



Jet Propulsion Laboratory
California Institute of Technology



INHABITING COSMOS, THE FIELD OF SPACE ARCHITECTURE

Design, Implementation and Innovation of Space Habitats – Developing and designing complex systems for human space exploration

2013 Talk at Disney Animation

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Profile

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

Raul Polit-Casillas

Space Architect – Advance design, configuration and construction techniques (HSF)

Professional

- **JPL NASA /Caltech** – Systems Engineer, Configuration and Structures group – (Instruments, thermo-mechanical engineering section)
 - NASA AES Habitation Team – Deep Space Habitat project
 - JPL A-Team Configurator
- **AIAA SATC** Space Construction Subcommittee Chair (Member, since 2006)
- **XAR SIDEREAL Initiative** – Founder and director (license architect), 2008-2011
- **Technological IVAM** – Inhabiting Cosmos Int. Exhibitions – IVAM 2011
- **Space Architecture and Sustainability Int. Seminar** – Director – UCV 2009-2011

Research

- Space Architecture
- Advance building, manufacturing and design techniques
- Model Based engineering
- Sustainable and adaptable design

Academic

- MSc - Master Science in Space Studies and Human Spaceflight – ISU 2011
- M.Arch - Master Architect, All specialties, UPV 2008
- Industrial Engineering Studies

- Caja Madrid International Postgraduate Scholarship Awarded, 2010-2012
- Fulbright Commission preselected Fellow
- ESA Full scholarship award, 2010
- JPL JVSFP Fellow



THE SPACE ARCHITECTURE FIELD: Profile

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Image: Construction of the International Space Station. Courtesy of NASA.



Affiliations and collaborations

Space Architecture Technical Committee (AIAA-SATC), Member (Since 2009)

Chair of the AIAA-SATC Space Construction Subcommittee

AIAA Space Construction Subcommittee, Chair (since 2012)

AIAA Professional activities and liaison Subcommittee, Vice-Chair (2011)

Cal Poly Pomona, Env. Design Dept. - Collaborator, reviewer, guest lecturer (2012)

Caltech / SciArc - Solar Decathlon – Guest speaker, mentoring of students (2012)

USC (CA) – Reviewer (2011-12)

Inter Nos POLIGRAFICO Foundation (Spain) – Vice President and collaborator

UCV - University (Spain) – Collaborator, Space Architecture Int. Seminar Director (2011)

Valencia Space Consortium (UPV, Valencia) – Collaborator (2010-11)

- **Jet Propulsion Laboratory:** History And Activity
- **SPACE ARCHITECTURE:** Evolution And Environments (Earth, Leo, PS, Deep Space)
- **REQUIREMENTS AND CONSTRAINS FOR LIVING IN SPACE...** Designing Complex Projects
- **ENGINEERING-ARCHITECTURE-ART:** Interdisciplinary Approach To Aerospace
- **VIRTUAL CONSTRUCTION OF SPACE HABITATS:** Designing Virtual Mockups For Aerospace:
- **CONNECTING WITH OTHER SECTORS:** Visualization And Construction



THE SPACE ARCHITECTURE FIELD: JPL

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



THE SPACE ARCHITECTURE FIELD: JPL -

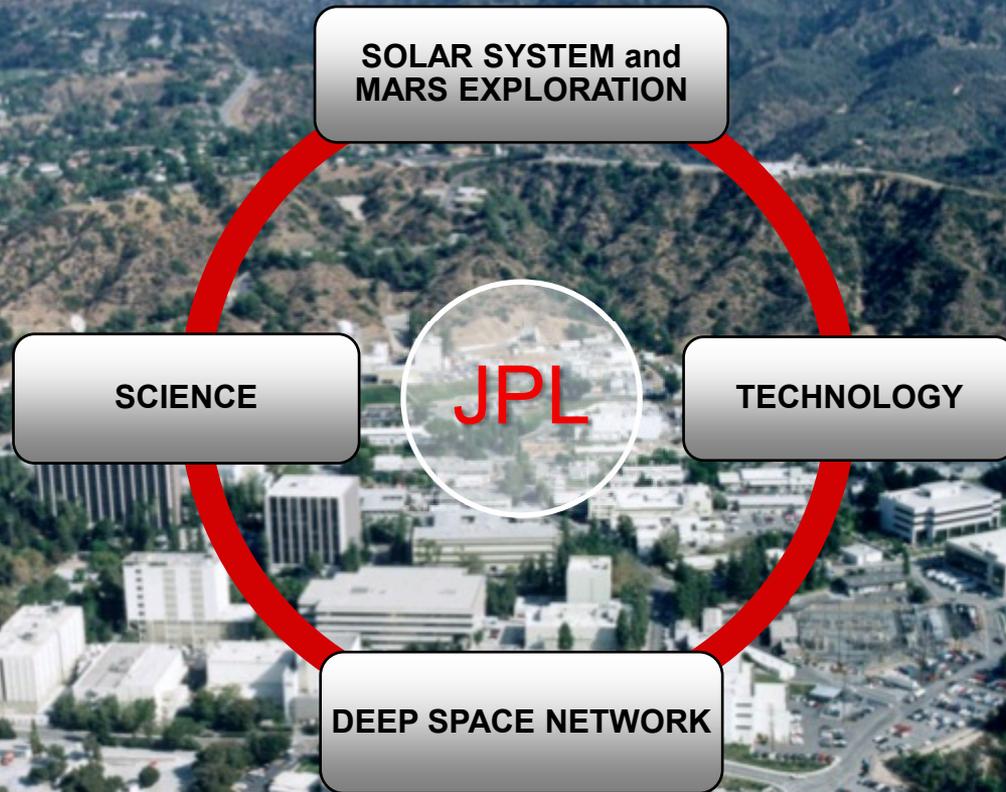
Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



HERE - Video of History of JPL – Public (you tube)

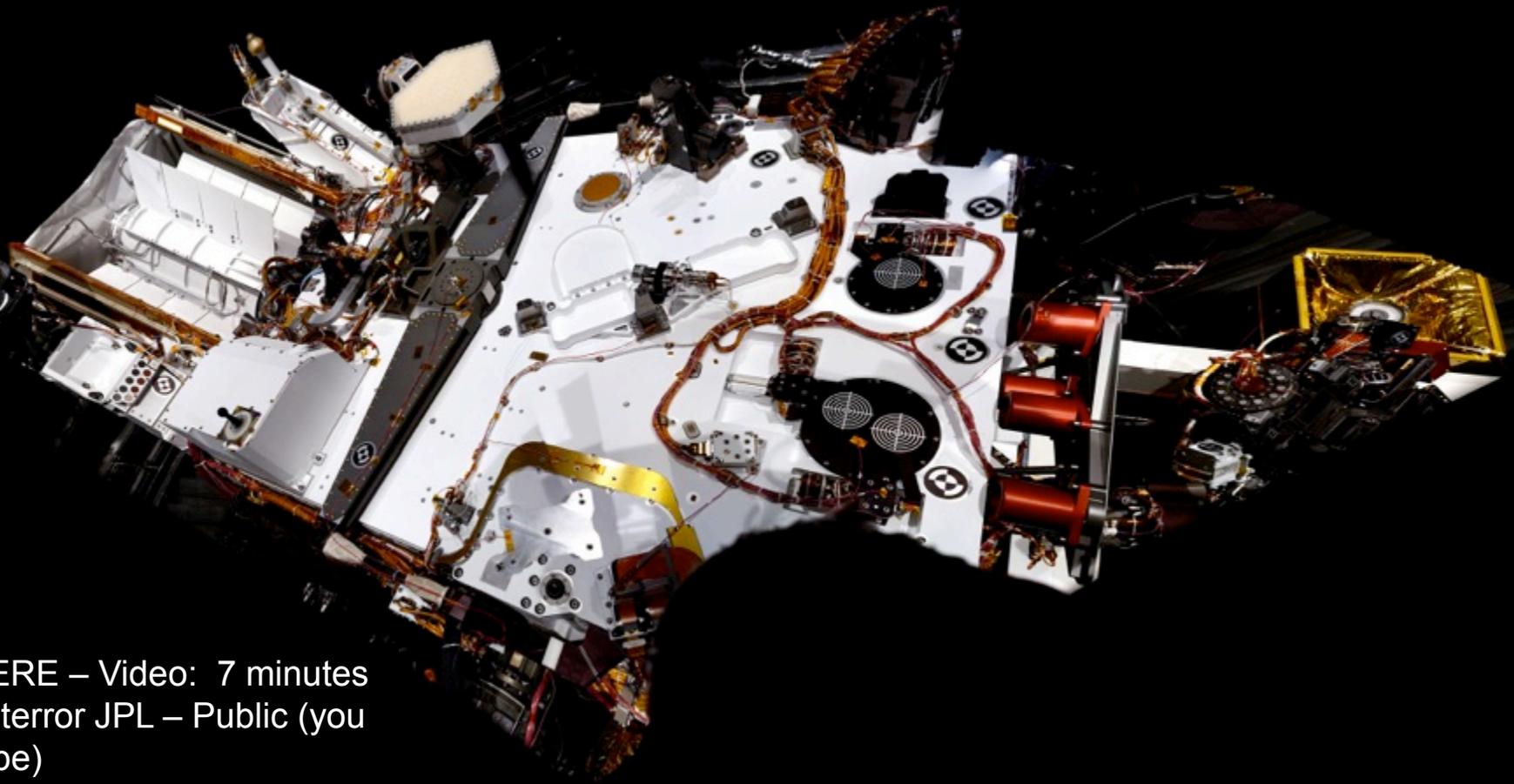
THE SPACE ARCHITECTURE FIELD: JPL -

PRESENT *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



THE SPACE ARCHITECTURE FIELD: JPL-

PRESENT *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



HERE – Video: 7 minutes
of terror JPL – Public (you
tube)

THE SPACE ARCHITECTURE FIELD: JPL -

FUTURE *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



HERE – Video: NASA
asteroid retrieval mission,
public (you tube)



History and environments

THE FIELD OF SPACE ARCHITECTURE

“Space Architecture is the theory and practice of designing and building inhabited environments in outer space”

Millenium Charter, Tx USA, 2002



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Past**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

Credit: Public Domain

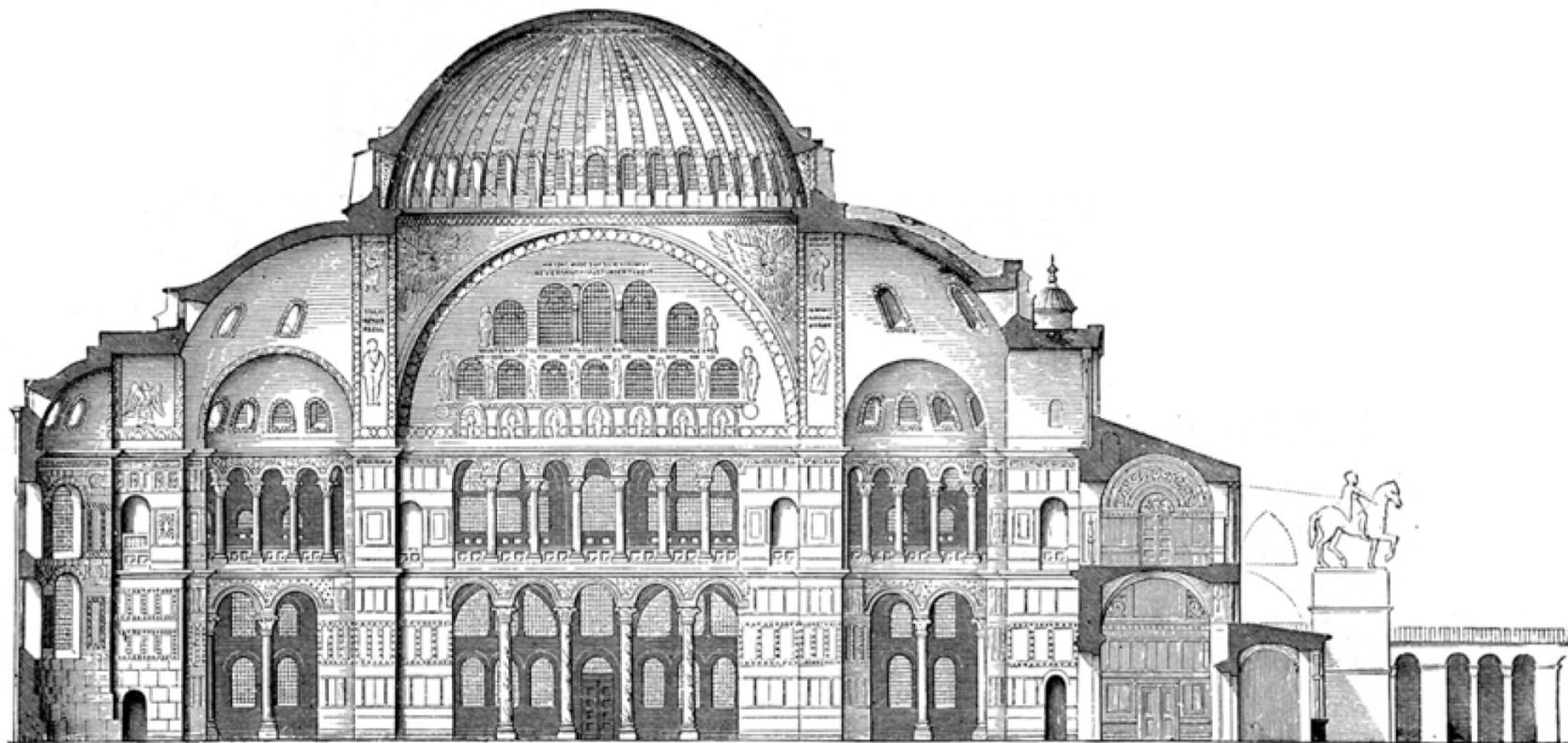
Mechanikoi, a constructive degree (Eastern Roman Empire):

- They mastered both construction science and technology as well as science, mathematics and astronomy
- Examples: Isidore of Miletus (H.Sofia), Heron of Alexandria (Robotics)
- **HAGIA SOFIA** (*Holy Wisdom, Istanbul, 537 A.C.*): Mathematics and science to study the cosmos allowed a better and impressive structural design... (Earthquakes)

THE SPACE ARCHITECTURE FIELD: **Past**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

