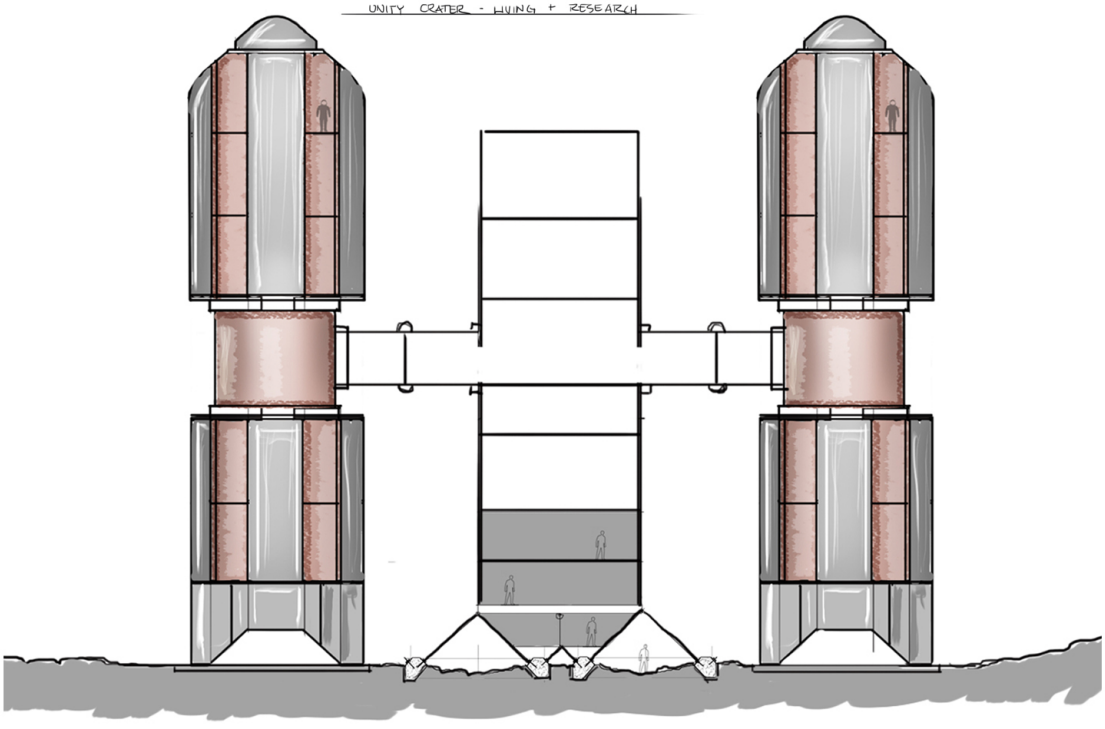
ISOLATED LIVING PODS
CORE RESEARCH TERMINAL

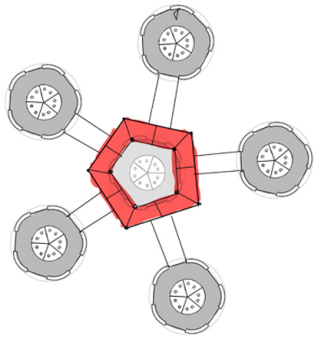


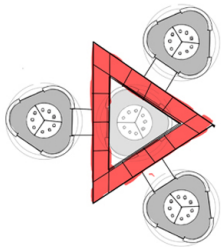
VERTICAL MOLECULE

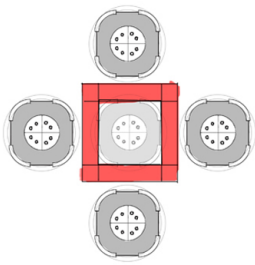


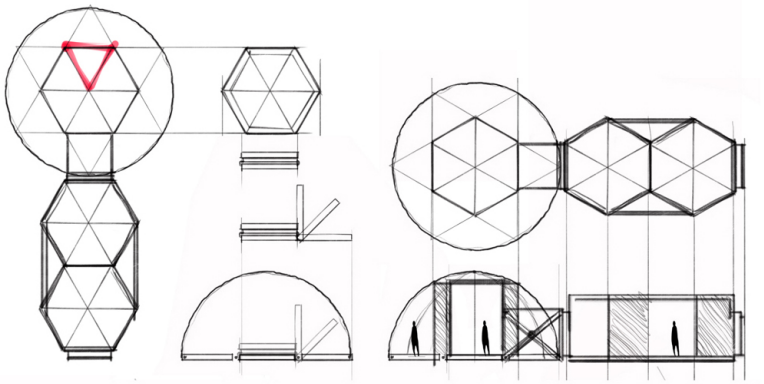
UNITY CRATER - LIVING + RESEARCH

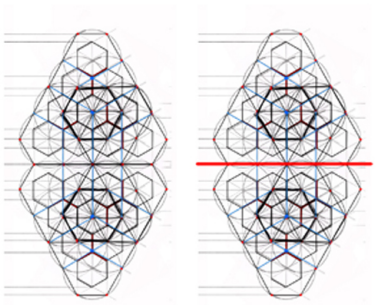


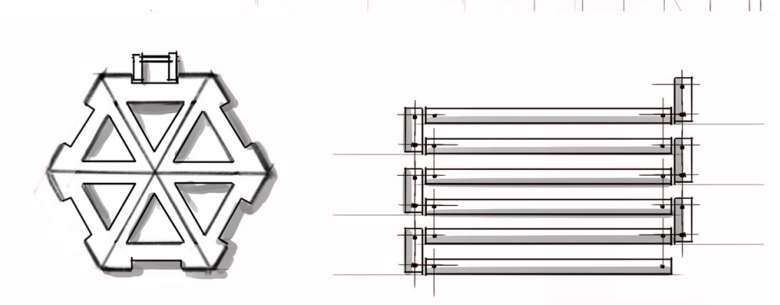


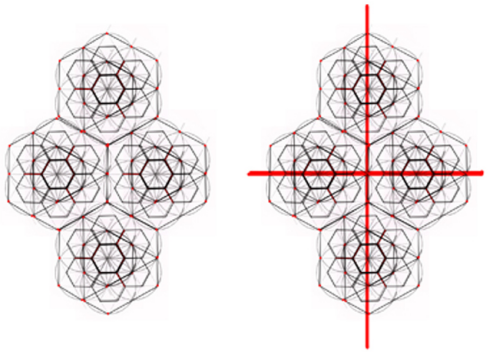


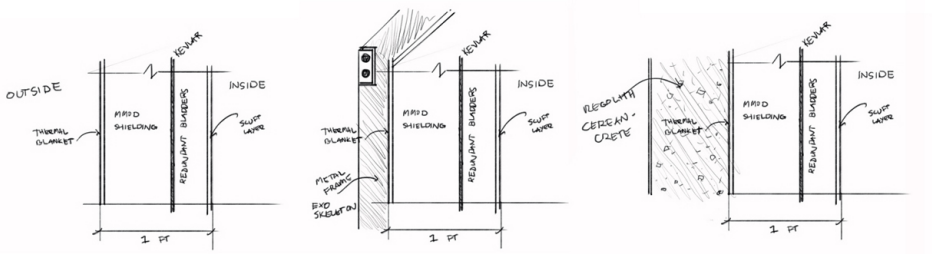











OUTSIDE
KEVLAR
INSIDE
THERMAL BLANKET
MAID SHIELDING
REJUVINAT BLADDERS
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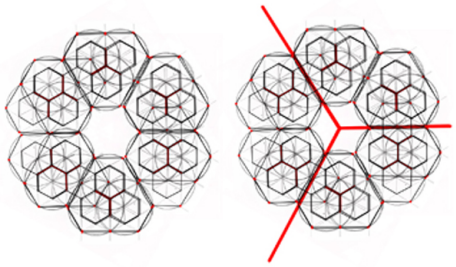
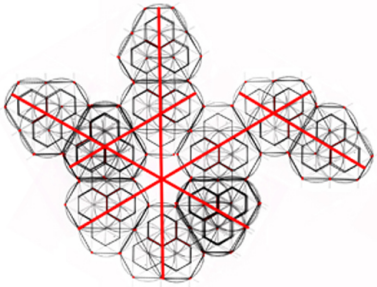
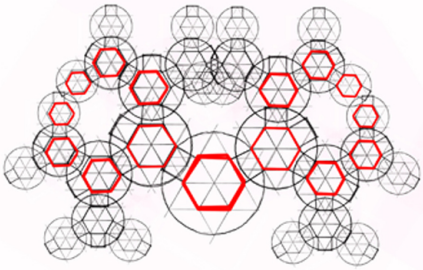
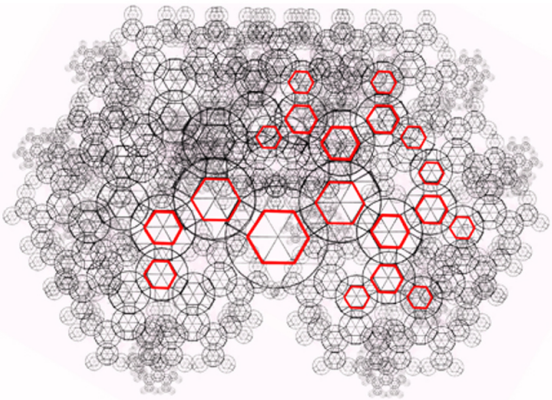
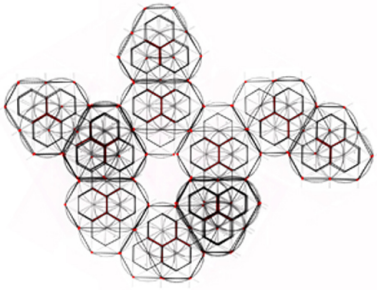
METAL FRAMIC
END SKELETON
REGOLITH CERCAN-CRETE

