우주강국으로 가는 길
패널 토론 자료

이 태 식 교수

한양 대학교 교수
국제우주탐사연구원 원장

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2013년 2월 26일(화)
한국과학기술회관 아나이스홀

과우회
과우봉사단
한국기술경영연구원

ISERI

Contents

Necessity of Space Exploration

Why We Go to the Space ?

Human Civilization

- Past : voyage to the new world
- Present : globalization through satellite
- Future : space development through planetary exploration

Global Partnership

- Successful space exploration through international collaboration
- Synergy on sharing resource, technology, human resource

Economic Expansion

- create various value added business
- Economic revitalize by new market

Scientific Knowledge

- Learn about origin of Earth and solar system
- Answer life' s most fundamental questions

Exploration Preparation

- Opportunities to test new technologies, experience for space exploration
- Learn ways to use resources found in space

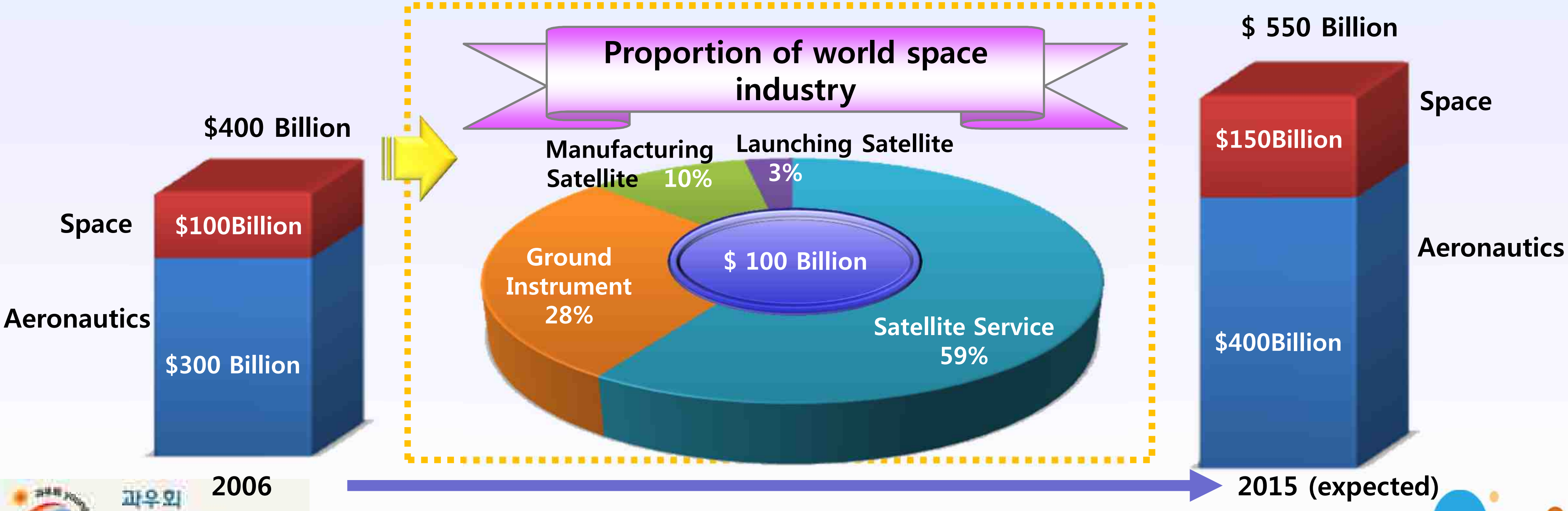
Public Engagement

- Inspire next generation to learn science, technology, engineering, math
- Learn real life applications of science technology

Necessity of Space Exploration

World Investment in Space Sector

- World investment of space industry is extremely increase for 2000s
- US and Russia's satellite navigation system and communication satellite, and investment by space developing country lead to space industry expansion
- Investment of Korea for space field is 1/70 of NASA, and 1/9 of JAXA



* Source: 우주산업 선진화를 위한 과학기술정책 방향, KISTEP

Necessity of Space Exploration

Fiscal Plans for Space Developed Country

Budget Proportion of NASA's Space Exploration

- Total Investment is $19 billion in 2011, space exploration investment is $4.2 billion (23%)

- NASA ISRU is comprised in Exploration Technology and Demonstrations, and budget is $1.5 billion (8.2%)

Budget Authority ($M)	FY 2010		FY 2011 Annualized CR		FY 2011 Authorization Act		FY 2012		FY 2013	FY 2014
Science	4,498	24%	4,469	24%	5,006	26%	5,017	27%	5,017	5,017
Aeronautics	497	3%	501	3%	580	3%	569	3%	569	569
Space Technology	275	1%	327	2%	512	3%	1,024	5%	1,024	1,024
Exploration System	3,626	19%	3,594	19%	3,706	20%	3,949	21%	3,949	3,949
Space Operation	6,142	33%	6,147	33%	5,508	29%	4,347	23%	4,347	4,347
Education	180	1%	183	1%	146	1%	138	1%	138	138
Cross-Agency Support	3,018	16%	3,019	16%	3,111	16%	3,192	17%	3,192	3,192
CoF and ECR	453	2%	448	2%	394	2%	450	2%	450	450
Inspector General	36	0%	36	0%	37	0%	38	0%	38	38
NASA FY 2012	18,724	100%	18,724	100%	19,000	100%	18,724	100%	18,724	18,724

