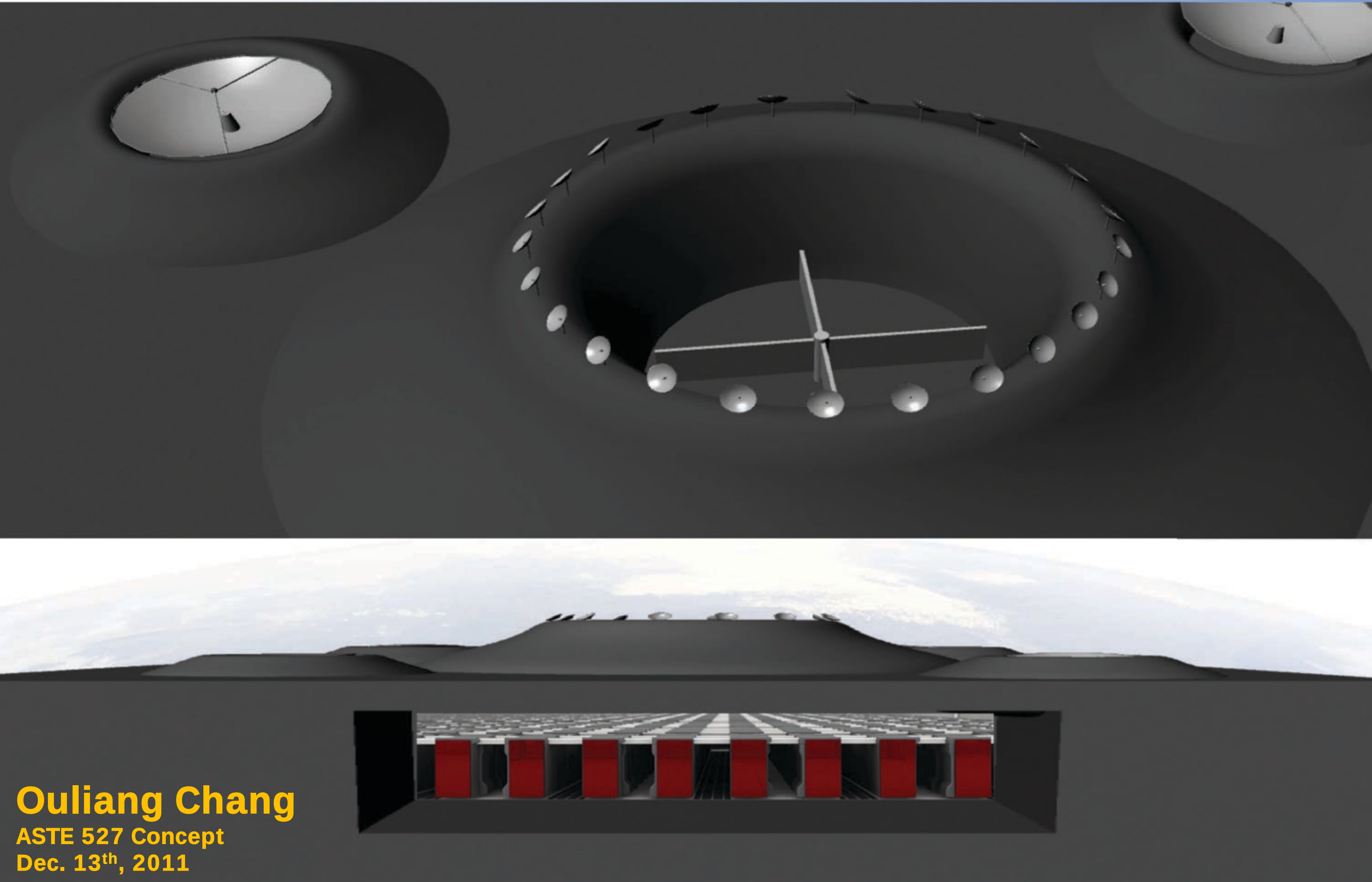
Lunar Supercomputer Complex

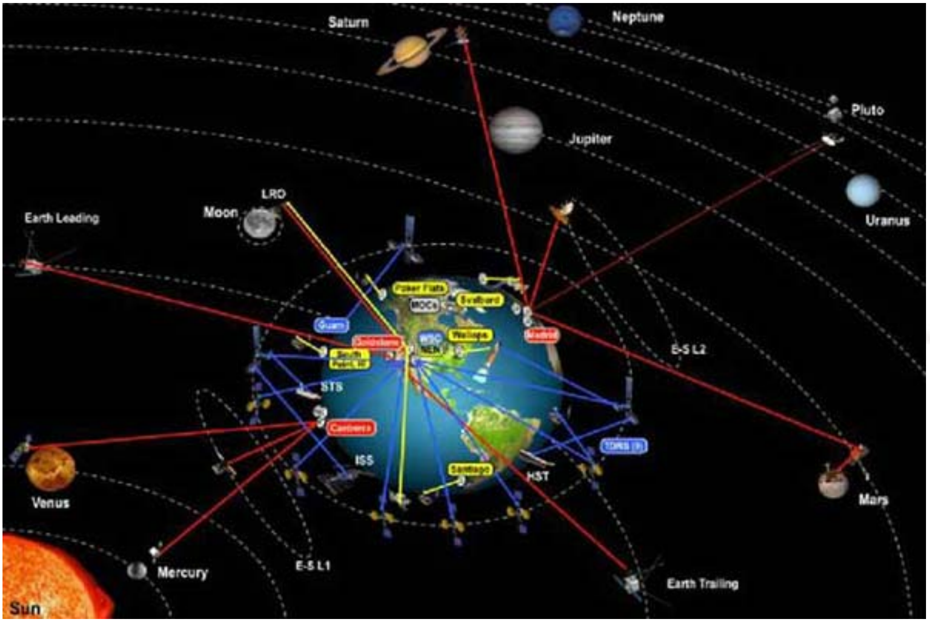
21st Century Deep Space Network Evolution Prospects

