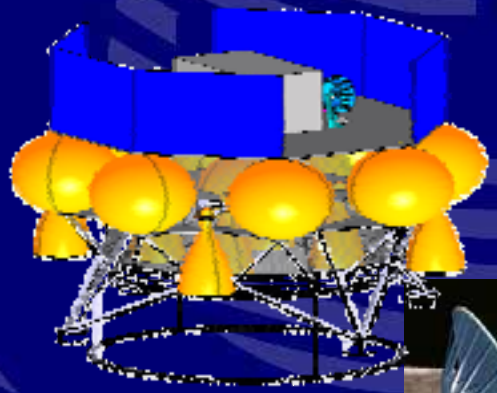
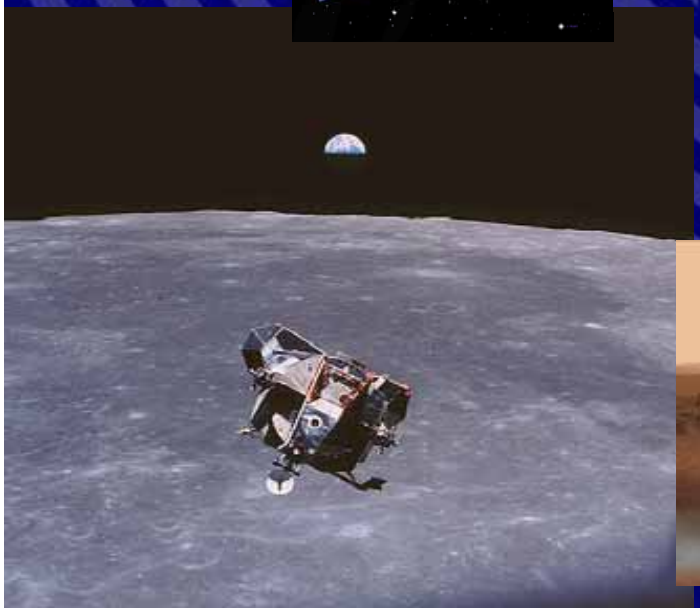
ILEWG REPORT ON SCIENCE AND EXPLORATION QUESTIONS :

Bernard H. FOING & ILEWG

Executive Director ILEWG





Global partnership between countries & agencies
ILEWG International Lunar Exploration Working Group

- Founded Beatenberg Int'l Conference1994, Hamburg 1995 (Charter)
- Sponsored and members appointed by agencies, with support by experts
- To develop an International Strategy for the Exploration of the Moon
- Forum and mechanism for communication and co-ordination
- To implement international co-operation and report to COSPAR

- **Website: http://sci.esa.int/ilewg**

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ILEWG Community events

- **ILEWG Int'l Conferences on Exploration & Utilisation of the Moon ICEUM**

  Beatenberg 94, Kyoto 96 , Moscow 98, ESTEC 2000, Hawaii Nov 2003, Udaipur Nov 04, Toronto Sept 05, Beijing Jul 2006, Sorrento Oct 07, ICEUM10/LEAG/SRR Port Canaveral 27-31 Oct 08

- **COSPAR: Washington 92, Hamburg 94, Nagoya 98, Warsaw 00, Houston 02, Paris 04, Beijing 06, Montreal 08, Bremen 10**
- **IAF/IAA: Houston 02, Bremen 03, Vancouver 04, Fukuoka 05, Valencia 06, Hyderabad 07, Glasgow 08, Daejong 09**
- **EGS/EGU lunar sessions: Hamburg 95, Vienna 97, Nice 98, The Hague 99, Nice 00 – 04, Vienna 05-06-07-08-09**

- **Website: http://sci.esa.int/ilewg**
- **Publications: 9 ICEUM proceedings + 7 books (Adv. Space Res.)**
- **Outreach: 18000 Google quotes**

ILEWG Executive Bureau

- ILEWG President (2006-2008): Prof Wu Ji
- Executive Director: Prof Bernard Foing (Past-President 1998-2000)
- Past-President (2004-2006) Prof Narendra Bhandari
- Vice-President (2006-2008) Dr Simonetta di Pippo
- Vice-President (2006-2008) Dr Michael Wargo
- Past Presidents: H. Mizutani, E. Galimov, M. Duke, C. Pieters
- Founding agencies (1994) : ASA, ASI, BNSC, CNES, DARA, ESA, ISAS, NASA, NASDA, RSA
- Joining agencies: ISRO (2000), CNSA (2002), CSA, DLR (2005)

