

# Create a **Concept Architecture**

M.Thangavelu

Department of Astronautical Engineering  
and The School of Architecture

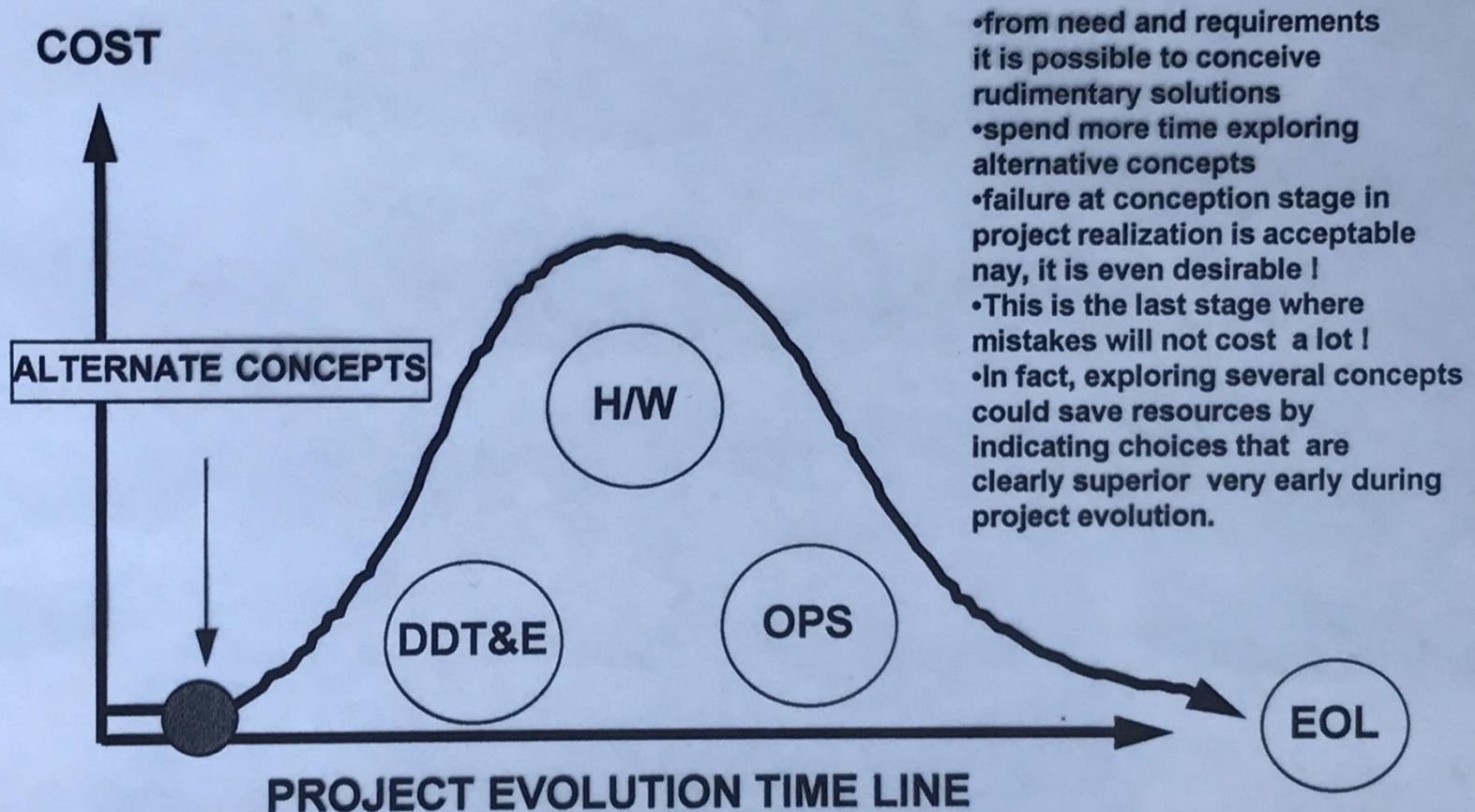
ASTE527

**What it is not about**

# What it is not About

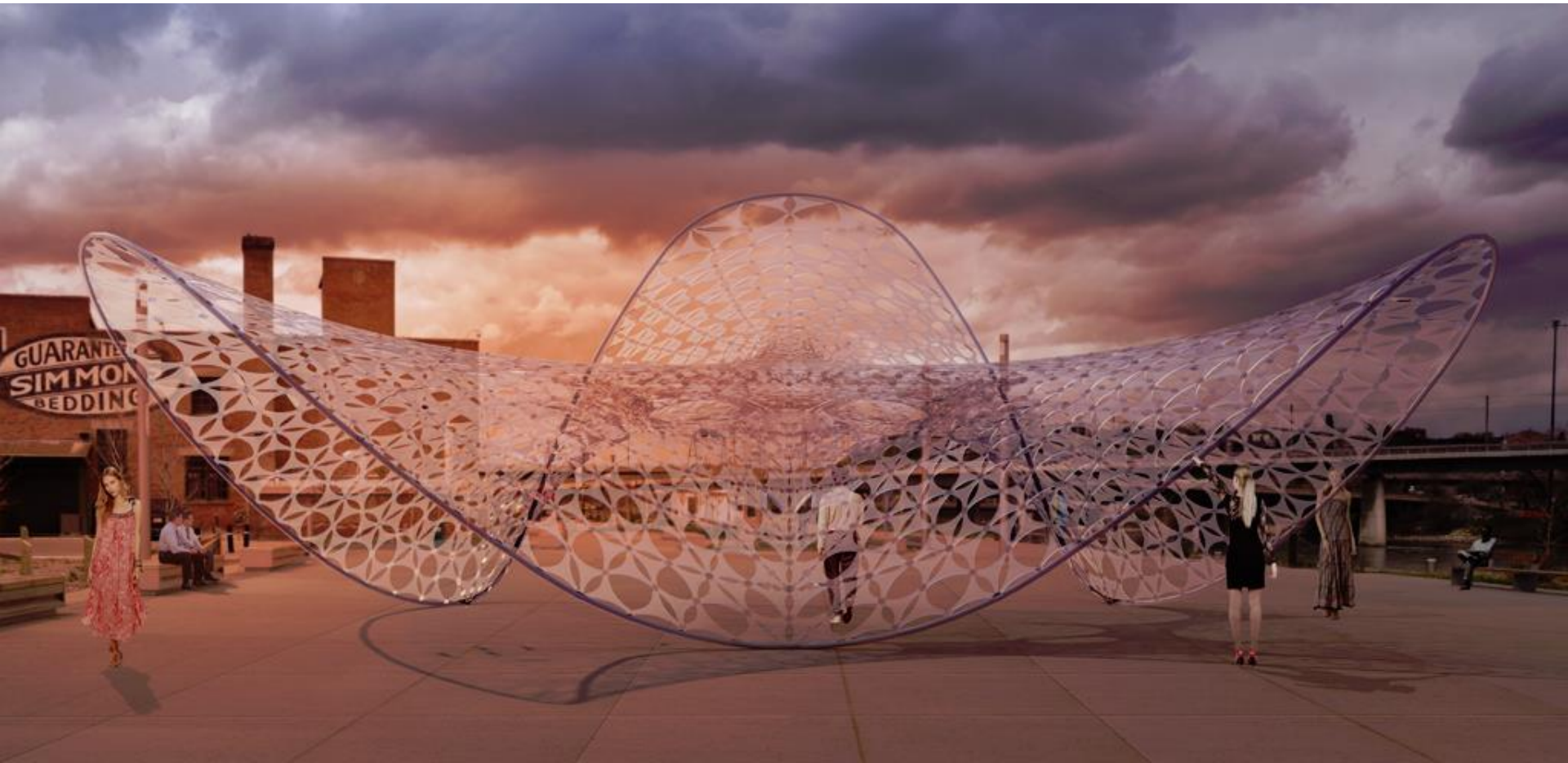
- SysML
- Model Based Systems Engineering
- IPPD
- Object Oriented Programming

## ALTERNATE CONCEPT GENERATION IS FASTER, CHEAPER, BETTER

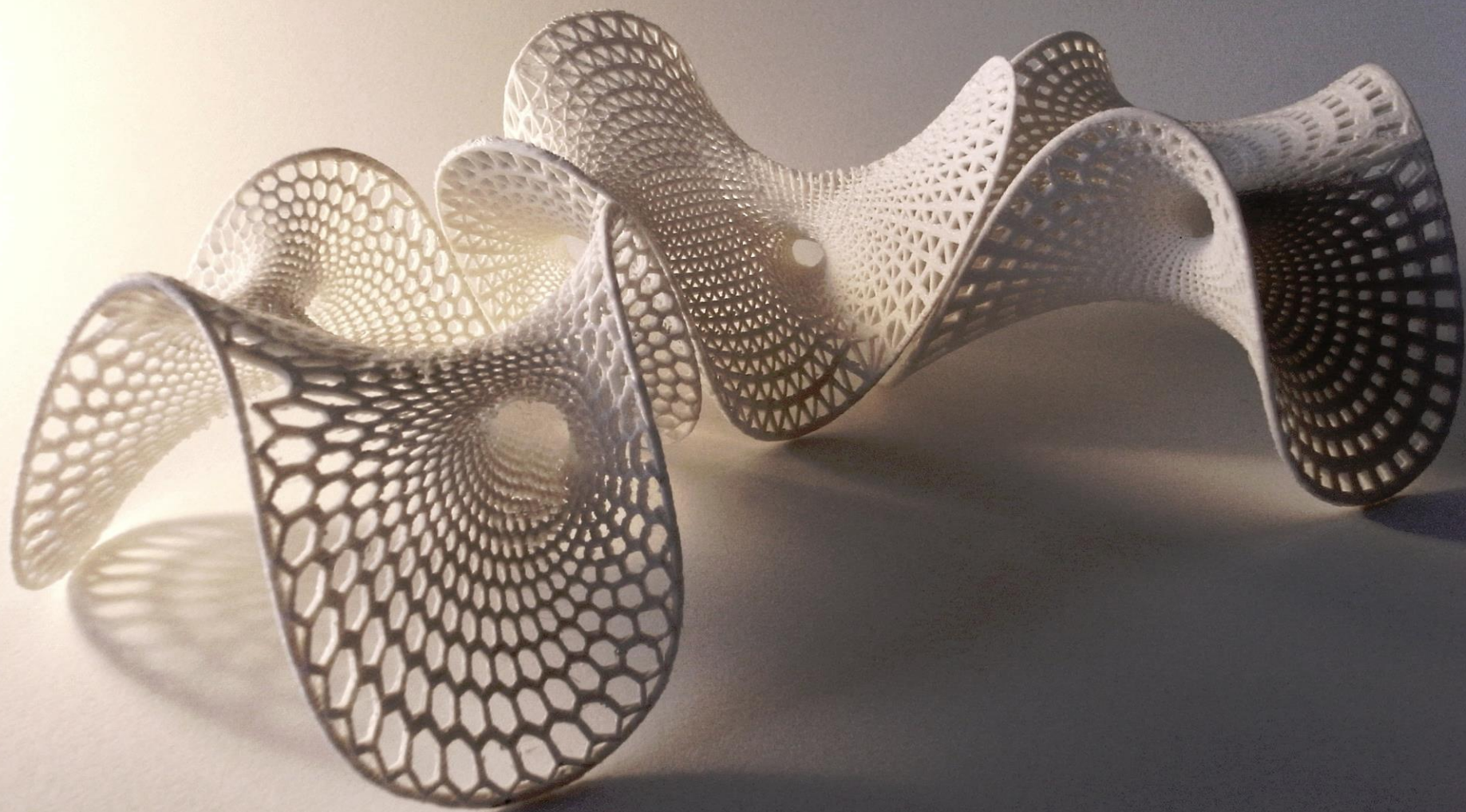




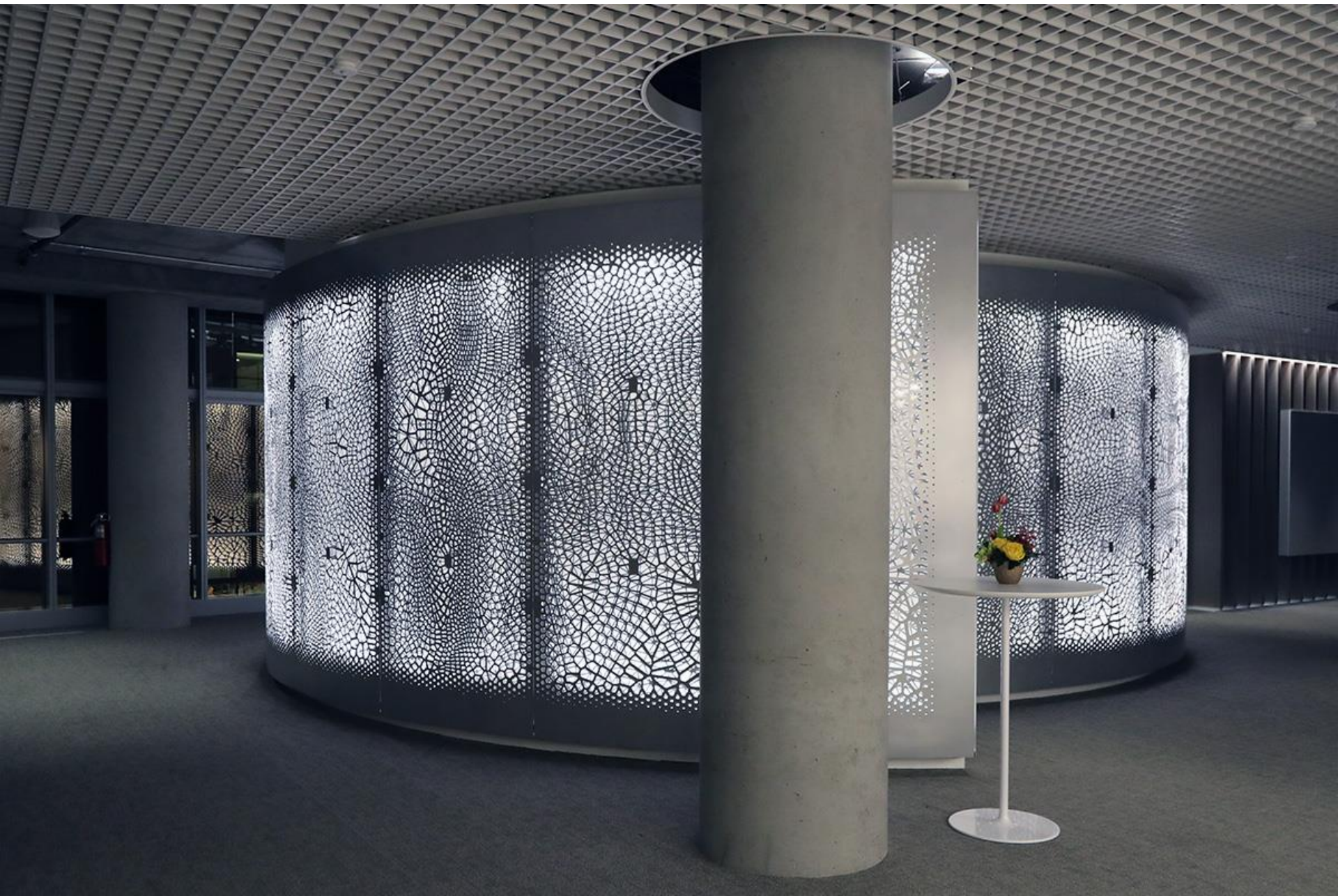




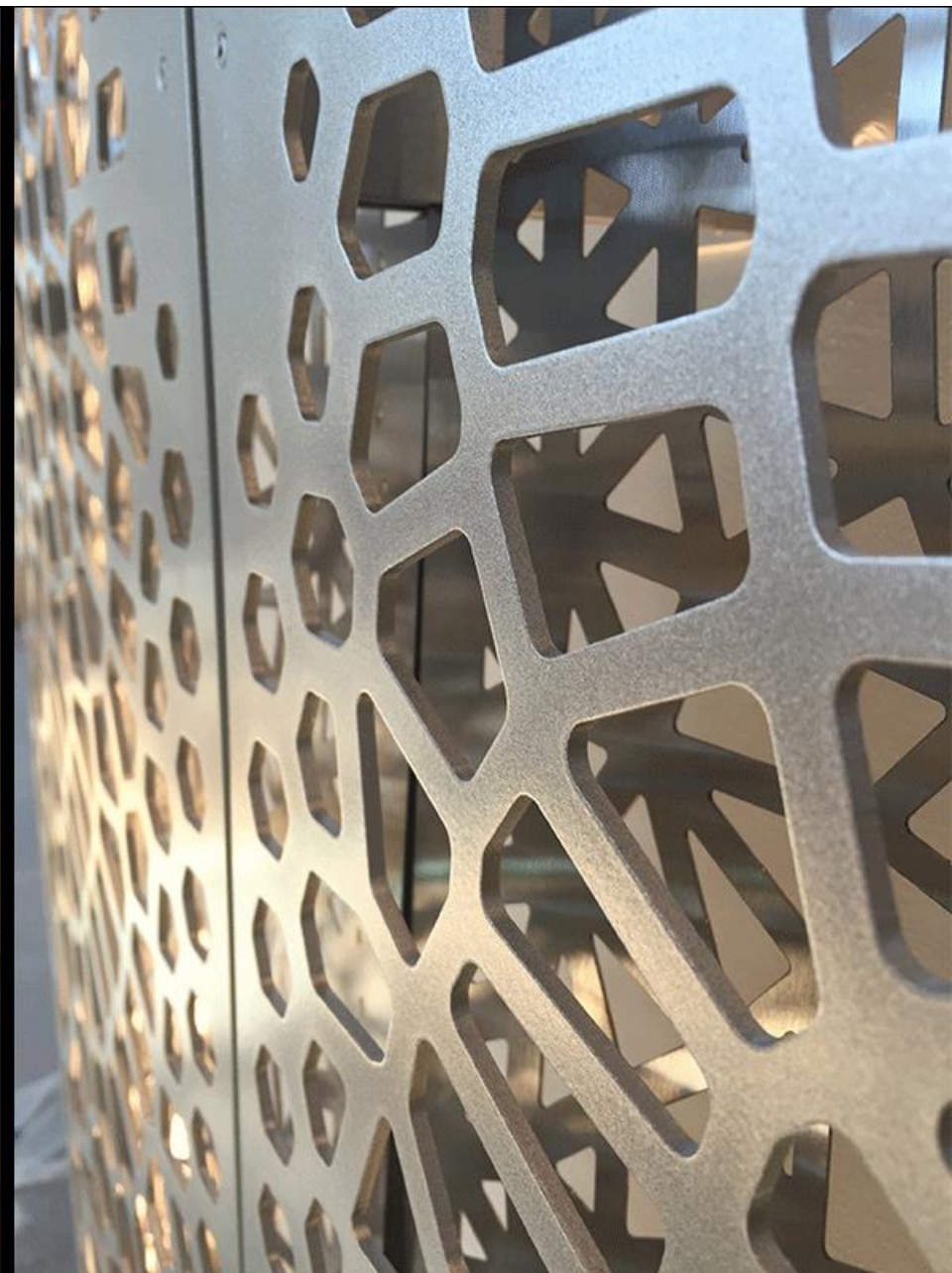














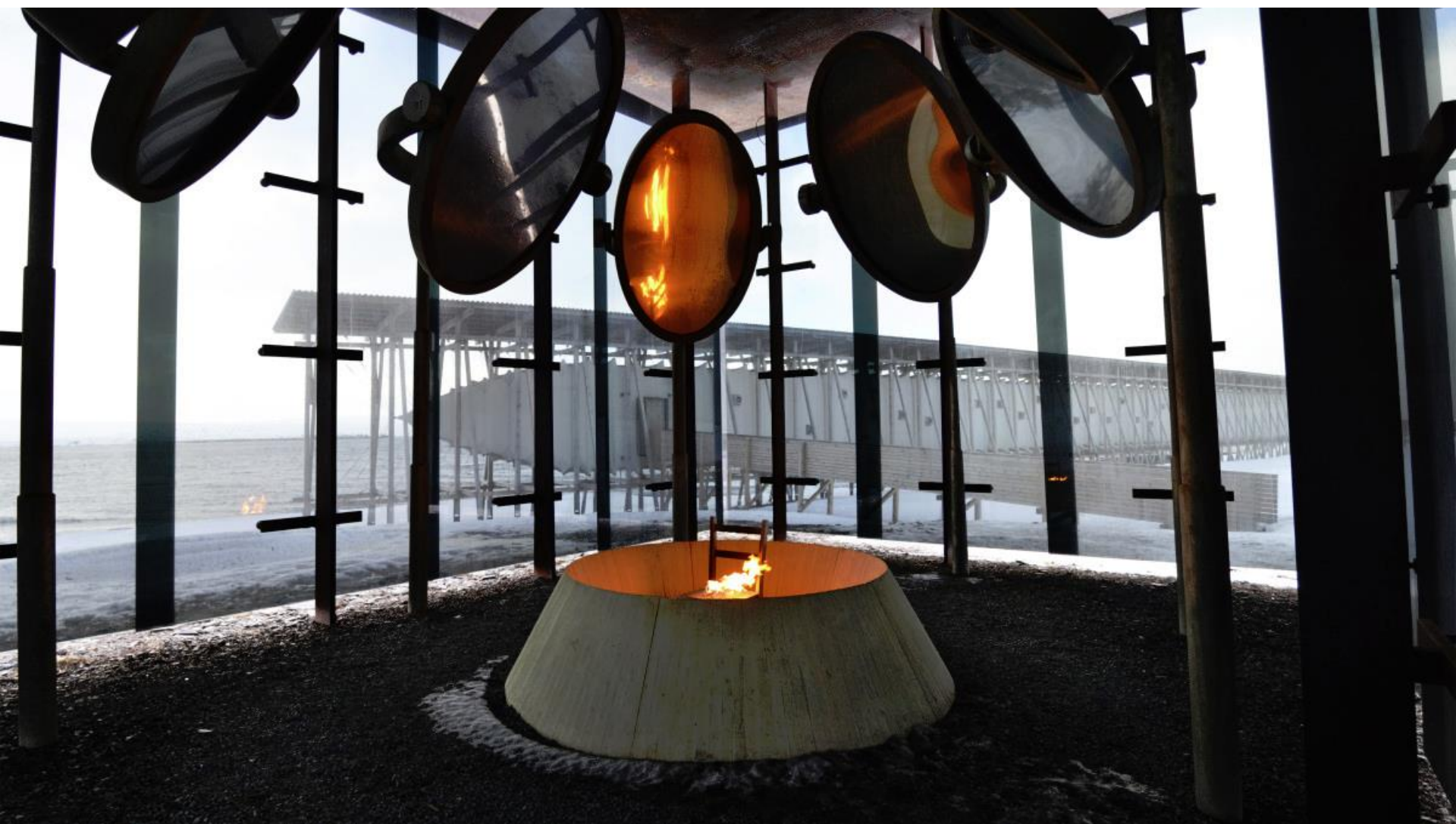












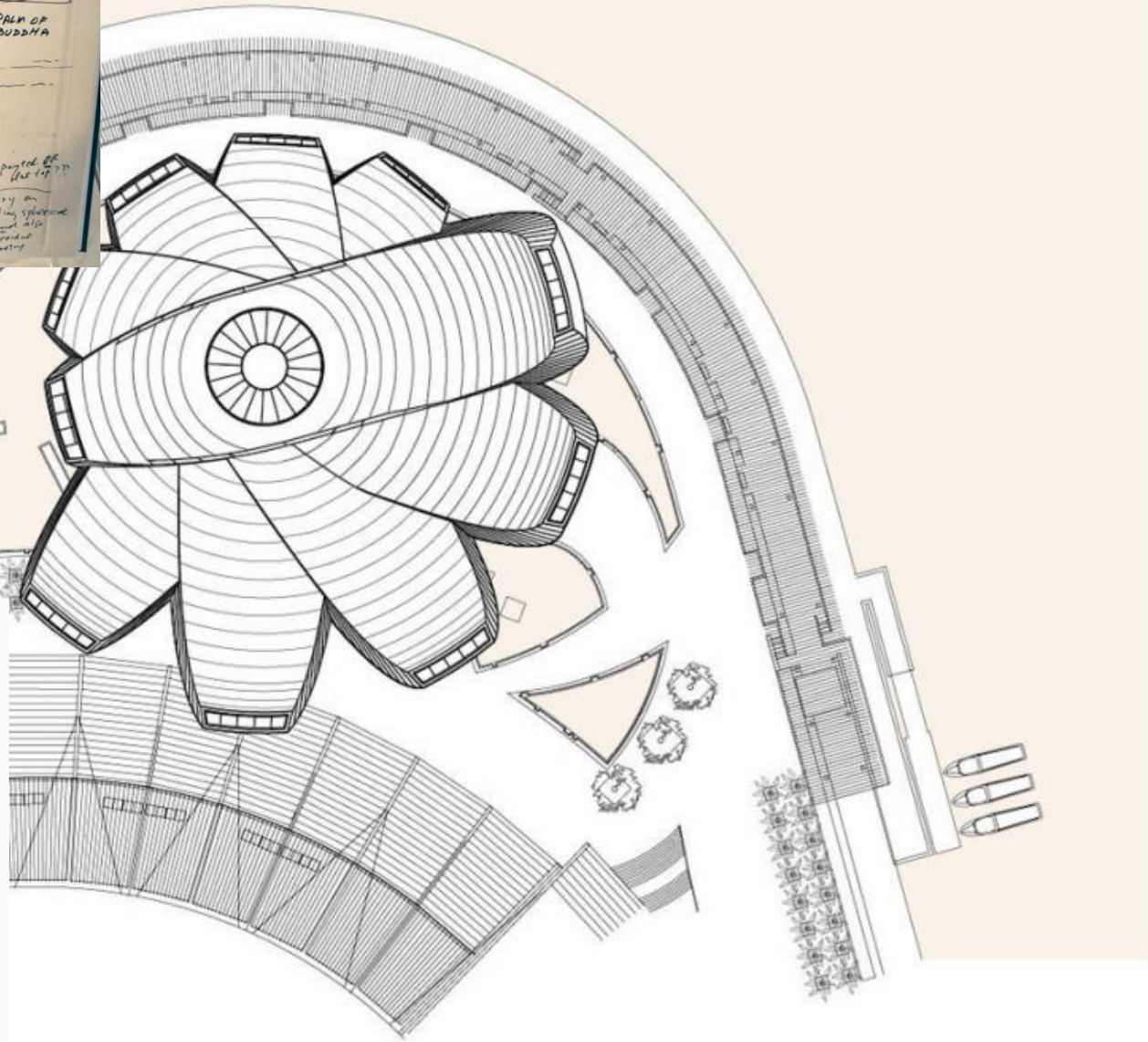
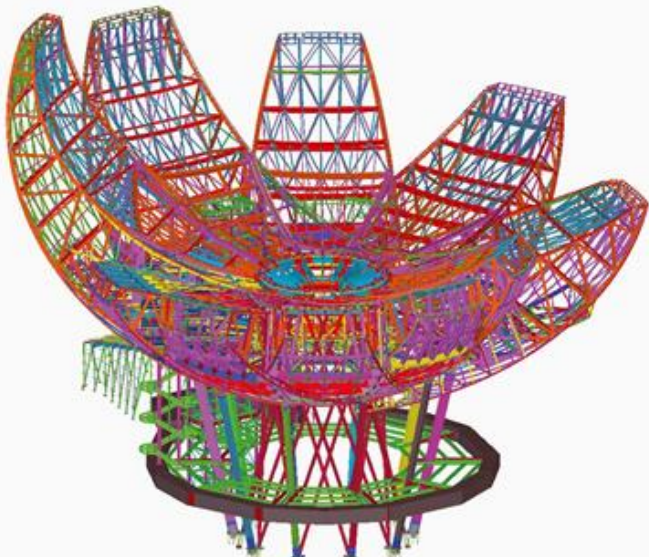
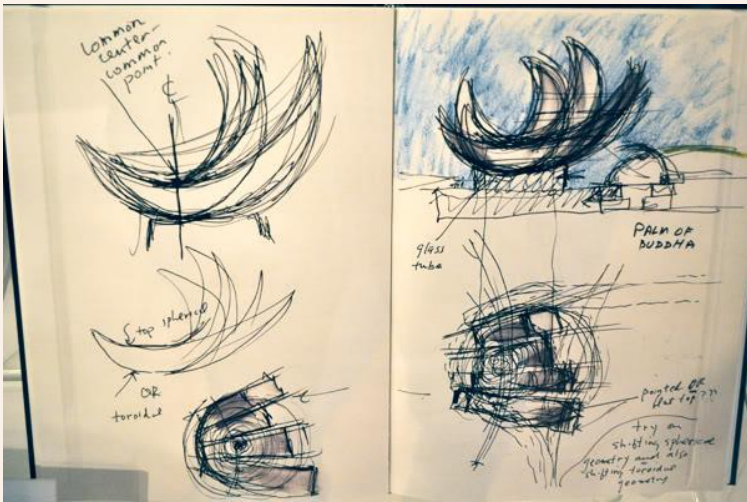






# Louise Bourgeois Fillette – Peter Zumthor













Civil Architects Imagine and Create 'em  
Darn'dest...thingys !



# Paul Saffo on Thought Classification

- **Druids and Engineers**
- There are two kinds of fools: one who says this is old and therefore good, and the other who says this is new and therefore better. The argument between the two is as old as humanity itself, but technology's relentless exponential advance has made the divide deeper and more contentious than ever. My greatest fear is that this divide will frustrate the sensible application of technological innovation in the service of solving humankind's greatest challenges.
- The two camps forming this divide need a name, and "Druids" and "Engineers" will do. Druids argue that we must slow down and reverse the damage and disruption wrought by two centuries of industrialization. "Engineers" advocate the opposite: we can overcome our current problems only with the heroic application of technological innovation. Druids argue for a return to the past, Engineers urge us to flee into the future.



# Leo Tolstoy on Mind – A Confession 1882

- To this one question, variously expressed, I sought an answer in science. And I found that in relation to that question all human knowledge is divided as it were into two opposite hemispheres at the ends of which are two poles: the one a negative and the other a positive; but that neither at the one nor the other pole is there an answer to life's questions. The one series of sciences seems not to recognize the question, but replies clearly and exactly to its own independent questions: that is the series of experimental sciences, and at the extreme end of it stands **mathematics**. The other series of sciences recognizes the question, but does not answer it; that is the series of abstract sciences, and at the extreme end of it stands **metaphysics**.
- “See that you remember”. And I awoke.

# Claude Shannon

---

# Richard Feynman

What I cannot create,  
I do not understand.

Know how to solve every  
problem that has been solved

Why const  $\times$   $\log$   $\text{PC}$

TO LEARN:

Bethe Ansatz Probs.

Kondo  $\rightarrow$

2-D Hall

accel. Temp

Non linear classical Hydro

$$(A) f = U(r, a)$$

$$g = 4(r \cdot z) U(r, z)$$

$$(B) f = 2|k \cdot a| (u \cdot a)$$

What it **IS** about

**Create  
A  
Concept**

# Scope

- ASTE527 History
- Course Purpose
- Concept Creation Principles
- Examples
- ASTE 527 Site :  
<https://sites.google.com/a/usc.edu/aste527/home>

# **ASTE527- Space Exploration Architectures Concept Synthesis Studio**

## **A Bit of History**

- Eb Rechtin SAE Program at USC 1988
- MALEO thesis Example
- Curriculum Development – Arch + Engg
- AE to AME to Architecture to ASTE
- ASTE Department offers a 3 unit elective

# ASTE 527 Goal

- Brainstorming for ideas
- Out-of-the-Box thinking
- Synthetic thinking v Analytical
- Bringing together to create something useful
- Art more than Science
- Creativity
- Imagination



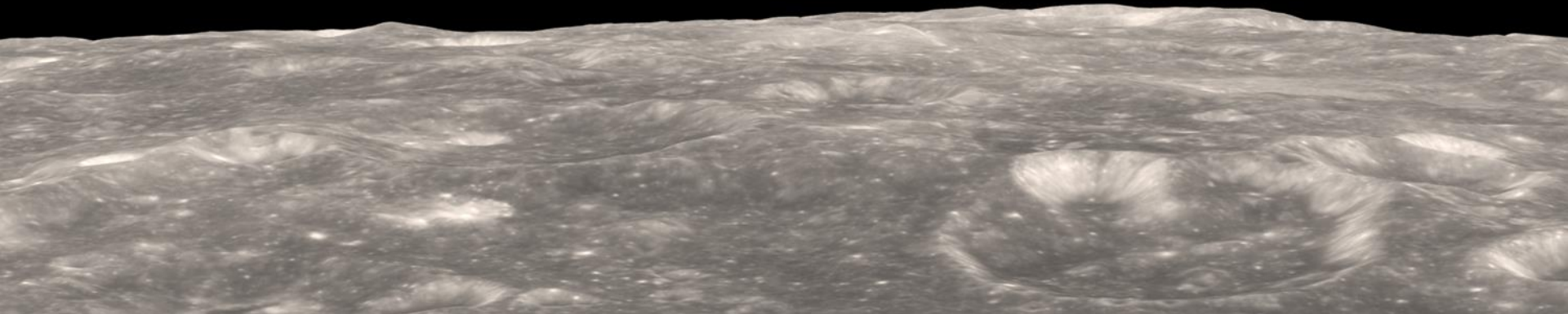
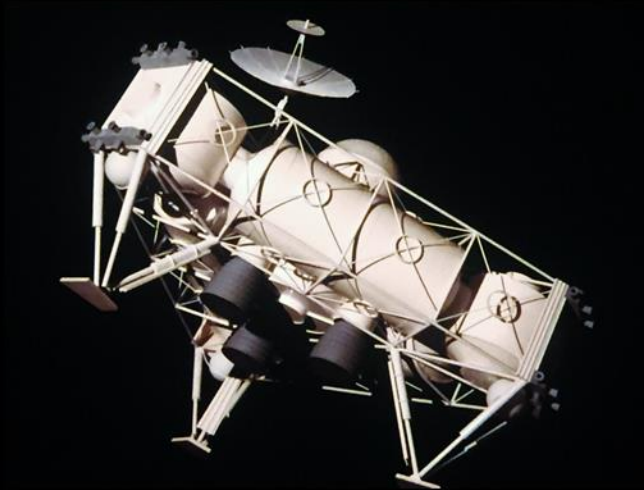
# Creative Processes

- Darwinian Evolutionary Process
- Random Walk
- Recursive
- Monte Carlo Method
- Julia & Mandelbrot sets
- Markoff Chain
- **Iowa Writers Workshop – be inquisitive, inclusive**
- Learn by “Pranging”

# ASTE 527 Examples

- MALEO
- NOMAD Explorer
- Lunar Cyclor - MOBIUS
- Lunar SuperComputer
- 3D Food for Space Missions
- Planetary Defense Moon
- ISS Commerce - Orbiting Hotels
- Lunar Agriculture
- SARA
- MOBIUS

