In-Situ Resource Utilization (ISRU) Construction Technology for Moon and Mars

- KICT President (Aug 2014 – Sep 2017)
- Founder and CEO of ISERI
- Professor, Hanyang University

Tai Sik Lee

International Space Exploration Research Institute

KICT Korea Institute of Civil Engineering and Building Technology

Hanyang University

Biography

Founder and CEO of ISERI
Professor (Hanyang Univ.)

Academic Background

- Kyunggi High School ('72)
- B.S. in Civil Engineering, Seoul National University ('78)
- MS and PhD in Construction Management, University of Wisconsin-Madison

Career Highlights

- (Former) President of the KICT
- (Former) President of the Korean Society for Railway
- (Former) President of the Korean Society of Civil Engineers
- (Former) Vice President of the Korean Federation of Science and Technology Societies (KOFST)
- (Current) Professor at the Department of Civil and Environmental Engineering, Hanyang University
- (Current) Director of the International Association for Automation and Robotics in Construction Civil Engineering
- (Current) Korean Representative for the OECD IFP
- (Current) Director of the Climate Change Center
- (Current) Director of the KOFST
- (Current) Vice President of the Korea Engineers Club

Awards

- Doyak Medal – the Order of Science and Technology Merit
- Presidential Award – the highest national honor bestowed a Korean Scientist and Engineer

International Space Exploration Research Institute

KICT KOREA INSTITUTE of CIVIL ENGINEERING and BUILDING TECHNOLOGY

HANYANG UNIVERSITY

Moon Village?

MBN

유럽 중심 국제달탐사연구단, 2030년까지 달기지 건설 추진

프린트 | 닫기

2017-06-04 15:44

↑ 지난 2일 국회의원 회관에서 열린 '문 빌리지 국회 포럼'에서 이태식 건설기술연구원장과 버나드 포잉 유럽우주국 박사, 조경태 국회 기획재정위원장(뒷줄 왼쪽에서 다섯째부터) 등이 참석자들과 함께 기념촬영을 하고 있다. <사진 제공=건설기술연구원>

우리나라가 달 탐사 프로젝트를 추진하고 있는 가운데 유럽을 중심으로 한 국제달탐사연구단이 오는 2030년까지 달에 유인 기지 건설을 추진하고 있는 것으로 알려져 주목된다.
지난 2일 서울 여의도 국회의원회관에서 열린 '우주 개발 다변화를 위한 문 빌리지 국회 포럼'에서 버나드 포잉 국제달탐사연구단 연구책임자(유럽우주국 박사)는 "미국과 유럽, 중국, 일본 등 우주 선진국을 중심으로 우주 현장 자원을 활용한 문 빌리지 건설을 추진하고 있다"고 밝혔다. 이날 포럼은 조경태 국회 기획재정위원장이 주최하고 한국건설기술연구원과 국제우주탐사연구원이 주관했다.
이날 포럼에서 포잉 박사는 "일단 달에 유인 기지를 조성하려면 궤도선과 착륙선을 통해 달에서 로봇을 활용한 각종 토질 조사를 거쳐야 하고 이후 거주 환경에 필요한 기지 건설이 필요하다"고 말했다. 그는 지난 2003년 유럽우주국이 쏘아올린 '스마트-1' 위성을 비롯해 다양한 국가의 위성들과 달 궤도·착륙선이 현재까지 달 토양에 대한 조사를 진행하고 있다고 밝혔다.

Moon & Mars Villages Construction Plan of International Lunar Exploration Working Group by 2030

한국경제

프린트 | 닫기

화성에는 '3D 프린팅 우주기지'

입력 2017-05-07 19:18 수정 2017-05-08 05:54

미국 항공우주국(NASA)은 지난 5일 '3D 프린팅 주거 챌린지' 1단계 우승자로 영국 건축설계회사인 포스터앤드파트너스와 브랜치테크놀로지 공동 연구팀, 알래스카 페어뱅크스대 연구진을 선정했다. 이 대회는 2030년 미국의 유인화성탐사 계획에 따라 3차원(3D) 프린터를 이용해 화성에서 우주인이 머물 거주지(그림)를 건설할 기초 기술을 확보하기 위해 마련됐다.

이번 대회엔 한국의 문엑스 컨스트럭션 팀을 비롯해 여러 나라의 대학과 설계회사 7개팀이 참여했다. 우승한 두 팀은 화성 거주지를 짓는 핵심 재료로 사용될 원통형 '코어'를 제작하는 테스트에서 가장 높은 점수를 받았다. NASA는 이 코어를 기본 재료와 구조로 활용해 실제 우주인의 거주지를 짓는다는 계획이다.

이 대회는 화성 거주지 설계, 3D 프린팅 건축 소재 개발, 실제작 등 모두 세 단계로 진행된다. 목표는 현무암과 비슷한 화성 흙이나 현지에서 버려진 물품을 활용해 대형 3D 프린터로 사람이 거주할 건물을 만드는 데 있다.

실제로 달과 화성에 주거지를 짓기 위해 엄청난 양의 건축 자재를 우주선에 실어보내려면 많은 예산이 소요된다. 우주 로켓의 탑재량이 많지 않을 뿐 아니라 가장 발사비가 싼 발사체로 불리는 스페이스X의 팰컨헤비 로켓을 이용해 1kg짜리 물체를 우주로 올려보내는 데만 2200달러가 든다. 그보다 먼 달과 화성까지 건축 자재를 보내려면 엄청난 비용이 들 수밖에 없다.

과학자들이 우주에 있는 재료를 조달해 기지를 건설하는 방법을 연구하는 이유다.

3D Printing Space Station on Mars

Living outside the Earth is a huge challenge

NASA's Centennial Challenges: 3D-Printed Habitat Challenge

About the Challenge

NASA and its partners are holding a $2.5 million competition to build a 3-D printed habitat for deep space exploration, including the agency's journey to Mars. The multi-phase challenge is designed to advance the construction technology needed to create sustainable housing solutions for Earth and beyond.

Phase 1 of the competition ran through Sept. 27, 2015. This phase, a $50,000 design competition, called on participants to develop state-of-the-art architectural concepts that take advantage of the unique capabilities 3-D printing offers. The top 30 submissions were judged, and prize money was awarded at the 2015 World Maker Faire in New York.

Phase 2 is now open and challenges competitors to demonstrate a recycling system that can create structural components using terrestrial and space-based materials and recyclables.

Phase 3, which is currently under development, will focus on fabrication of complete habitats and will follow completion of Phase 2.

Rules and Registration

More information on Phase 2, including rules and how to sign up, can be found here.

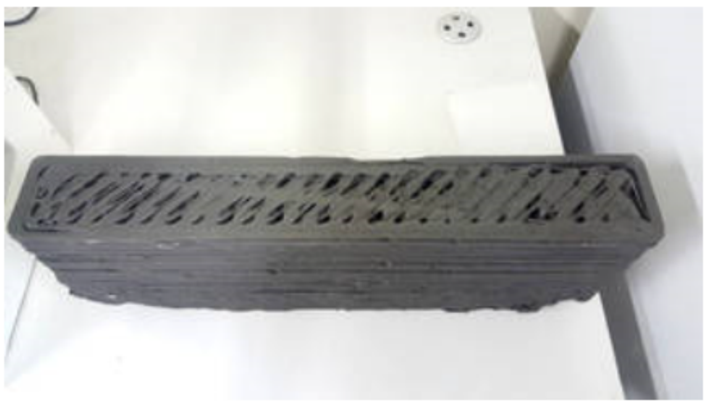
Key Dates

- October 6, 2016: Phase 2 registration opens
- January 31, 2017: Phase 2 registration closes
- March 31, 2017: Phase 2, Level 1 submission deadline
- May 31, 2017: Phase 2, Level 2 submission deadline
- August 24-27, 2017: Phase 2, Level 3 head-to-head ground competition at Caterpillar Edwards Demonstration & Learning Center near Peoria, Illinois

Is a Moon Village really possible?

