

[62-492]

Mars Habitat:

BUILDING AN ATMOSPHERE

Tuesday 10:30-11:50 CFA 214
Friday 10:30-11:50 Hunt Basement

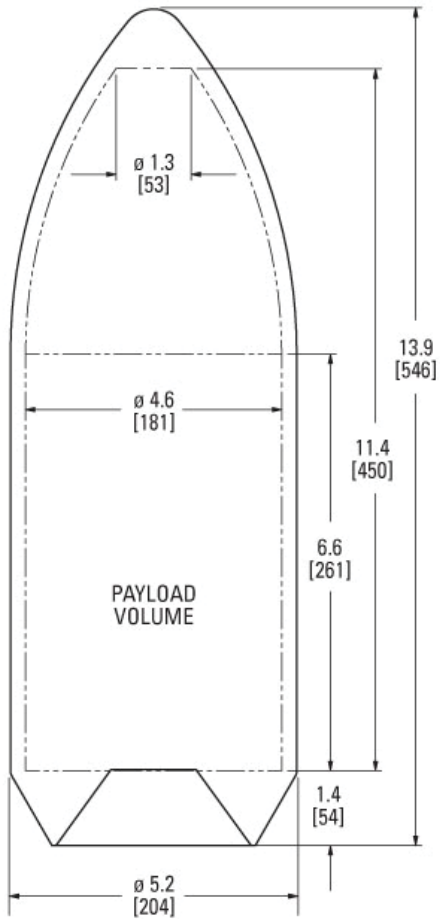
NASA projects a possible human presence on Mars as early as 2030s. Before such an event can happen, we must develop systems capable of sustaining life on the red planet, lightweight and small enough to make the journey and resilient enough to survive without help from home. Many agree that the first step towards proving we can create a sustainable habitat is to design one first for plants. Recognizing that this habitat may not only be a place to survive but thrive and be a beacon and remote connection to and for life on Earth, this design-build seminar challenges students from across campus, from science, engineering, art, and architecture, to come together to develop a concept for an inflatable or deployable habitat creating an atmosphere for Earth life on Mars.

This course challenges us to design an “air-tight” / “closed loop” / lightweight deployable or inflatable habitat to house plants on Mars, projected within technologies available in 20 years.

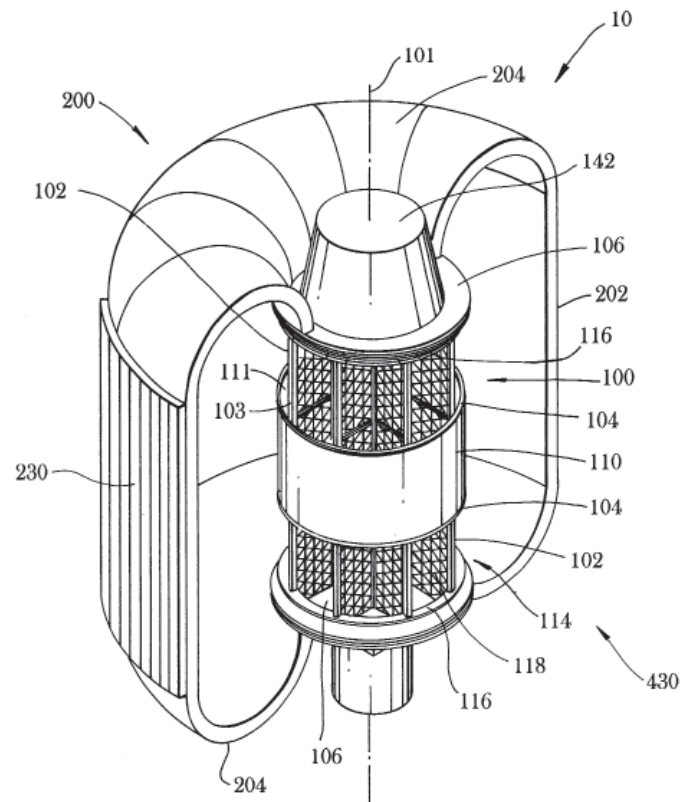
instructor: christina ciardullo / cciardul@andrew.cmu.edu
ann kalla visiting fellow 15-16 / carnegie mellon university school of architecture