Necessity of Space Exploration

Fiscal Plans for Space Developed Country

Budget Proportion of CSA's Space Exploration

- Total Investment is $3,700 million in 2011, space exploration investment is $1,600 million (41%)
- CSA focus on exploration system instead of space vehicle
- CSA invests on lunar exploration rover about $1,100 million(10%of total budget) for involving International Space Exploration Coordination Group(ISECG)

PROGRAM ACTIVITY ALIGNMENT TO GOVERNMENT OF CANADA OUTCOMES ($M)

Program Activity	Forecast Spending 2009 - 2010	Planned Spending						Government of Canada Outcomes
		2010-2011		2011-2012		2012-2013		
Space Based Earth Observation (EO)	84.2	88.7	23%	108.4	29%	106.2	34%	A Clean and Healthy Environment
Space Science and Exploration (SE)	145.7	185.4	47%	156.1	41%	95.9	31%	A Strong and Mutually Beneficial North American Partnership
Satellite Communications (SC)	17.7	19.7	5%	14.4	4%	11.7	4%	A Safe and Secure Canada
Generic Technological Activities In Support of EO, SE and SC	54.3	46.2	12%	48.4	13%	48.9	16%	An Innovative and Knowledge-Based Economy
Space Awareness and Learning (AL)	9.3	8.1	2%	8.2	2%	8	3%	A Vibrant Canadian Culture and Heritage
Internal Services	46.2	42.8	11%	42.9	11%	42.1	13%	Not Applicable
TOTAL	**357.3**	**390.8**	**100%**	**378.4**	**100%**	**312.7**	**100%**	

NASA Exploration Technology Development

NASA Space Technology Investments

- Space Technology investments enable future human and scientific exploration of near-Earth asteroids, the Moon, and Mars, just as current and past mission successes were supported by previous technology investments.
- Significant progress in technology areas such as space power systems, entry, descent, and landing systems, propulsion, radiation protection, and cryogenic fluid handling are essential for space exploration beyond low Earth orbit.

Space Technology Investments

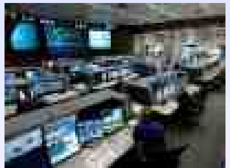
- SMALL BUSINESS INNOVATIVE RESEARCH **(SBIR)** AND SMALL BUSINESS TECHNOLOGY TRANSFER **(STTR)**
- PARTNERSHIP DEVELOPMENT AND STRATEGIC INTEGRATION
- CROSSCUTTING SPACE TECHNOLOGY DEVELOPMENT **(CSTD)**
- EXPLORATION TECHNOLOGY DEVELOPMENT (ETD)

NASA Exploration Technology Development

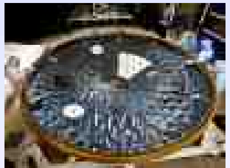
Expanding Human Presence Into the Solar System

- The Exploration Technology Development Program (ETD Program) develops long-range technologies to enable human exploration beyond Earth orbit
- ETD Program also integrates and tests advanced exploration systems to reduce risks and improve the affordability of future missions