ILEWG Task Groups (2000 -) & NASA et al. themes 2006

- **Science of, on and from the Moon -> Scientific Knowledge**
  Pursue scientific activities that address fundamental questions about the history of Earth, the solar system and the universe - and about our place in them.
- **Technologies and Resource Utilisation -> New Technologies**
  Test technologies, systems, flight operations and exploration techniques to reduce the risks and prepare future missions to Moon, Mars and beyond.
- **Human Aspects, and Lunar Bases -> Human Civilization**
  Extend human presence to the Moon to enable eventual settlement.
- **Collaborative Roadmap & Moon-Mars Synergies -> Global Partnerships**
  Challenging, shared and peaceful activity that unites nations
- **Social, Economical Commercial, Societal Aspects -> Economic Expansion**
  Expand Earth's economic sphere, and conduct activities with benefits to home
- **Education Public Outreach & Young Lunar Explorers -> Public Engagement**
  To engage the public and youth students, and help develop the high-tech workforce required to address the challenges of tomorrow.

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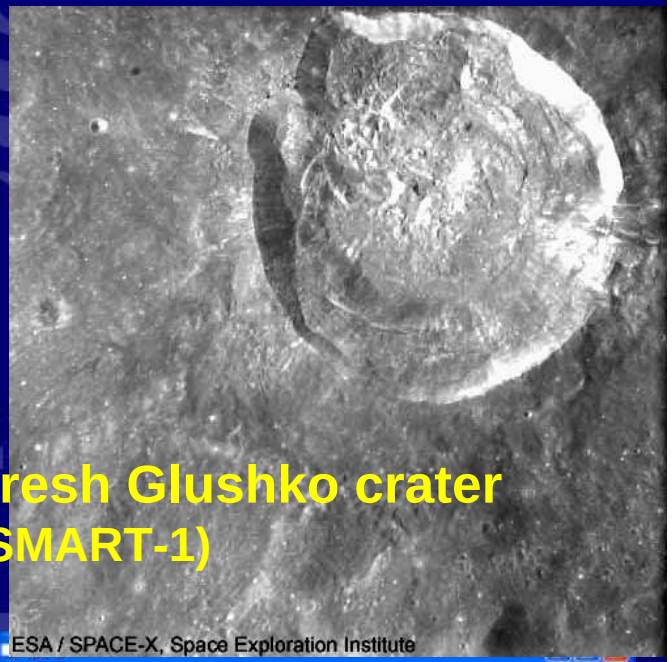
Science: What processes shape Earth-like rocky planets?

Moon laboratory for Comparative planetology

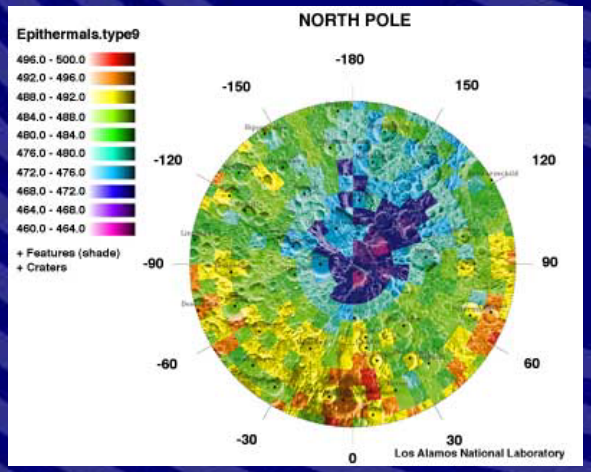
Geophysics & Geochemistry

cratering,
Impacts,
volcanism,
tectonics,
erosion,
volatiles

Hadley rille near Apollo 15 site (SMART-1)



Fresh Glushko crater (SMART-1)



Prospector H map

Cassini crater
Impacts and lava (SMART-1)

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Science of Moon: Formation and evolution of rocky planets