HAGIA SOFIA



Credit: Public Domain

THE SPACE ARCHITECTURE FIELD: **Past**

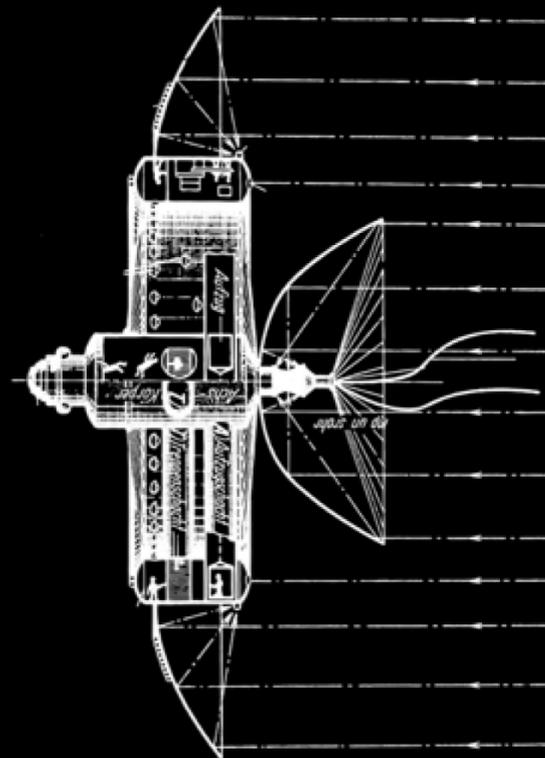
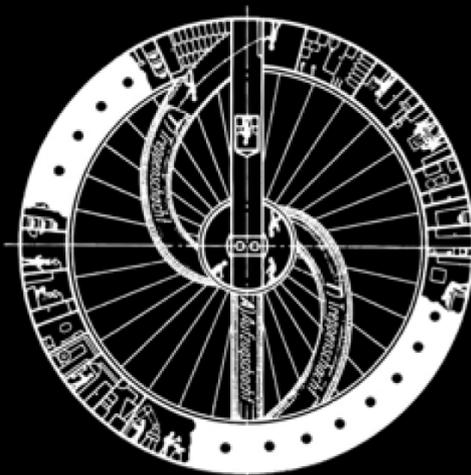
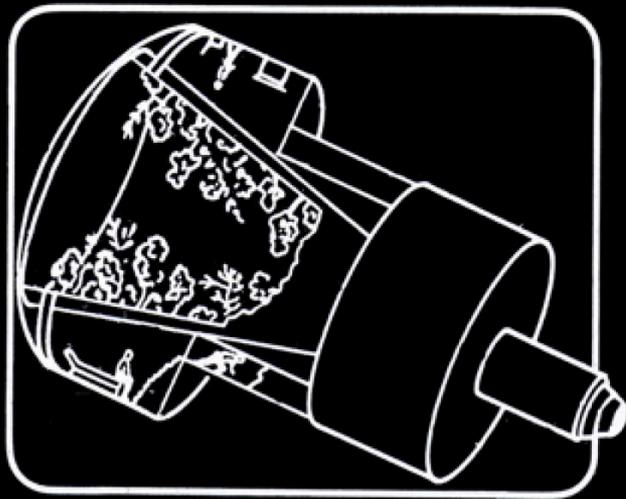
Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

Public Domain
HAGIA SOFIA



THE SPACE ARCHITECTURE FIELD: Past

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Credit: Public Domain

THE SPACE ARCHITECTURE FIELD: Past

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

APPOLLO
TELESCOPE
MOUNT

SATURN
WORKSHOP

MICRO
METEOROID
SHIELD

SLEEP
COMPARTMENT

WARD ROOM

WASTE
COMPARTMENT

AIRLOCK
MODULE

MULTIPLE DOCKING
ADAPTER

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Present

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

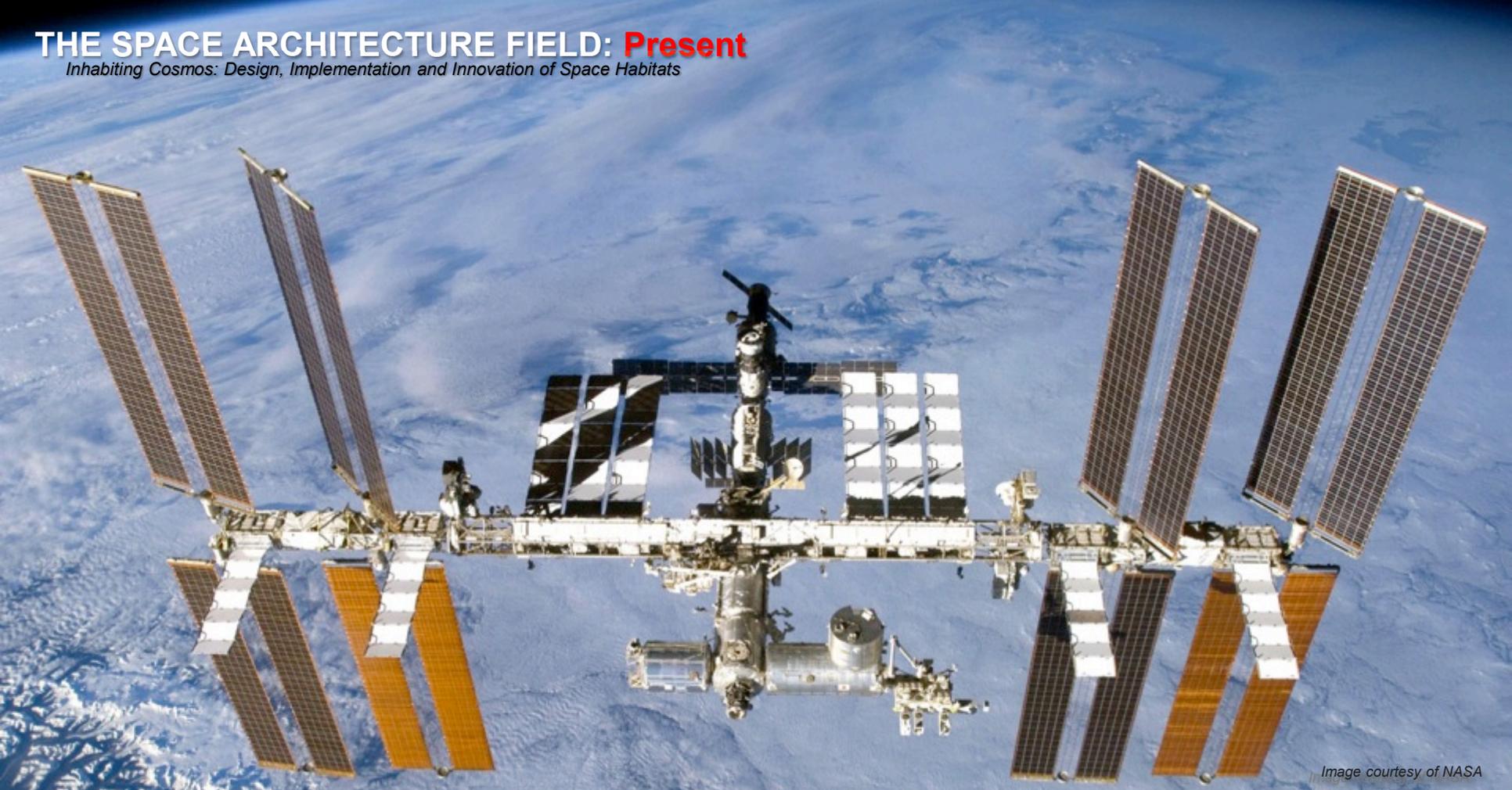


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Present

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Image courtesy of NASA



THE SPACE ARCHITECTURE FIELD: **Future**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

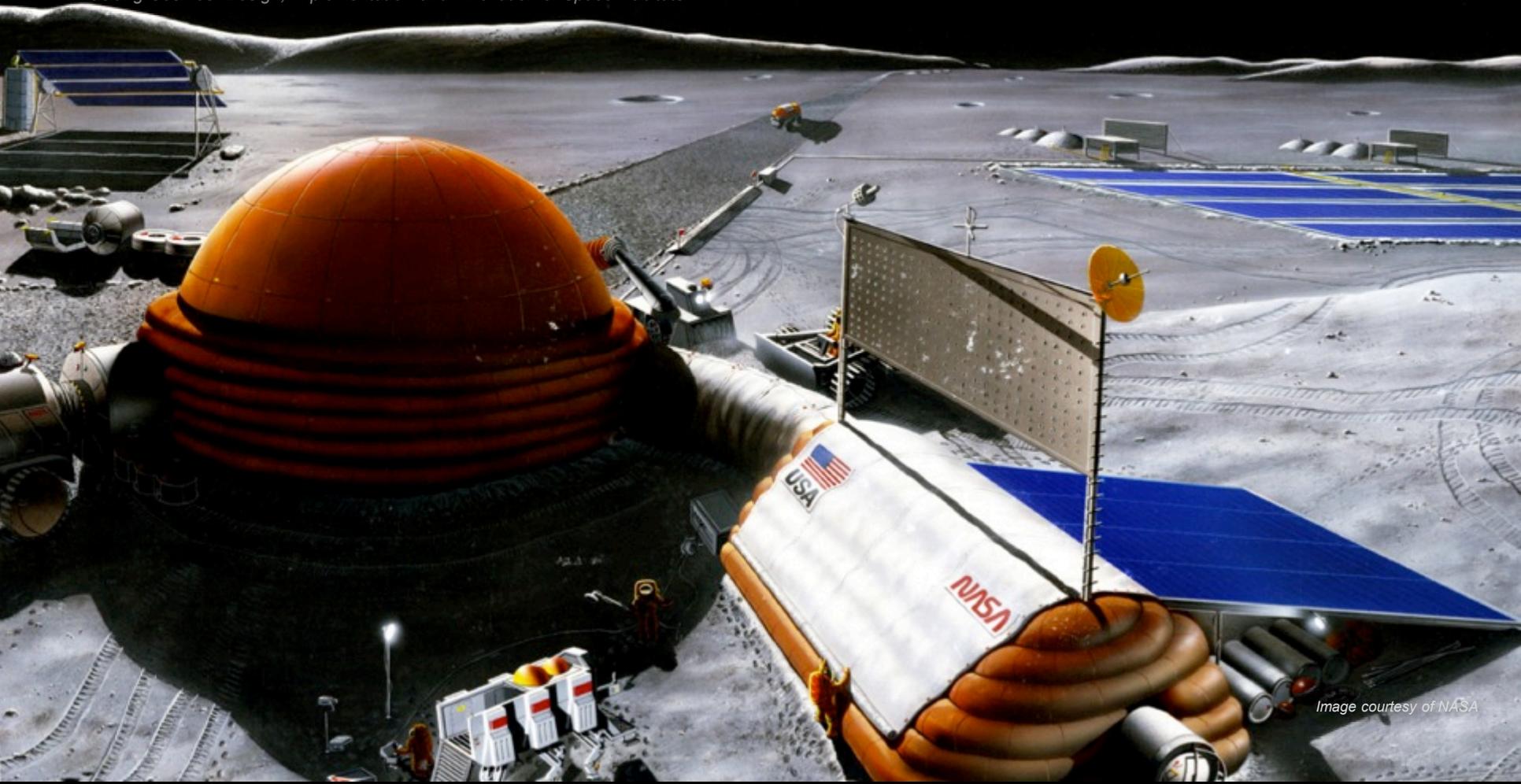


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Future**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

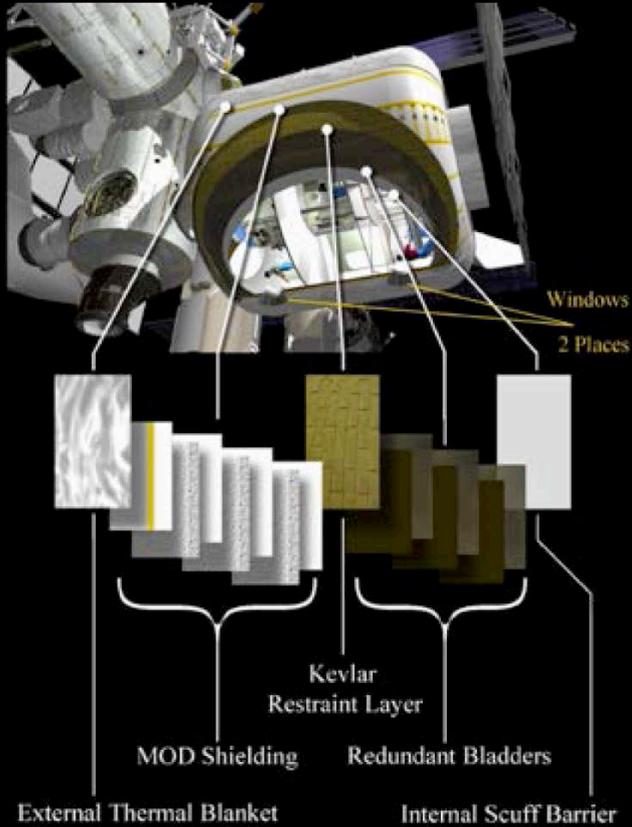


Image courtesy of NASA

Image courtesy of NASA

ENVIRONMENTS FOR **SPACE ARCHITECTURE**

THE SPACE ARCHITECTURE FIELD: **Earth**

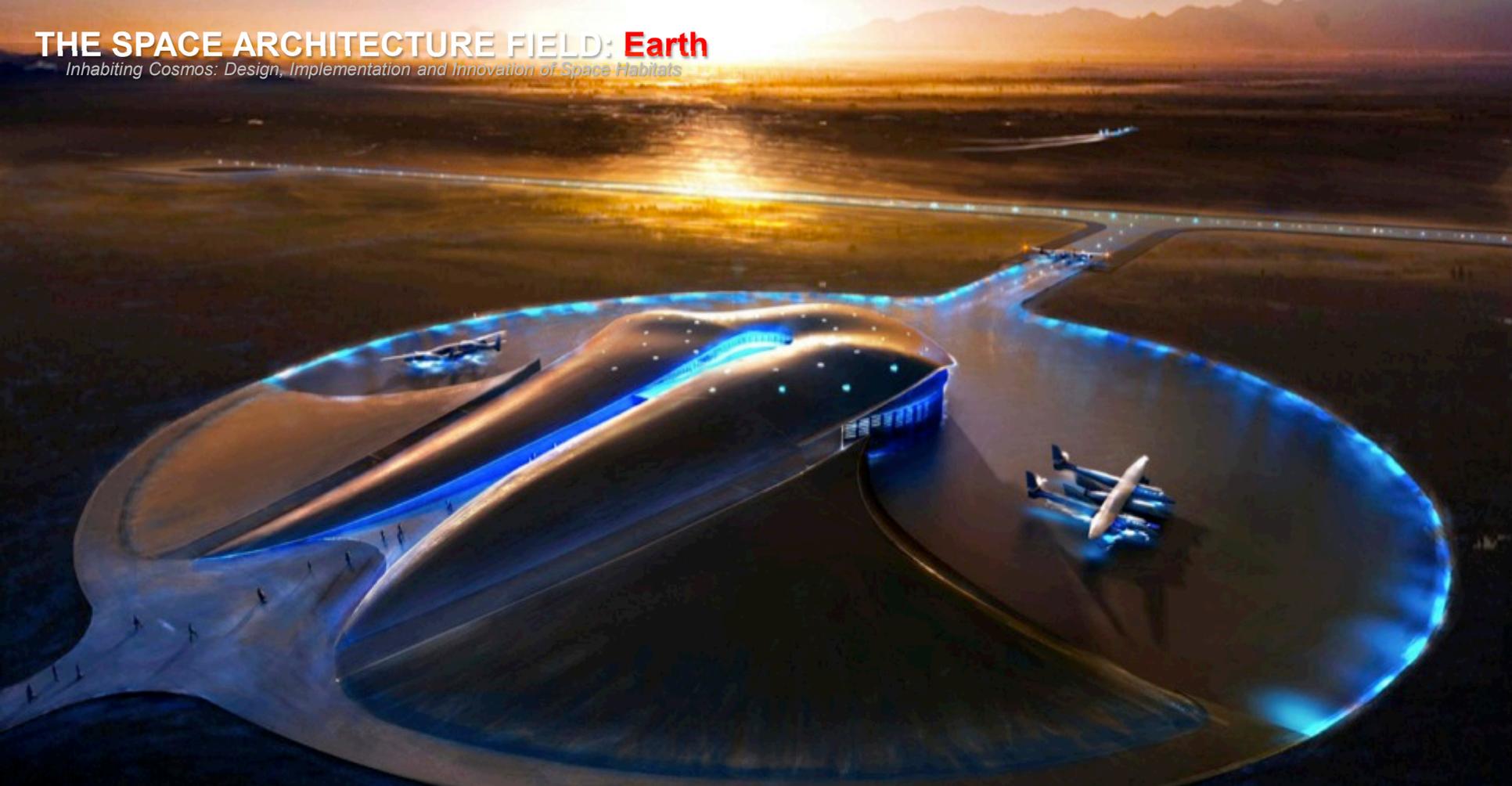
Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Earth**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



