CONTENTS

I. Introduction of KICT

KICT's Footprints

1948 Ministry of Home Affairs Construction Department Research Institute of Civil Engineering founded

1961 Ministry of Land and Construction National Construction Institute

1983 Name changed to National Construction Research Institute (Research function separated)

1988

1999 Integration

2004 Ministry of Science and Technology

2013 Ministry of Science, ICT and Future Planning Korea Research Council for Industrial Science and Technology

2016 33 years since foundation, 68 years since establishment

1983 Foundation Korea Institute of Civil Engineering and Building Technology established

1988 Ministry of Construction

1999 Integrated with National Construction Research Institute

2008 Ministry of Knowledge Economy

2014 Ministry of Science, ICT and Future Planning National Research Council of Science & Technology

Step 01 Research and development

- National infrastructure performance enhancement technology
- Territorial disaster-reacting technology
- Environmental territory composition technology
- Construction-based conversion complex technology
- High-performance construction material technology

Step 02 Policy establishing and technology support

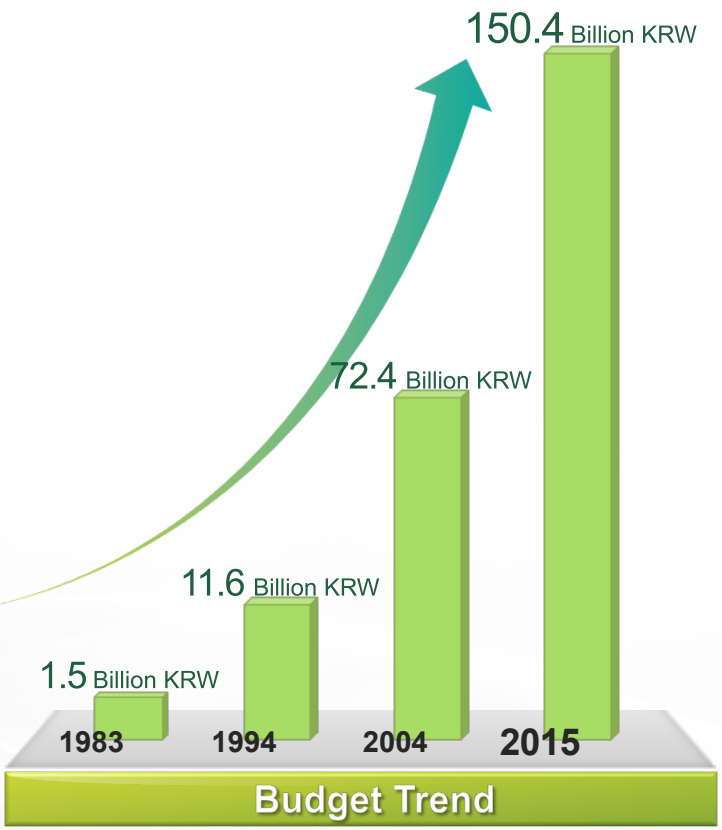
- National construction technology policy establishment and industrial field technology support

Step 03 Quality certification and testing tasks

- Construction and equipment quality certification
- Approval · designation, examination and testing

Budget and Human Resources

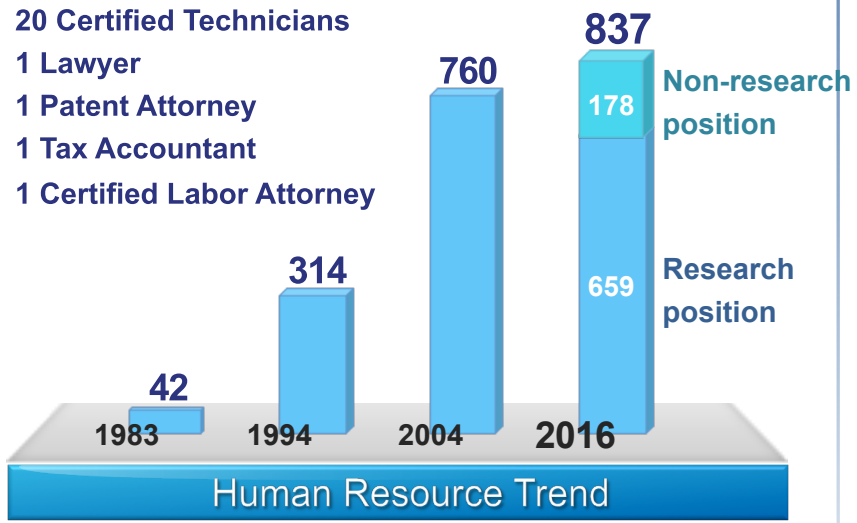
Budget Status



[As of December 2015]

Human Resource Status

354 Doctorates
20 Certified Technicians
1 Lawyer
1 Patent Attorney
1 Tax Accountant
1 Certified Labor Attorney



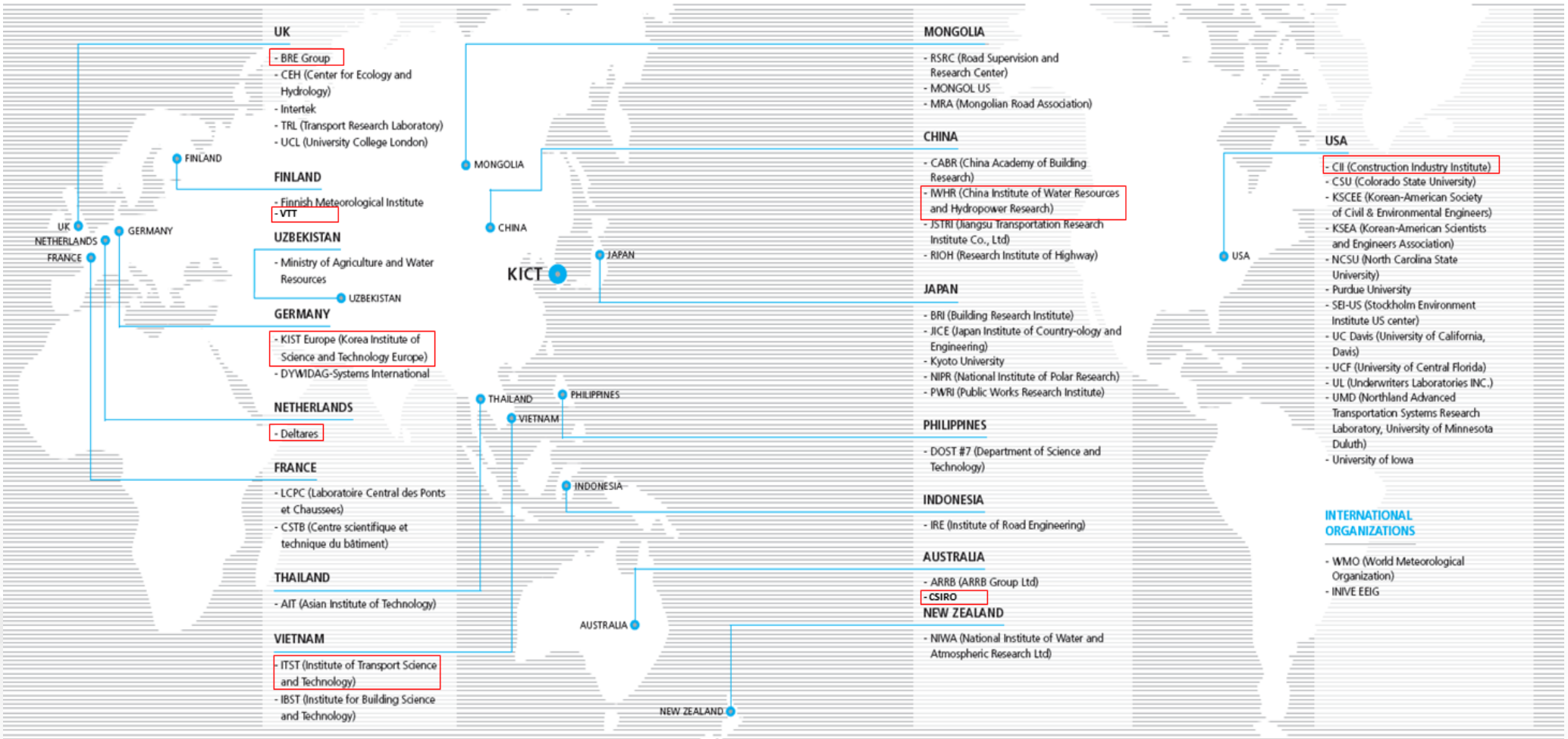
[Statistics : researchers holding doctorate degree (unit: person)]

Department	Doctorate	Department	Doctorate
Construction Policy Research Institute	23	Hydro Science and Engineering Research Institute	51
Highway and Transportation Research Institute	37	Environmental and Plant Engineering Research Institute	36
Structural Engineering Research Institute	43	Building and Urban Research Institute	40
Geotechnical Engineering Research Institute	46	Fire Research Institute	19
ICT Convergence and Integration Research Institute	28	Etc.	31
Total: 354			