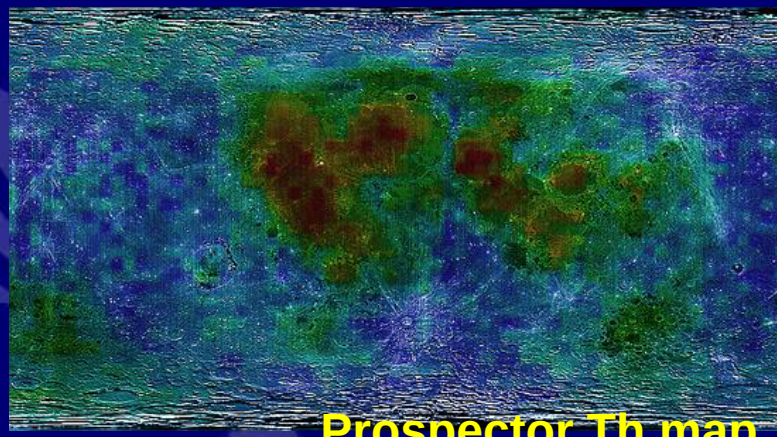
Origin of the Moon: geochemistry

Evolution of Earth/Moon system

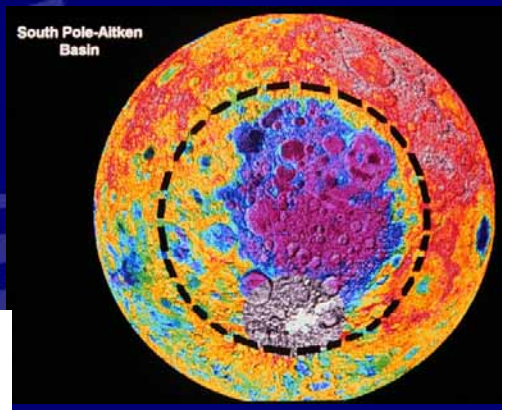
Impact craters and bombardment history in the inner solar system

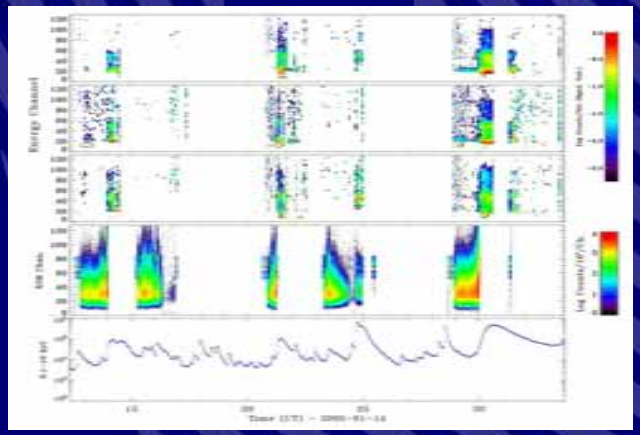
South Pole Aitken Basin

Large impact basins

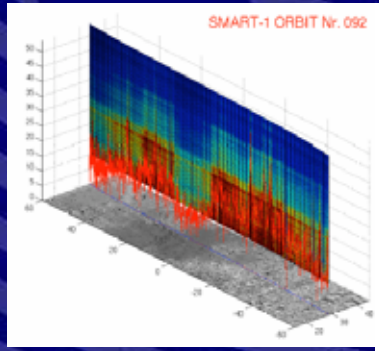


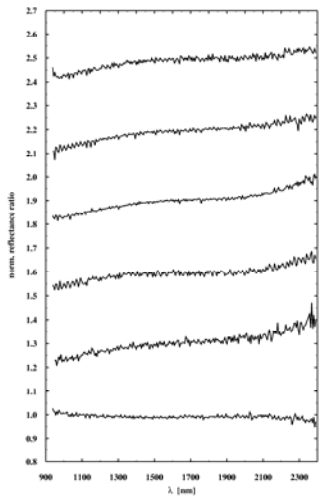
Prospector Th map





SMART-1 X-ray Element fluorescence





SMART-1 Infrared mineral spectroscopy

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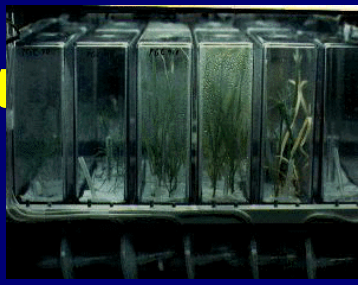
BHF 2008