July 7, 2017

Six Teams Earn Honors, Prize Money in Second Construction Level of NASA Challenge to 3-D Print a Habitat



A beam 3-D printed by team MoonX of South Korea, who won first place in the 3D-Printed Habitat Challenge, Phase 2: Level 2 competition. For this level, teams had to 3-D print a structure for bend testing.
Credits: Courtesy of team MoonX

NASA has awarded a total of $201,023 to teams of citizen inventors that have reached the latest milestone of NASA's 3D-Printed Habitat Challenge, completing the Phase 2: Level 2 Beam Member competition. The teams are working to find ways to 3-D print habitation structures using recyclables and simulated Martian soil, a technology goal that could support deep space exploration and advance construction capabilities on Earth.

For this level, which is the second of three sub-competitions within Phase 2, teams had to 3-D print a beam for bend testing. Scores were calculated based on the material composition and the maximum load of the beam at failure.

The winning teams are:

1st place: Moon X Construction of Seoul, South Korea *(International team, not eligible for prize money)*

2nd place: Form Forge of Oregon State University, Corvallis - $67,465

3rd place: Foster +Partners | Branch Technology of Chattanooga, Tennessee - $63,783 *(earned first place and $85,930 in Phase 2: Level 1)*

4th place: University of Alaska of Fairbanks - $35,573 *(earned second place and $14,070 in Phase 2: Level 1)*

5th place: CTL Group Mars of Skokie, Illinois - $34,202

6th place: ROBOCON of Singapore *(International team, not eligible for prize money)*

A Moon Village is really possible!

A Moon Village is really possible!

Hyperloop Changes the Paradigm of Traffic!


MK뉴스 인쇄하기

韓 하이퍼루프 연구 참여

건설기술硏 컨소시엄, 글로벌 공모전서 선발

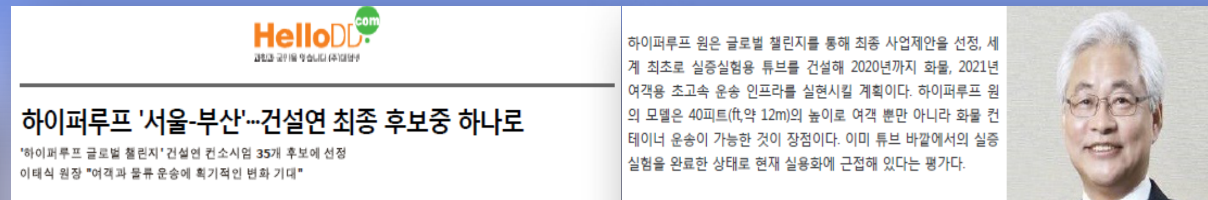
기사입력 2017.01.09 14:50:08 | 최종수정 2017.01.09 19:09:33

우리나라 기술이 전 세계에서 주목받는 신개념 초고속 교통수단인 `하이퍼루프(Hyperloop)` 개발 프로젝트에서 핵심 역할을 할 가능성이 커졌다. 하이퍼루프란 대표적 혁신가 일론 머스크 테슬라모터스 CEO가 주창한 초고속 교통·물류운송 수단으로, 낮은 기압의 튜브 속을 초고속 탄환열차가 주파하는 개념이다.

한국건설기술연구원(KICT)은 하이퍼루프원이 전 세계를 대상으로 한 `하이퍼루프 글로벌 챌린지` 도전과제 공모에서 한국건설기술연구원·한국교통연구원·한양대 컨소시엄의 `하이퍼루프 연구단`이 최종 후보 35개 중 하나로 선정됐다고 9일 밝혔다.

이태식 KICT 원장(사진)은 "세계 100개국 2600개 팀이 참여한 공모에서 35위 안에 든 것은 대단한 쾌거로, 한국에 유치하도록 노력하겠다"고 밝혔다.

Participation in Hyperloop Research


HelloDD.com

하이퍼루프 '서울-부산'…건설연 최종 후보중 하나로

'하이퍼루프 글로벌 챌린지' 건설연 컨소시엄 35개 후보에 선정

이태식 원장 "여객과 물류 운송에 획기적인 변화 기대"

하이퍼루프 원은 글로벌 챌린지를 통해 최종 사업제안을 선정, 세계 최초로 실증실험용 튜브를 건설해 2020년까지 화물, 2021년 여객용 초고속 운송 인프라를 실현시킬 계획이다. 하이퍼루프 원의 모델은 40피트(ft,약 12m)의 높이로 여객 뿐만 아니라 화물 컨테이너 운송이 가능한 것이 장점이다. 이미 튜브 바깥에서의 실증실험을 완료한 상태로 현재 실용화에 근접해 있다는 평가다.

고속 교통 및 물류운송 수단으로, 낮은 기압의 튜브 속을 초고속 탄환열차가 주파하는 개념이다.

이태식 원장에 의하면 건설연 ... 하이퍼루프 과제를 제안, 타당성에서 높은 평가를 받았다. 또 한국은 고속철도를 운영하고 있으며 건설연의 보유 기술 등에서도 높은 점수를 얻었다.

KICT – Semi Finalist in Hyperloop One Global Challenge

Hyperloop will be realized soon

국가기간뉴스통신사 연합뉴스

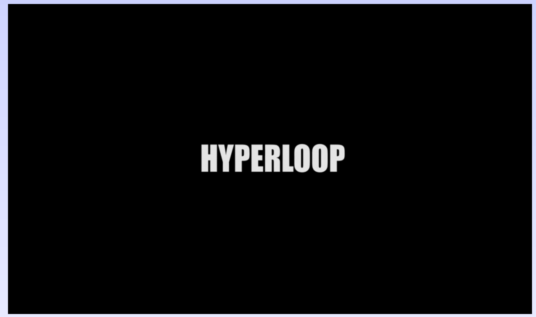
건설기술연구원 HTT사와 '하이퍼루프' 사업 협력

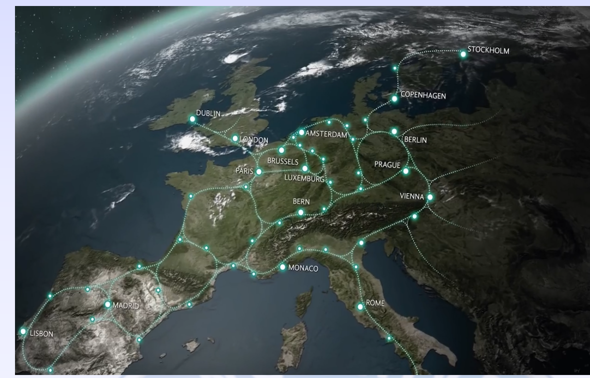
송고시간 | 2017/06/15 17:15

(부산=연합뉴스) 박창수 기자 = 한국건설기술연구원은 15일 부산 벡스코에서 차세대 초고속 이동수단인 하이퍼루프를 개발 중인 미국 HTT(Hyperloop Transportation Technologies)사와 업무협약을 했다.