THE SPACE ARCHITECTURE FIELD: **Low Earth Orbit**

(LEO)

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

MIR Space Station

Construction depends on the habitat:

Type I: Pre-integrated habitats - All done on Earth - MIR

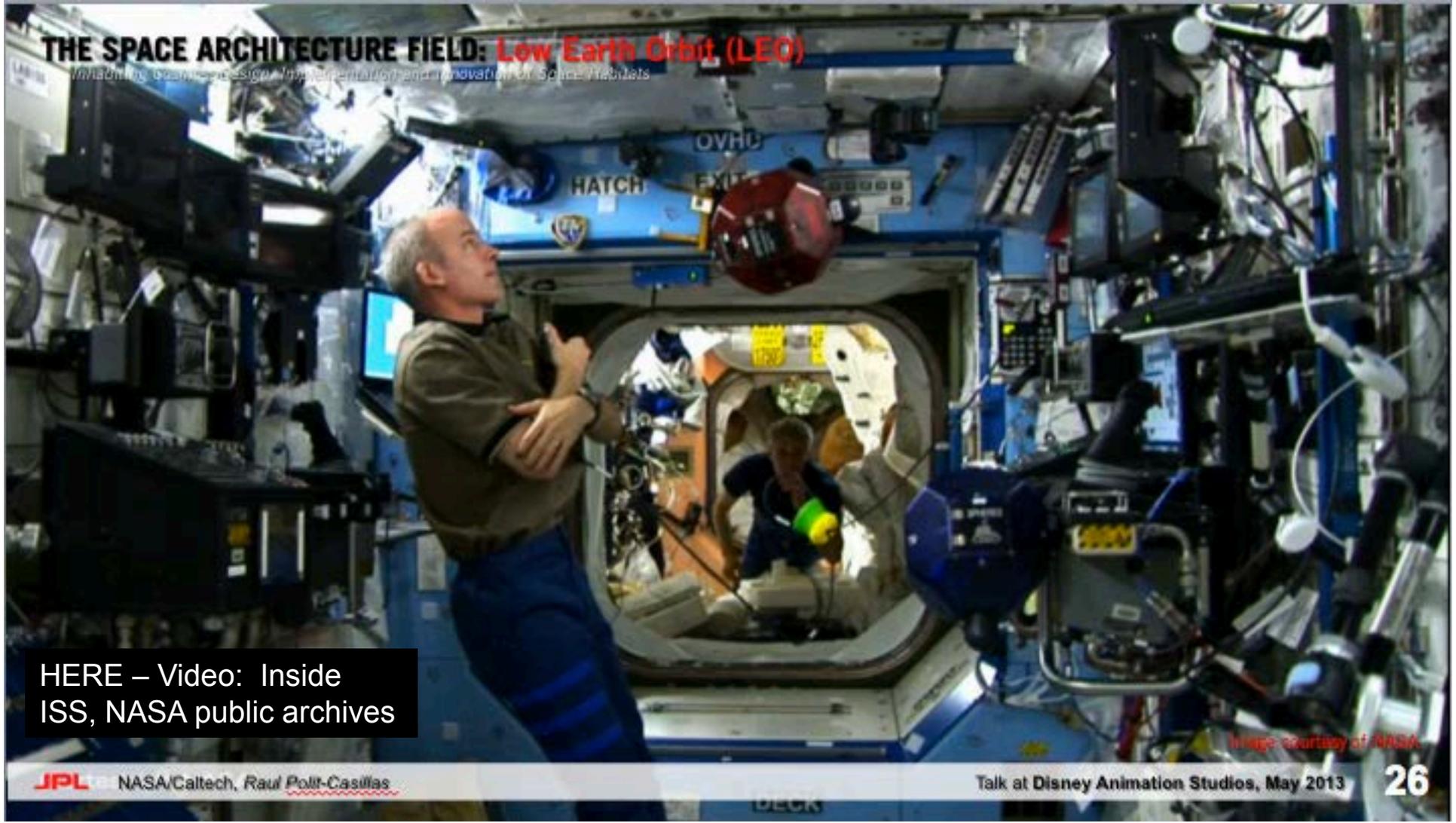
Type II: Prefabricated habitats - Assembly and integration - Transhab

