Moon Village のゴールを定義してみる

第1回宇宙探査の将来を考える会
2019年8月30日

稲谷芳文


MOON
VILLAGE ASSOCIATION


Moon Village Association
The concept of a "Moon Village" is the ensemble of all efforts from private, governmental and others, aiming to explore and use the moon in a sustainable manner. It is not a literal village on the moon, it is not an "*International Space Station on the moon*" and it is not a single science facility.
Read more

What is the Moon Village Association?

The Moon Village Association (MVA) was created in June 2017, to foster the implementation of the Moon Village

A forum to advance development of the Moon Village involving Industry, government, space agencies, international organizations / NGOs, and the Public at large

A catalyst stimulating a virtuous cycle of investments for the development of a lunar economy aiming to settle humankind on the Moon as well as cultural inspiration for future generations

Individual Members:
150 from 34 countries

MOON VILLAGE ASSOCIATION

Institutional Members:
8 from 7 countries

LOCKHEED MARTIN

ispace

TEAM INDUS MOONSHOT

YUZHNOYE design office

OFFWORLD

CISLUNAR INDUSTRIES

PT SCIENTISTS

FOR ALL MOONKIND

Working Groups

Moon Village Architectural Concepts & Issues WG

Moon Village Standards WG

Human Factors WG

Moon Market, Missions & Economics – Forecasts and Financials WG

Lunar Data Harmonization WG

Moon Village Critical Services WG

Moon Village & Exploration Analogues WG

Cultural Considerations WG

Outreach WG

Coordination and Cooperation WG

月の上に社会を作る

考えておくべきことは・・・・

1. ソサエティの規模・・何人の持続的・常時滞在？移住？
2. ソサエティ運営のルール，文化，世代を継ぐ？
3. どのような活動をする？どのような価値を生み出す？
4. 経済的に自立する？
5. 持続的に滞在できる仕掛けは？
6. 現地の資源や資材をどのように
   調達し輸送する？

月・火星上に社会を作る・・・仮定をおく

2050 – 2100 程度の未来を想定

社会の規模＝社会としての要件

地球への依存を最小化

経済的に自立する

社会の構成員が現地で価値を生み出す

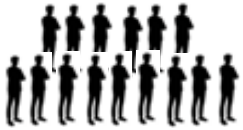
・・・・・

有人探査，滞在の規模･･･ソサエティのサイズ

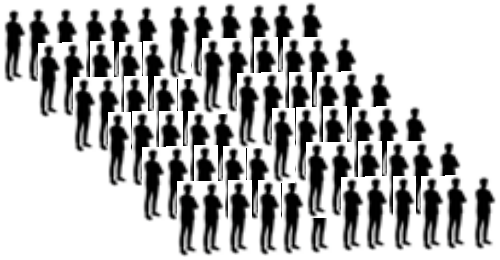
APOLLO

ISS / LOP-G ?

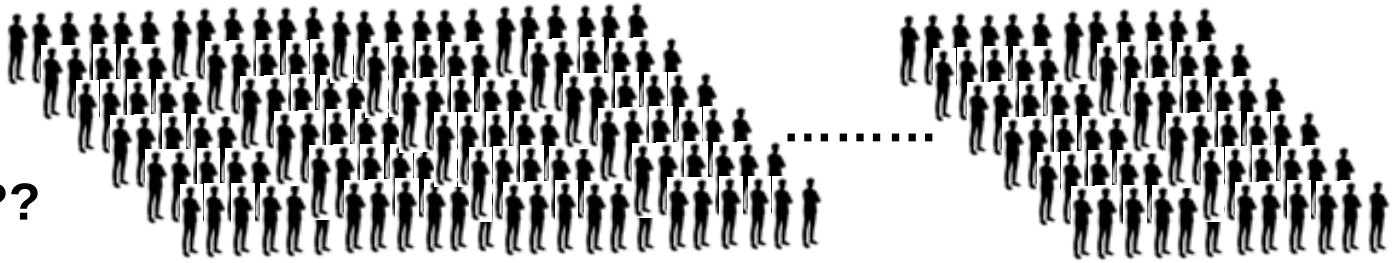
Initial Moon Base?



Dunbar’s Number
150-250
“Everybody knows Everybody” Community



1000
Society members ??



月・火星上のソサエティはどういうものと相似か？

Antarctic Base

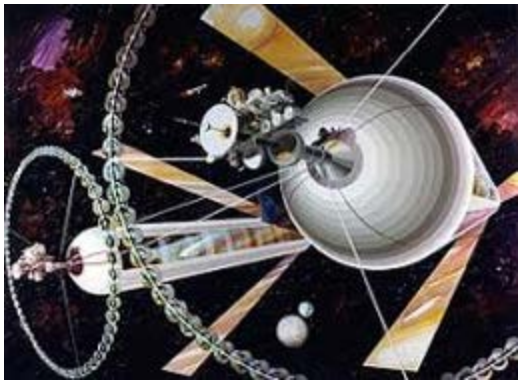
Amundsen-Scott south pole station
200 in summer, 100 in winter (isolated)

Arctic Science Village
Ny Alesund

Former Coal Mining Base
operated by private company
30 researchers & 20 operators

Space Colony

Onil, J.K. et.al.



10-1000 thousand inhabitants
In Earth-Moon Lagrange pt.

Cruise Liner

3000 passenger / guest & 1000 crew

月・火星上で何をして価値を生み出すのか?

科学探査
資源採掘
生産・建設，維持管理サービス
エンターテインメント
教育・広告・宣伝
テレオペレーション・ゲーマー
セメタリーサービス
旅行・観光
ツーリスト・ビジターへのサービス
ビジネスサービス
……