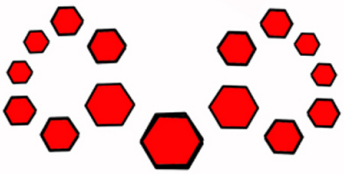


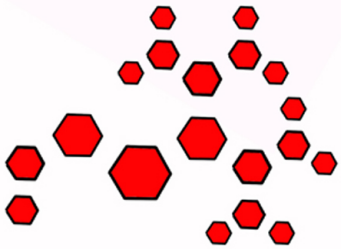


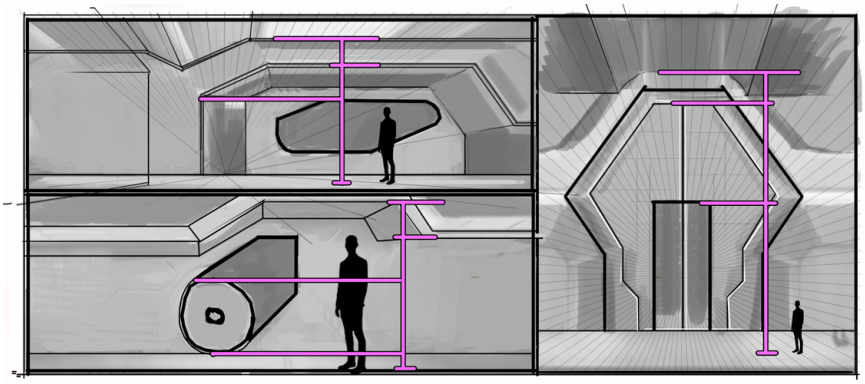












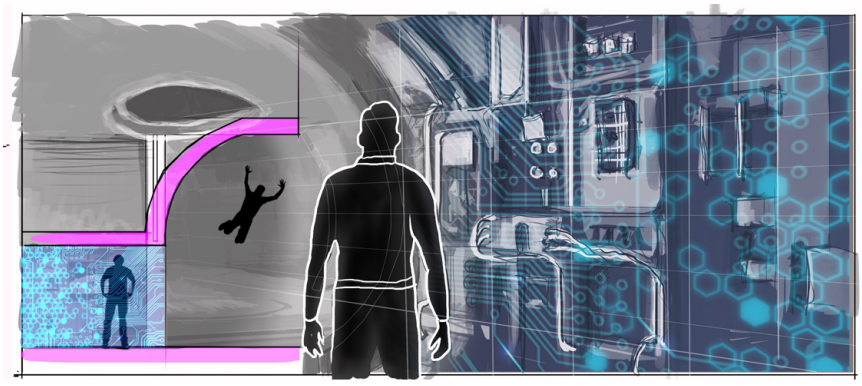
SCALE IN RELATION TO HUMANS

Scale is an element of design that is important on Earth, and can still be applied to designing on other worlds. Although walking will be basically impossible, the micro-gravity would still allow humans to sit, stand, and lean on things. Scale becomes important in defining spacial hierarchies. Large spaces for working on machines, medium spaces to socialize and gather, and small spaces for personal use.



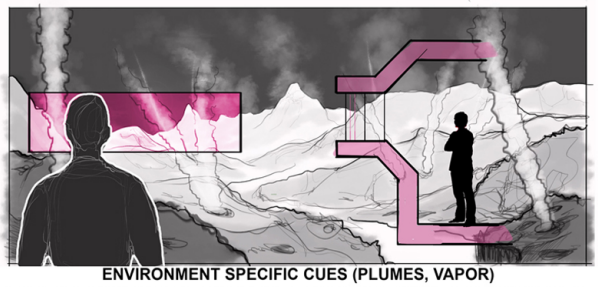
TRANSITS OF OTHER PLANETS

Although it would be great to have earth transit the sun, scientist think that the earth transit would be a very rare occurance from the viewpoint of Ceres. However other planets would be visible transiting the sun, such as Venus, and Mars. This would be the Cerean equivalent of a solar eclipse, not in the same effect, but rather a celestial event that would be able to be experienced, putting into perspective the relationship of this new world.



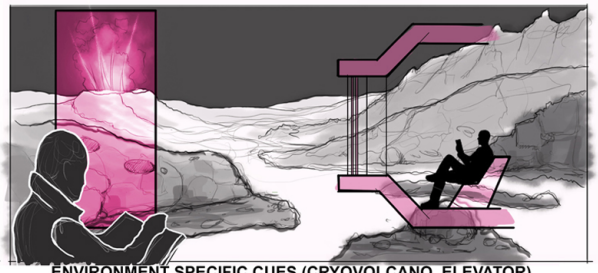
MECHANICAL (CIRCULATION) / PURE (FREE FUNCTION)

On Earth, we often hide mechanical things from view, almost as if they are not part of the building. In some cases, that makes sense, however on a mission like this, it is inevitable to get rid of all the mechanical things. Rather than hide them, exposing them as transitional elements as access ways helps to give a more pure experience to volumes that may be larger and plainer.



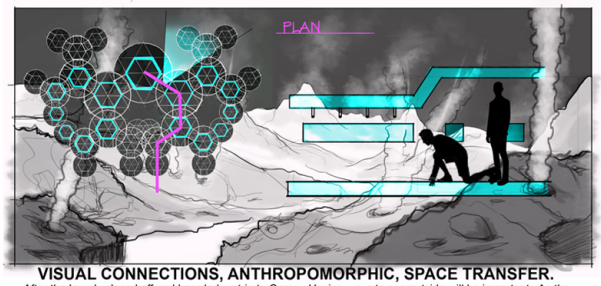
ENVIRONMENT SPECIFIC CUES (PLUMES, VAPOR)

Ceres is a world unto itself. Part moon-like, part ball of ice, part rocky/dusty. In the Cerean year it will become most active in the 500-600 day summer, which will be still very cold, but very active. As Ceres gets closer to the sun, the planet begins to breath vapor, pluming, and leaking out of the cracks. It is a seasonal cue, just as much as snow and rain, leaves falling, or birds chirping on Earth.



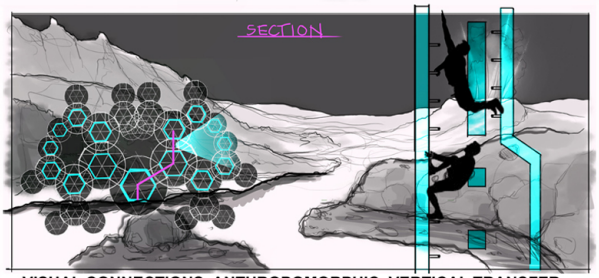
ENVIRONMENT SPECIFIC CUES (CRYOVOLCANO, ELEVATOR)

Ceres large ice volcano has been puzzling scientists and researchers. What we do know is that it would be a bright spot visible from ground level, and would be activated as we know it, almost constantly. This is a specific site phenomena that no human has ever experienced first hand. This would act as a bearing to orient to, and a sensory cue that frames a very dynamic and alive environment.



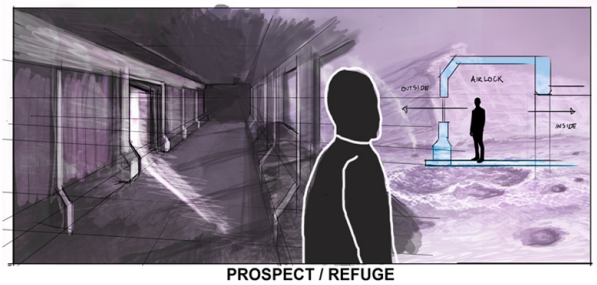
VISUAL CONNECTIONS, ANTHROPOMORPHIC, SPACE TRANSFER.

After the largely closed off and boarded up trip to Ceres. Having ways to see outside will be important. As the gravity is extremely low, the need for large volumetric spaces would be redundant. Mostly, the circulations and living spaces will be rather tight. some of these tight access ways will need to be interesting, offering human scale openings to take a moment and look.



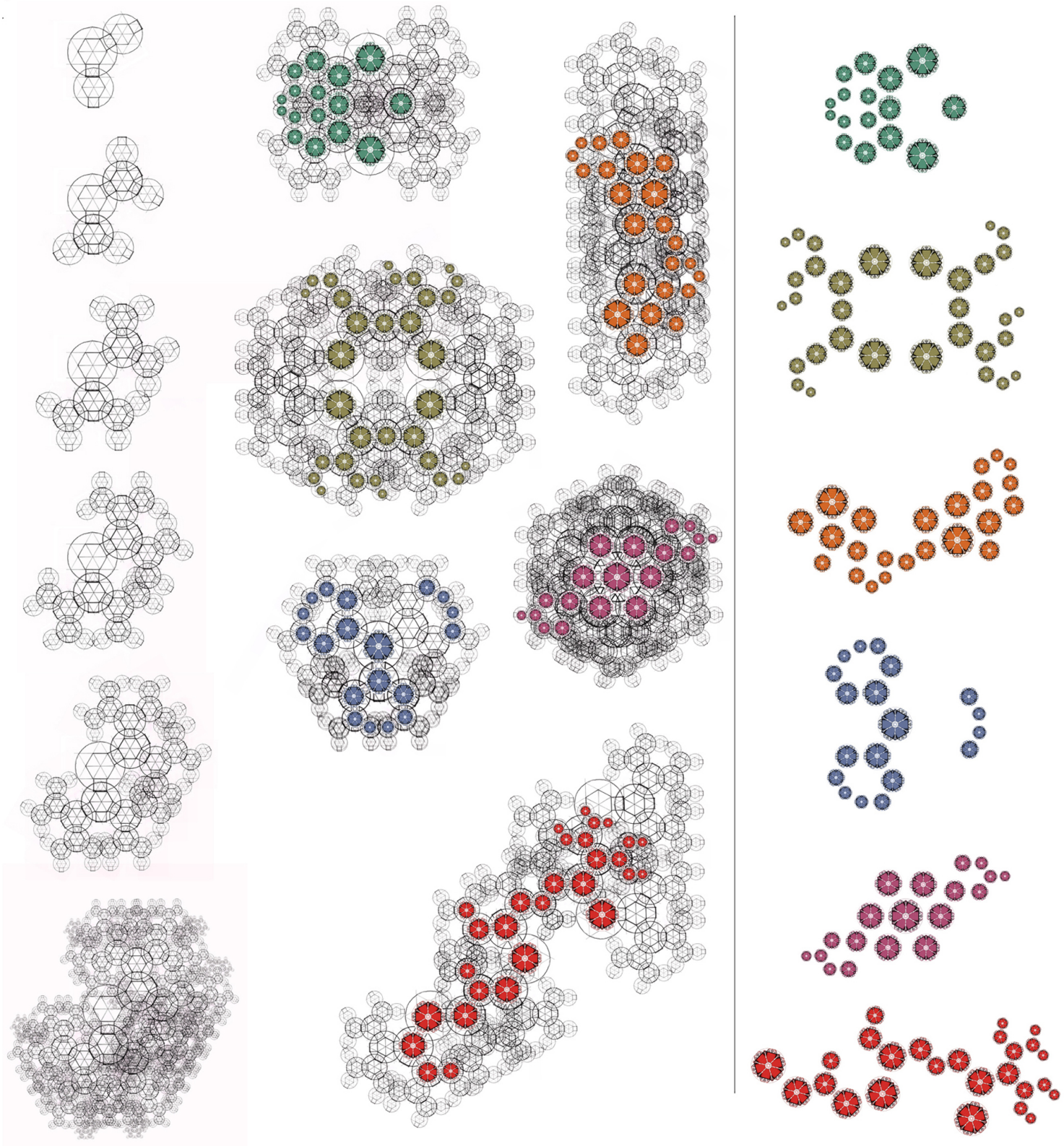
VISUAL CONNECTIONS, ANTHROPOMORPHIC, VERTICAL TRANSFER.