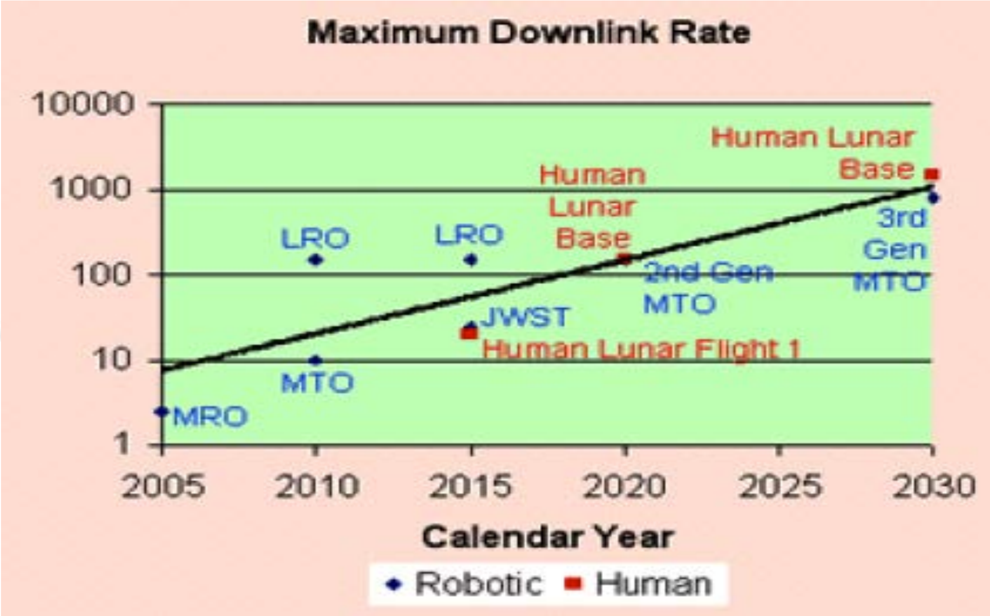


Ouliang Chang
ASTE 527 Concept
Dec. 13th, 2011

Background

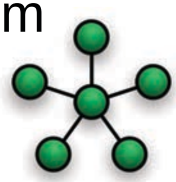
- More and more missions are flying simultaneously and need to be supported



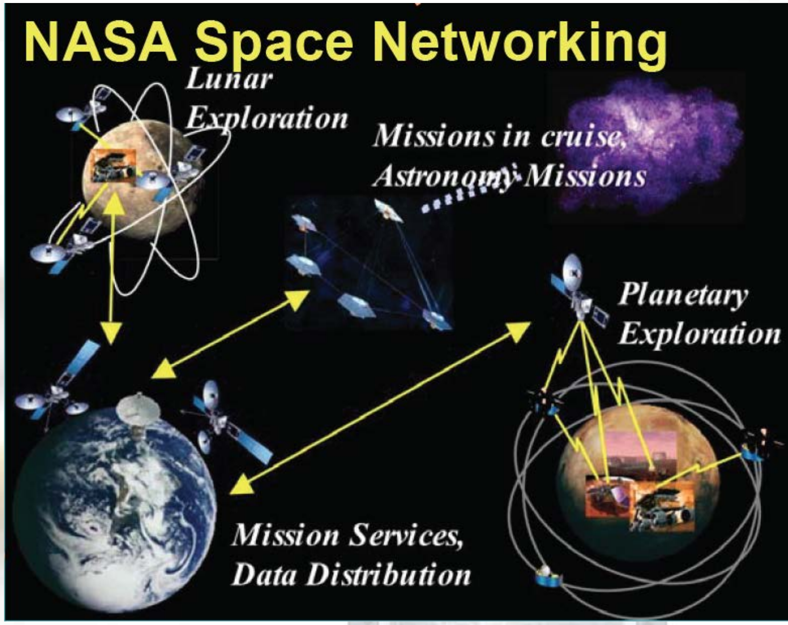


Challenges

- Require larger bandwidth communication / data-processing links to Earth
- Current DSN's overloaded bandwidth becomes an emerging problem
- Earth-centric-processing space network (star topology)
- Unreliable, less redundant, potential comm. traffic jam

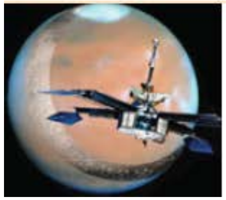


by 2015 ?



Challenges

- Lunar industrial & settlement development: first phase (tele-) robotic
- Slow communication & feedback control
- Some operations may require real time fast computing capability
- Bottleneck for advanced technology employment