MVA, Space Settlement Summit@LA 2018での議論などから

社会を構成する有人滞在の施設の設計は
どういうことを考えて作る？

radiation exposure

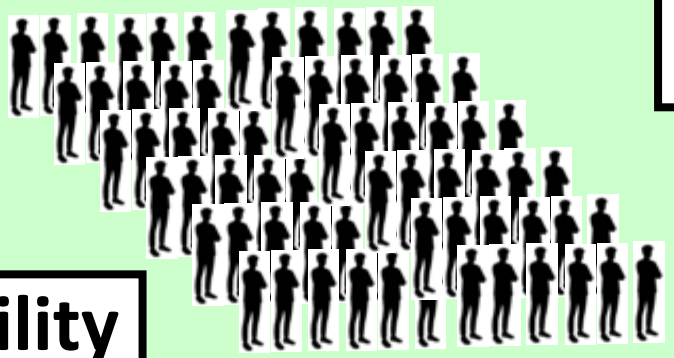
transportation

food / water

accommodation

communication

environment control



life support

emergency action

Operation flexibility

information

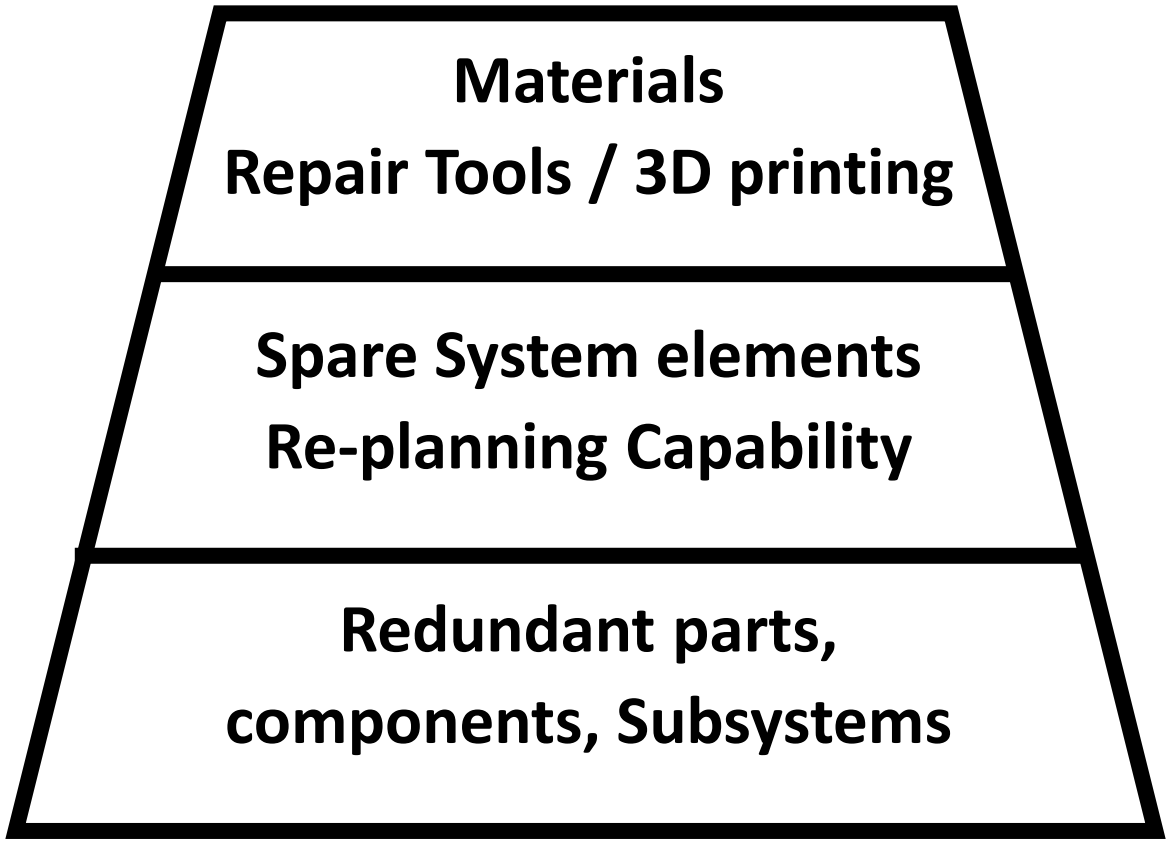
entertainment

evacuation

深宇宙における持続的有人滞在のシステムアーキテクチャー

故障しない信頼性，冗長性と，故障に対する耐性から現地での再構成，修理，製造へ

- Survivability
- Flexibility
- Reliability



サバイバビリティのための現地での製造・・・3DPの技術

®Relaivity Space

Flexible, aoutomated production of rocket production

Propellants of the future: oxygen + methane.

Enhanced mission reliability by simplifying engine igniters, turbopumps, reaction control thrusters, and vehicle pressurization systems.

As a bonus, these propellants are the easiest to eventually make on Mars.

THRUST
18,500 LBF-VAC

ISP
>360 SEC

CYCLE
OPEN EXPANDER

Aeon has completed over 100 test fires.

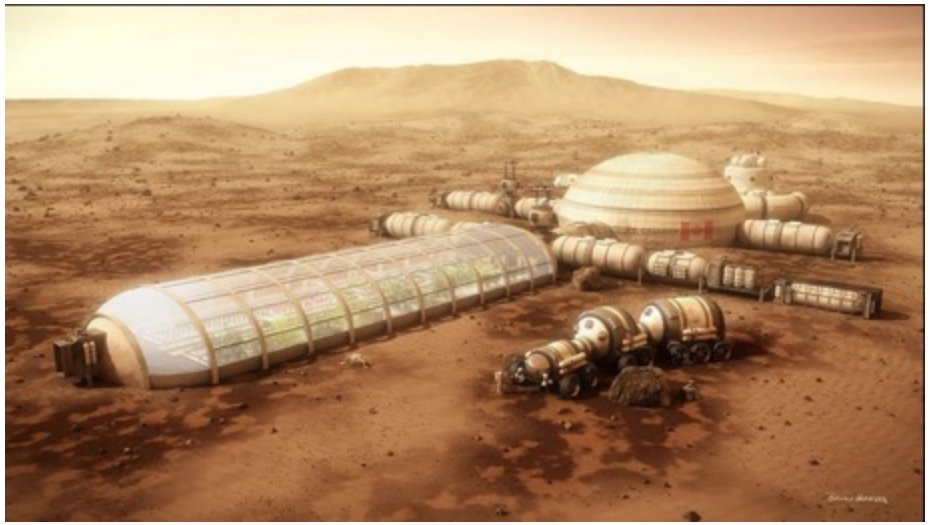
Quicker production. Faster iteration.

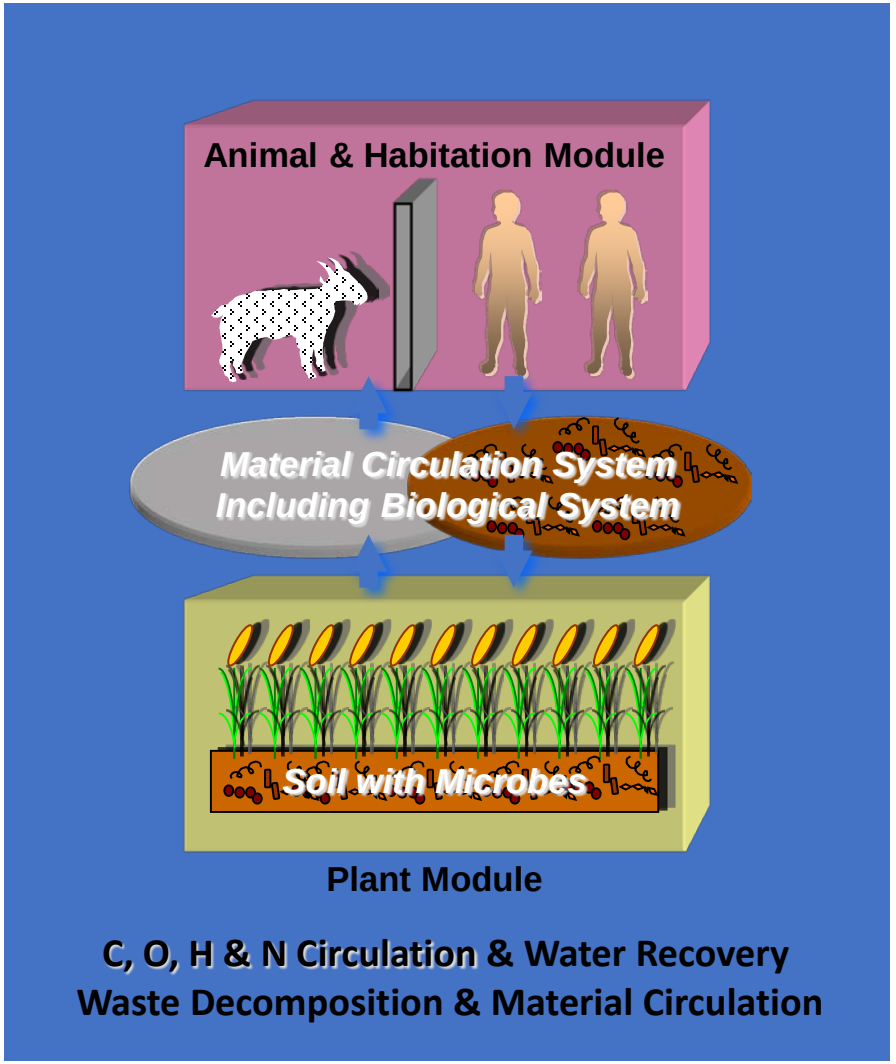
An evolvable engine design coupled with 3D printing of every component unlocks agility from development through operation.