[As of March 2016]

KICT's international cooperation status

- International cooperation with **45 institutions in 16 nations over the world**



- International cooperation with US Army Corps of Engineers (USACE/ ERDC, USACE FED)
- Institutional exchange with global R&D institutions such as VTI (Sweden), NRC-IRC (Canada), NGI (Norway), CSIRO (Australia), Fraunhofer (Germany)
- Commissioned training for construction technology in UAE MBRSC, Iran Engineering Society, etc. for advancement to countries in Middle East (in progress)

Organization Structure

President

Auditor

Audit and inspection Division

Construction Industrial Innovation Center

Vice President

Planning and Coordination Department

Administration Management Department

Future Convergence Research Institute

Space Construction Research Center in KICT

Construction Policy Research Institute

Global Cooperation Department

Highway and Transportation Research Institute

Structural Engineering Research Institute

Geotechnical Engineering Research Institute

ICT Convergence and Integration Research Institute

Organization Structure

Prof. Tai Sik Lee <President of KICT>
Ph.D., Univ. of Wisconsin-Madison, USA

Space Construction Research Center in KICT

Dr. Hyu Soung Shin <Head of Center>
Ph.D., Univ. of Wales Swansea, UK

Dr. Jang Keun Lee <Simulant/Regolith>
Ph.D., Ohio State Univ., USA

Dr. Yong Ho Yoo <Ext. Envir. Monitoring>
Ph.D., Inha Univ., South Korea

Dr. Ho Sang Ahn <Ext. Envir. Control>
Ph.D., Auburn Univ., USA

Mr. Myoung Bae Seo <3D Printing>
MSc., Chosun Univ, South Korea

Dr. Sung Chul Hong <Sensing/GIS/VR>
Ph.D. Univ. of Wisconsin-Madison, USA

Mr. Hong Chul Lee <Micro Drilling>
MSc. Chonbuk Nat. Univ., South Korea.

Dr. Chang Baek Cho <Structural Design>
Ph.D., Chung-Ang Univ., South Korea

Dr. Tae Young Yoon <Numerical Modelling>
Ph.D., North Carolina State Univ., USA

Dr. Kyu Hyun Ko <Thermal Dynamics>
Ph.D., KAIST, South Korea

Mr. Myung Jae Son <Aerospace Eng.>
BSc., Chungnam Nat. Univ., South Korea

II. Background of ISRU in Construction

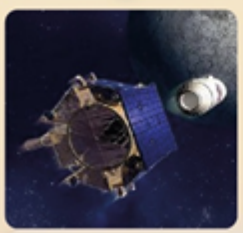
Direction of space construction

- 3 aspects to consider: new idea, low cost, high efficiency
- 3 demanded core values: trustworthiness, applicability, progressiveness

As-Is

- **Limited lunar environment copy**
  - limited environment (vacuum, temperature)
  - Soil bin bound test materials
  - Small scale test for core technologies

- **High cost high risk missions**
  - Focused on exploration robot's function improve -ment for surviving extreme environment
  - Limited missions due to extreme environment
  - Mission success decided by environmental influence



- **Distanced exploration for space resources**
  - Measuring resource distribution, topography, environment via distanced exploration
  - fragmentary, relative data, errors

To-Be

- **Progressed space technology evaluation environment**
  - Closer to lunar environme → Mars environment applicable
  - Non-bound materials → Trustworthiness, applicability secured
  - Testing scale fit for site exploration

- **Low cost high efficiency exploration operation**
  - Local resource constructed shielding wall
  - Protecting site exploration and analyzing devices
  - Longer mission lifespan due to less influence by environmental factors

- **Space resource site exploration**
  - Site exploration, underground exploration proves distanced exploration data
  - More exact data secures trustworthiness
  - Securing data by stratums to achieve progressiv -eness and scientific contribution

ISRU technology development

Human Space Exploration to the Moon/Mars ♪

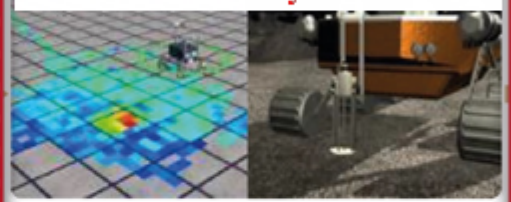
Due to limits of cost / space in projectile – limits of resources from the Earth♪

ISRU

Definition of ISRU(In-site Resource Utlization)

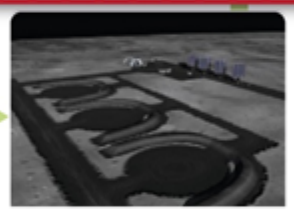
Space resource distanced exploration

Space resource exploration and analysis



Space resource site exploration

Gathering resources



Construction of site exploration supporting infrastructure

Propulsion fuel

Energy source

Surval support Utilizing space resources

Processing

Characterization of resource/material

ISRU's Goal

Mass Reduction

- Less weight reduces projectile cost
- Local fuel supply increases device recycle rate

Cost Reduction

- Less propulsion fuel by providing midway fuel station
- Oxygen/water for astronaut's survival - obtained at the site

Risk Reduction

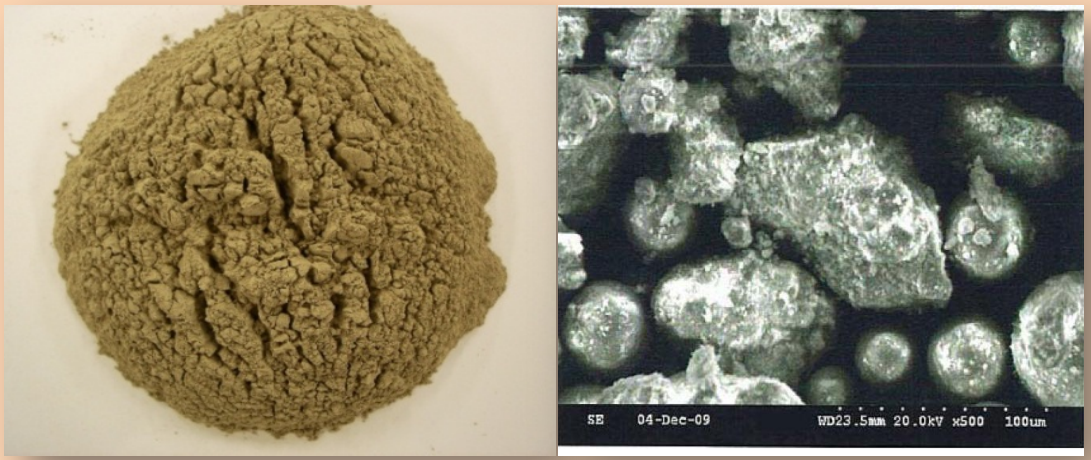
- Due to device recycle rate increase, risk reduced due to less number of launches on Earth
- Shielding wall construction reduces mission risk in the space

ISRU "Living off the land"

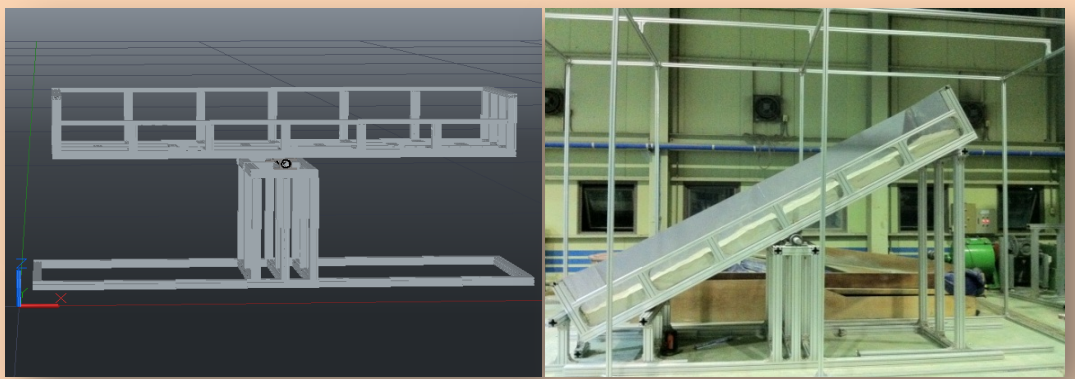
Ⅲ. Korean Researches on Space Construction Technology

KICT Researches on Space: Geotechnical Engineering

(from Hanyang University)♪



KOHLS-1(Korea Hanyang Lunar Simulant-1)