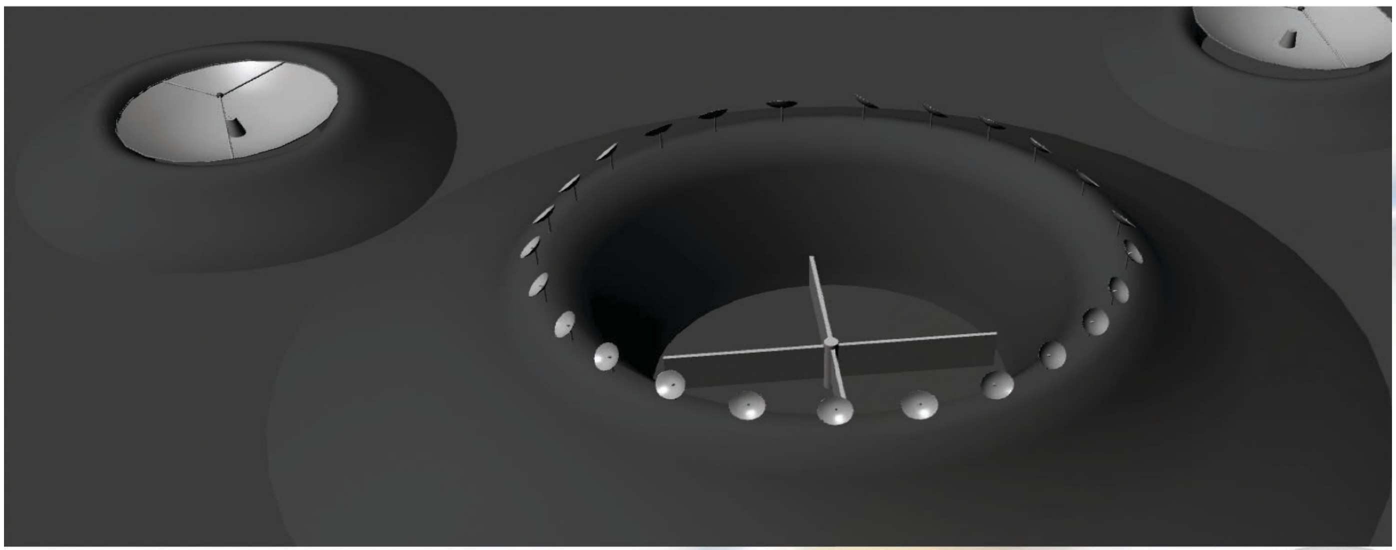


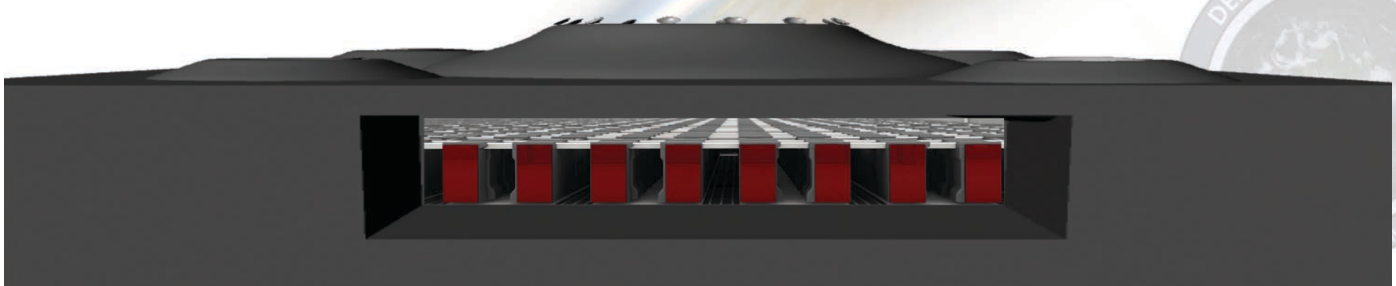
Preliminary solar system reconn. via brief flybys. → Detailed Orbital Remote Sensing.

Proposal

Build a lunar supercomputer complex, including:

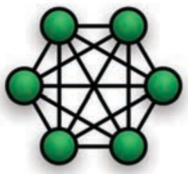
- Communication antennae arrays
- Supercomputing and data storage facility
- Auxiliary systems: power, shielding and cooling, etc.