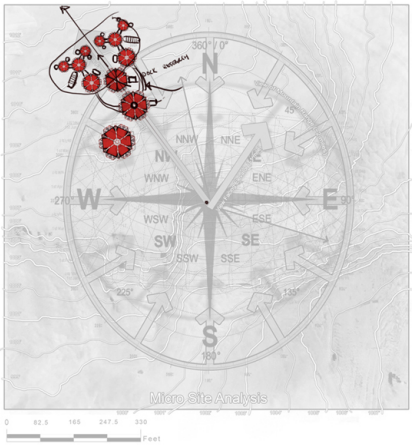
Vertical circulation is another thing to consider on Ceres. The low gravity allows a human to effortlessly jump into the volume of tube like structures. Walking on the planet will be likely not a possibility, unless developed over a long period of time. These conditions will be very close to that of zero gravity, and requires new ways to circulate architecture.



PROSPECT / REFUGE

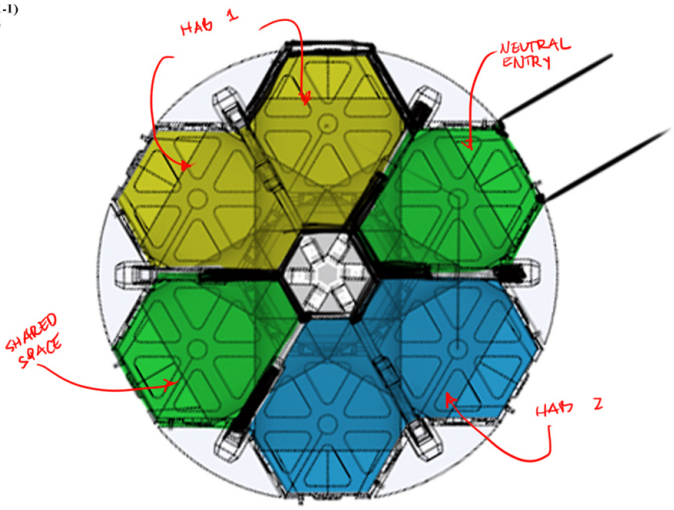
Once on the planet, it would be typical for the workers to be outside often doing maintenance or setting up other construction projects. And airlock acts as both an elemental barrier, providing a place that shelters from the outside, and acts as a transitional machine to enter the habitat space.

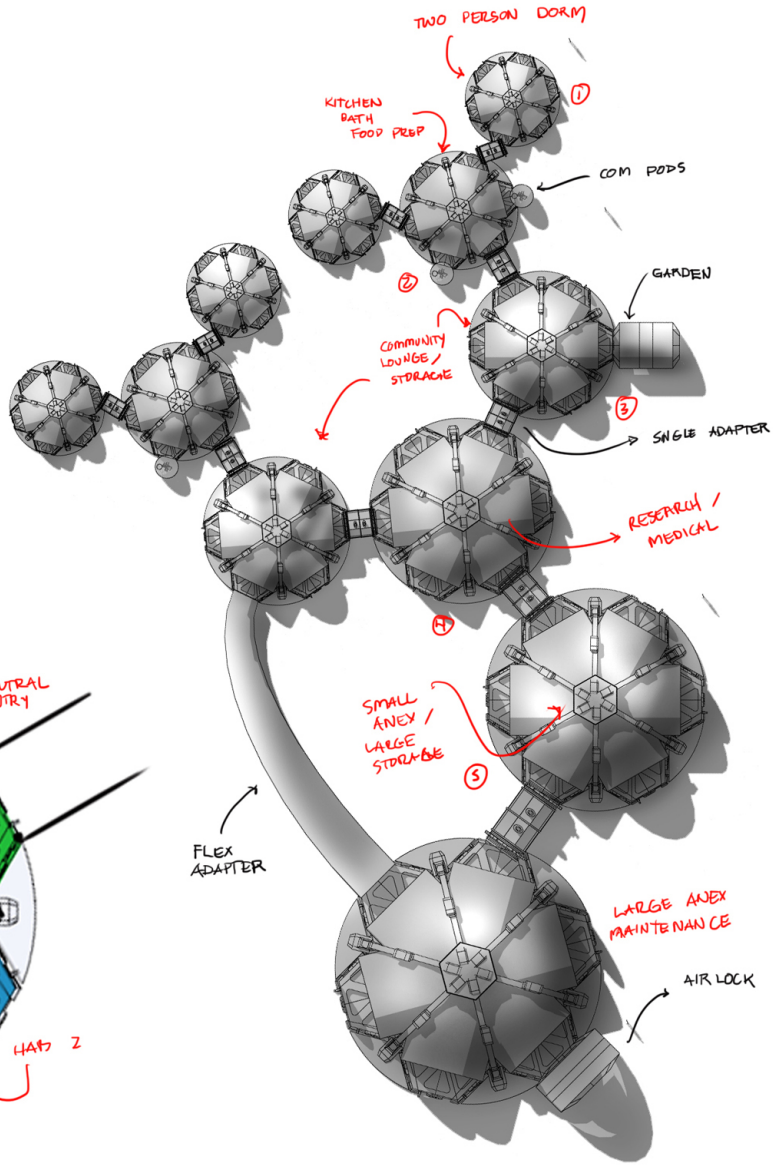


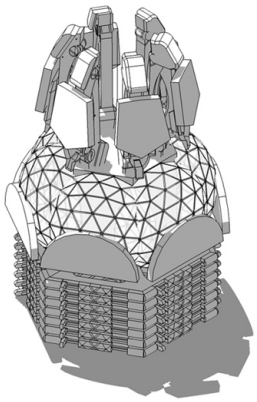


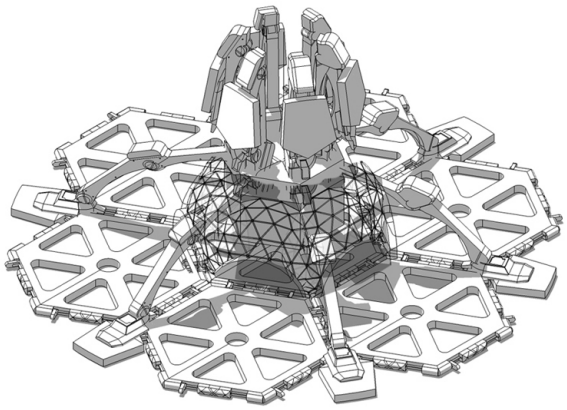
4 double dorm pods (8 person) smallest (1)
Kitchen, Eating, Food prep, Food storage bathrooms (2)
Lounge , relaxing, excercising, resistance bands, storage (3)
Research Lab, Medical Lab, Storage (4)
Small Anex, garage, storage, (5)

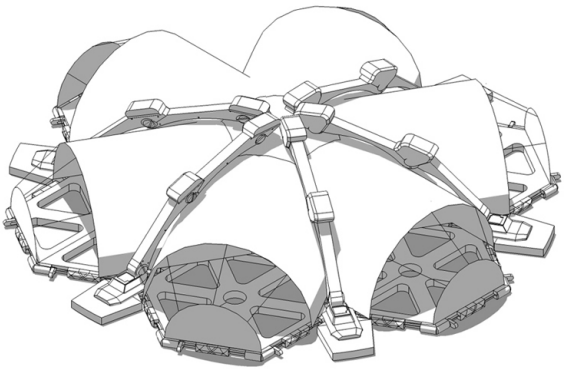
Attachments:
single tube connector (1-1)
tri tube connector (1-2)
airlock small
airlock large
garden and plants
animals and stock
Private Pod
Communication Vessel