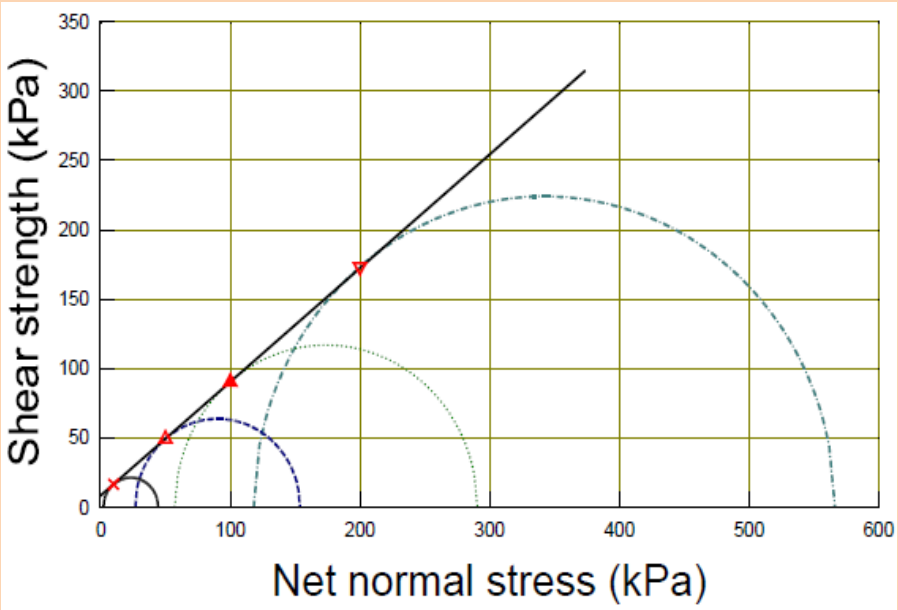
Lunar Analogue Test Environment

Lunar Concrete

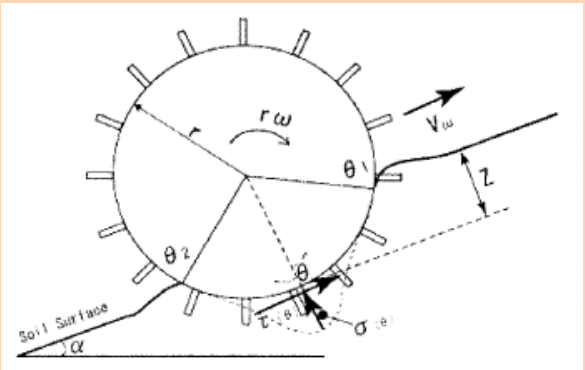
KICT Researches on Space: Geotechnical Engineering

KLS-1 Physical Properties and Application

(from KICT)♪



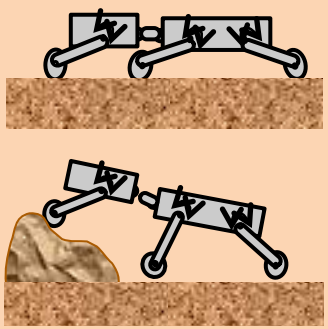
Soil	ø (degrees)	C (kpa)	Source
JSC-1	**45**	**1.00**	Willman et al .(1995)
	45.02	1.65	KICT test
FJS-1	32.5 ~ 39.4	3~8	Kanamiri et al. (1998)
	39.39	8.13	KICT test
KLS-1	44.91	1.85	KICT



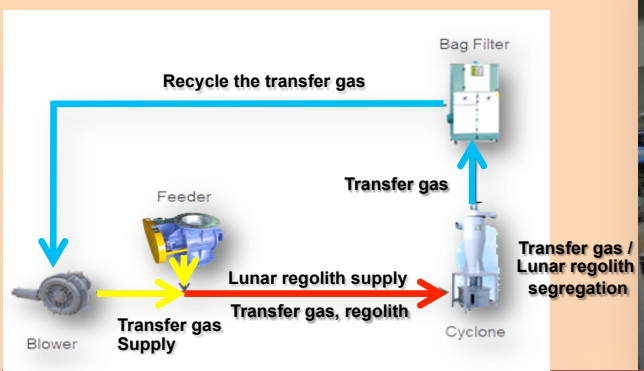
Obtain the optimal wheel system for maximum traction force

KICT Researches on Space: Geotechnical Engineering

(from Hanyang University)♪



ERTER (Extreme Rough Terrain Exploration Rover)



Pneumatic Transportation

Lunar Anchor

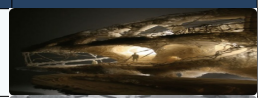
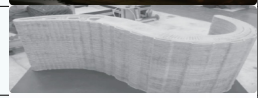
Application Target & Materials

- Application Target : Con. Materials, Scaffold, Structure, Building (Partial Print + Assembly)
- Utilized Materials : Cement, construction wastes resource, nylon, ceramic, sand, synthetic resins, etc.

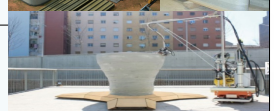
Construction Materials / Scaffold

Organization	Country	Scope	Material	Usecase
Skanska	Swe-den	Connection	Nylon	
DesignLab Workshop	USA	Brick	Ceramic	
Keio Univ. & Takenaka Komuten	Japan	Scaffold	polyvinyl chloride resin	
Arup	U.K	Connection	Steel	
MIT MEDIA LAB	USA	Scaffold	synthetic Resin	

Members / Structures

Organization	Country	Scope	Material	Usecase
Softkill Design	U.K	Partial Print + assembly	Plastic	
Loughborough University	U.K	Partial Print + assembly	Concrete	
Universe Architecture	Nether-Lands	Partial Print + assembly	Fiber reinforced concrete	
DUS Architects	Nether-Lands	Partial Print + assembly	polypropylene	
Dini Tech Corp.	Italy	Fully Print	Sands, Seawater, magnesium	

Building

Organization	Country	Scope	Material	Usecase
USC School of Engineering	USA	Building	Concreate /Ceramic	
IAAC	Spain	Structure	Con-creat e	
Yingchuang New Materials Inc.	China	Partial Print + assembly	Cement, Construction wastes	

Space and Future Construction

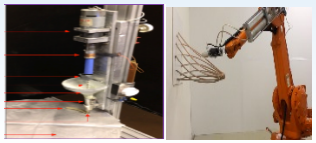
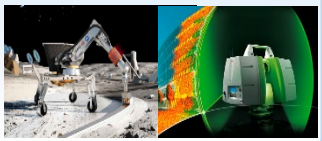
Organization	Country	Scope	Material	Usecase
NASA	USA	Building	Moon concreate	
ESA (European Space Agency)	Europe	Building	Concreate	
-	-	Partial Print + assembly	Construction wastes, Polymer	

KICT Researches on Space: 3D Construction Printing

3DP Core Technologies

1. Equipment

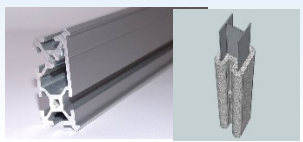
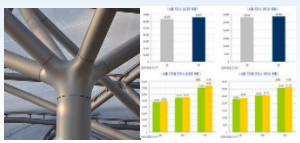
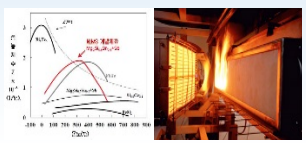
- 3DP Equipment based on Gantry Carne

- Nozzle Control Device and SW

- 3DP Equipment Based on Robot Manipulator

- Field Application Manual

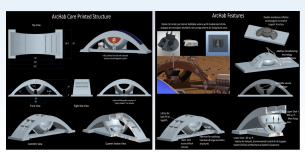
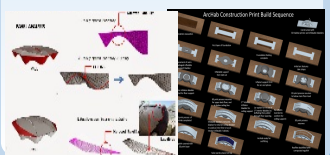
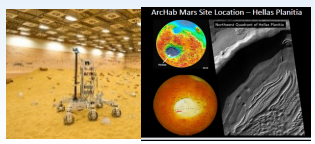
- Commercialization Method of 3DP Technology