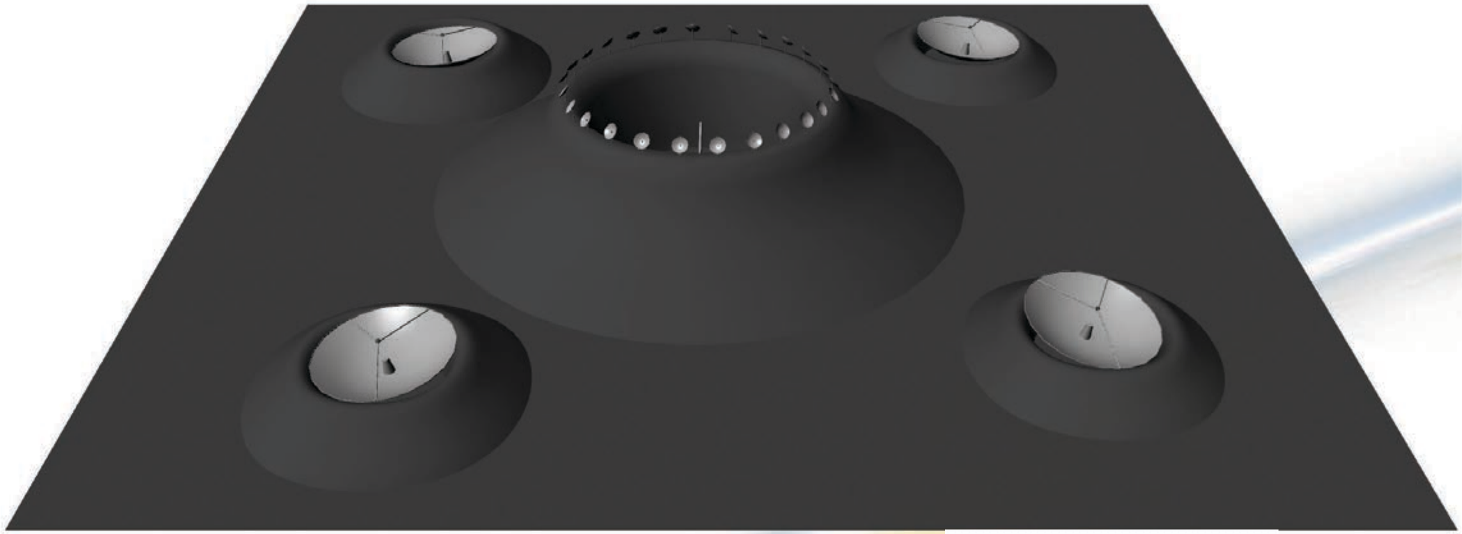


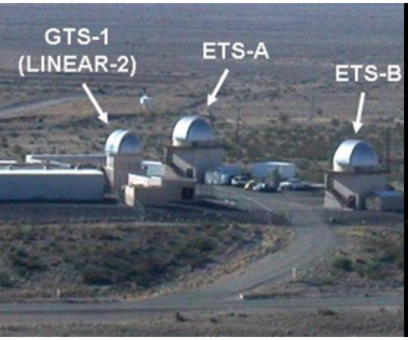


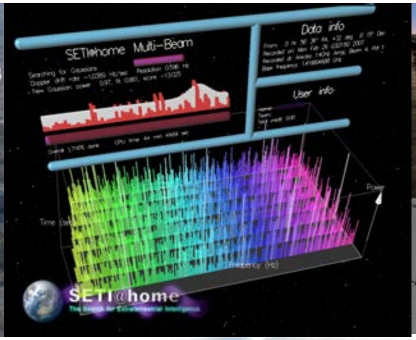
Rationale

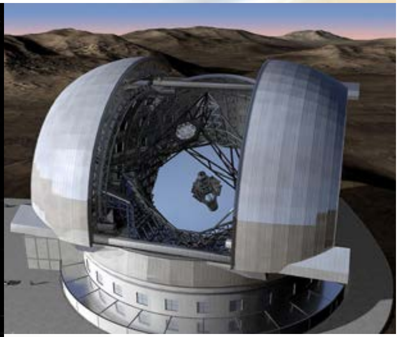
- A highly reliable, broader bandwidth lunar DSN center in cislunar space regimes as well as for deep space missions
- Contributing to build a faster, more redundant space network
- Supercomputing and data processing support for future lunar activities

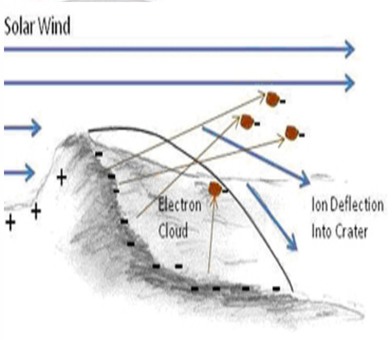






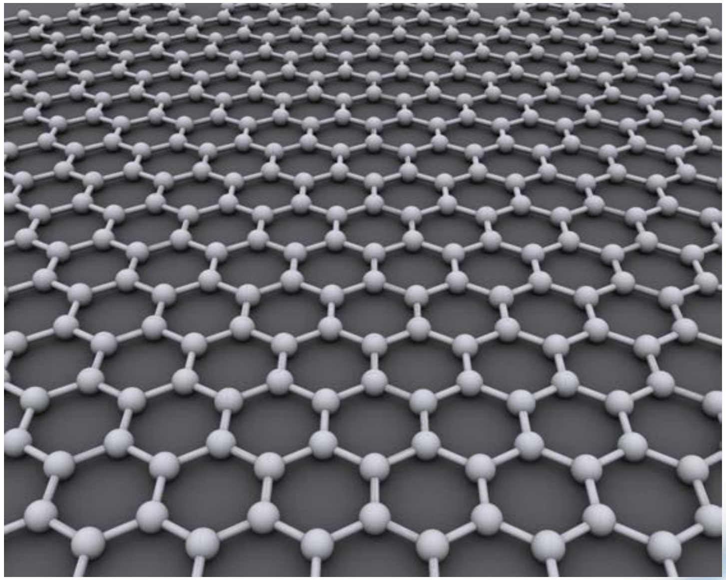






Assumptions

- Time frame: the next 10 ~ 15 years.
- Some lunar industrial development and architectures already took place
- High temperature superconductor materials (40K - 60K)
- Graphene and related composite material
- Substantial water available deeply underneath the lunar regolith ?



Location

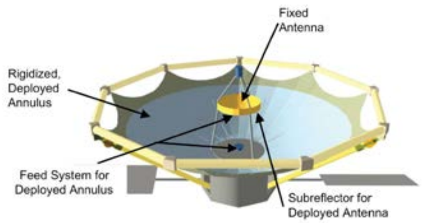
- Far side, close to polar region
- Continuous sunshine on the rim of crater
- Constant deep shadow area in the crater
- Potential lunar water ice underneath the regolith

