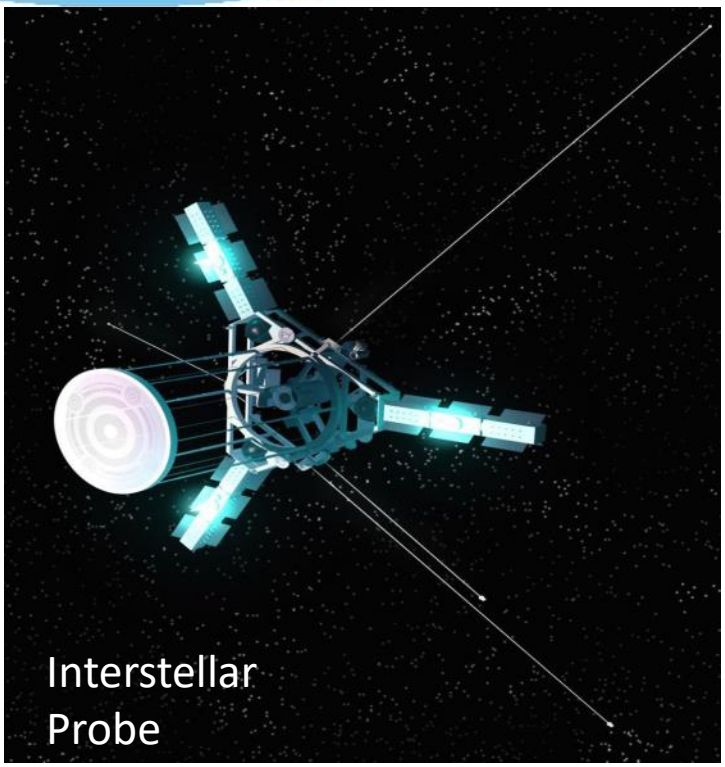
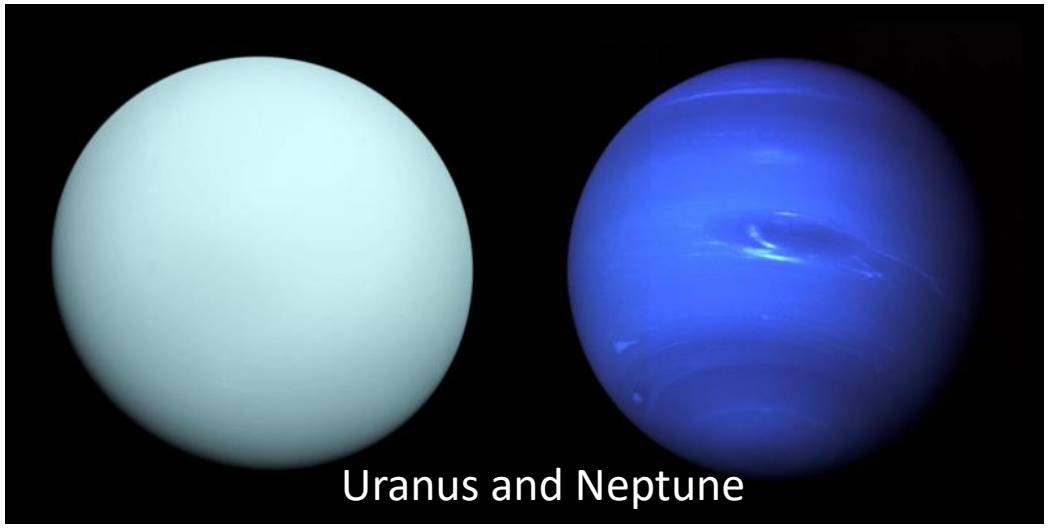
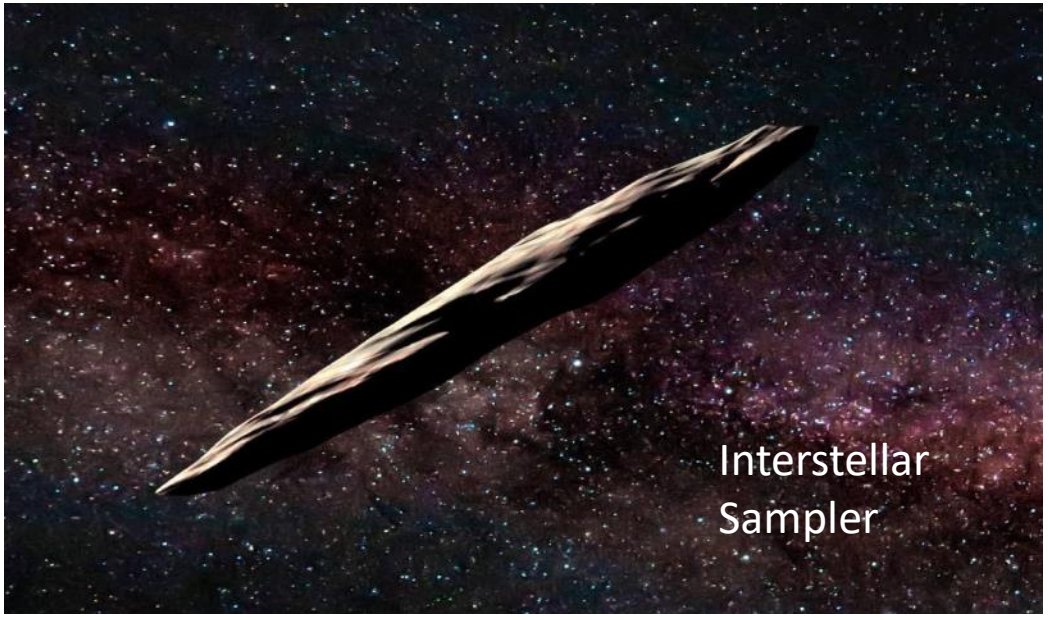
Space Technology and Instrumentation for the Second Half of the Twenty First Century: *Visions for 2050 – 2061*