# Module Assembly in LEO(MALEO)

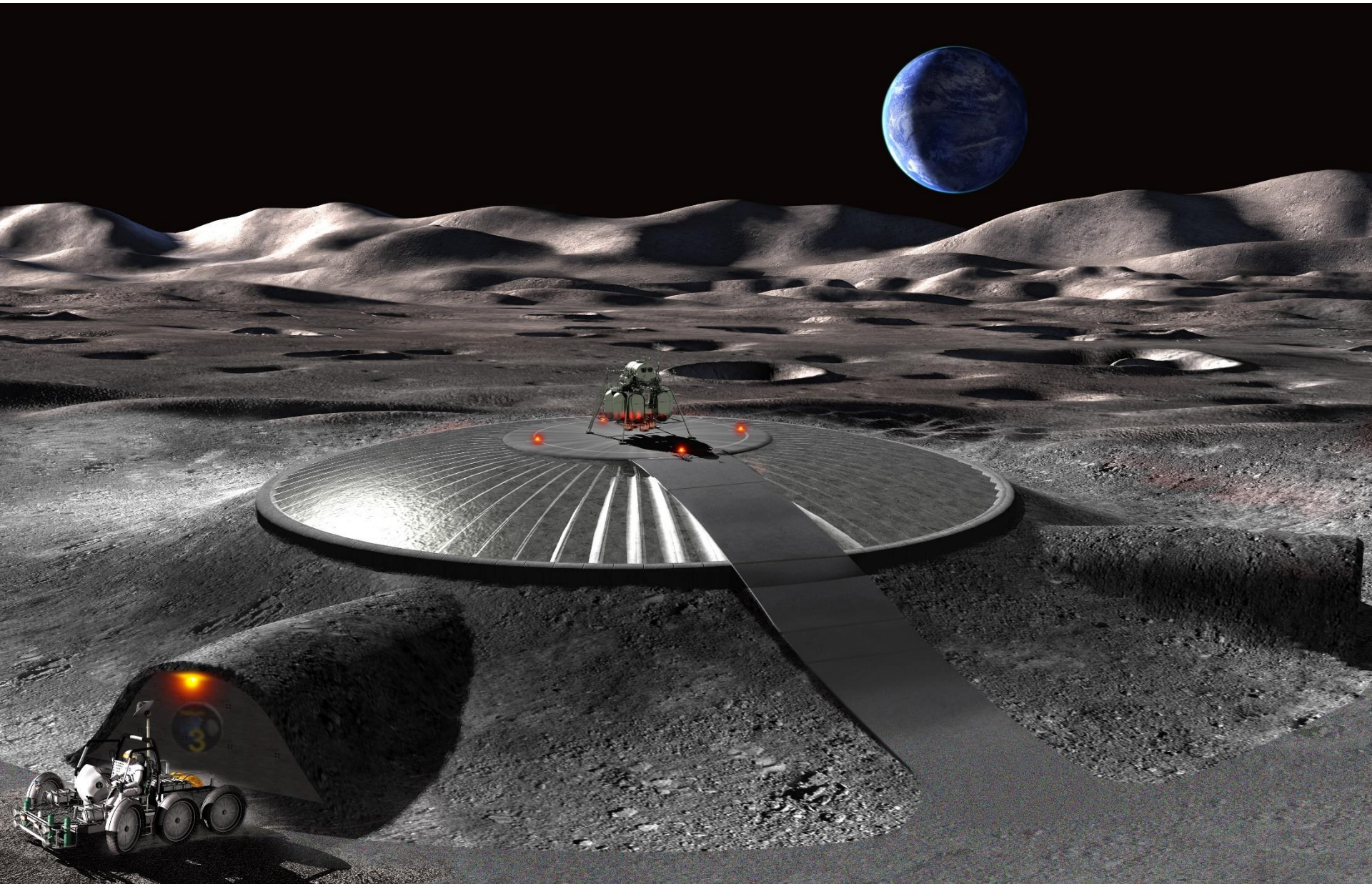


# NOMAD Explorer II



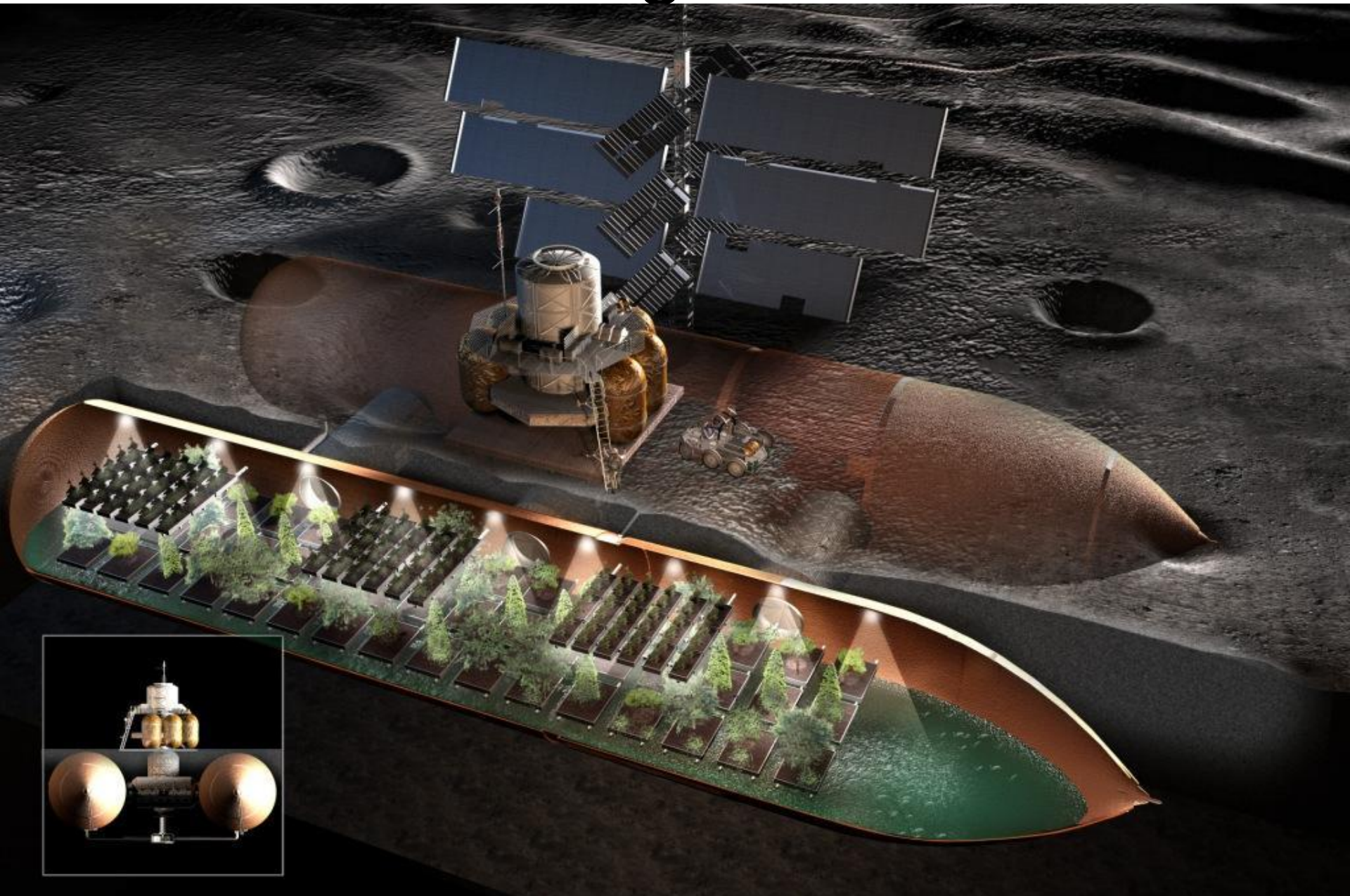


# Lunar South Polar Landing Pad



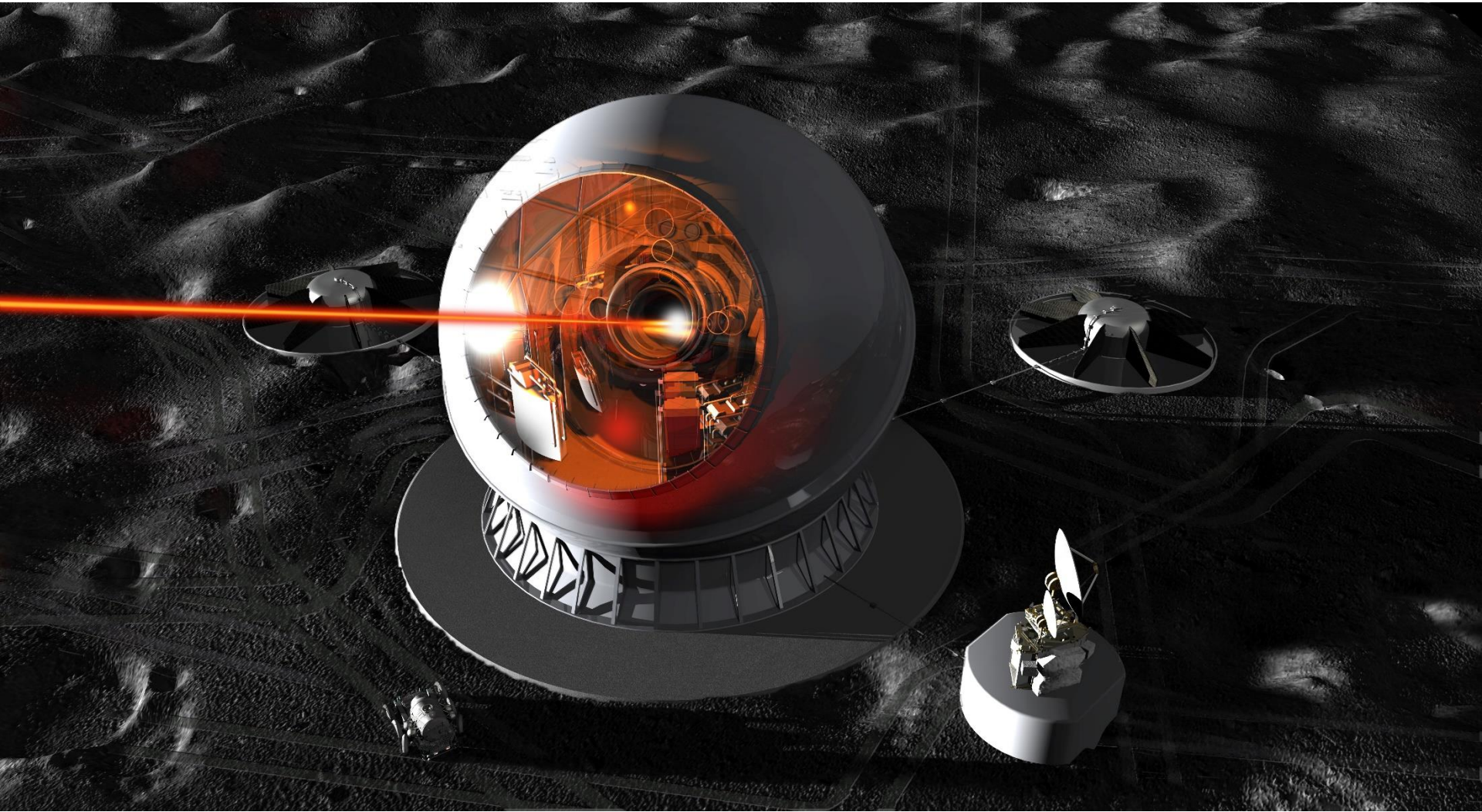


# Lunar Agriculture

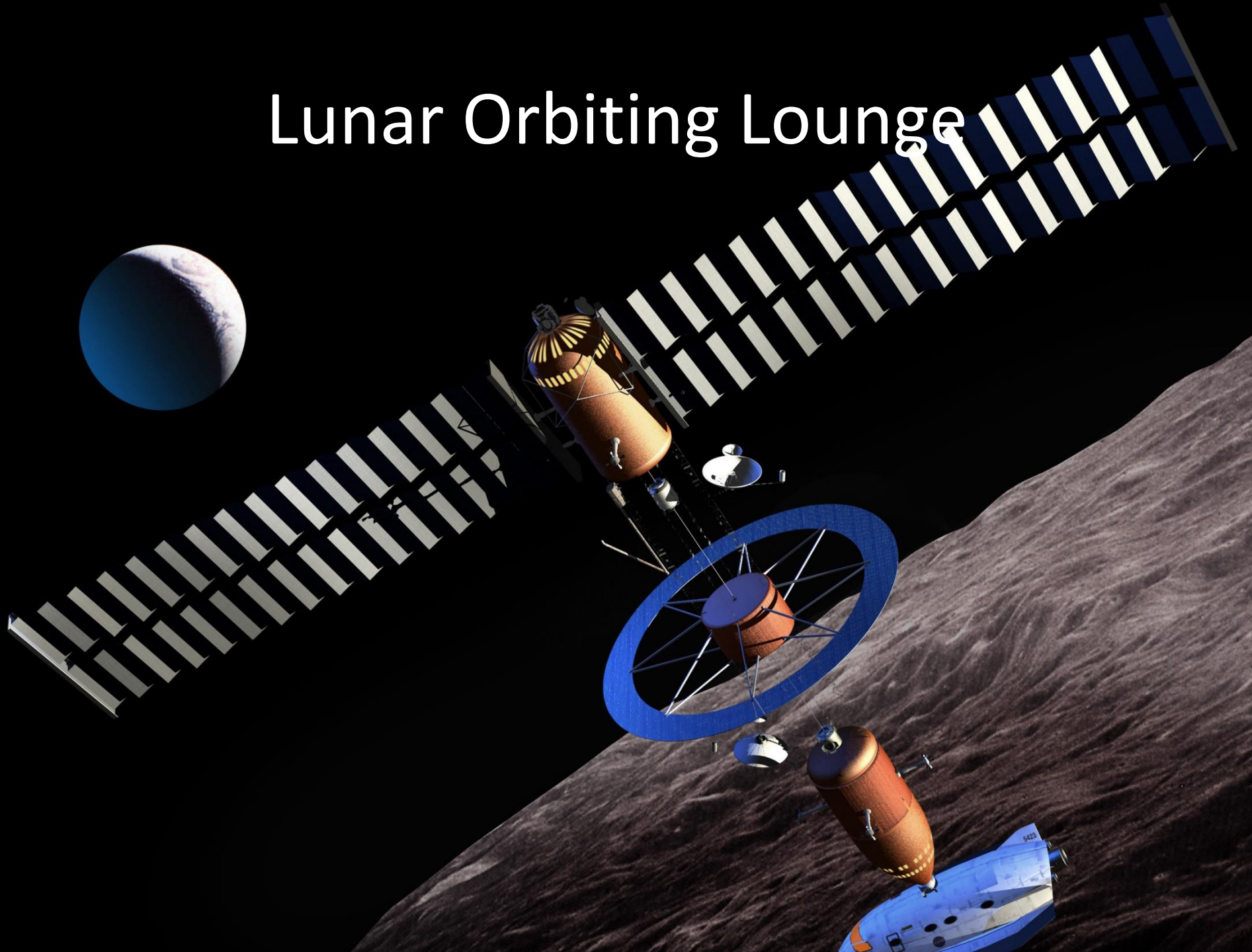




# Planetary Defense from our Moon

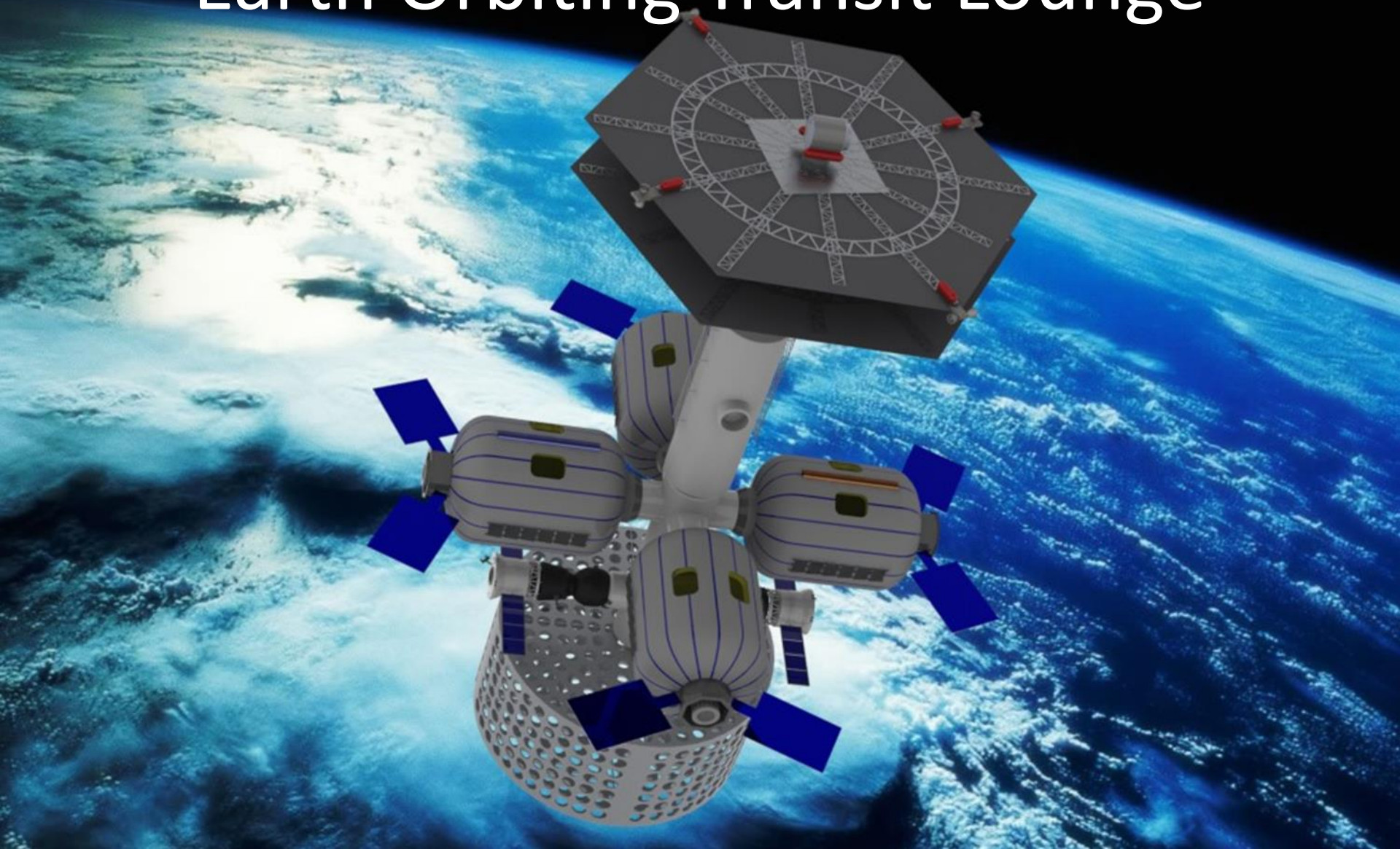


# Lunar Orbiting Lounge





# Earth Orbiting Transit Lounge



# Lunar SuperComputer





# 3D Food for Space Missions



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ASTE527

# **Why Concept Creation ?**

- **One of the important tasks of the System Architect**
  - **Providing alternative choices to the client**
  - **In a timely manner**
  - **Back office IR&D**
- **Choices allow planners to plan, pick and choose between options in a dynamic environment**
- **Biggest Blunders are Made on First Day**

**Unleash  
Imagination**

# Constraints

- Every tool, every process constrains or dictates human imagination
- Computers, software and user interfaces(top level architectures) all conspire to channel and restrain creativity in specific ways.
- How to unleash human imagination ?
- Human mind, free of tools, is the ...
- Ultimate Imagination Machine

# Operating Domain

- **Need**
- **Imagination**
- **Creativity**
- **Innovation**
- **Knowledge**

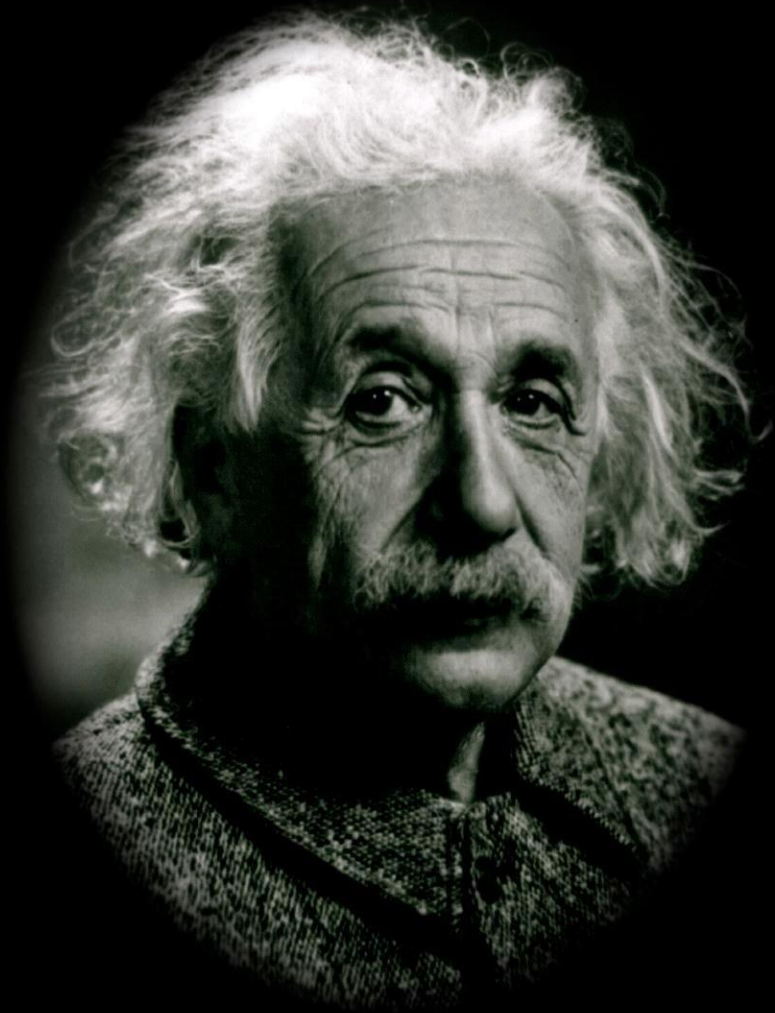


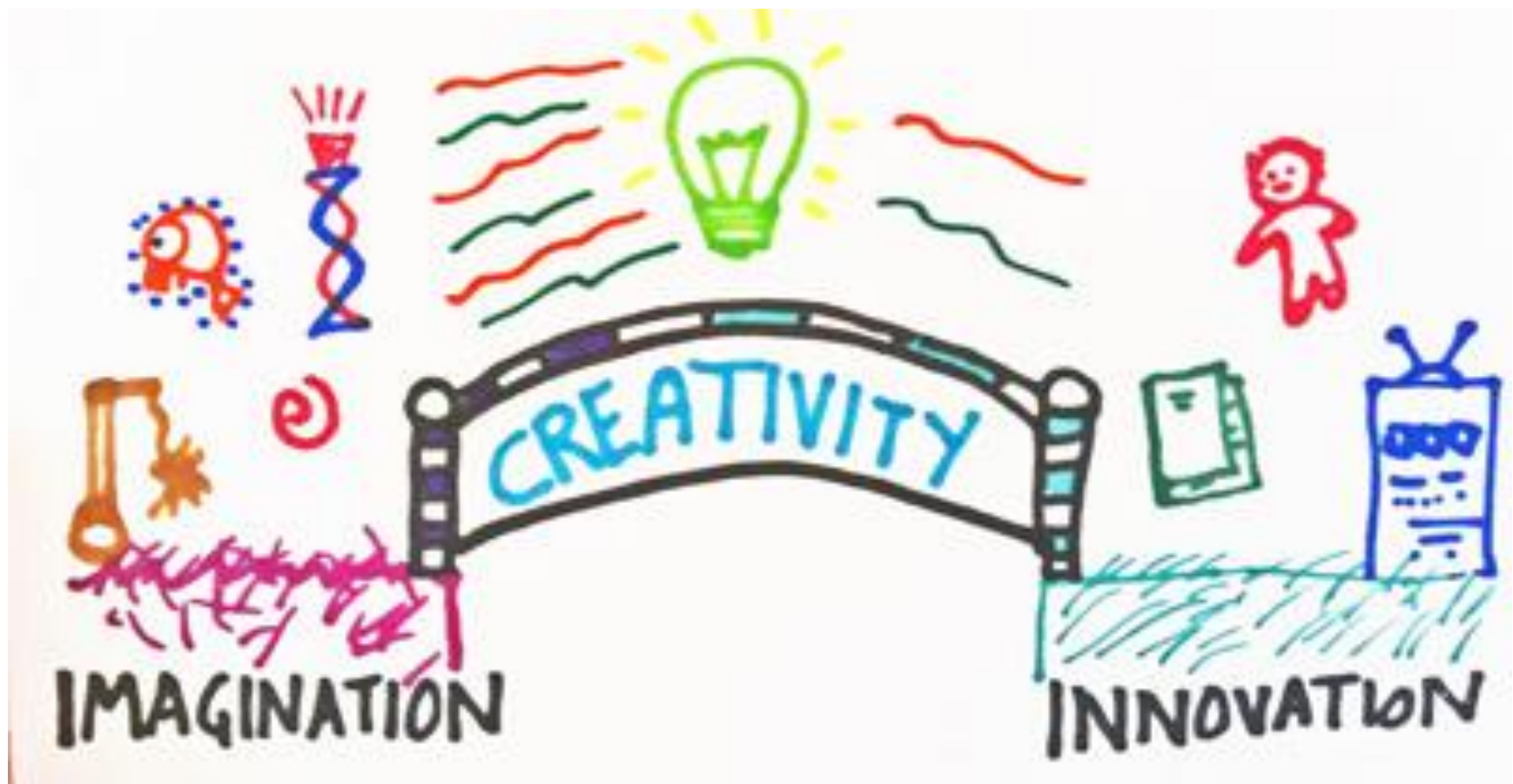
# Knowledge is the Fruit of Imagination

## Quote Transmission 001: Einstein and Imagination

“Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand.”

- Albert Einstein





# Imagination

- Exercise in Imagination
- Exercise in Creativity
- If you can dream it, you can build it
- Vision
- Objective Oriented
- “You Can’t Depend On Your Eyes or Judgement When Your Imagination Is Out of Focus”

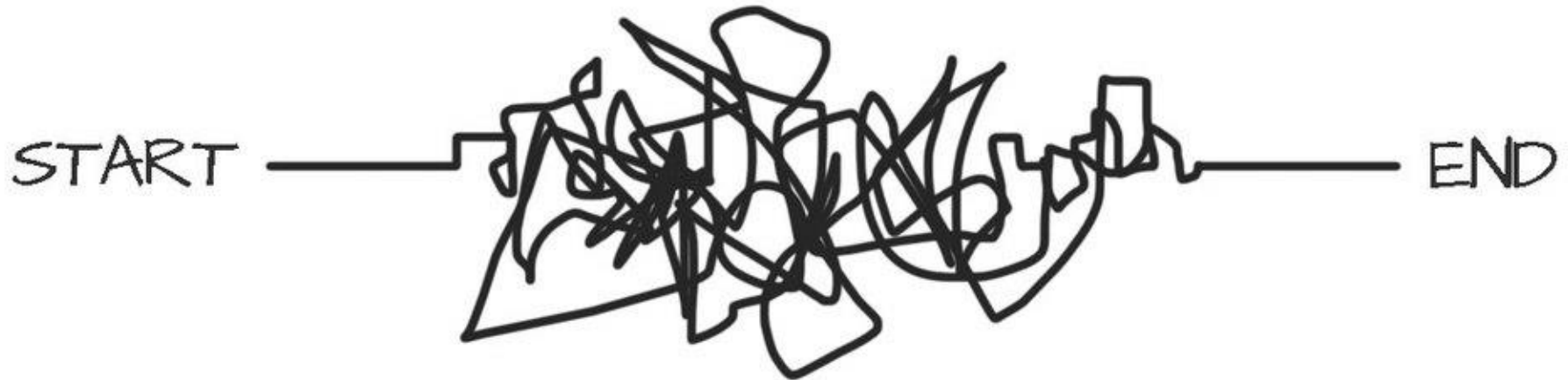


YOU CAN'T USE UP  
CREATIVITY  
THE MORE YOU USE  
THE MORE YOU HAVE

Maya Angelou

# Imagination process is not A Structured Method

THE CREATIVE PROCESS



# **Creative Brain**

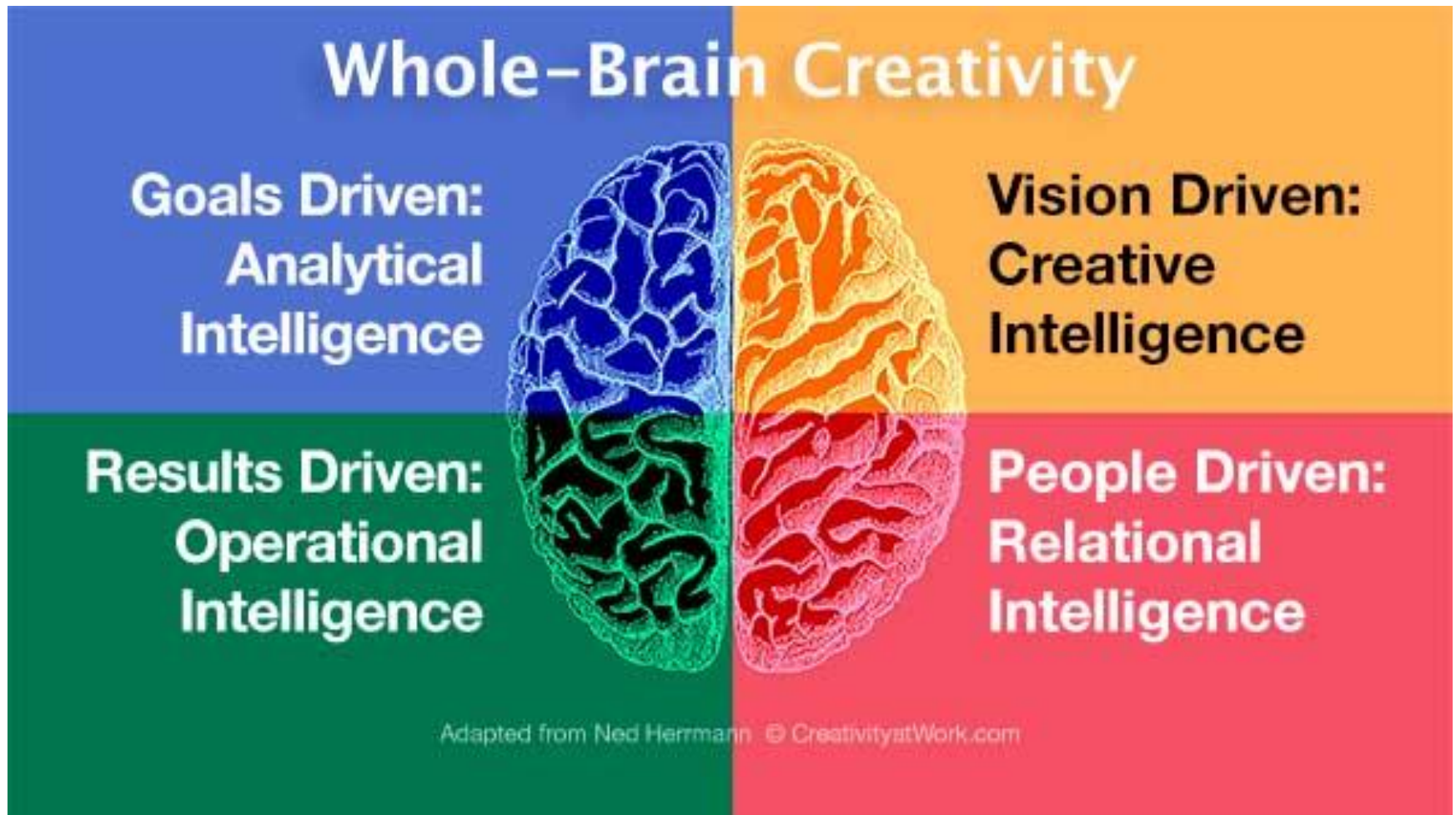


# The Brain

- Amazing Organ
- Complex System
- Ability to Create
- Synthetic Function
- Math and Science as Art Forms
- Science and Technology as Art of the Times
- Plasticity



# The Corpus Callosum

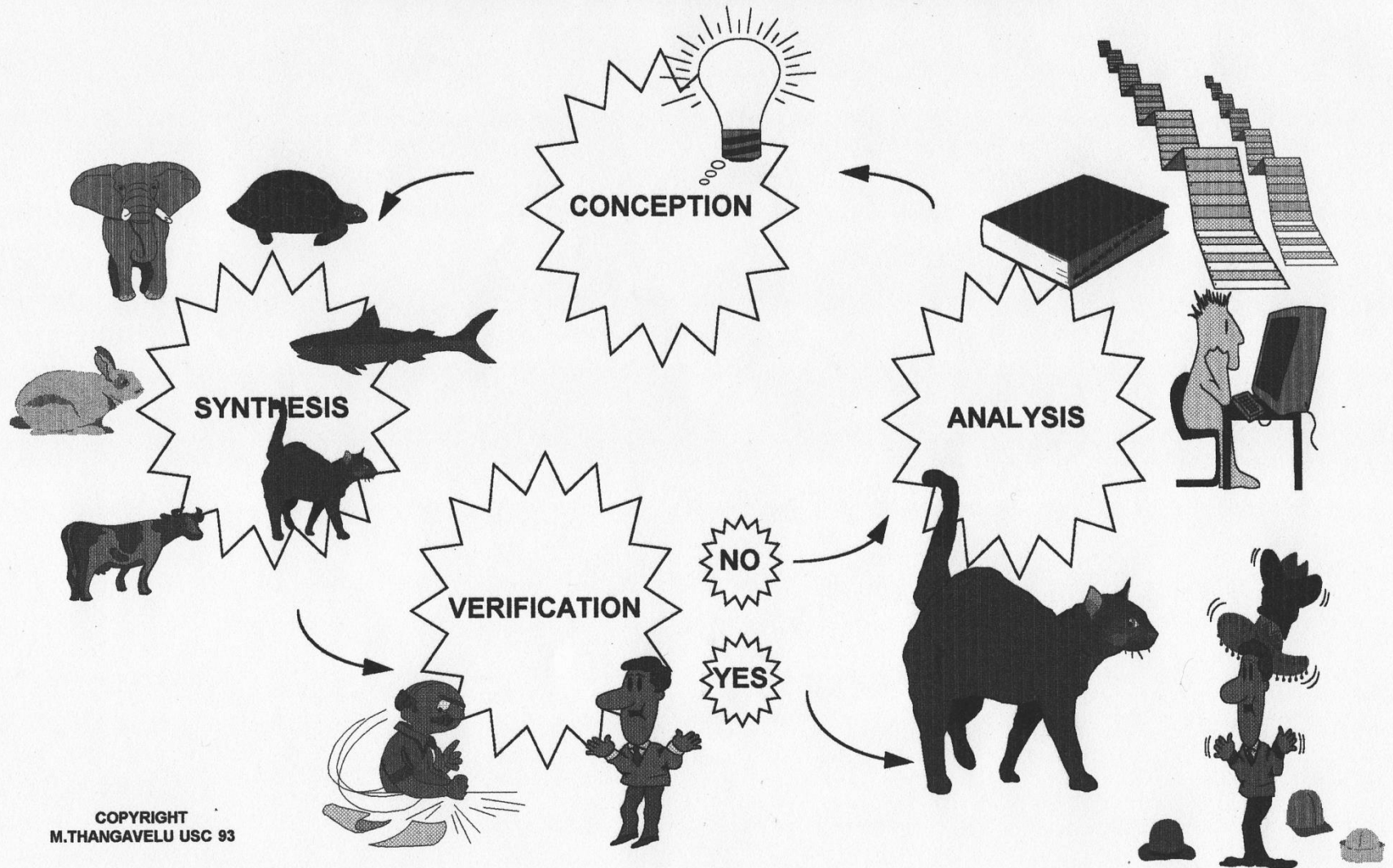


# Communicate

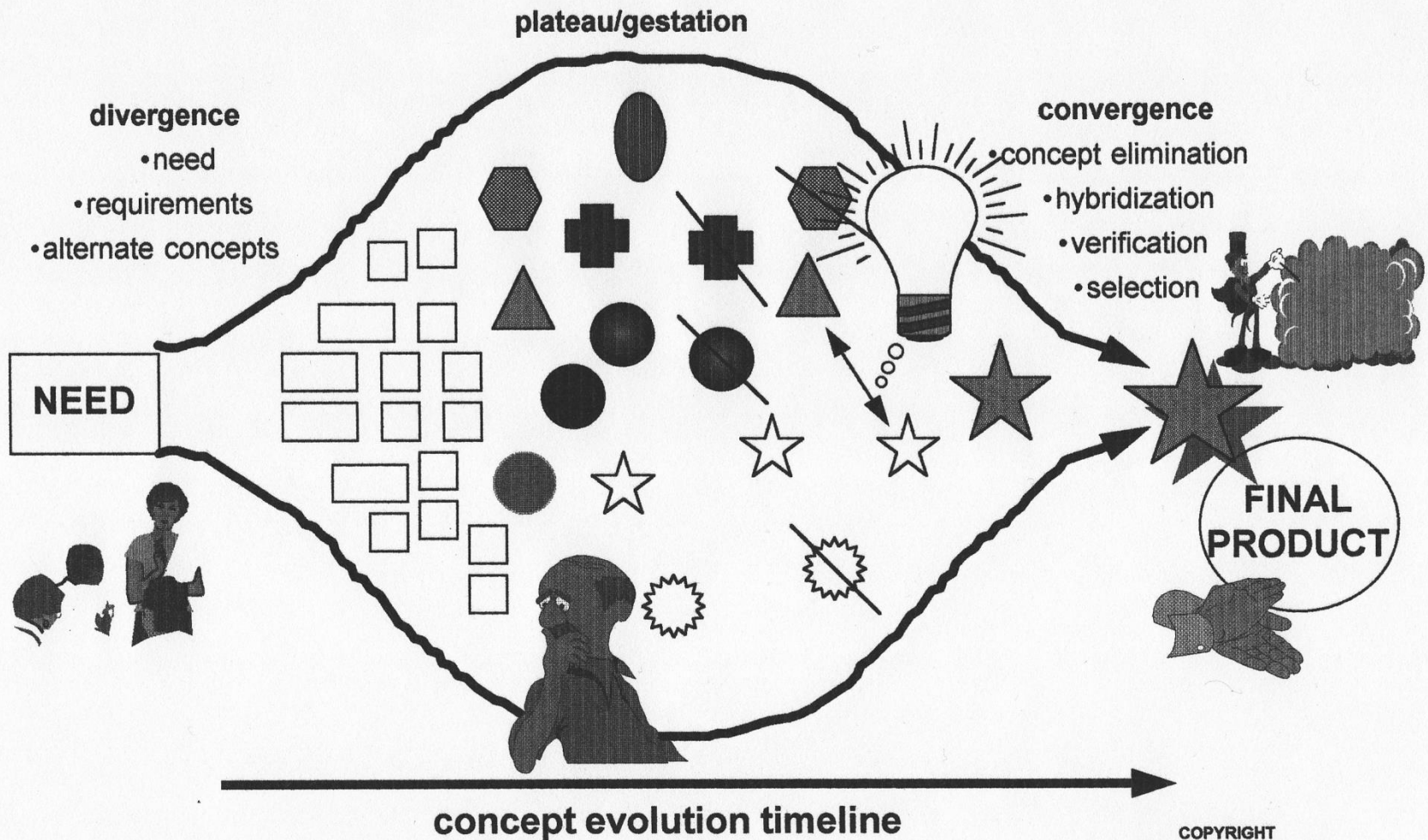
- Many dynamic parameters
- Changing Context
- Anticipate
- Communicate Vision
- Update Vision
- Tweak and Share Vision regularly – Bezos, Jobs
- Build Common Model