Cross section of a Lunar Polar Crater

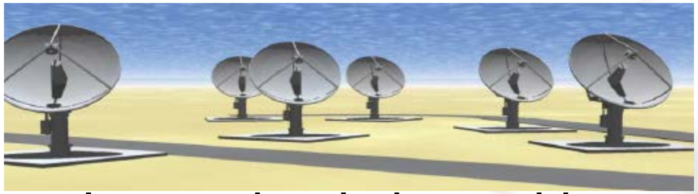
Complex Subsystems

Communication antennae

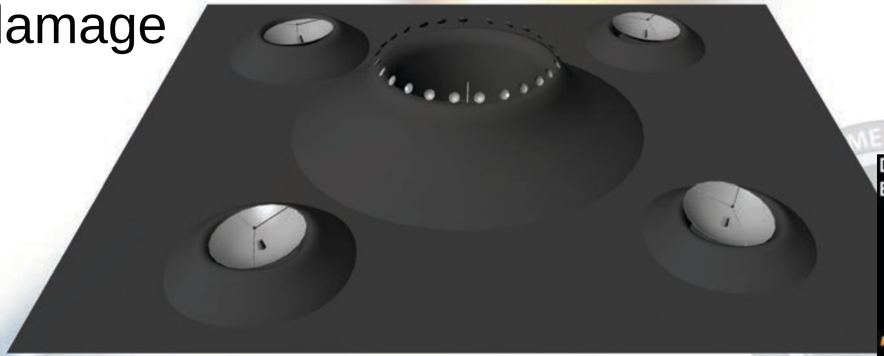
- Mission links: multiple vastly-large inflatable antennae (3~5 km) made from graphene membrane composite



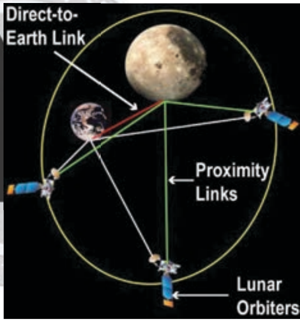
- Local/earth links: large arrays of small steerable antennas on the rim of crater



- If asteroid impact early warning is issued by supercomputer system, antennae graphene membrane could be rolled up and folded for stowing in a controlled manner to avoid damage



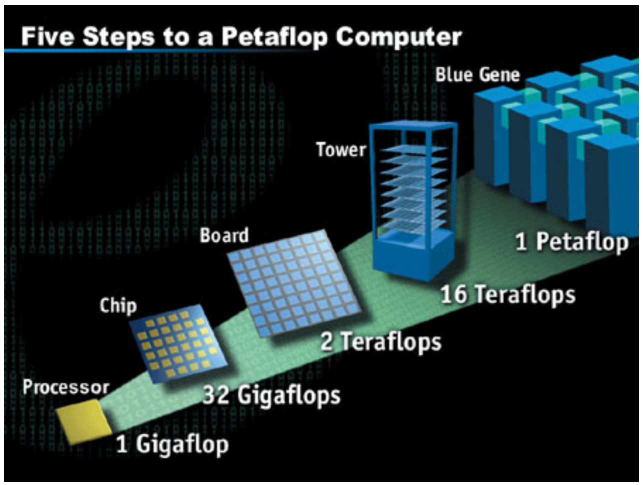
- Data relay via lunar orbiter satellites, besides direct-to-earth links