Fewer components. Designed for automation.

Our process reduces the number of component interfaces, making full robotic automation of engine production possible.

ISRU(In-situ resource utilization)
月・火星での資源，資材，エネルギーの調達
宇宙農業から生態系の構築へ



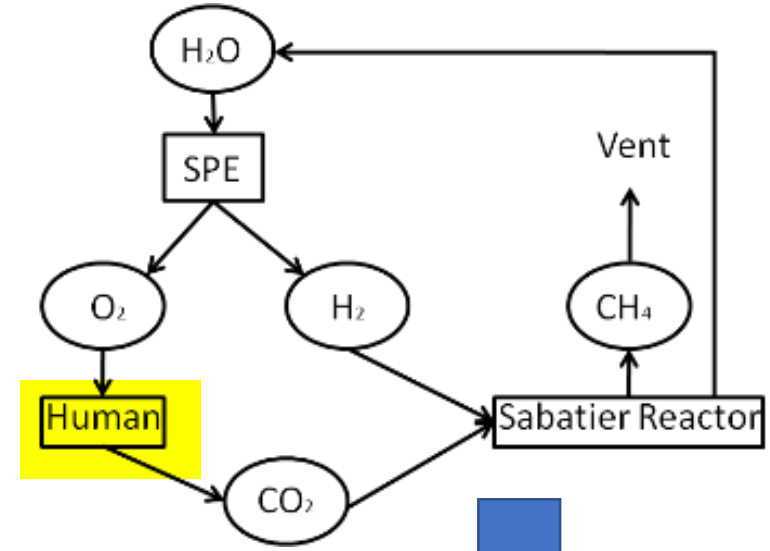


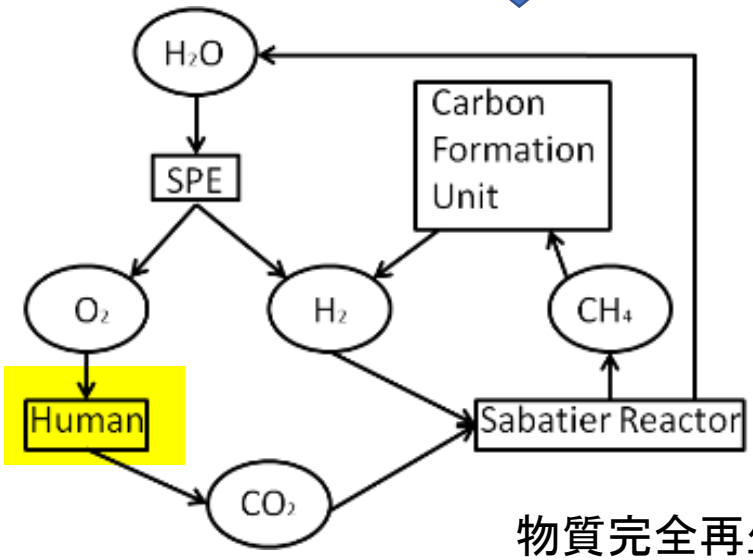
バイオスフェアでの実験・・Lessons Learned

コロンビア大学，アリゾナ大学

有人滞在生命維持：物質再生から火星資源利用へ

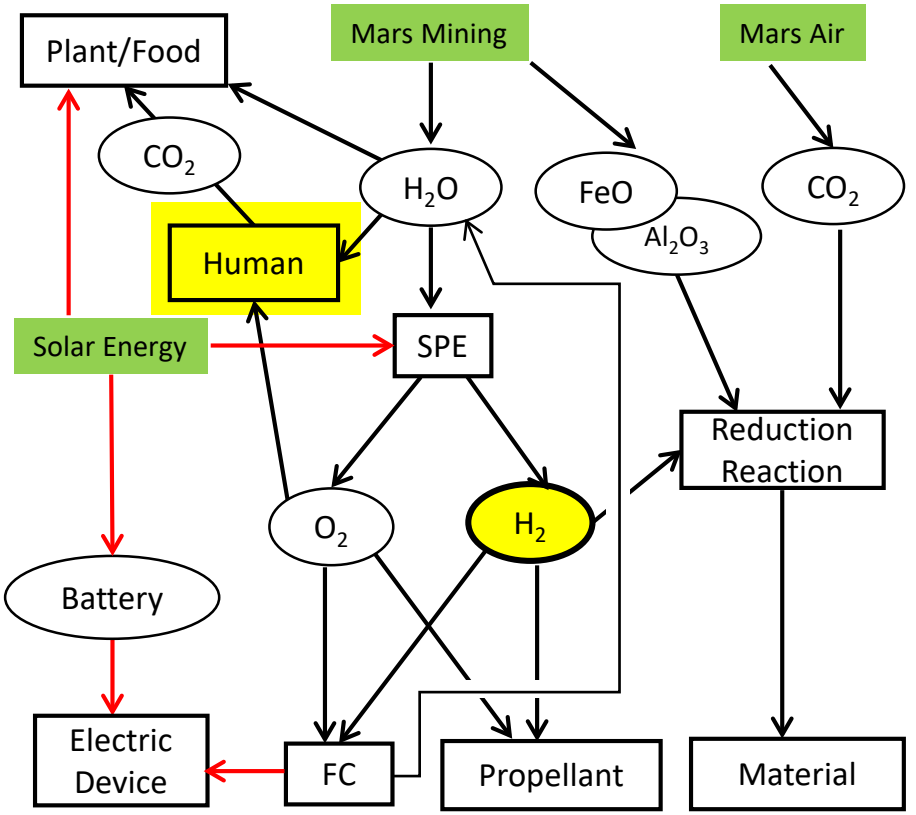
宇宙ステーション（空気再生率=50%）



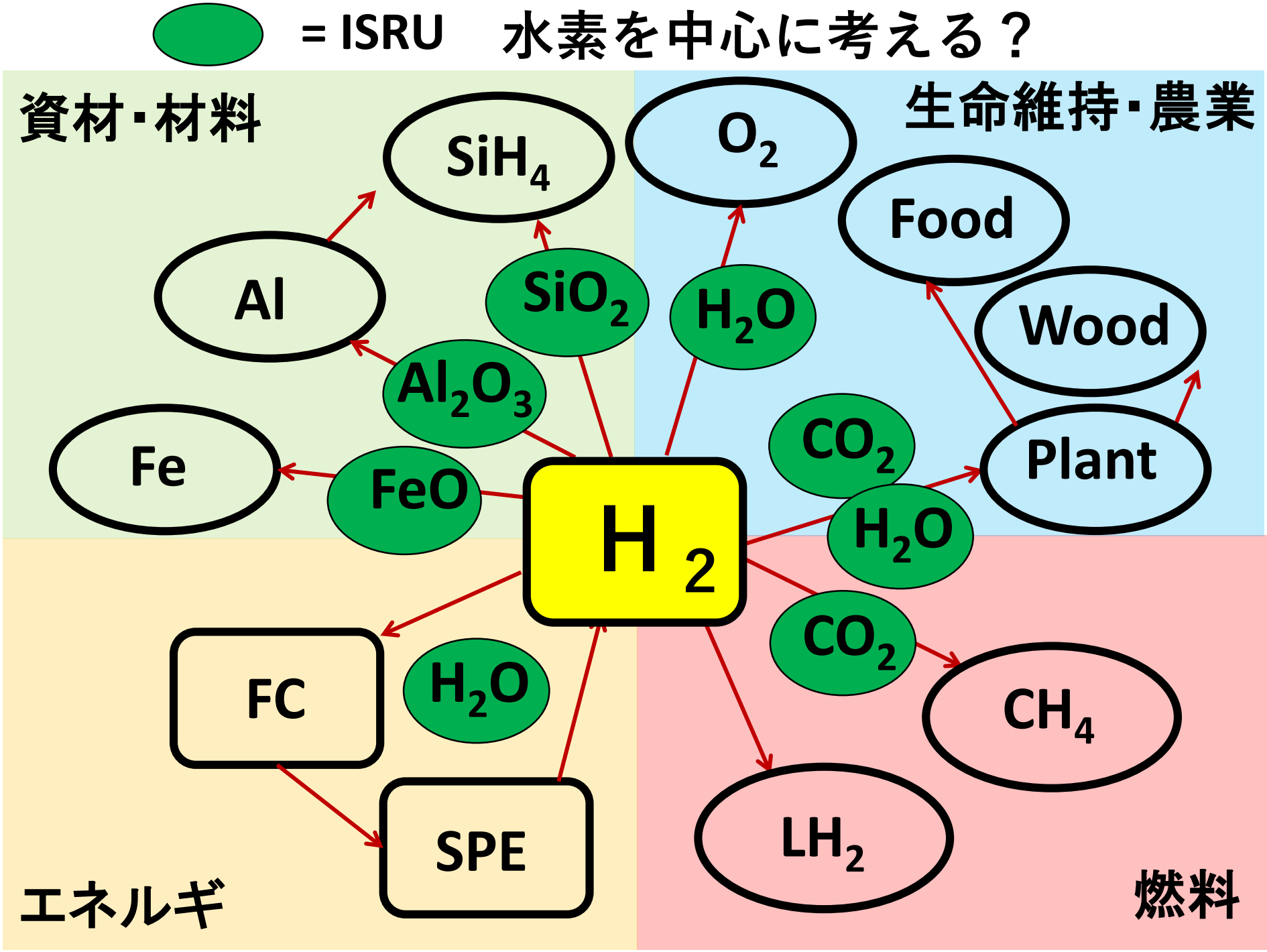


物質完全再生型

現地資源最大利用



SPE: Solid Polymer Electrolyte (水電解装置)
FC: Fuel Cell

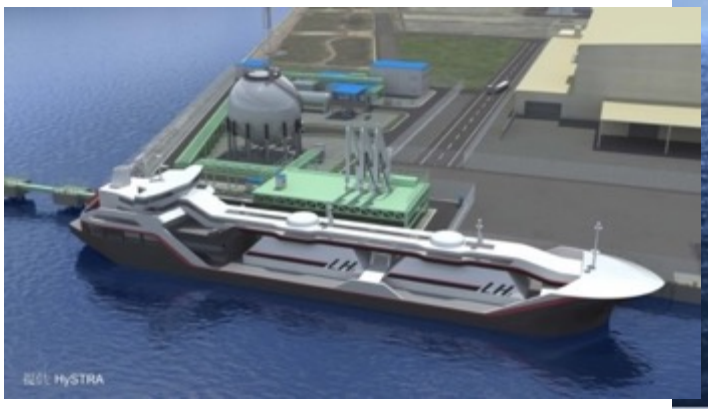

= ISRU
水素を中心に考える？
資材･材料
生命維持･農業
エネルギ
燃料
SiH4
O2
Food
Al
SiO2
H2O
Wood
Al2O3
Fe
FeO
H 2
CO2
Plant
H2O
FC
H2O
CO2
CH4
SPE
LH2