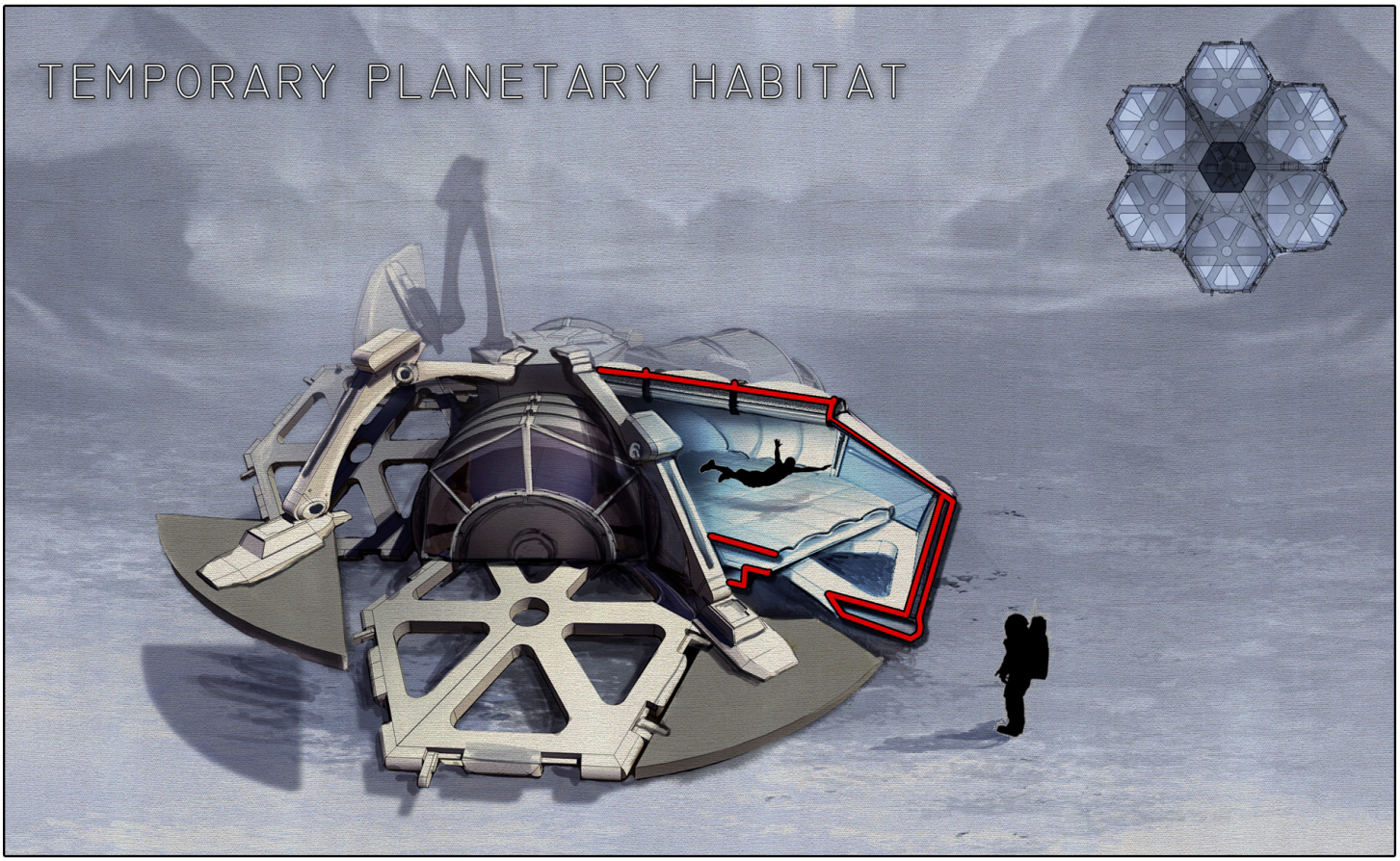






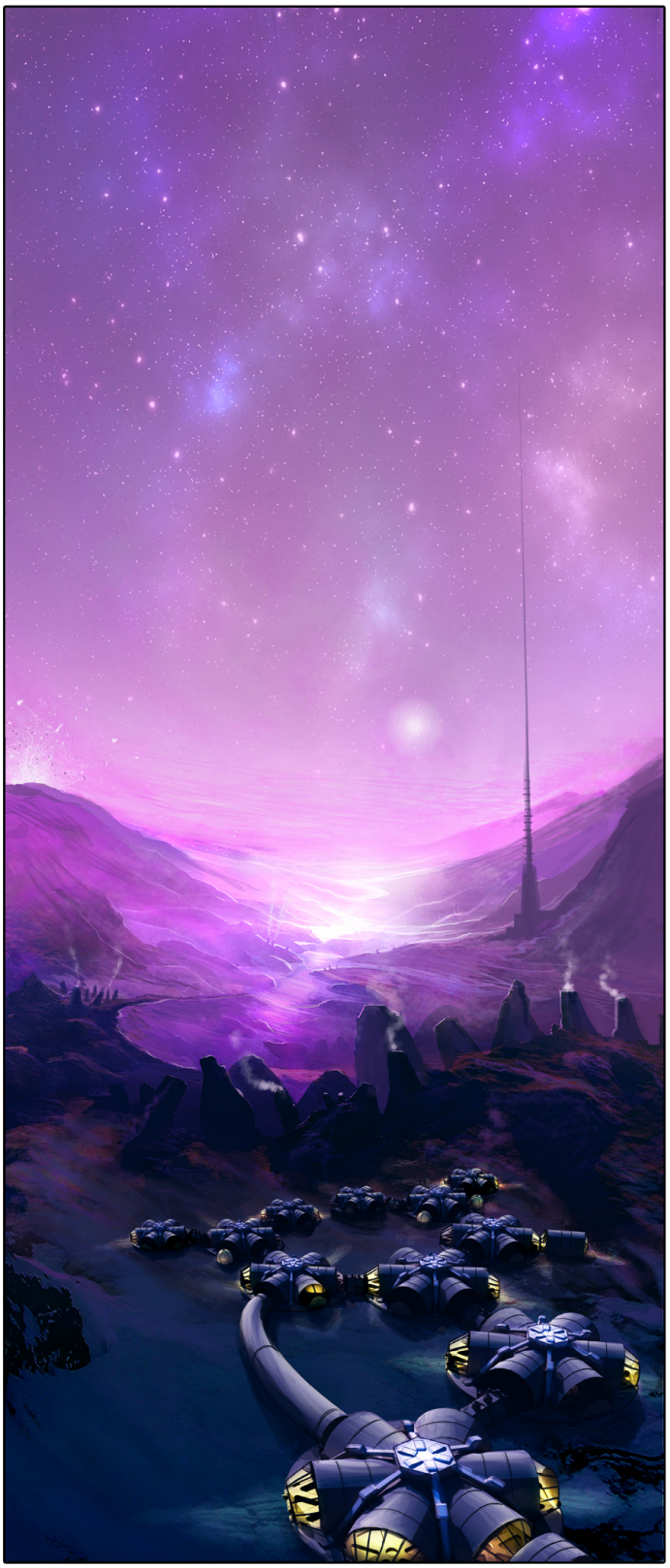





TEMPORARY PLANETARY HABITAT

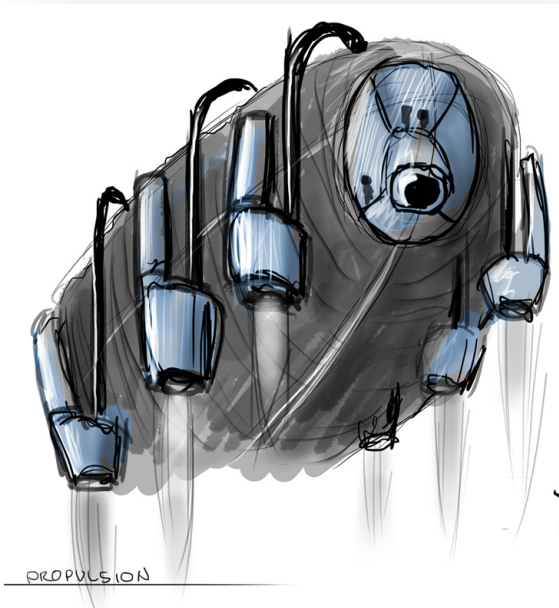






11

[M.R.L] CLASS 1 MOBILE RESEARCH LABORATORY



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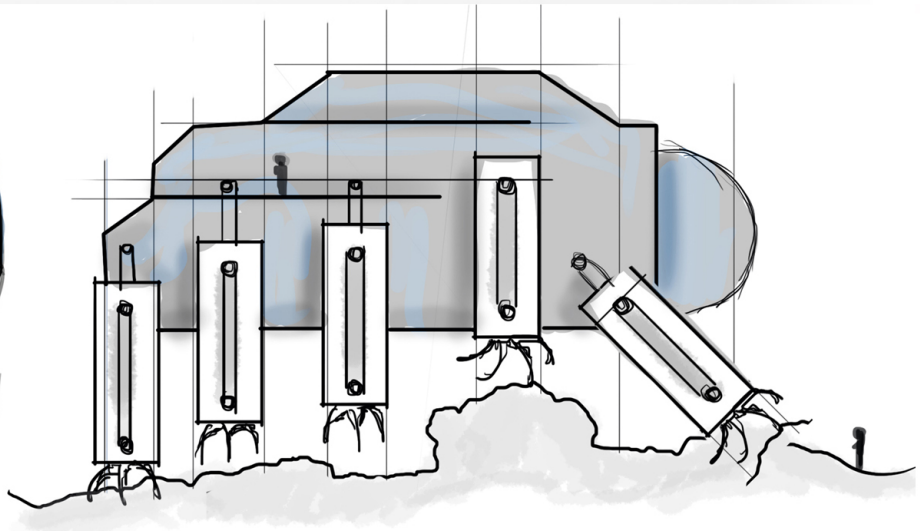
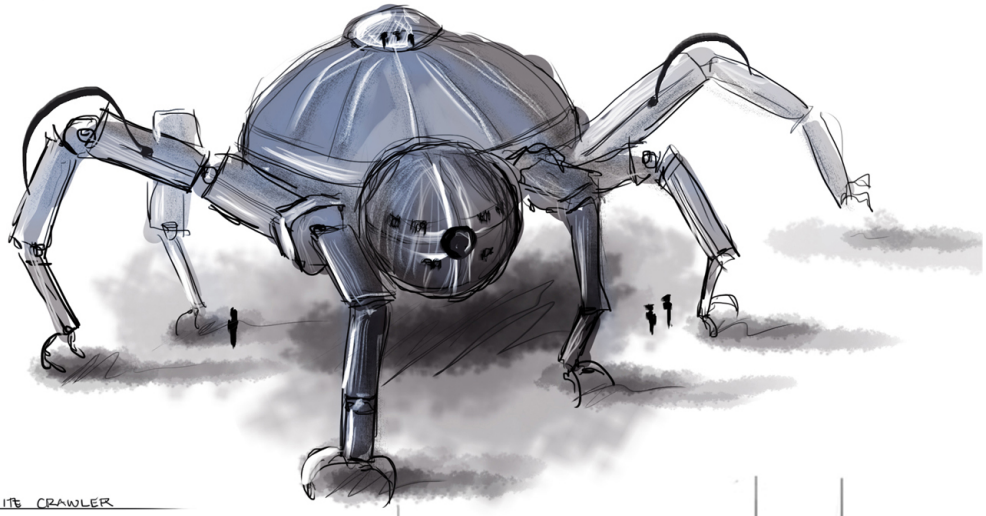
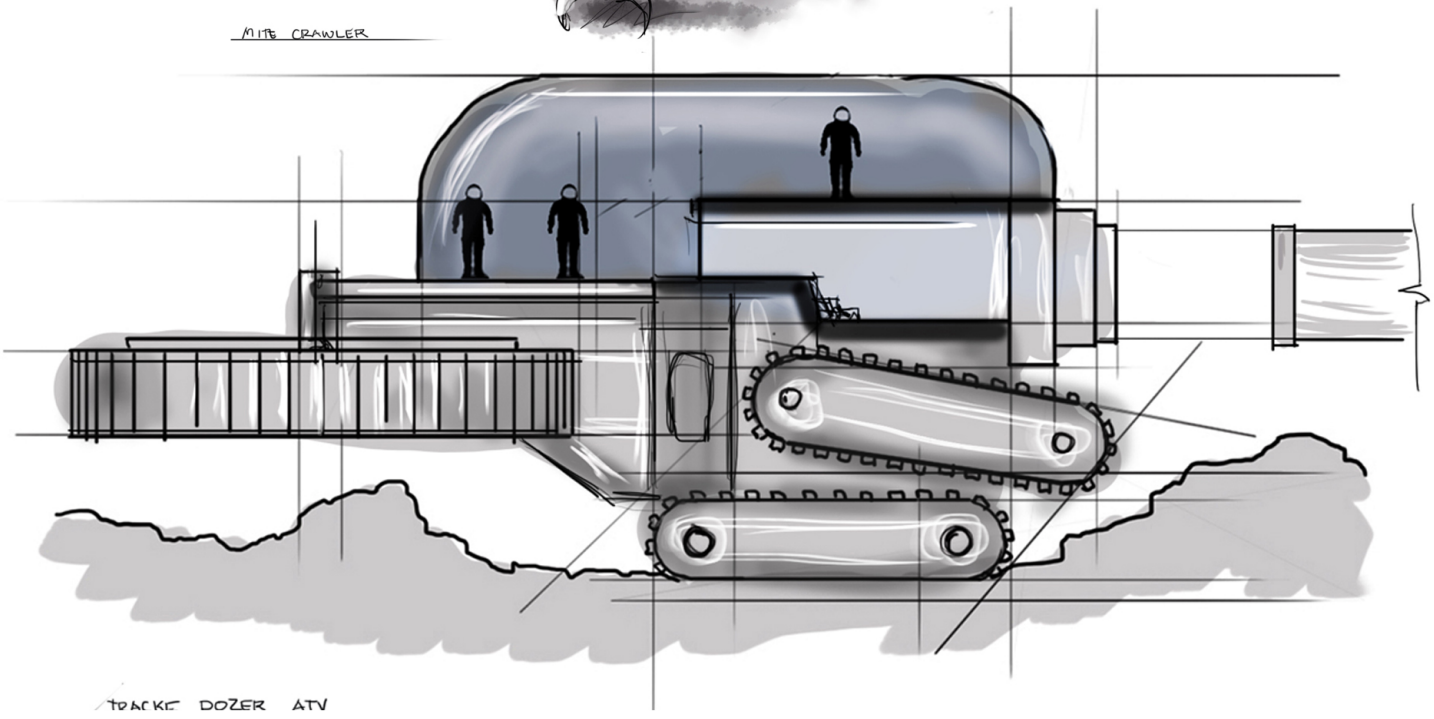