KICT & HTT are going to cooperate about 'HYPERLOOP'

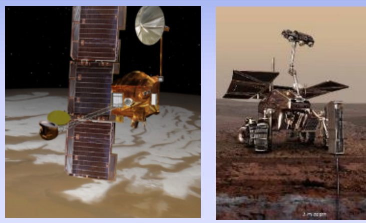
가 파트너십을 맺고 기술개발에 협력하고 있다.





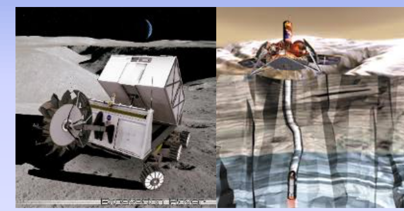
What is In Situ Resource Utilization (ISRU)?

Resource Assessment (Prospecting)



Assessment and mapping of physical, mineral, chemical, and volatile/water resources, terrain, geology, and environment

Resource Acquisition

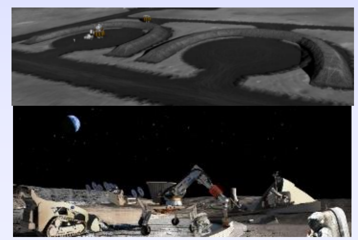


Drilling, excavation, transfer, and preparation/ beneficiation before Processing

In Situ Manufacturing

Production of replacement parts, complex products, machines, and integrated systems from feedstock derived from one or more processed resources

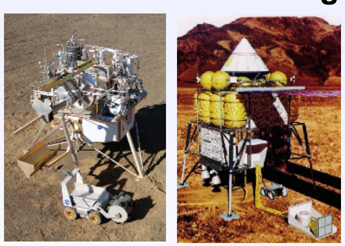
In Situ Construction



Civil engineering, infrastructure emplacement and structure construction using materials produced from in situ resources

- **Radiation shields, landing pads, roads, berms, habitats, etc.**

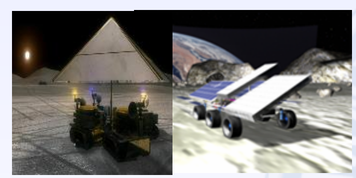
Resource Processing/ Consumable Production



Processing resources into products with immediate use or as feedstock for construction and/or manufacturing

- Propellants, life support gases, fuel cell reactants, etc.

In Situ Energy



Generation and storage of electrical, thermal, and chemical energy with in situ derived materials

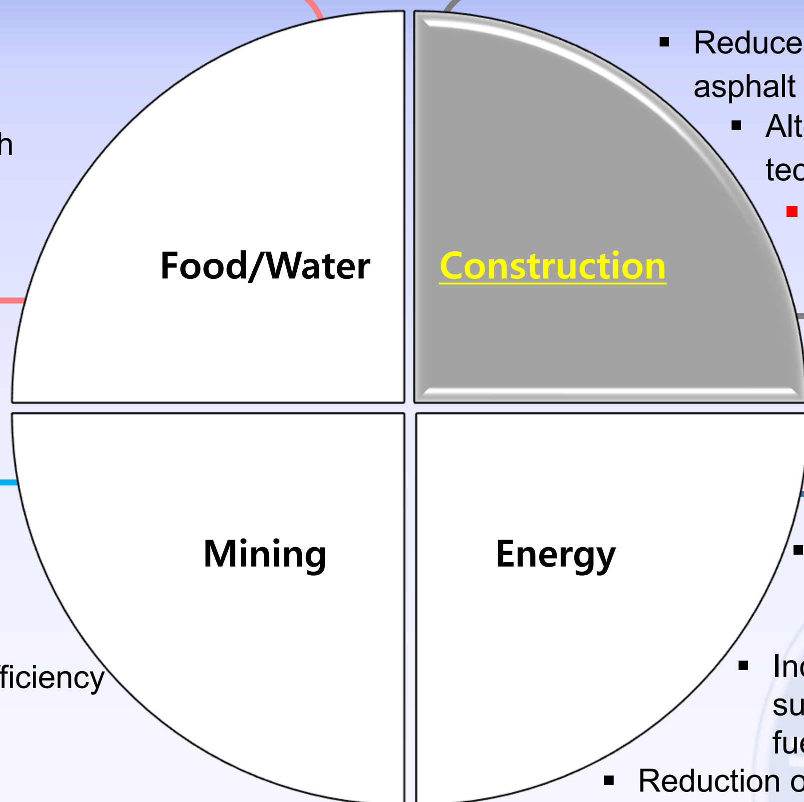
- Solar arrays, thermal storage and energy, chemical batteries, etc.

ISRU involves any hardware or operation that harnesses and utilizes 'in-situ' resources to create products and services for robotic and human exploration

G. Sanders (2017), ISRU and Earth

ISRU Is Synergistic with Terrestrial Needs

JSC Engineering: HSF Exploration Systems Development



Food/Water
- Improve water cleanup techniques
- Advance food/plant growth techniques and nutrient production

Construction
- Reduce or eliminate cement and asphalt – **renewable materials**
  - Alternative construction techniques – **3D printing**
  - **Remote** operation and automation

Mining
- Increase safety
- Reduce maintenance
- Increase prospecting mining, and processing efficiency
- Improve environmental compatibility

Energy
- More efficient power generation, storage and distribution
- Increase renewable energy: Use sun, thermal, trash, and alternative fuel production
- Reduction of Carbon Dioxide emissions

Promote *Reduce, Reuse, Recycle, Repair, Reclamation* …for benefit of Earth, and living in Space.

G. Sanders (2017), ISRU and Earth

Technology Areas (TA)

Breakdown Structure of ISRU Construction Technologies

ISERI Key TAs

NASA 2005 ISRU Road Map

- In-Situ Resource Utilization 13.0
  - Surface Construction 13.5
    - Site Planning 13.5.1
      - Site Survey & Characterization 1.5.1.1
      - Architectural Layout & Master Planning 13.5.1.2
      - Civil Engineering Design 13.5.1.3
      - Geospatial Information System (GIS) Configuration Control Tool 13.5.1.4
    - Surface & Subsurface Preparation 13.5.2
      - Road Construction 13.5.2.1
      - Foundation Construction 13.5.2.2
      - Utilidor Construction 13.5.2.3
      - Terrain Shaping, Grading & Rock Clearing 13.5.2.4
      - Underground Structures 13.5.3.5
      - Soil Stabilization (Mars Dust) 13.5.3.6
    - Structure & Habitat Fabrication 13.5.3
      - Construction Techniques & Methods 13.5.3.1
      - In Situ Building Materials 13.5.3.2
      - Access & Handling Equipment 13.5.3.3
      - In Situ Robotic / Human Construction Equipment 13.5.3.4
    - Radiation & Micro Meteoroid Debris Shielding 13.5.4
      - Radiation Shelters 13.5.4.1
      - Shields for Nuclear Reactors 13.5.4.2
      - Micrometeoroid Shielding 13.5.4.3
    - Structure & Site Maintenance 13.5.5
      - Integrity & Preventative Maintenance 13.5.5.1
      - Waste Management 13.5.5.2
      - Facility Management 13.5.5.3
    - Landing & Launch Site 13.5.6
      - Landing/Launch Pads 13.5.6.1
      - Plume Debris Shielding 13.5.6.2
      - Exhaust Flame Management 13.5.6.4
      - Sheltered Propellant and Consumables Farms 13.5.6.5
      - Mars Lightning Protection 13.5.6.6

R. Mueller (2017). Construction with Regolith, CLASS / SSERVI / FSI, The Technology and Future of In-Situ Resource Utilization (ISRU), March 6, 2017.