This course is taught in collaboration with Responsive Mobile Environments [48-528]
instructor: Daragh Byrne, Intel Special Faculty, IDeATe Network / daraghb@andrew.cmu.edu

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Payload Fairing of a SpaceX Falcon Heavy



Deployable Schematic for NASA TransHab / Bigelow Aerospace B330

Background

Inflatable / Expandable Structures

Since the early 1960s, NASA has been studying the use of inflatable or expandable structures to design a habitat that is lightweight and compactable for launch, but voluminous for the vacuum of space and the near vacuum of the Martian environment. This design course will focus on membrane pressure vessels and investigate the physics, geometry, and systems components that may go into the design of an inflatable habitat for the Martian surface, capable of supporting a human atmosphere inside.



Goodyear/NASA 1961
"Advanced Man in Space – AMIS"
24 diameter inflatable torus



NASA TransHab 1990s
"Transit Habitat" for Mars
Rigid Core with
Cylindrical Inflatable



Bigelow B330
to dock with ISS 2016
Inflatable Sphere



image: Foster+Partners

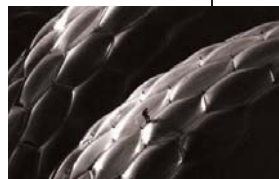
Sustained human
presence on Mars

1960

Frei Otto 1961
Soap Bubble Experiments
and Tensile Structures

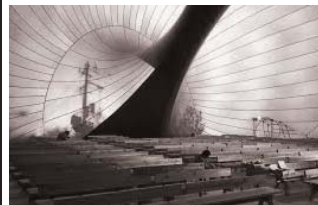


1990



Grimshaw Architects
Eden Project 2000

2010



Anish Kapoor 2013
Ark Nova
Inflatable Concert Hall

2050



Felix Candela 1972
Munich Olympic Stadium



Rem Koolhaas &
Cecil Balmond 2006
Serpentine Gallery

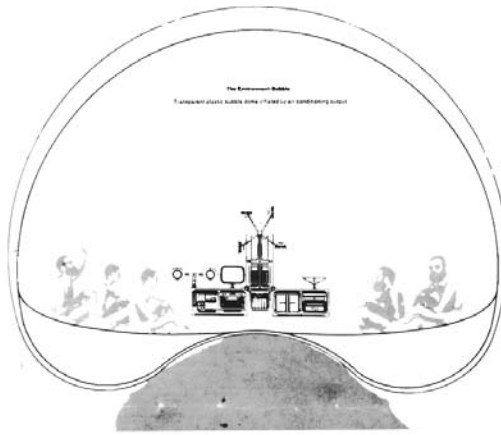
Lightweight inflatable and tensile structures were explored heavily in architecture and structural engineering beginning around the same time. With a very different approach, attitude, and constraints, the possibilities and potentials of these structures were explored to fantastical ends. **Somewhere between the imagination and testing of the design profession and the rigors of science and engineering, through the mutual goals of space exploration, is where we hope to position our investigations in this course.**

Background

Closed Environments



NASA Spacesuit, Shuttle 1981
Modified Air Force High Altitude Suit

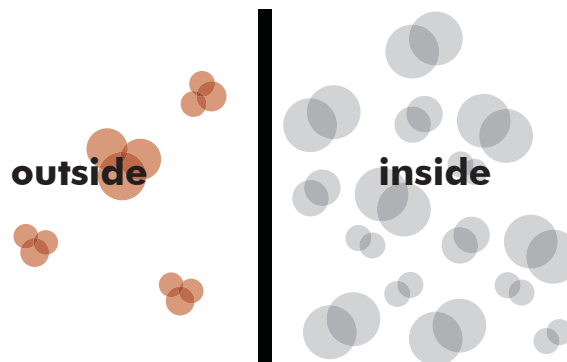


Reyner Banham, "The Environment Bubble."
A Home is Not a House, 1965



Buckminster Fuller, "Dome Over Manhattan"
Starting with the Universe, 1960.