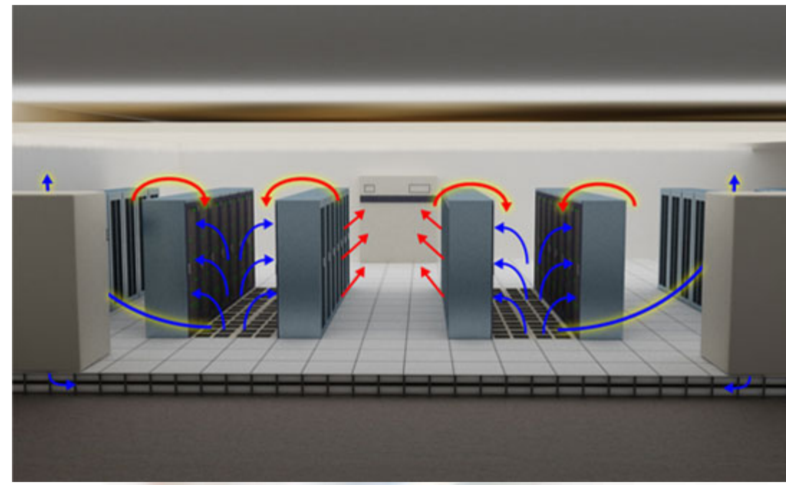


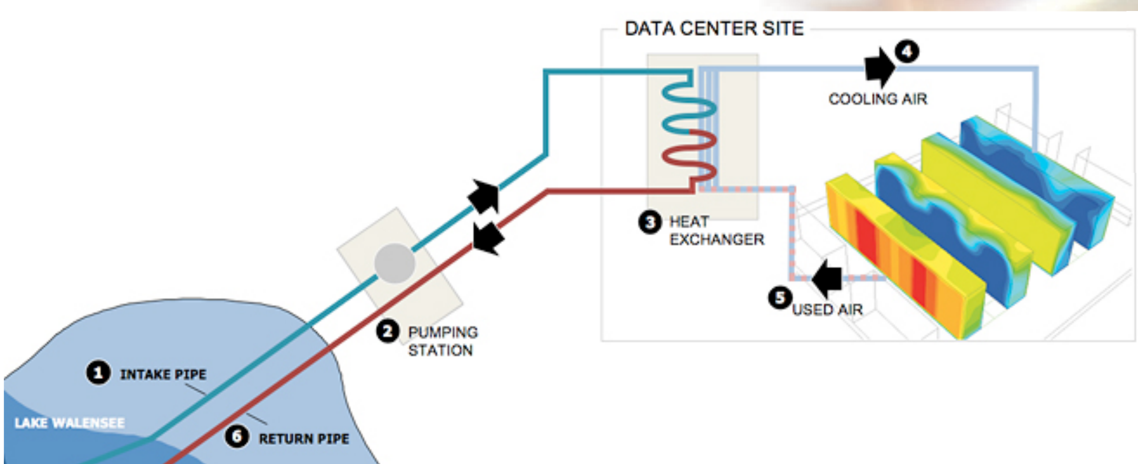
Complex Subsystems

Supercomputer architecture

- Hierarchy; Combine some power together to become great one







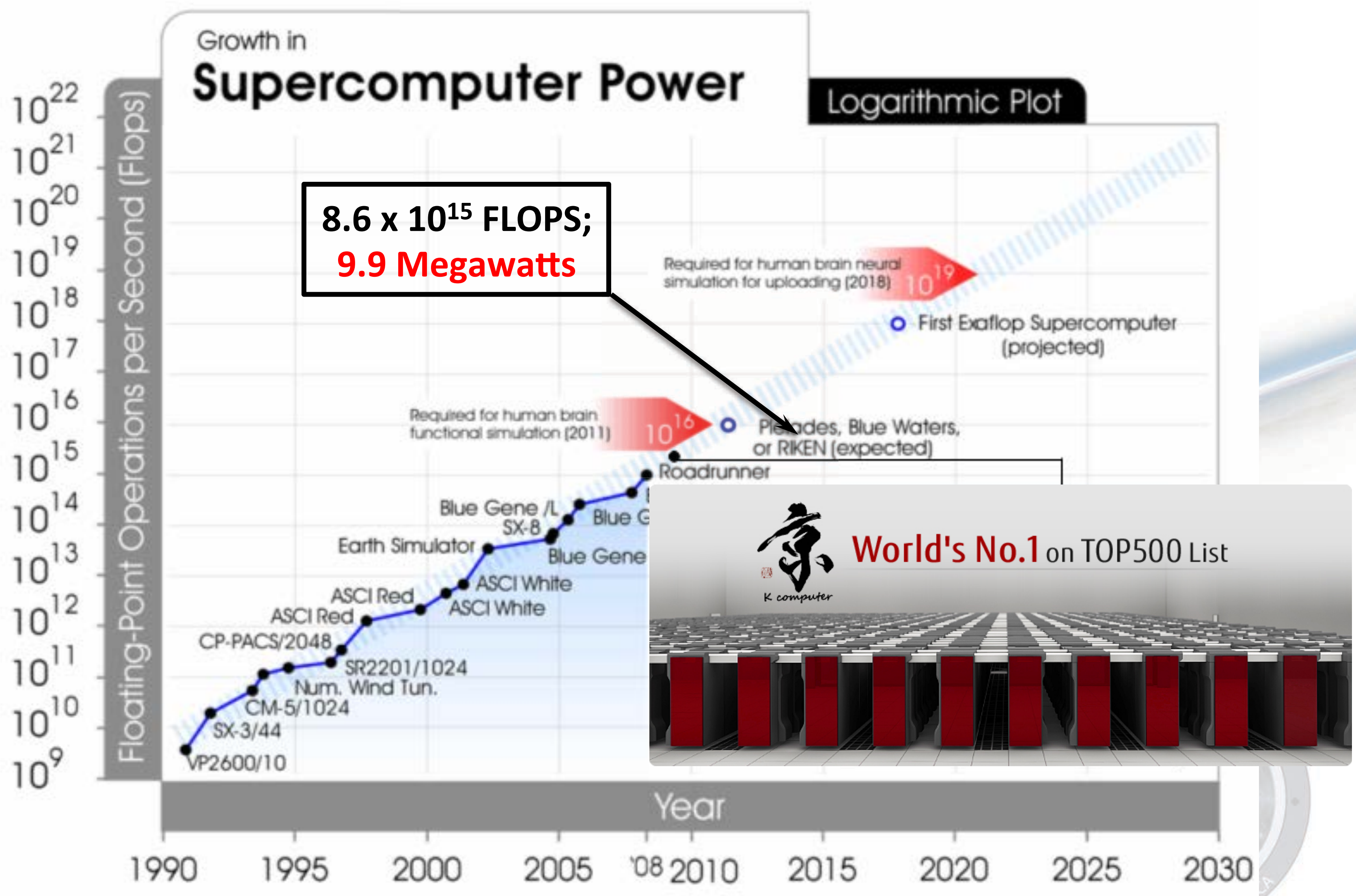
Complex Subsystems

Supercomputer comparison

	Ranking 06/2011	Processing speed (teraflops)	Cores	Power (KW)	Space	Storage	Dissipation heat	Cooling system
Desktop PC		0.05	2~6	0.15	15'' x 7" x 16"	~ Terabyte	925,200 joules or 880 BTUs per hour	Air cooling only
USC HPCC by Dell/Sun/IBM	63th	126.4	17,280	N/A	Each rack cabinet is 78''x24''x46''; Hundreds to thousands cabinets	Tens of Petabytes	Each node under full utilization dissipate 1,260,000 Joules or 1200BTUs per hour; Thousands to tens of thousands nodes	Primarily air cooling + HVAC
NASA Pleiades by SGI	7th	1,088	111,104	4,102				
China Tianhe-1 by NUDT	2nd	2,566	186,368	4,040				
Japan K Computer by Fujitsu	1st	8,162	548,352	9,899				
Germany SuperMUC by IBM in operation 2012		3,000	110,000	N/A				Micro-channel liquid cooling
Data Center Google Finland			1,000,000	50,000	68,680 square foot building	~ Exabyte	N/A	Seawater cooling