地上における水素エネルギ社会の構築

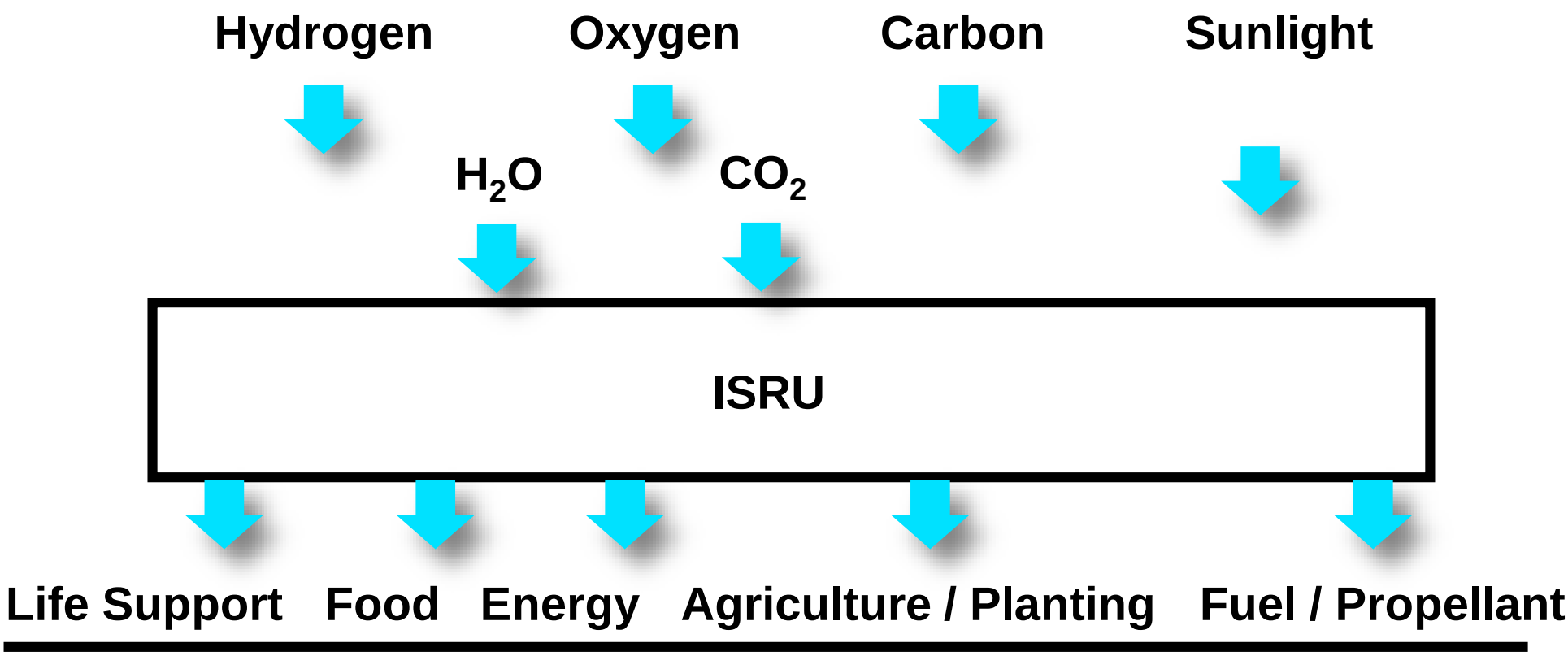
Distribution and filling

Use of hydrogen and related technology

Generation of hydrogen from unlimited and renewable sources



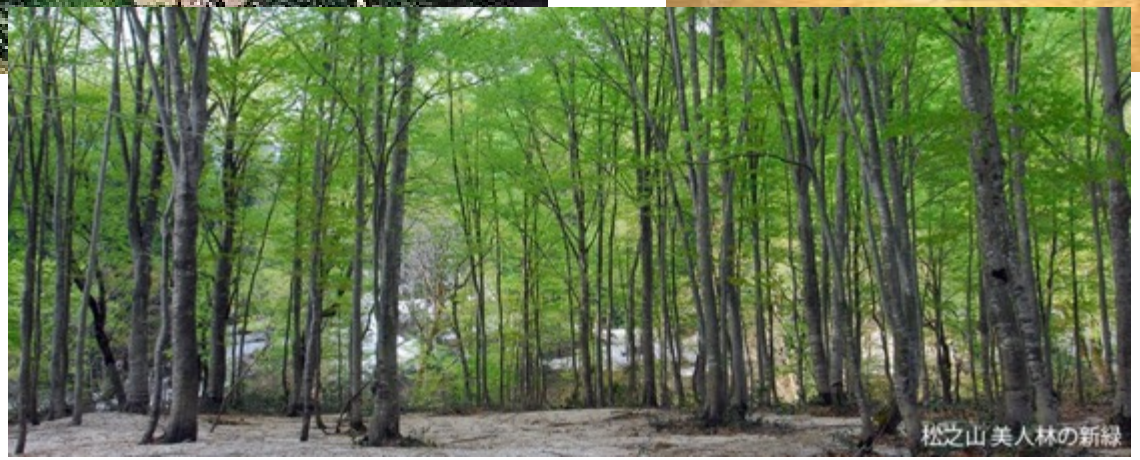
Necessary Stuff & Missing Stuff on the Moon & Mars



Hydrogen / H_2O
Possibly found in the South Pole

Carbon / CO_2 from Earth ?
Residual Propellant of Landers / Human Waste / Abandoned Stuff ….

光合成による炭素の固定
月・火星に森林を栽培



40 Ceder trees / person needed for producing O2 by Photosynthesis

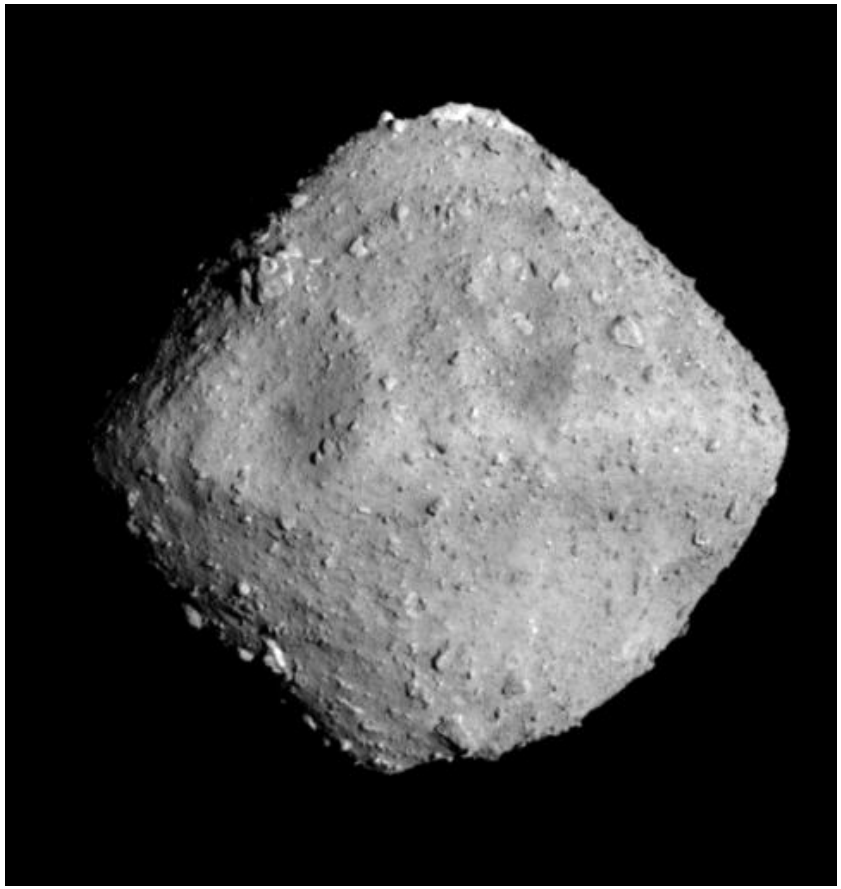
Necessary Carbon =

Growing Ceder trees for human breathing = 3160 kg / person

Human Breathing = 96 kg / year / person

月では炭素をどう調達するか

C-type (Carbonaceous) Asteroid to be a carbon source ?
to be carried & impacted to the Lunar Surface ?



Ryugu : a C-type Asteroid
Hayabusa2 is now visiting
ISAS/JAXA

Total Number of Near Earth Asteroid: 18937
C-type (Carbonaceous) Asteroid: ~50
Comets: 107

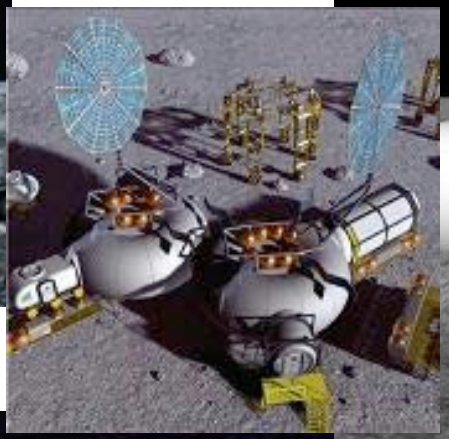
C-concentration of Carbonaceous Chondrite = 2-3%: ISAS Hayabusa2 team will make sure by Sample Return & Analysis