For architects the idea of enclosure is an investigation into the physical material space of the boundary between “inside” and “outside.” While on earth, this boundary can be fluid, porous, and sometimes not exist physically at all, in space the environmental conditions of our body and the vacuum dictate there must always be some material medium at the pressure differential; a material which holds pressure on our bodies, whether that is a suit, a habitat, or a dome over an entire city. While long term ideas might include the physical transformation of the Martian atmosphere by physio-chemical means, in the short term future, we must rely on that material medium. But it’s form, organization, and material and structural characteristics will determine much about how we will be able to live, interact, and work in space or on the surface of another planetary body without it’s own atmosphere.

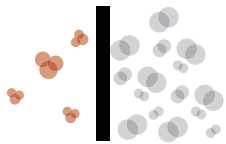
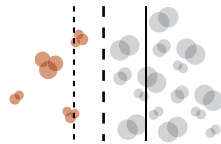
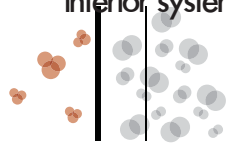
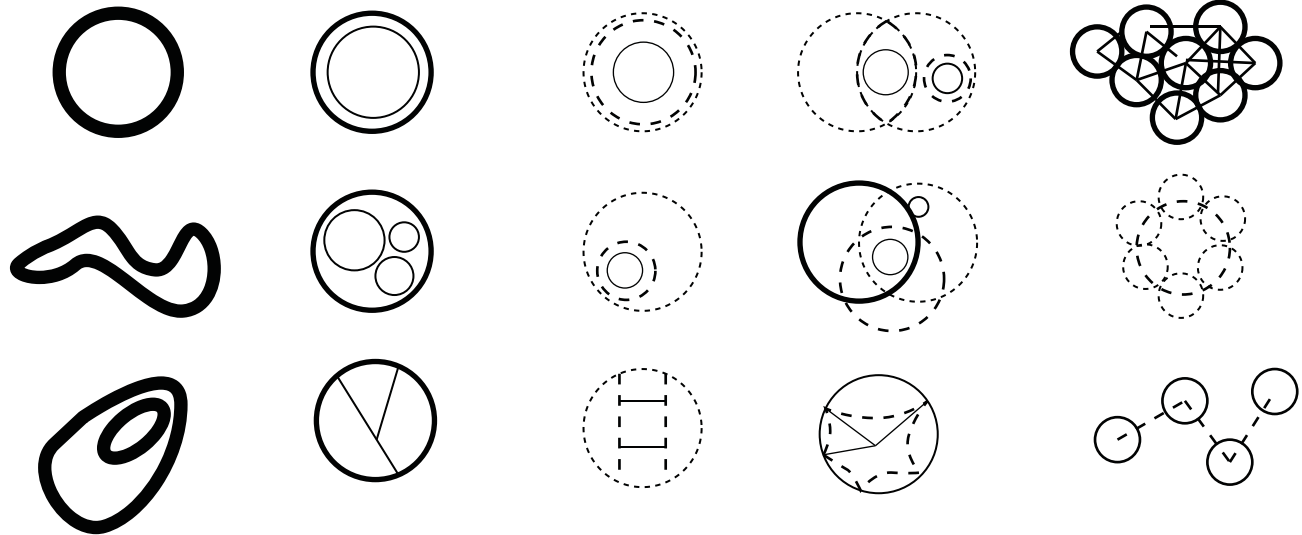


Background

Investigation/Premise

This material boundary between two atmospheres in studies to date is often embodied in one encompassing layer. Our interest is in how we can manipulate, and even delaminate that boundary through **geometry**, **material properties**, **interior systems**, and **exterior networks**, so that even in a place which requires an envelope we can try to achieve some integration with the environment and explore the possibilities and potentials of tension and inflatable structures.

membrane geometry

membrane functions and
interior systemsexterior networks and
systems integration

We will research the Martian environment and respond to **energy**, **water**, **wind**, **solar radiation** (both visible light and harmful higher energy waves). Through identifying physical functionalities of the envelope from pressure considerations to systems considerations for the interior, as well as an understanding of the project in both a compacted and expanded formal state, we can begin to further breakdown what an inflatable structure might look like, always testing geometry and structure through analytic tools and analogue physical mockups.