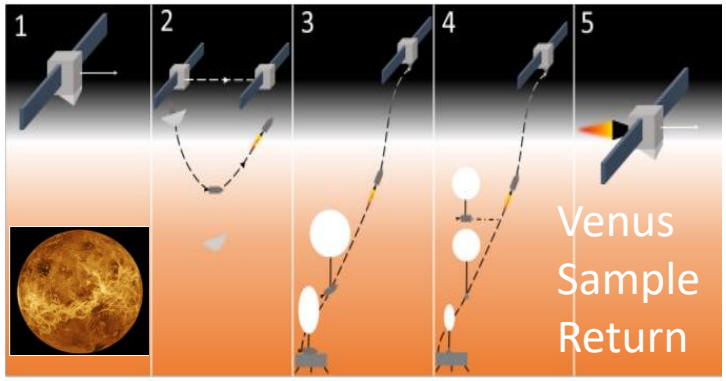
Manuel Grande,

The 2061 Game!









What we've heard at the meeting

- Need to match up science requirements with available technologies
- But mustn't forget that the science is primary

The devil is in the detail!

Evolution of exploration modes

- Remote sensing from Earth (surface or orbit), from Moon or L-point
- Interplanetary → interstellar (!) cruise
- Planetary Flyby
- Planetary or Satellite Orbiter
  - Single platform
  - Multi-platform/probes/penetrators
  - SmallSats
- Lander on planet or satellite surface, probes including balloons etc.
- Surface sample return + sample curation/analysis at Earth
- Long Range surface/atmospheric mobility
- Subsurface Explorers (Europa ?, Enceladus ?)
- Manned exploration ??? (e.g. “geologist return mission ”!)
- “Disruptive approaches”: Autonomy, New propulsion methods, In situ manufacture, Quad-copters….