Processes and Products

Construction: Roads, Landing Pads, Structures, Plume Protection

Key TAs

Area Leveling/ Grading/Berms

Autonomous & Tele-operation

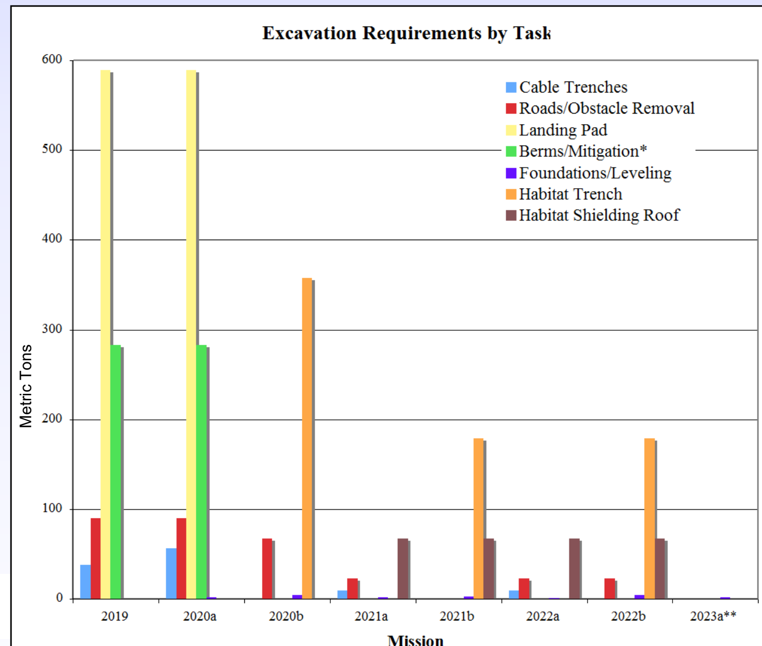
Surface & Subsurface Evaluation

Waterless Concrete

Additive Construction

Sintered/Fabricated Pavers

Combustion Synthesis



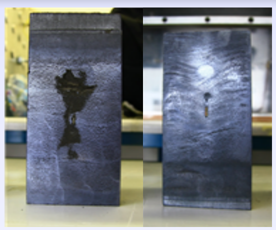
G. Sanders (2017), ISRU and Earth

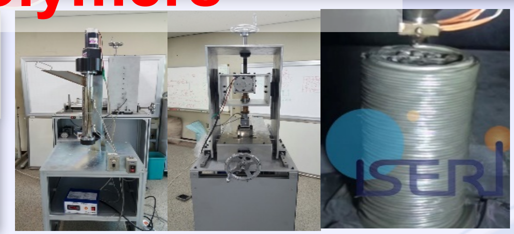
ISERI Vision

International Space Exploration Research Institute

Develop on
In-situ Resource Utilization (ISRU)
construction technologies
which can contribute to
manned exploration to the Moon & Mars

ISERI Goal





Lunar/Mars Simulant (KOHLS-1/KMS-1)	Planetary Structure Member (Lunar/Mars-crete)	Entry, Descent & Landing (EDL) Infrastructure (Landing Pad/Rover)	Planetary Additive Construction System (PACS)	Lunar Test bed (Vacuum Chamber)

Develop additive construction technology using regolith binding technology with polymer additives

ISERI History

2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | Future 2020

ISERI Research Projects

A Project for National Space Lab of National Research Foundation of Korea, Development of Extreme Rough Terrain Exploration Rover (ERTER) for Rough Terrain Exploration

NSL

ISERI

A Project for Inducement of Global Research & Development Center(GRDC) of National Research Foundation of Korea, "ISERI(International Space Exploration Research Institute)"

International Research Projects

NASA R^3 (Regolith Resources and Recovery) Proposal

NASA RP(Resource Prospector) Opportunities Agreement

Participation for NASA 'LUNABOTICS' Robotic Mining Competition

NASA Dome Enclosure Technologies for Pressurizing Lunar Pits Proposal

Starting AIAA SReTC(Space Resource Technical Committee) 'Mars Vacuum Chamber Working Group'

Participation for NASA 3D Habitat Challenge (Centennial Challenge)

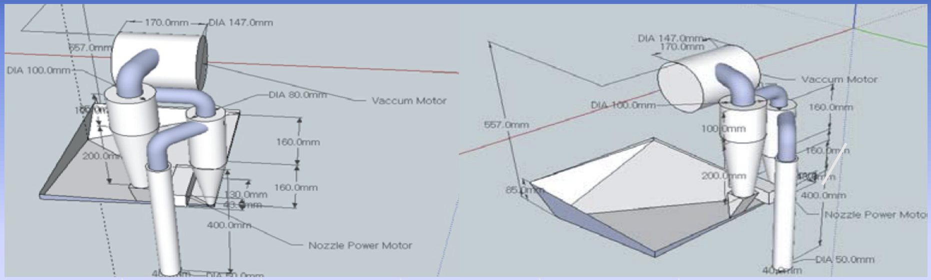
Key Research Results

Research Projects

NSL

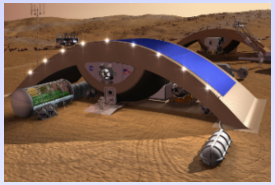
National Research Foundation of Korea Development of Space Basic Original Technology (NSL, National Space Lab)
“Development of Extreme Rough Terrain Exploration Rover for Rough Terrain Exploration”

Closed Cycle Mining & Transportation System (2011-2013)

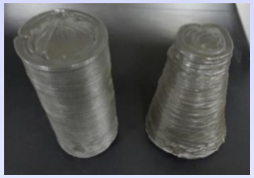


Global Research Development Center (GRDC)
“International Space Exploration Research Institute”

3D-Printed Habitat Challenge (2015- 2018)

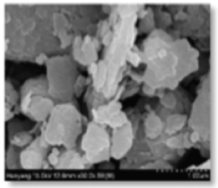


Phase 1
“Design”



Phase 2
“Structural Member”

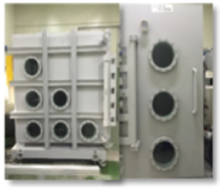
Key Research Results

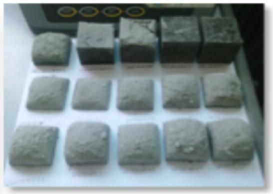
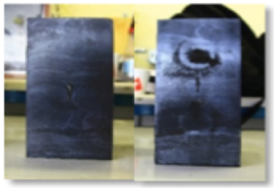
Lunar/Mars Simulant


Rover

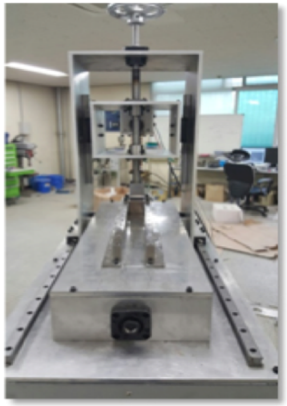

Lunar Test bed

Vacuum Chamber

Structural Materials



3D Printer

Key Research Results

NASA's 3D-Printed Habitat Challenge Competition

Structural Member Competition (2016. 12 ~ 2017. 8)

2016. 12. — 77 Applicants

Level 1 — 2017. 3. — 19 Entries

Level 2 — 2017. 5. — 7 Semi-finalists

Level 3 — 2017. 8. — 3 Finalists

Level 2 Competition (May, 2017)

1st place

https://www.nasa.gov/directorates/spacetech/centennial_challenges/3DPHab/6-teams-earn-prize-money-in-second-level-of-challenge