Type III: In-situ Resources Habitat - Future planetary surfaces bases

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Low Earth Orbit (LEO)**

Imagining, designing, implementing and innovating on Space Habitats



HERE – Video: Inside
ISS, NASA public archives

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Deep**

Space *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

NASA Orion Deep Space Concept

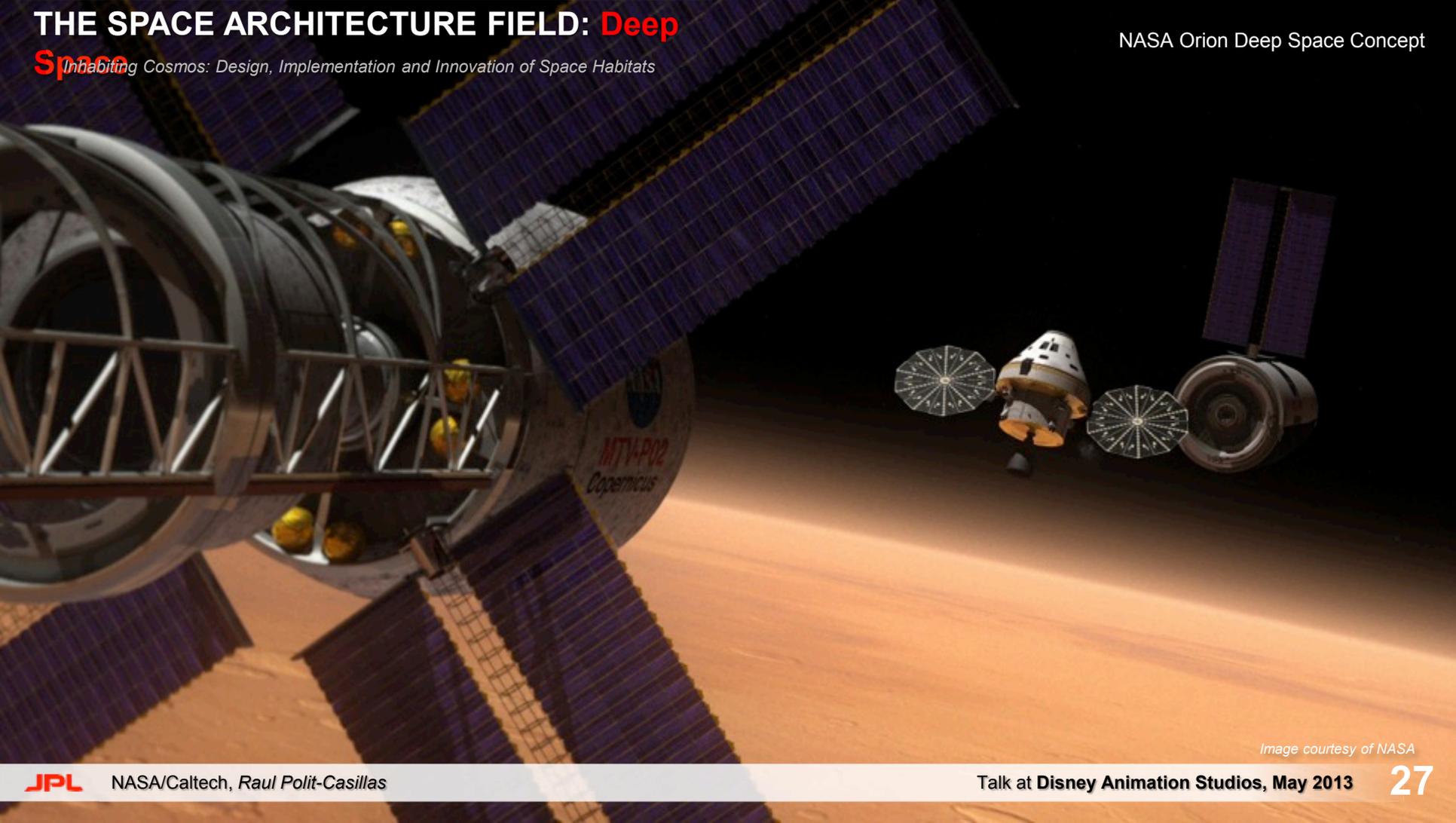


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Other Planetary**

Surfaces

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

NASA Constellation Moon Base

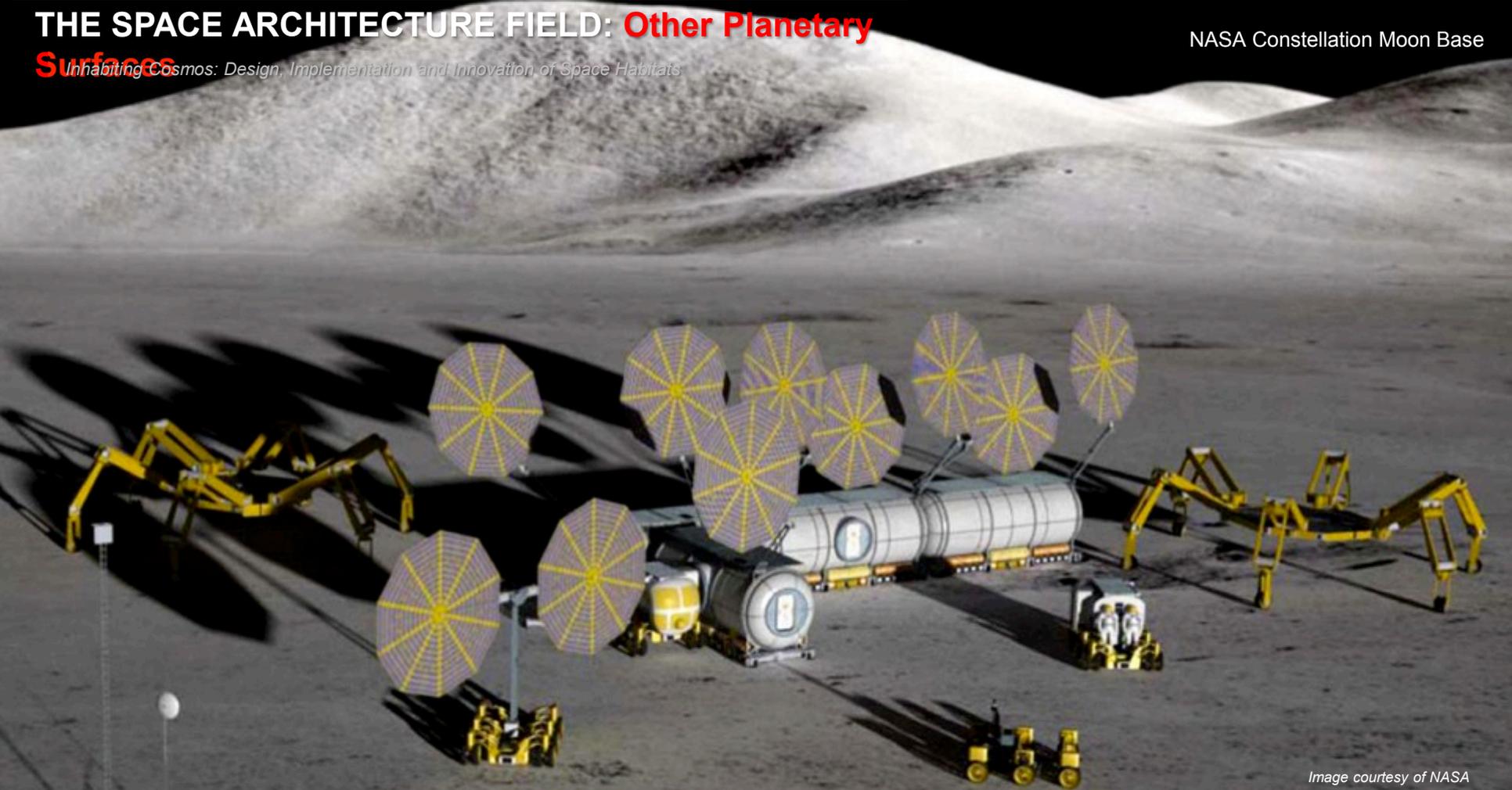


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Other Planetary**

Surfaces

Humanity's Cosmos: Design, Implementation and Innovation of Space Habitats

NASA JPL Athlete + Microhab

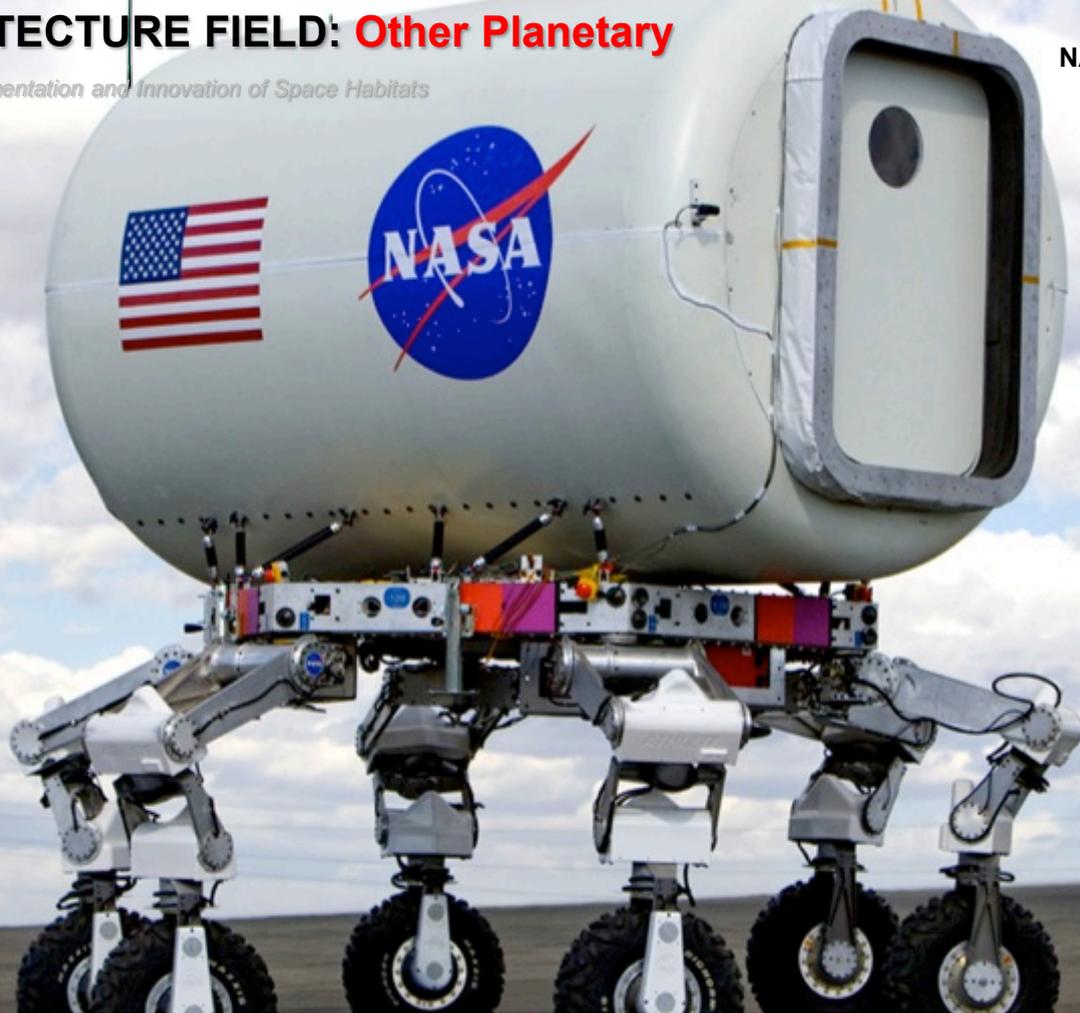


Image courtesy of NASA / JPL

THE SPACE ARCHITECTURE FIELD: Other Planetary

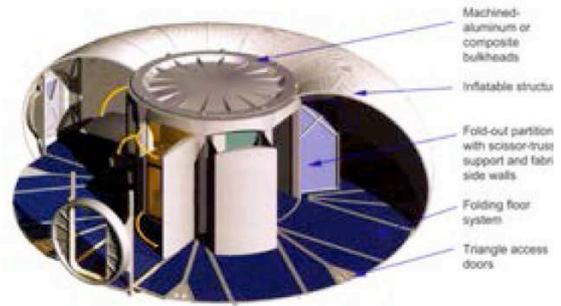
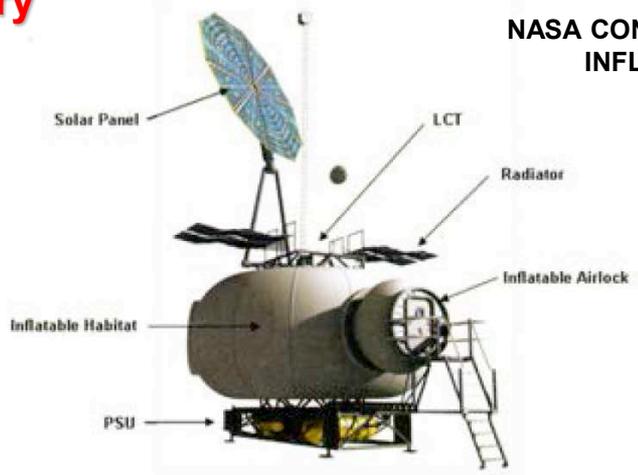
Surfaces

W. H. Rousebal, *Exosmos: Design, Implementation and Innovation of Space Habitats*



Image courtesy of NASA – As Published in AIAA – Out of this world

NASA CONSTELLATION INFLATABLE HAB





REQUIREMENTS AND CONSTRAINTS FOR LIVING IN SPACE...

Image courtesy of NASA

CONFIGURATION, DESIGN, ARCHITECTURE: DSH-HDU

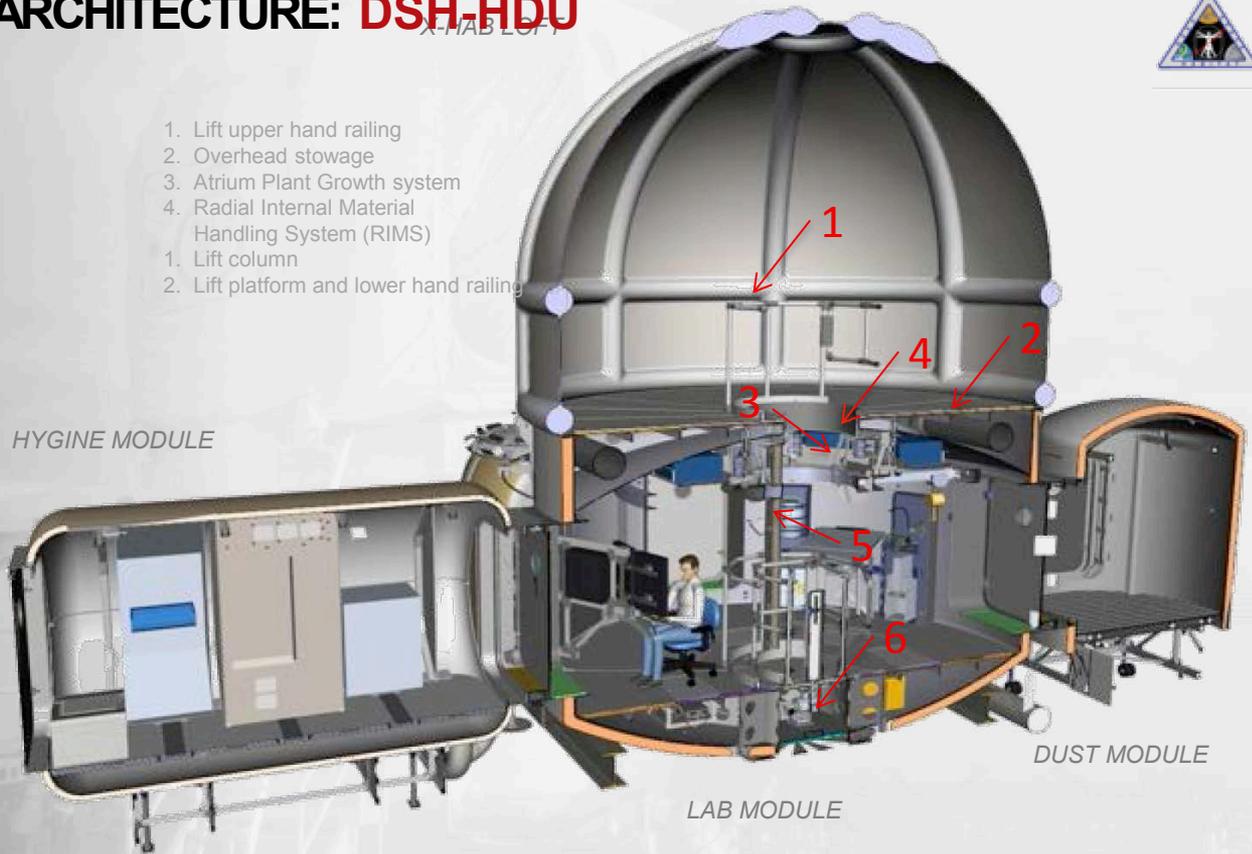
Introduction, background and overall portfolio



HDU Micro-Hab Hygiene Module

- 1. Lift upper hand railing
- 2. Overhead stowage
- 3. Atrium Plant Growth system
- 4. Radial Internal Material Handling System (RIMS)
- 1. Lift column
- 2. Lift platform and lower hand railing

HYGINE MODULE



LAB MODULE

DUST MODULE

Image courtesy of NASA / Configurator Dr. Scott Howe

THE SPACE ARCHITECTURE FIELD:

Constraints *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

CONSTRAINTS DRIVE US...

- Radiation
- Pressure differential
- Isolation
- Extreme temperatures (insulation)
- Micrometeorites
- Gravity cond. (LEO, Moon, Mars...)
- Physical / Chemical / Mechanical cond.
- Dust Composition and mechanics
- Tribology
- LEO and Orbit-Transfer Environment
- Designs with no precedents and low TRL
- Etc.



Image courtesy of NASA

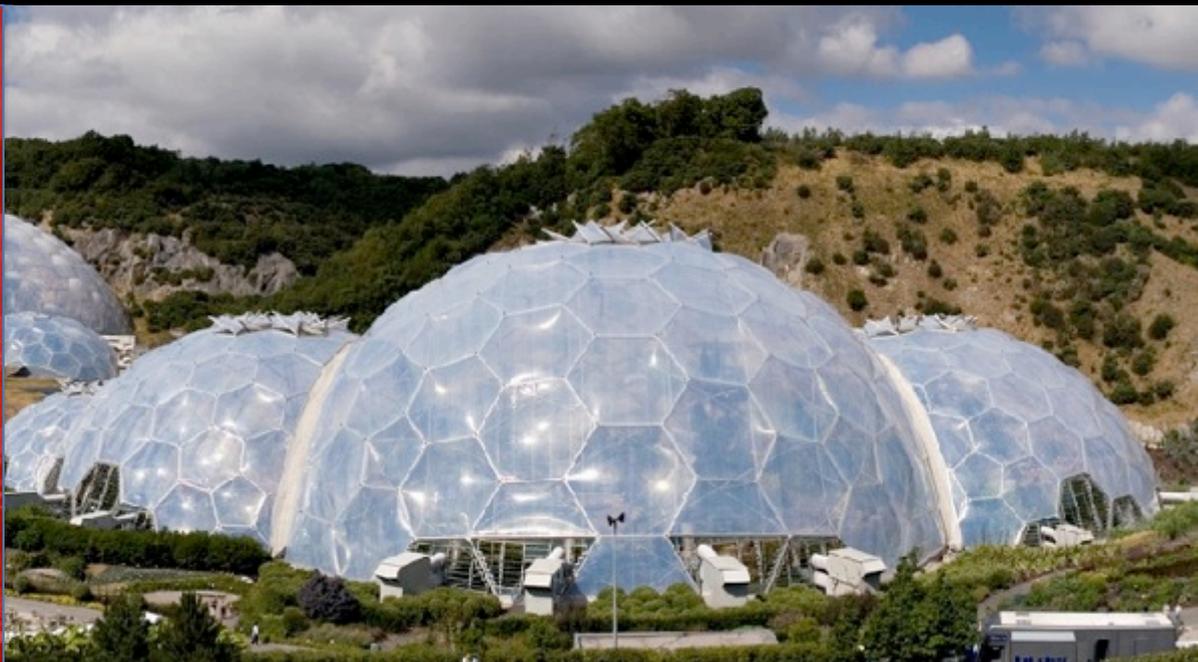
THE SPACE ARCHITECTURE FIELD:

Requirements *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

REQUIREMENTS (quantity, quality and synergy)

- **Functional:** characteristics...
- **Performance:** quantifying
- **Interface:** dependencies between parts

- **Trade-offs:** from lower levels, iterative
 1. Energy generation and management
 2. Structure and design
 3. Sustainability (function, energy...)
 4. Affordability
 5. Adaptability
 6. Habitability (human factors)
 7. Construction and implementation



Credit Public – Jürgen Matern

THE SPACE ARCHITECTURE FIELD: NASA

HDU *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



Lab Module

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: NASA

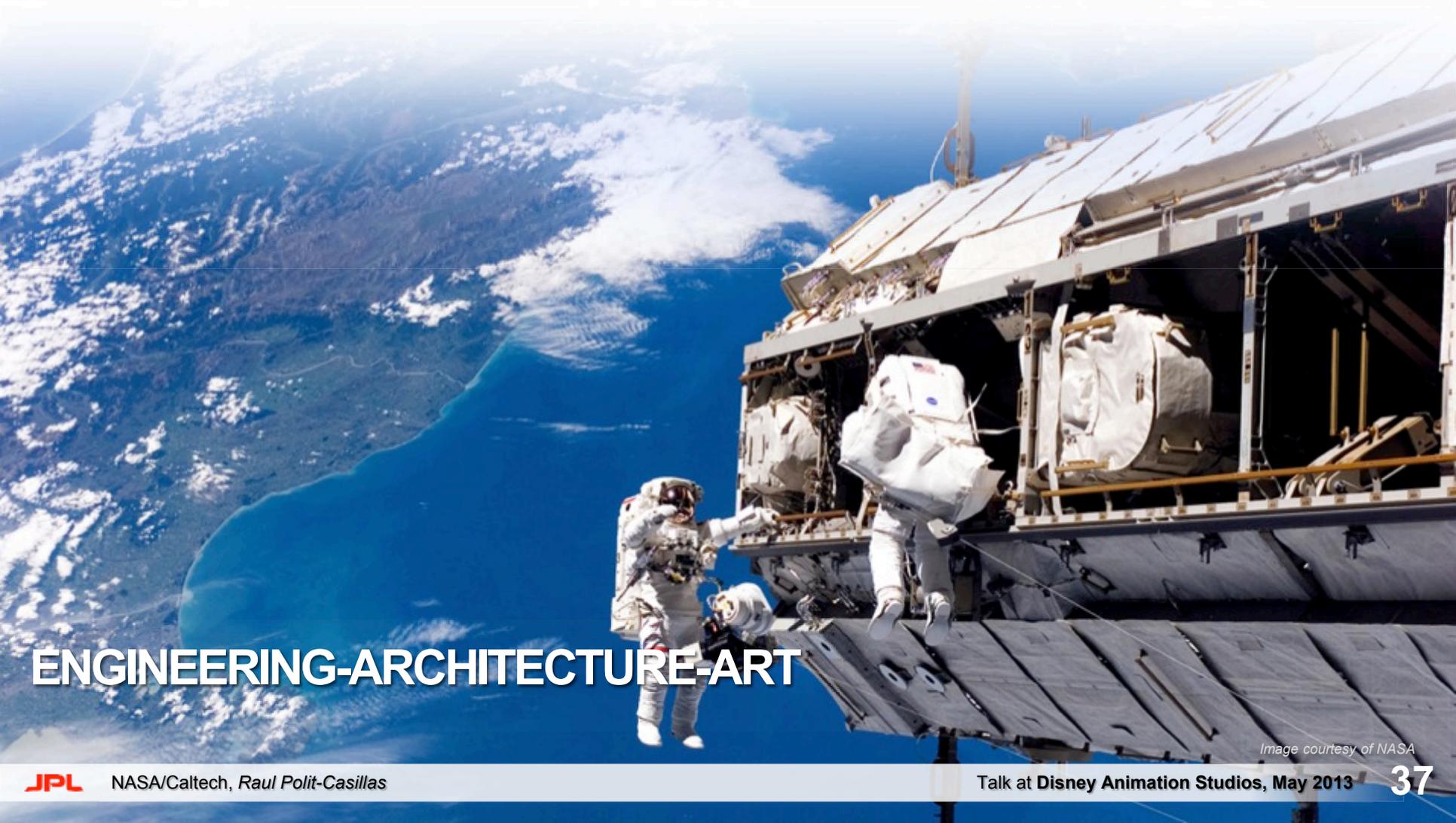
HDU *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