H2050 Extreme Environments

High/Low temperature electronics

High/Low temperature operations

High pressure operations

Radiation tolerance

Highly corrosive environments

Unknowns in the environment…

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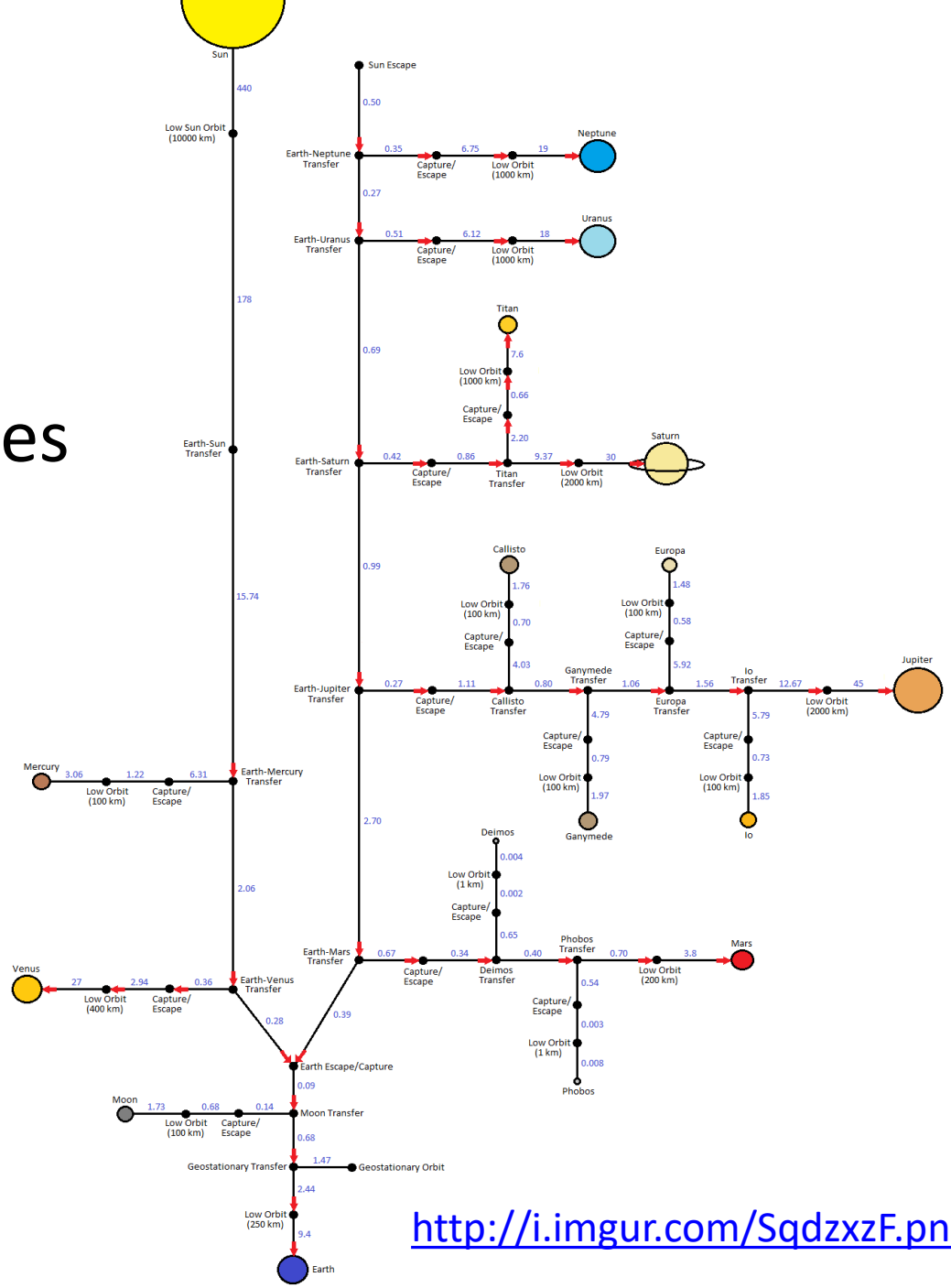
Need new power and propulsion technologies

Blue numbers - Delta-V in km/s required to go from one node to the next
Red arrow - Aerocapture/aerobraking possible, reducing one-way delta-v.

To find the delta-v required to go from the Earth to another planet/moon and/or back to the Earth, add up the delta-v's along the path.
All burns occur at a low periapsis for best use of the Oberth effect.