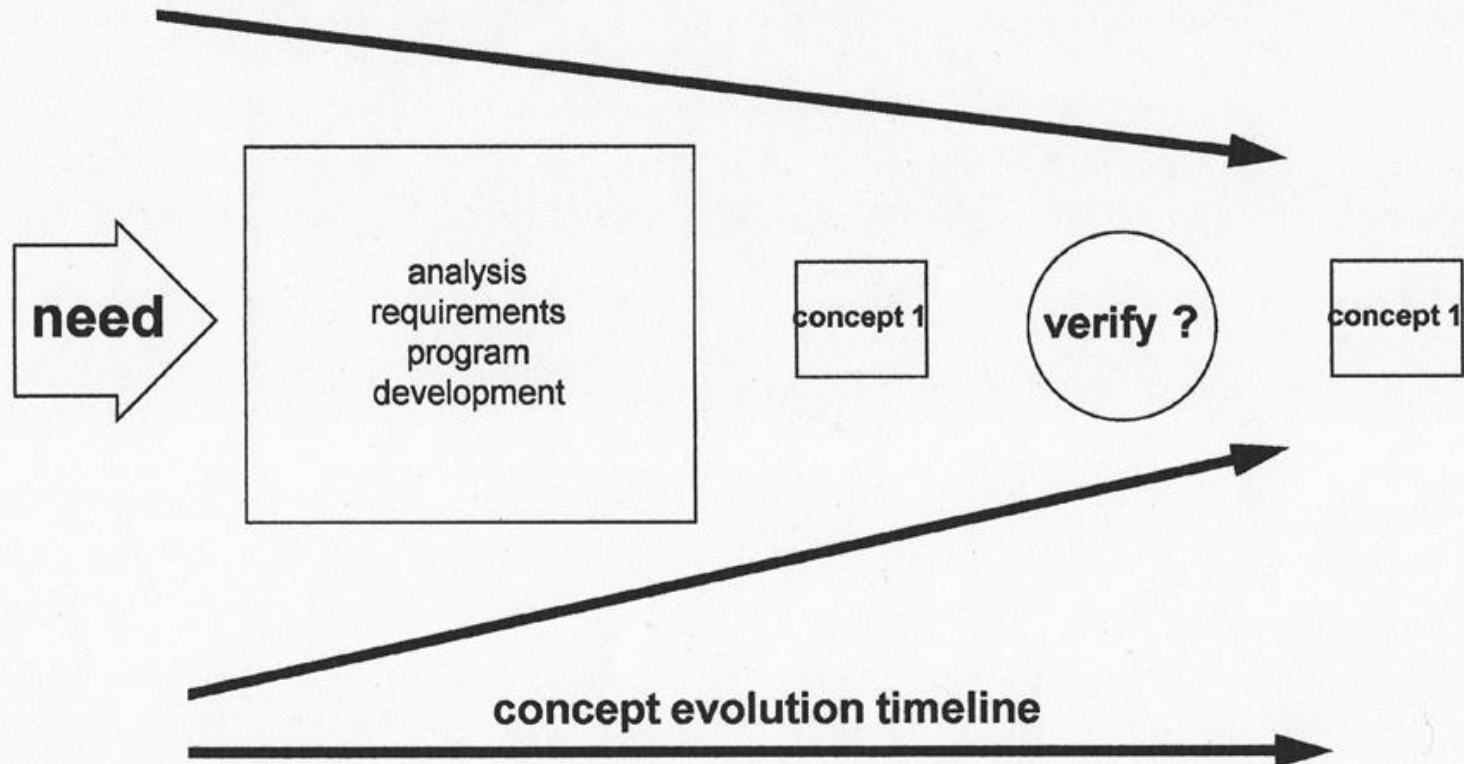
# ALTERNATIVE ENGINEERING CONCEPT GENERATION AND REFINEMENT IS AN ITERATIVE PROCESS



# CONCEPTION PROCESS

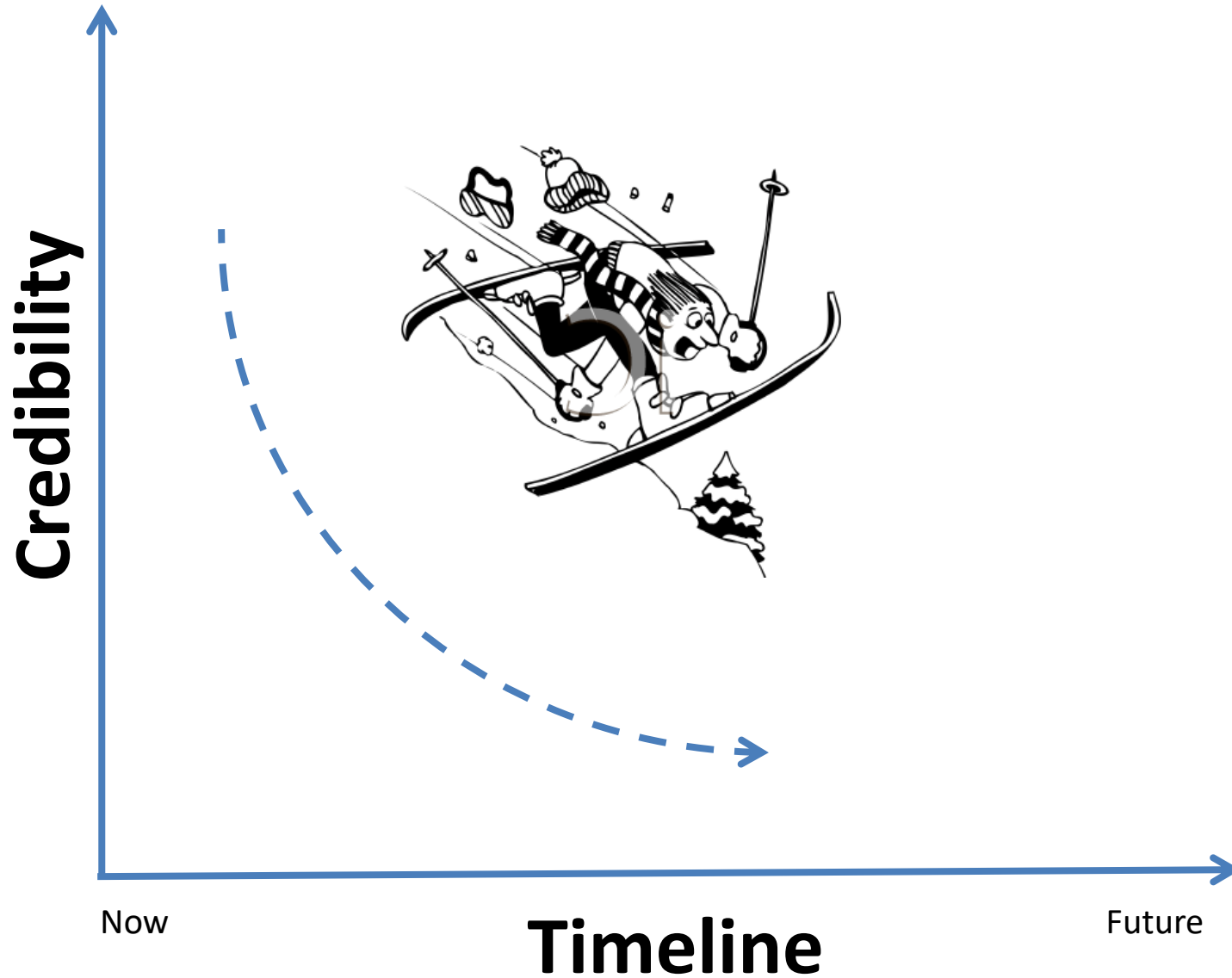


## AVOID TUNNEL VISION SYNTHESIS

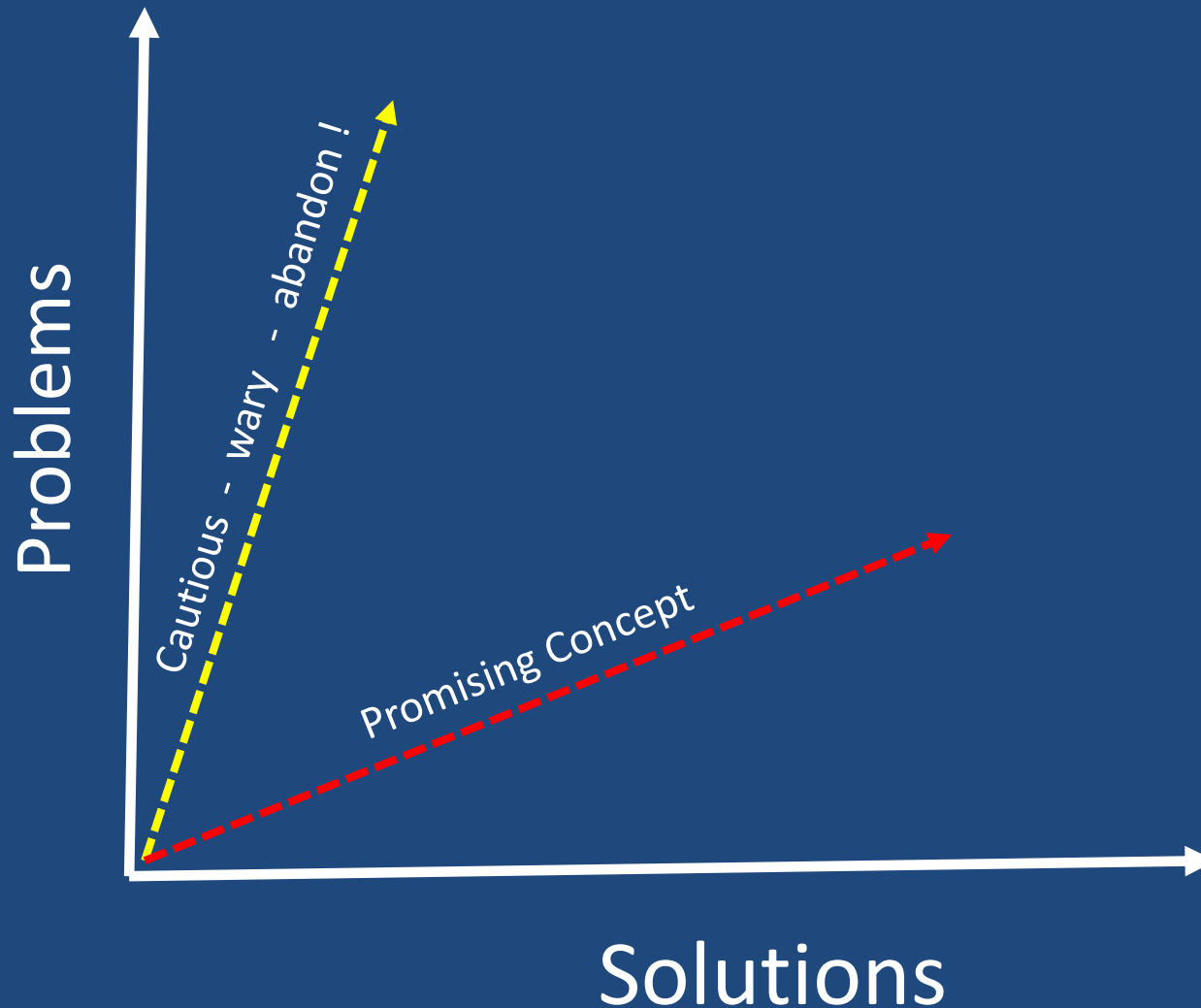




# Beware the Credibility Downhill Slope !



# Complex Concepts Creation



# **Concept Architecture Pointers**



# The Nature of Complex Projects

- Wicked Problem
- Dynamic and fast changing Context
- Parameters change
- Need to keep up with many variables
- Many times solved “out of bounds”
- Many times solved by introduction of new parameters
- Rapid Creation - Seize the opportunity

# Create Alternative Concepts

- **International Space Station**
  - Several iterations
  - Several incarnations
  - Global Political solution
- **STS Space Shuttle**
  - Several Concepts
  - Economic Solution
- **Apollo**
  - Several Concepts
  - Lunar Rendezvous

# What is a Concept Architecture ?

- A simple way to project an idea for a complex project
- Elevator Pitch
- Give idea a storyline
- Make it a story
- Credibility counts !
- Present it as a Set of slides
- 10 minutes – 15-20 slides Max



# Create a Concept - Steps to Follow

- Catchy Title
- **Context** – Current or near term, avoid warp speed other fantastic stuff
- **Problem** - Define/Bound Need
- **Rationale** - Make and support it
- **Assumptions** and Ground Rules – Establish & Bound it
- **Concept** – this is where you spend your time
- **Merits and Limitations**
- **Future Studies**
- References
- Backup Slides

# The Philosophy

- Architect first
- Engineer next
- Just like you build a home
- Create alternative concepts
- Pitch them against each other
- Develop hybrids
- Propose strong-boned concepts
- Solve wicked problems “out of bounds”.

# The Process

- Create Alternative Ideas
- Pre Proposal Phase
- Pre Engineering
- Create the Concept first
- Architect first
  - Program development, qualitative
- Engineer it next
  - Analyses, trades

# The Process

- Start in your area of Expertise
- Use Associative Logic
- Make Connections
- Visualize
- Sans Show Stoppers
- Complete the Process
- Tweak and
- Repeat



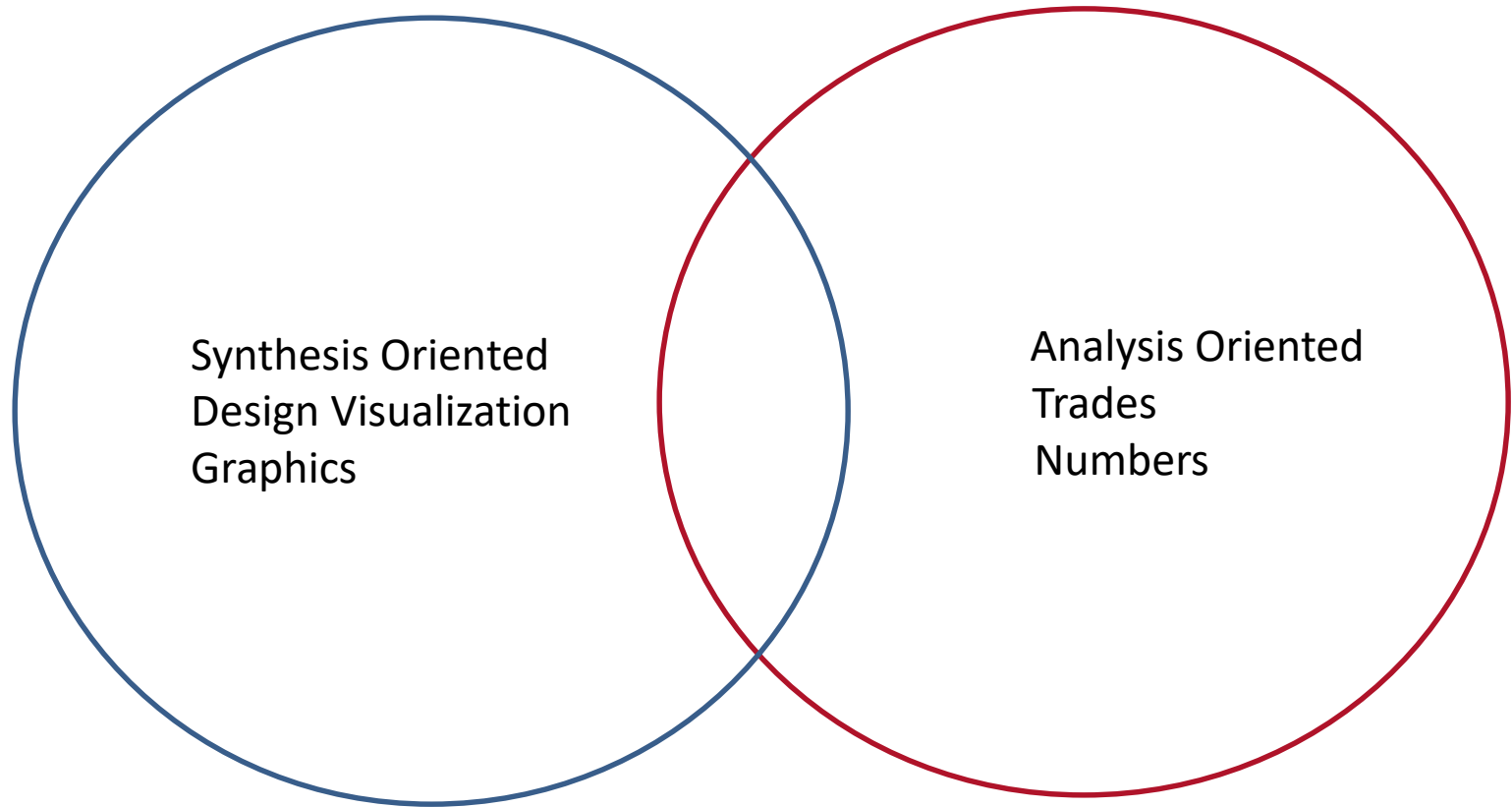
# Create a Concept - Steps to Follow

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# Architecting vs. Engineering

- Architecting is a qualitative process
- Engineering is a quantitative method
- Architecting addresses – **why, what, when, where**
- Engineering defines and bounds – **how, how much ?**
- Architect first, engineer next
- Concept Creation is an up front, top level, Architecting process -**Synthesis**
- It creates a range of choice for the client
- Create first, Optimize later

# Architecture & Engineering



# The Wicked Problem

- Complex problem
- One of a kind
- Not cookie cutter
- Many dynamic variables
- Moving goal posts
- Introduce new parameters
- Solved “out of bounds”



# Tools

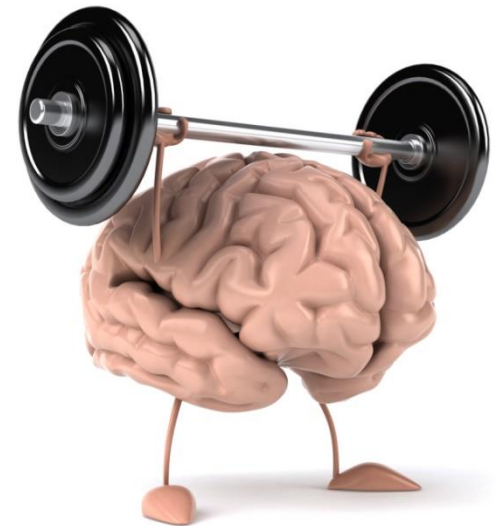
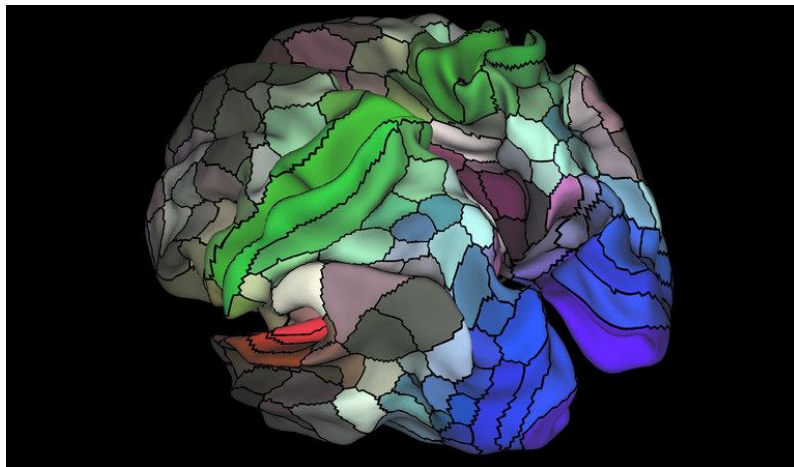
- Context – Sense and Sensitivity
- Associative Logic - Connections
- Lateral Thinking
- Analogies
- Intuition – Lessons Learned –Experience
- Heuristics
- Imagination
- Creativity

# Priming the Mind

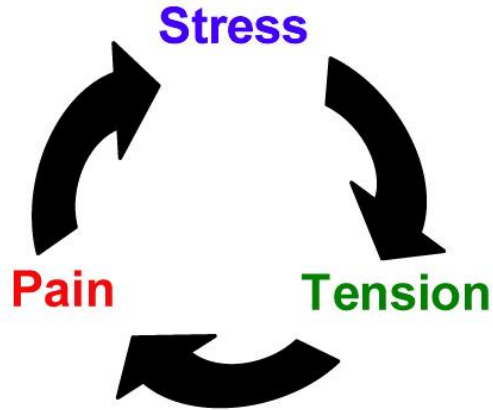
- Plug into data stream
- Chaos
- Lot of noise
- Input parameters
- Include Conflicts

# Creative Synthesis - Hegel ?

- Thesis, Antithesis – Synthesis
- Human Connectome Project
- The conflict between what is ideal or impossible and that which is possible is essential for creative synthesis



# Creative Tension



- "There's a tension between feasibility and desirability," Thangavelu said. "But the conflict between what's possible and what's daydreaming is necessary to arrive at creative, passionate solutions."





# MOBIUS

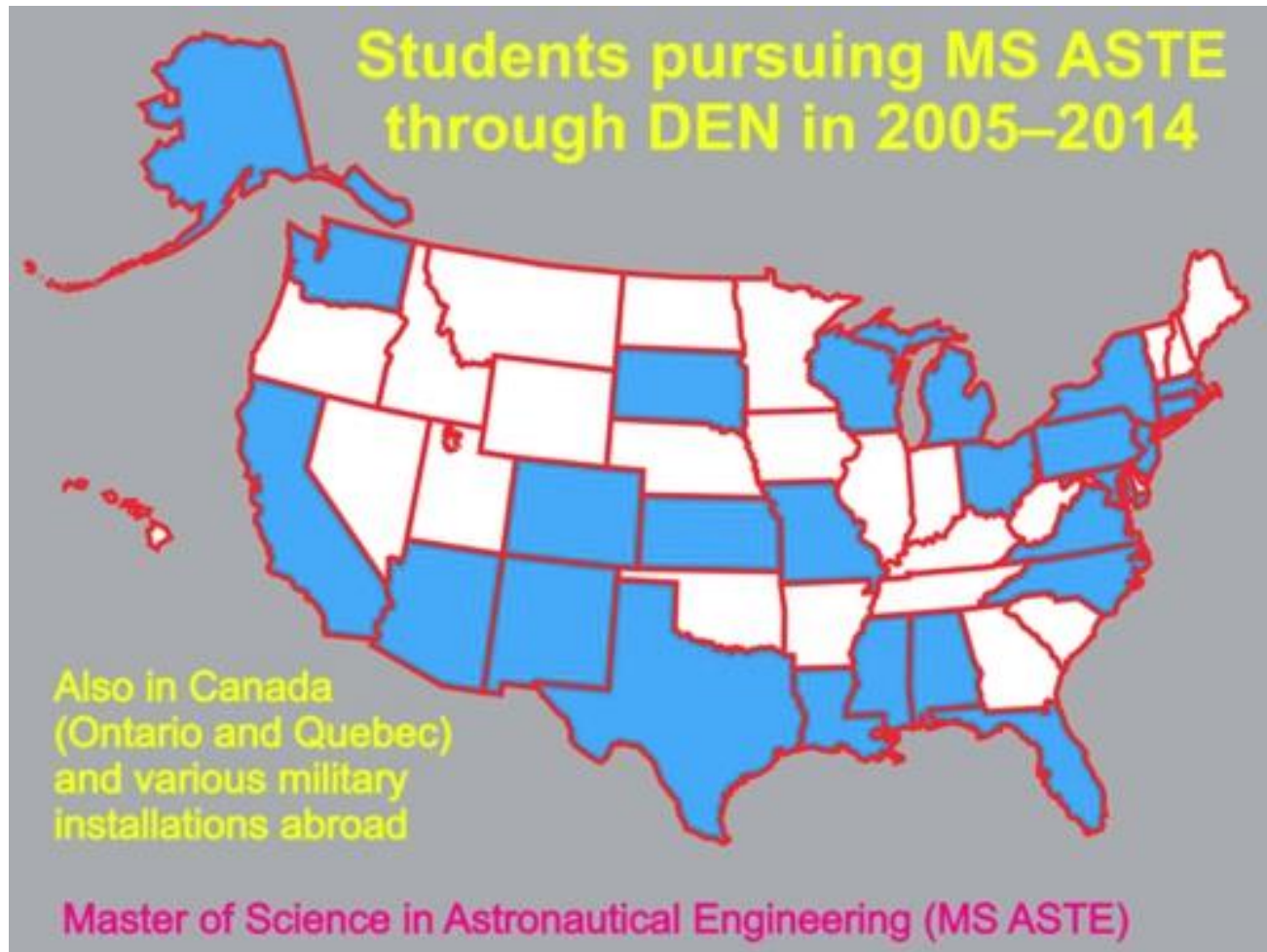
## Supersynchronous Earth Orbits for Lunar Missions (An Evolutionary Strategy for Lunar Tourism)

**Madhu Thangavelu**

ASTE Department, Viterbi School of Engineering  
University of Southern California

AIAA Space Conference, Long Beach CA, 2016

# USC Astronautical Engineering



# ASTE 527 Space Concepts Studio

- Since 1993
- 3-unit elective modeled after Architecture Design Studio
- Focus on Concept Creation
- Rapid Complex Ideation
- Architecture + Engineering tools
- No time for engineering optimization rigor
- Concepts help planners make choices-may or may not work, expands breadth of investigation

# ASTE527 - Secrets Revealed !

- Borrow from other professions that deal with complex “wicked” problems
- Solve using “out of bounds” approach
- Associative Logic
- Connections
- Case Studies
- Lectures from creative professionals
- Iterative process – till you get it right !
- Sandbox for creativity – Writer’s Workshop



# ASTE 527 Graduate Space Concept Synthesis Studio Web Site

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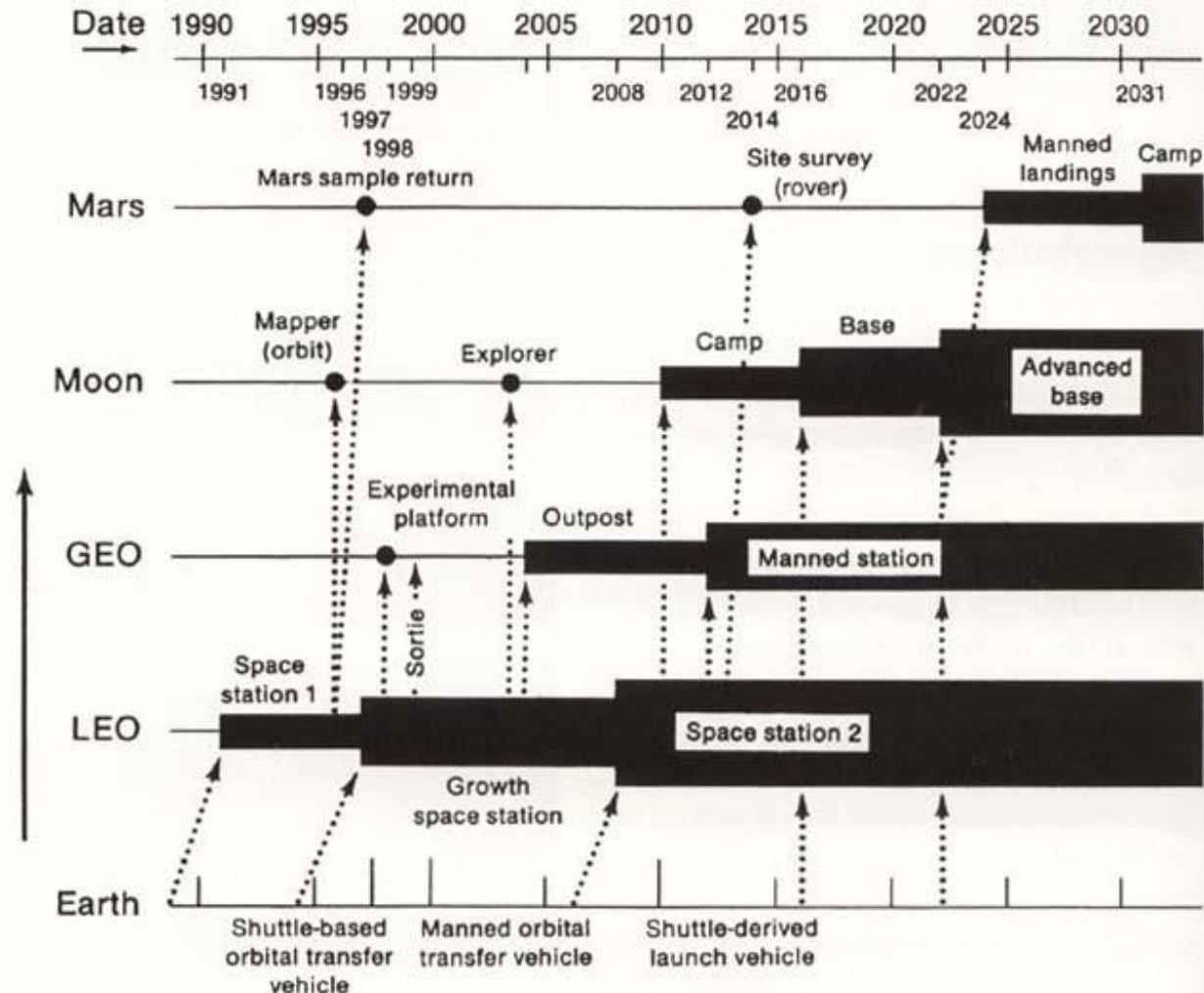
- <https://sites.google.com/a/usc.edu/aste527/home>

# NASA SP509 – Puttkamer, Burke, Roberts

Figure 2

## Baseline Scenario

If NASA continues its business as usual without a major increase in its budget and without using nonterrestrial resources as it expands into space, this is the development that might be expected in the next 25 to 50 years. The plan shows an orderly progression in manned missions from the initial space station in low Earth orbit (LEO) expected in the 1990s, through an outpost and an eventual space station in geosynchronous Earth orbit (GEO) (from 2004 to 2012), to a small lunar base in 2016, and eventually to a Mars landing in 2024. Unmanned precursor missions would include an experiment platform in GEO, lunar mapping and exploration by robot, a Mars sample return, and an automated site survey on Mars. This plan can be used as a baseline scenario against which other, more ambitious plans can be compared.



# ISS Future

- End of mission 2024
- NASA Plan – Deorbit
- ISS Consortium
- Send to Moon
- Some Alternatives
  - Bring more partners into program
  - Turn over to private sector
  - Historical Artifact -Park in high orbit
  - Disassemble and bring back to Earth

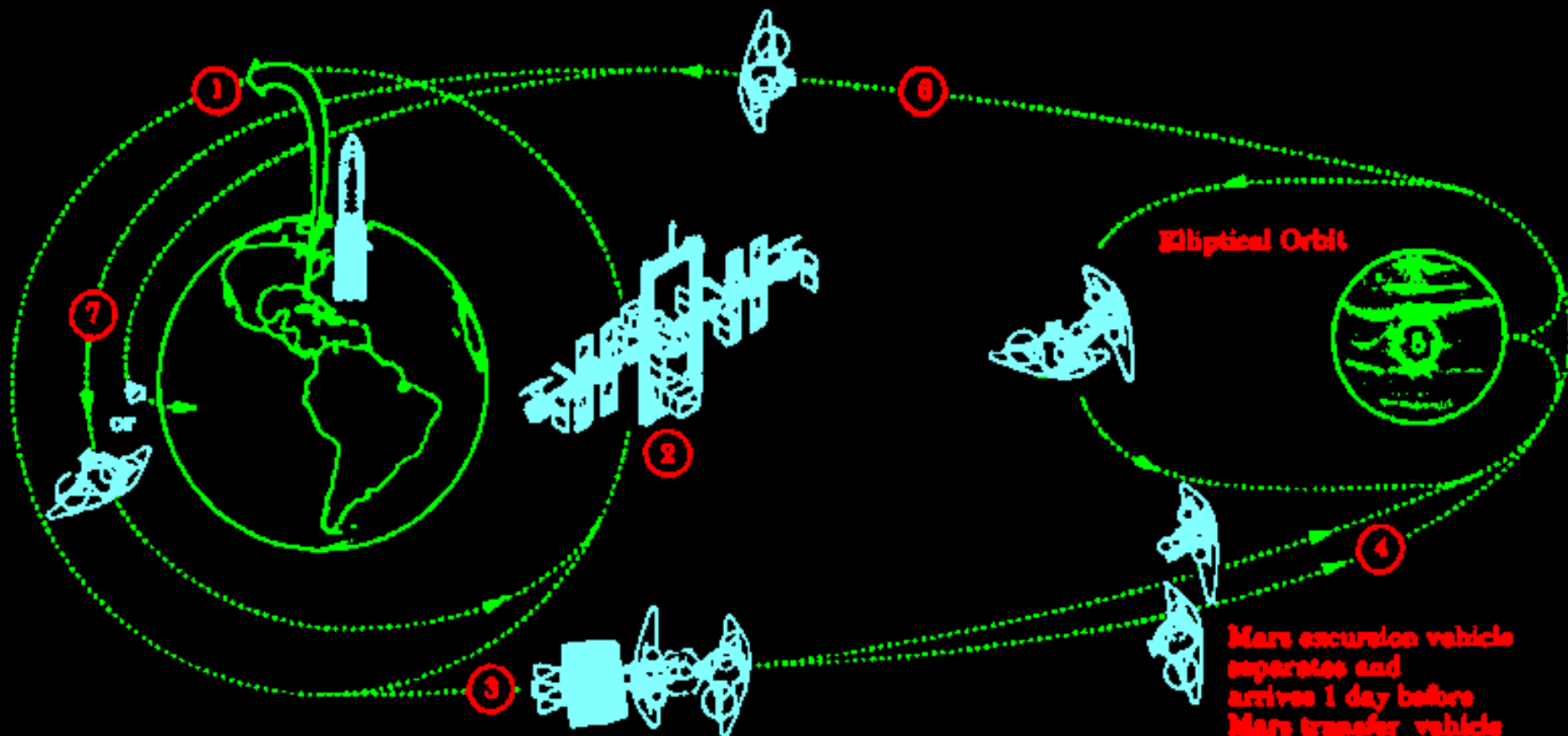
# Evolution of ISS as Spacecraft Integration Platform

- Original purpose
- Repurpose -Gerstenmaier
- Commercial Use
- Large Spacecraft assembly - MALEO – ISU 1988
- USC Space Concept studies – Evolution of ISS 1&2
- <https://sites.google.com/a/usc.edu/aste527/home>
- International Space Transit Vehicle
- Cosmic Mariner

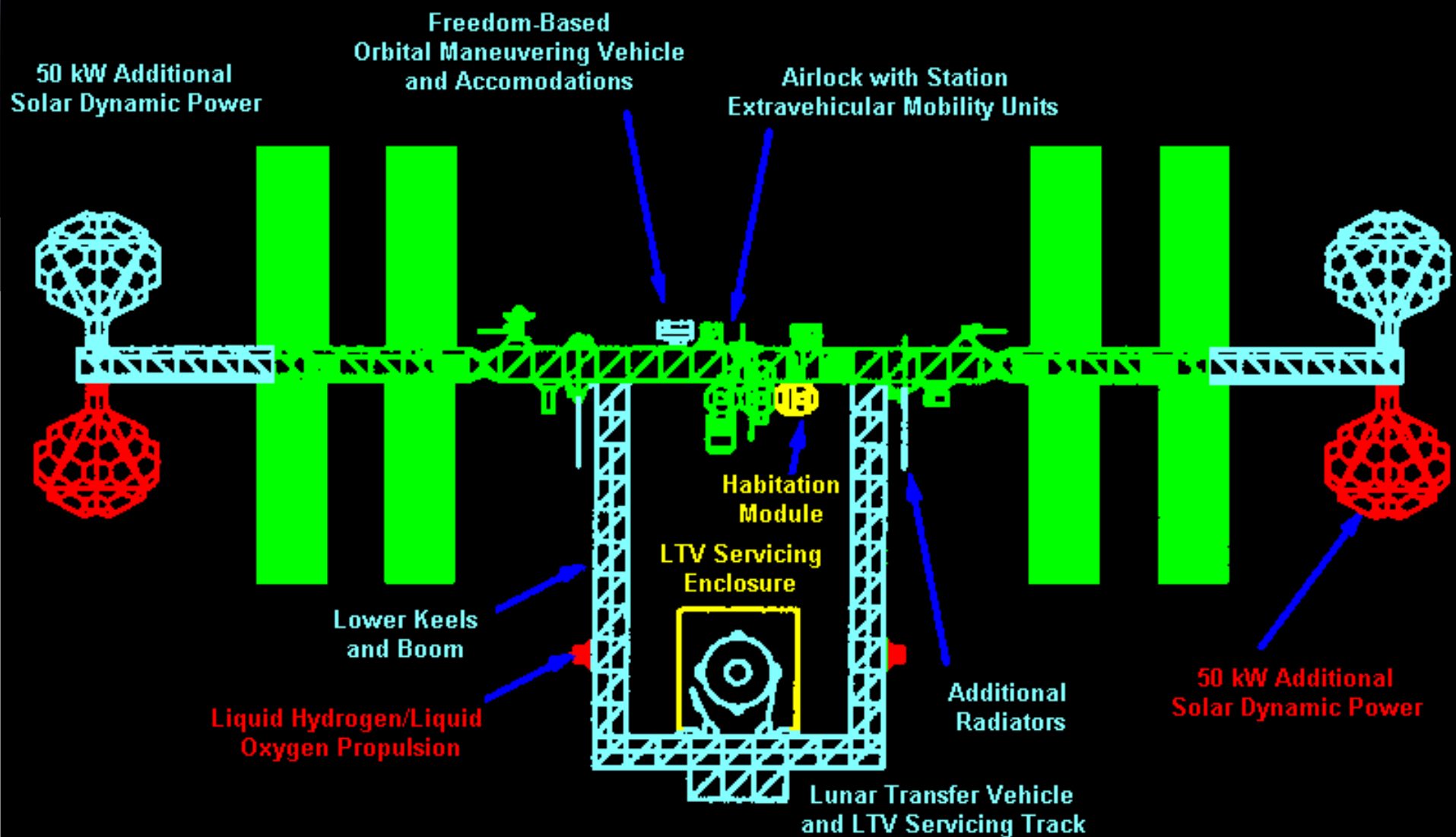


# Space Exploration Initiative[SEI]





- |  |  |
|--|--|
| ① Payload delivered to Space Station Freedom   | ⑤ Excursion vehicle to/from Mars surface         |
| ② Mars transfer vehicle mated with payload at Freedom  | ⑥ Trans-Earth phase with transfer vehicle        |
| ③ Trans-Mars phase with Mars transfer vehicle  | ⑦ Transfer vehicle aerobrake maneuver and return |
| ④ Mars transfer vehicle remains in Mars orbit;<br>Mars excursion vehicle descends to surface |  |



# MALEO : MODULE ASSEMBLY IN LOW EARTH ORBIT

- A strategy to build and commission a lunar surface habitat complex by integrating several modules in LEO using the ISS and her crew, and ship it to the lunar surface using custom propulsion systems, thereby avoiding the infrastructure otherwise needed to construct one piece by piece, and eliminating the clingy dust nuisance that hampers lunar surface activity.