Lab Module



Image courtesy of NASA- JPL



ENGINEERING-ARCHITECTURE-ART

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Conceptual Sketch**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

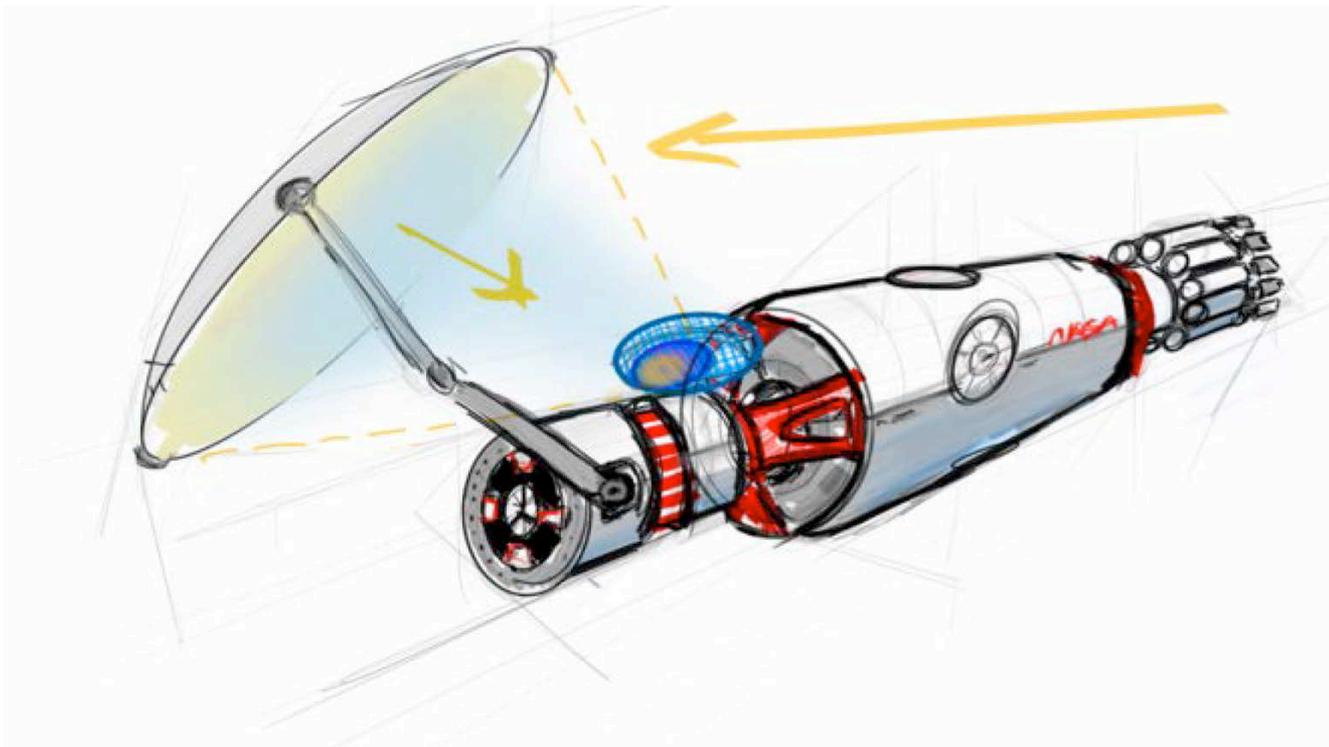


Image courtesy of NASA-JPL

THE SPACE ARCHITECTURE FIELD:

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD:

Illustration

Unsettling Cosmos: Design, Implementation and Innovation of Space Habitats

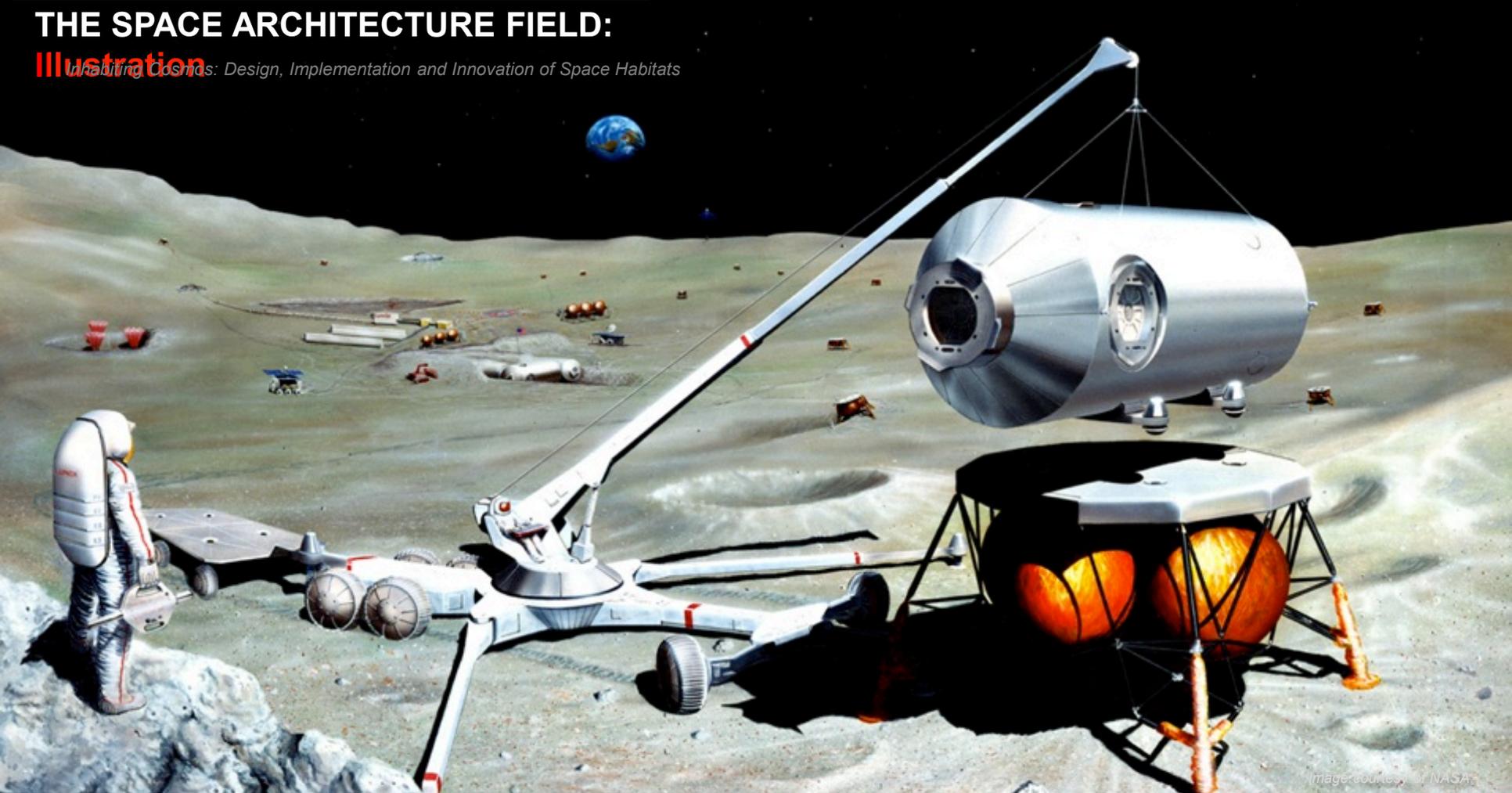


image courtesy of NASA

THE SPACE ARCHITECTURE FIELD:

Illustration *Understanding Cosmos: Design, Implementation and Innovation of Space Habitats*



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Fast 3D**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

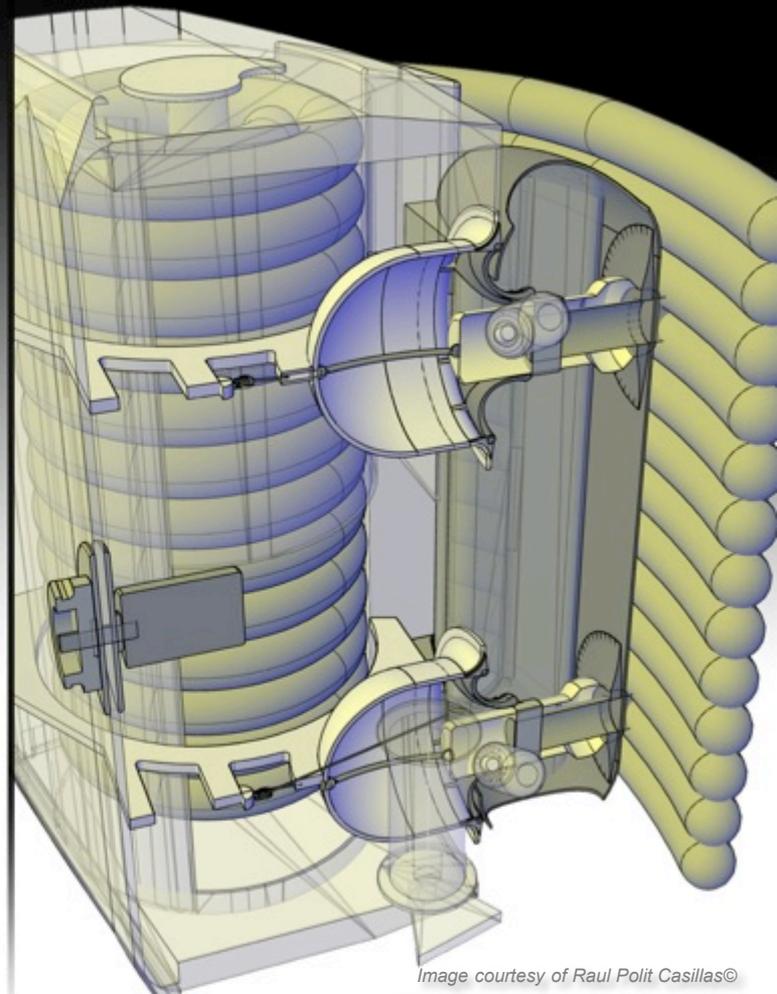
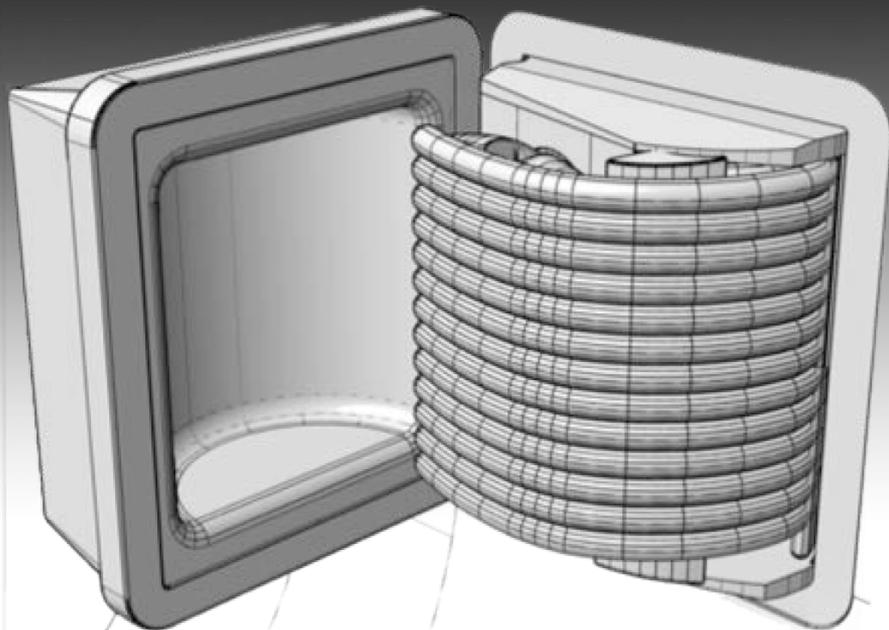