Objectives

As an interdisciplinary team we will investigate the “building of an atmosphere” using NASA’s identified interest in inflatable technologies. Through the use of a flexible, deployable, expandable membrane structure we will investigate potential materials, geometries, structures, networks, and interior systems. By putting together designers, engineers, and scientists we can hope to achieve something quite unique.

Together we will **explore**, **design**, and **create** a full scale prototype for potential application to a Mars surface habitat which demonstrates

- inflatable/expandable architecture
- a closed loop plant growth system
- a place that can be shared remotely with people on Earth

Additionally we be **speculating**, and **documenting** the potentials, difficulties, and rewards of an interdisciplinary design approach.

Learning Outcomes

This course, open to students of design and architecture, engineering, and sciences is a unique experiment to work together on a concept design for a Mars inflatable habitat. For students in the sciences and engineering, this course offers an opportunity for students to use their skills in the create design process, to design, test, and fabricate their own unique creations in a new setting: to take a principle, derive their own unique idea, and create it. For students of architecture and design, this course offers the inspiration and rigor of the sciences and engineering against which to test ideas. For both, it introduces them to different pedagogical approaches to learning and to the skills and intelligence of other disciplines, and challenges them to find ways to work together towards the successful execution of a mutual goal. We will learn

- to learn from, teach, and communicate with eachother about your discipline
- to develop an understanding of tension structures and pressure vessels
- to develop an understanding of Mars design conditions and precedent research
- work with both architecture and engineering design tools
- skills in fabrication
- how to execute a successful built project

Expectations / Grading

- Students are expected to be exploratory, creative, and imaginative.
- Students are expected to be independent minded and develop designs based on their self-driven research and interests in the Martian environment, fabrication, and design systems.
- Students are expected to test, to fail, and test again. Design is iterative. Keep making.
- Students are expected to contribute and share knowledge and skills from their own disciplines in collaboration with other students, to teach eachother as much as learn.
- Groups are expected to work together creating work as a synthesis of all disciplines
- Groups are expected to work together towards the fulfillment of a collective final design solution.

Final Grade:

Assignment 1	10%
Assignment 2A	10%
Assignment 2B	10%
Assignment 2C	10%
Assignment 3	10%
Final Deliverables	50%

Each of these assignments will be evaluated based roughly on the following criteria:

Project Creative Merit (50%)

Competency/Skills	20%
Takes Risks	20%
Solves Problem	20%
Thinks Innovatively	20%
Connects/Synthesizes	20%

Individual Effort (50%)

Leadership/Teamwork	40%
Individual Contribution to Deliverables	40%
Participation	20%