Complex Subsystems

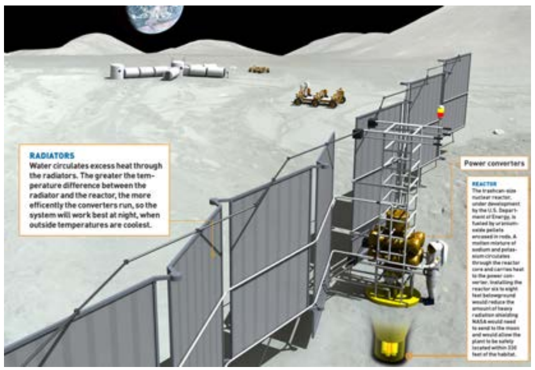
Supercomputer power projection

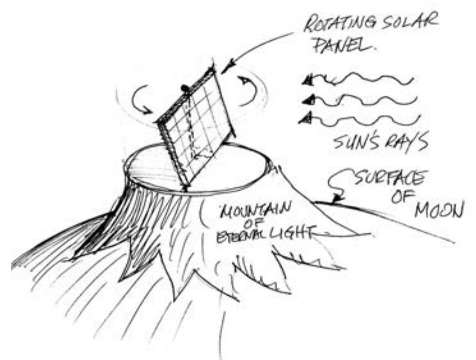


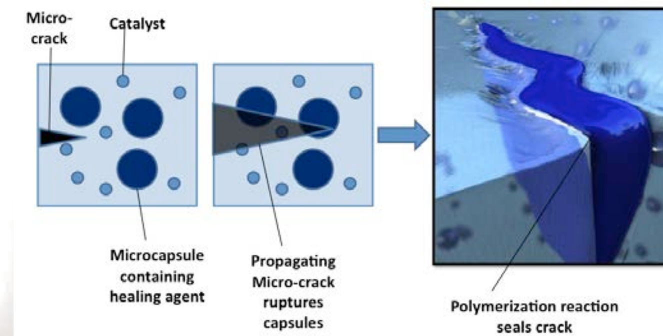
Complex Subsystems

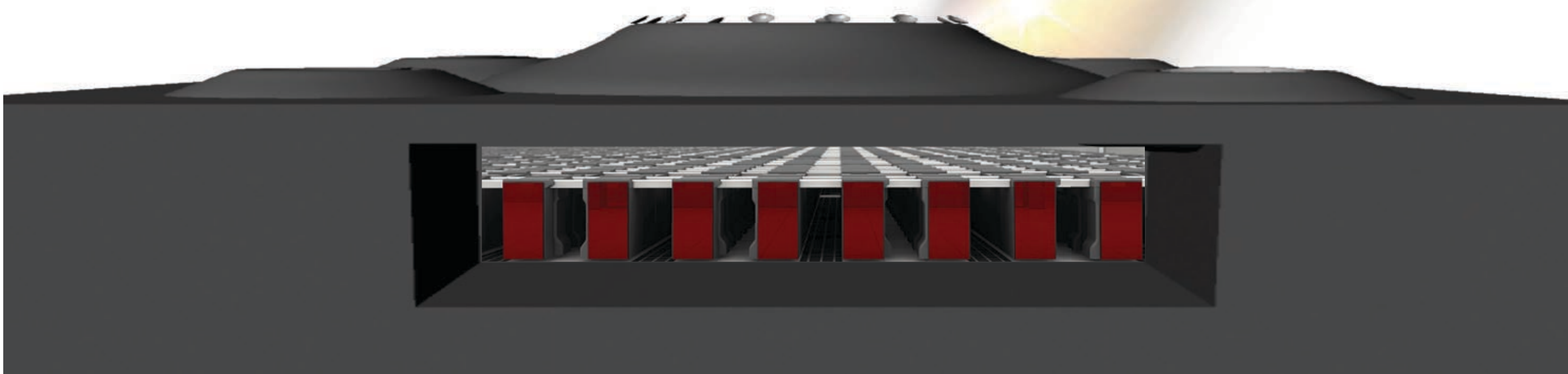
Auxiliary systems: power, shielding

- Need at least a 10 MWatt power generator
- Supercomputer is installed deeply underneath the lunar regolith to protect against the radiation environment







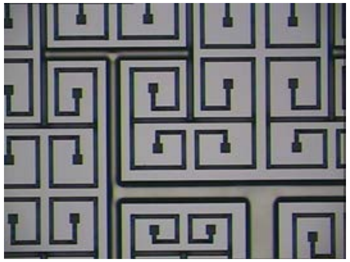


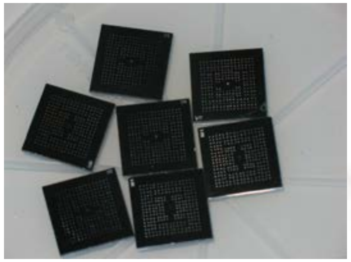
Complex Subsystems

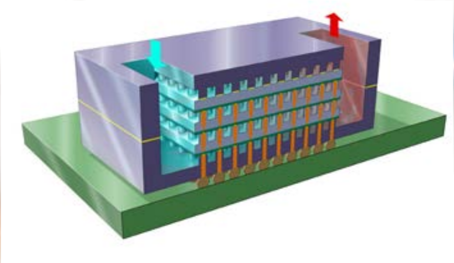
Auxiliary systems: cooling

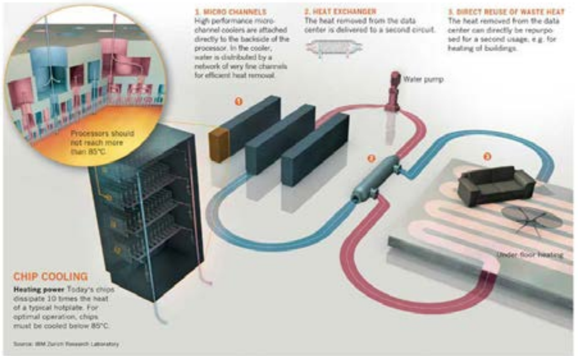
A hierarchical liquid cooling system

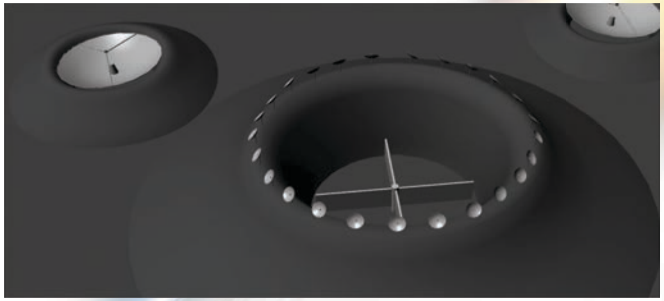
- Microscale liquid cooling on chip via micro-channels
- Macroscale heat exchange: heat reuse, super-large radiator fans and heat conduction by lunar ice
- Reduce waste heat through use of superconducting materials