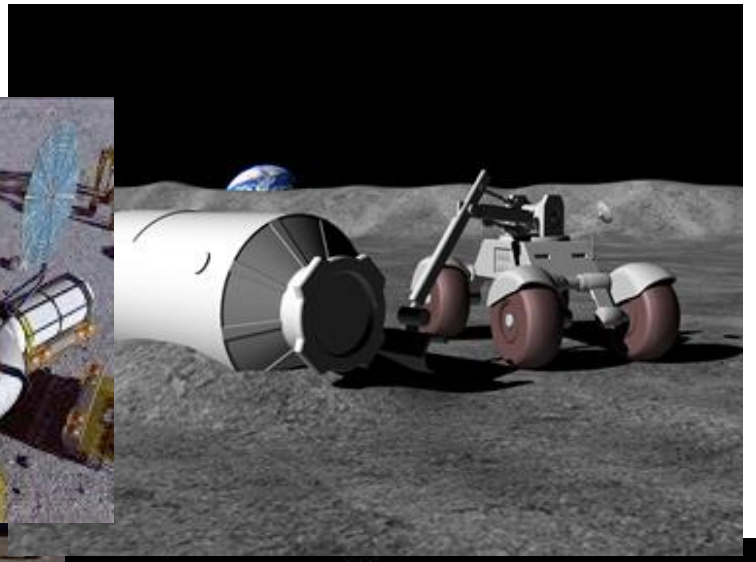
Ryugu	**Volume**	**0.38km^3**
	Average density	**1.2**
	Mass	**456×10^6 ton**

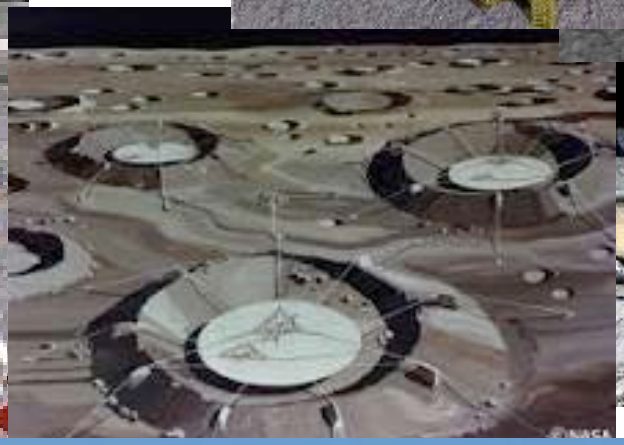
Total Carbon on Ryugu： 10 million ton
(assuming ～ 2% fraction)

Internal Asteroidal boc
Rubble pile ?? -----
easy to remove &
carry small portion ?