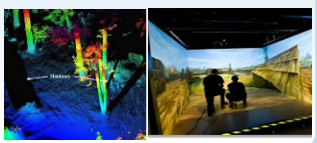

2. Material

- Mixing Technology of Material and Binder Based on ISRU

- Material Hardening Technology

- Material Stacking Technology

- Material Performance Evaluation

- Commercialization Method of 3DP Material

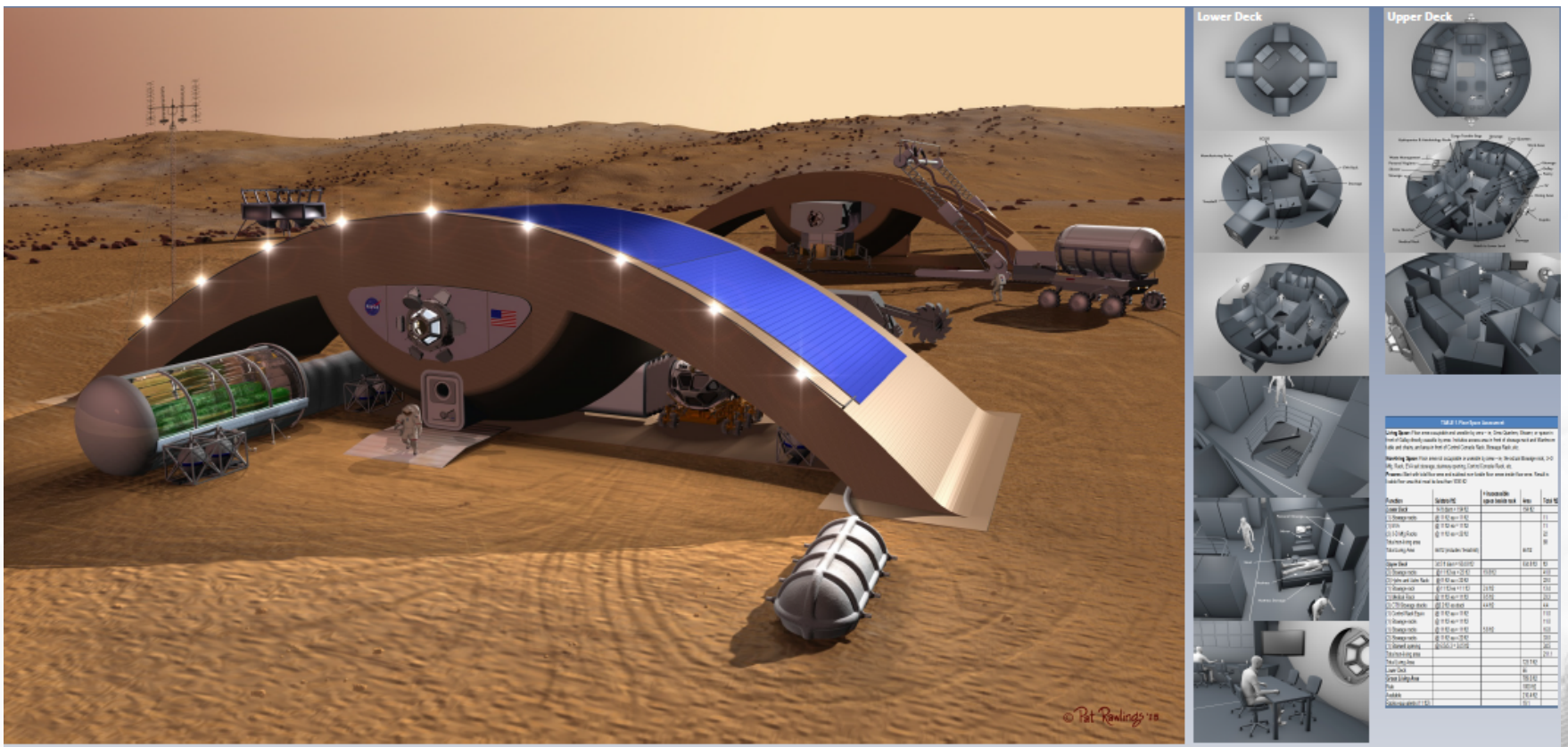

3. Design, Construction and Monitoring

- Structure & Habitat Architectural Design

- 3DP Construction Process

- Optimization Technology of Construction Management


- Monitoring Technology of Construction Site

- Manual, Guideline, Stability Evaluation


International Collaboration

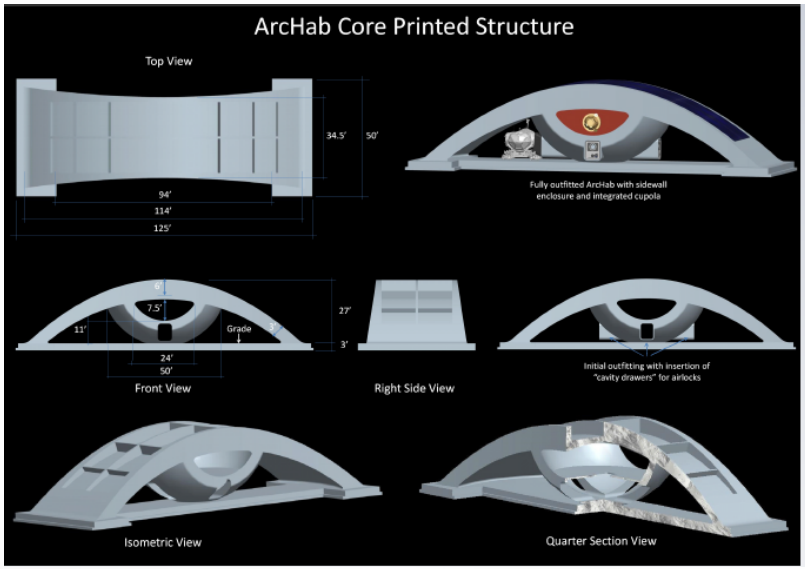
- Architectural design concept for Mars habitat jointly developed by KICT, Hanyang Univ. and XArc
- The concept is living in a cave without having to be in a cave
- The ArcHab is a departure from traditional planetary habitat design using a basic form factor as a core s hell to accommodate a variety of outfitting options.
- The thickness of the arc provides robust radiation protection and added shelter

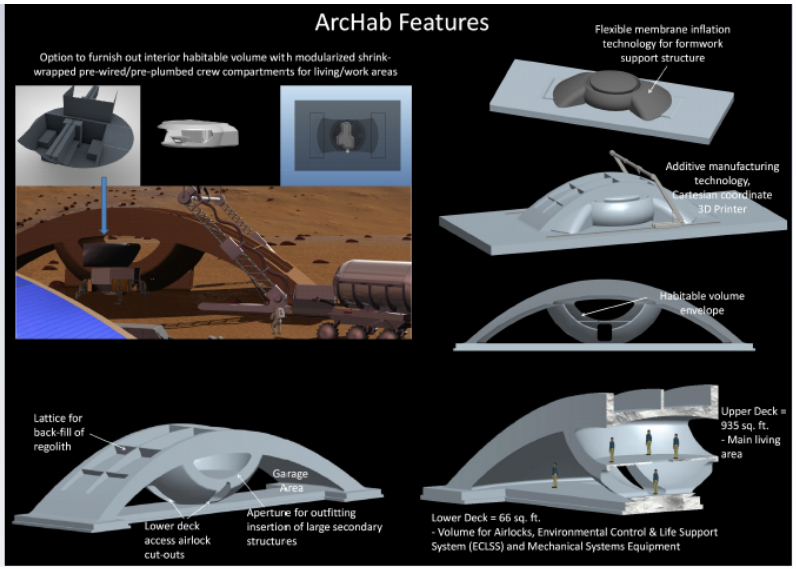


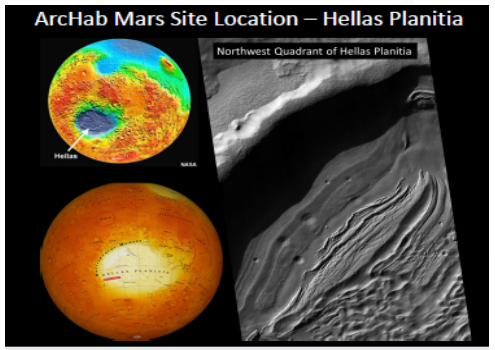
<"ArcHab", Design Concept for Mars Habitat>

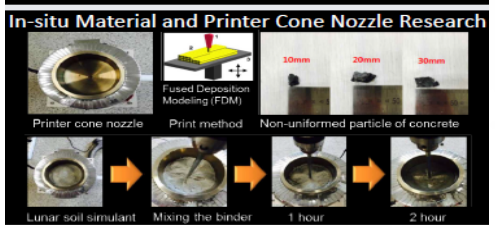
KICT Researches on Space: 3D Construction Printing

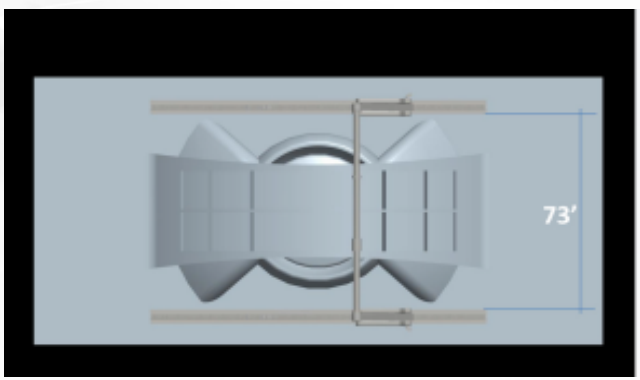
- Construction of the ArcHab is with a process using in-situ material of Martian soil (Regolith)
- Our current concept employs a semi-autonomous process due to the need of supporting inflatable bladd ers to maintain arc curvatures during the printing process
- Maintaining the arc curvatures is the greatest challenge for ArcHab 3D print constructability