TARDIGRADE CRAWLER



MITE CRAWLER



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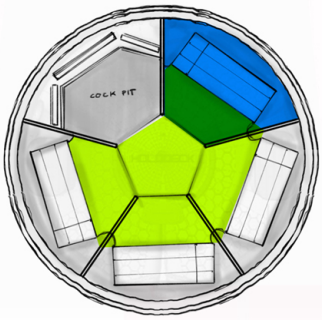
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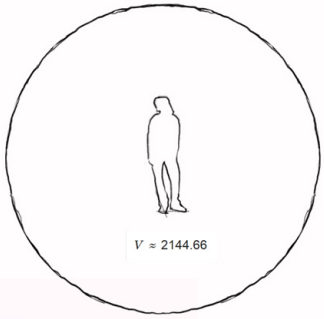
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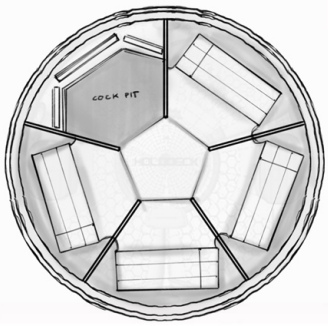
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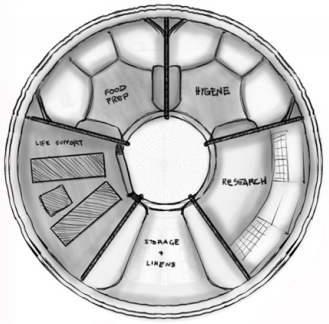
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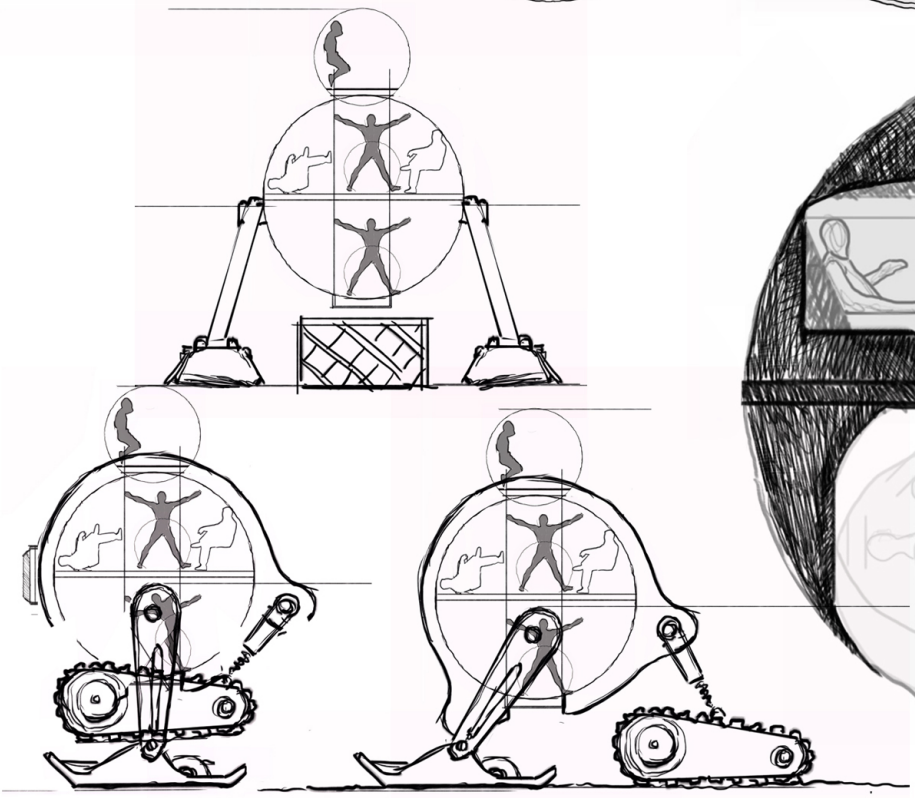
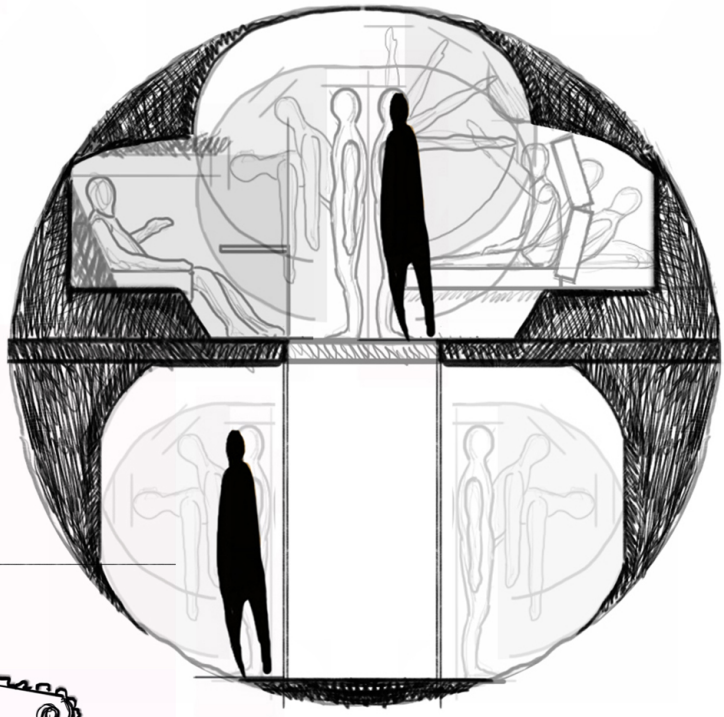
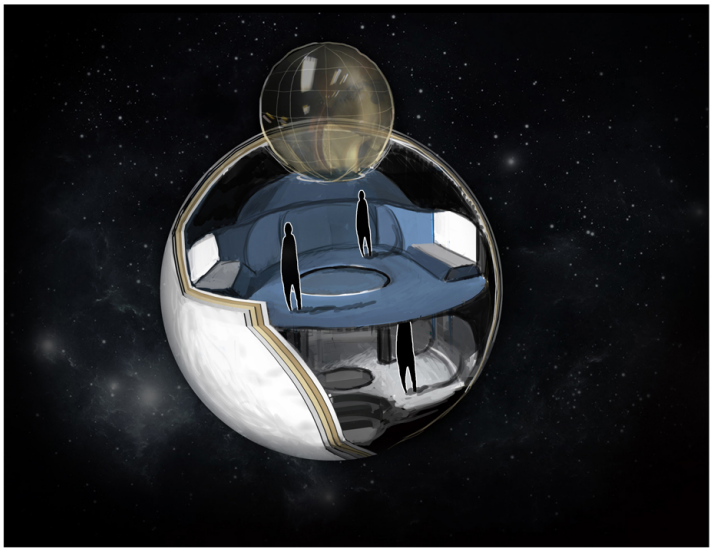
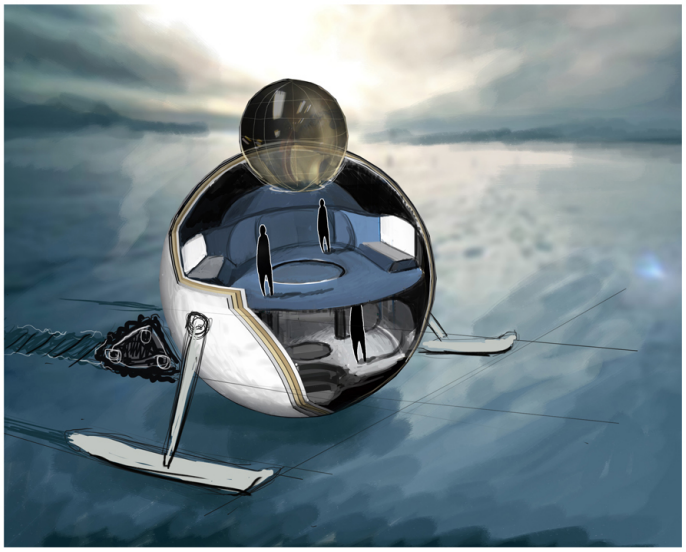
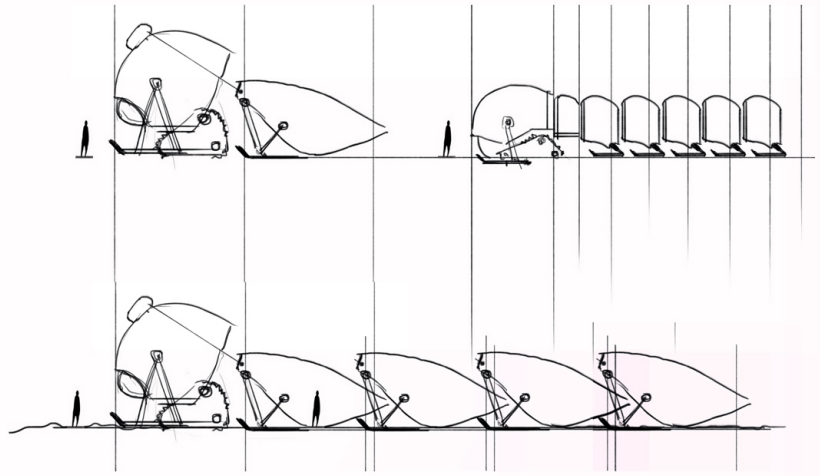
HYGENE
LIFE SUPPORT
RESEARCH
STORAGE + LINENS