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Methods

systems teams

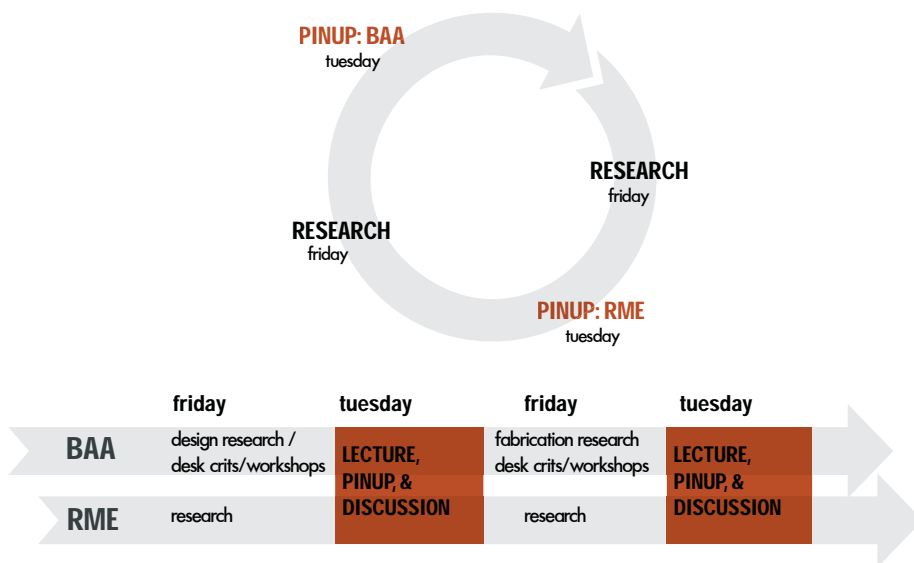
energy

water

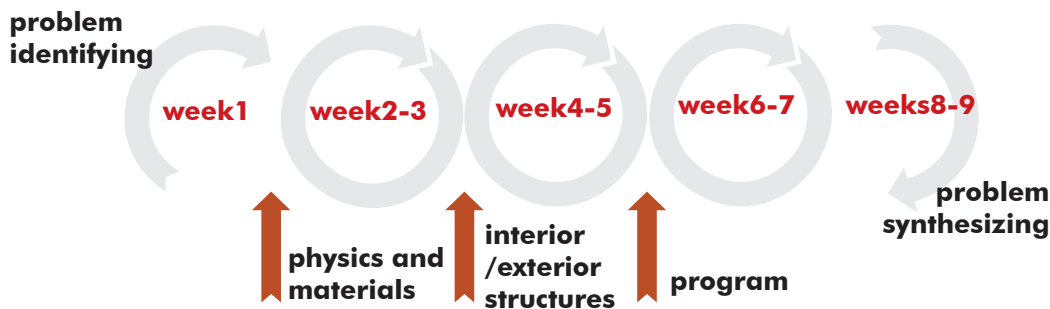
solar

wind

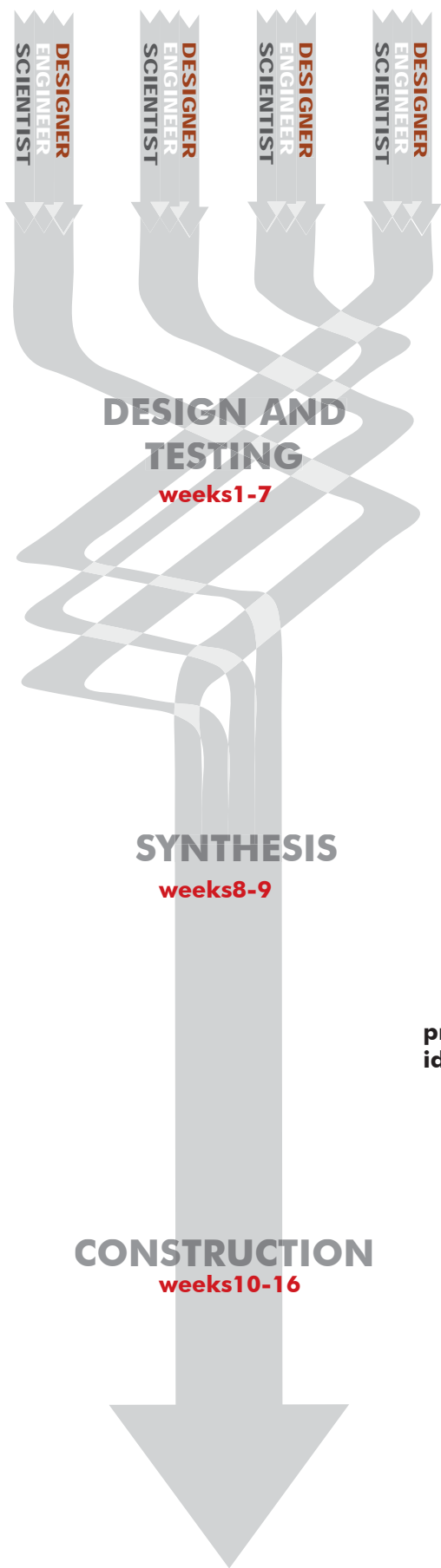
This course will capitalize on the unique strengths of each discipline to come together to produce a novel solution. Groups of interdisciplinary students will work together in small groups to investigate through design, analysis, and fabrication. While all teams will deal with pressure vessels, each interdisciplinary team will be tasked to additionally research and respond to a particular Martian environmental condition as they test their designs.