Advanced In-Space Propulsion


Autonomous Systems and Avionics

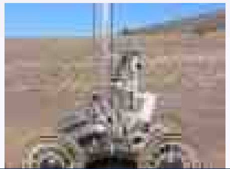

Cryogenic Propellant Storage and Transfer


Entry Descent and Landing Technology

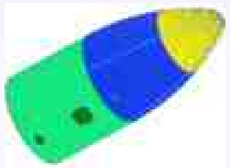

Extravehicular Activity Technology


High-Efficiency Space Power Systems


Human Robotic Systems


In-Situ Resource Utilization


Life Support and Habitation Systems


Lightweight Spacecraft Materials and Structures


Multi-Mission Space Exploration Vehicle


Deep Space Habitat


Autonomous Precision Landing Systems

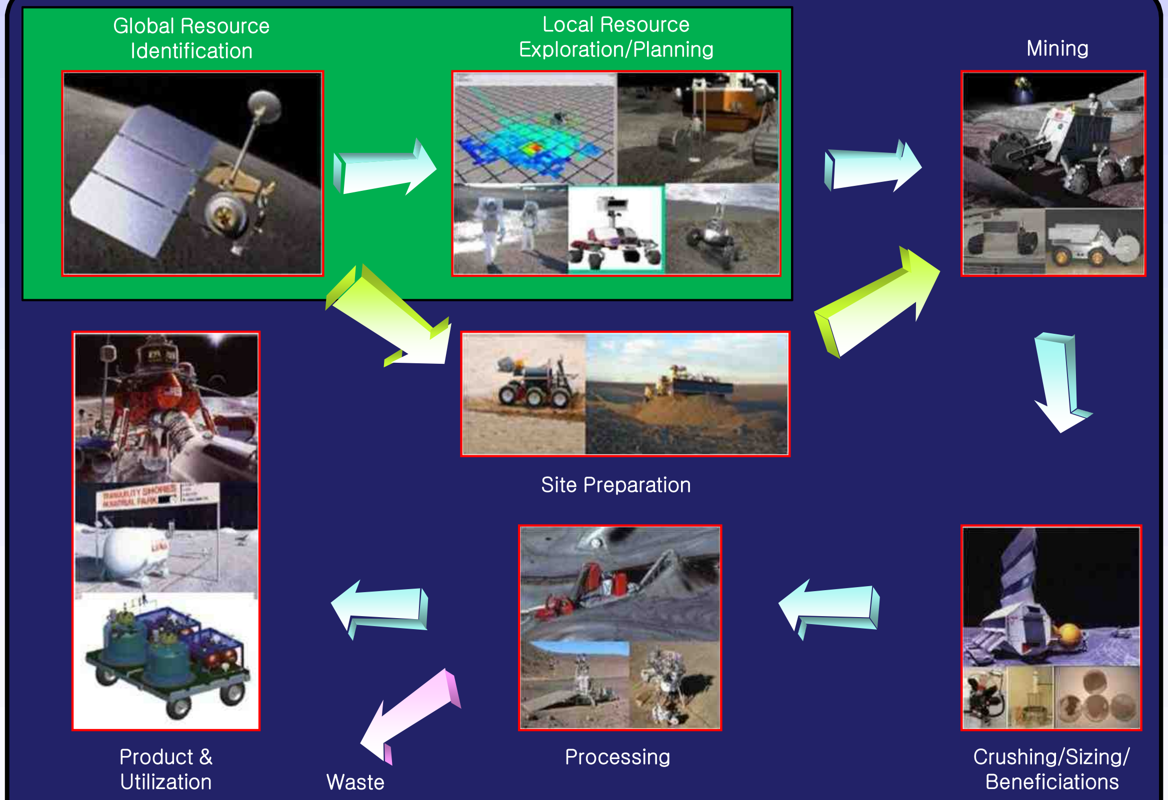

Analogs

NASA ISRU

NASA In-Situ Resource Utilization (ISRU)

- **Lunar ISRU**
  - ➢ Cost of Transportation to the Moon is US $2million/kg
  - ➢ Space development needs lots of materials and using resource on site is required
  - ➢ To succeed ISRU process, various technologies should be integrated

- **Benefits of ISRU**
  - ➢ Produce science and exploration hardware instead of consumables
  - ➢ Increased safety, crew exploration time, and self-sufficiency
  - ➢ Technology spin-in/spin-offs help recycling on Earth & Space economy



- Source: Gerald Sanders, NASA In-Situ Resource Utilization Architecture, Development, & Demonstration, Dasan Conference (2009. 10)

NASA ISRU

Why ISRU into Space Exploration Roadmap

- **NASA and International Mission statements calls for the sustainable human exploration of the Moon, Near-Earth asteroids, and Mars**

- **Common Exploration Goals and Objectives are Strongly influenced by ISRU**
  - **Extend Human Presence**: Continually increase the duration and level of self sufficiency at all destinations
  - **Develop Exploration Technologies and Capabilities**: Develop and validate tools, technologies, and systems that extract, process, and utilize resource to enable exploration missions
  - **Perform Science to Support Human Exploration**: Characterize available resources at destinations
  - **Stimulate Economic Expansion**: Encourage commercial services and create new markets, including markets for discovered resources
  - **Enhance Earth Safety**: Test techniques to mitigate the risk of asteroid collisions with Earth

- Source: Gerald Sanders, Benefits to Space Exploration from In-Situ Resource Utilization with Lunar Surface and L1/L2 Propellant Refueling, 2012 GLEX Conference

NASA ISRU

Main Areas of ISRU and Applicable Mission Elements

Manned Mission Elements

ISRU Main Areas

	EVA	Life Support	Power	Propulsion	Manufact-uring	Habitats	Science
Resource Characterization & Mapping							
Geotechnical & mineral characterization	X				X	X	X
Water/volatile characterization in regolith/so	X	X	X	X			X
Consumable Production							
Oxygen	X	X	X	X		X	
Hydrogen		X	X	X			
Methane			X	X			
Water	X	X				X	
Nitrogen		X				X	X
Cleaning & Inert Gases (CO_2, He)	X						X
Plant growth media & feedstock		X					
Manufacturing feedstock					X		
Energy Production & Storage							
Thermal energy storage & gen			X			X	
Electrical energy gen			X				
Manufacturing & Reuse							
Part fabrication					X		
Hardware scavenging & recycling					X		

- For ISRU Systems and capabilities to be effective, multiple surface elements must be integrated
- Civil Engineering & Construction is one of the main areas of ISRU