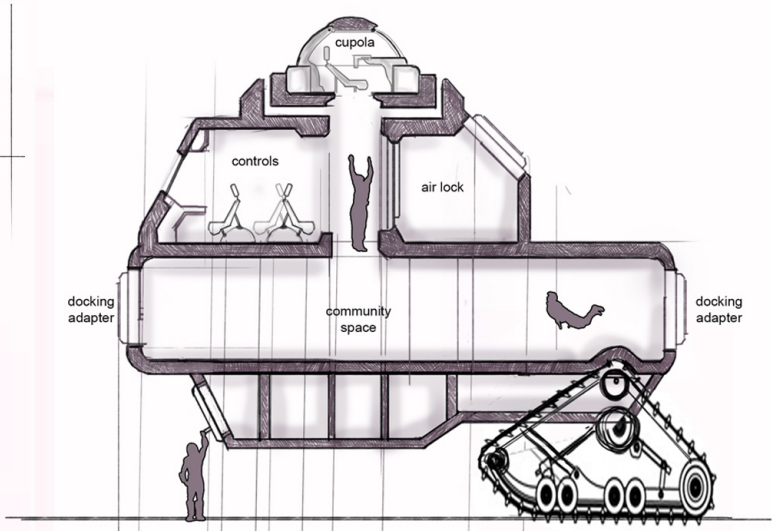


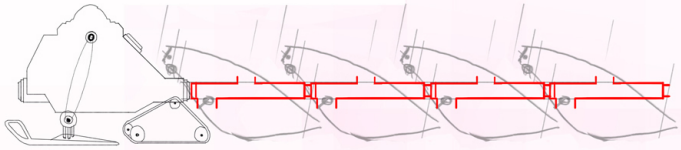


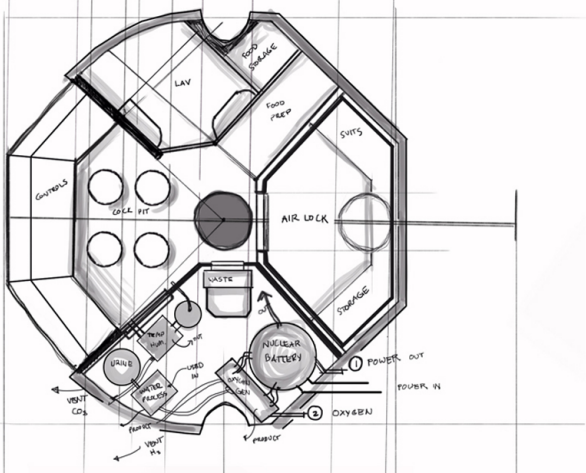







cupola
controls
air lock
docking adapter
community space
docking adapter

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FOOD STORAGE
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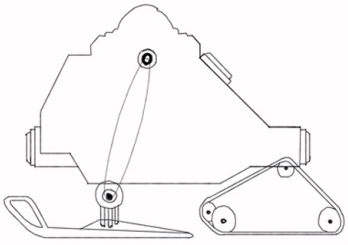
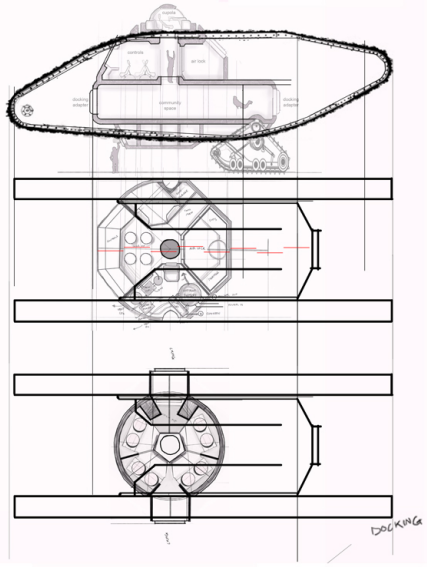
OXYGEN
VENT CO2
VENT O2

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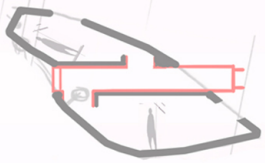

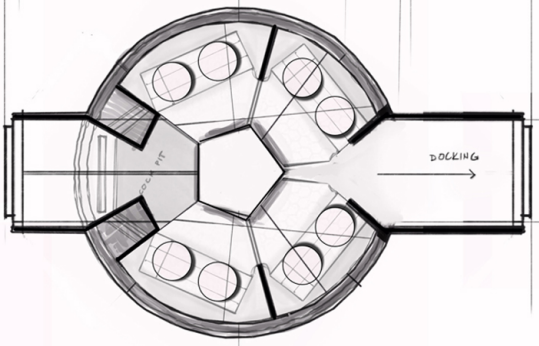
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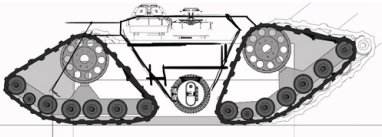
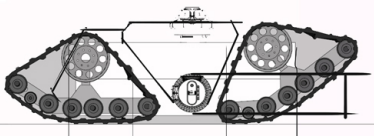
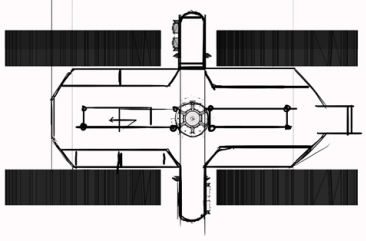
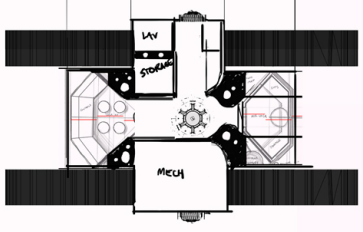
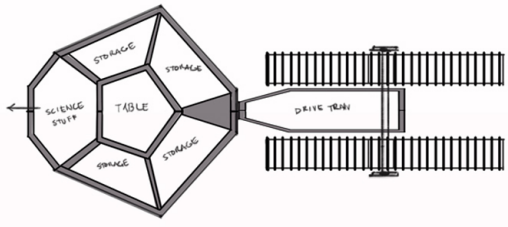
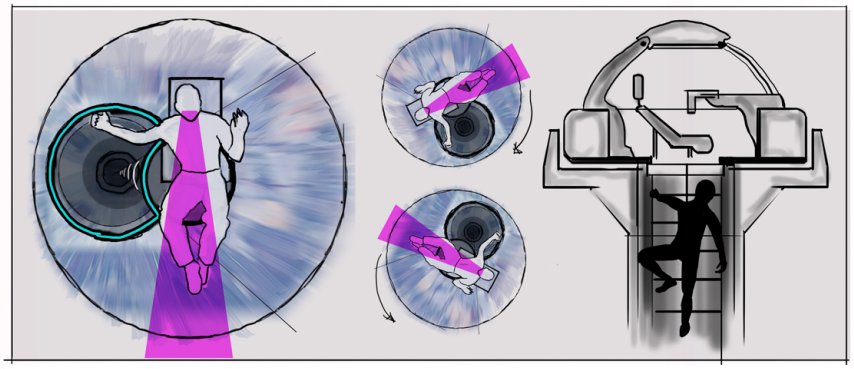






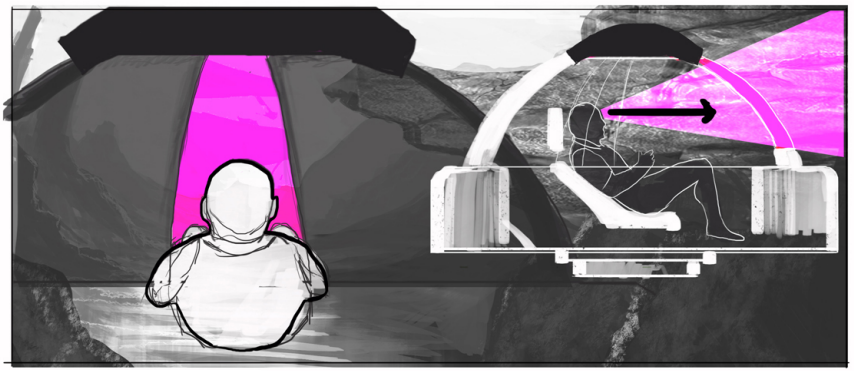

LAV
STORAGE
MECH


STORAGE
STORAGE
SCIENCE STUFF
TABLE
DRIVE TRAIN
STORAGE
STORAGE



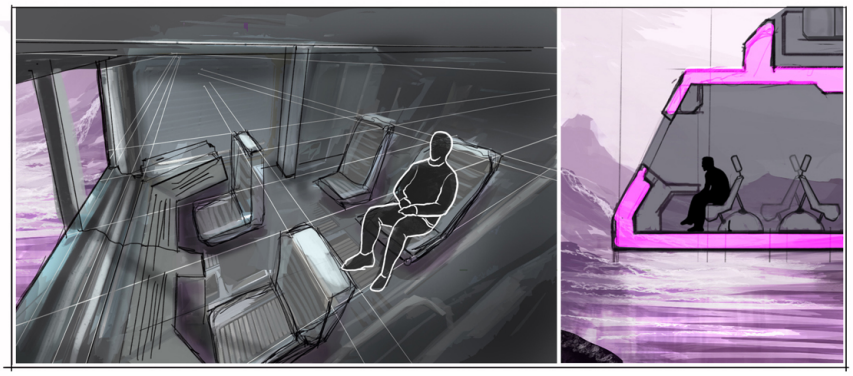
CUPOLA LOOKOUT (ACCESS)

The cupola will be the one true space to experience a multitude of things. This is one of the few destinations on the deep space module, and doubles as a lookout and view port on the mobile research lab. The compressed vertical corridor is tight, but once you get to the top, you are the only one experiencing that view.



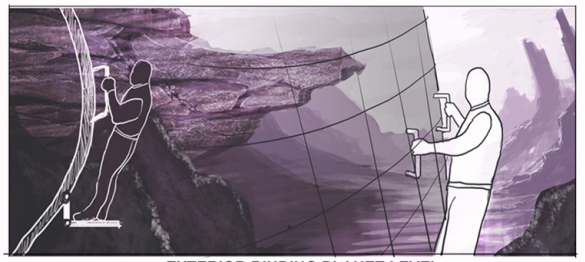
CUPOLA LOOKOUT (PLANETARY EXPERIENCE)

The cupola will function exactly the same on the research lab as it did in space, however it will offer a quite different experience. While the research team is out living for weeks at a time, this can offer the same escape as deep space conditions. however this also allows for navigation assistance, as the crew can only physicall look forward.



COCKPIT / CONTROLS

The control center is a multi-functional space. It acts as the main piloting center for the craft in deep space, as well as the same for the mobile research lab. This space also acts as harnesses for landing. I would imagine having removable panels that would cover up the window for deep space flight, but would open up for planetary use. typically there isn't a window when piloting deep space flights.



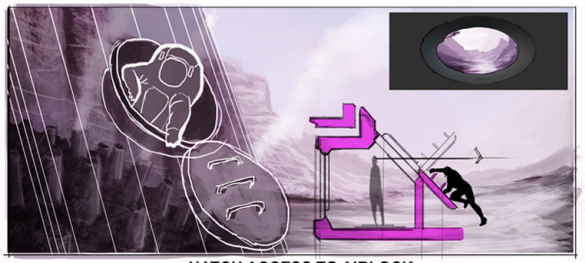
EXTERIOR BINDING PLANET LEVEL

The robotic mobile research laboratory will be able to function on a wide range of functions. Propulsive, and motor drive tracks. This thing can crawl and fly. But for short term EVA's, it may be necessary for a person outside to hitch a ride, rather than go back into the air lock and de-pressurize. The human must be able to leach on for a temporary time frame.



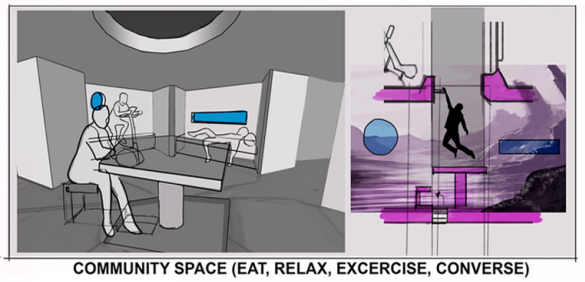
EXTERIOR BINDING SKY LEVEL

On Ceres, research may not always be accessible by the large vehicle. Airdrops may be a way that all humans to get to places that would be too risky for the research lab to reach. The human would be harnassed and then released whenever the altitude is appropriet. With Ceres low gravity, the Viper jetpack will make for easy landing and take off.