Image courtesy of Raul Polit Casillas©

THE SPACE ARCHITECTURE FIELD: **Fast**

Realistic 3D *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

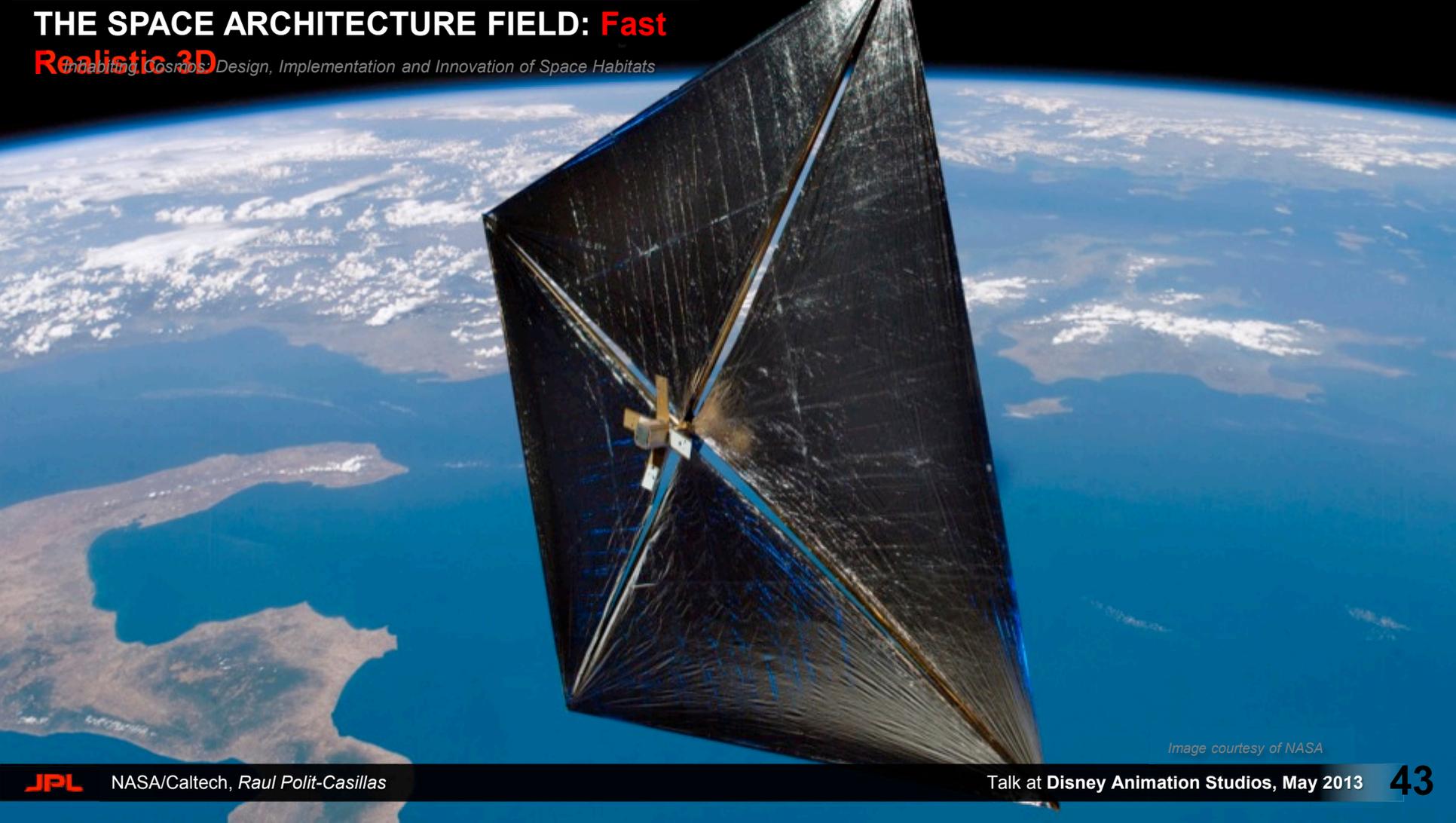


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Hyper**

Realistic
Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

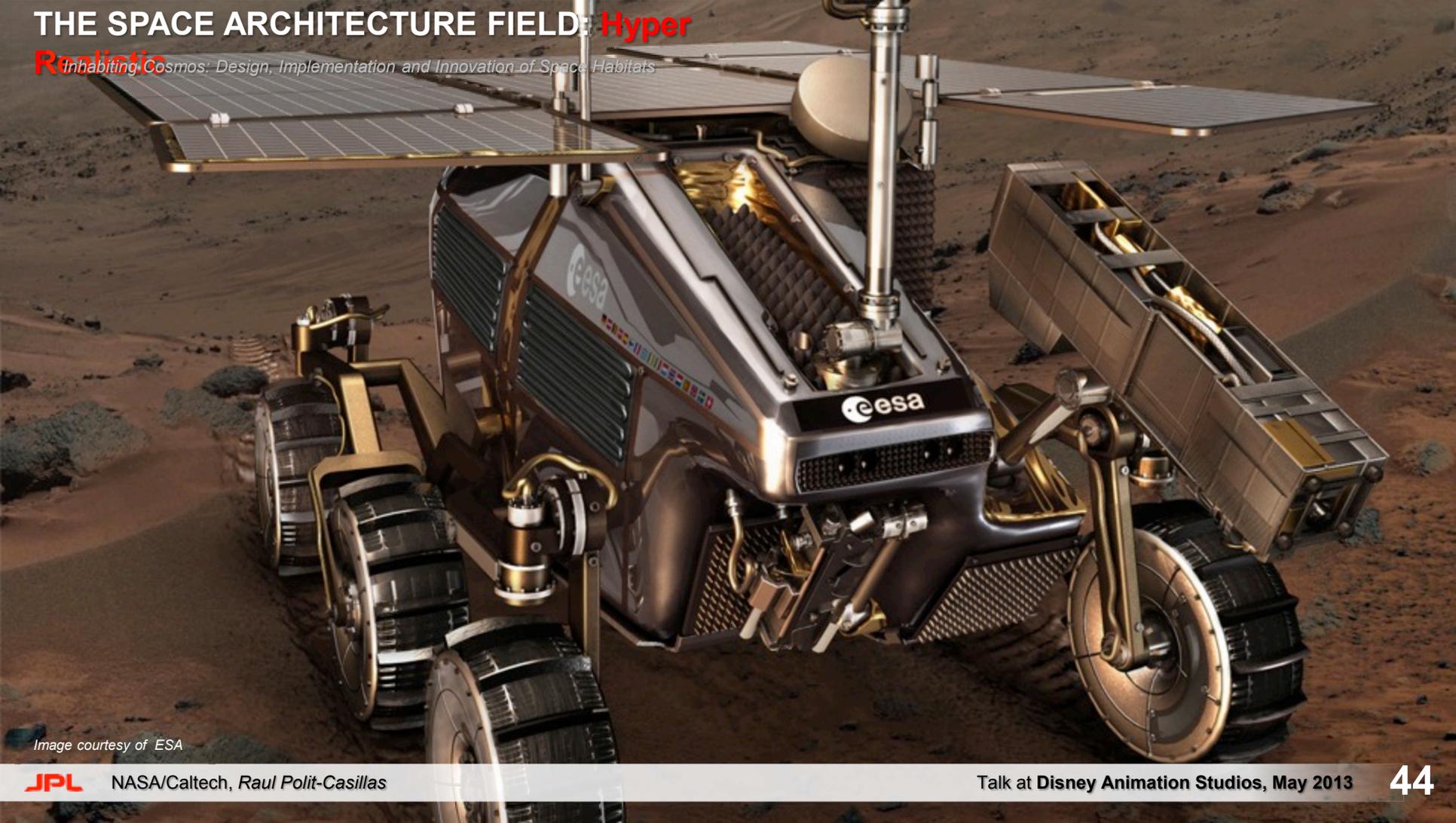


Image courtesy of ESA

VIRTUAL CONSTRUCTION OF SPACE HABITATS



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Miniature**

Mockup *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

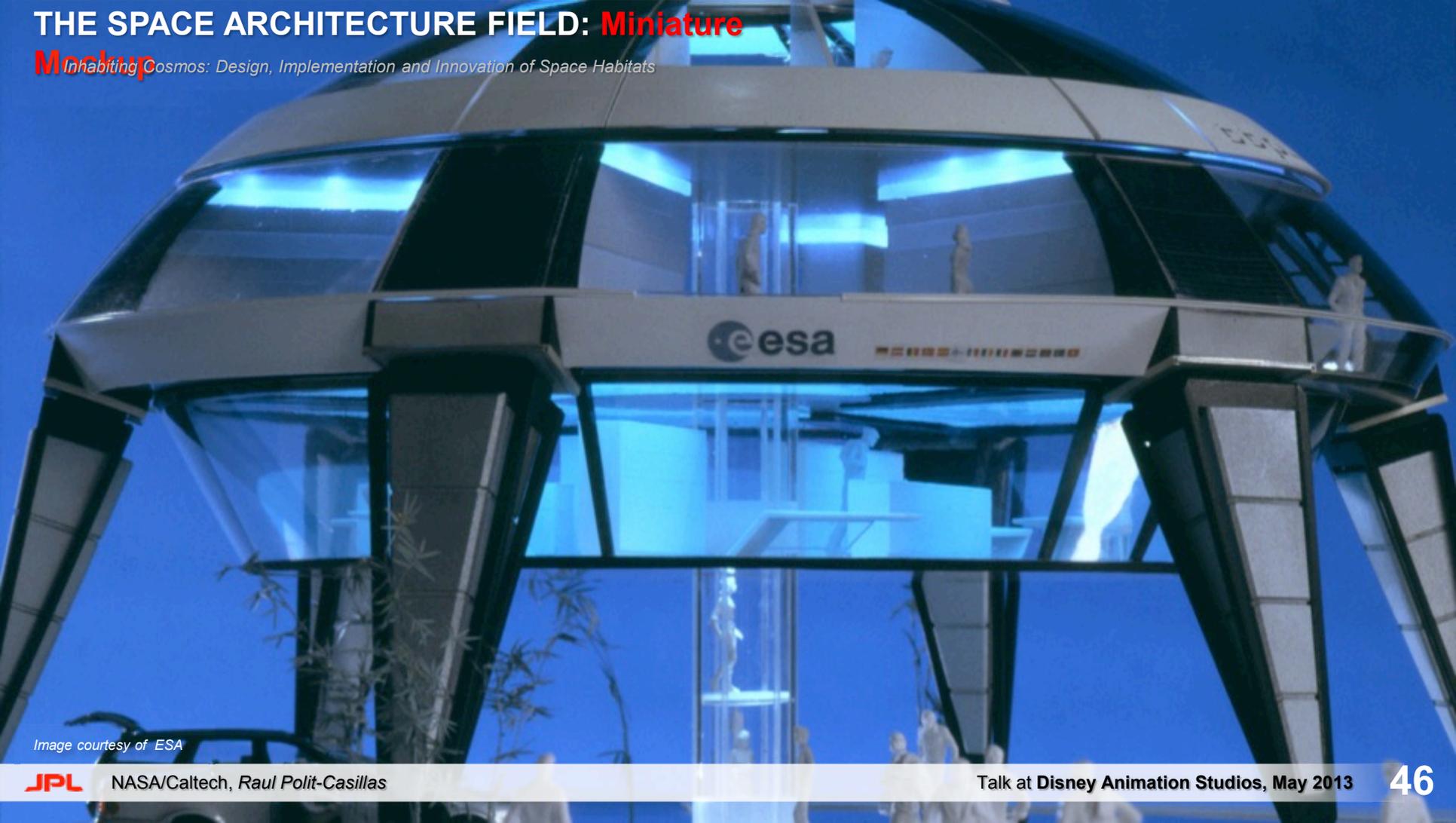


Image courtesy of ESA

THE SPACE ARCHITECTURE FIELD: **Advance Virtual**

Model *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

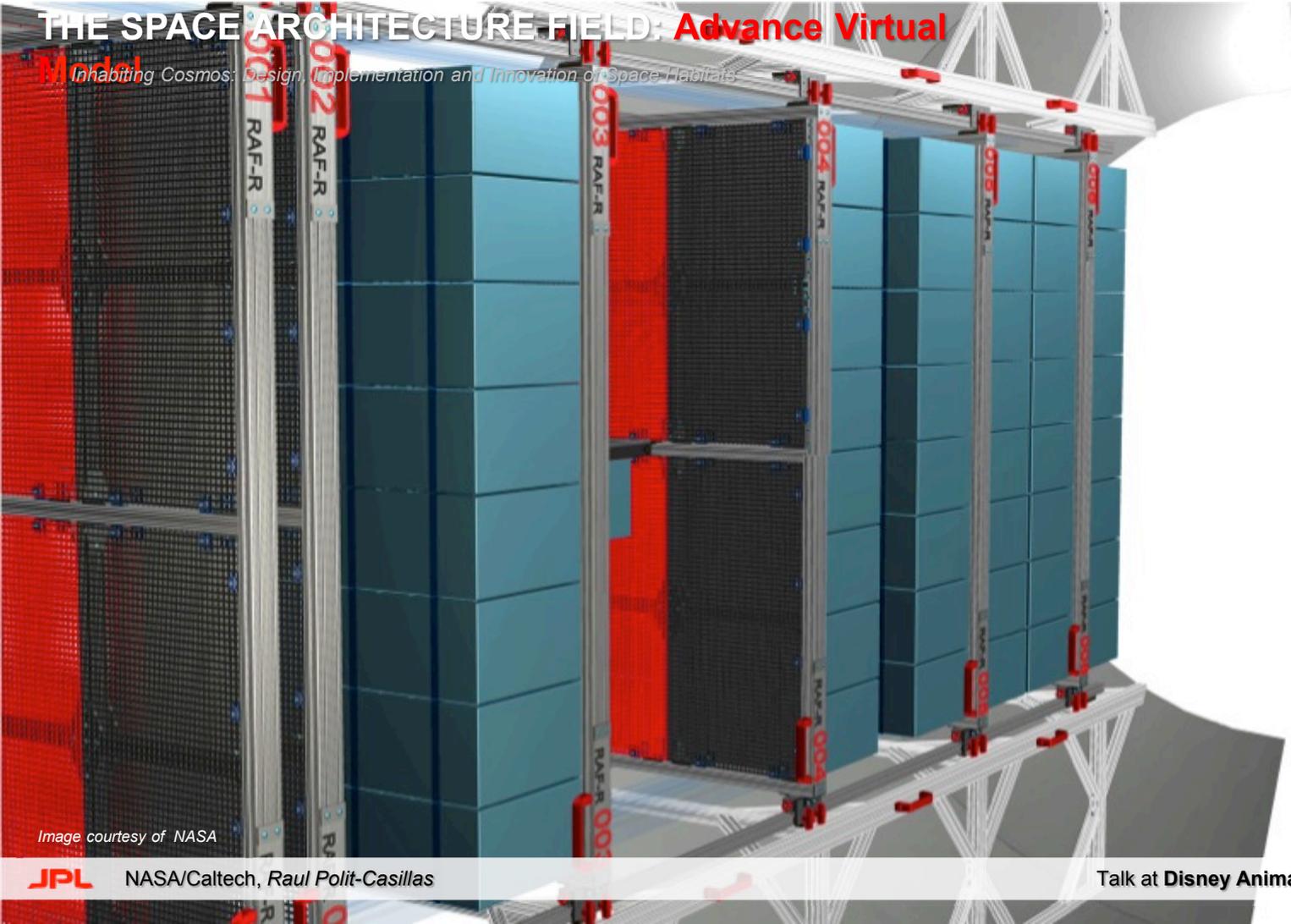


Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: **Advance Virtual Construction Models**