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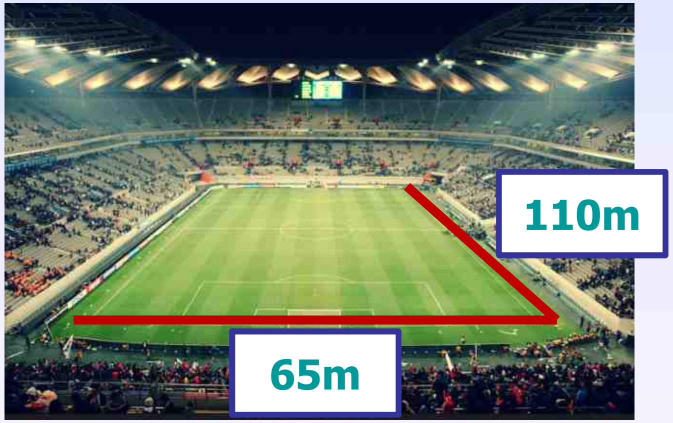
NASA ISRU

Oxygen Extraction from Regolith for Energy

Excavation rate required for 10MT O_2/yr

- Hydrogen reduction at poles(~1% extraction efficiency) : 150kg/hr
- Carbothermal reduction(~14% extraction efficiency) : 12kg/hr
- Small excavators(<200kg) can excavate 150 to 200kg/hr

10 MT of oxygen per year requires excavation of soccer field to a depth of 0.6 to 8cm(1% and 14% efficiencies)



10 MT of oxygen per year requires a regolith excavation rate of **~ 4 cups per minute**

Strategy for Lunar Exploration with ISRU

- **Three Parts to Analyzing the Impact of ISRU on Exploration Programs**

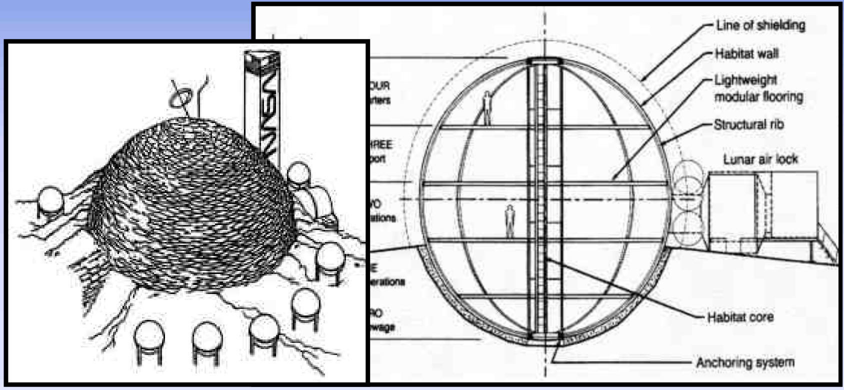
  - **Propellants/Consumables**: What are the propellants/consumables that can be made and what form/where are the products used/delivered?
  - **Infrastructure**: What is the mass, power, volume of ISRU plant and infrastructure (power, storage tanks, etc.) to make the propellants?
  - **Cost of ISRU**: What is considered when determining the cost of ISRU vs. Non ISRU program? Only ISRU unique development or all infrastructure required? Are launch costs considered?

- **Process to demonstrate ISRU ability to support Lunar Exploration**

  - **Step 1: Perform robotic precursors** for resource characterization and critical technology assessments
    - Lunar regolith excavation, oxygen extraction, and O_2 storage and transfer
    - Water/volatile characterization, extraction, and processing into O_2/Fuel
  - **Step 2: Perform Pilot operations in Early short duration missions**
    - Pre-deploy and produce product before crewed missions to minimize risk
    - Life support and radiation shielding consumables to extend mission or increase science/exploration equipment delivery
  - **Step 3: Deploy full scale operations;** Increase commercial involvements

History of Lunar Outpost Concept

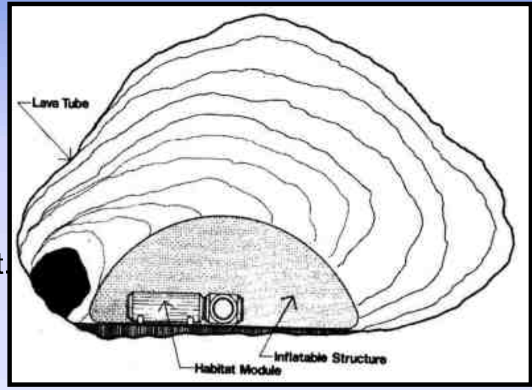
Various Lunar Outpost Concept (1988~ 1992)



"Sandbagged" lunar habitat
(Roberts,M., NASA_KSC)

"Inflatable habitation for the lunar base"

The inflatable habitat, consists of a spherical pneumatic envelope with floor, walls, and equipment.