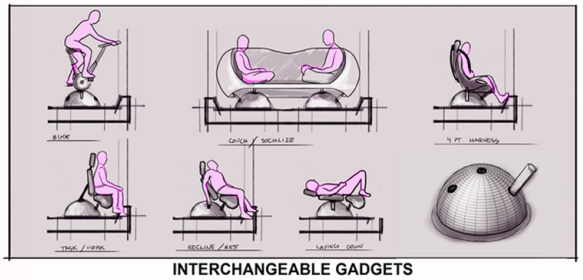
HATCH ACCESS TO AIRLOCK

An airlock wouldn't be a typical "experience" to look at, however when you take into consideration the preparation that goes into dressing for an EVA, it is quite a process. After hours of breathing pure oxygen, and de-pressurizing in the hatch, the first glimpse of the planet scape would be an a great reward.



COMMUNITY SPACE (EAT, RELAX, EXCERCISE, CONVERSE)

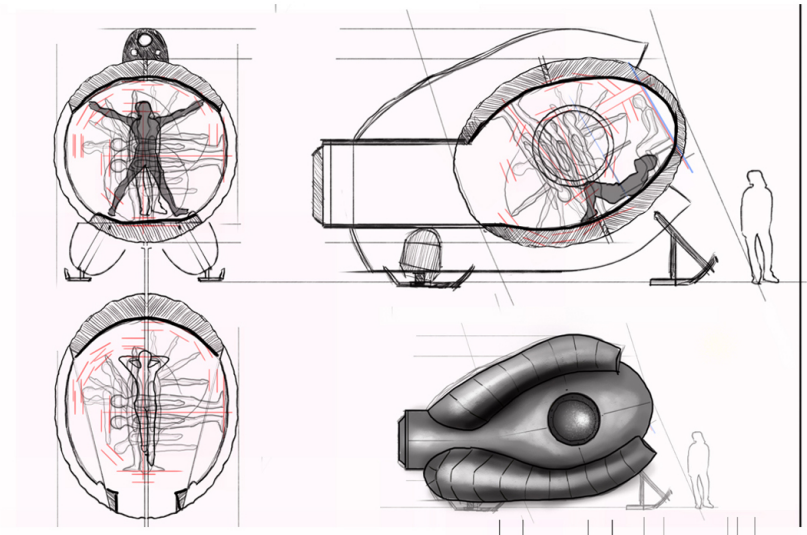
The community space is the primary open space of the mobile research lab. A place where one can eat, relax, exercise, converse, etc. Made up of mostly robotic and transformable components (seats, tables, chairs, etc), this place becomes a place to store things, to gather, and to provide volume in an otherwise small machine.

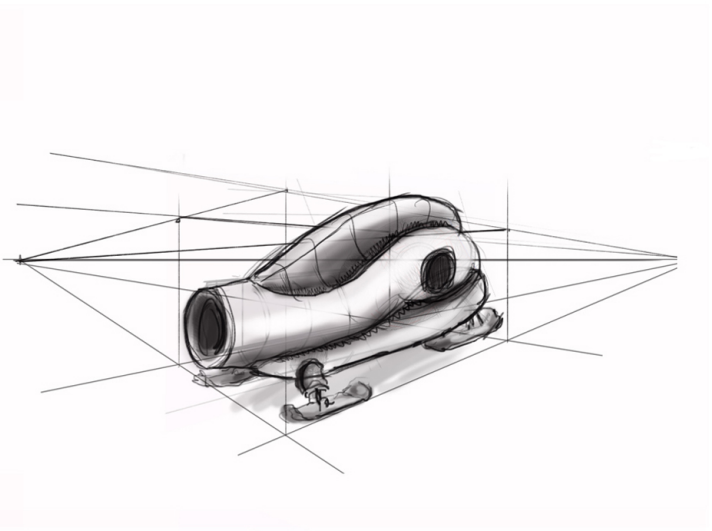


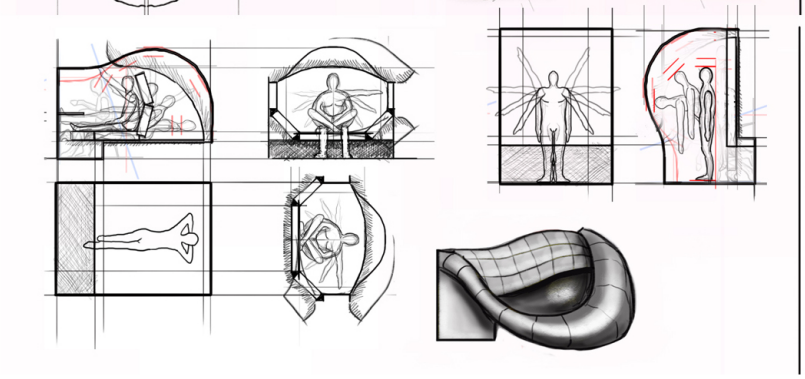
INTERCHANGEABLE GADGETS

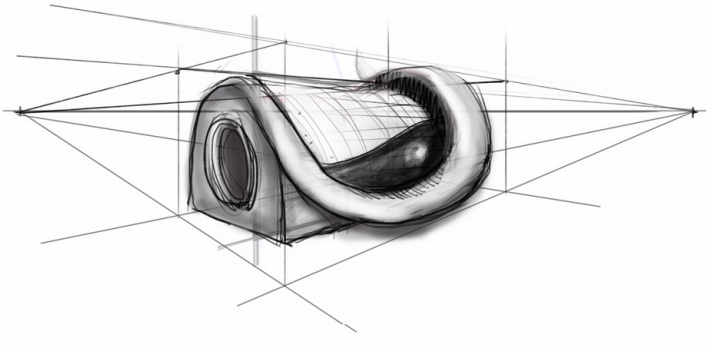
Having the ability to modify the environment is important. Sometimes, open space needs to be open space, but other times it can still serve a purpose of some other activity. One may want to bike, run, sit, sleep, lounge, work, or be harnessed for landing. I imagine a quickly adaptable form of interchangeable gadgetry that suits to what the human may want or need.

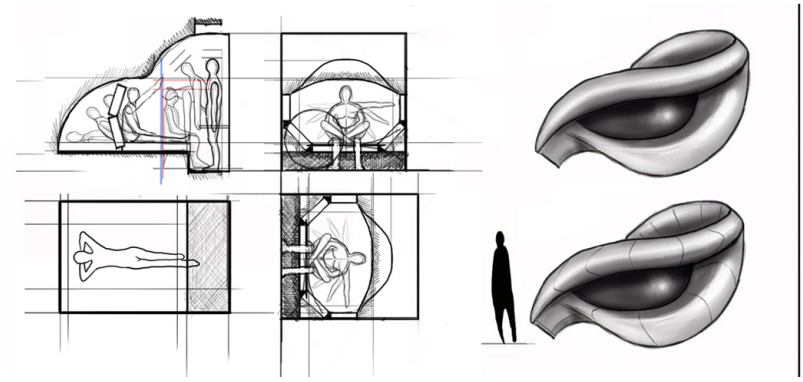
[M.R.L] CLASS 1 MOBILE RESEARCH LABORATORY