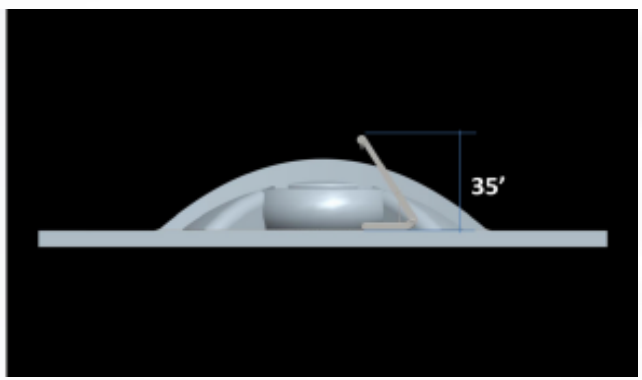


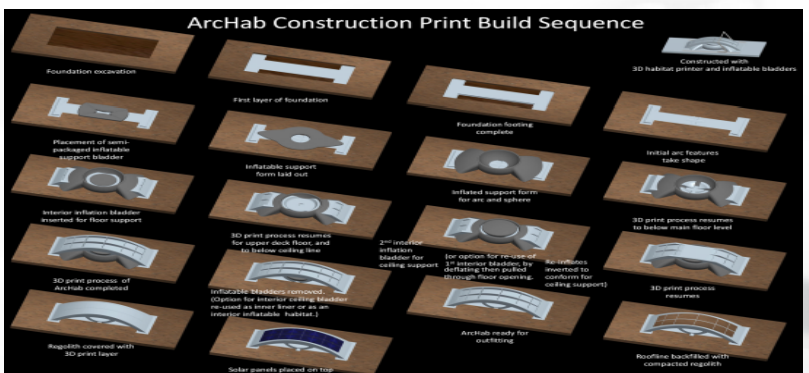




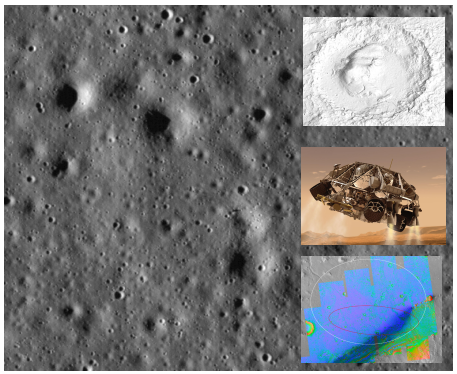




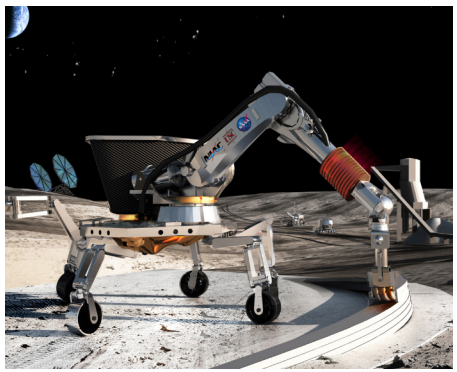




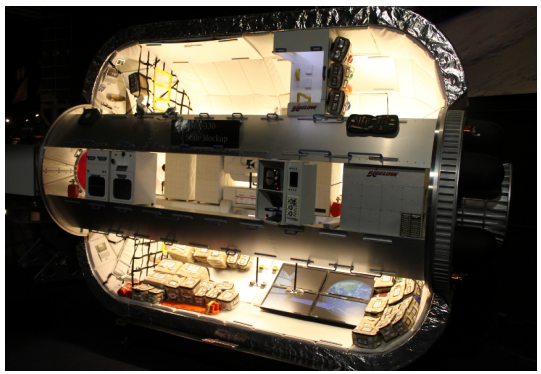
BIM on GIS Platform for Space Researches



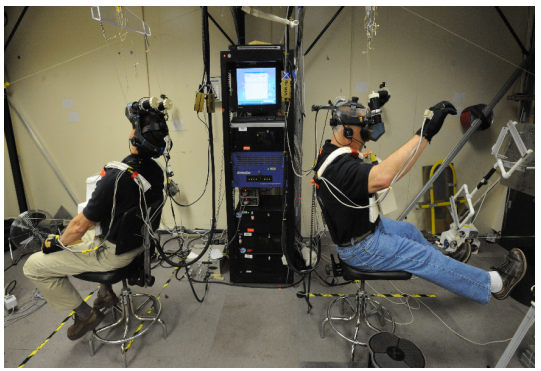
Site Selection for Landing and Habitat



Construction Simulation/Management



Facility Management



VR for Astronaut Training

BIM/GIS Open Platform

BIM(Building Information Modeling)

- Indoor facilities in Micro Scale
- A set of single building objects
- A set of single building objects' property

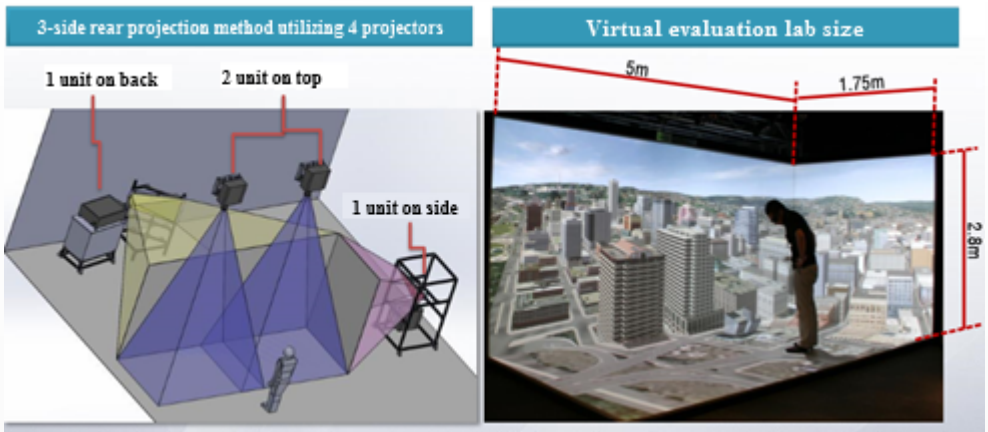
GIS(Geographic Information System)

- Indoor facilities in Micro Scale
- A set of single building objects
- A set of single building objects' property

KICT Researches on Space: Building Information Modelling(BIM)

Virtual evaluation laboratory (BIM Room) established

Roles and Functions of Virtual Evaluation Lab



Nation's first 3-side Virtual Evaluation Lab constructed
Strong immersion brings realistic feeling as in real situations

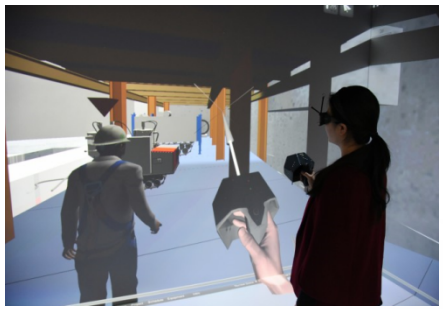
Expected effects

- 3-dimensional design blueprint review and construction process simulation test
- Various simulation possible including city view, disaster, noise, etc.

Future utilization plans

- 3-dimensional design evaluation and certification for National SOC facilities
- Disaster evacuation simulation based on virtual reality

Reported by various media

The Dong-A Daily News, 04/03, journalist Song Gyung Eun
"KICT Reveals the First VR-utilized 'Virtual Evaluation Lab' in Nation"
Chosun Ilbo, 04/12, journalist Park Geon Hyung
"Floating Car in Front and into Nuclear Plant... Rise of MR Virtual Experience Technology"
YTN, 04/03, journalist Kin Jin Doo
"Shall We Build Bases on the Moon ... Virtual Reality for Construction"
CNEWS, 04/03, journalist Kim Guk Jin
"Introducing BIM ROOM at Korea Institute of Civil Engineering and Building Technology."
Money Today, 04/04, journalist Ryu Jun Yeong
"Can be anywhere in 'BIM Room' - Space · South Pole · Site of Disaster"

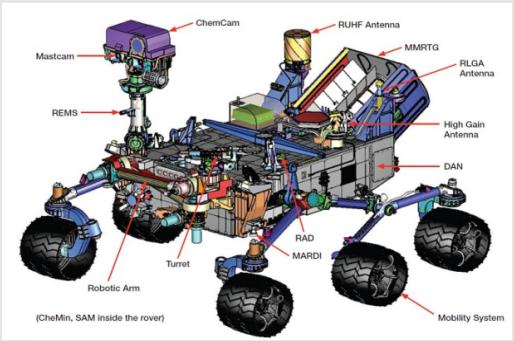
KICT Researches on Space: Building Information Modelling(BIM)

- Lidar surveying system on rover & analysis/management system of spatial surveying information
- On-site information treatment & size minimizing system
- VR visualization and data control system in the KICT's BIM room

On-site spatial information

- **Moving platform for surveying**
- **Hybrid sensing such as Lidar etc.**
- **Data transmission**

Hybrid Lidar & 3D camera sensors on rover

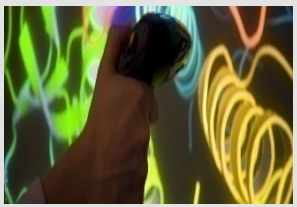


Prototype moving platform for surveying

VR visualization of spatial data

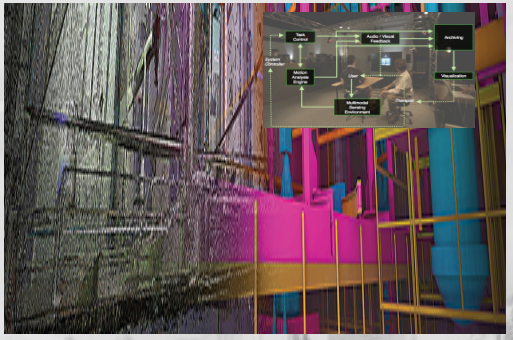
- **3D VR software**
- **Image control devices**