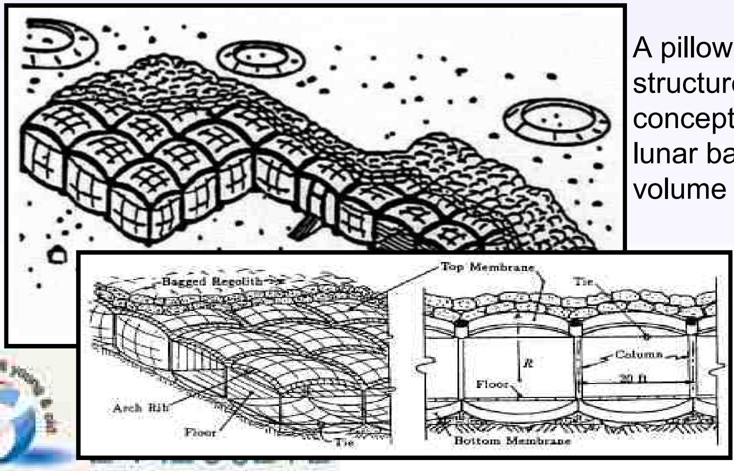
Lunar "lava tube" habitat
(Daga, A.W., Integrated space Corp.)

"Evolving concepts of lunar architecture: The potential of subselene development."

The tube would not require any radiation shielding.

1988 — 1990 — 1991 — 1992

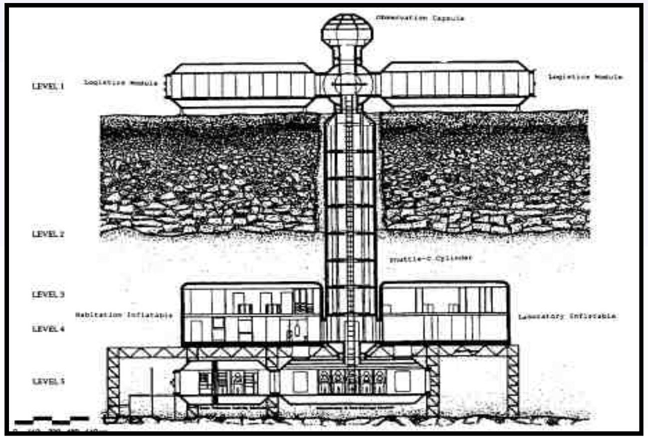
"Tuft pillow" Inflatable modules habitat
(Vanderbilt,M.D., Colorado State University)



"Structures for a lunar base"

A pillow or box-shaped structure is a possible concept for a permanent lunar base and optimizes volume for habitation.

Genesis II Advanced lunar outpost
(Moore,G.T., University of Wisconsin)



"Structures for a lunar base"

Outpost is Connected by lunar surface to underground and use energy from outside of the surface part.

History of Lunar Outpost Concept

Various Lunar Outpost Concept (1992~ 2012)

ATHLETE habitat (NASA_KSC)

"Development of the Tri-ATHLETE Lunar Vehicle Prototype"

ATHELETE can act individually or physically connect together through a structural pallet to transport and manipulate vessel.

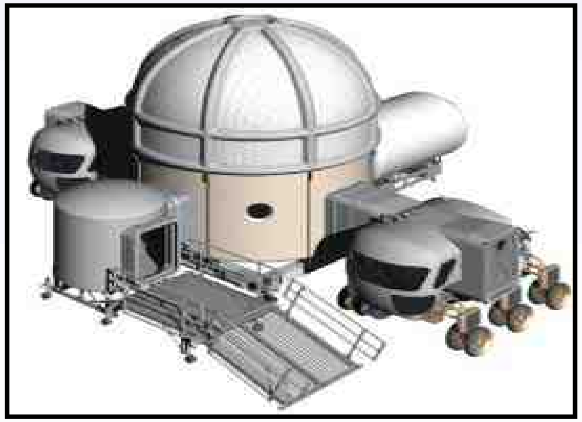
2004 ··· 2010 2011

Lunar Base Habitat (Shimizu Corp.)

"Lunar Bases Project"

Each hexagonal cube combination could make a construction like honeycomb pattern. It's structurally stable.

Lunar Base Habitat(NASA_KSC)

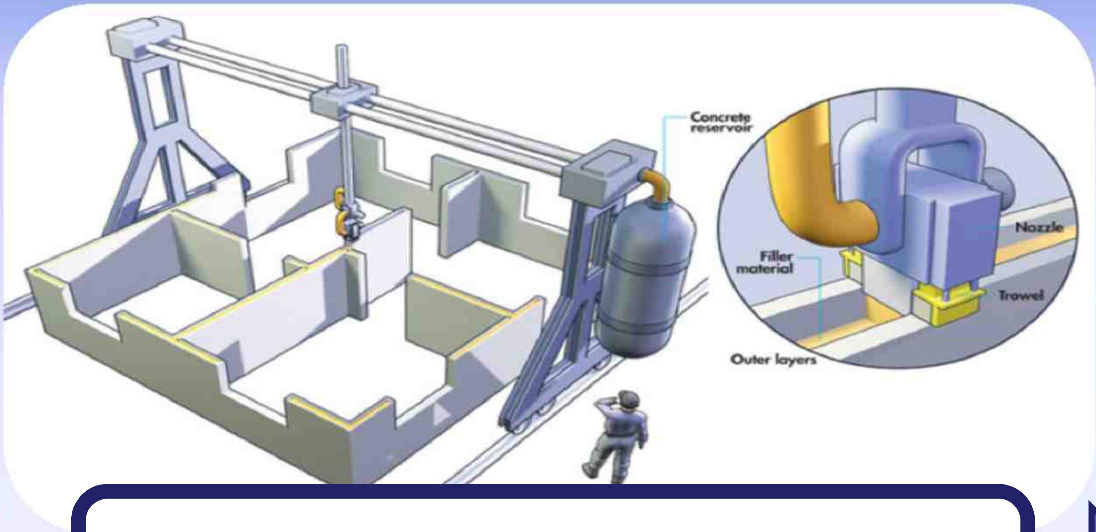


"X-Hab(Exploration Habitat) Project"