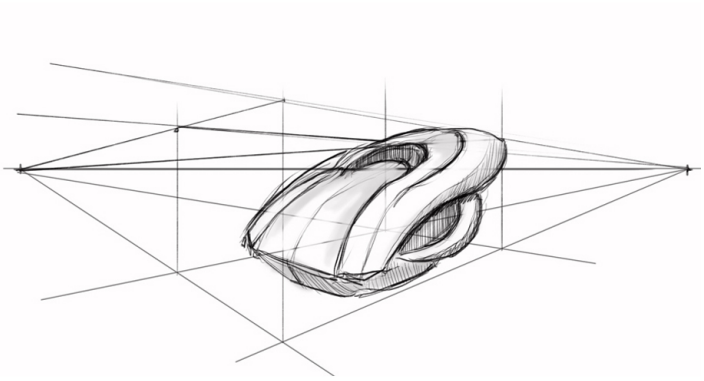




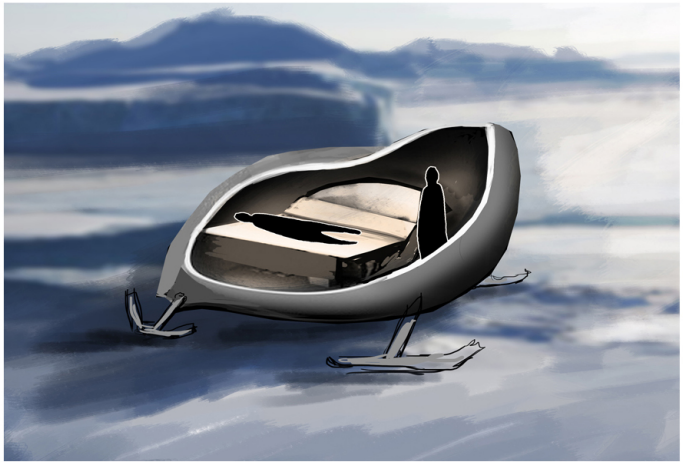


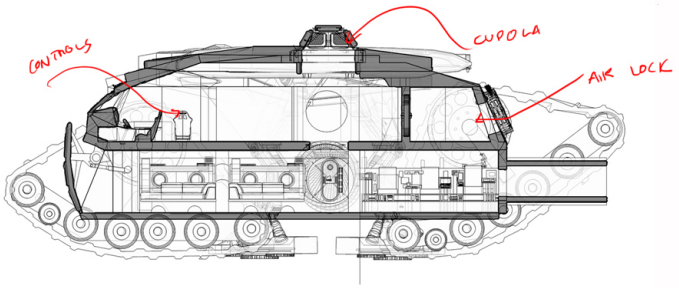


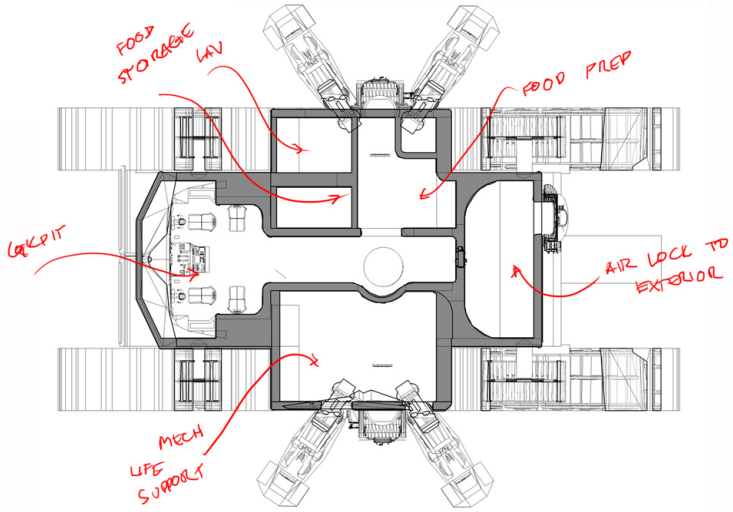


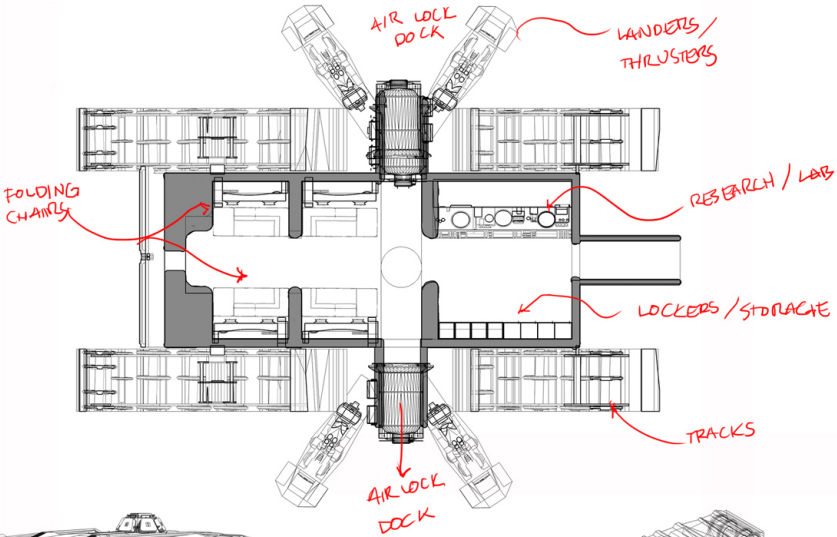


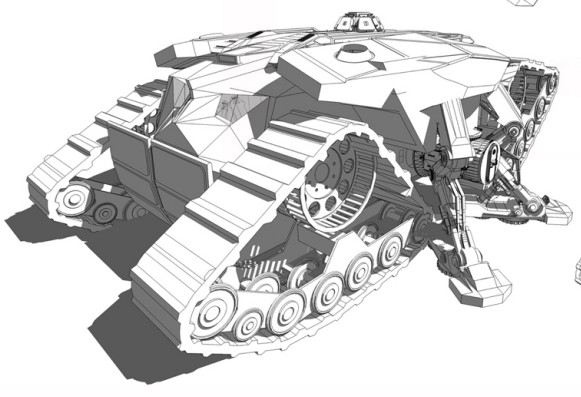


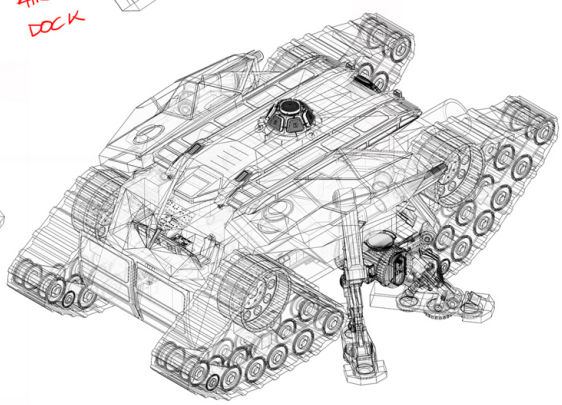



CONTROLS
CUPOLA
AIR LOCK


FOOD STORAGE
LAV
FOOD PREP
COCKPIT
AIR LOCK TO EXTERIOR
MECH LIFE SUPPORT

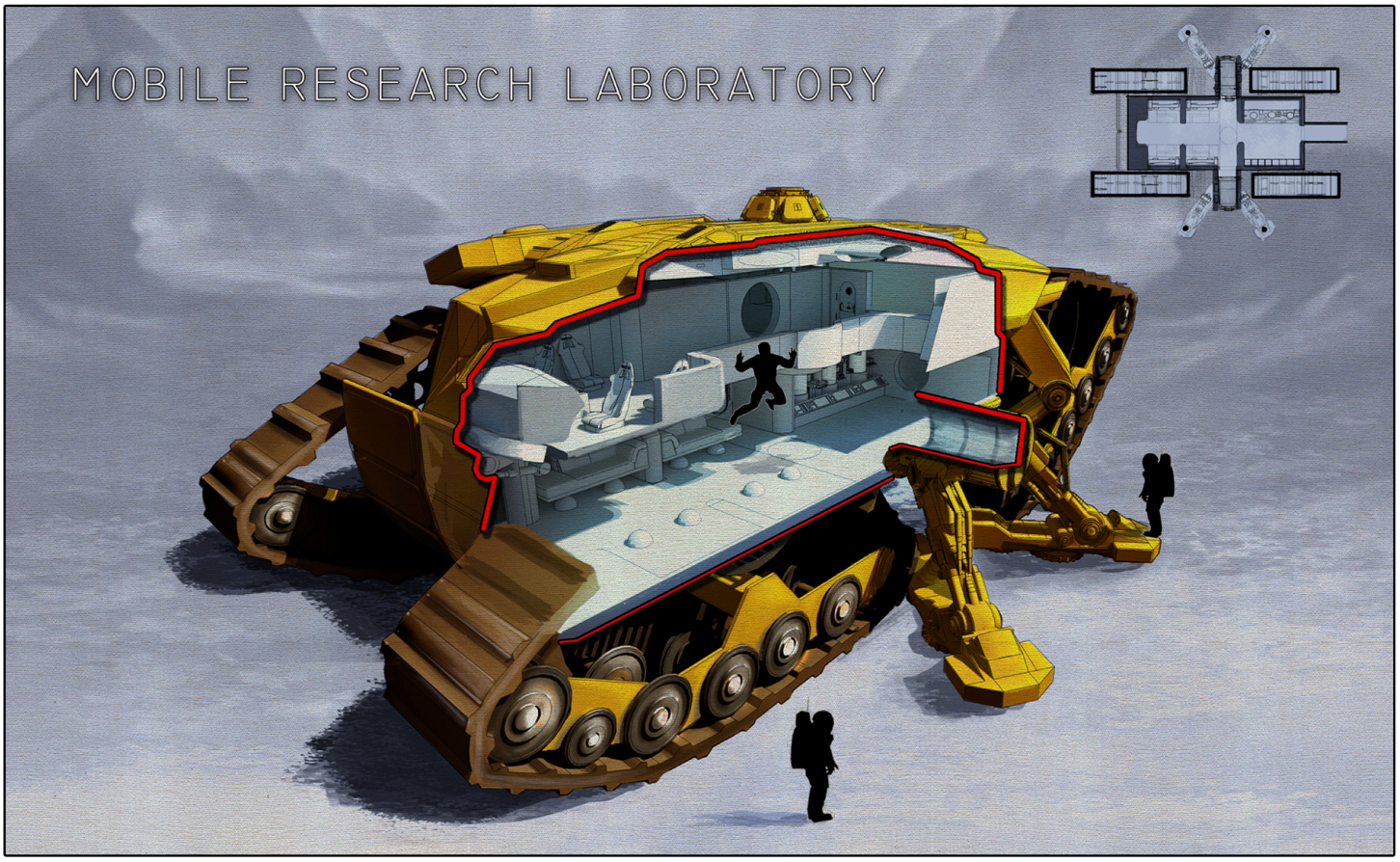

AIR LOCK DOCK
HANDLERS / THRUSTERS
FOLDING CHAIRS
RESEARCH / LAB
LOCKERS / STORAGE
TRACKS
AIR LOCK DOCK

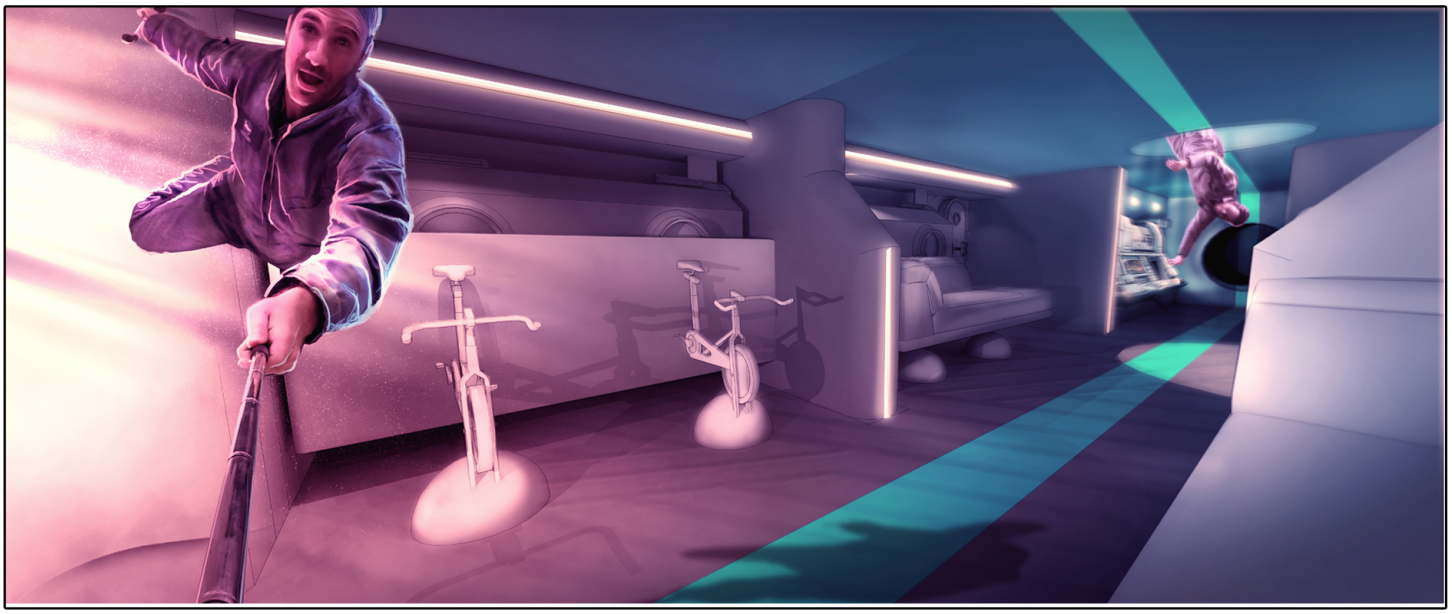




11

[M.R.L] CLASS 1 MOBILE RESEARCH LABORATORY









This book is the accumulation of a year and half of research, discovery, and process which seeks to provide inspiration for future designers, scientist, and engineers in hopes to add to the conversation of humans in extreme environments. As an ongoing side project, there will be components added which seek to design and envision the major components where the thesis leaves off. The space elevator, and the space station are vital for colonization of the asteroid belt. The next few years my goal will be to visualize and illustrate the long term colonization, in better hopes of understanding the needs both mechanically and in terms of the progression of humans in space.

For more information: www.kennylevick.com