The class will be held in parallel to an IDEATE physical computing class. We will meet together once a week for lecture and to share ideas for eventual integration into the physical structure.



We will follow a two week cycle of design/analysis and prototype fabrication. In interdisciplinary teams, making will inform design and design will continually be iterated. Beginning with the basic physics of atmosphere, mars, and the space environment, every two weeks we will introduce a variable to integrate into the design, each iteration building on each other, leading towards an eventual design synthesis of all design team ideas into one full scale proposal.



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Course Schedule

1	T 1/12	Introductions
	F 1/15	[Lecture] Space Stations / Tension Structures
2	T 1/19	[Discussion] The Challenge of Mars
	F 1/22	[Workshop] Grasshopper
3	T 1/26	[PINUP 2A] Pressure Vessels
	F 1/29	[Lecture] Air Tight: TransHab&NASA Inflatables
4	T 2/2	[Lecture] Sensing Plants [PINUP: RME]
	F 2/5	[Workshop] ANSYS
5	T 2/9	[Lecture] Dynamic Membranes [PINUP 2B]
	F 2/12	Desk Crits + Fabrication
6	T 2/16	[Lecture] Closed Loop Systems [PINUP: RME]
	F 2/19	Desk Crits + MechETA
7	T 2/23	[Lecture] Space at CMU [PINUP 2C] Systems
	F 2/26	Desk Crits + ArchTA
8	T 3/1	[Lecture] Poetics in Space [PINUP: RME]
	F 3/4	Collective Review

9	T 3/15	[Lecture] Seeing like a Rover
	F 3/18	Synthesis: 3 Options

10	T 3/22	
	F 3/25	Synthesis:1 Option

11	T 3/29	Coordination
	F 4/1	

12	T 4/5	Coordination
	F 4/8	

13	T 4/12	Coordination
	F 4/15	[SOFT OPENING] Carnival

14	T 4/19	
	F 4/22	

15	T 4/26	
	F 4/29	

16	T 5/3	
	F 5/5	

Guests

D.Turnshek, M. Wood-Vasey
(arch TA)

I.Oppenheimer, R.Heard
K.Kennedy/NASA (remote)

Sprouts IO, G.Kantor
(mechE TA)

C.Madiji, YL Park
R.Tursky

L.Poulet/ESA (remote)
(mechE TA)

J.Apt, S.Lee, D.Wettergreen
(arch TA)

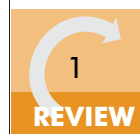
D.Goods, L.Burgess

J.Vertesi

CMU Interdisciplinary Panel

NASA Guest Critics

Combined



REVIEW

REVIEW

MIDREVIEW

SOFT OPEN

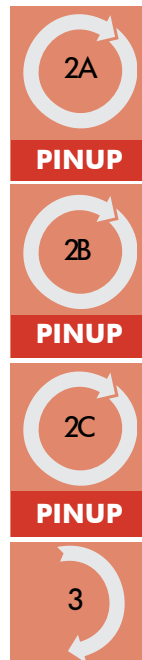
FINAL

ALTERNATE

RME



BAA



PINUP

CONSTRUCTION



Assignment 1

Each team will take on one of the following systems:

Sunlight and Radiation

Protection from Mars: Wind, Dust, CO₂ frost

Protection of Mars: Redundancy, Containment

Energy

Water Sourcing and Circulation

In your teams, begin to research the Mars conditions pertinent to your system. Discuss and identify the questions/problems that your system will need to address and how these conditions will affect plant occupants and human remote interaction. Consider the conditions in Assignment 2, and what other questions you seek to answer throughout the semester. We will revisit these questions in week 8.

Some issues might include:

scale of habitat

pressure differential

rate of plant oxygen respiration/production

artificial v natural light for plant growth

scale, type, and number of plants

redundancy

relationship of habitat to earth

Print or Write these questions out on post-its / cards / pieces of paper. On Tuesday Jan 15 we will share these questions with each other, narrow, and identify which are necessary for further exploration, and separate into project teams with particular focus.