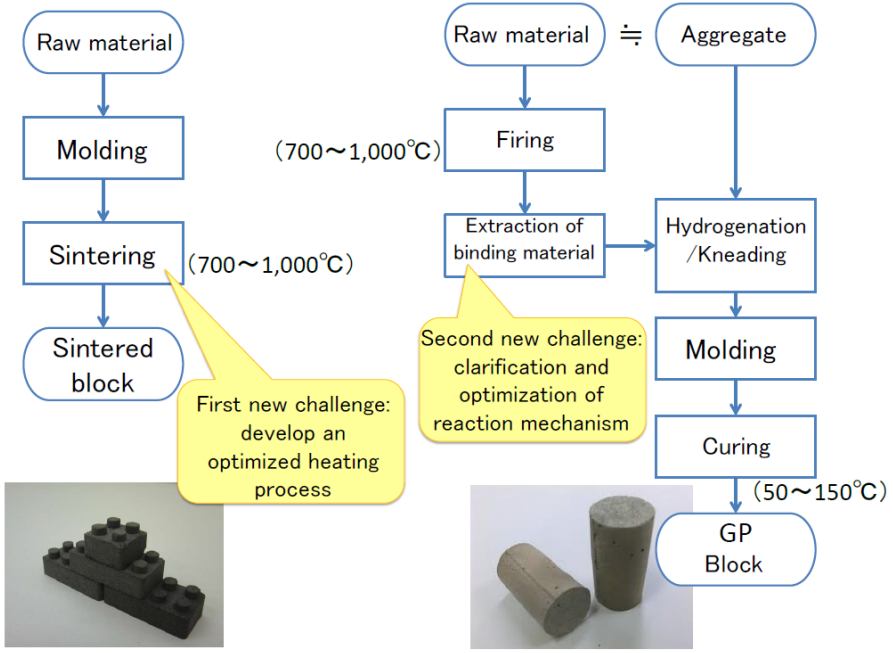
月面における基地建設

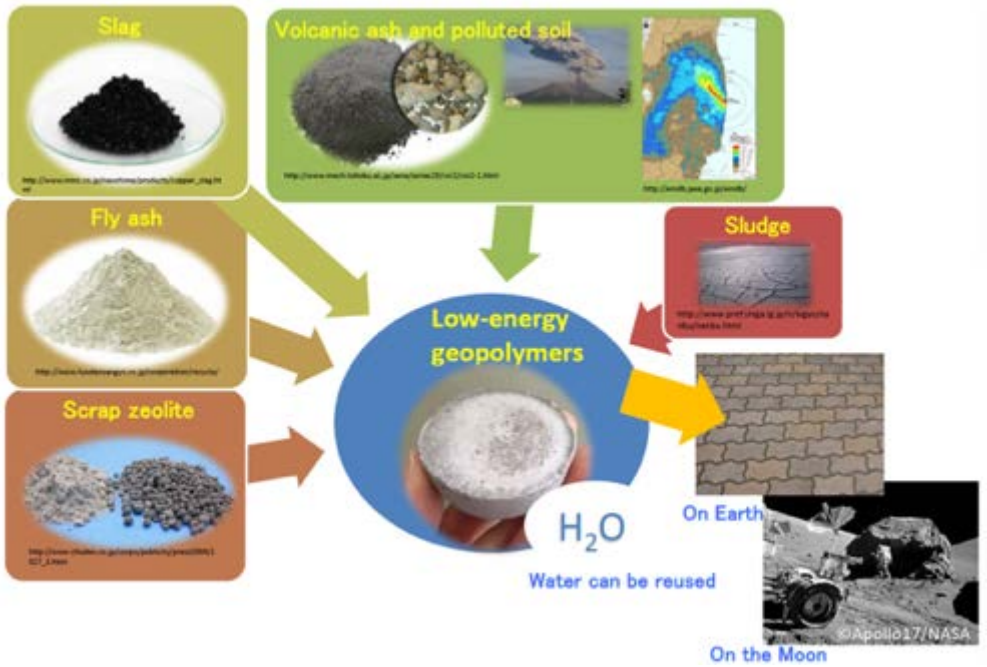




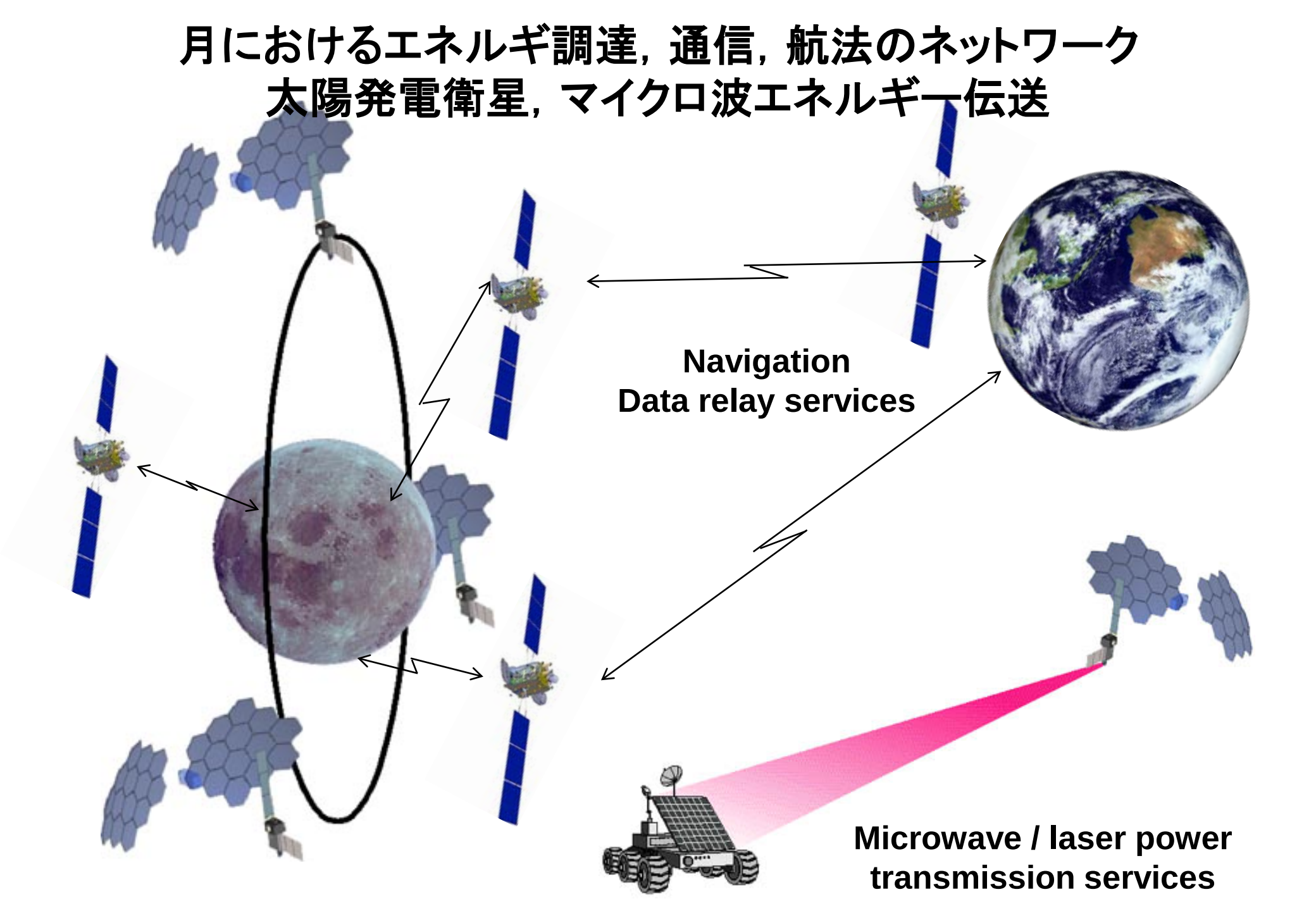


月のレゴリスを建設資材に

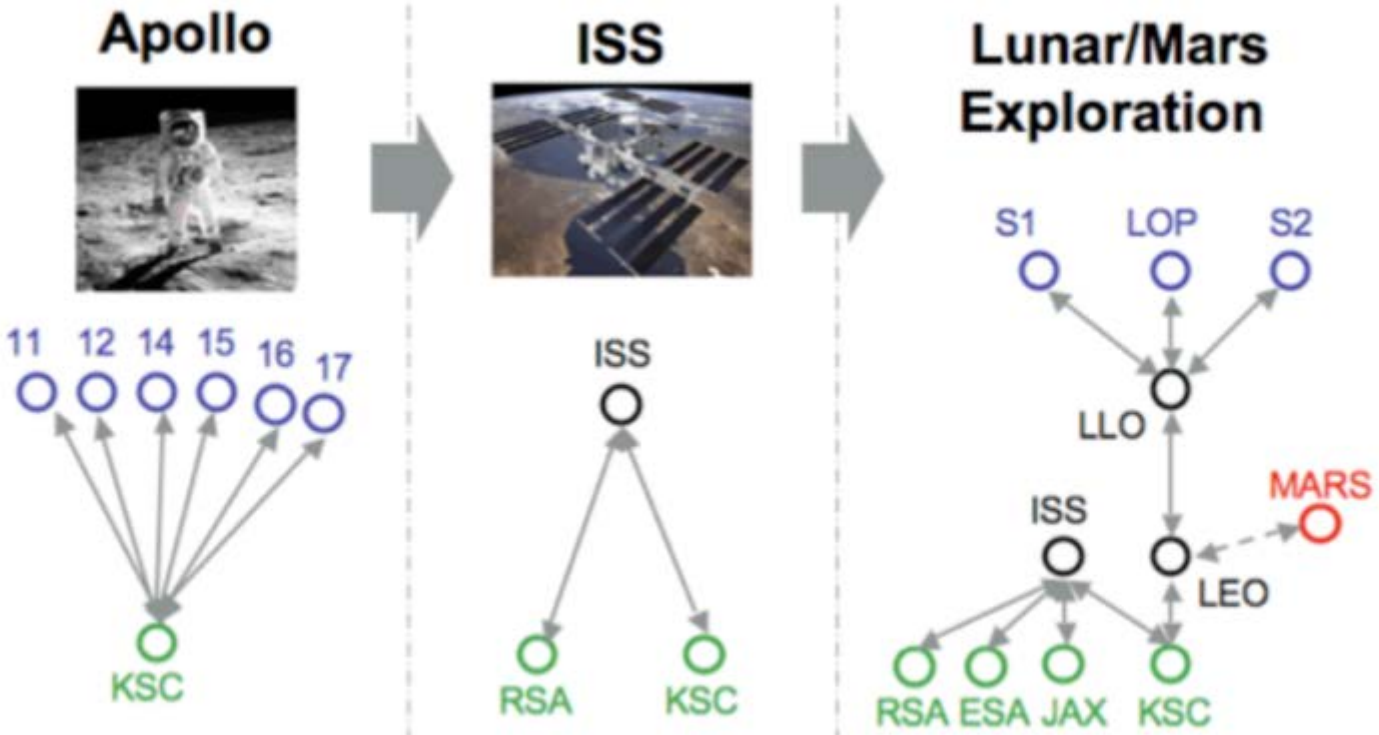




月におけるエネルギ調達，通信，航法のネットワーク
太陽発電衛星，マイクロ波エネルギー伝送



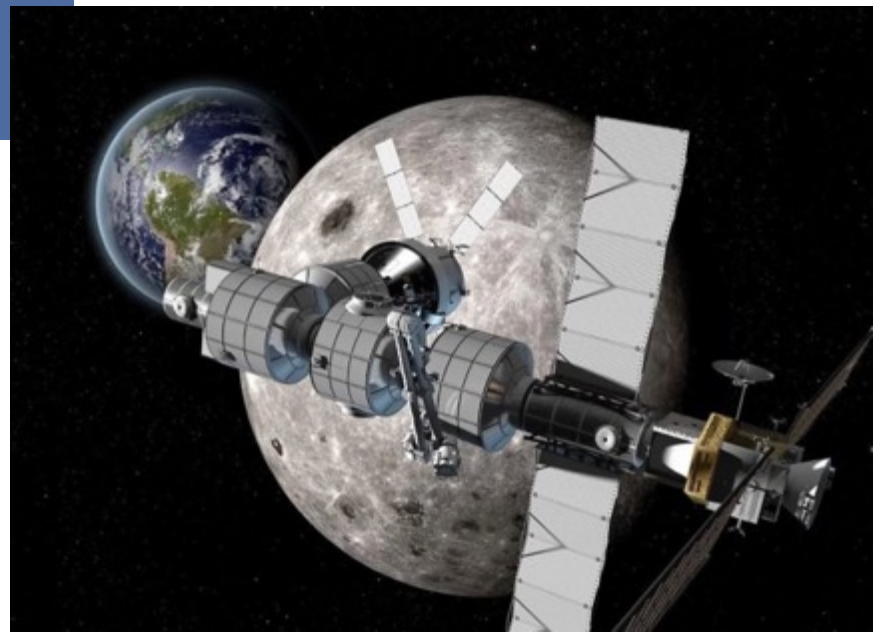
単発ミッションと持続的滞在のためのサプライチェイン



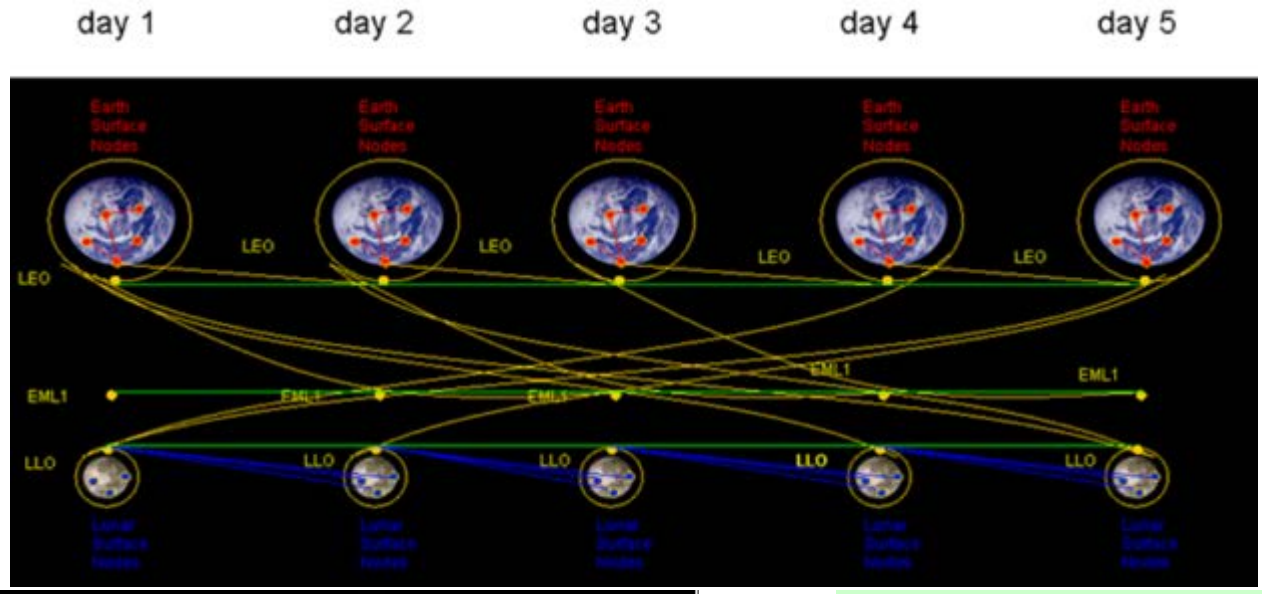