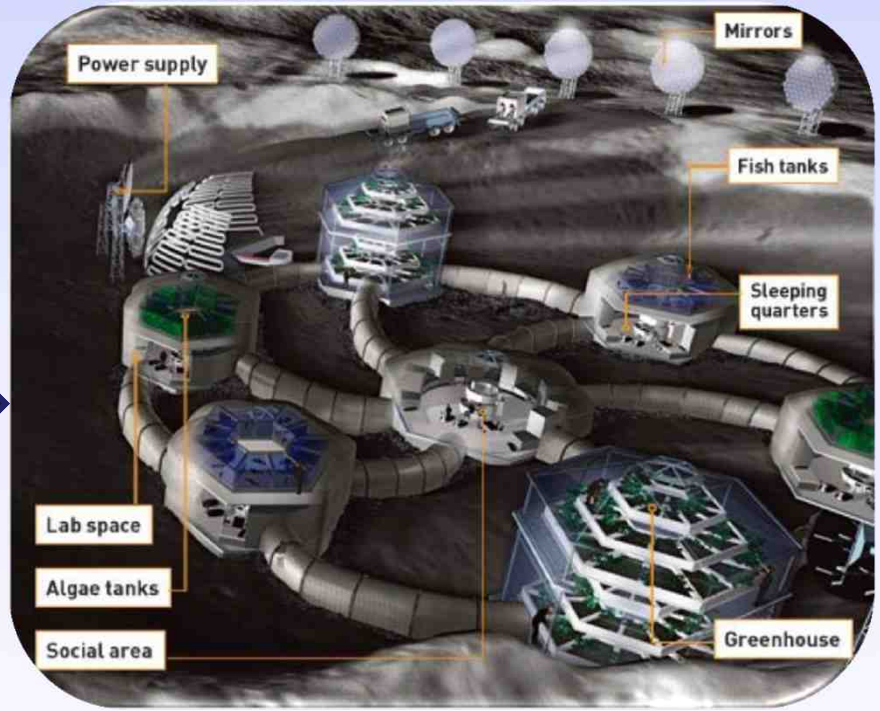
This project focused at exploration habitat system using by ISRU.

History of Lunar Outpost Concept

Future Construction ISRU Concept



Using 3D Printing Construction



Space construction

Lunar Simulant and Lunar Concrete

Lunar Simulant KOHLS-1(left) and SEM image(right)

Lunar Concrete Prototype

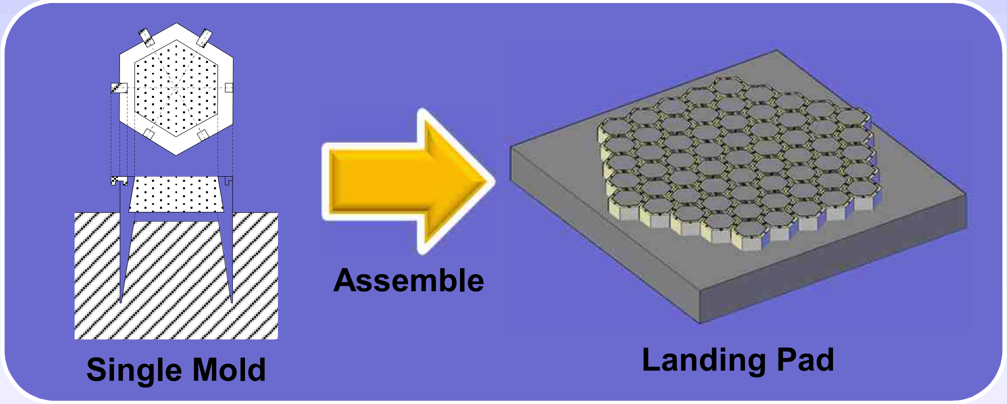
- Lunar soil is fundamental for lunar surface exploration
- ISERI developed lunar simulant KOHLS-1 as 5th country
- ISERI is focusing on developing appropriate chemical composition of lunar simulant

- Using in-situ material is important to building structures on lunar surface
- ISERI developed lunar concrete by using lunar simulant
- Performance of lunar concrete is proper to use structural materials

Future Space Exploration Technologies

Construction on the Lunar Surface

- To prevent lunar dust problem, lunar landing pad is required for lunar development
- ISERI is conceiving lunar landing pad construction by assembling of single lunar concrete mold
- Structural analysis and fabricating single mold prototype is on going