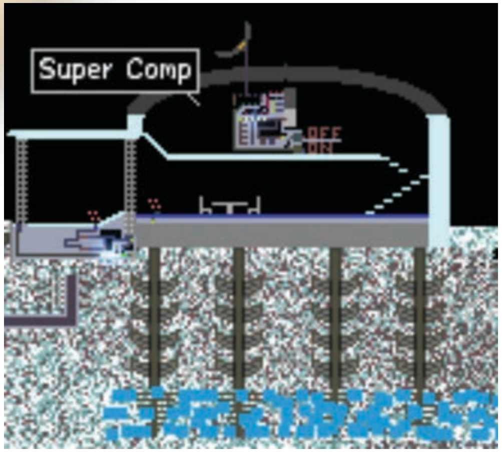








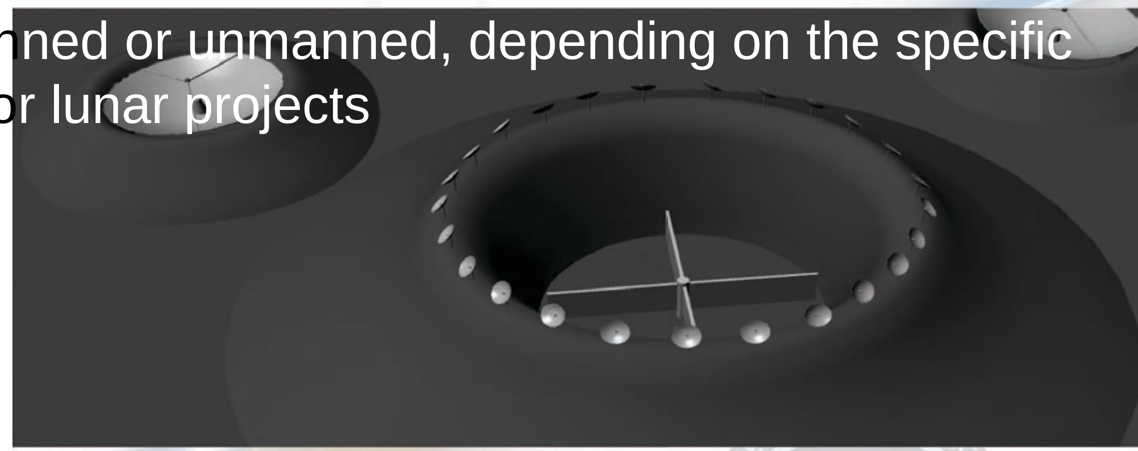


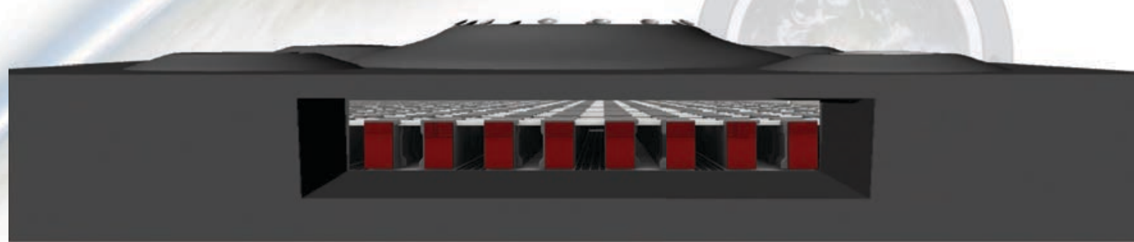


Evolution

A lunar based DSN center

- **Easily scalable in both antennae bandwidth and computing capability**
- Both large inflatable antennae and arrays of small steerable antennas are modular, expandable, low cost manufacturing and operations
- The supercomputing power is increased by adding banks over time, as other critical technologies are also evolved.
- In first phase it will be fully autonomous, evolved in stages.
- In long term, it could be manned or unmanned, depending on the specific purpose of mission support or lunar projects





Conclusions

Merits

- **A highly reliable, broader bandwidth lunar DSN center** for comm. and data processing in cislunar space regimes as well as for deep space missions
- Contributing to **a faster, more redundant and resilient space network**
- **Supercomputing and data processing support** for future lunar activities
- Better computer system reliability
- Abundant silicon dioxide supplies for electronics components

Challenges

- **Asteroid impact early detection system**: roll up and fold large inflatable antennae graphene membrane in a controlled manner to avoid damage
- **Radiation shielding**: install the supercomputer deeply under the regolith
- Power demand keeps increasing: nuclear power plant
- Cooling efficiency: super large radiator

Future Quantitative Study

- Radiation shielding thickness. How deep the supercomputer need to put below the regolith to obtain an acceptable radiation environment?
- Nuclear plant really necessary? Is solar power supply abundant for lunar supercomputer complex (20 MWatt) ?
- Calculate the cooling efficiency and the radiator plane size

Thanks for your attention !
Comments and Questions