Planetary Additive Construction System (PACS)

Goal: ISERI ISRU Construction Technologies

Objective

Develop **Planetary Additive Construction System (PACS)** to Manufacture **Lunar/ Mars-crete**

Challenges

- Use **indigenous/ recycle-able** materials **without water, cement, sand**
- Construct a **non-linear structure**
- Protect humans from the harsh environment (**cosmic rays/**dust/temperature fluctuation)
- Operate a construction system in a space environment (vacuum)
- **Automate** the entire process

Technologies

- Develop a Korean **lunar/Mars simulant**
- Develop a **mechanism for binding** lunar/Mars-crete **(types/ratio of polymeric composites**)
- Develop 3D **equipment** and **automated additive construction system**
- Develop **radiation shielding materials** using **lunar/Mars-crete**

PACS Technology Model

Goal: ISRU Construction Technologies

Planetary Additive Construction System

Planetary Information

Basalt Rocks

1. Develop lunar/Mars simulant

Lunar Simulant(KOHLS-1)

Mas Simulant(KMS-1)

Raw Materials (**Indigenous/ Recycle**)

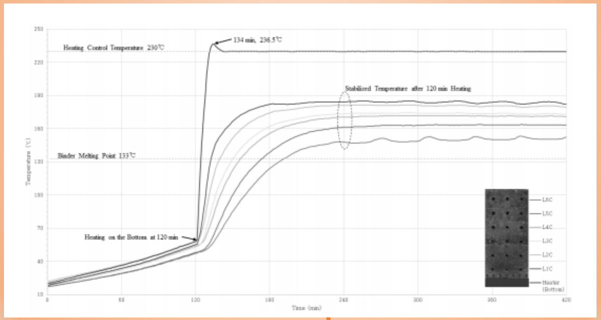
Applicable Polymer (LP, HP)

2. Develop a **mechanism for binding** lunar/Mars-crete

Type/Content Ratio of Polymeric Composites

Manufacturing Conditions (Heating Time/Temperature)

Temperature on the Time for Curing Polymeric Lunar Concrete



3. Develop 3D **equipment** & **automated additive construction system**

Automated Additive Construction System

3D Printed Lunar/Mars-crete

4. Develop **radiation shielding materials**

Radiation Shields

PACS – Sub Technologies (1/4)

Sub- Goal: Indigenous Construction Material

Objective

Develop **Korea Mars Simulant (KMS-1)**

Challenges

Simulate the **properties of Mars regolith** (**mineralogy, chemical composition**, particle size, and physical properties)

Develop a **manufacturing process** for **mass feedstock production**

Results

KOHLS-1(Korea Hanyang Lunar Simulant, 2008)

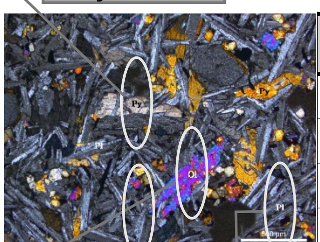
KOHLS-1

Lunar-crete

Rover

Test Bed

- **The source rock** of KMS is a basalt mined from the riverside of Hantangang River, in **Yeoncheon-gun**, Gyeonggi-do, South Korea
- Various particle sizes are obtained through crushing with a disk mill



Mineral	wt%
Plagioclase feldspar	48.9
Olivine	31.0
Pyroxene	14.2
Magnetite	5.8

Composition	Regolith		Simulant		
	Viking 1	Curiosity	JSC Mars-1	MMS	KMS-1
SiO2	43	42.88	43.48	49.4	45.404
TiO2	0.66	1.19	3.62	1.09	1.8
Al2O3	7.3	9.43	22.09	17.1	21.858
Cr2O3		0.49	0.03	0.05	0.059
FeO/Fe_2O_3	18.5	19.19	16.08	10.87	12.505
MnO	-	0.41	0.26	0.17	0.109
MgO	6	8.69	4.22	6.08	3.406
CaO	5.9	7.28	6.05	10.45	9.174
Na2O	-	2.72	2.34	3.28	2.737
K2O	<0.15	0.49	0.7	0.48	2.124
P2O5	-	0.94	0.78	0.17	0.537
SO3	6.6	5.45	0.31	0.1	0.025

Mineralogical/Chemical Composition

PACS – Sub Technologies (2/4)

Sub- Goal: Application of Polymers to Bind Regolith

Objective

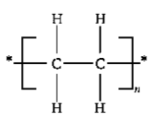
Develop a **mechanism for binding** lunar/Mars-crete

Challenges

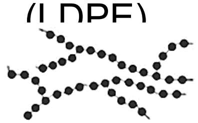
Find optimum types, content ratio under optimum manufacturing conditions
Test various properties (heating time, temperature) and performance (strength, density) of polymeric binders through experiments

Results

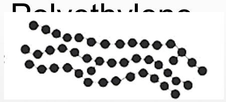
Polyethylene



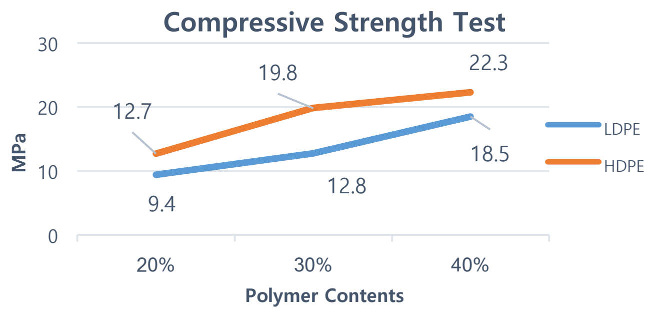
Low Density Polyethylene (LDPE)

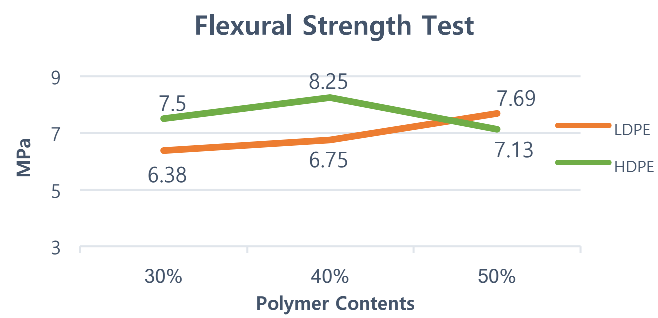


High Density Polyethylene



- Test results of strength performance on lunar-create specimens





ASTM C109 (5cm * 5cm * 5cm)

- The higher content of binder, the higher compressive strength
- HDPE binder has higher compressive strength than LDPE binder

ASTM C78 (4cm * 4cm * 16cm)

- The higher content of binder, the higher flexural strength (LDPE)
- The flexural strength was increased up to 40% (HDPE)

PACS – Sub Technologies (3/4)

Sub- Goal: Automated Additive Construction System

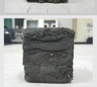
Objective

Develop 3D equipment and **automated additive construction system**

Challenges

Develop automated processes of PACS
Design the optimum nozzle for 3D printer
Manufacture and test lunar/Mars-crete

Results

Contents	Manually Layered Lunar-crete	PACS Lunar-crete
Polymer 20%		
Polymer 30%		

- **Main operation processes include preheating, feeding, mixing material, binding and extruding**
- **Nozzle was developed through a lot of experiments and tests***
  - **Extruding performance increases as amount of polymer content increases**
  - **The 3D printed lunar-crete was verified to be more compressive than manually layered lunar-crete,** increase efficiency(reduced time, waste) and performance of binding
    - 20%: 3D printed (29.56 Mpa**) > manual (23.92MPa)
    - 30%: 3D printed (33.45 Mpa) > manual (24.48MPa)