New System Architecture Needed in ・・・・

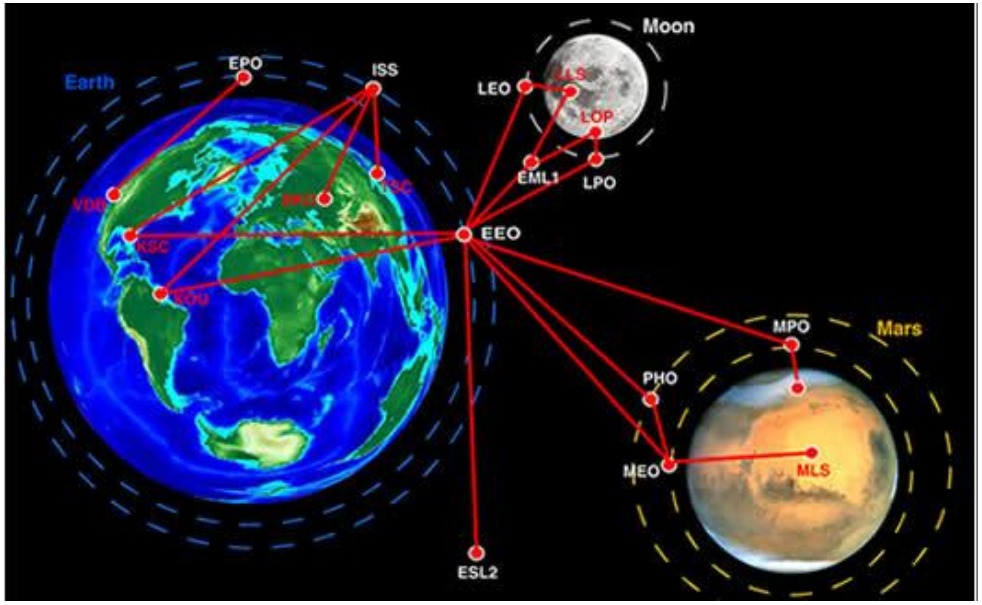
SPACE LOGISTICS ENGINEERING
SUPPLY CHAIN MANAGEMENT
IN-SITU RESOURCE UTILIZATION & POWER GENERATION
LONG DURATION HABITATION & TRAVEL
ORBITAL INFRASTRUCTURE
・・・・・・

SLS, Orion and Lander
NASA Gateway に向けた輸送システム



地球ー月ー火星間でのトラフィックネットワーク





Sustainable Human Presence

↓

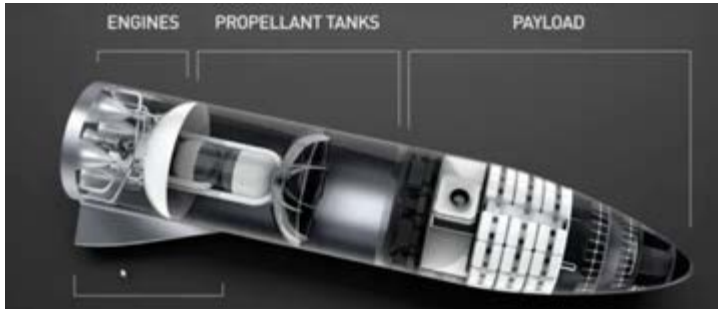
Space Logistics and Supply Chain Management

↓

New Architecture of Space Transportation

地上から地球周回軌道への輸送

高頻度大量輸送の航空機的システムの構築による２桁のコストダウン



民間主導の月火星探査・移住

Blue Origin / SpaceX

月・火星における持続的な社会の構築のために必要なこと

社会の規模，生み出す価値，地球依存を減らすための仕掛け

深宇宙，月，火星上での持続的滞在のシステムアーキテクチャー

可能な限り現地での資源エネルギ調達・・H，O，Cの調達

サバイバビリティオリエンテドなシステム:再構築，修理や再製造の仕掛け

サプライチェインのマネジメント，スペースロジスティックス，低コストな輸送システム