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

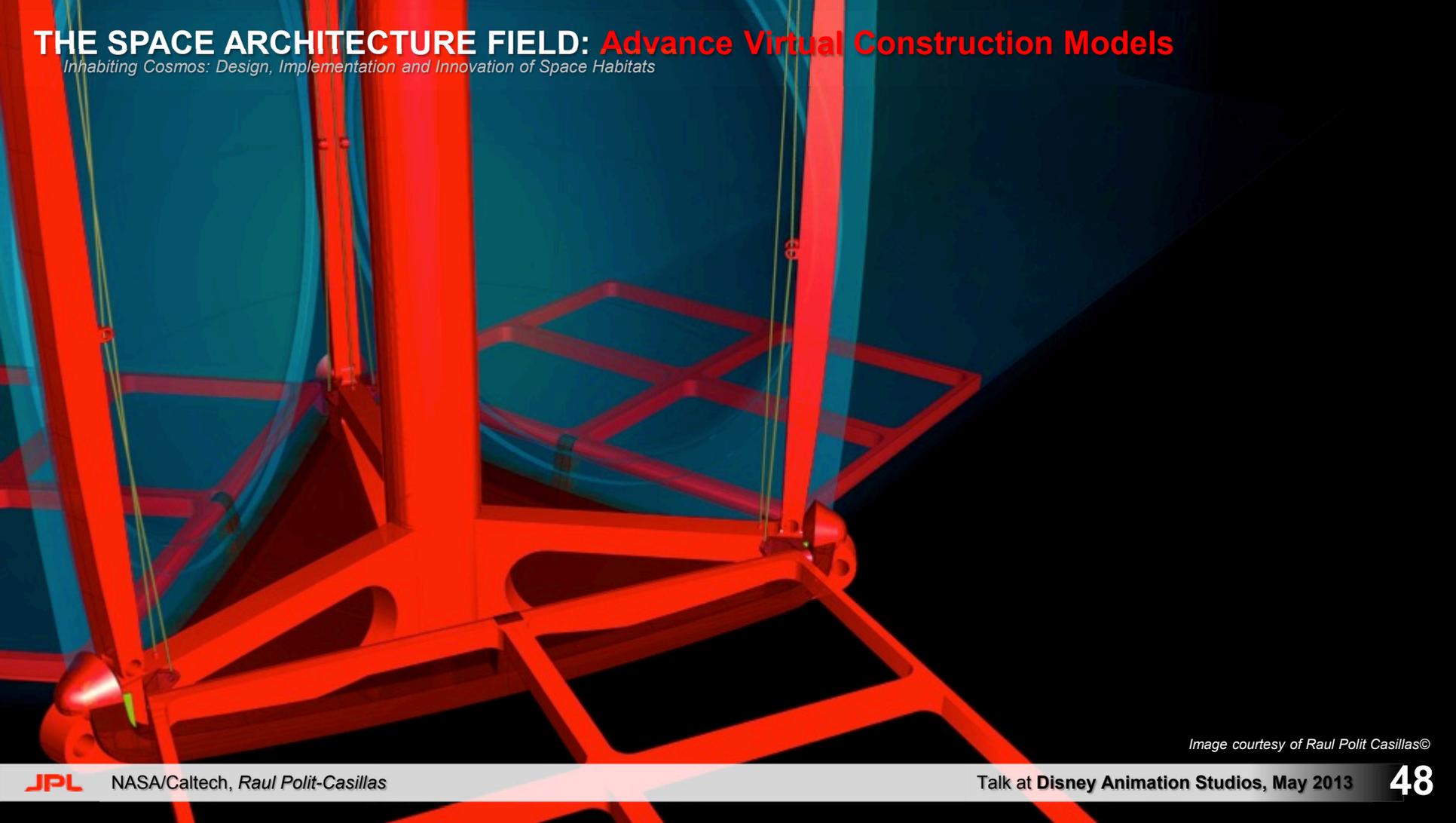


Image courtesy of Raul Polit Casillas©

THE SPACE ARCHITECTURE FIELD: Full-size Mockups

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



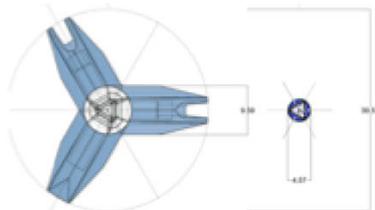
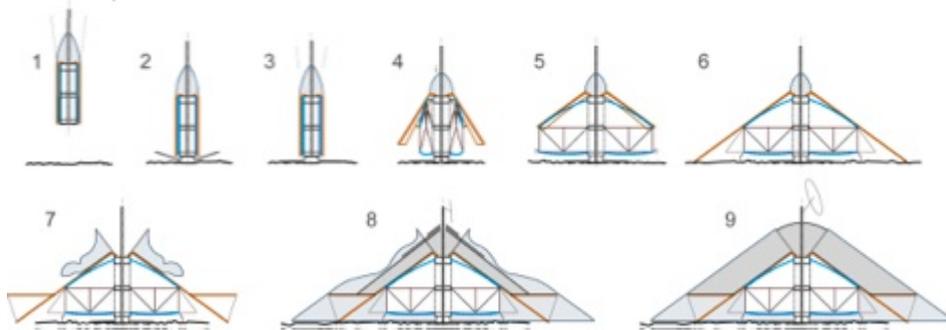
Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Student Example

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

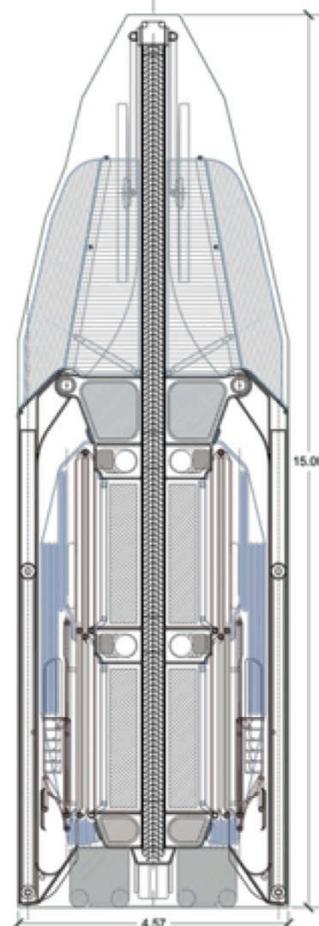


Image Credit: ESA - EADS



Self deployable habitat for a crew of 6. Fitting within the 4.5 m diameter of an Ariane V launcher fairing volume, mass and energy budgets should be reduced to maximum.

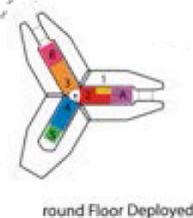
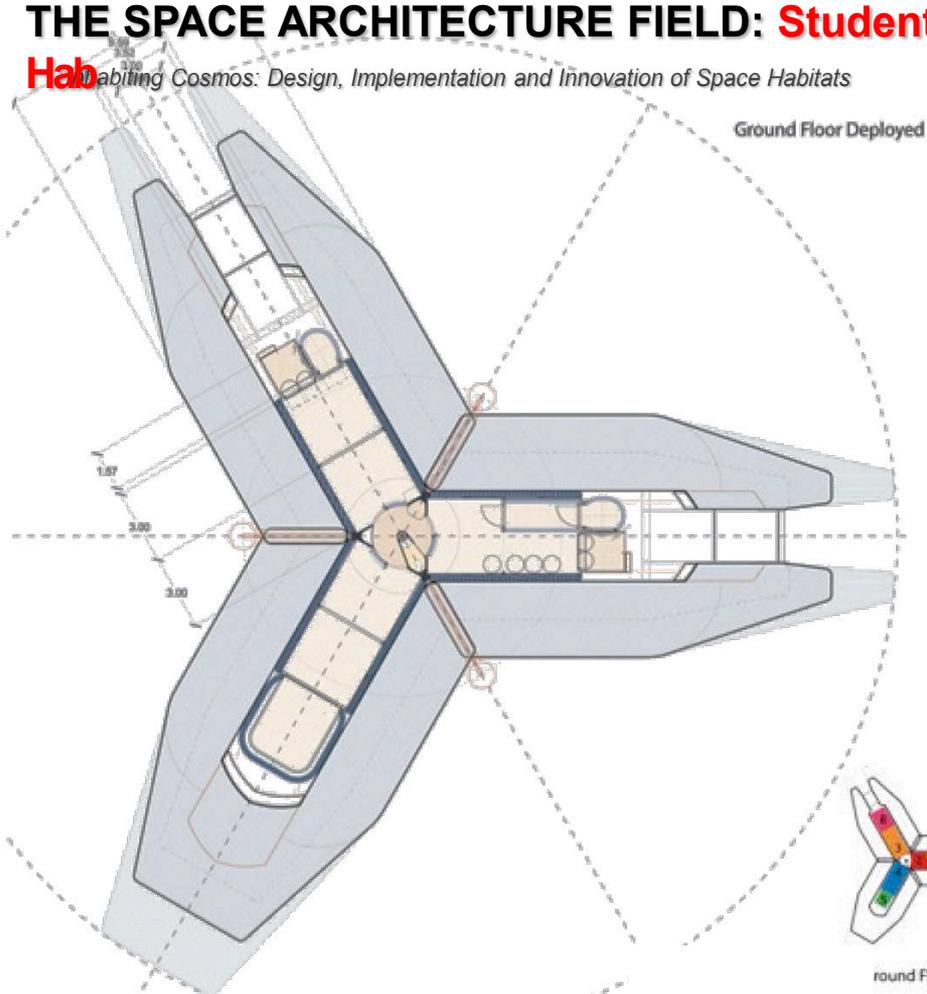
COMPLETE COMPLEX SYSTEMS: SELF DEPLOYABLE LUNAR



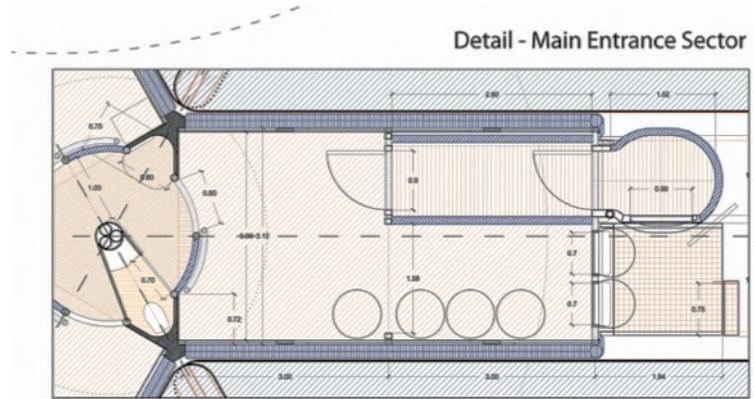
HAB

THE SPACE ARCHITECTURE FIELD: Student - Self Deployable Lunar

Hab Habiting Cosmos: Design, Implementation and Innovation of Space Habitats



round Floor Deployed

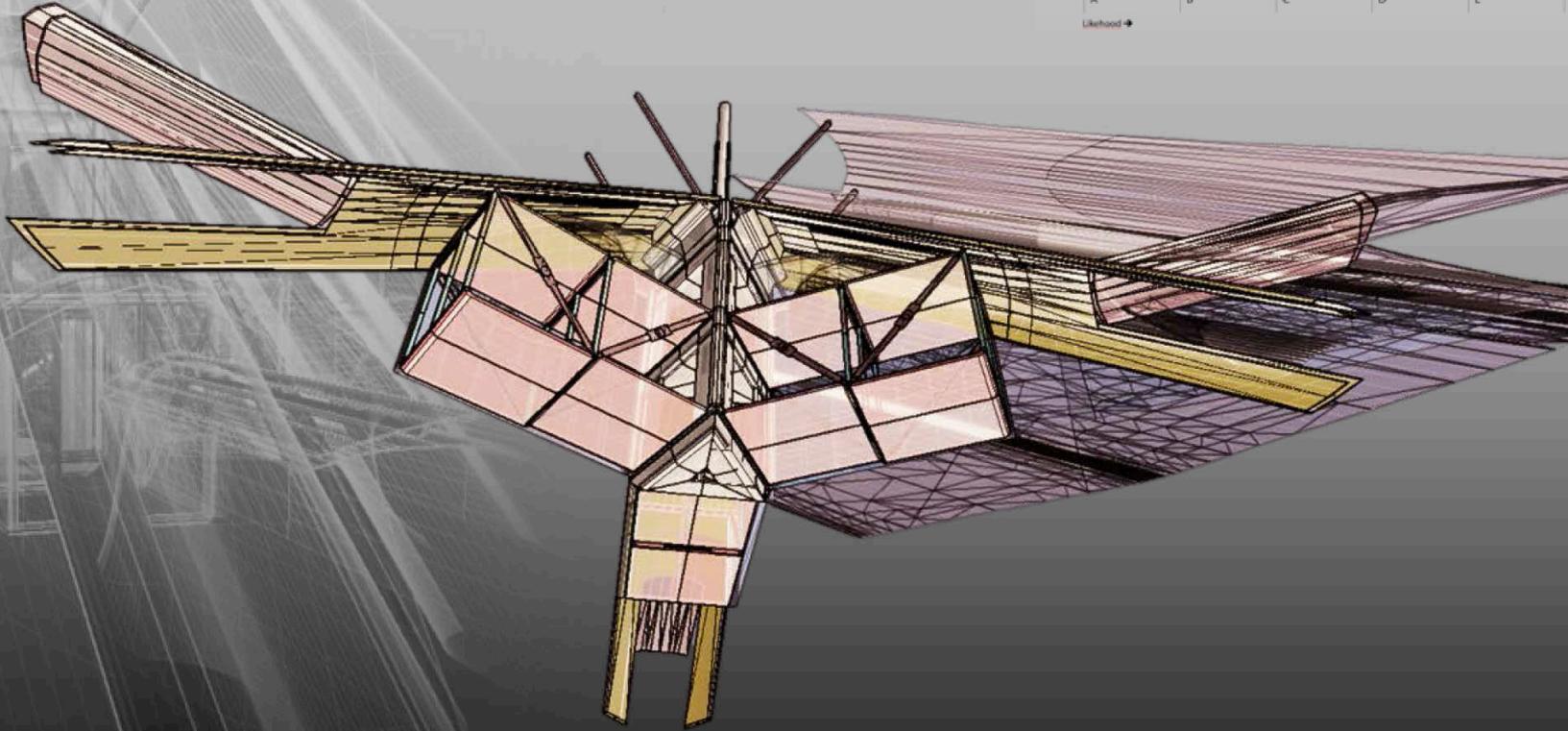
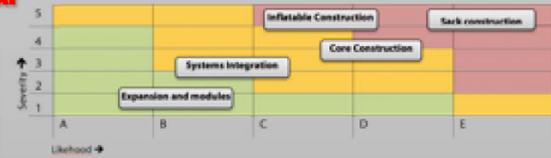