*ASTM C109(5cm * 5cm * 5cm)   ** *29.56Mpa* =4287.165psi, *1psi = 0.006895 Mpa*

PACS – Sub Technologies (4/4)

Sub- Goal: Protect Human from Space Radiation

Objective: Develop **radiation shielding materials**

Challenges: **Test the shielding feasibility of lunar/Mars-crete**

Evaluate the shielding effectiveness of shielding materials against high-energy space radiation

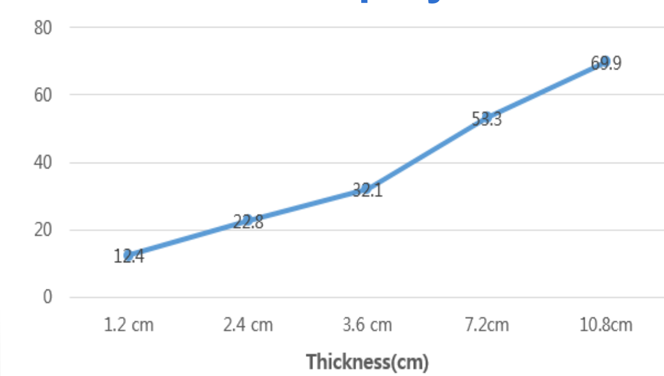
Results

Irradiation Experiment

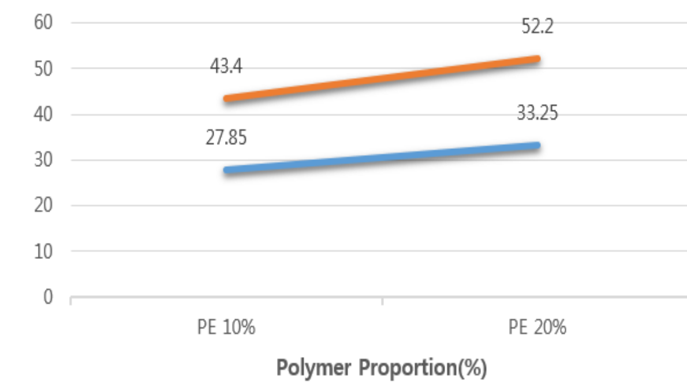
Cf-252 (2.3Mev) Neutron Irradiator

Korea Atomic Energy Research Institute

- **Radiation irradiation tests of lunar-crete investigate that the effectiveness of shielding might be improved according to the thickness and polymer content**



Gamma-rays



Neutron

Sub- Goal: Protect Human from Space Radiation

Objective — Develop **radiation shielding materials**

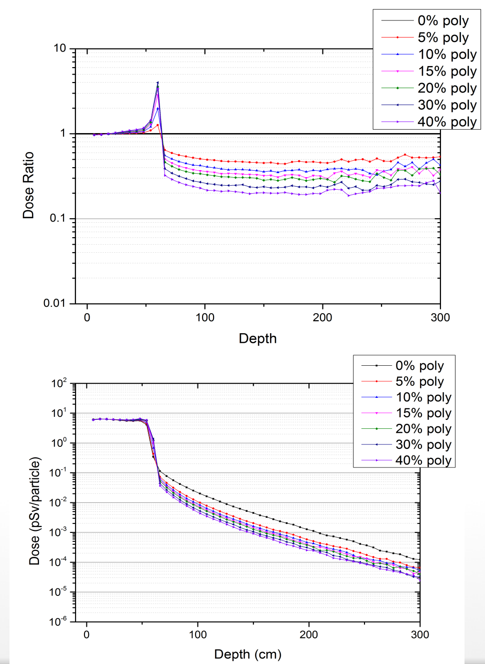
Challenges — Test the shielding feasibility of lunar/Mars-crete

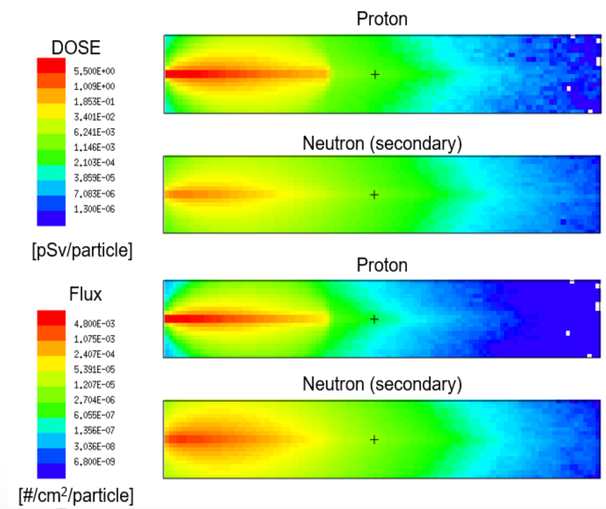
Evaluate the shielding effectiveness of shielding materials against high-energy space radiation

Results

Computer Simulation

- **Polymer content of lunar-crete has an effect on the effectiveness of radiation shielding**





Conclusion

Goal: ISRU Construction Technologies

Planetary Additive Construction System

Current (2017.09)

Inputs:
- Planetary Information
- **Basalt Rocks**
- Raw Materials (**Indigenous/ Recycle**)
- **Applicable Polymer (LP, HP)**

1. Develop lunar/**Mars simulants**
   - **Lunar Simulant(KOHLS-1)**
   - **Mars Simulant(KMS-1)**

2. Develop a **mechanism for binding lunar/**Mars-**crete**
   - **Type/Content Ratio of Polymeric Composites**
   - **Manufacturing Conditions (Heating Time/Temperature)**

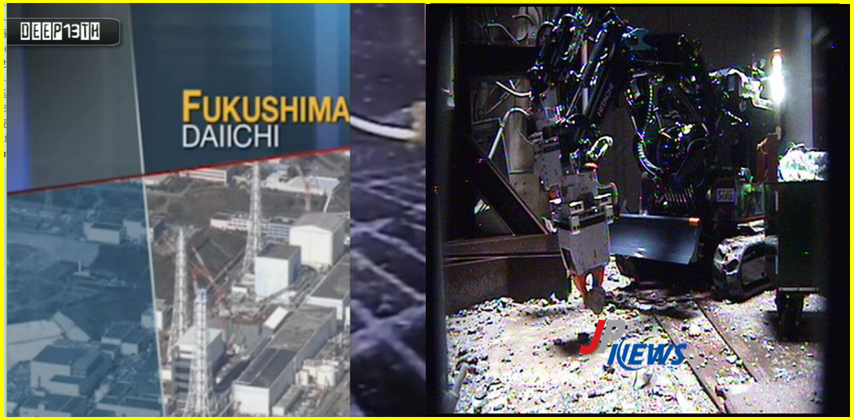
3. Develop **3D equipment** & **automated additive construction system**
   - **3D Printer Nozzle**
   - **3D Printed lunar-crete**