Assignment 2

Over the course of the next six weeks, you will iteratively:

research the environmental conditions of Mars

design an appropriate geometric and material response to those conditions

analyze your geometry with physics and engineering tools

document your design incorporating documentation tools from all the disciplines

prototype a physical mockup of your geometry

Your design must meet the following constraints:

- an air tight envelope capable of handling pressure differential
- a collapsible structure fitting inside the payload of the SLS/Falcon Heavy
- considers both plant occupants and human remote interaction
- demonstrates the capacity of your geometry to respond to a Mars environmental condition within the system your team is investigating

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week2-3

[2A] Pressure Vessels & Material Experimentation

- Begin to research the Martian environment related to your system
- Experiment with variable density liquids and air in alternative materials to develop unique geometries derived from basic physics and material principles
- Incorporate Grasshopper Physics tools to help your documentation
- Each group member develop a documentation language and start to see how your documentation languages start to overlap or can be combined
- Experiment with the creation of a physical representation of your geometry

F 1/15 Intro to Pressure Vessels

T 1/19 Research Discussion

F 1/22 Workshop in Grasshopper
& Physics Simulation

T 1/23 PINUP



week4-5

[2B] Interior Partitions & Exterior Connections

- Continue to research the conditions of the Martian environment related to your system
- Incorporate ANSYS tools to help your documentation
- Consider programmatic developments being suggested by RME
- Taking these conditions into consideration develop a system creating interior layers, documenting each layer's performative function. Is there any benefit to having multiple layers?
- Think of a method of connecting multiple geometries to each other and what kind of docking systems you can imagine, for what purpose. Is there any benefit to creating multiple v. one?
- Develop physical construction techniques

F 1/29 "Air Tight" Remote Lecture

T 2/2 Research Discussion RME

F 2/5 Workshop in ANSYS

T 2/9 PINUP



week6-7

[2C] Program, Form & Network

- Begin to combine your research and geometric solutions. Where are the overlaps? Synergies?
- Incorporate programmatic functions being developed by RME
- Continue to develop Physical Construction techniques
- Make a physical representation of your geometry

F 2/12 Group Crit

T 2/16 Research Discussion RME

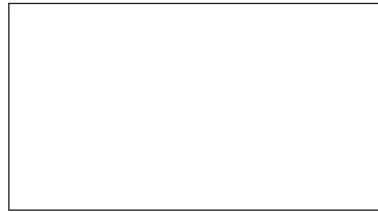
F 2/19 Desk Crit / MechE TA

T 2/23 PINUP

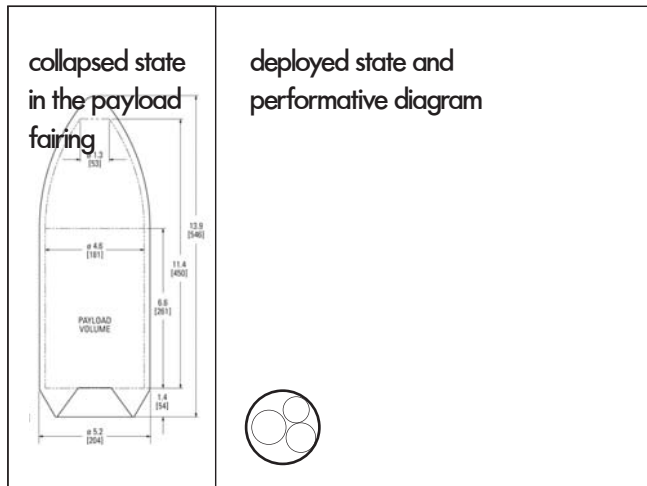
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Deliverables

These documents will not be new each time, but rather evolutionary documents that are built upon and revised with each iteration.

