APPLIED SPACE ARCHITECTURE
Advance Constructive Design Or How To Bring Space Down To Earth So We Can Keep Sending Mankind To The Stars…
2012 Seminar at Caltech
Raul Polit-Casillas, Space Architect at JPL – Advance design and construction techniques, HSF

- JPL NASA /Caltech – JVSRP Researcher, Affiliate - NASA Habitation Team (since 2011)
- AIAA SATC Space Construction Subcommittee Chair (Member, since 2006)
- XAR SIDERREAL Initiative – Founder and director, since 2008
- Technological IVAM – Inhabiting Cosmos Int. Exhibitions – Curator, since 2011
- Space Architecture and Sustainability Int. Seminar – Director – UCV, since 2010

- MSc - Master Science in Space Studies and Human Spaceflight – ISU 2011
- M.Arch - Master Architect, All specialties, UPV 2008
- Industrial Engineering Studies
- Licensed Architect and builder
- NASA Ames summer Intern, 1999
- Caja Madrid International Postgraduate Scholarship Awarded, 2010-2012
- Fulbright Commission preselected Fellow
- ESA Full scholarship award, 2010
- JPL JVSRP Fellow
CONTENT

• SPACE ARCHITECTURE: Evolution, milestones and interdisciplinary approach…
• DESIGN: Requirements, constrains and environments
• CONSTRUCTION: Implementing on Earth and beyond…
• CONCLUSIONs
“Space Architecture is the theory and practice of designing and building inhabited environments in outer space”

Millenium Charter, Tx USA, 2002
Mechanikoi, a constructive degree (Eastern Roman Empire):

- They mastered both construction science and technology as well mathematics and astronomy
- Key architects: 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)
PAST First Projects of Space Stations

Herman Potočnik Concept, 1929  Credit: Public Domain

Konstantin Tsiolkovsky, Concepts (1897)
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Architectural Constructive and Design Processes

Image courtesy of NASA

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NASA Skylab, 1979
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FUTURE... (near?)

NASA Moon Base Concept, 1980

Image courtesy of NASA
DESIGN: Advance Architecture in space

1. Constraints
2. Requirements
3. Environments
   1. EARTH
   2. LEO
   3. Deep Space
   4. Other Planetary Surfaces
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.
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
NASA Inflatable Base – McMurdo (Antarctica)

Image courtesy of NASA
LOW EARTH ORBIT (LEO)

http://www.nasaimages.org/STS_Expedition13 - Life-in-Orbit
DEEP SPACE

NASA Orion Deep Space Concept

Image courtesy of NASA
OTHER PLANETARY SURFACES

NASA HDU Module

Image courtesy of NASA
1. Lift upper hand railing
2. Overhead stowage
3. Atrium Plant Growth system
4. Radial Internal Material Handling System (RIMS)
5. Lift column
6. Lift platform and lower hand railing
See the full page for details.
DEPLOYABLE MOON HABITAT

Master research:
Designing a habitat within the 4.5 m diameter of a launcher fairing

• Volume
• Mass
• Function
DEPLOYABLE MOON HABITAT

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Architectural Constructive and Design Processes
DEPLOYABLE MOON HABITAT

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CONSTRUCTION: Implementing process

1. **Iteration** with the design process
2. **Environment** constraints
3. Technology **requirements**
4. Testing the **untestable**…
5. Dependencies…
6. **Energy**!
7. **Control**
8. **Human / Robot / Machine** interaction
Construction depends on the habitat:

Type I: Pre-integrated habitats
   All done on Earth – E.g. MIR

Type II: Prefabricated habitats
   Assembly and integration – E.g. Transhab

Type III: In-situ Resources Habitat
   Future planetary surfaces bases – E.g. Moon

TOOLS and PROCESS and SYSTEMS
Energy, design and construction crisis:

Human constructions certainly pose many architectural challenges on Earth.

- World electricity generation will increase 77% from 2006 to 2030 (UN)
- Building are responsible of:
  - 40% of energy consumption
  - 36% of CO2 emissions (Europe)
  - 72% of the total electrical power (USA)

Consequently, architecture is the biggest energy consumer sector...
### CONSTRUCTION Processes - Energy

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

Image courtesy of NASA

APPLIED SPACE ARCHITECTURE

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Sustainable Architecture

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Pattern Study to map a cylindrical volume using flexible elements (CTB)
CTBs MAPPER: Elements

1. CABLE
2. METALLIC CORE
3. METAL STAPLER BRACELET
4. RUGGERIZED SURFACE
5. PRESSURE POINTS (TO CLOSE)
6. COMPOSITE WINGS
7. NEEDLE
8. METALLIC TIP (REMOVABLE)
9. TEETH OF THE TIP


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CTBs MAPPER: The tool

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Architectural Constructive and Design Processes

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CTBs MAPPER: Robotic Architecture Process

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SPACE ARCHITECTURE / ENGINEERING:

1. It brings an extreme test bed for both technologies/concepts as well as procedures/processes…
2. Design and construction (engineering) always go together, specially with complex systems
3. Requirements (objectives) are crucial. More important than the answers are the questions…

   Requirements / Tools-Techniques / Processes

4. Different environments force architects and engineering to think out of the box… For instance there might not be gravity forces.
5. Architectural complex problems have common roots: in Space and on Earth

   Lets bring Space down on Earth so we can keep sending Mankind to the stars from a better world…
6. Have fun been architects and engineers…!!!

   This time is amazing and historical We are changing the way we inhabit the solar systems!
IMPLEMENTING Space Habitats
Applied Architectural Constructive and Design Processes

THANK YOU...