4. Develop **radiation shielding materials**
   - **Feasibility of Radiation Shielding**

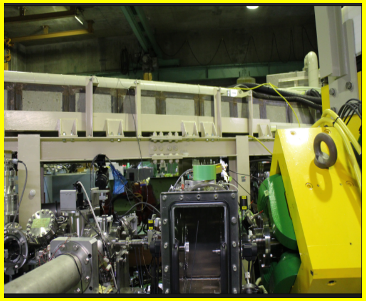
Future Works: Application Plans

Develop shielding materials to protect against high energy radiation

Emergency shielding

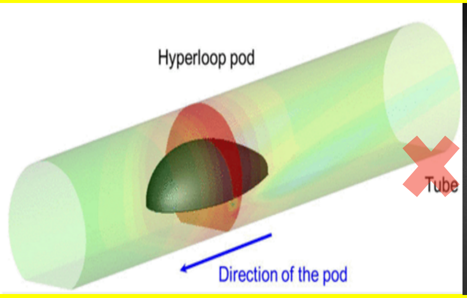


Radiation shielding facility
(Strength/Density/Shielding effectiveness/CO_2)

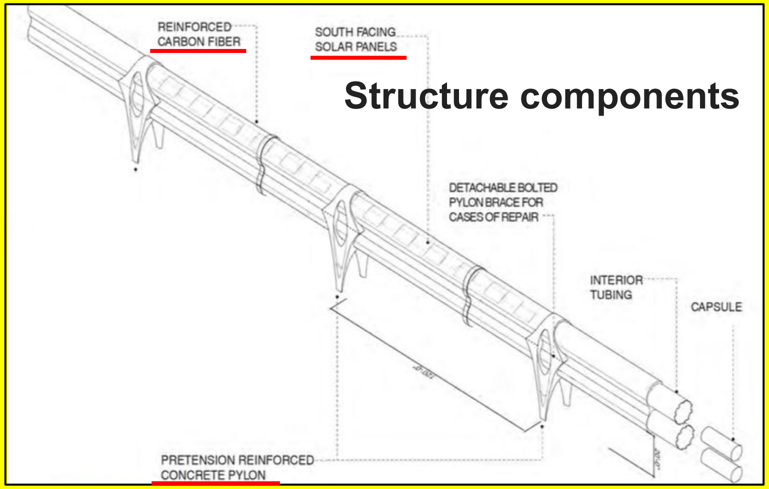


Apply PACS approach to construct Hyperloop (Korea: Hypertube)

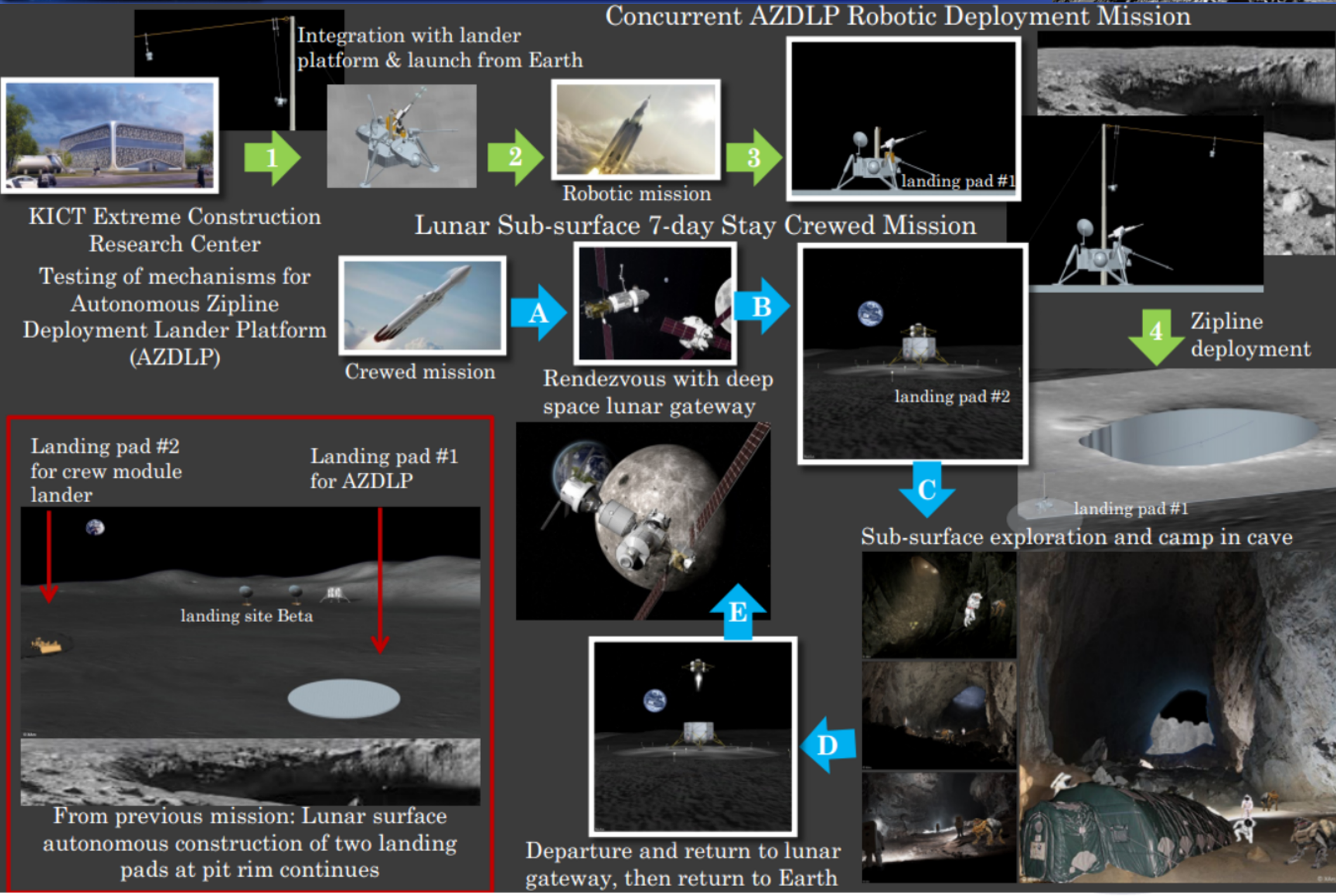
A pod-like vehicle propelled through a reduced-pressure tube that would exceed airliner speed



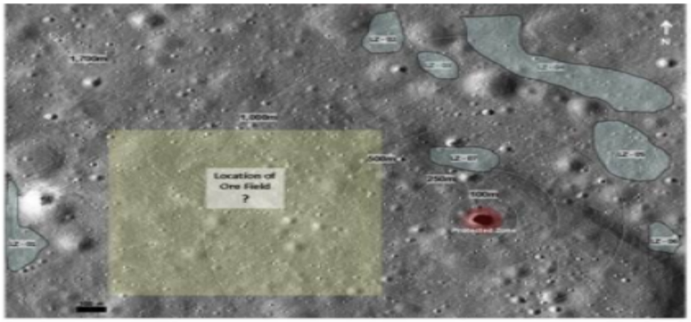
Mars' atmosphere is about 1% the density of the Earth's



How to build the Moon Village



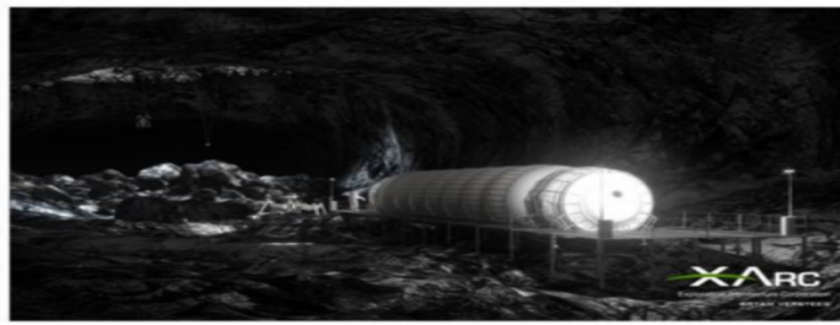
We have the roadmap already! Dreams do come true!!