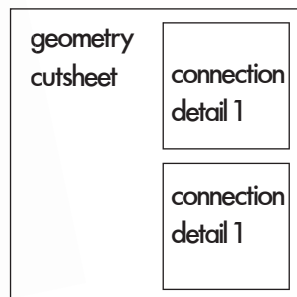
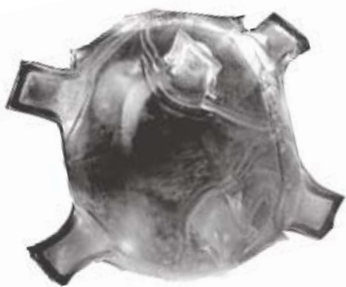


Digital Presentation on the Martian conditions you are investigating and responding to



36 X 48 Panel documenting your geometry

- MUST include a combined method of documentation from each discipline including properties of physics, material, and environmental factors
- MUST describe/diagram its performative properties as per your system question
- MUST include the object in both the collapsed and inflated state
- MUST indicate the pressure boundary and network diagram



Physical Prototype representing your geometry

and supporting documentation of the physical prototype, including:

- construction details
- inflatable cutsheet



Assignment 3

week8 In a week long charette, four teams will combine into two. These teams will develop, combine, and incorporate ideas and geometries from the other project working towards the development of a combined, synthesized project, incorporating ideas from RME.

week9 Following the break, two teams will combine into one. This team will development of a combined, synthesized project, incorporating ideas from RME.

Deliverables will follow the same format at the previous assignments.

Construction

You will have most of the second half of the semester to construct the prototype. The organization of schedules, build time, and delegation of tasks will be accomplished by the student team.

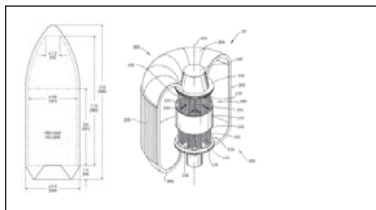
Material Orders must be placed one week in advance of their need.

Deliverables



Full Scale Physical Prototype that

- represents the geometry of the design for Mars
- a collapsible structure fitting inside the payload of the SLS/Falcon Heavy
- sustains plant occupants
- does not require exterior power sources



Digital Presentation

- demonstrates how the design geometry responds to Martian conditions
- demonstrates the design in both collapsed and expanded form
- includes construction details and cut sheets
- places this project within the history of space habitats/vehicle design
- explains the significance of this design in both space exploration and human interaction on Earth
- describes the process

supporting interdisciplinary faculty

ideate (physical computing)	Daragh Byrne
mechanical engineering	Paul Steif
civil engineering	Irving Oppenheim
field robotics	David Wettergreen
field robotics/agriculture	George Kantor
SOFT robotics / mech.engineering	Carmel Majidi
SOFT robotics	Yong-Lae Park
materials science	Robert Heard
moon arts	Lowry Burgess
physics	Diane Turnshek
planetary sciences	Michael Wood-Vasey (UPitt)
astronaut	Jay Apt (Tepper School)
science and humanities scholars	William Alba

software, facilities, and fabrication support

architecture fabrication lab	Richard Tursky	
IDeATe fabrication lab	Zach Ali	
grasshopper support	Jeffrey Montes (architect)	space@jetportal.net
ansys support	Karthik Chandrashekaraiah	kc1@andrew.cmu.edu
architecture TA (your "go to")	Amy Rosen	amr@andrew.cmu.edu

supporting guests

Space Architecture	Brent Sherwood, NASA JPL
Inflatables & Space Architecture	Kriss Kennedy, NASA JSC
NASA Artist in Residence	Dan Goods, NASA JPL
NASA Director of Partnerships	Gary Martin, NASA Ames
Planetary Sciences	NASA Glenn
Representative	SpaceX
MELLISSA (closed loop systems)	Lucie Poulet, DLR
SproutsIO (hydroponics)	Kamal and Jennifer Farah, SproutsIO

extracurricular activities

The class will have continuous interaction with students in the IDEATE course. We will also share some overlap with architecture students designing for long term habitation. We will schedule space movie nights and an observation night open to the university to encourage dialogue and overlap between all those interested in the advancement of space. The architecture school will also host a panel discussion with leaders in the field. While attendance is not mandatory, these activities are meant to support and enhance your education.