Landing and take-off delta-v might vary depending on thrust-to-weight ratio and aerodynamics.
Gravity assists can lower the required delta-v.
Transfer orbits are assumed to be Hohmann transfer orbits.
If using very low thrust propulsion such as ion engines, multiply required delta-v by about 1.5.

Delta-v's calculated using the Vis-Viva equation.



http://i.imgur.com/SqdzxzF.png

Enabling technologies

- **Power**: For outer Solar System Nuclear is a must!
- **Propulsion**: require paradigme changes to reach the full Delta V dimension of the proposals.
- **Communication**: radio or laser links, other techniques?
- **Machine Learning/Autonomy:**
- **Miniaturisation**
- **Resolution and sensitivity**
- **Silulation**
- **Disruptive technologies**

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Galileo Galilei

1. Identified key problems
2. Took existing tech and developed it
3. Used it to solve problem
4. Left both science and engineering enhanced
5. Was DISRUPTIVE

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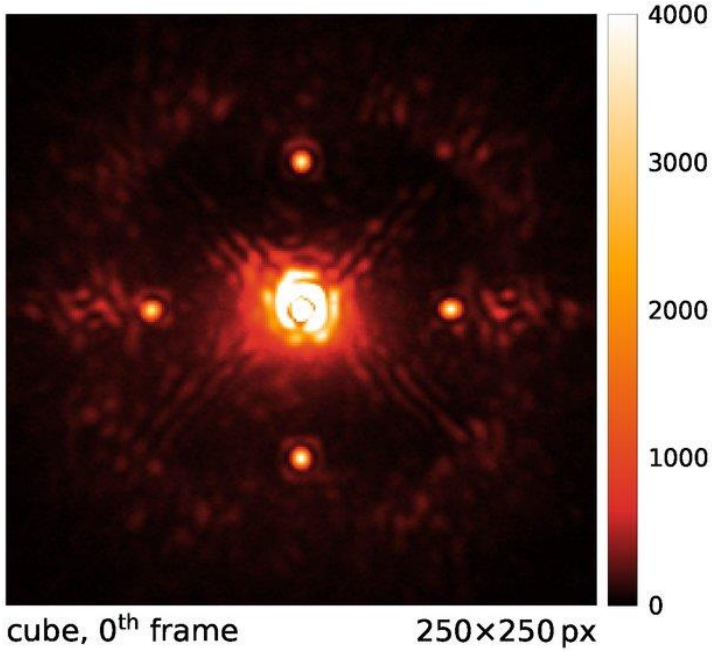
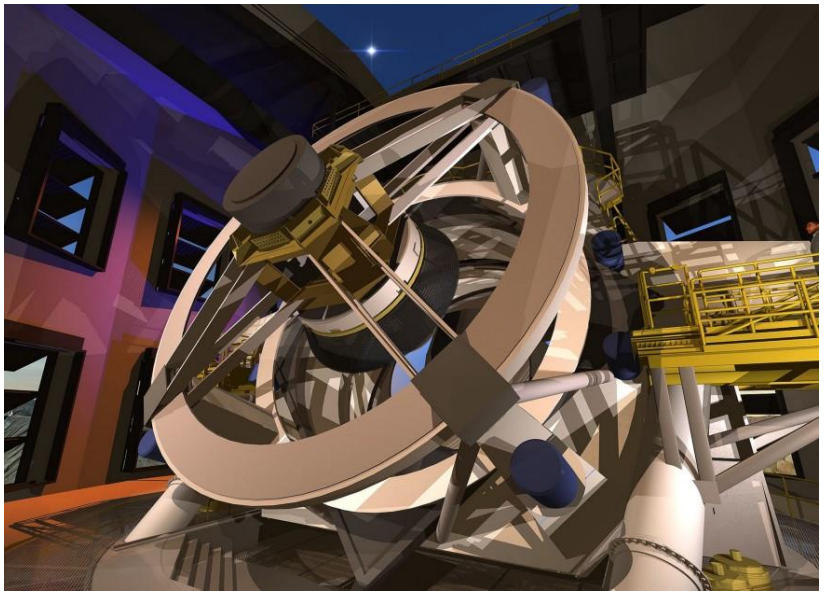
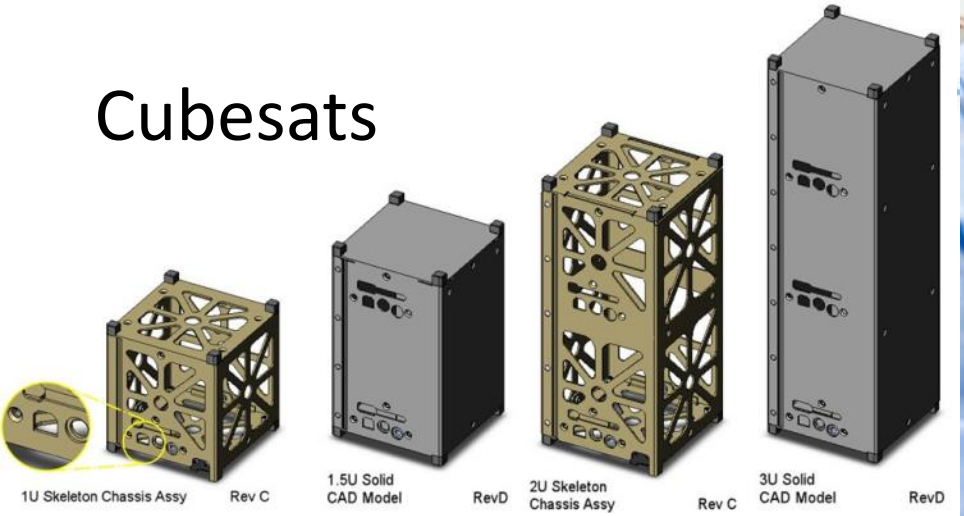
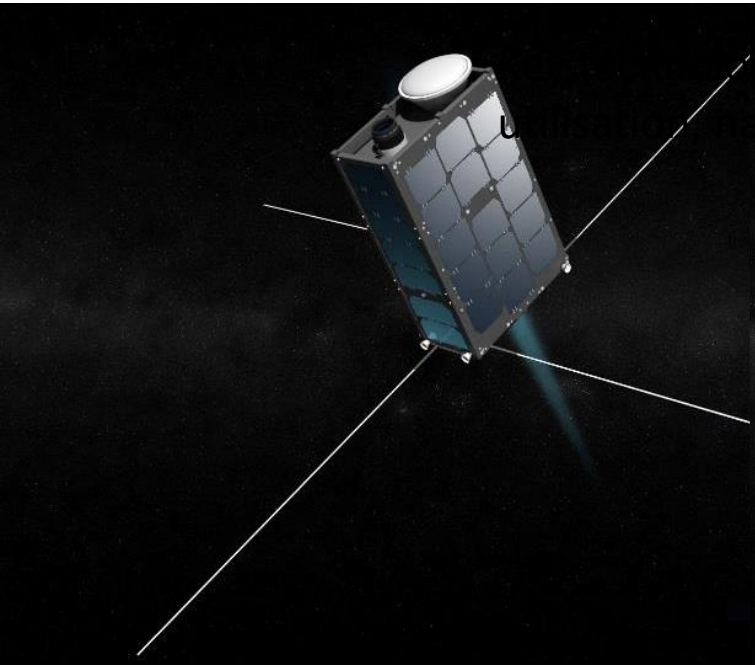
Machine Learning