TechViz

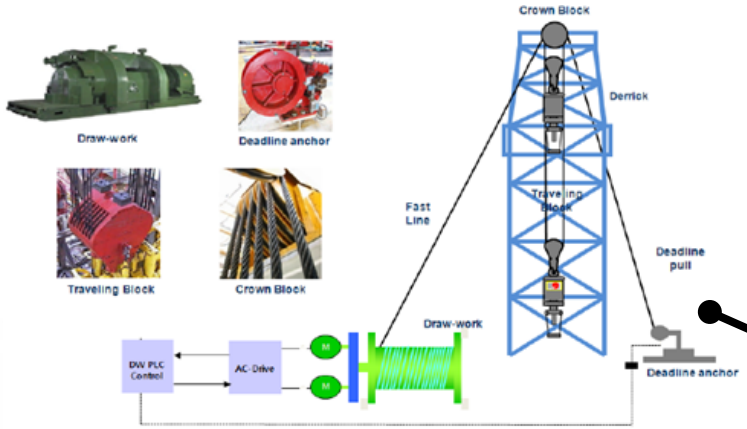


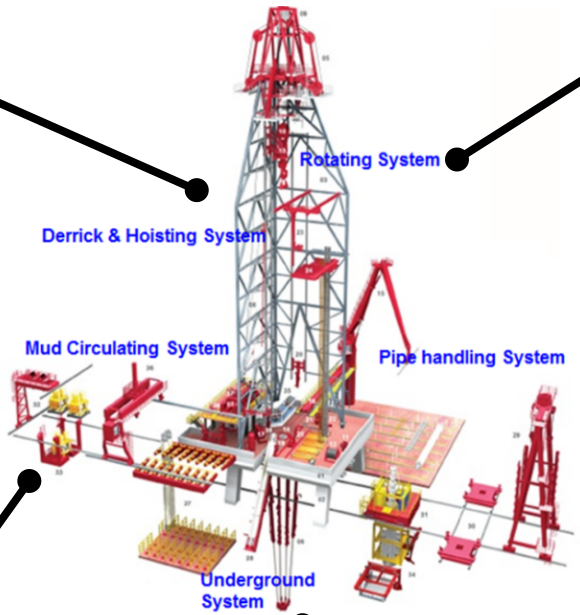
Scenarios of utilization of spatial information on site at KICT

Visualization & control of spatial data at KICT 's BIM room



Current Drilling Technologies in Construction



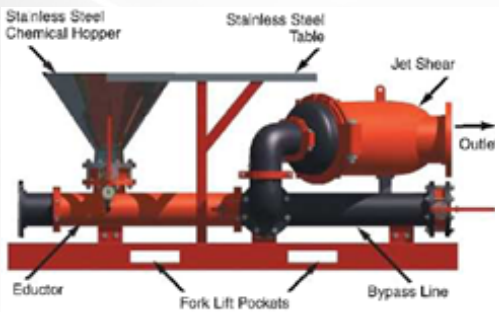


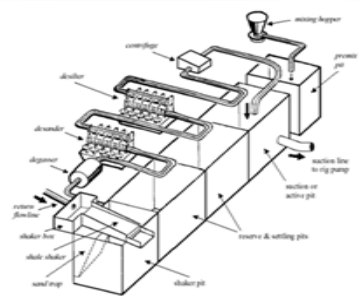
Derrick and hoisting systems: :
Providing installation space for drill pipe
Unnecessary features

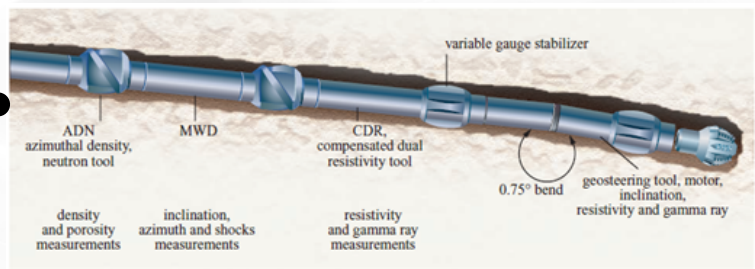
Rotation System :
Device for rotating the drill pipe
Non-hydraulic drive required

Mud Circulation System: :
Clay emissions, Drill bits lubrication
Unnecessary features

Drilling direction control systems :
Drilling depth of up to 1m
on Moon and Mars



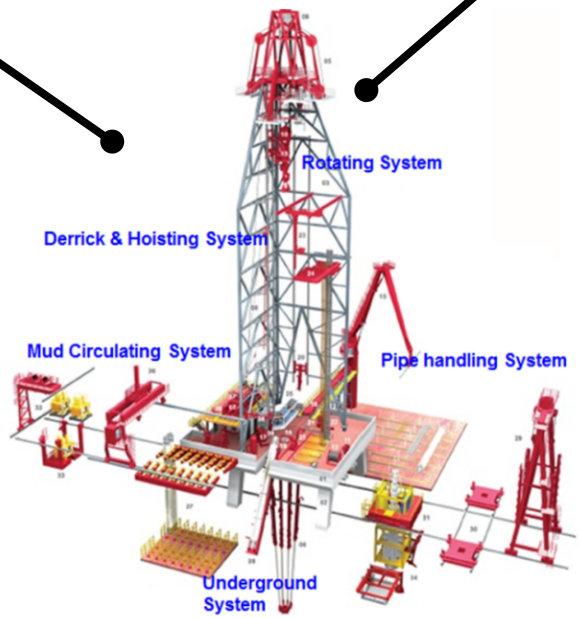




Space Implementation

Drill rig automation systems :

Necessary features for exploration Equip.



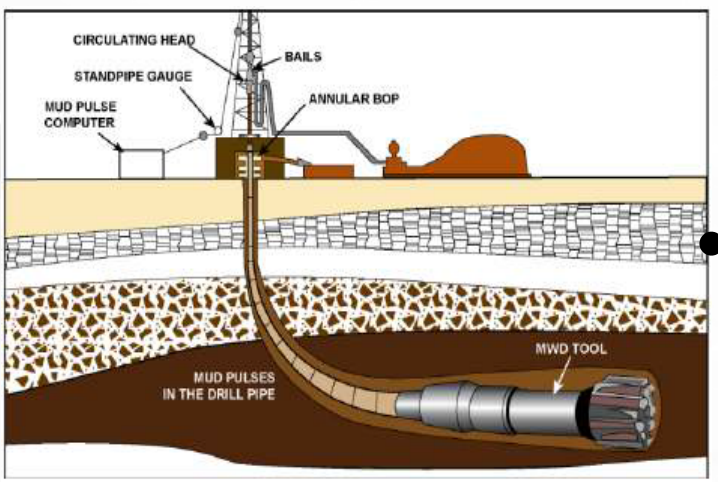
Hallow ice core drill system :

Drilling equipment for the Polar Climate Change Research

Necessary features for exploration Equip.

Measurement while drilling(MWD) :

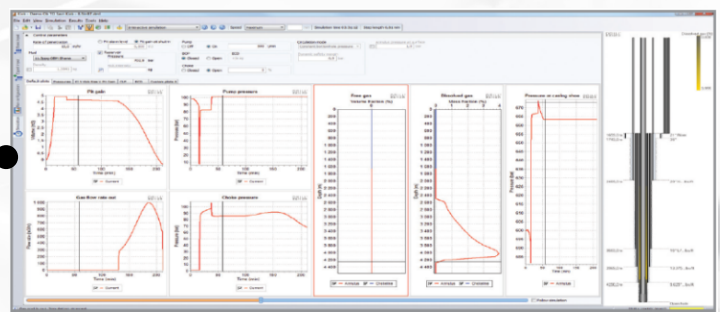
Necessary features for exploration Equip.



Drilling simulation :

Drillbench dynamic simulation & control

Necessary features for exploration Equip.