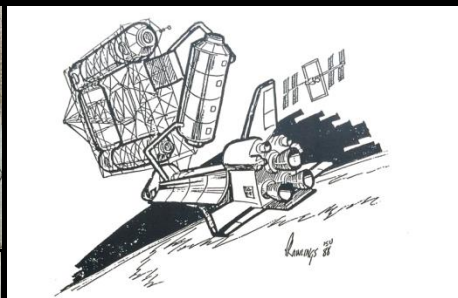
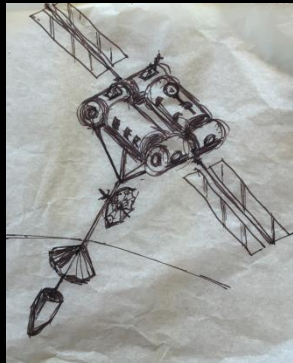


Figure 5. Space station Freedom assisted MALEO LHB-1 Assembly using the STS as the primary platform (4 module configuration)

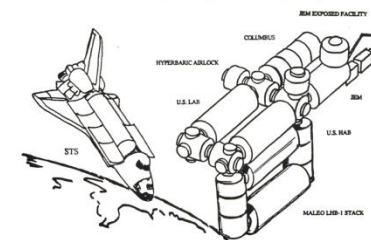
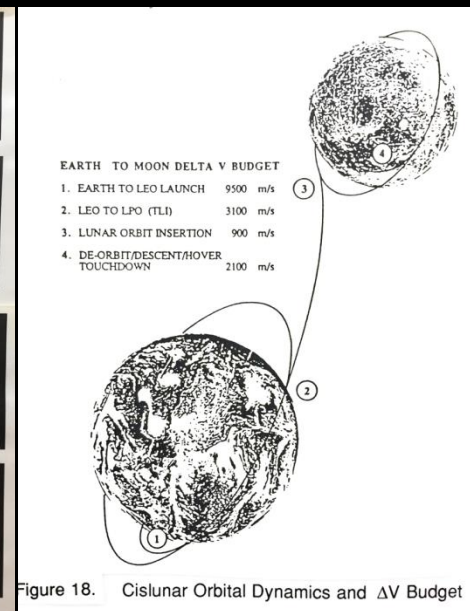
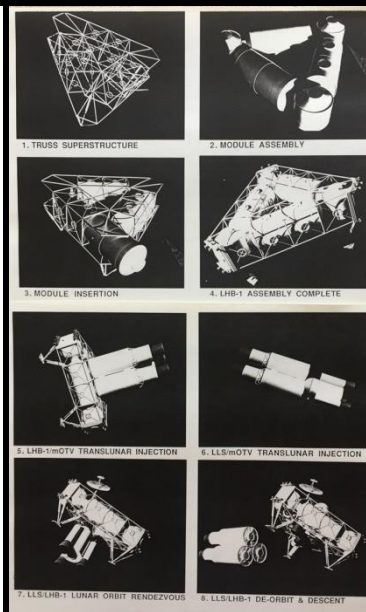


Figure 6. A 4 module MALEO LHB-1 Assembly connected to the manned core of Space Station Freedom

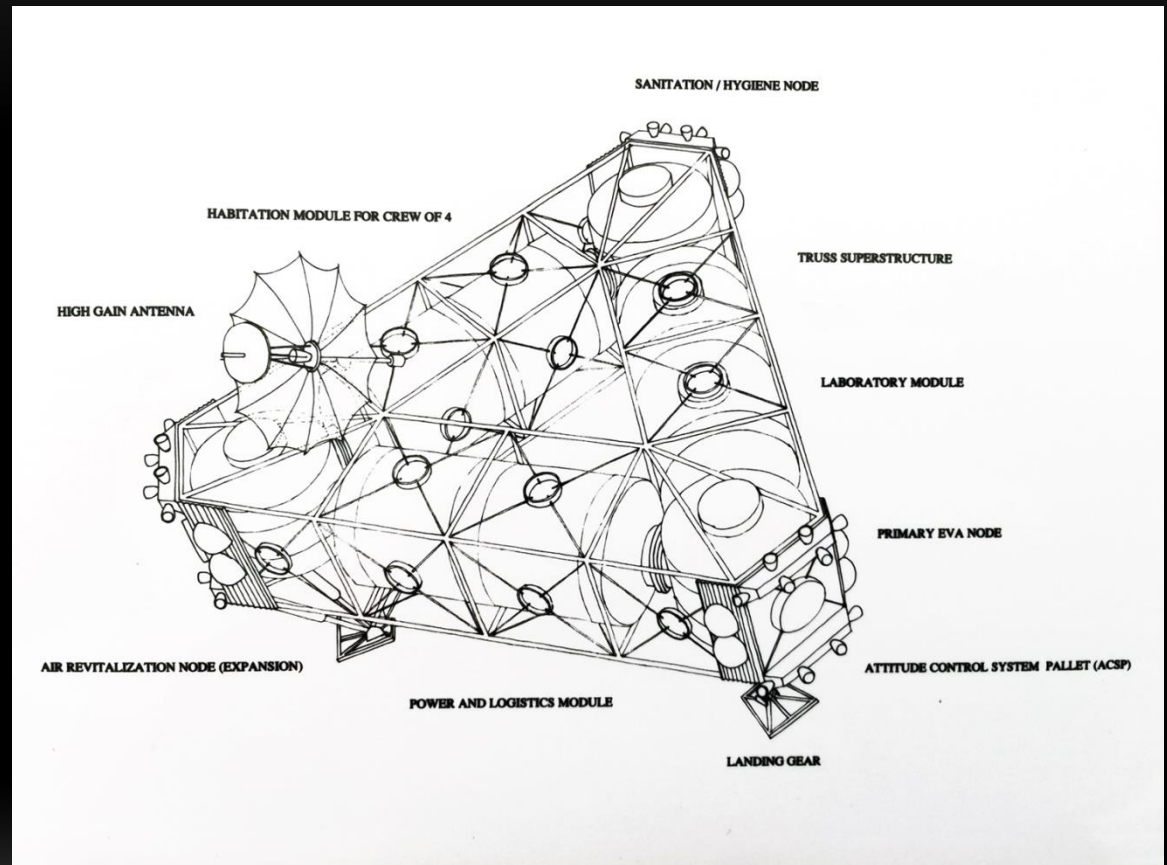


- First proposed at the inaugural summer session of the International Space University at MIT in 1988
- First presented and published at the 1988 IAC in Bangalore, India
- Several subsequent publications including USC 1988, IAC Dresden 1990, ASCE 1992, JBIS 1993

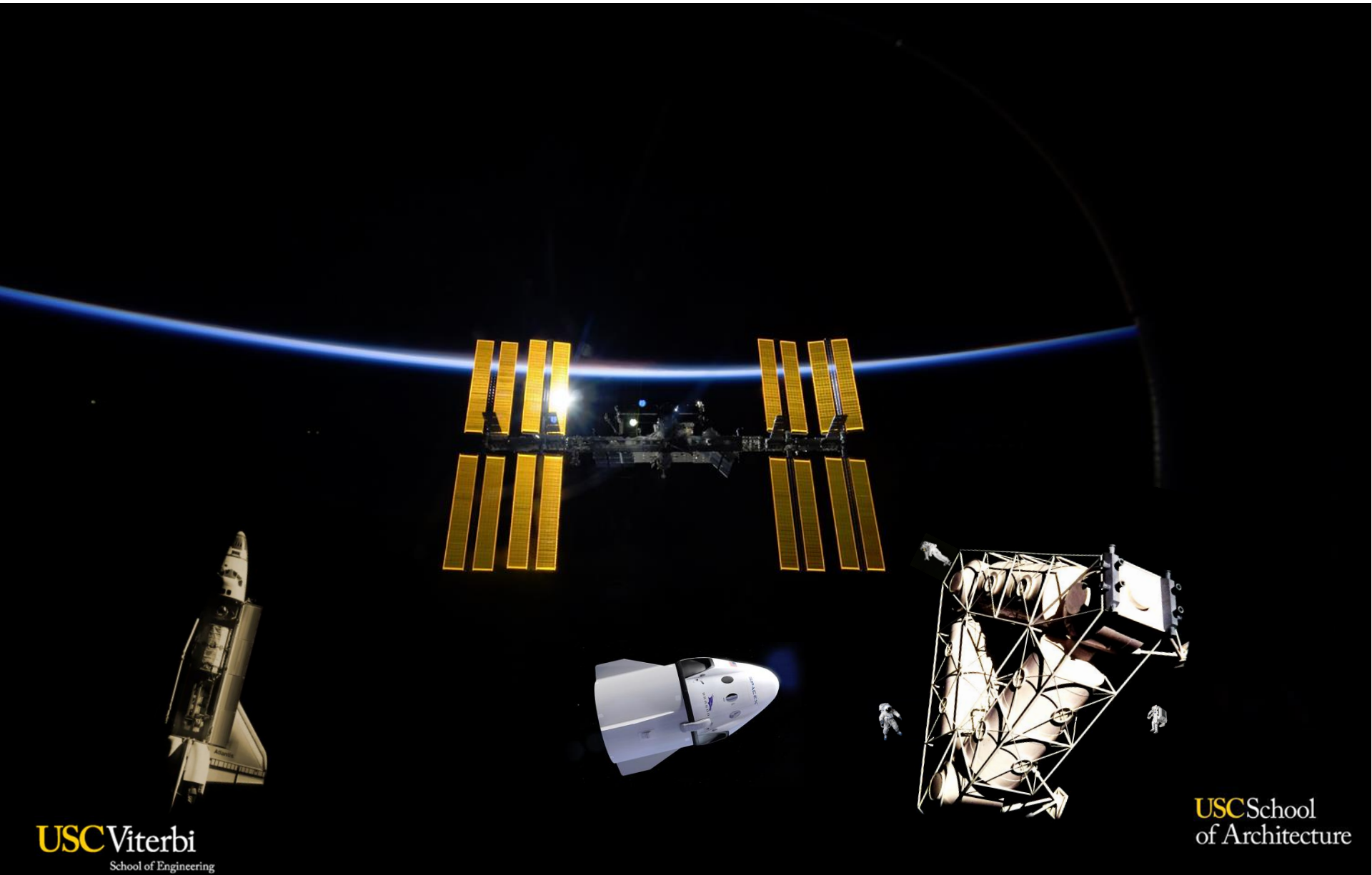


# MALEO - SALIENT FEATURES

- **Payload Summary [MT]**
- Habitat Module = 15
- Lab Module = 15
- Power/Logistics = 15
- ECLSS Node = 5
- Sanitation/Hygiene = 5
- Airlock/EVA = 10
- Truss/Landing gear = 10
- 100kWSolar Arrays/Comm = 5
- Unpress.Electric Rover X2 = 10
- Attitude Control Pallet X3 = 6
- **Touchdown Mass ~100MT**
- + lander propulsion stack

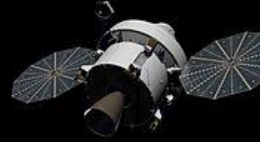


# MALEO Assembly with ISS Crew – Note SpaceX Dragon



# MALEO Lunar Deorbit & Landing





# Earth Station: Global ISS Marketing Future of Human Spaceflight A Lunar Cruise

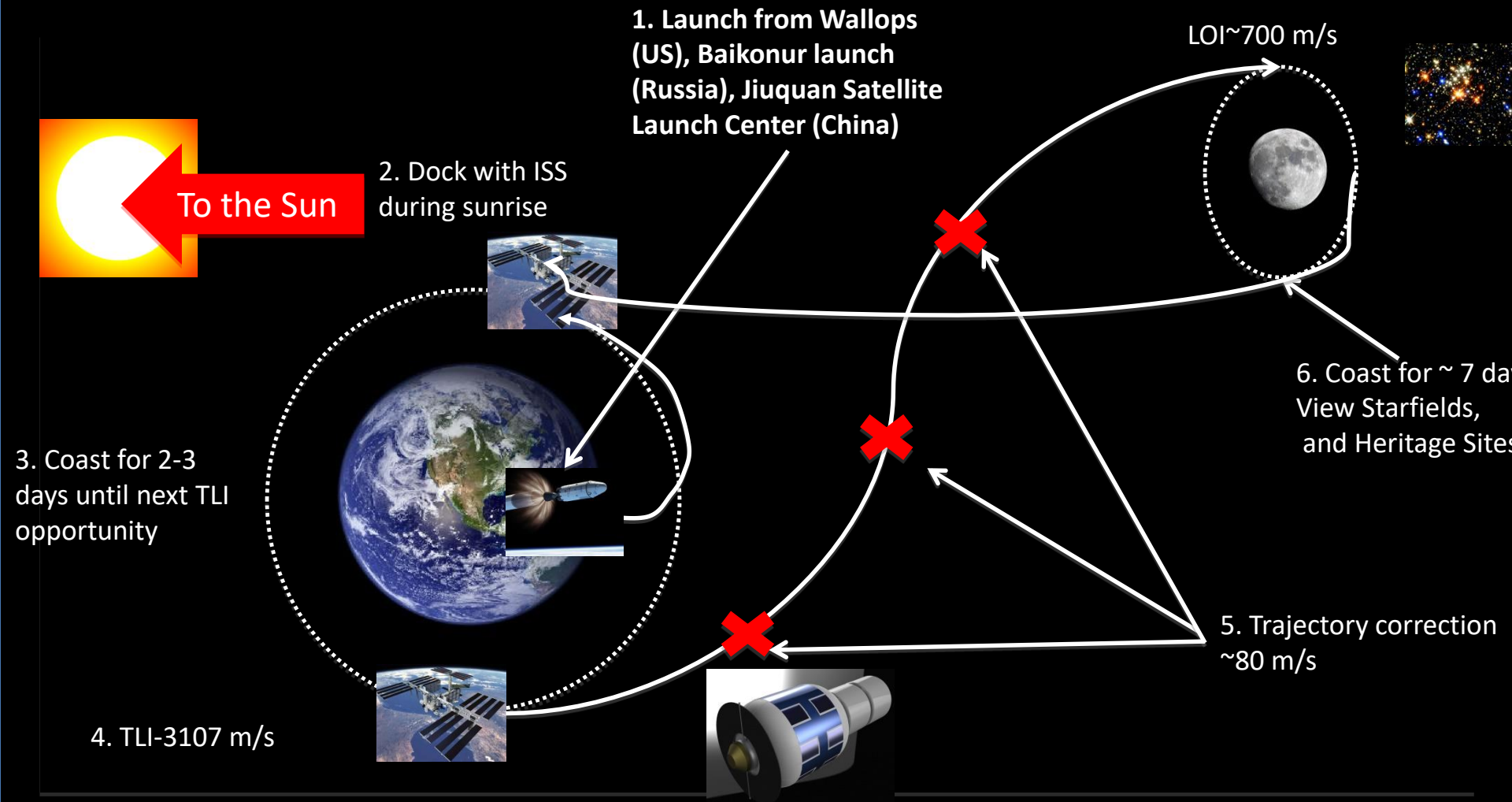
Michael Barrucco



**ASTE 527** Space Exploration Architectures Concept Synthesis Studio  
Team Project, Fall 2010, Astronautical Engineering Department,  
Viterbi School of Engineering, University of Southern California



# Concept of Operations



- TEI Day 11
- Moon re-aligned with ISS Orbital Plane

- LOI Day 4
- Moon aligned with ISS orbit plane

• Moon at EOI

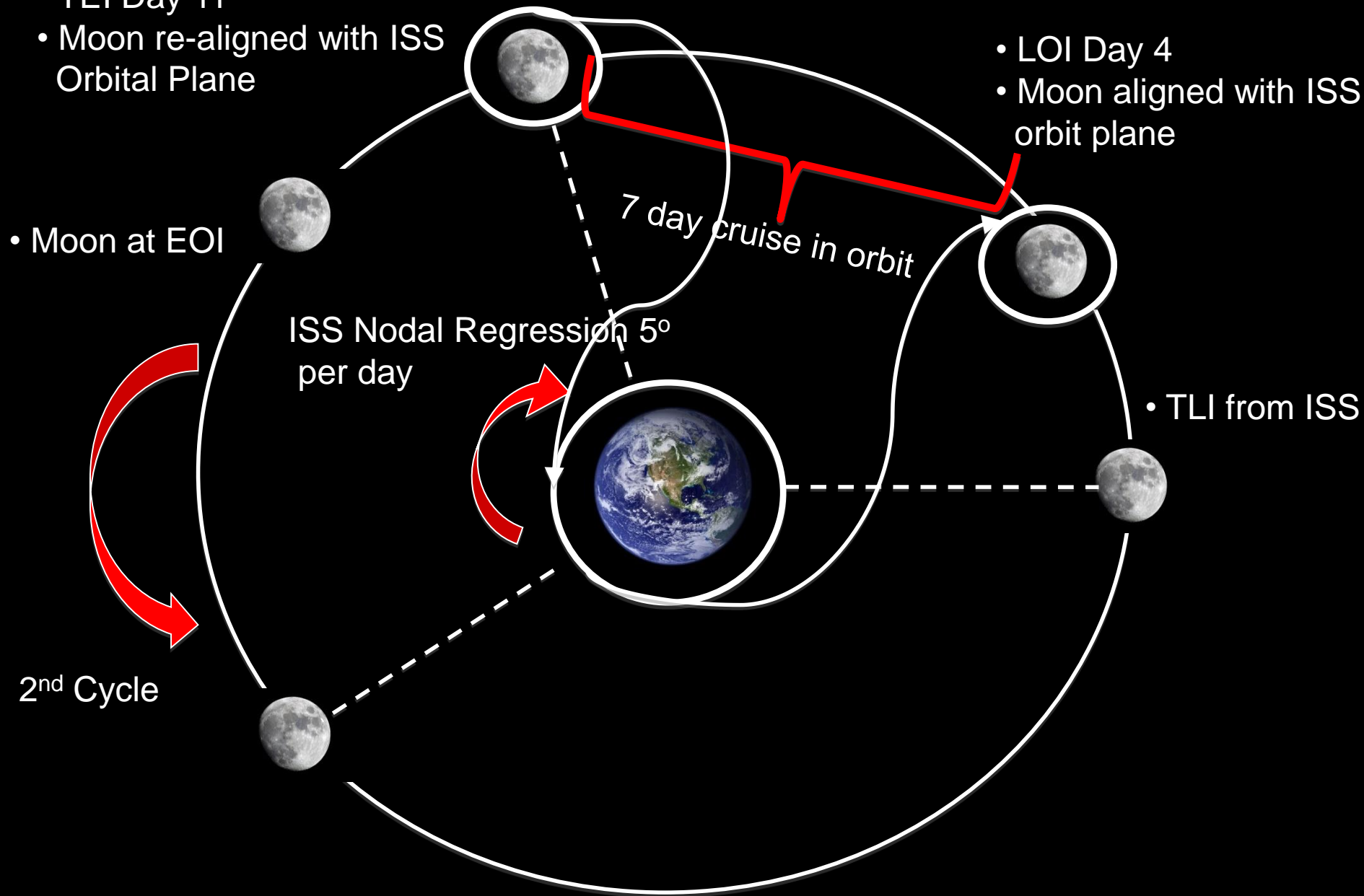
7 day cruise in orbit

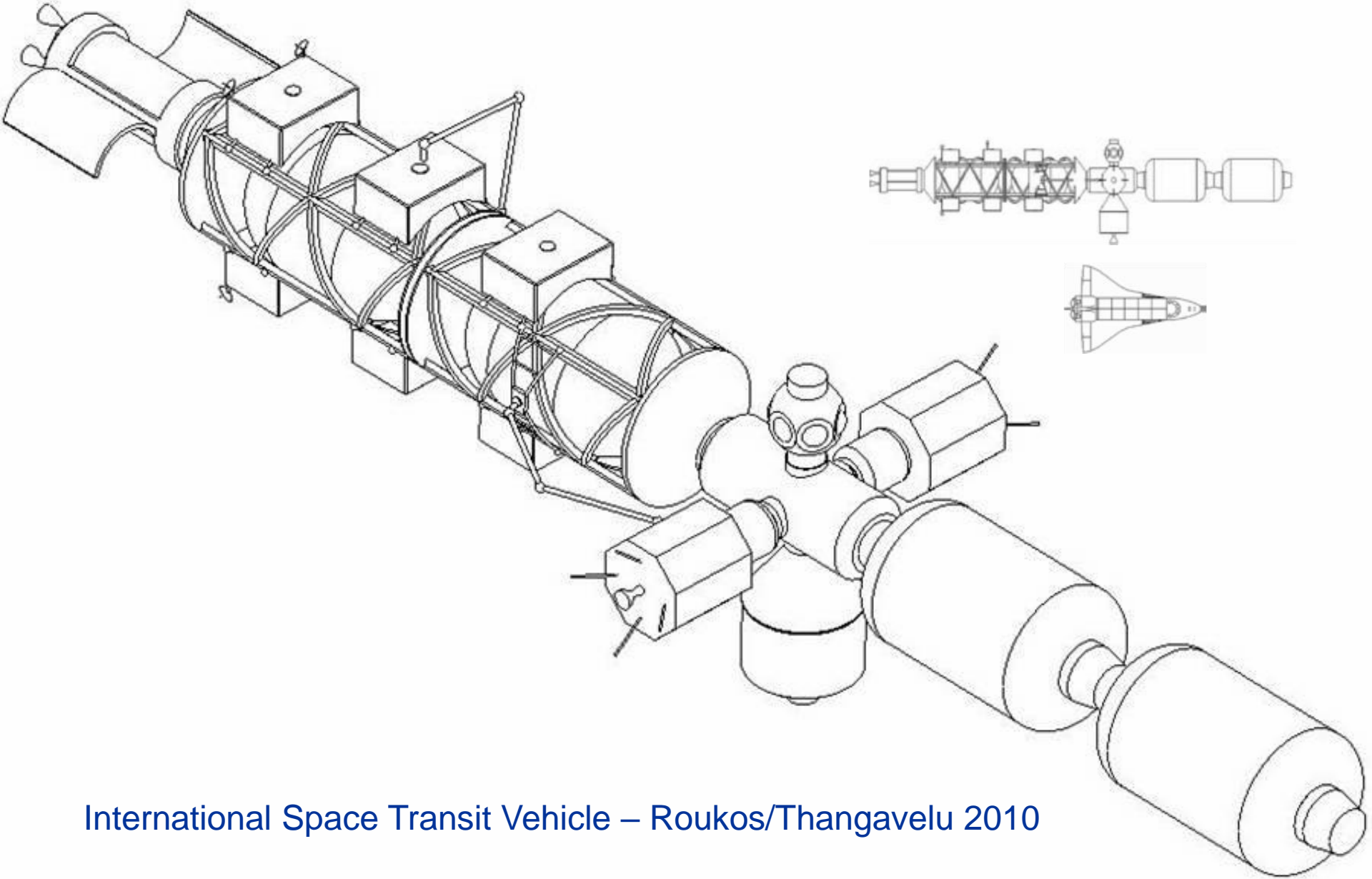
ISS Nodal Regression  $5^\circ$  per day

• TLI from ISS

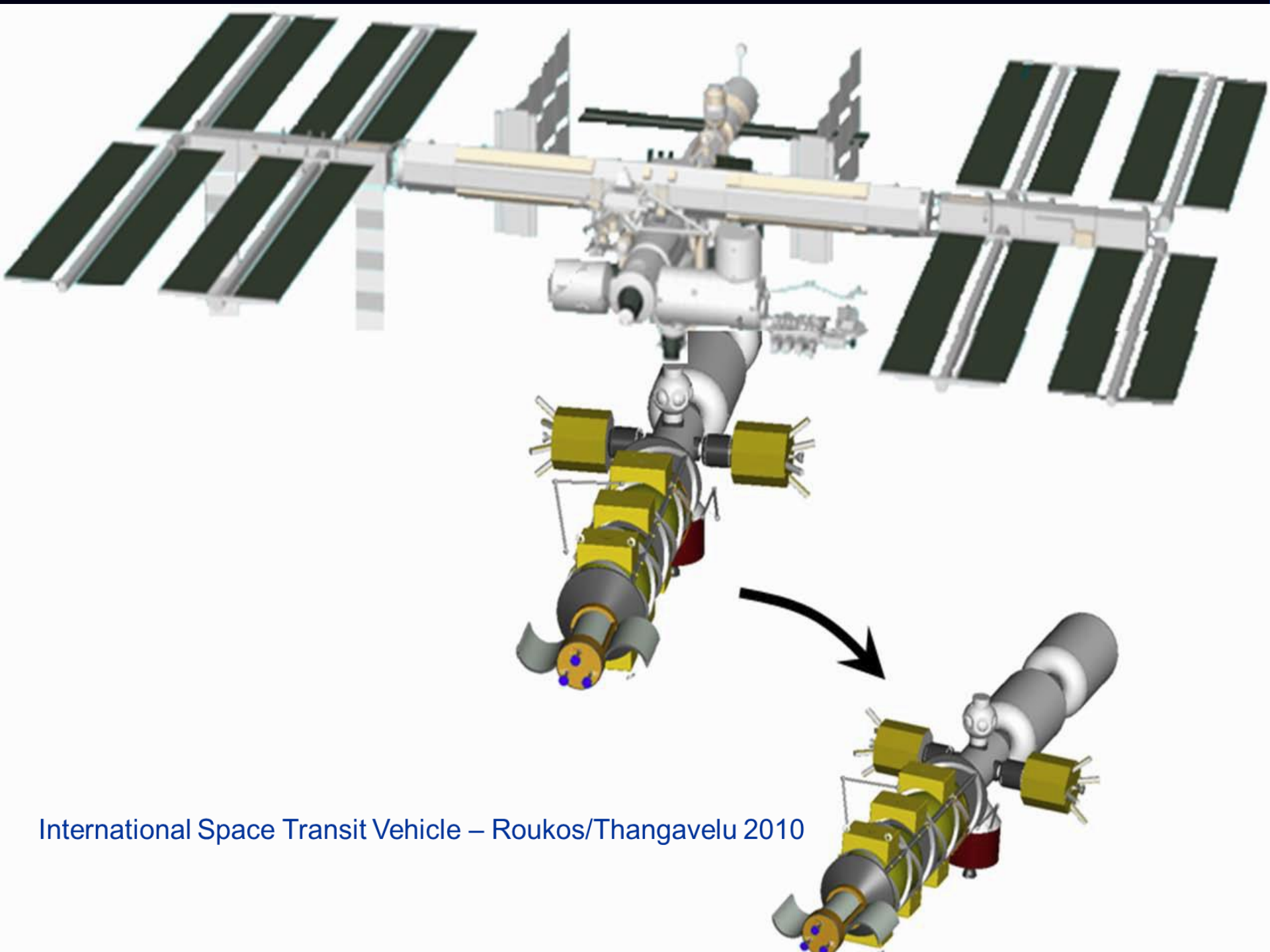
2<sup>nd</sup> Cycle

Cis-Lunar Cruise





International Space Transit Vehicle – Roukos/Thangavelu 2010



International Space Transit Vehicle – Roukos/Thangavelu 2010



**AIAA SPACE 2012**

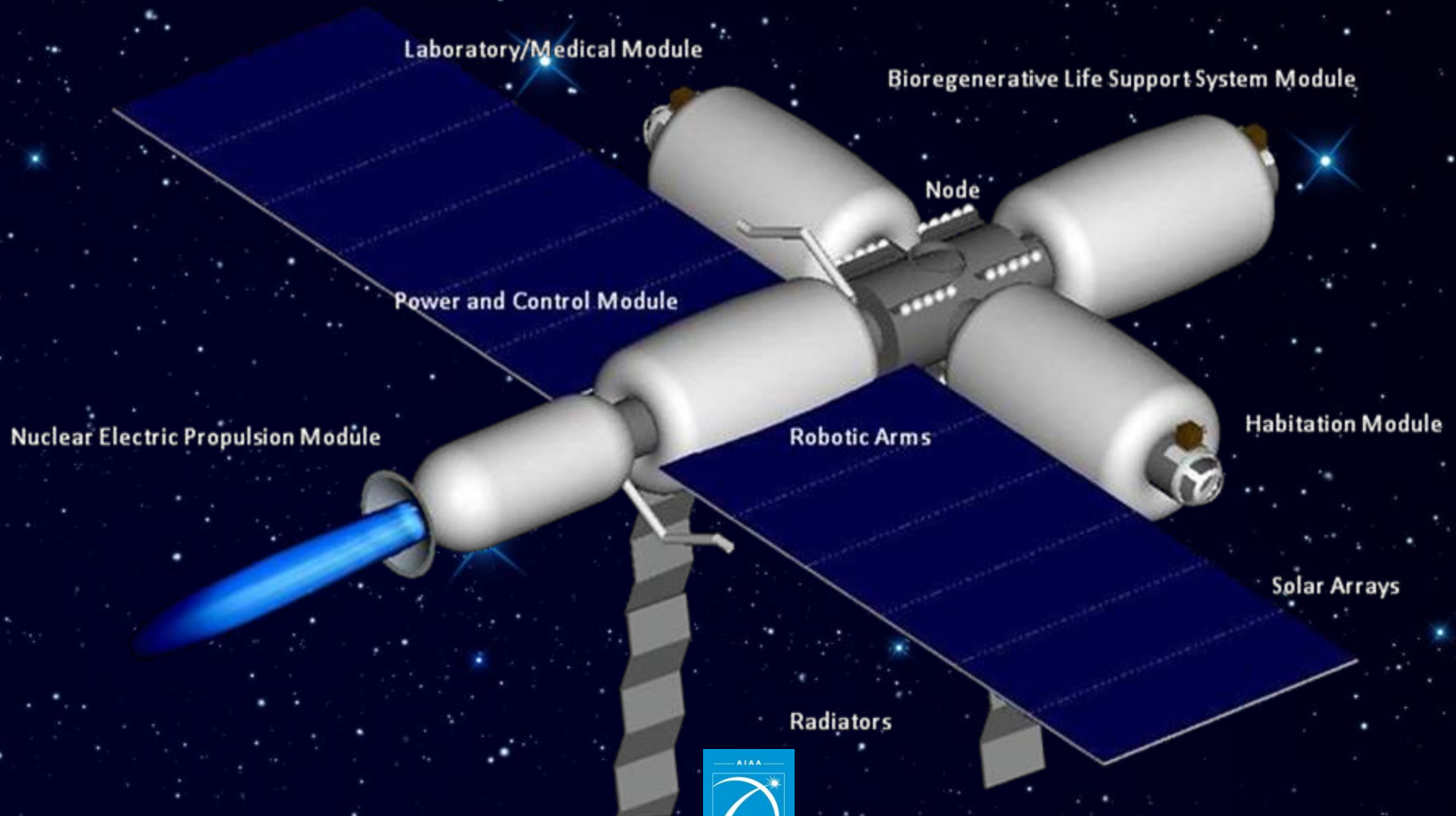
**September 13, 2012**  
**Perry Edmundson**