Fabricate Single Mold and Strength Test

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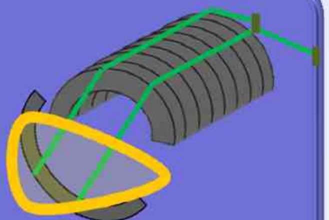
Future Space Exploration Technologies

Construction Technology by 3D Printing

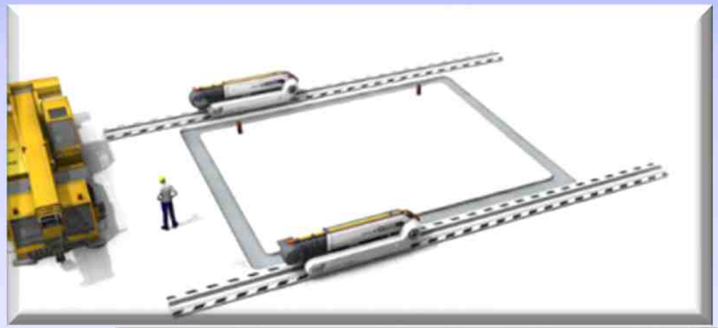
Regolith

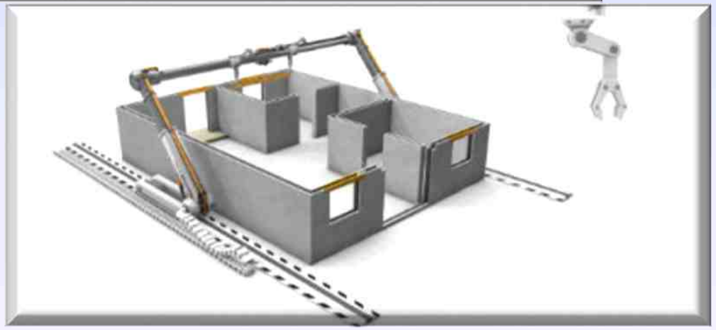
3D Printing Technology



Lunar Habitat

- Combining lunar concrete technology and 3D printing technology derive unmanned automation construction on the Moon
- It is able to build various shape of structure





- 3D Printing Construction spend low cost ($4,000) to build house
- It can figure out housing problems in underdeveloped country

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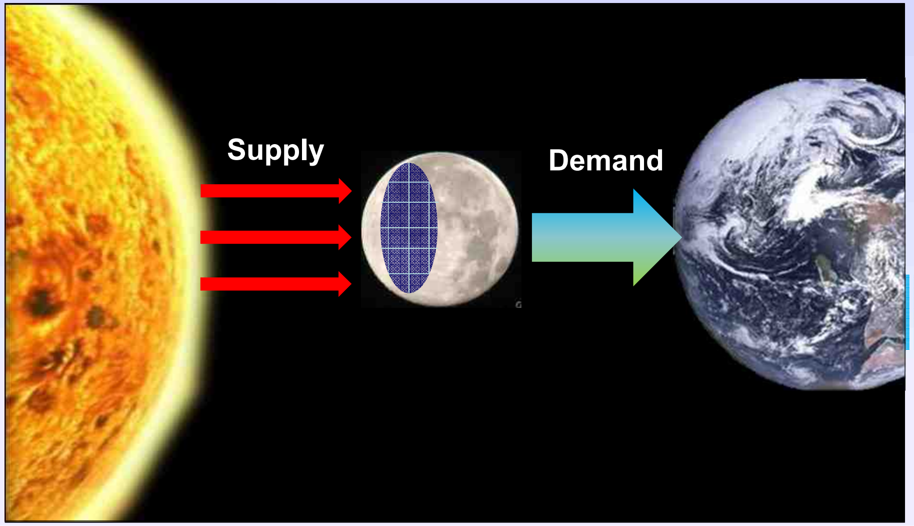
Future Space Exploration Technologies