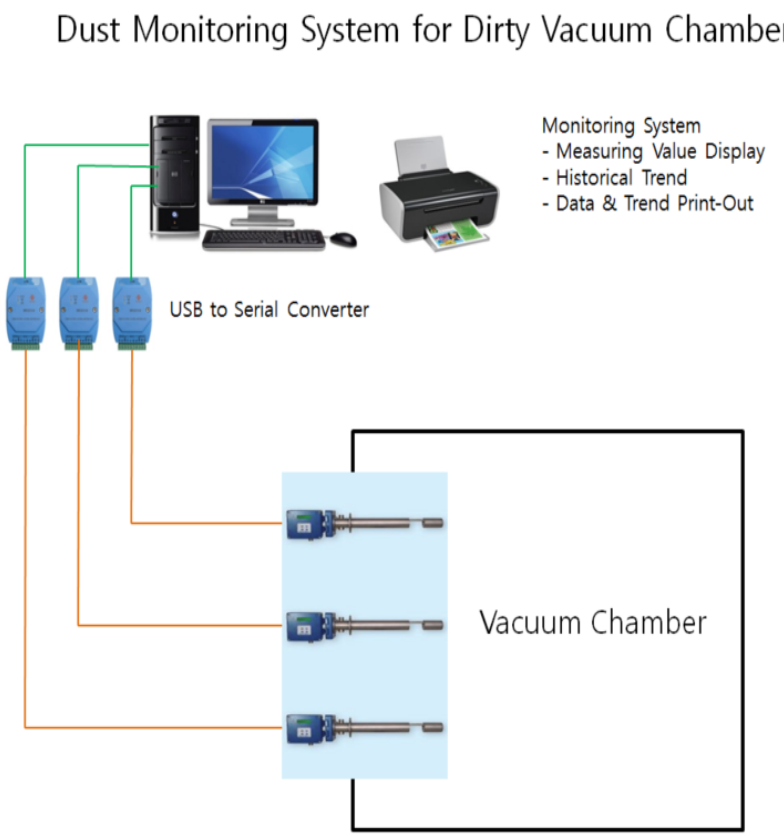


Application for Dust Control in Vacuum Condition

Ventilation
(Coal Mine & Tunnels)

Particle Characteristic in Vacuum

Dust Monitoring System(Light Extinction)

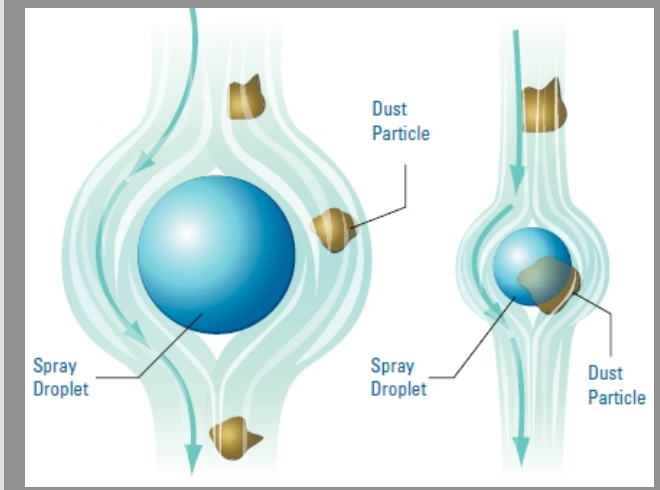


Dust Control in the Worst Condition(Coal Mine & Tunnels)

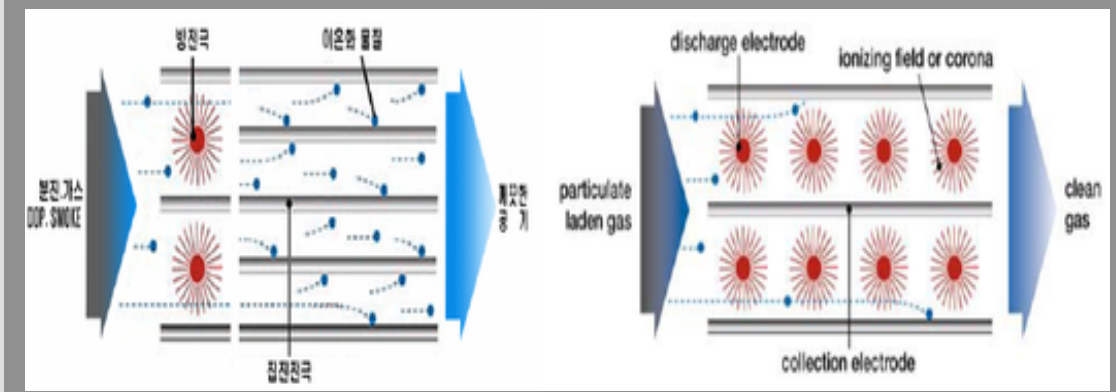
oal Mine Environm ent♪

Dust Control ♪

Spray Solution♪ : need to substitute for water ♪



Dust Collector♪



: Low Power & Miniaturization♪

KICT Researches on Space: Dust Control & Monitoring

Dust controlled Vacuum Chamber under design

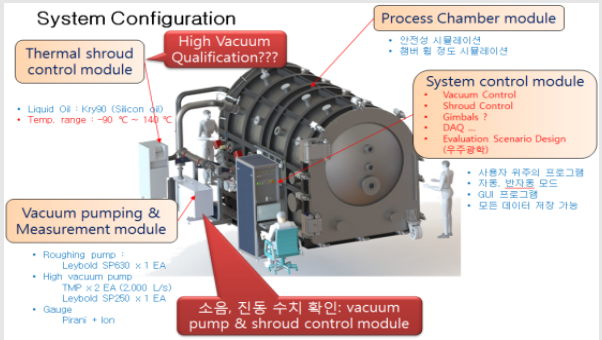
Lab. Scale Pilot Chamber

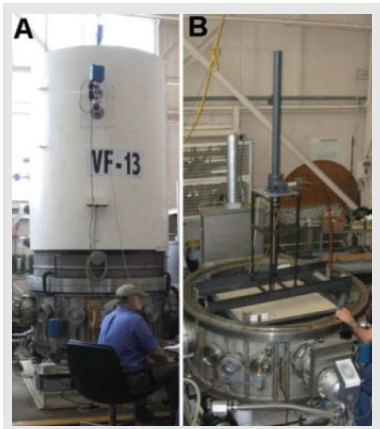
- **Dimension :** Φ1000×1300L
- **Temp. :** -190℃/+150℃
- **Vacuum Pumping System**
- **Utility etc.**

Big Scale Vac. Chamber (under design)

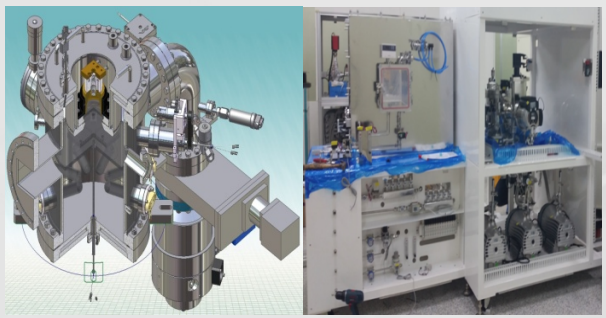
- **Size: 50m^3 (D 4m xL 4m)**
- **Vacuum: 10^{-6} torr**
- **Temp.: -190℃/+150℃•**
- **Dust Control & Monitoring**
- **Other Contamination Cond.**