**Evolution of the  
Space Cruise Ship  
“Cosmic Mariner”**

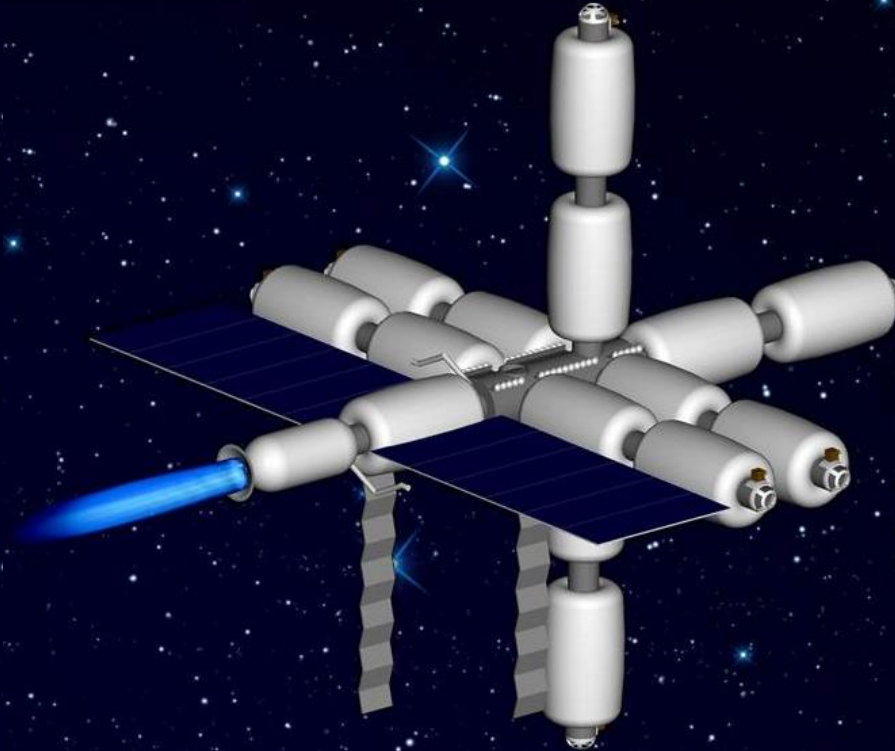
**Edmundson, P. &  
Thangavelu, M.**



# Main Elements



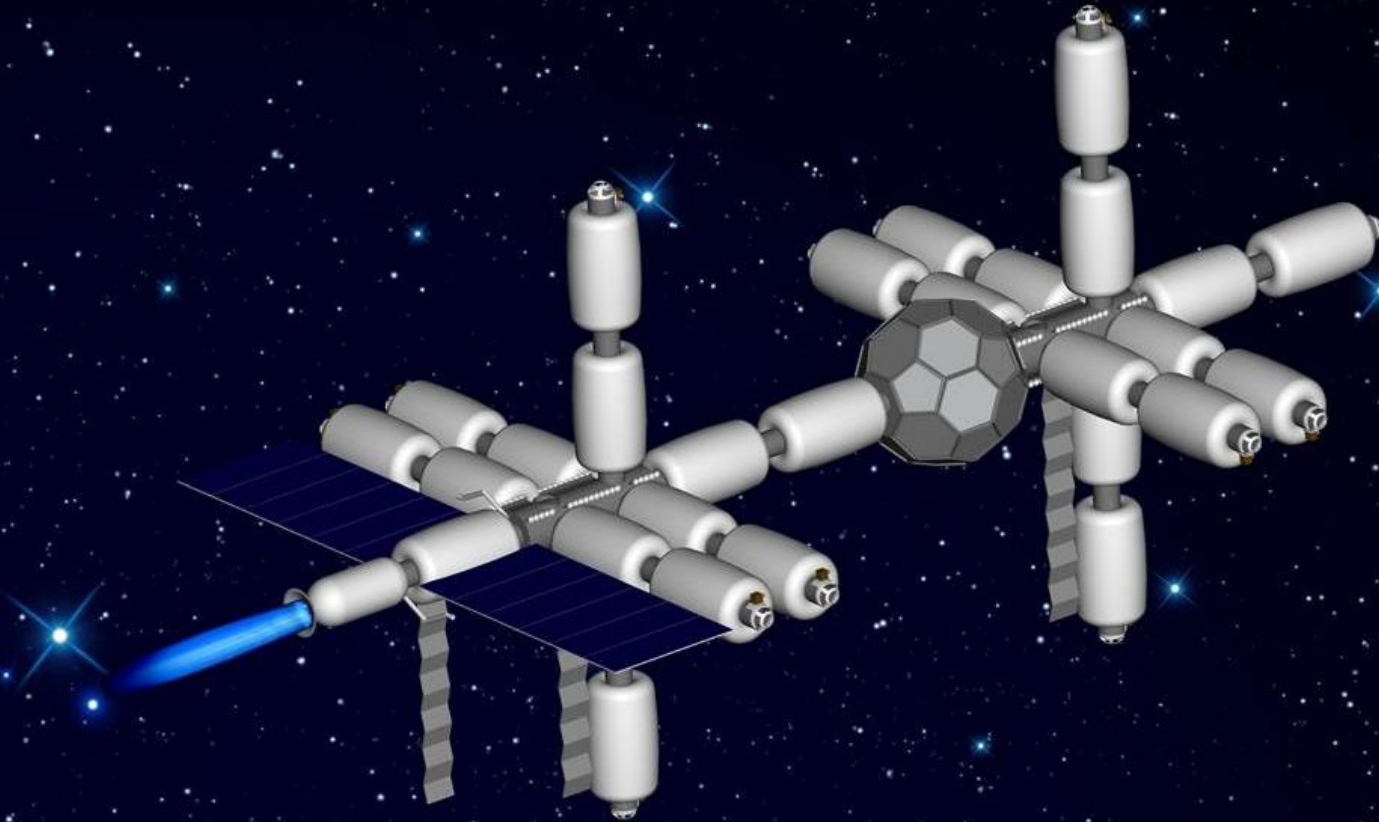
# Future Evolution



Expansion to accommodate 50 passengers for travel  
in cislunar space by 2030



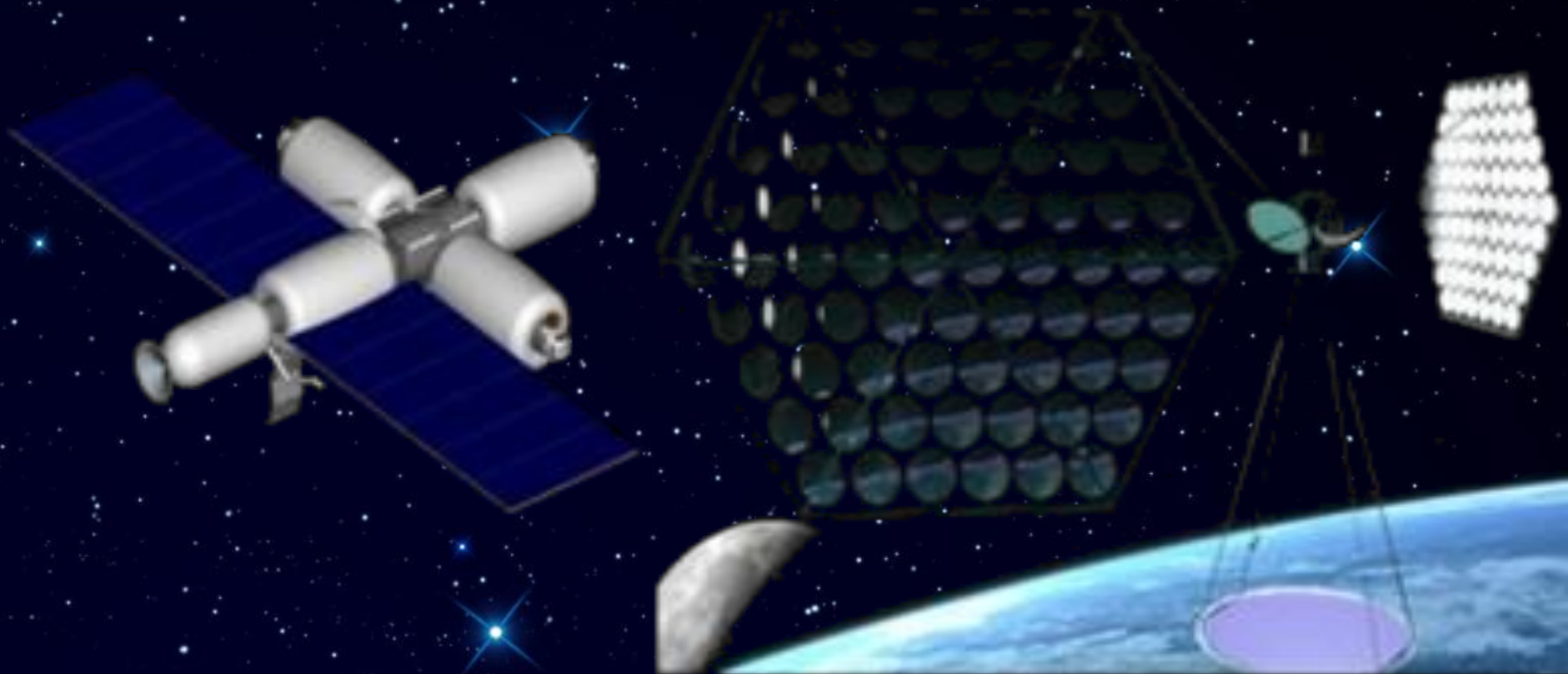
# Future Evolution



Expansion to accommodate 100 passengers for  
interplanetary travel by 2050

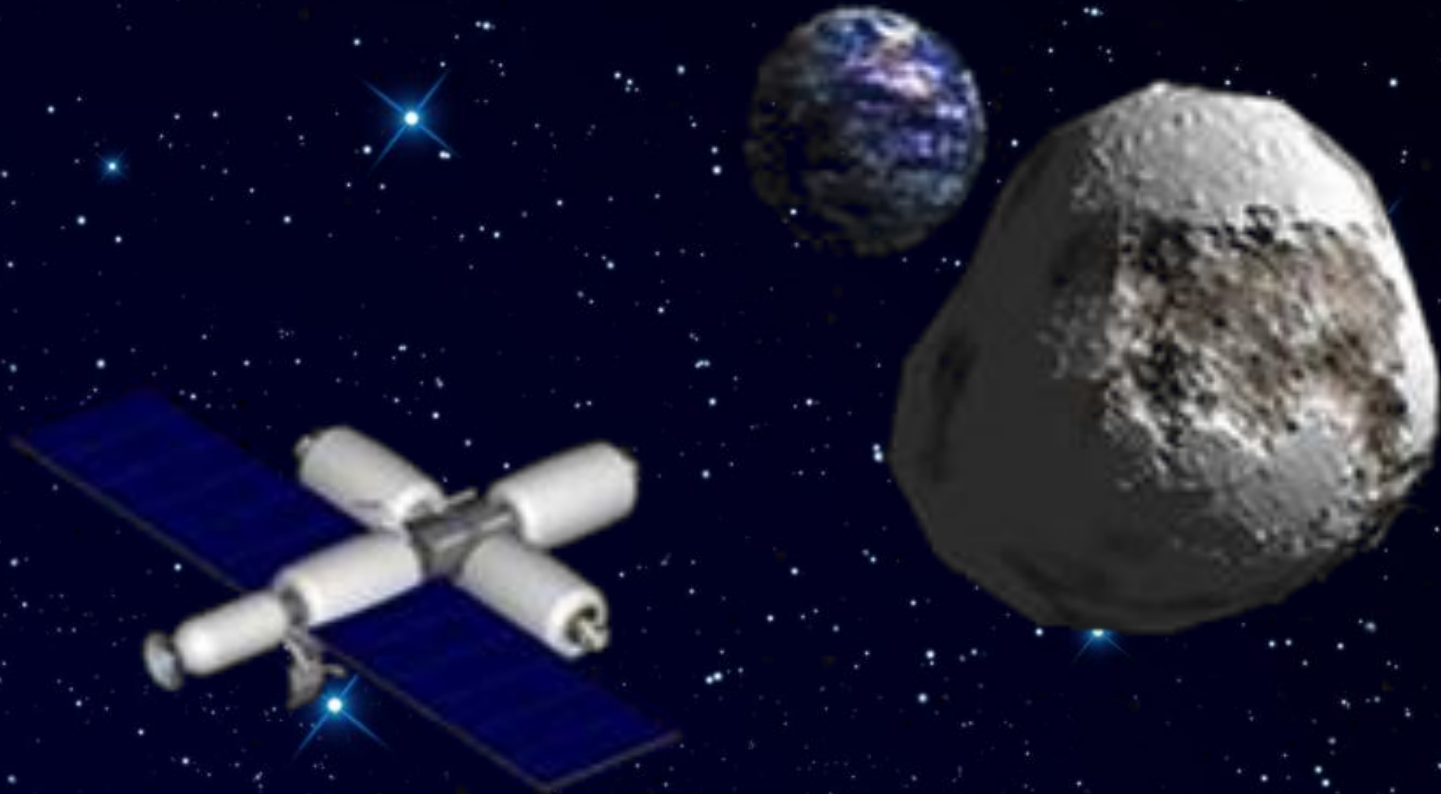


# Follow-on Missions



Support of Space-Based Solar Power Satellite  
Construction

# Follow-on Missions

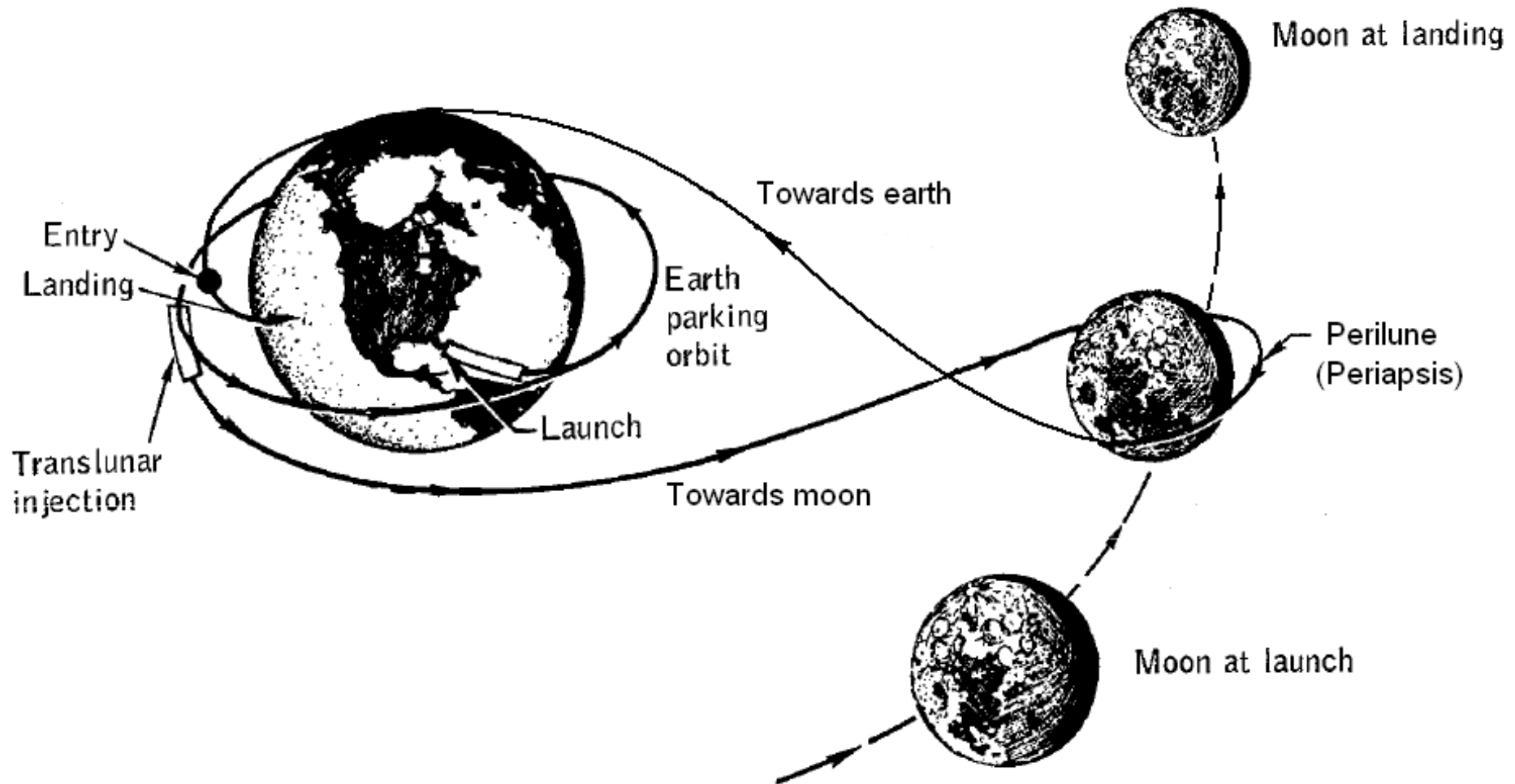


Exploration of Near-Earth Asteroids

# Cislunar Orbits

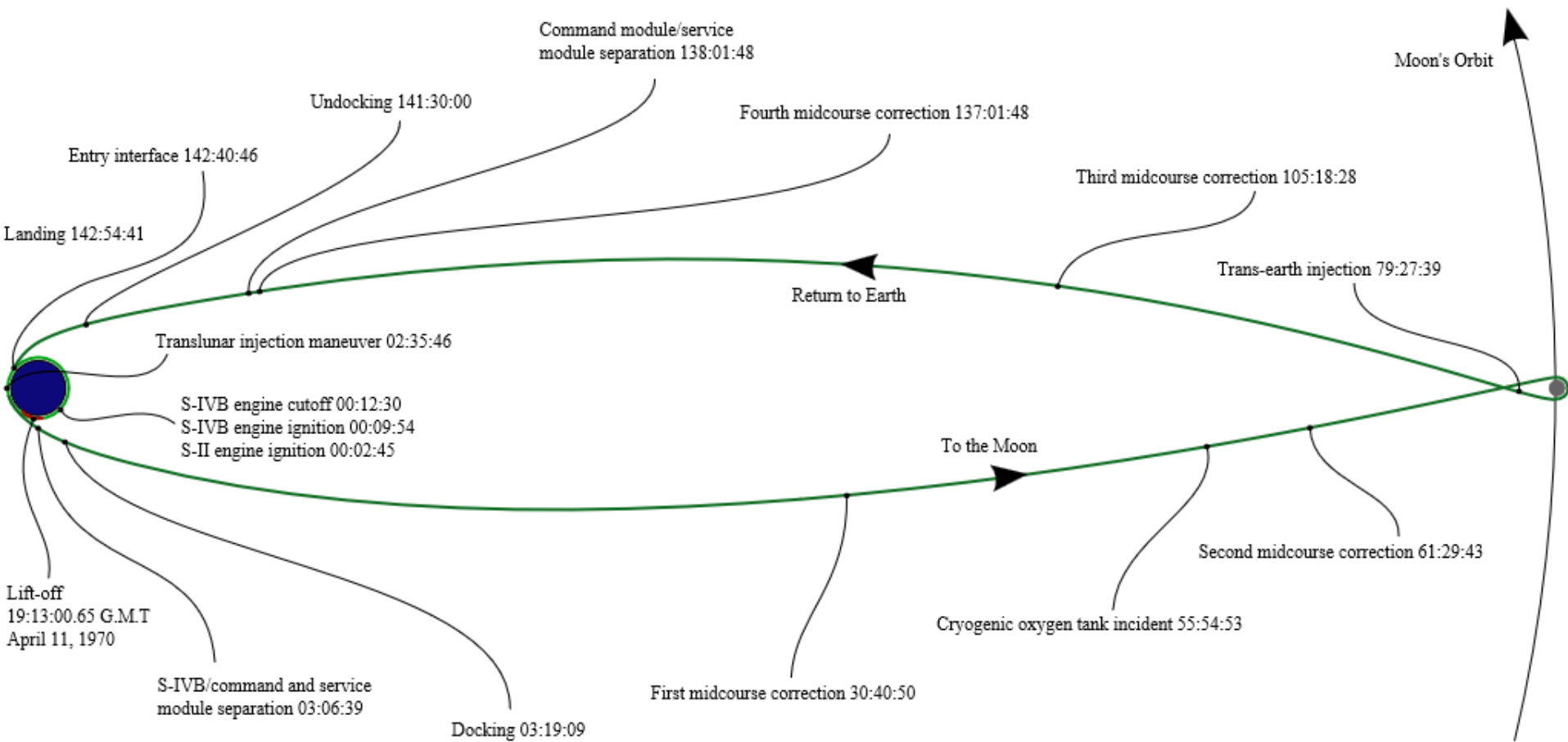
- Free Return
- Halo
- Lagrange
- Weak Stability Boundary
- Backflip
- Frozen Orbits
- Resonant Orbits
- Cycler

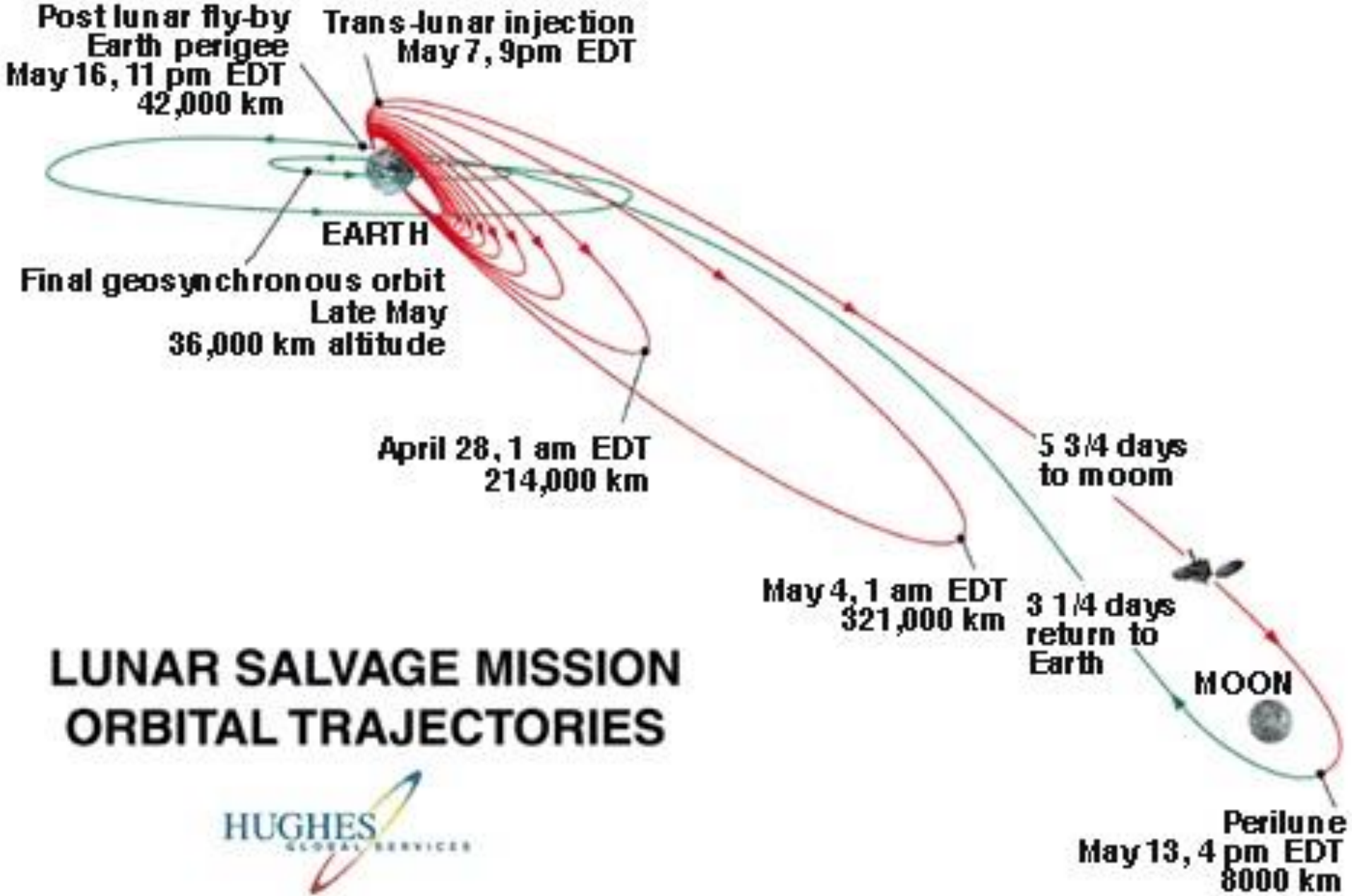
# Apollo Free Return Trajectory

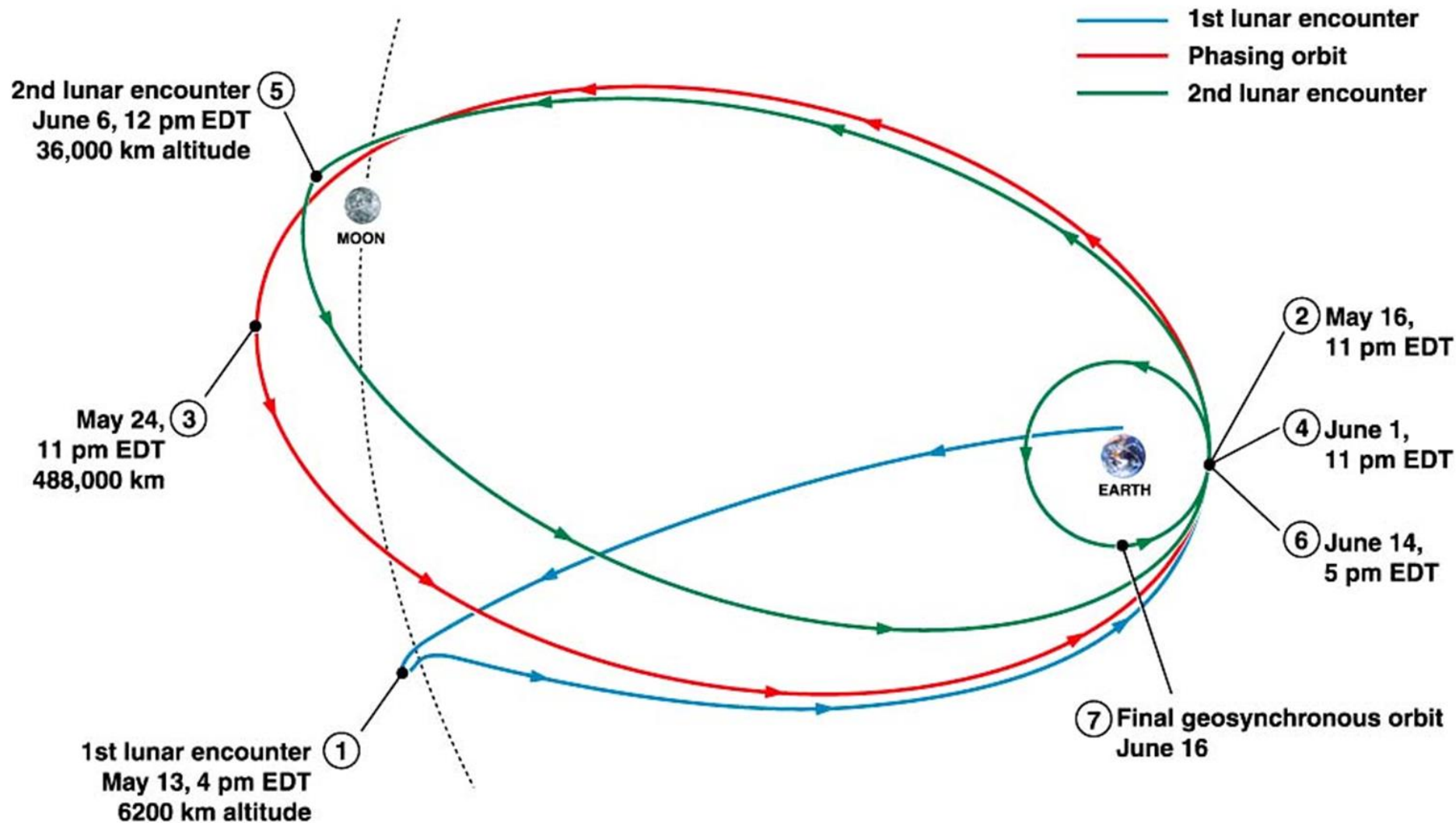




# Apollo 13 Free Return Timeline







## HGS-1 2nd LUNAR FLYBY ORBITAL TRAJECTORIES

# Supersynchronous Earth Orbit

- Beyond GSO
- High Eccentricity
- Resonant Period Design
- Cyclers





# MOBIUS

## An Evolutionary Strategy for Lunar Tourism

**Mehdi Lali, Madhu Thangavelu**

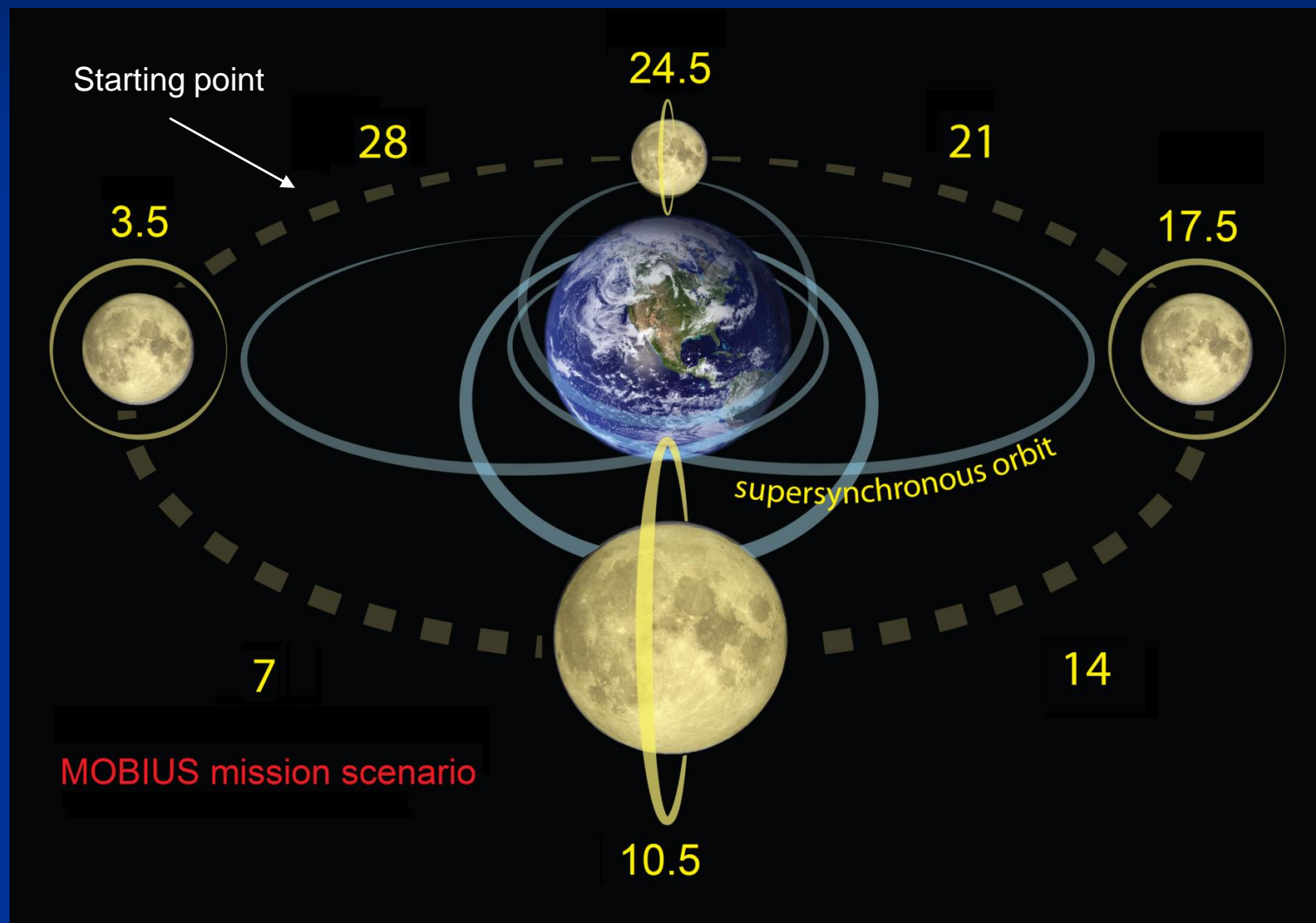
ASTE Department, Viterbi School of Engineering  
University of Southern California

**AIAA Space Conference, Long Beach CA, 2016**



# Mission Elements

Quartet of Resonant Supersynchronous Orbits



# MOBIUS Rationale

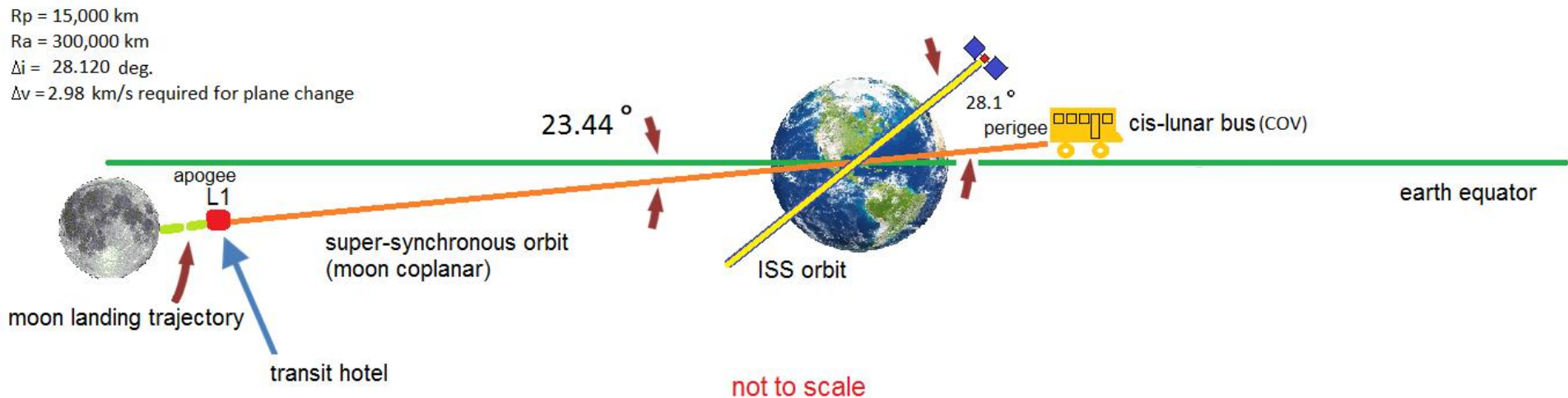
- Space Activity as opposed to Space Exploration
- Self-Sustainable Space Architecture
- Revenues from Missions used to fulfill Objective
- Use ISS beyond Retirement 2024
- Incremental Approach
  - Phase 1 - lunar approach
  - Phase 2 - lunar orbit
  - Phase 3 - lunar landing



# Mission Elements

## Cislunar Transit Orbit (CTO)

Edge-on illustration of MOBIUS Cislunar Transit Orbit (CTO)

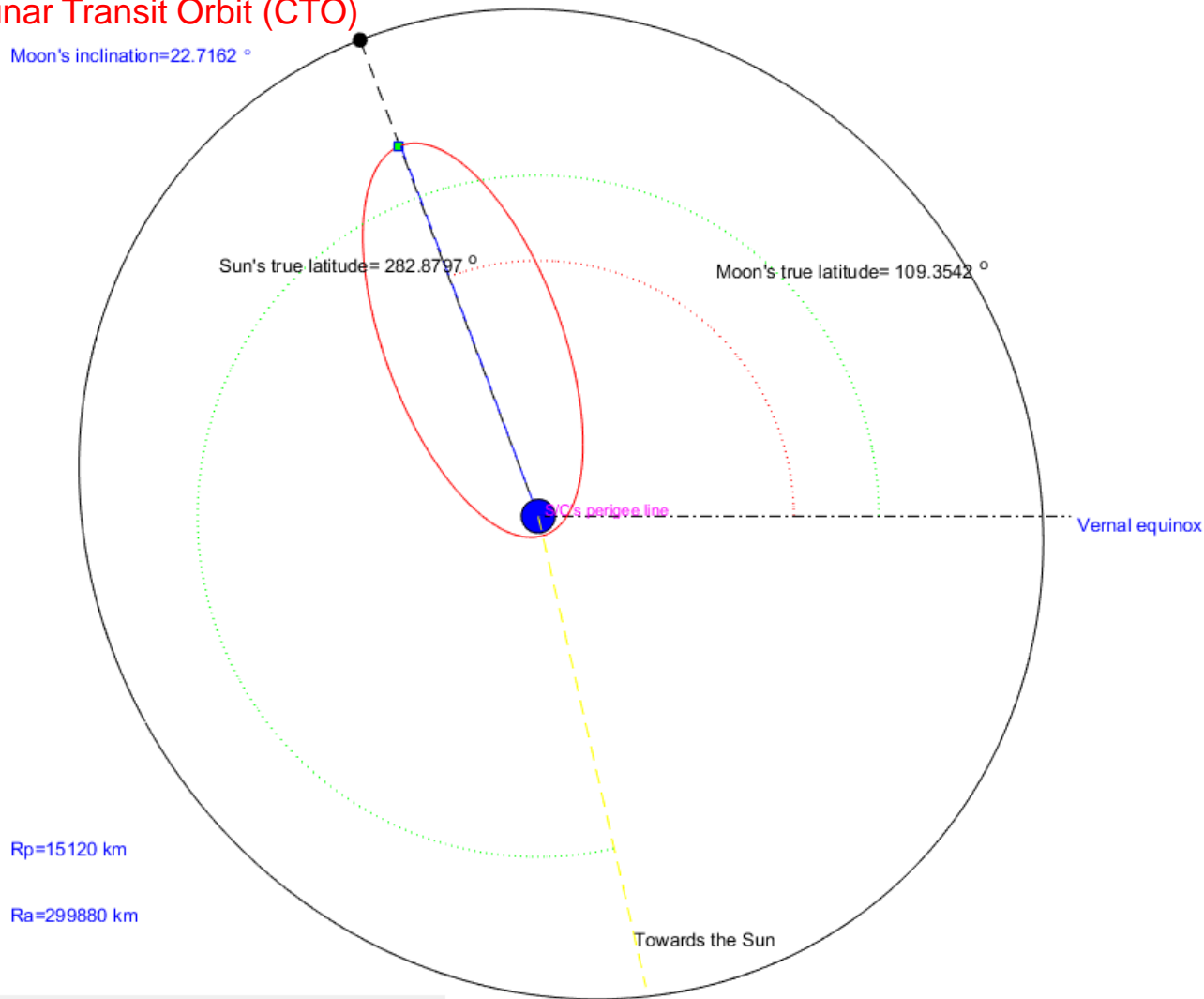




## Mission Elements - Earth-Moon Supersynchronous Orbit

- Cislunar Transit Orbit (CTO)

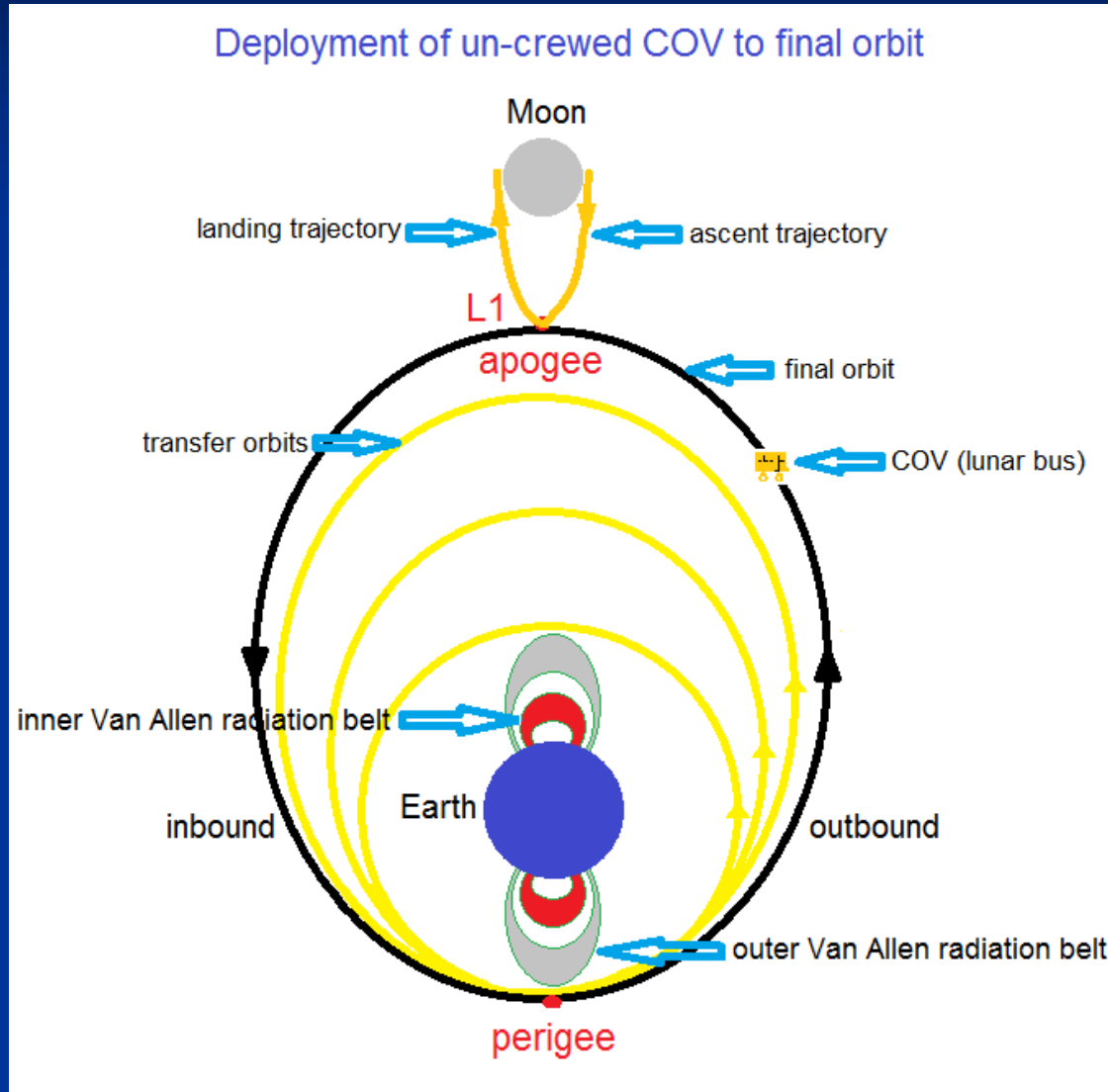
Moon's inclination=22.7162 °



Moon & S/C's positions in January 1, 2016 (UTC=00.00.00)