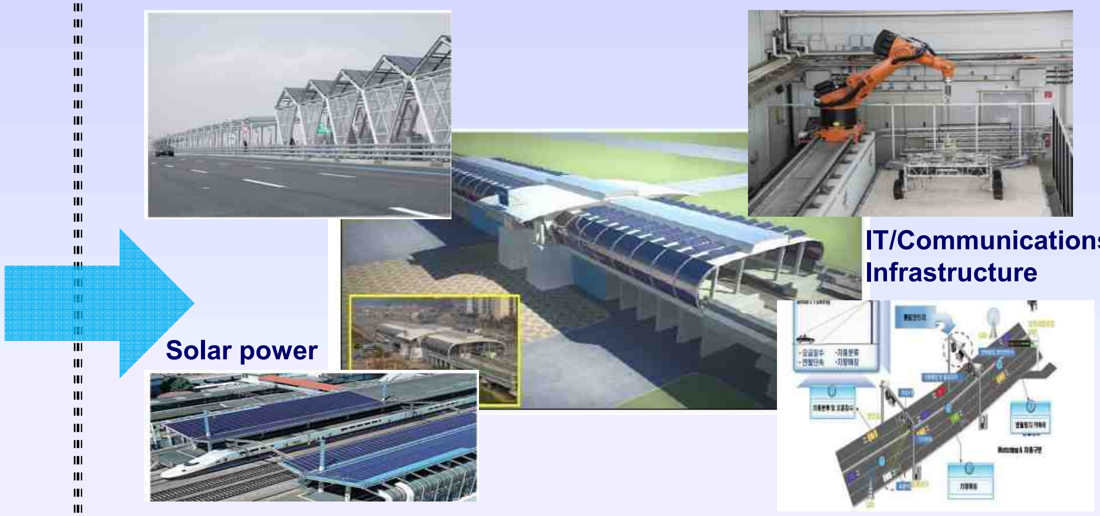
Solar Power

Lunar Solar Power Generation



- Construct solar panels on the Moon's far side to collect solar energy and transmit to the Earth
- **No Pollution, Green Energy, Sustainable Energy**

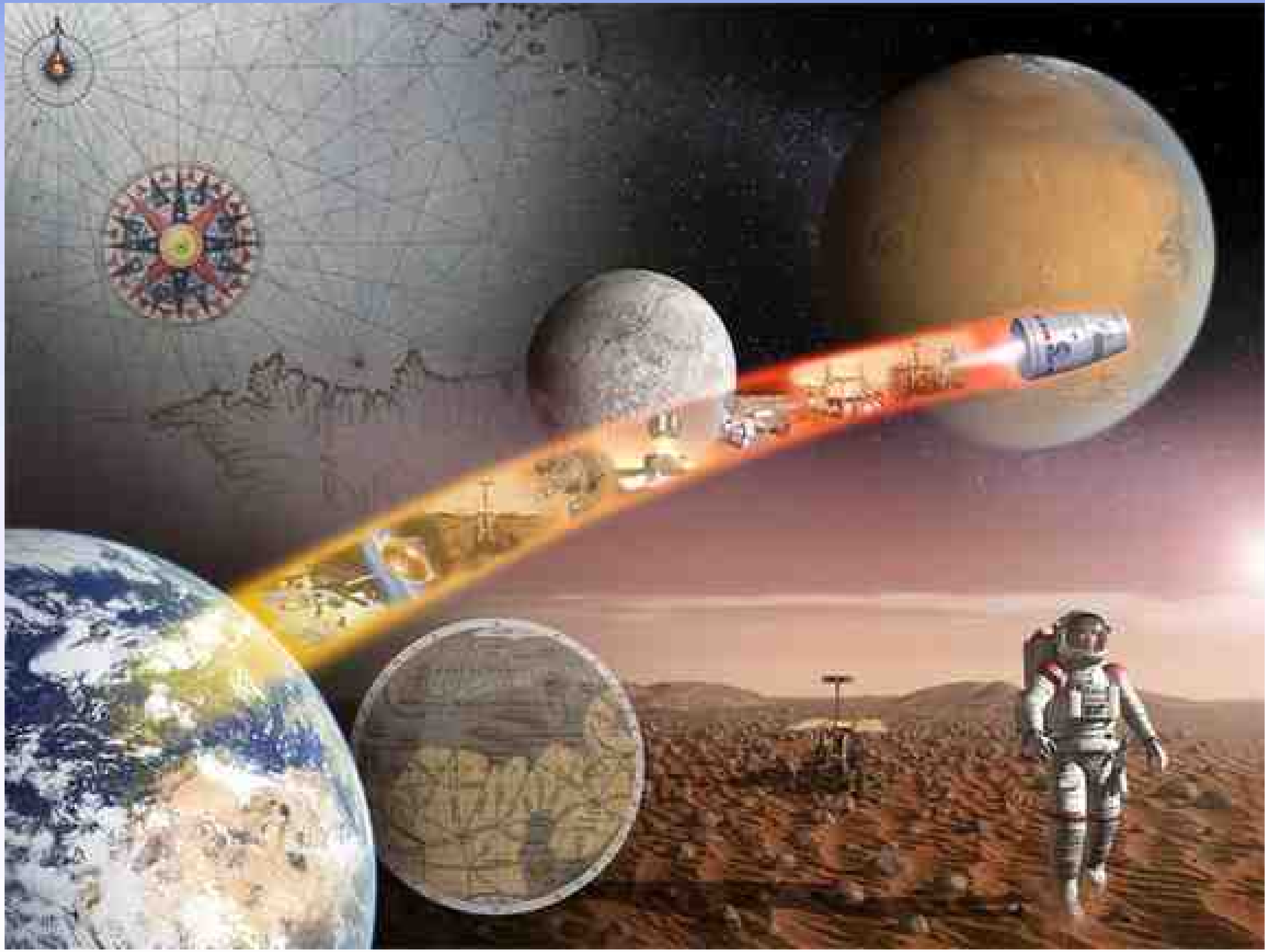
Solar Highway



- Solar highway can be a renewable source of energy and extend life span of road
- 1000MW nuclear power plant is substituted by 200km of solar highway
- New concept of sustainable energy development using existing facilities without natural damage

☞ **Sustainable Engineering**

Thank You



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