PROGRAMME DISTRIBUTION

A	MAIN ACCESS	12 m ²
B	SECONDARY ACCESS	12 m ²
1	DUST CONTROL	3.2 m ²
2	ACCESS OPERATIONS/STORAGE	14 m ²
3	LIVING AREA / KITCHEN	18 m ²
4	SCIENCE AREA	18 m ²
5	GREEN HOUSE	10 m ²
	COMMON AREAS/BATHROOM	4.8 m ²
	TOTAL	92 m²

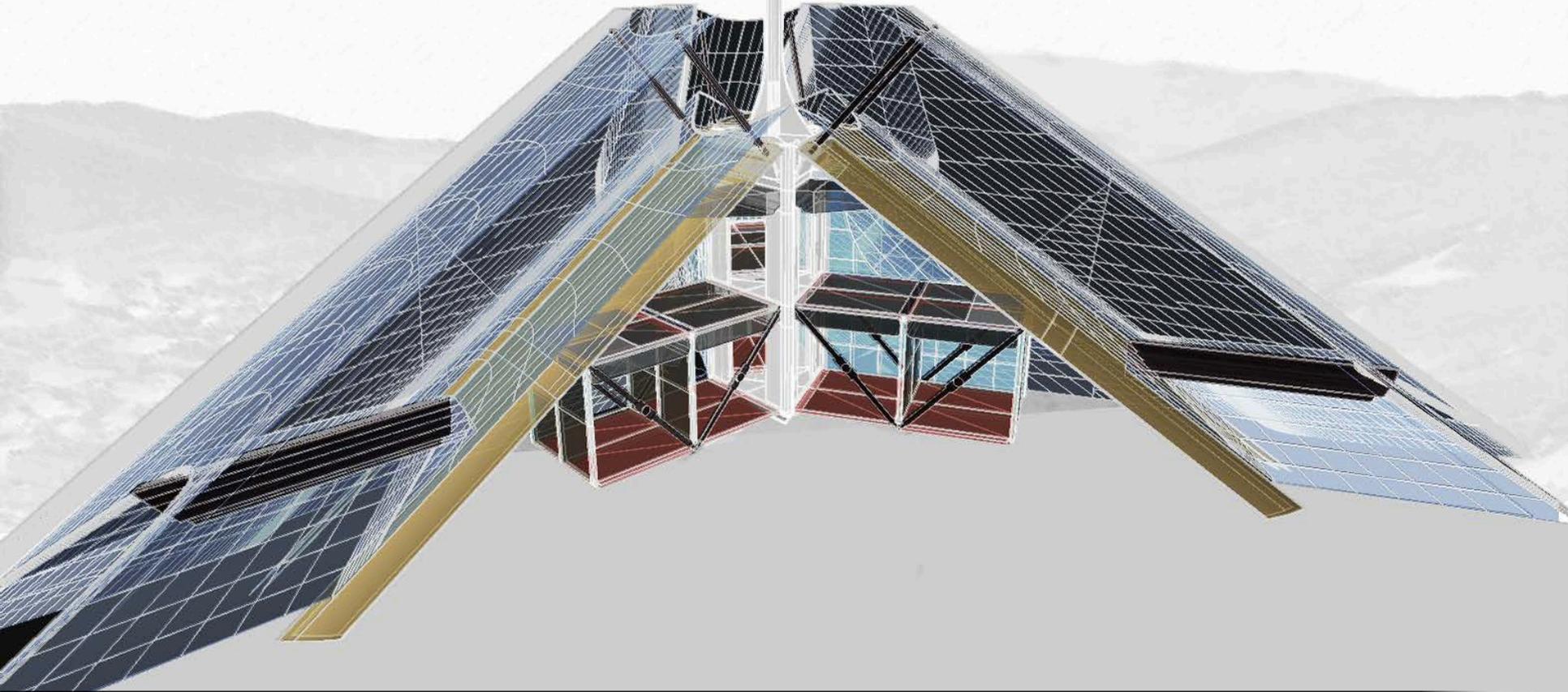
THE SPACE ARCHITECTURE FIELD: Student - Self Deployable Lunar

Hab Habiting Cosmos: Design, Implementation and Innovation of Space Habitats



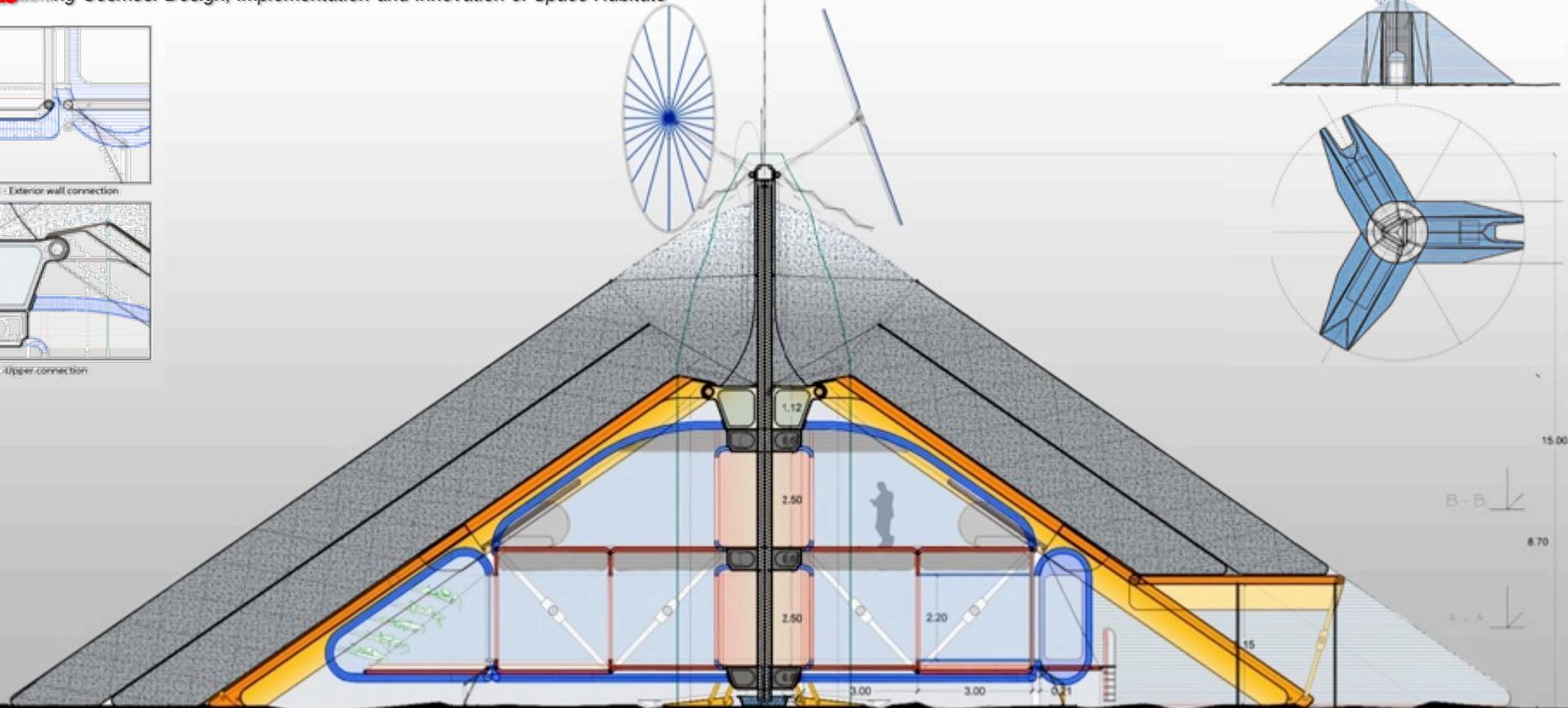
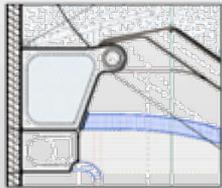
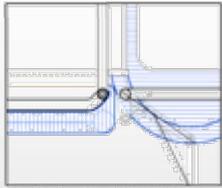
THE SPACE ARCHITECTURE FIELD: **Student - Self Deployable Lunar**

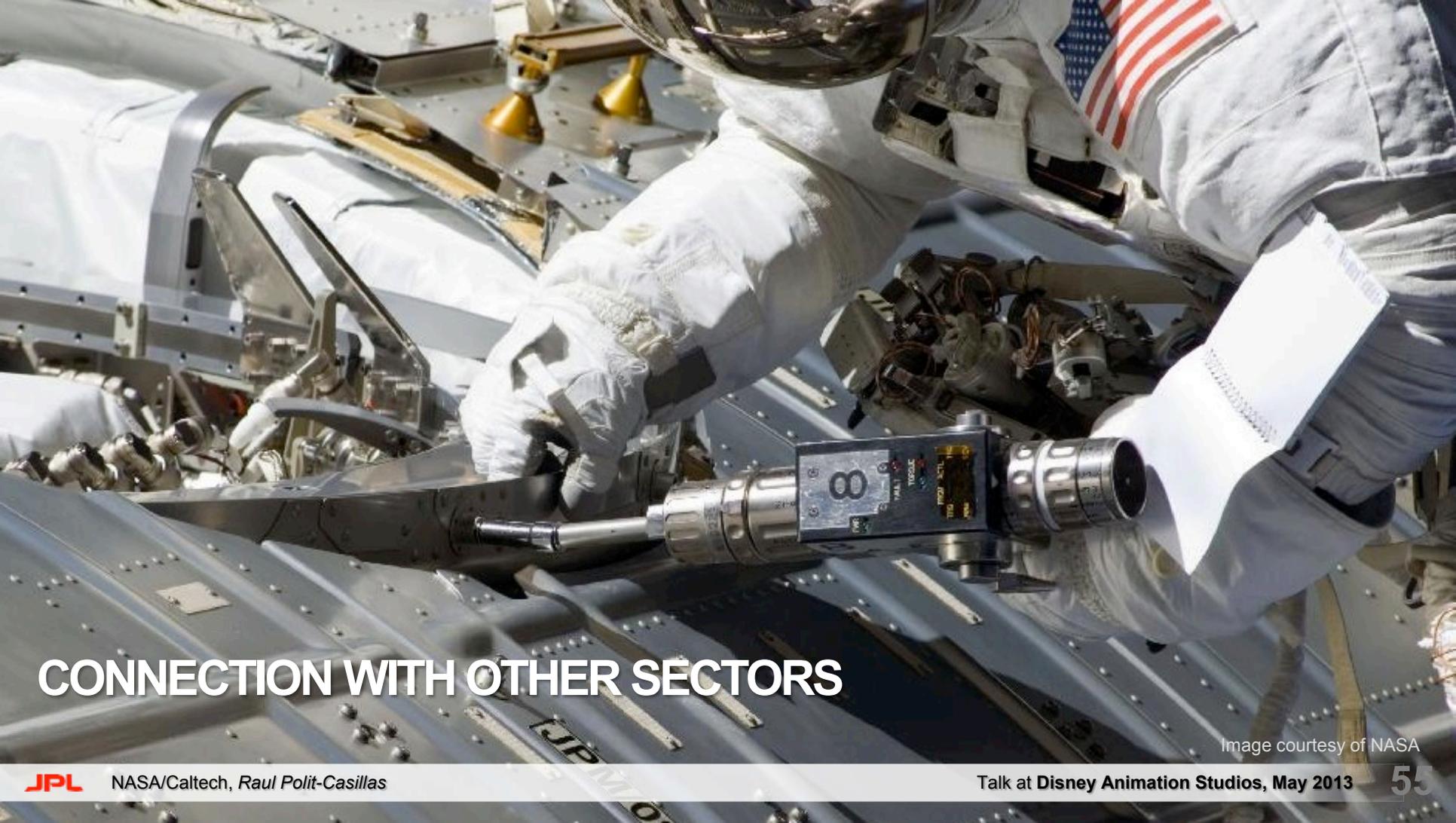
Hab *inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*



THE SPACE ARCHITECTURE FIELD: Student - Self Deployable Lunar

Hab Habiting Cosmos: Design, Implementation and Innovation of Space Habitats





CONNECTION WITH OTHER SECTORS

Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Education and

Media

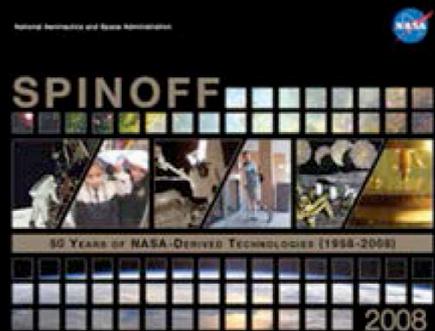
Charting Cosmos: Design, Implementation and Innovation of Space Habitats



THE SPACE ARCHITECTURE FIELD: Science and Tech

Spinoff *Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats*

National Aeronautics and Space Administration



THE SPACE ARCHITECTURE FIELD:

Construction *Inhabiting, Design, Implementation and Innovation of Space Habitats*

	SPACE ARCHITECTURE	TERRESTRIAL ARCHITECTURE
Active Systems	HIGH PERFORMANCE SYSTEMS	
	Human life in space requires energy consumption from active technologies (ECLSS, TCS, etc.)	Dependency on comfort standard and consumer technologies
	Efficient and stable energy sources (Solar, Fuel Cells...)	Similar energy sources and generation technologies
	ENERGY AUTONOMY	
	Long-term space architecture formulations	Small scale building as a autonomous energy system
Passive Systems	INSULATION	
	Unique test bed (e.g. extreme temperature)	Transferrable techniques (e.g. joint-less architecture)
	Aerospace Spinoffs (e.g. aerogel insulation strips)	Advanced materials and concepts (e.g. TIM)
	LOCAL RESOURCES	
	Class II/III habitats would use in situ resources (ISRU)	Ancient architecture techniques (e.g. earth sheltering)
	PASSIVE DESIGN TECHNIQUES	
	Advanced innovative tools (e.g. systems engineering)	Advanced architecture design trends (e.g. BIM)
Management	SYSTEMS INTEGRATION	
	Integrates many more systems and variables	Next generation architecture requires complex integration
	Balance between habitability and requirements	New energy protocols and concepts are needed
	ARCHITECTURE PERSPECTIVE	
	Earth-based space architecture is an actual connection	Mobility, technology integration, interactivity or energy autonomy within architectural standpoint
	SUSTAINABILITY	
	Space agencies and industry shown an increasing concern	Applications of space technologies in architecture
HUMAN RESOURCES		
	'Space architects' multidisciplinary approach in contact with hard science and space technology	Professionals directly involved with innovative architecture



Image courtesy of NASA / JPL

THE SPACE ARCHITECTURE FIELD: Design and Environment

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats



Image courtesy of NASA

THE SPACE ARCHITECTURE FIELD: Q&R

Inhabiting Cosmos: Design, Implementation and Innovation of Space Habitats

Image courtesy of NASA



THANK YOU...

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