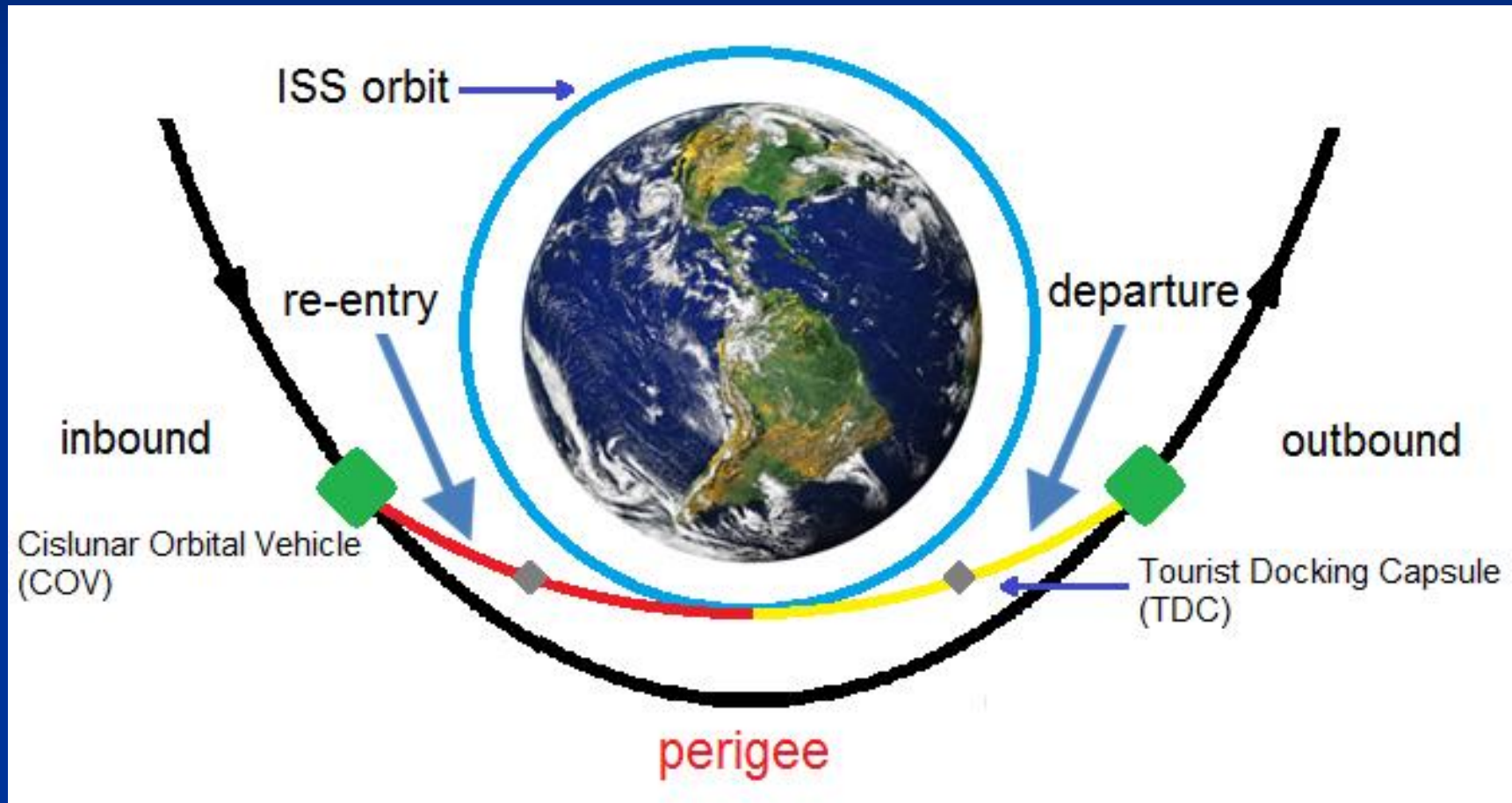
# Concept





# Concept

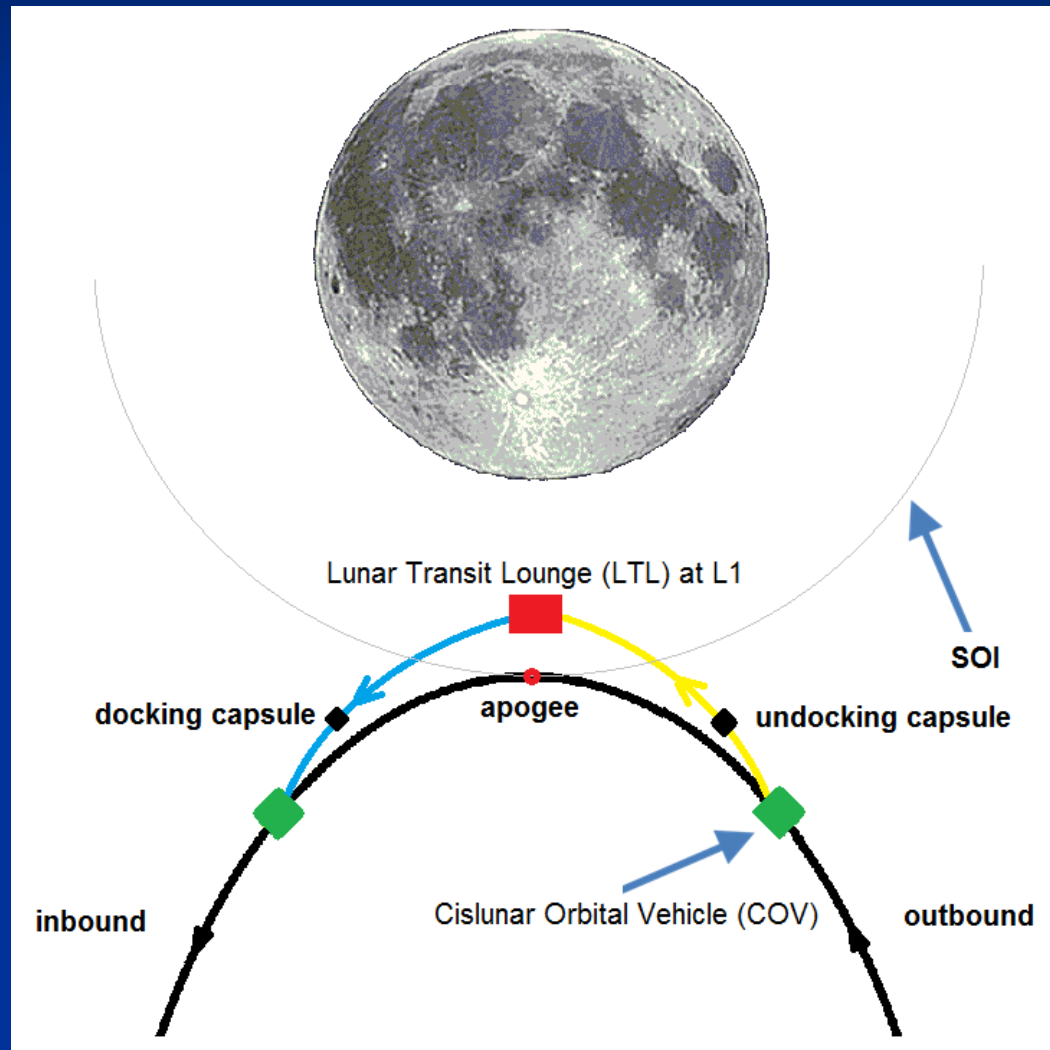
## Perigee Rendezvous





# Concept

## Apogee Rendezvous



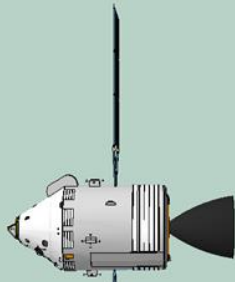




# Mission Elements

- The main elements of the proposed mission design architecture are as follows:
  - ❑ International Space Station (ISS)
  - ❑ Cislunar Orbital Vehicle (COV)
  - ❑ Tourist Docking Capsule (TDC)
  - ❑ Cislunar Propulsion System (CPS)
  - ❑ Lunar Transit Lounge (LTL)
  - ❑ Lander
  - ❑ Lunar surface facilities

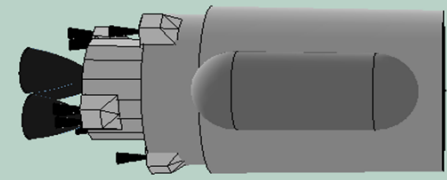
# MOBIUS Mission Elements



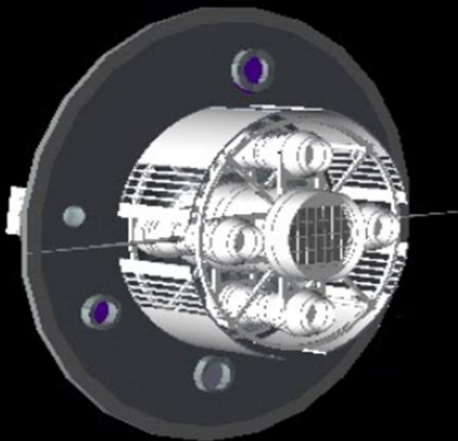
Orion /Dragon/New Glenn



Commercial ISS



Upper Stage



Lunar Transit Lounge



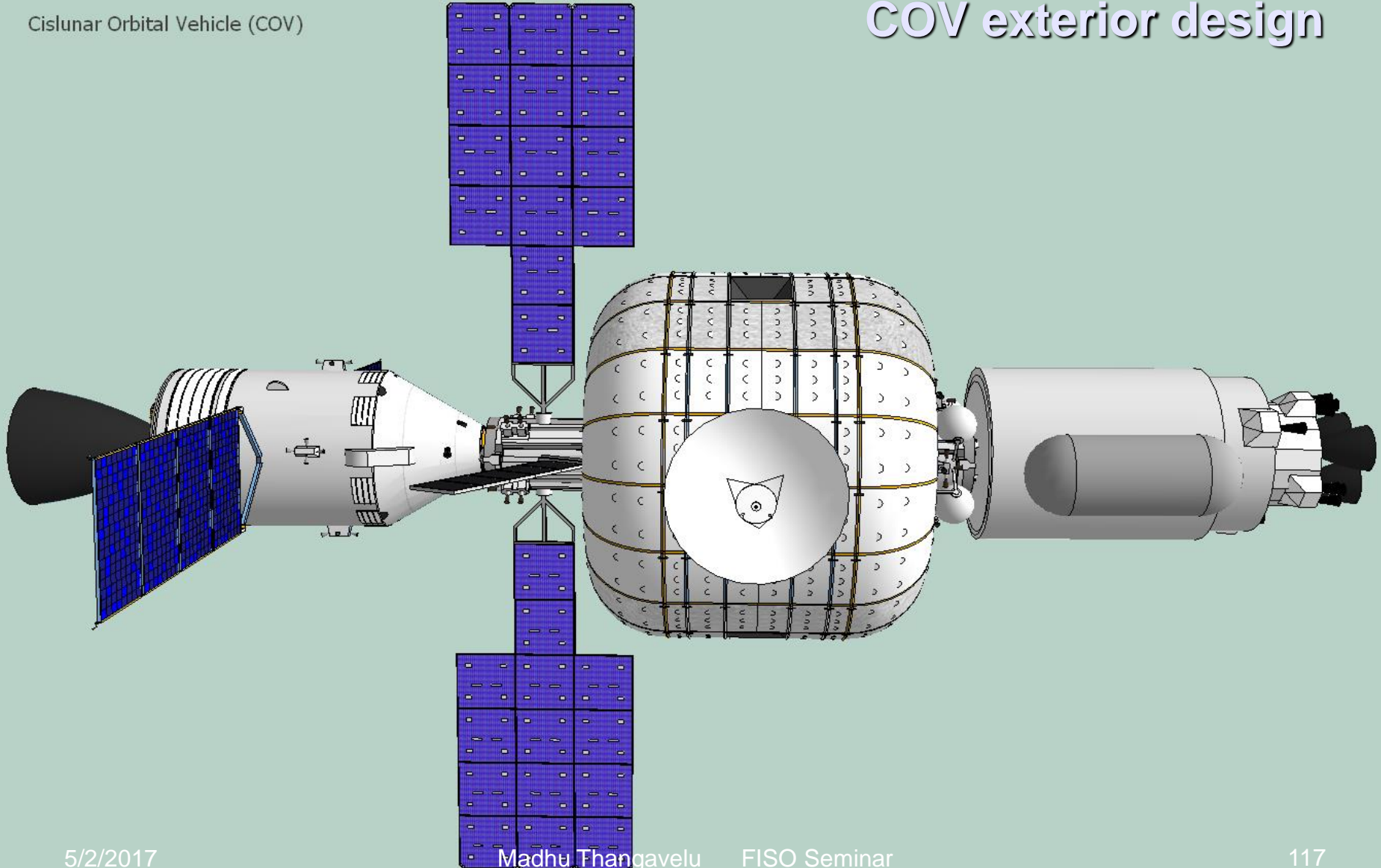
Lunar Lander



# Earth-Moon Transfer Orbit Habitat

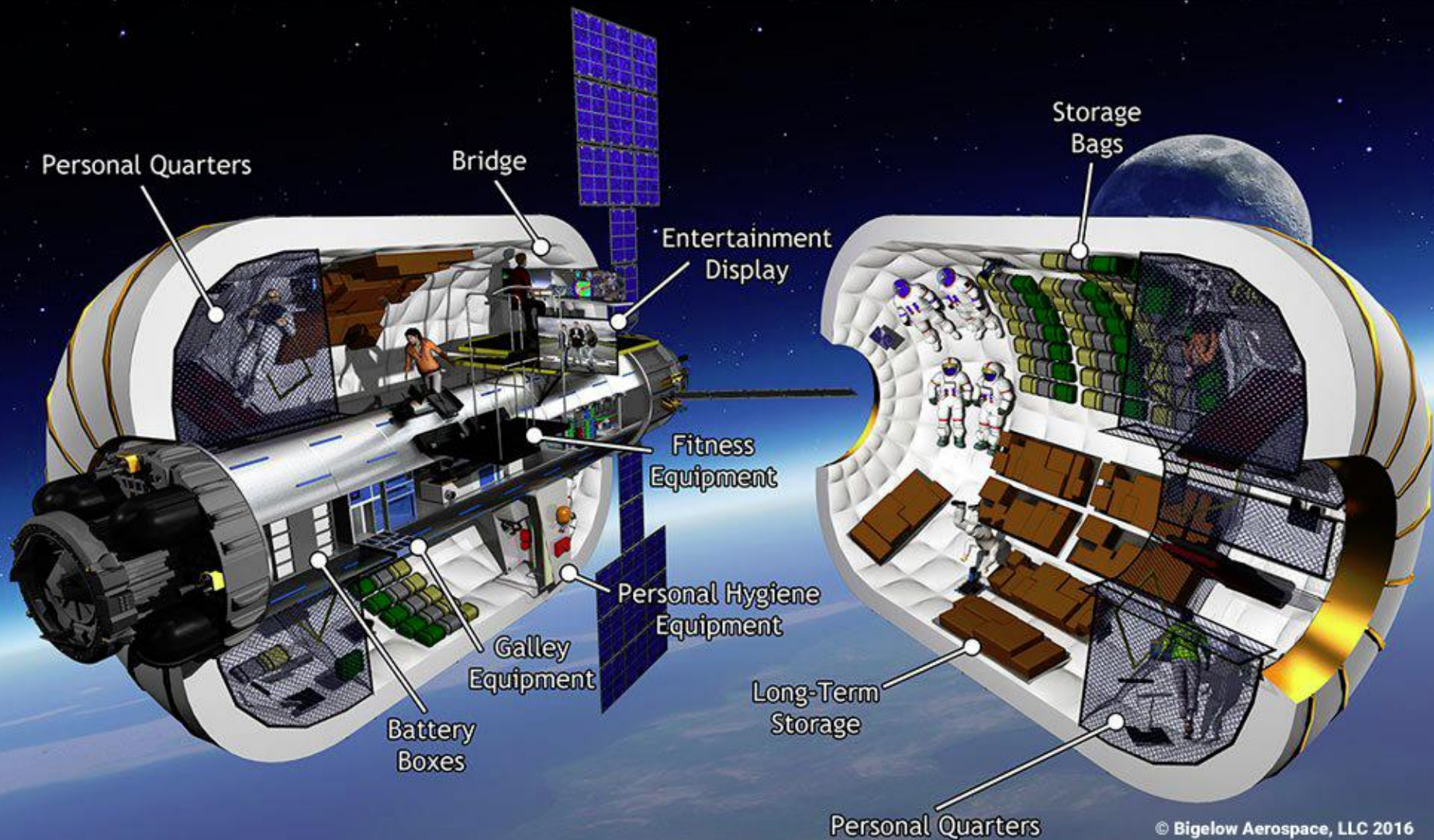
Cislunar Orbital Vehicle (COV)

COV exterior design





# Bigelow BA330 Reference



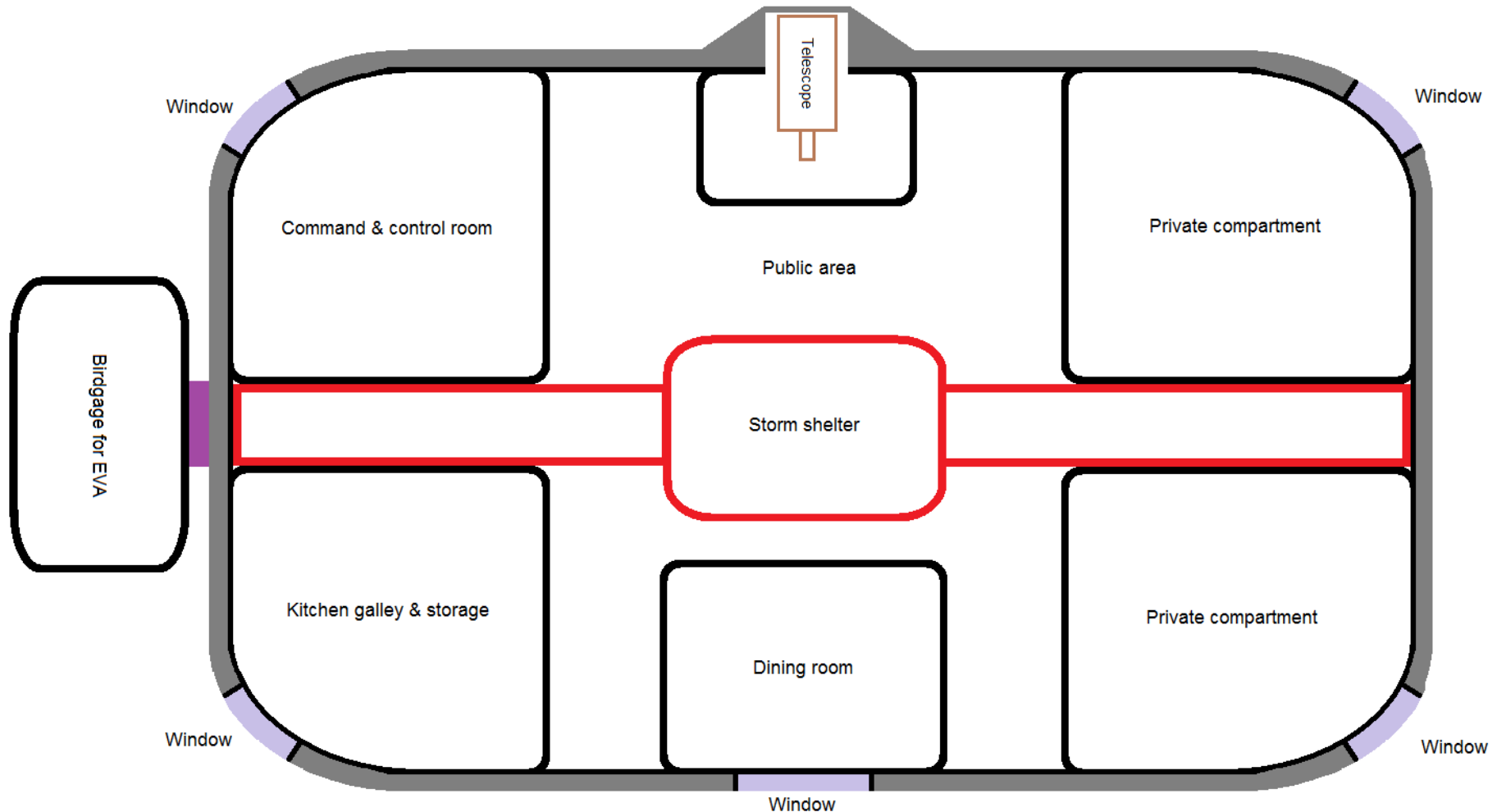




# Mission Elements

COV interior cutaway

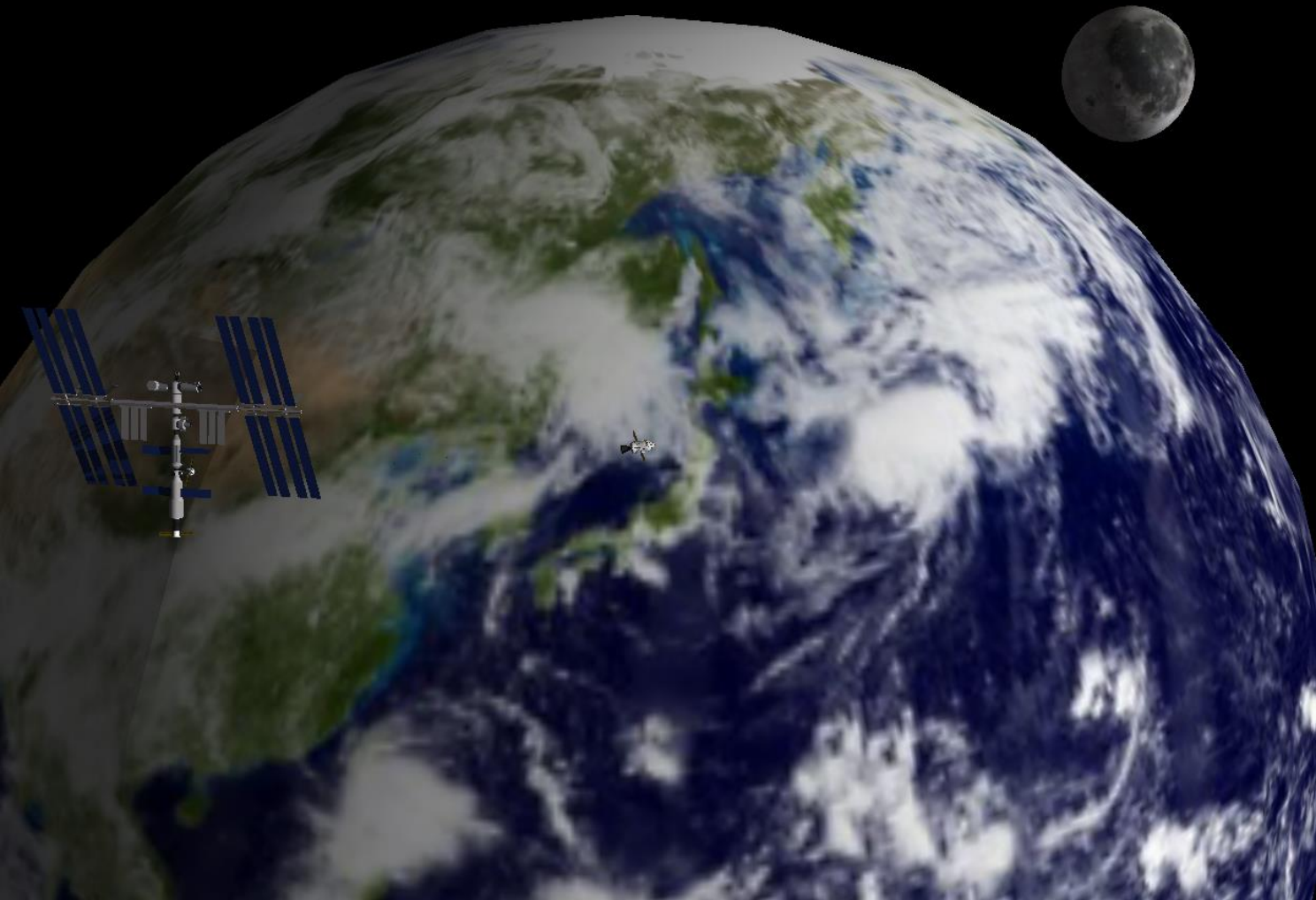
2D schematic of COV interior design





# Concept

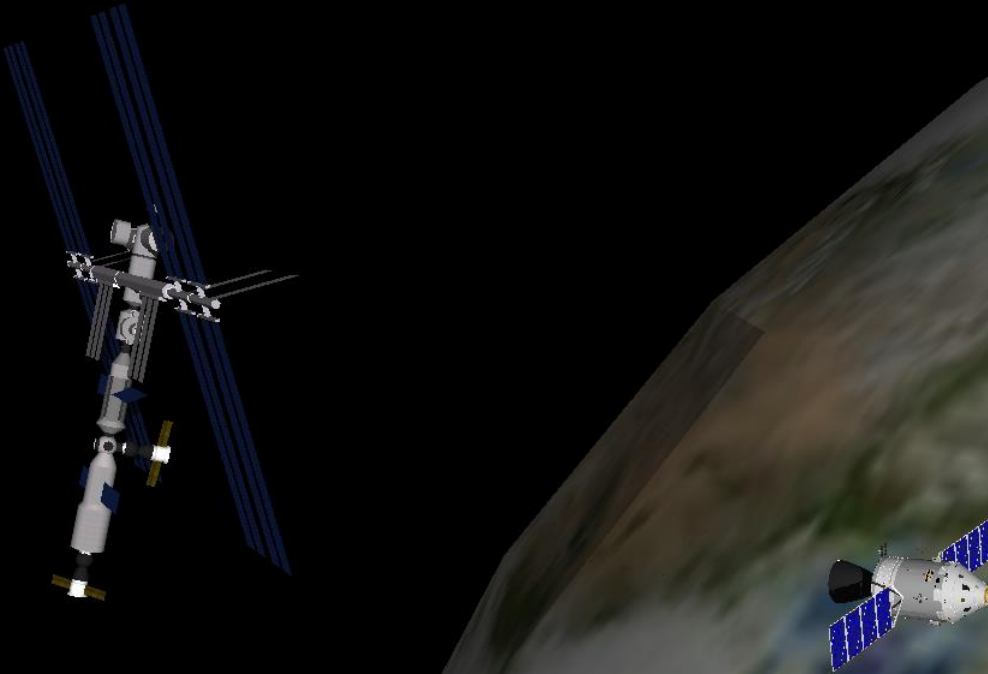
Capsule departs from the ISS





# Concept

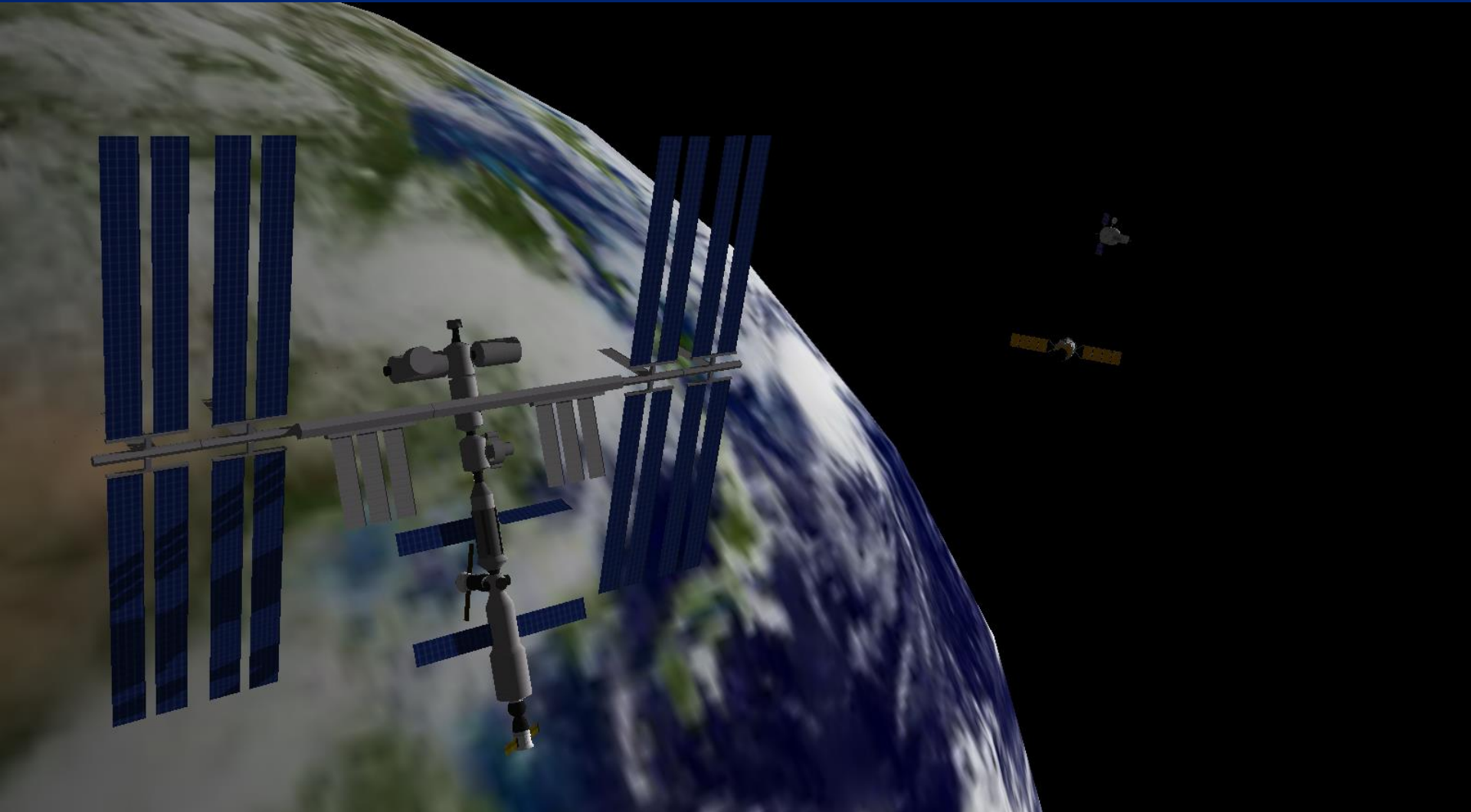
Capsule departs from the ISS





# Concept

Capsule departs from the ISS

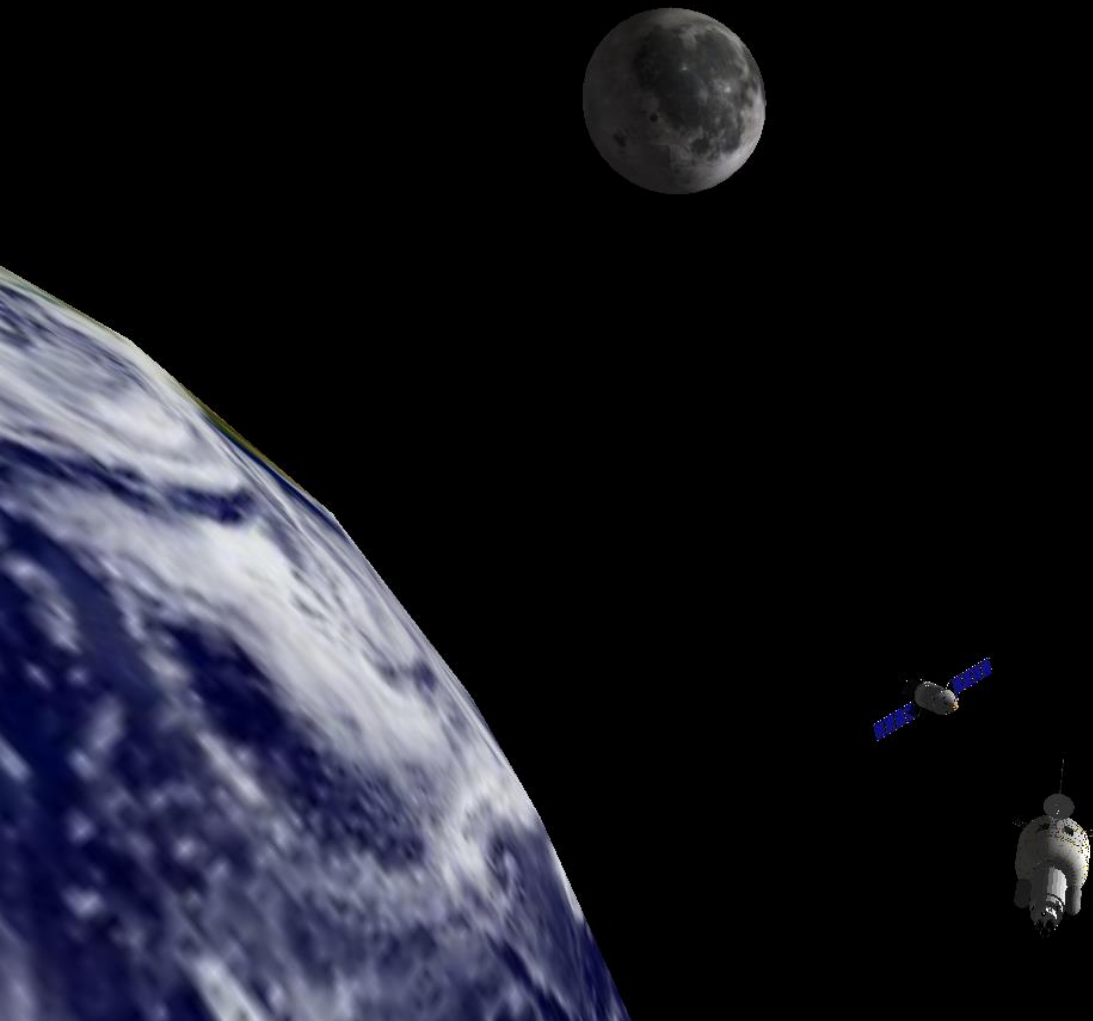






# Concept

Capsule is about to dock with COV





# Concept

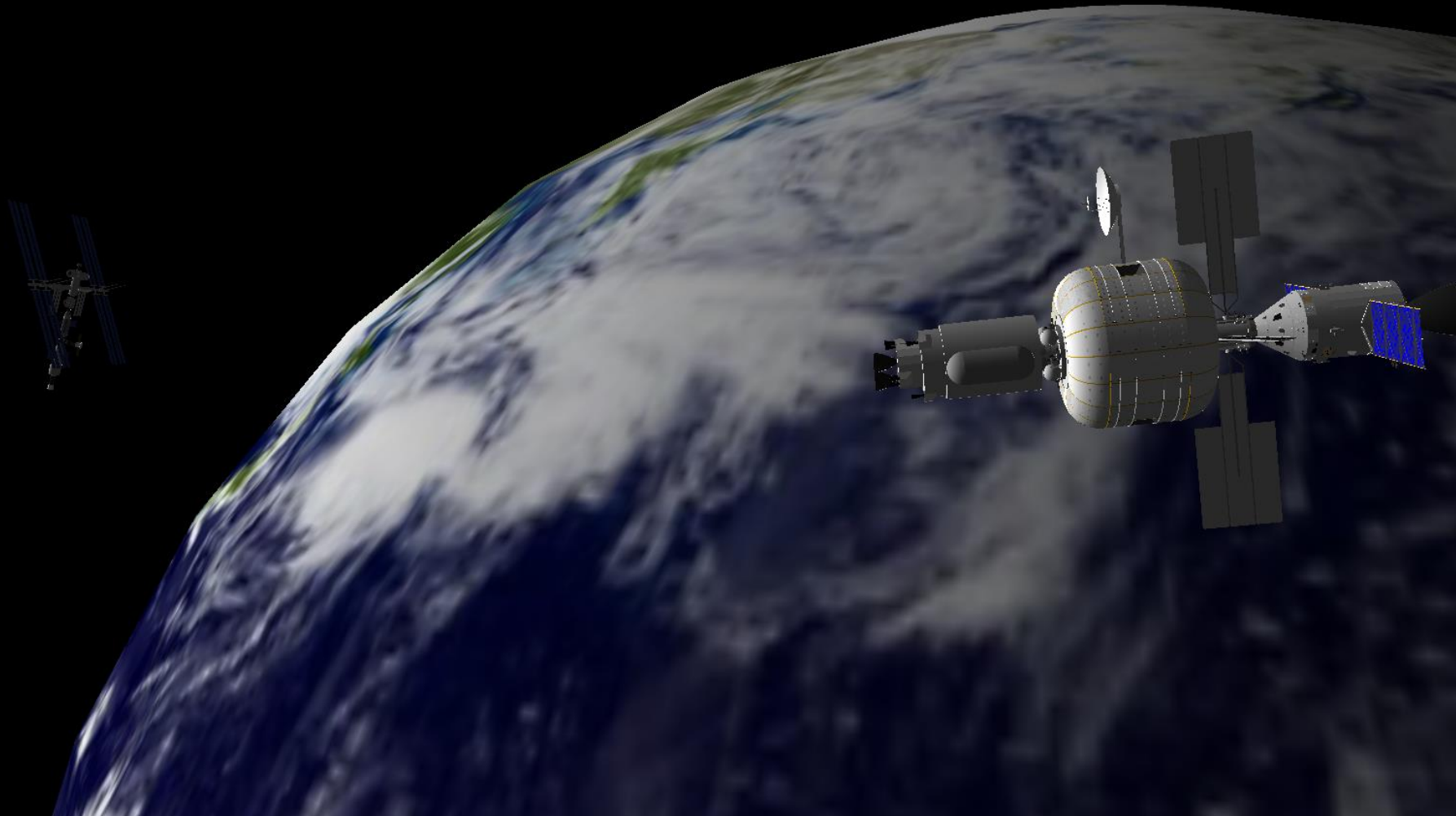
Capsule is docked with COV





# Concept

Ready for Cislunar Injection (CLI)





# Concept

On its way ...