Low temp. High vacuum, Big scale C hamber



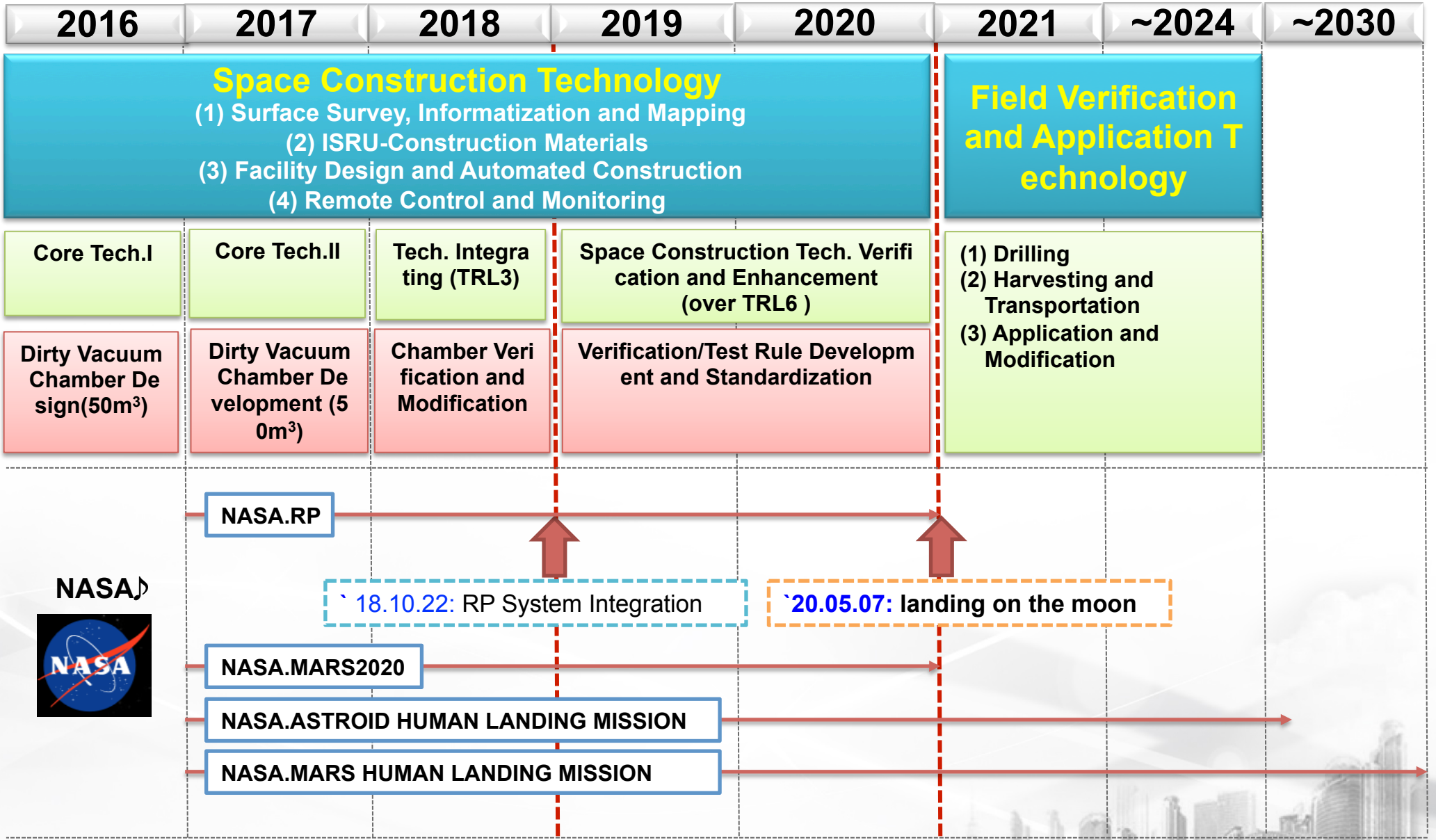


Dust control & monitoring



[Ref. : Development and Testing of an ISRU Soil Mechanics Vacuum Test Facility, 2014)]

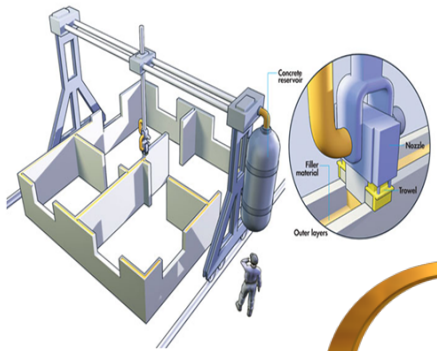
Program Roadmap with NASA missions



Ⅳ. Concluding Remarks

Contribution on value addition on construction industry

Synergies Effect by 3D printing system & Automation construction collaboration



Build a new residential environment through **Sustainable Development**

Utilizing in **Extreme Environment**

Build up **Lunar Habitat Environment**

"Korean Construction Technology Will Work in Space … Make Space Fund"

매일경제

한국 건설기술 우주서도 통할것…우주펀드 만들자

이 태 식 한국건설기술연구원장

"미국, 러시아, 중국이 주도하는 우주 개발에서 한국은 열등생일 뿐일까요? 돈이 되는 본격 개발은 달이나 화성에 도착한 후부터입니다. 우주항공에선 뒤졌을지 몰라도 우주건설에서는 앞서갈 준비가 돼 있습니다." 한양대에서 교편을 잡다가 국가 건설기술개발을 전담하는 정부출연연구원을 이끌고 있는 이태식 한국건설기술연구원장(63)은 호기심 많은 '홍안의 소년'이었다. 인터뷰를 위해 자리를 잡자 마자 '달 콘크리트'를 들어 보였다.

"달은 중력이 없다보니 먼지가 일어나면 8개월 동안 연무 상태가 지속됩니다. 이런 조건에서 지구의 흙알갱이보다 훨씬 미세한 분말 형태의 흙을 가지고 기자와 거주시설을 지어야 하죠. 무중력 진공 상태에서 콘크리트를 타설하는 기술을 개발하려고 4㎥짜리 '더티 배큠(dirty vacuum)' 시설을 건설해 이것을 만들어냈습니다. 적어도 이 기술은 우리가 미국 나사(NASA)보다 앞섰습니다."

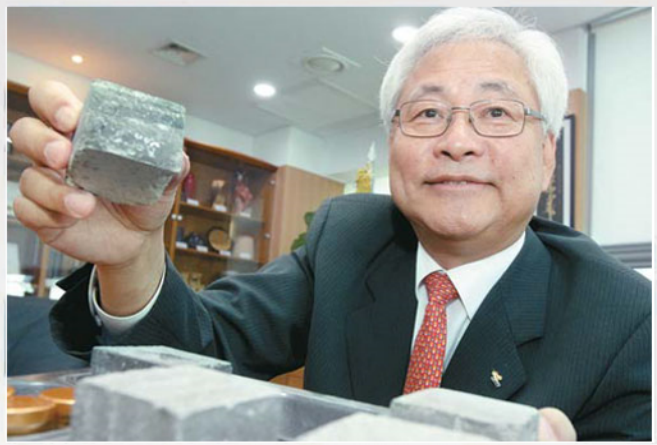
돌이켜 보면 세계 10위권 경제대국 한국의 초석은 건설기술이 벌어다 준 중동의 오일머니였다. 건설기술은 프로젝트 파이낸싱을 뒷받침할 금융의 약세 탓에 수주 규모로는 세계 6위 수준. 그러나 기술력에선 세계 어느 나라와 견줘도 뒤떨어지지 않는다고 한다.

"NASA의 연구인력 1만5000명 중엔 건설기술자도 상당수 있습니다. 우주의 극한 환경에서 도로를 놓고 건물을 짓는 일이 관건인데 일단 우주개발이 본격화되면 우리의 저력

10년뒤 사업 지금 참여해야
대기업 등 1200억 펀드 조성해
달착륙선 개발 韓 이름 올리자

이 발휘될 여지가 큽니다."

이 원장은 경기고와 서울공대를 다니면서 연극반 활동을 해왔다. 과학자 이전에 예술인적 자질을 가지고 있다보니 상상력이 지나친 건 아닐까. "우주개발은 까마득한 미래의 일이라고 생각하기 쉬운데 10년, 20년 뒤 시작될 프로젝트는 지금부터 참여해야 가능합니다. 그때 가서 선진국들 사이에 숟가락을 얹으려 해도 받아주지 않죠. 그동안 마인드 부족으로 우리가 낄 여지가 별로 없었지만 드디어 절호의 기회가 왔습니다."



이태식 한국건설기술연구원장이 무중력 진공상태에서도 만들 수 있도록 개발한 '달 콘크리트'를 들어 보이고 있다. 〈아승환 기자〉

미국과 캐나다가 주도하던 달 착륙선 '랜더(Lander)' 프로젝트에서 캐나다가 빠지게 된 상황을 설명했다. "캐나다 대신 지분 참여를 하려면 1200억원 정도가 필요하죠. 일단 여기 들어가야 무궁무진한 우주개발의 기회를 잡을 수 있어요. 정부도 국가 R&D 사업 등을 통해 일부를 투자하고, 나머지는 삼성이나 현대 같은 대기업에서 참여했으면 좋겠어요. '우주펀드'를 만들자는 거죠."

인터뷰하면서 '빅 히스토리' 프로젝트를 포함해 그동안 그가 구상하고 도전했던 아이디어가 쉴 새 없이 쏟아져 나왔다. "우주개발 기술은 로또 같은 게 아닙니다. 달이나 행성 환경은 크게 남극과 북극 같은 혹한지역과 심해저 환경, 사막 같은 혹서지역으로 나눌 수 있습니다. 현재 인류가 거주하는 지역은 지표면의 10%도 되지 않습니다. 우주건설 기술은 지구의 나머지 90%를 거주 지역으로 삼을 기술을 개발하는 겁니다. 스핀오프(spin off)가 아니라 스핀온(spin on)이라고 할 수 있죠."

이 원장은 연구원이 얼마 전 두바이와 제로에너지주택 건설 지원 MOU를 체결한 사실을 소개했다. 태양광을 이용해 전기를 자체 생산해 내는 건설기술이다. "제로에너지 주택은 달이나 행성 거주공간의 기본 콘셉트이고 우주개발에 바로 적용될 수 있는 기술입니다. 이제 두바이 사막을 넘어 우주로 가는 것이 목표입니다." 그는 중동을 사로잡은 한국 건설기술의 저력이 무엇인지 아느냐고 묻더니, 첫째는 근면이었고 둘째는 도로 교량 발전소 등 모든 인프라 스트럭처를 동시에 제공하는 종합건설과 매니지먼트 역량이었다고 자답했다. "우주개발에 필요한 것도 바로 종합설계와 매니지먼트 노하우죠. 연구 역량을 우주 진출에 맞추고 국가 중심의 종합적이고 유기적인 협력 시스템을 갖추는 게 그래서 필요합니다. 우주 시대는 이미 와 있어요. 다만 널리 퍼져 있지 않을 뿐이죠. 기회를 먼저 잡는 나라가 승자가 될 겁니다." 이창훈 기자

Source: Maeil Business Newspaper 2015.10.11.

An idea that is not dangerous is unworthy of being called an idea at all.♪

(Oscar Fingal O'Flahertie Wills Wilde)♪

Thank you for listening.