Remote Sensing Measurements: 2008 – 2018

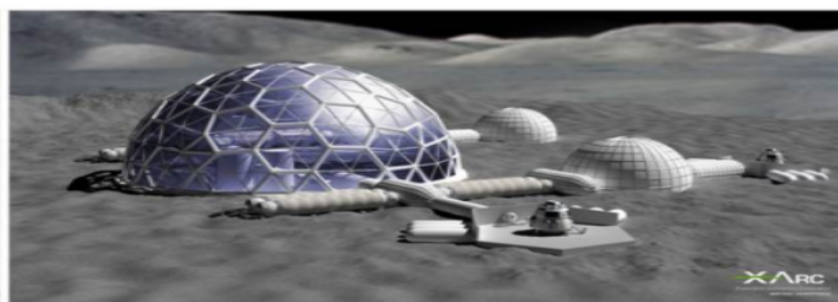
Scientific Robotic Reconnaissance Missions: 2018 – 2020

Human & Robotic Reconnaissance: 2020 – 2025



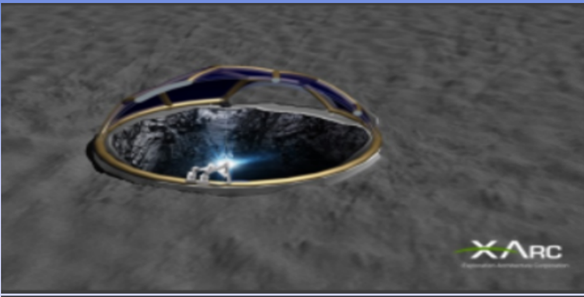
Long Duration Stay Outpost: 2025 – 2050

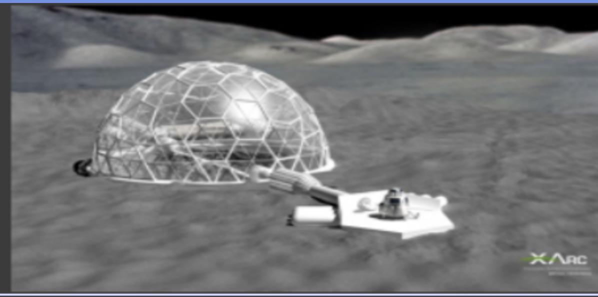
Settlement Construction Begins: 2050+

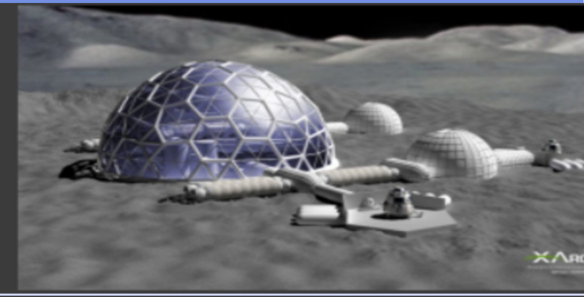


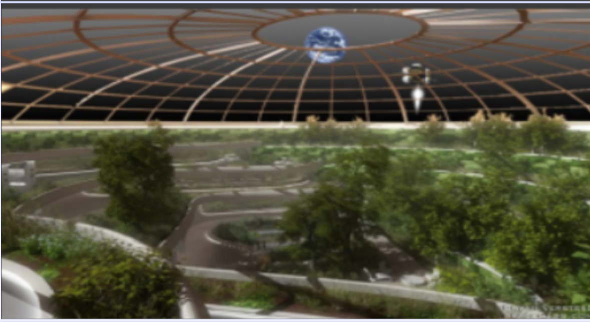
Settlement Phase: Latter Part of the 21st Century

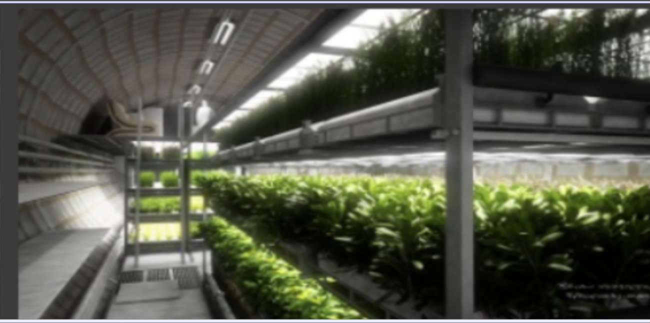
Imagine the Future

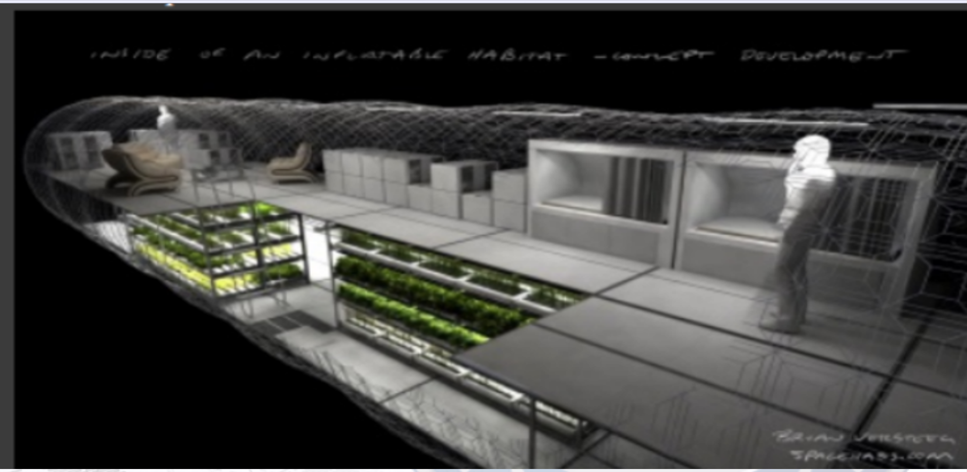






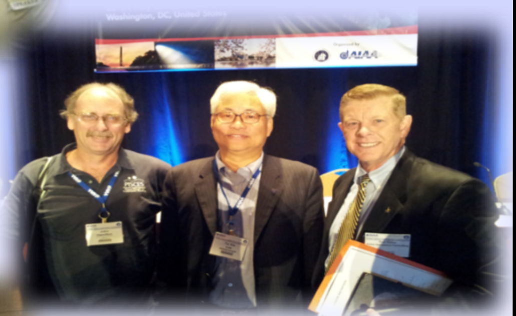




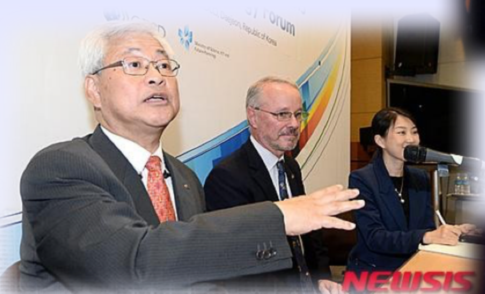


Strategic Cooperation with Global Experts

Kris Zacny, Harrison “Jack” Schmitt, Yoseph Bar-Cohen



John Hamilton & Rob Kelso



David Miller @ NASA

Buzz Aldrin (Astronaut of Apollo 11& Moon Walker)

THE 18th WORLD KNOWLEDGE FORUM

October 17th through 19th, 2017
in Seoul, Korea

Henk Rogers

Bernard Foing & Johann-Dietrich Worner

Bob Richards

Growth of the Next Generation

THANK YOU

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