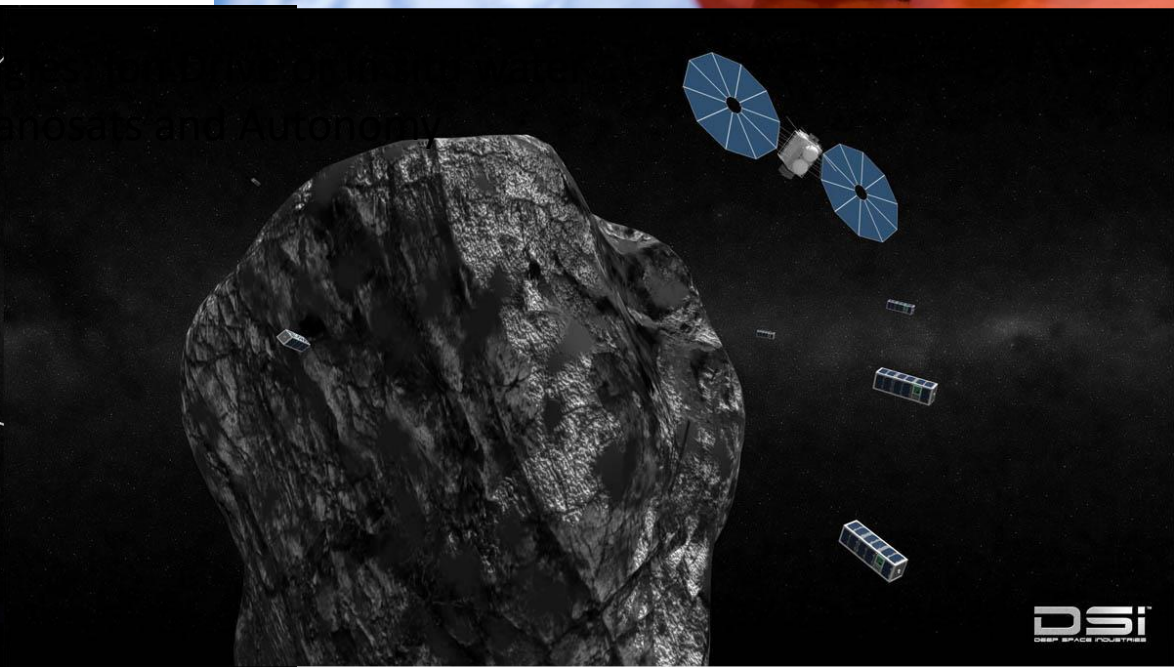




Cubesats







Key technologies: Ion Drive/In situ water utilisation, Nanosats, Autonomy

Luxembourg to support space mining

By Jonathan Amos
BBC Science Correspondent

3 February 2016 | Science & Environment

Near-Earth asteroids could be a source of high-value minerals

The Luxembourg government has signalled its intention to get behind the mining of asteroids in space.

It is going to support R&D in technologies that would make it possible and may even invest directly in some companies.

The Grand Duchy will also put in place a legal framework to give operators who are based in the country the confidence to go about their business.

Former European Space Agency boss Jean-Jacques Dordain is to be an adviser.

Metal Detectors and Archaeology

- A 1995 survey on metal detecting in England, by the Council for British Archaeology, concluded that of the hundreds of thousands of artefacts recovered by detectorists every year, only a fraction was being reported to museums.
- Three-quarters of archaeological field units had experienced raids of their excavations by detectorists, and between 1988 and 1995 illicit metal detector users damaged at least 188 scheduled ancient monuments
- Archaeology lives and breathes on context. Knowing exactly what comes from where, the soils in which it lies, and the relationships or associations between artefacts, features and other forms of evidence, is critical for interpreting archaeological remains
- In areas where archaeologists have been constructive, detectorists are much more confident in reporting their finds. And they have been recovering a lot of useful material - metal detected finds have, for instance, significantly contributed to understanding Iron Age coinage, and also the deposition of Bronze Age metal hoards in south-east England.
- For battlefield archaeology, carefully executed metal detecting surveys have revealed invaluable information. Conversely, unsystematic metal detecting, without reporting or recording, has denuded some battlefields of crucial evidence.

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The future will not be how we expect!

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Innovation and Foresight Oportunities:

- ***New Rockets/Launch systems***
- ***Nuclear generators (RTG etc) (inc solar sails)***
- ***Machine Learning***
- ***Autonomy and on-board data reduction***
- ***Low cost systems (incl. cubesats, penetrators)***
- ***Advanced fabrication techniques***
- ***Miniaturisation - Instrument on a chip***
- ***New Detector technologies***
- ***Large planetary telescopes…***
- ***Sample Return and Curation***
- ***Simulation***
- ***Laboratory experiments***