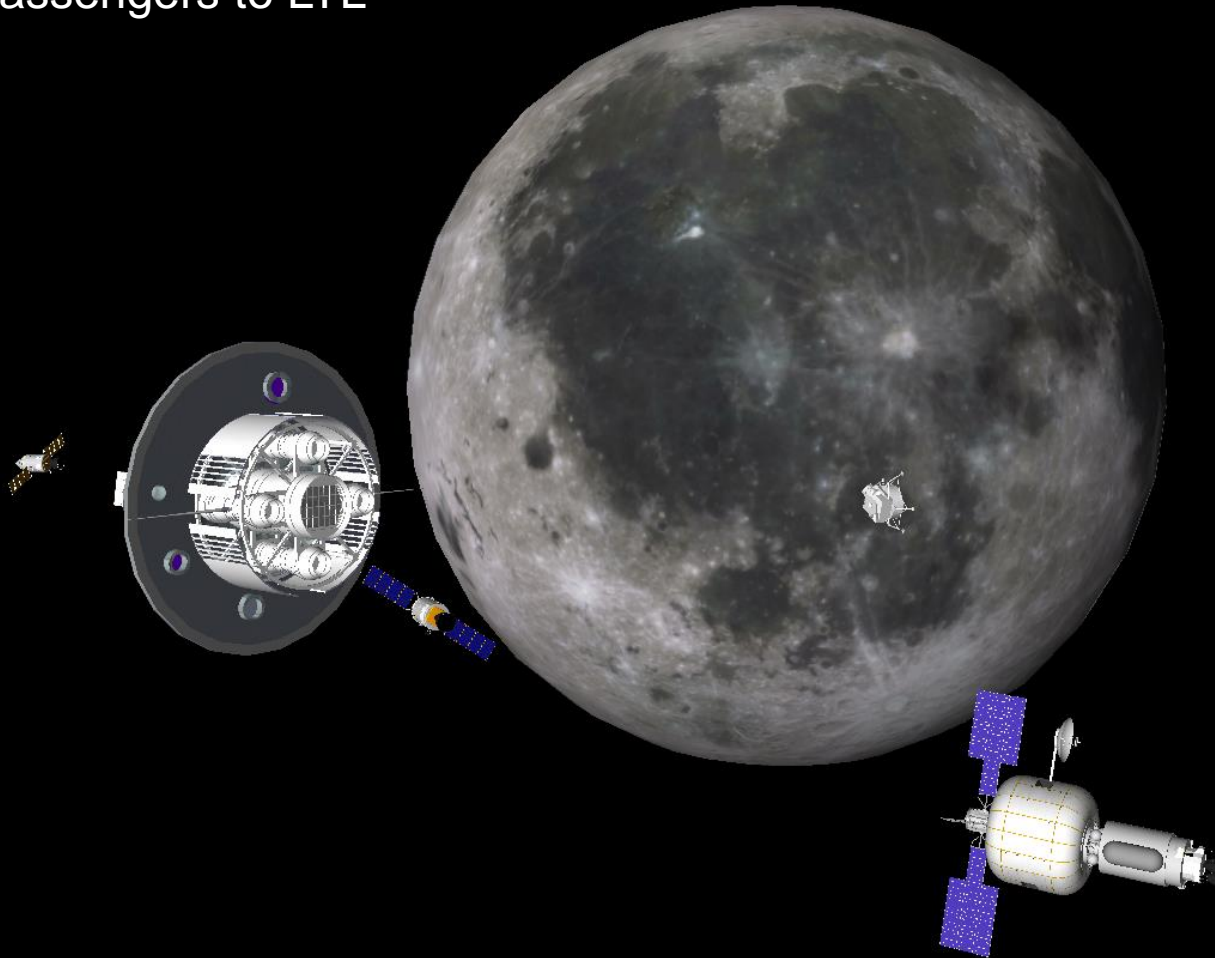




# Concept

## Apogee Rendezvous

Transferring passengers to LTL

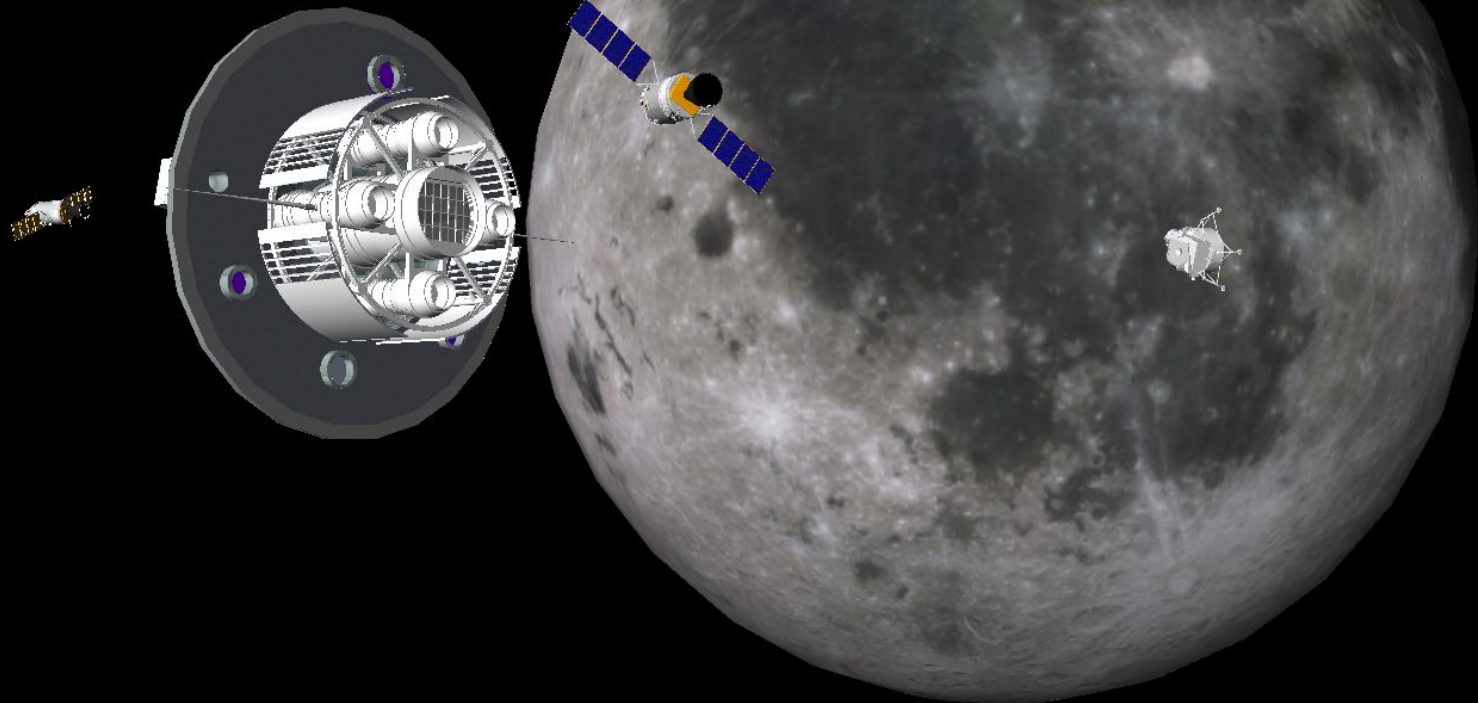




# Concept

## Apogee Rendezvous

Lunar Transit Lounge (LTL)





# Merits & Limitations

- Optimal
- Affordable
- Feasible with current technologies
- Viable
- Free Return Trajectory- If there is an injection anomaly, the vehicle stack will return to Earth orbit without help for abort.





# Merits & Limitations

- Evolutionary, phased approach-maximize revenue operating budget.
- Requires a little station-keeping due to RAAN precession over time.
- Plane change at perigee can be costly unless ISS' inclination is changed after retirement to be aligned with that of the Moon.
- Earth's Van Allen Belt could be challenging so proper shielding is essential.







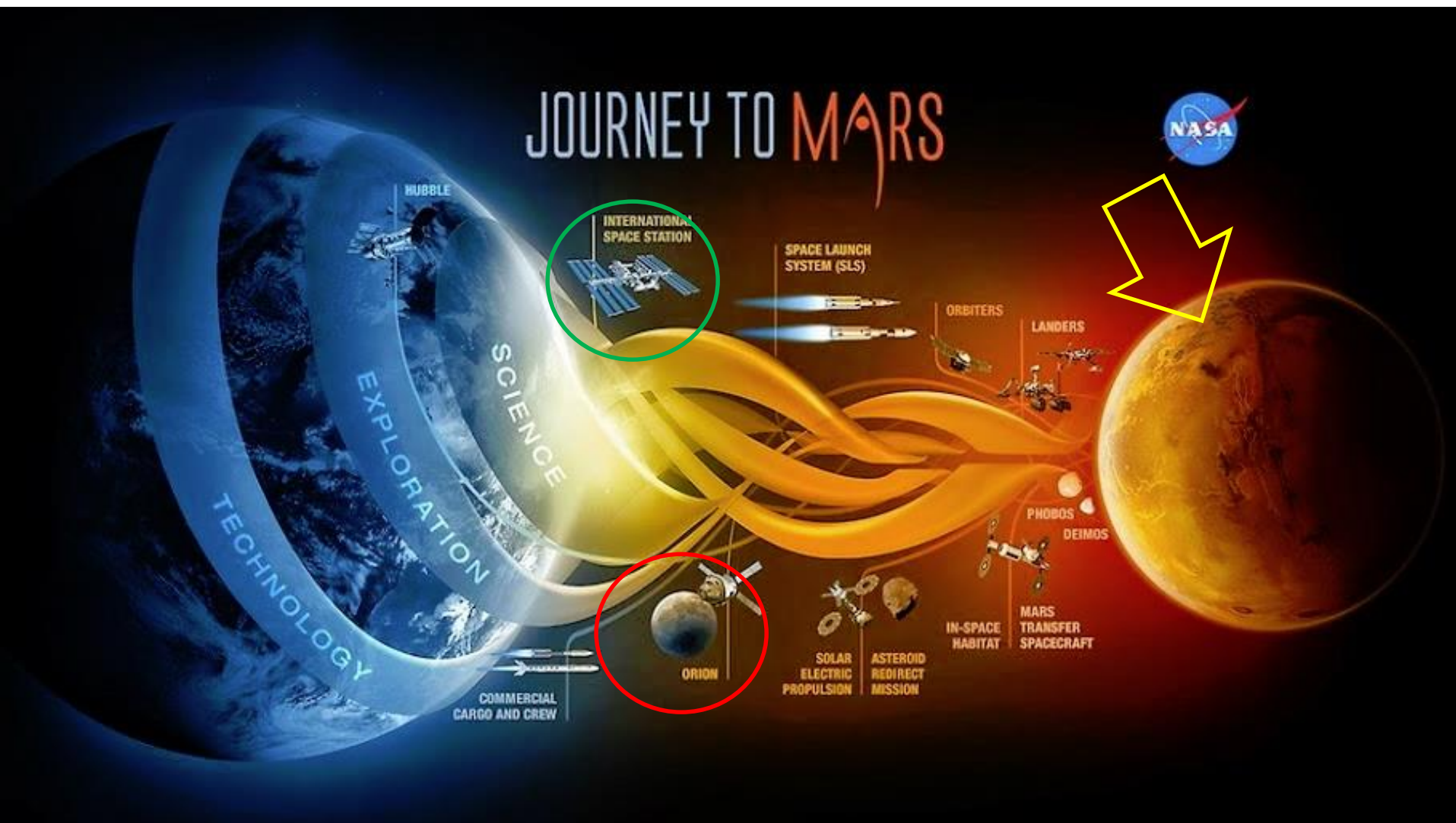
# Questions, Comments?

Welcome to the future of lunar tourism!



Mehdi Lali  
Astronautical Engineering Department  
University of Southern California  
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# Evolution - From Here to There Before



# Acknowledgement

- This concept was developed by Mehdi Lali, graduate student in the ASTE527 Graduate Space Architecting Studio (aka Space Concepts Creation Studio) in Department of Astronautical Engineering within the Viterbi School of Engineering at USC. Studio slides may be accessed at :  
<https://sites.google.com/a/usc.edu/aste527/home>
- Look under team project “LunaRevolution”



# References

- Aldrin, Thangavelu et al., (2001) [http://buzzaldrin.com/files/pdf/2001.12.15.REPORT\\_FOR\\_NASA-JPL\\_Evolutionary\\_Space\\_Transportation\\_Plan\\_for\\_Mars\\_Cycling\\_Concepts.pdf](http://buzzaldrin.com/files/pdf/2001.12.15.REPORT_FOR_NASA-JPL_Evolutionary_Space_Transportation_Plan_for_Mars_Cycling_Concepts.pdf)
- Barrucco, M.,(2010)Earth Station: Global ISS Marketing, Future of Human Spaceflight, A Lunar Cruise, Space Concepts Studio Final Presentation, USC ASTE 527.
- Bate, R, Mueller, D, White, J, (1971) Fundamentals of Astrodynamics, Dover publications, Inc.
- Belbruno, E., Carrico, J.,(2000) Calculation of weak stability boundary ballistic lunar transfer trajectories Read More: <http://arc.aiaa.org/doi/abs/10.2514/6.2000-4142>
- Chobotov, V.A.,(2002) Editor, Orbital Mechanics, (AIAA Education) 3rd Edition, ISBN-13: 978-1563475375
- CLIA(2015) Cruise Line International Association 2014 North American Cruise Market Profile, [http://www.cruising.org/docs/default-source/research/clia\\_naconsumerprofile\\_2014.pdf](http://www.cruising.org/docs/default-source/research/clia_naconsumerprofile_2014.pdf)
- Cohen, M.,(2008) Testing the Celentano Curve:An Empirical Survey of Predictions for Human Spacecraft Pressurized Volume, SAE Technical Paper Series, 2008-01-2027, [http://www.astrotechture.com/Human\\_System\\_Integration\\_files/SAE-2008-01-2027%20\(2\)\\_1.pdf](http://www.astrotechture.com/Human_System_Integration_files/SAE-2008-01-2027%20(2)_1.pdf)
- Cornelisse, J.W, Rocket propulsion and spaceflight dynamics,(1979) ISBN 13: 9780273011415 Pitman Pub.
- Craig, D.(2016) An Overview of NASA's Evolvable Mars Campaign, FISO talk, [http://images.spaceref.com/fiso/2015/061015\\_doug\\_craig\\_nasa\\_hq/Craig\\_6-10-15.pdf](http://images.spaceref.com/fiso/2015/061015_doug_craig_nasa_hq/Craig_6-10-15.pdf)
- Cruzan, J.,(2016) Evolvable Mars Campaign and Technology Development, Director, Advanced Exploration Systems Human Exploration & Operations Mission Directorate NASA Headquarters, [https://www.nasa.gov/sites/default/files/atoms/files/jcrusan\\_evolvablemarsstrategy.pdf](https://www.nasa.gov/sites/default/files/atoms/files/jcrusan_evolvablemarsstrategy.pdf)
- <http://www.nap.edu/catalog/18801/pathways-to-exploration-rationales-and-approaches-for-a-us-program>
- Dorfman, S.(2013) AsiaSat-3 Rescue: The Real Story Part 1
- <http://www.hughescgheritage.com/asiasat-rescue-the-real-story-part-1/>
- Dorfman, S.(2013) AsiaSat-3 Rescue: The Real Story Part 2
- <http://www.hughescgheritage.com/asiasat-3-rescue-the-real-story-part-2/>
- Edmundson, P, and Thangavelu, M.,(2012), Cosmic Mariner, AIAA Space 2012, Long Beach CA
- Gerstenmaier, W.,(2016) Statement by: NASA at a Crossroads: Reasserting American Leadership in Space Exploration, Statement of William H. Gerstenmaier Associate Administrator for Human Exploration and Operations National Aeronautics and Space Administration before the Subcommittee on Space, Science, and Competitiveness Committee on Commerce, Science, and Transportation United States Senate.

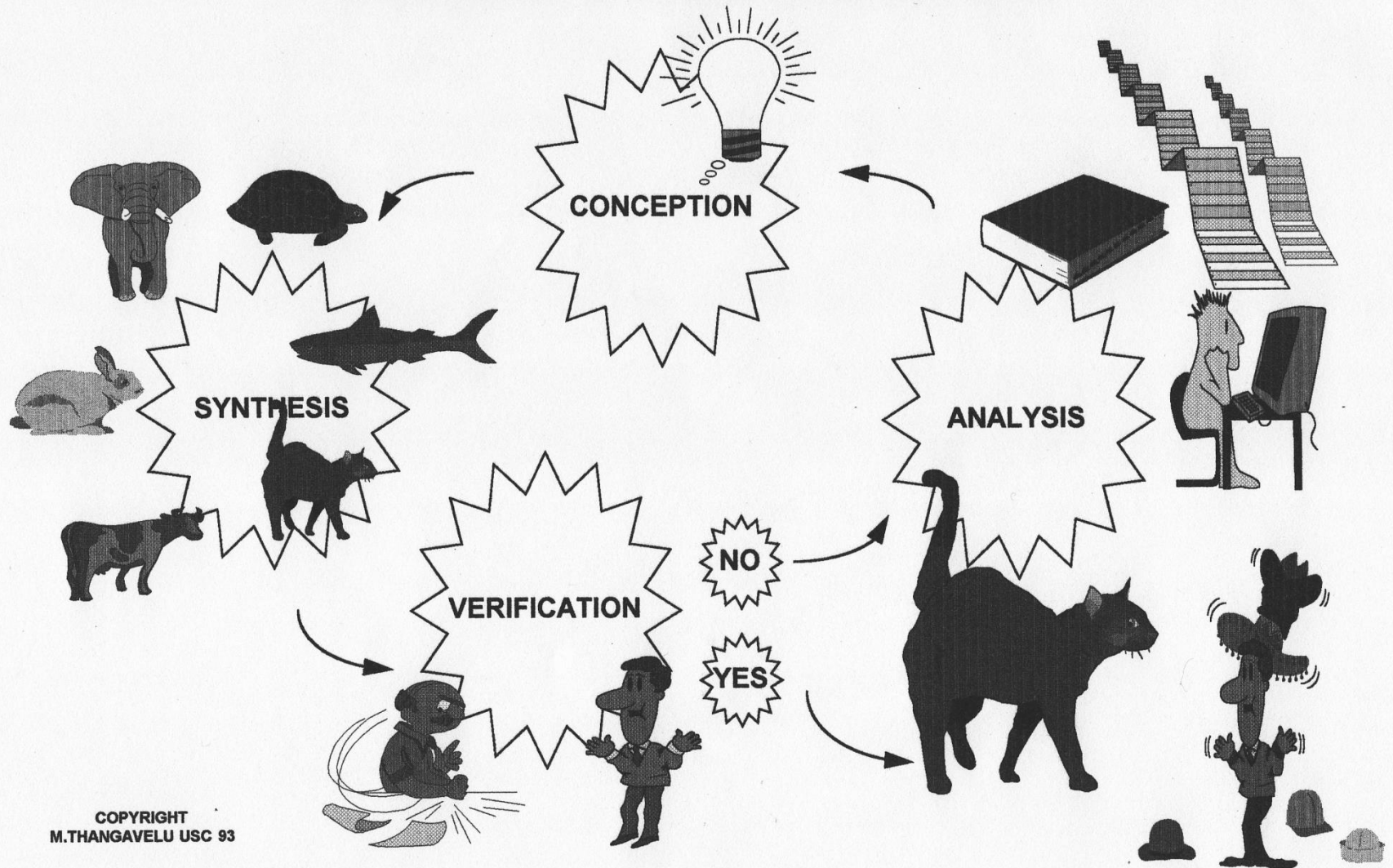


- Lali, M. and Thangavelu, M.(2016) MOBIUS:An Evolutionary Strategy for Lunar Tourism, AIAA Space 2016, Long Beach, CA
- Leib, Ely and Leib Erica(2005) Stable Constellations of Frozen Elliptical Inclined Lunar Orbits, Journal of the Astronautical Sciences, vol. 53, No. 3, July-Sept 2005, pp. 301-316
- Lieb, E&E.,(2005)Constellations of Elliptical Inclined Lunar Orbits Providing Polar and Global Coverage Paper AAS 05-343, AAS/AIAA Astrodynamics Specialists Conference, August 7-11, 2005.
- Marburger III, J.,(2006) Keynote Address, 44th Robert H. Goddard Memorial Symposium, Director, Office of Science and Technology Policy, Executive Office of the President, The White House.
- Mendell, W.,(1985) Ed. Lunar Bases and Space Activities of the 21st Century, Lunar and Planetary Institute, 1985
- NASA SP NASA SP-509(1992) Scenarios Space Resources, McKay, McKay and Duke eds.,  
<https://settlement.arc.nasa.gov/scenarios/preface.html>
- Nock, Kerry.,(2002)Express Transportation Architecture For Human Mars Exploration <http://www.gaerospace.com/space-exploration/express-transportation-architecture-for-human-mars-exploration/>
- OST Inc., <http://www.ostinc.com/#!rocketost/c1vw1>
- Rehtin, E.(1990) Systems Architecting: Creating & Building Complex Systems, <https://www.amazon.com/Systems-Architecting-Creating-Building-Complex/dp/0138803455>, Prentice Hall,
- Roukos, D., and Thangavelu, M.,(2010) The International Space Transit Vehicle, AIAA Space 2010, Long Beach, CA
- Schrunk, Sharpe, Cooper, Thangavelu(2007) The Moon: Resources, Future Development and Settlement,  
<https://www.amazon.com/Moon-Resources-Development-Settlement-Springer/dp/0387360557>
- Ridenoure, R.,(2013) Beyond GEO, commercially: 15 years... and counting, The Space Review,  
<http://www.thespacereview.com/article/2295/1>
- Salvatore, J.,(2013) The Chief Technologist's view of the HGS-1 mission, The Space Review  
[http://www.hughesscgheritage.com/asiasat-3-rescue-the-real-story-part-2/Hughes Aircraft Co.](http://www.hughesscgheritage.com/asiasat-3-rescue-the-real-story-part-2/Hughes_Aircraft_Co)
- Thangavelu, M.,(1990) MALEO: Modular Assembly in Low Earth Orbit A Strategy for and IOC Lunar Base,  
<http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19910012857.pdf>
- Thangavelu, M., etal., (2012) Architectural Concepts Employing Co-Robot Strategy and Contour Crafting Technologies for Lunar Settlement Infrastructure Development, AIAA Space 2012 Conference, Pasadena, CA.,
- Uphoff, C., Crouch M.A., (1991) Lunar Cyclor Orbits with Alternating Semi-Monthly Transfer Windows,  
<http://cbboff.org/UCBoulderCourse/documents/LunarCyclorPaper.pdf>
- Wertz, J. R., (1999) Editor, Space Mission Analysis and Design, Microcosm Press, CA, 1999
- Zuber, M. et al MIT's GRAIL Homepage, <http://Moon.mit.edu/spacecraft.html>



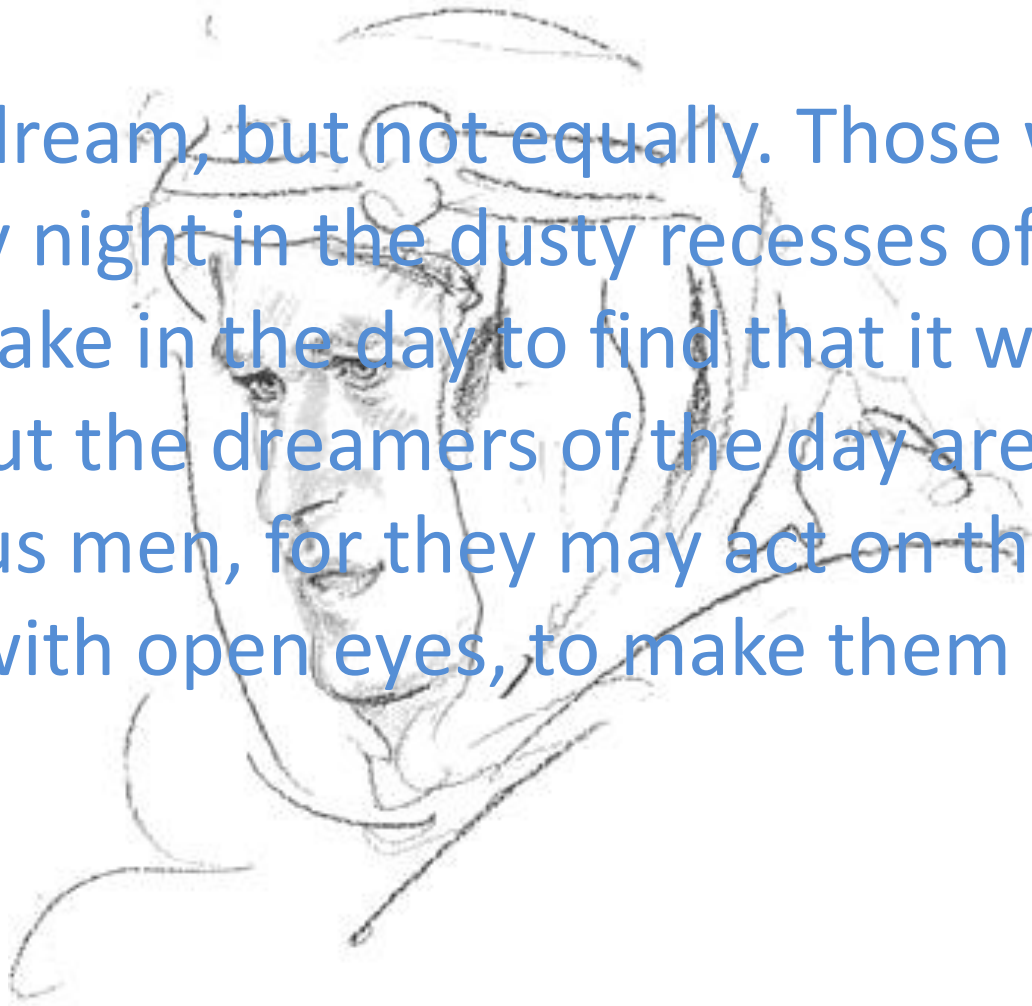
**Philosophy, Visions, Policies,  
Architectures, Concepts, Engineering**

# ALTERNATIVE ENGINEERING CONCEPT GENERATION AND REFINEMENT IS AN ITERATIVE PROCESS



# T.E. Lawrence

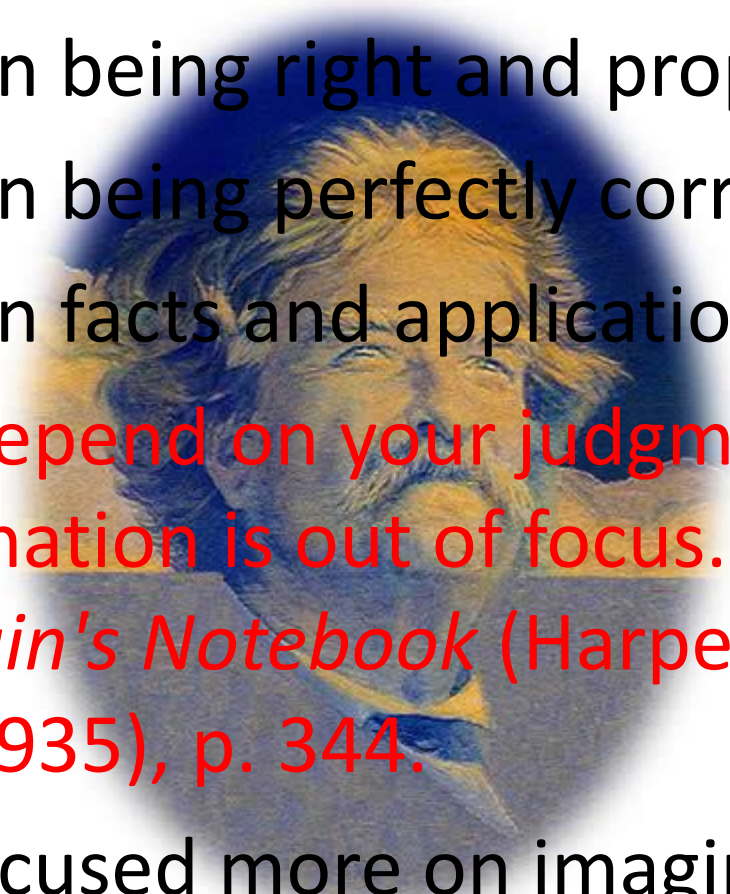
- All men dream, but not equally. Those who dream by night in the dusty recesses of their minds, wake in the day to find that it was vanity: but the dreamers of the day are dangerous men, for they may act on their dreams with open eyes, to make them possible.





# Education

- We focus on being right and proper
- We focus on being perfectly correct
- We focus on facts and application of laws.
- You can't depend on your judgment when your imagination is out of focus.  
- *Mark Twain's Notebook* (Harper and Brothers, 1935), p. 344.
- Wish we focused more on imagination



# Architecting vs. Engineering

- Architecting is a qualitative process
- Engineering is a quantitative method
- Architecting addresses – **what, when, where**
- Engineering defines and bounds – **how, how much ?**
- Architect first, engineer next
- Concept Creation is an up front, top level, Architecting process -**Synthesis**
- It creates a range of choice for the client
- Create first, Optimize later

# The Wicked Problem

- Complex problem
- Many dynamic variables
- Moving goal posts
- Introduce new parameters
- Solved “out of bounds”

# Heuristic

- Murphy's Law
- Parkinson's Law
- Augustine's Laws
- Akin's Laws
- Surgeon's Heuristic - The eye cannot see what the mind cannot comprehend.

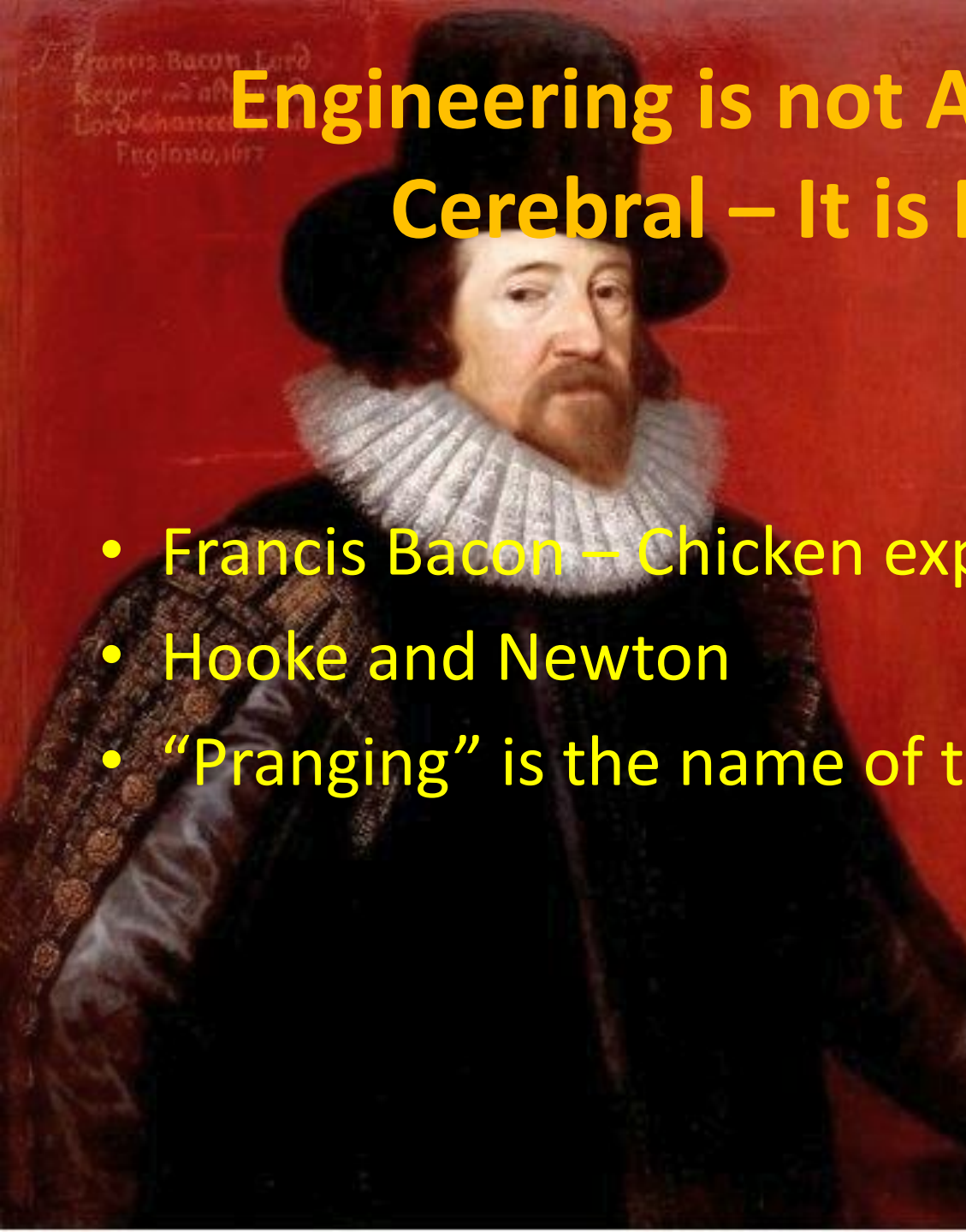


# Critical Skill - Connections

- Synthetic Intelligence
- Context and Associative Logic
- Looking for Patterns
- Apply Heuristics
- Quilting
- Common Model – Debate and Discussion

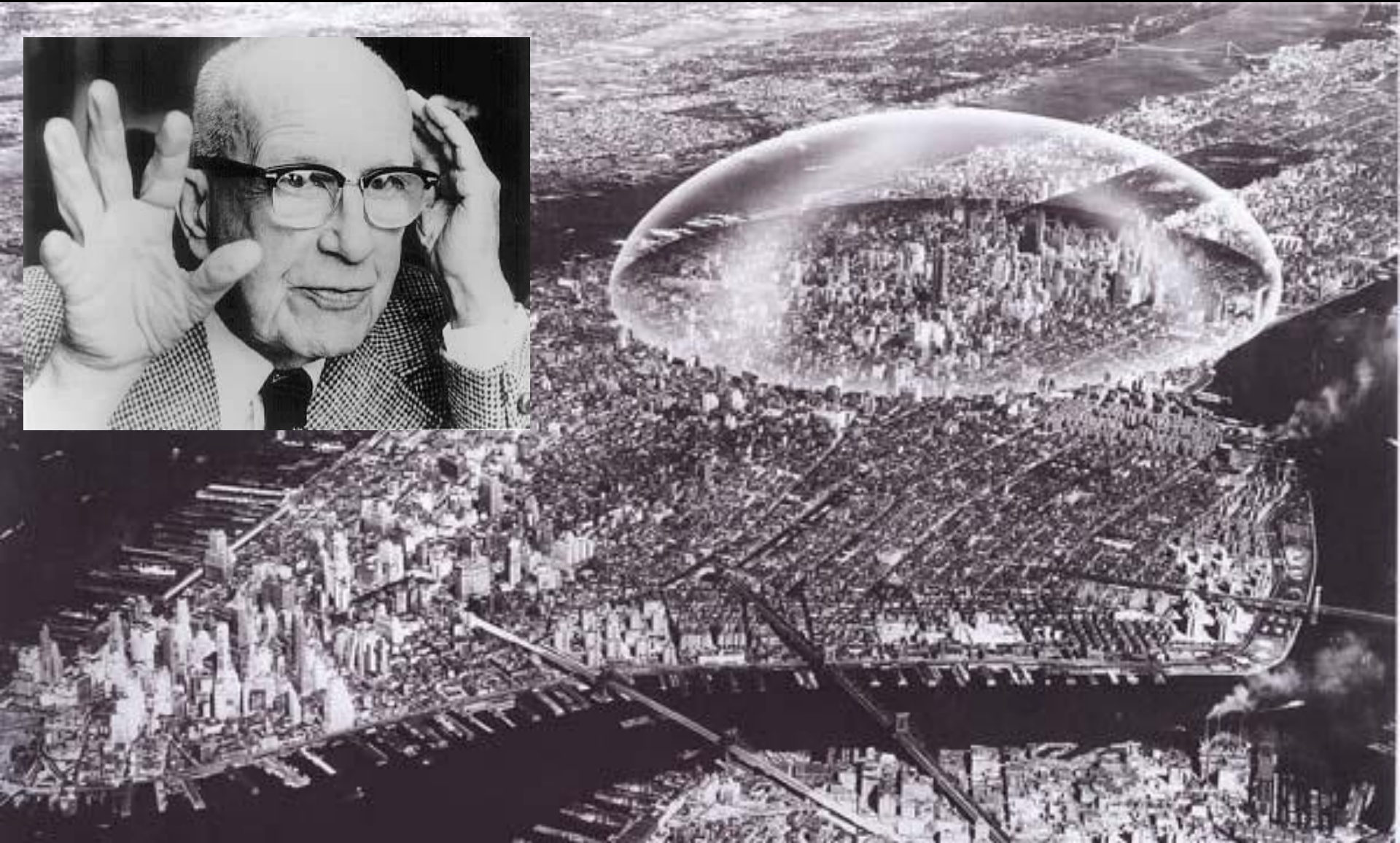
# Engineering is not Abstract, not Cerebral – It is Physical

- Francis Bacon – Chicken experiment
- Hooke and Newton
- “Pranging” is the name of the game



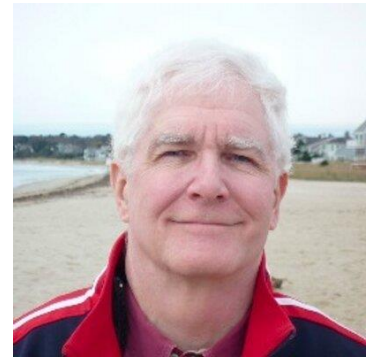


# Spaceship Earth – Buckminster Fuller

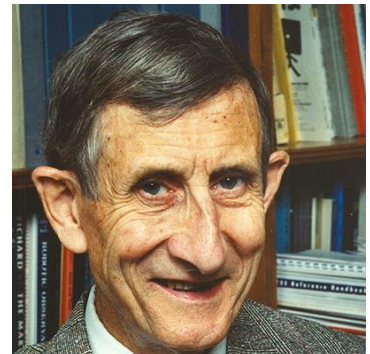
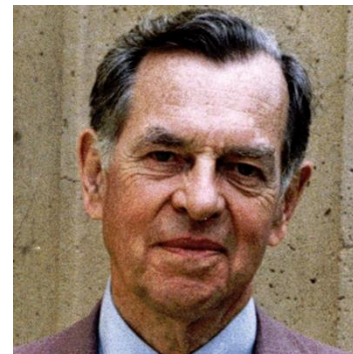


# New Space Paradigms

- Musk – Settle other planets –human survival insurance
- Bezos – Protect and make Earth beautiful
- Marburger III – Economic sphere of influence
- Campbell - Return of the Hero
- Dyson – Beautify our Universe
- Frank White –Overview Effect



Dr. John H. Marburger III (1941–2011)





# Nathan Myrsvold Intellectual Ventures

## IRRADIATING FOOD TO PERFECTION

Grilling food over an open flame is a practice as old as humanity itself. Indeed, it's likely that we are human precisely because we learned to grill our food. Perhaps it is this primeval connection that makes grilled foods such as hamburgers so mouth-watering: we're hard-wired by evolution to find comfort in the heat of the grill, the smell of the smoke, and the taste of the food. Although grilling food is so simple that our ancestors managed to do it eons ago, mastering the heat of the grill is a culinary challenge of the highest order.

Wafting smoke gives form to the turbulent air that rushes skyward past the patties, much like what happens in a chimney. Heat from the burning fuel causes adjacent air to expand, making it more buoyant. As the hot air rises, it cooks the food and creates a draft that sucks more air in to fuel the fire.

Food must be relatively thin to cook properly in the intense radiant heat and scorching air rising from the coals. Food that is too thick will burn on the outside before heat can penetrate to its core.

A layer of ash should coat the coals before food goes on the grill. The ash dims the coals' glow, moderating the heat they radiate. The ash also reduces the chimney effect by insulating the coals from the air.

A variable air vent allows the grillster to control the flow of air into the fire. Starve the coals of fresh air to cool them and slow the chimney effect; open the vents to turn up the heat.



Grills are definitely *not* nonstick surfaces. The high temperatures at which charcoal grills operate would make most nonstick coatings unstable. Coating food in oil works, but can cause flare-ups that coat the food with soot. The best way to avoid sticking is to preseason the grill with a patina much as you would an iron skillet or steel wok (see *How to Season a Wok*, page 53).

Drippings are the real secret to the unique flavor of grilled food. As these complex chemical solutions combust, they coat the food with a panoply of aromatic and delicious compounds.

Flames may seem to flicker above charcoal, but these fiery tongues are actually little plumes of incandescent carbon soot. The superheated air is turbulent; it lifts soot particles off the coals and allows them to react with carbon dioxide in the air to produce carbon monoxide. The flammable monoxide burns with a hot but faint blue flame at 1,600 °C / 2,900 °F or higher, which heats the soot particles so much that they glow with an intense white light that masks the dim fire from the monoxide.

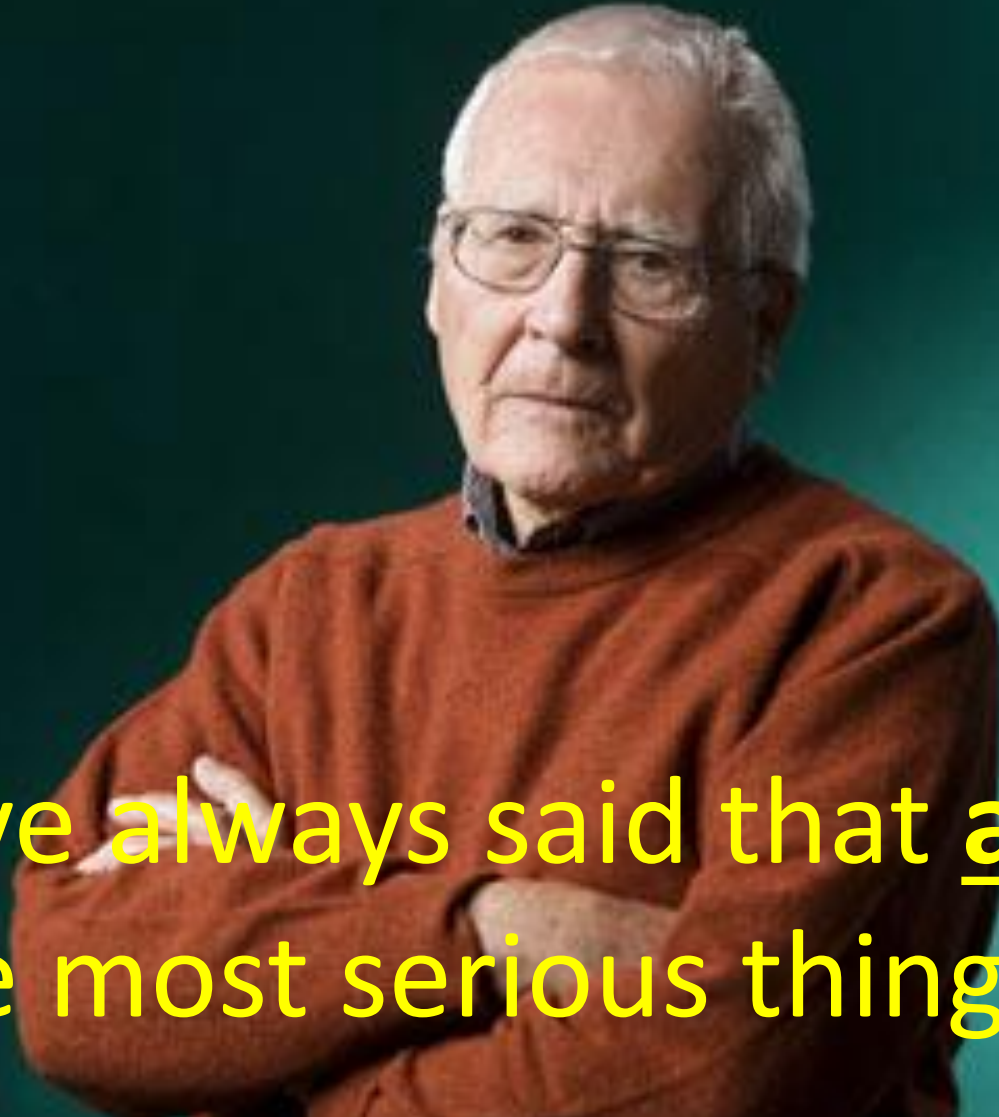
Glowing coals generate temperatures well above the 700 °C / 1,300 °F required to emit light in the visible part of the spectrum. The bright orange light emitted by the center of the embers indicates a temperature above 1,100 °C / 2,000 °F. Pockets between the coals are hotter still; there, burning carbon monoxide heats soot to at least 1,400 °C / 2,550 °F!

# George Church – CRSPR CaSg



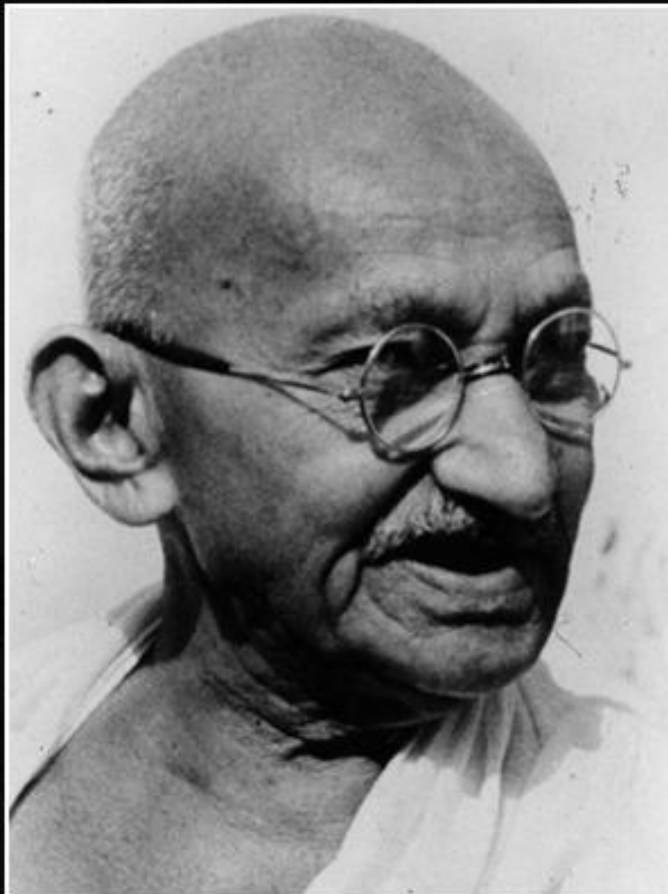


# Prof. James Lovelock on Adaptation to Climate Change



"I've always said that adaptation is  
the most serious thing we can do"

# Mohandas Gandhi



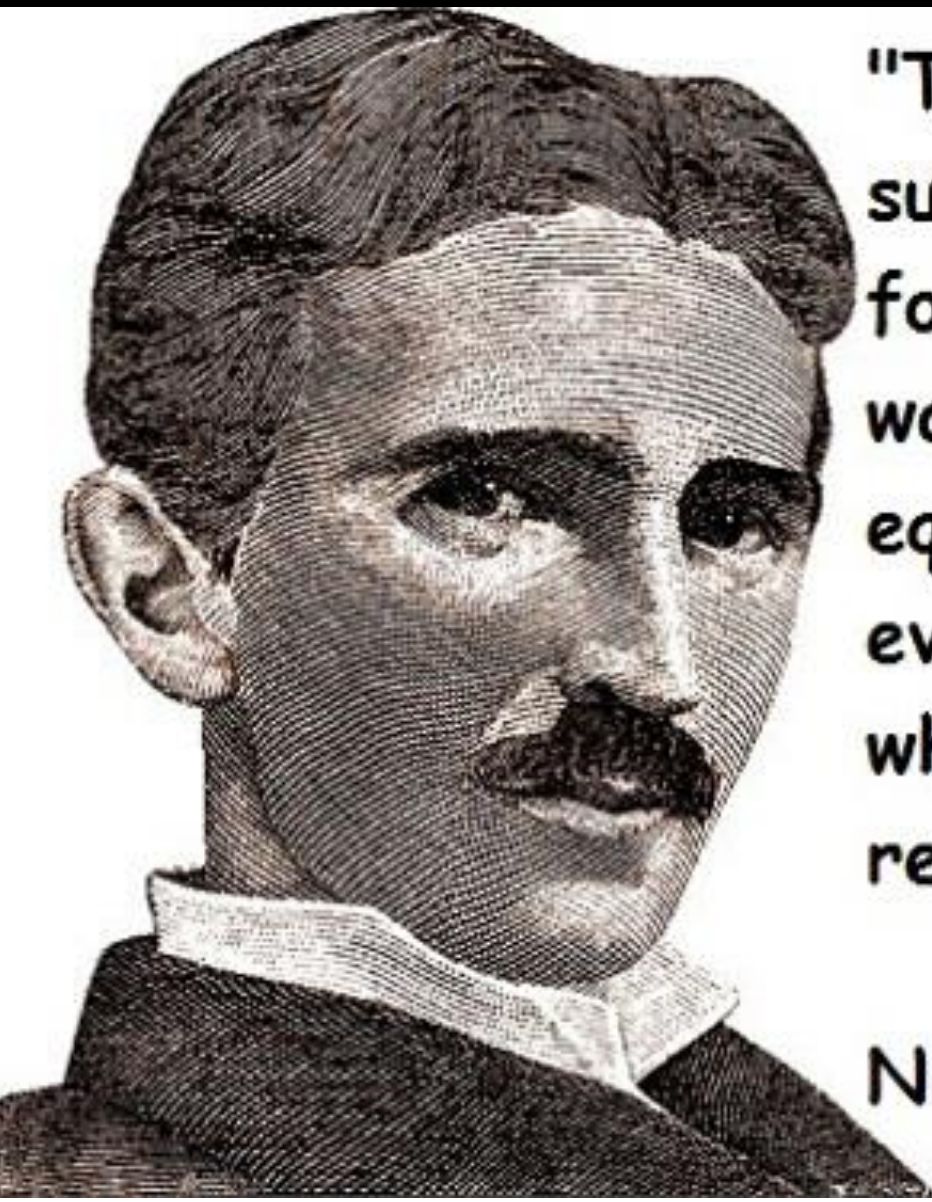
Seven Deadly Sins Wealth without work  
Pleasure without conscience Science  
without humanity Knowledge without  
character Politics without principle  
Commerce without morality Worship  
without sacrifice.

— Mahatma Gandhi —

**AZ** QUOTES



# Nikola Tesla



"Today's scientists have substituted mathematics for experiments, and they wander off through equation after equation, and eventually build a structure which has no relation to reality."

Nikola Tesla



# Carl Sagan

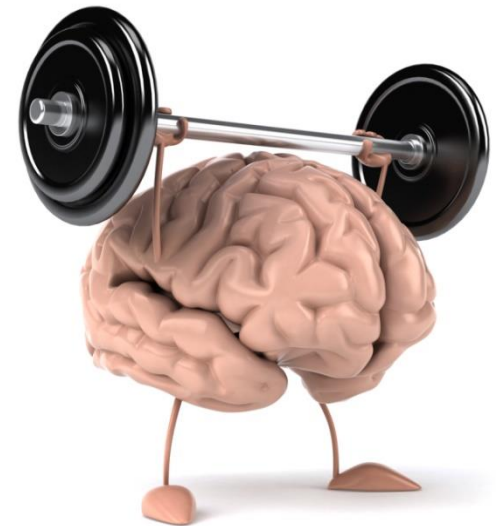
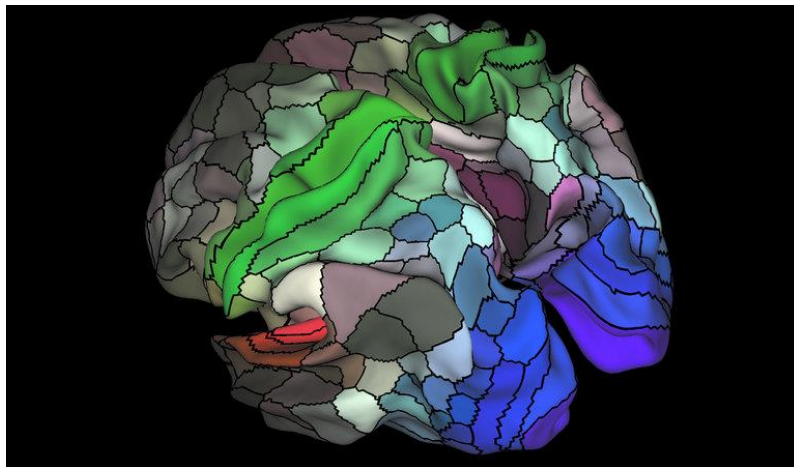


“It is the tension  
between creativity  
and skepticism that  
has produced  
the stunning  
and unexpected  
findings of science”

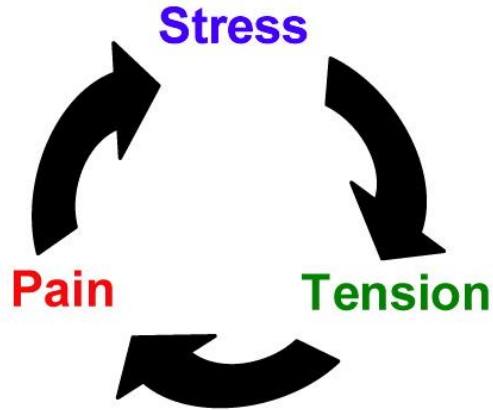
*Carl Sagan*

# Creative Synthesis - Hegel ?

- Thesis, Antithesis – Synthesis
- Human Connectome Project
- The conflict between what is ideal or impossible and that which is possible is essential for creative synthesis



# Creative Tension



- "There's a tension between feasibility and desirability," Thangavelu said. "But the conflict between what's possible and what's daydreaming is necessary to arrive at creative, passionate solutions."



# Be Wary of Riding A Dead Horse

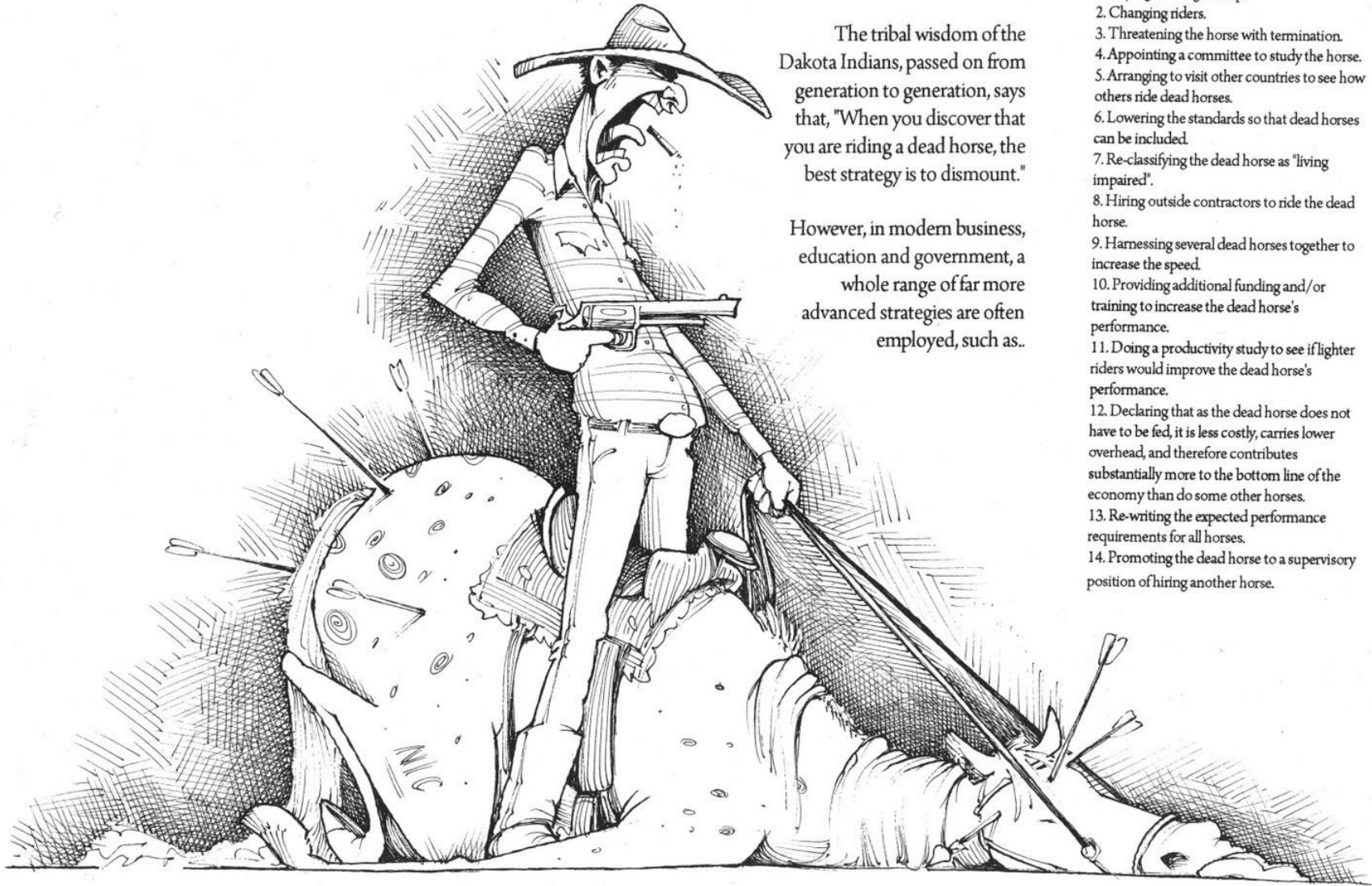
- Riding a Dead Horse
- The tribal wisdom of the Dakota Indians, passed on from generation to generation, says that –
- when you discover that you are riding a dead horse, the best strategy is to dismount.

# THE DEAD HORSE THEORY

The tribal wisdom of the Dakota Indians, passed on from generation to generation, says that, "When you discover that you are riding a dead horse, the best strategy is to dismount."

However, in modern business, education and government, a whole range of far more advanced strategies are often employed, such as..

1. Buying a stronger whip.
2. Changing riders.
3. Threatening the horse with termination.
4. Appointing a committee to study the horse.
5. Arranging to visit other countries to see how others ride dead horses.
6. Lowering the standards so that dead horses can be included.
7. Re-classifying the dead horse as "living impaired".
8. Hiring outside contractors to ride the dead horse.
9. Harnessing several dead horses together to increase the speed.
10. Providing additional funding and/or training to increase the dead horse's performance.
11. Doing a productivity study to see if lighter riders would improve the dead horse's performance.
12. Declaring that as the dead horse does not have to be fed, it is less costly, carries lower overhead, and therefore contributes substantially more to the bottom line of the economy than do some other horses.
13. Re-writing the expected performance requirements for all horses.
14. Promoting the dead horse to a supervisory position of hiring another horse.



# **Advanced Medicine - Transplants**

## Nobel Prize in Physiology or Medicine 1960

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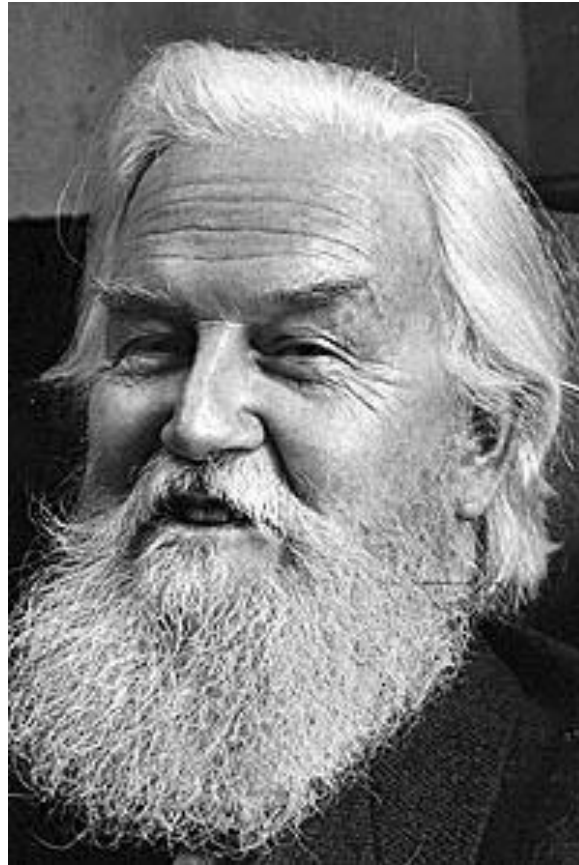
- ❑ Peter Brian Medawar (1/2)
- ❑ Discovery of acquired immunological tolerance
  - The graft reaction is an immunity phenomenon
  - 1950s, induced immunological tolerance to skin allografts in mice by neonatal injection of allogeneic cells



*Great events in history of transplantation*



# Surgeon's Heuristic - Robertson Davies Corollary

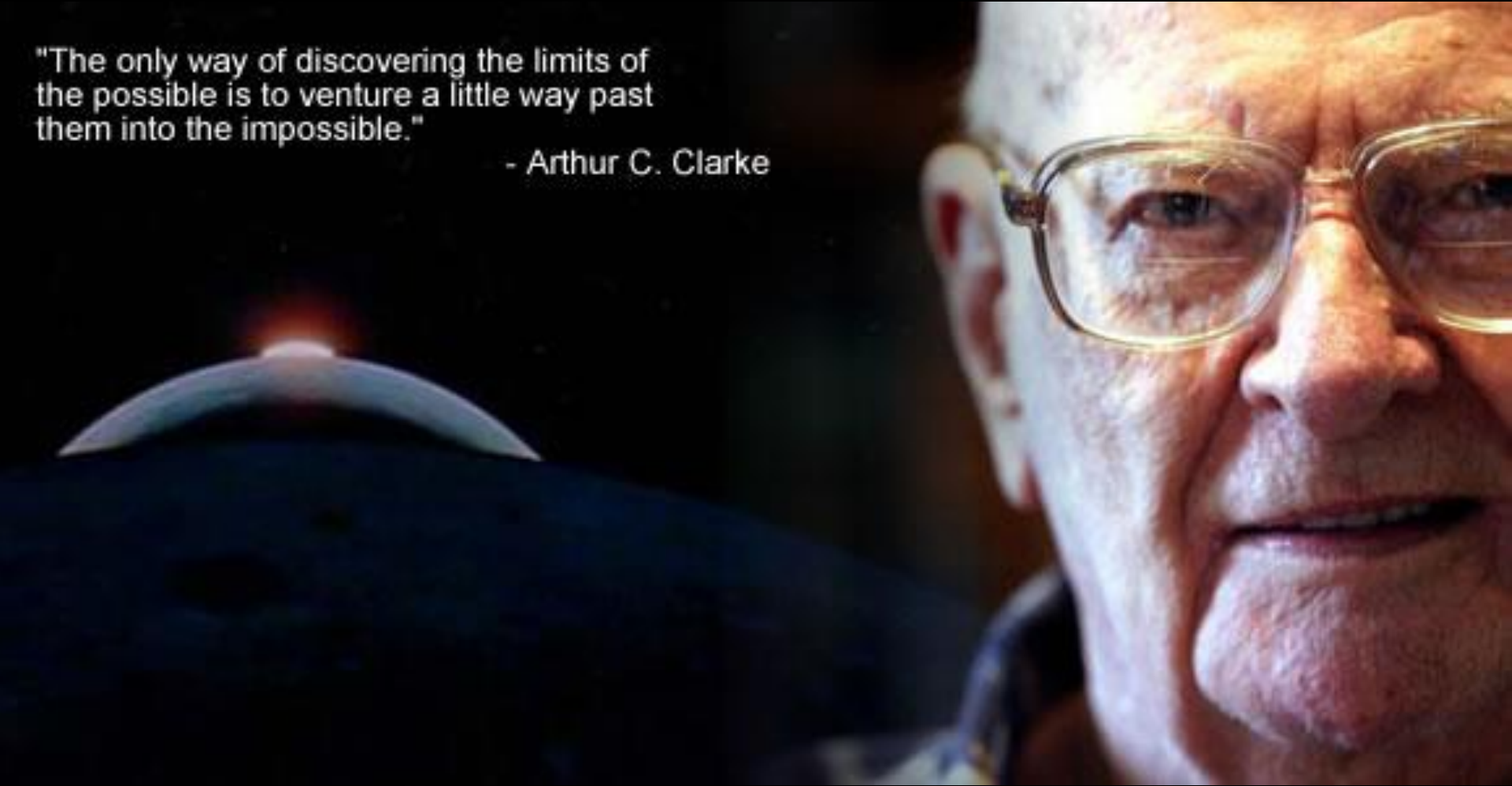


The eye cannot see  
what the mind cannot comprehend

# Arthur C. Clarke

"The only way of discovering the limits of the possible is to venture a little way past them into the impossible."

- Arthur C. Clarke



A scene from 2001: A Space Odyssey

# Lesson from Scriptures



- **Brahma - Generator**
- **Vishnu – Operator**
- **Shiva – Destroyer/Transformer**



**Philosophy, Visions, Policies,  
Architectures, Concepts, Engineering**





"Whoops—I accidentally pressed 'elevator pitch.' "

# References

- Alexander, Christopher (1977) Pattern Language, [https://en.wikipedia.org/wiki/Pattern\\_language](https://en.wikipedia.org/wiki/Pattern_language)
- Alexander, Christopher(1968) Notes on the Synthesis of Form, [https://monoskop.org/images/f/ff/Alexander\\_Christopher\\_Notes\\_on\\_the\\_Synthesis\\_of\\_Form.pdf](https://monoskop.org/images/f/ff/Alexander_Christopher_Notes_on_the_Synthesis_of_Form.pdf)
- Darwin, Charles (1859) On the Origin of Species, <https://www.gutenberg.org/files/1228/1228-h/1228-h.htm>
- Eb Rechtin – Systems Architecting;Craeting and Building Complex Systems, [https://www.amazon.com/Systems-Architecting-Creating-Building-Complex/dp/0138803455/ref=pd\\_sim\\_14\\_9?encoding=UTF8&pd\\_rd\\_i=0138803455&pd\\_rd\\_r=PNN9XQ95V57K7XYQXTT&pd\\_rd\\_w=QlhBG&pd\\_rd\\_wg=GB7BM&psc=1&refRID=PNN9XQ95V57K7XYQXTT2](https://www.amazon.com/Systems-Architecting-Creating-Building-Complex/dp/0138803455/ref=pd_sim_14_9?encoding=UTF8&pd_rd_i=0138803455&pd_rd_r=PNN9XQ95V57K7XYQXTT&pd_rd_w=QlhBG&pd_rd_wg=GB7BM&psc=1&refRID=PNN9XQ95V57K7XYQXTT2)
- <https://vimeo.com/47159242>
- Bariso, J.,(2017) - This Original Letter From Jeff Bezos to Amazon Shareholders Teaches Some Extraordinary Lessons in Leadership, <https://www.inc.com/justin-bariso/20-years-ago-amazons-jeff-bezos-sent-an-extraordinary-letter-to-shareholders.html>
- Bariso, J.,(2015) Steve Jobs Knew How to Run a Meeting: Here's How He Did It, <https://www.inc.com/justin-bariso/8-essential-lessons-from-this-meeting-led-by-a-young-steve-jobs.html>
- Bezos, J.,(1997) Day 1 Letter to Shareholders, <https://www.sec.gov/Archives/edgar/data/1018724/000119312517120198/d373368dex991.htm>
- Boston Dynamics Changing Your Idea of What Robots Can Do, <http://www.bostondynamics.com/>
- Brand, Stewart(1968-72) The Whole Earth Catalog, [https://en.wikipedia.org/wiki/Whole\\_Earth\\_Catalog](https://en.wikipedia.org/wiki/Whole_Earth_Catalog)
- Brockman, J., Editor, Edge <https://www.edge.org/>
- Burke, J., Connections,(1979, 1994, 1997) [https://en.wikipedia.org/wiki/Connections\\_\(TV\\_series\)](https://en.wikipedia.org/wiki/Connections_(TV_series))<https://www.youtube.com/playlist?list=PLShSu-Q4iw9IRWwpUbCnEk6PorqG8LQTM>
- Burke, J.,(1985) The Day the Universe Changed, [https://en.wikipedia.org/wiki/The\\_Day\\_the\\_Universe\\_Changed](https://en.wikipedia.org/wiki/The_Day_the_Universe_Changed)
- Churchman,West(1967) Wicked Problems, <https://punkrockor.files.wordpress.com/2014/10/wicked-problems-churchman-1967.pdf>
- Dakota Indian Lore – [http://www.peakmotivation.com/\\_content/Dead\\_horse.pdf](http://www.peakmotivation.com/_content/Dead_horse.pdf)
- Drucker, Peter
- Einstein, Albert
- Fuller, Buckminster(1968)Operating Manual for Spaceship Earth, [https://en.wikipedia.org/wiki/The\\_Day\\_the\\_Universe\\_Changed](https://en.wikipedia.org/wiki/The_Day_the_Universe_Changed)
- Feynman, Richard, Lectures in Physics, <http://www.feynmanlectures.caltech.edu/>
- Gates, Bill., <https://www.gatesnotes.com/>
- Gates, Bill(1995) The Road Ahead, [https://openlibrary.org/books/OL807148M/The\\_road\\_ahead](https://openlibrary.org/books/OL807148M/The_road_ahead)
- Gladwell, Malcolm <http://gladwell.com/>
- Gould, S.J.(1996) Full House, The Spread Of Excellence From Plato To Darwin, <ftp://169.158.189.34/pub/Evolucion/StephenJGould/Gould,%20Stephen%20Jay%20-%20Full%20House.pdf>
- Griffin, Brand– <http://spacearchitect.org/pubs/AIAA-2014-4404.pdf>
- Herbert Simon( <https://www.amazon.com/Sciences-Artificial-Herbert-Simon/dp/0262691914>, [https://monoskop.org/images/9/9c/Simon\\_Herbert\\_A\\_The\\_Sciences\\_of\\_the\\_Artificial\\_3rd\\_ed.pdf](https://monoskop.org/images/9/9c/Simon_Herbert_A_The_Sciences_of_the_Artificial_3rd_ed.pdf)
- Jobs, S.(2005) Stanford U commencement Address, <http://news.stanford.edu/2005/06/14/jobs-061505/>
- Madni, Azad(2012) Elegant Systems Design: Creative Fusion of Simplicity and Power, <http://onlinelibrary.wiley.com/doi/10.1002/sys.21209/abstract>
- Medawar, Peter <http://www.ox.ac.uk/news/science-blog/peter-medawar-oxford-path-nobel-prize>
- Muirhead,Brian (2012) Systems Engineering, Architecting and Model Based SE Challenges and Opportunities, <https://www.slideshare.net/NASAPMC/brian-muirhead-v12712>
- Muirhead, Brian(2012) Architecting the Next Crewed Missions to the Moon, <https://www.slideshare.net/NASAPMC/muirheadbrian>
- Toga, Arthur - <https://bhi.embs.org/2017/arthur-toga-phd/>
- Twain, Mark
- Rittel, Horst(1973) Dilemmas in A General theory of Planning, <http://www.cc.gatech.edu/fac/ellendo/rittel/rittel-dilemma.pdf>
- Lovelock, J., Gaia Hypothesis [https://en.wikipedia.org/wiki/Gaia\\_hypothesis](https://en.wikipedia.org/wiki/Gaia_hypothesis)
- Safdie, Moshe
- Silver,Nate , <https://fivethirtyeight.com/>
- Shannon, Claude [https://www.youtube.com/watch?v=z2Whj\\_nL-x8](https://www.youtube.com/watch?v=z2Whj_nL-x8)
- Robinson, Ken (2006)Do Schools Kill Creativity ? [https://www.ted.com/talks/ken\\_robinson\\_says\\_schools\\_kill\\_creativity](https://www.ted.com/talks/ken_robinson_says_schools_kill_creativity)
- Robinson, Ken (2011) Out of Our Minds, [https://www.amazon.com/Out-Our-Minds-Learning-Creative/dp/1907312471/ref=as\\_li\\_tf\\_tl?tag=teco06-20&ie=UTF8&camp=1789&creative=9325&creativeASIN=0520271440&linkCode=as2](https://www.amazon.com/Out-Our-Minds-Learning-Creative/dp/1907312471/ref=as_li_tf_tl?tag=teco06-20&ie=UTF8&camp=1789&creative=9325&creativeASIN=0520271440&linkCode=as2)
- Church, George(2017)Edge.Org, The Augmented Human Being, [https://www.edge.org/conversation/george\\_church-the-augmented-human-being](https://www.edge.org/conversation/george_church-the-augmented-human-being)
- Prigogine, Ilya(1984) Order out of chaos: Man's new dialogue with nature, [https://deteritorialinvestigations.files.wordpress.com/2015/03/ilya\\_prigogine\\_isabelle\\_stengers\\_alvin\\_tofflerbookfi-org.pdf](https://deteritorialinvestigations.files.wordpress.com/2015/03/ilya_prigogine_isabelle_stengers_alvin_tofflerbookfi-org.pdf)
- Csikszentmihaly,iMihaly(2004) Flow, the secret to happiness, [https://www.ted.com/talks/mihaly\\_csikszentmihalyi\\_on\\_flow](https://www.ted.com/talks/mihaly_csikszentmihalyi_on_flow)
- TEDCrunch, Top 20 talks on TED, <https://techcrunch.com/2012/08/21/ted-reveals-top-20-most-watched-talks-sir-ken-robinson-tops-the-list/>
- Tolstoy, Leo(1880) A Confession, <http://www.arvindguptatoys.com/arvindgupta/confessions-tolstoy.pdf>
- Venter, Craig(2011) Life at the Speed of Light, Synthetic Biology at NASA Ames, [https://www.youtube.com/watch?v=KTzG\\_HIUu9c](https://www.youtube.com/watch?v=KTzG_HIUu9c)