Expanding life beyond Earth

- Bacteria and extremes of life: Survival, replication, mutation and evolution
- Extraterrestrial botanics: Growing plants on the Moon (tulips, mustard Arabidopsis, Tagetes Petula, ...)
- Animals: physiology and ethology on another planet
- Closed Ecological Life Support Systems
- Greenhouses, Local Food Production
- Living off the land
- Support to human exploration
- Permanent human presence
- Biospheres on the Moon
- Planetary and environment protection issues
- Protection of Earth life (Noah's ark , DNA bank)



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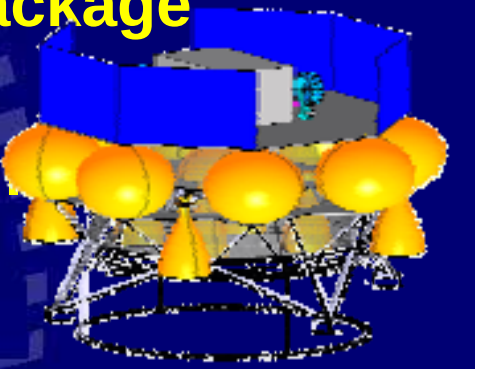
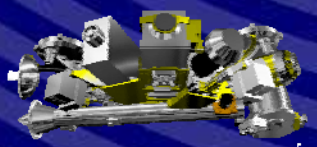
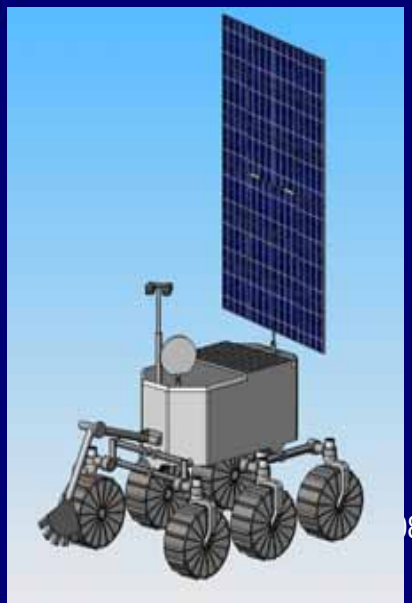
ILEWG Technology Task Group: What can be tested on the Moon?

- *New technology and system level engineering demonstration*
  - Remote sensing miniaturised instruments
  - Surface geophysical and geochemistry package
  - Instrument deployment and robotic arm
  - Close mobility, nano-rover, sampling , drill
  - Regional mobility: rover, navigation
- *Robotic laboratory*
  - Mecha-electronics-sensors
  - Tele control, Telepresence, Virtual reality
  - Autonomy, Navigation,
  - Artificially intelligent robots







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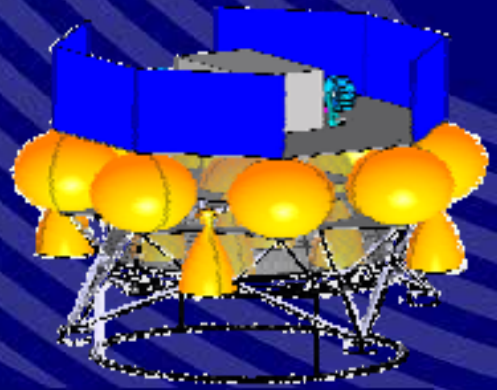
ILEWG Technology Task Group: What can be tested on the Moon?

- *In-Situ Utilisation of lunar resources*
  - Regolith, Oxygen, glasses, metals utilisation
  - Long term: He 3 extraction
- *Establishment of permanent lunar infrastructure*
  - Life sciences laboratories & Life support systems
  - Large astronomical facilities (VLF, interferometers)
- *Environmental protection aspects with humans*
- *Planetary protection validation for Mars*



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Travelling, Living, Working, Settling: Elements for Human Moon/Mars Exploration

- Advanced Launch /access to space
- Orbital Infrastructure
- Crew Exploration Vehicle
- Transport/ communication
- Habitable Descent / Ascent Vehicle

- Surface Power Generation
- In-Situ Fuel Production
- Robotic outposts and rovers

- Habitation Modules
- Workshop
- Scientific Laboratories
- Greenhouse / Agriculture Module
- Medical Centre

- Pressurized Rover
- Advanced EVA Suit
- Life Support Systems

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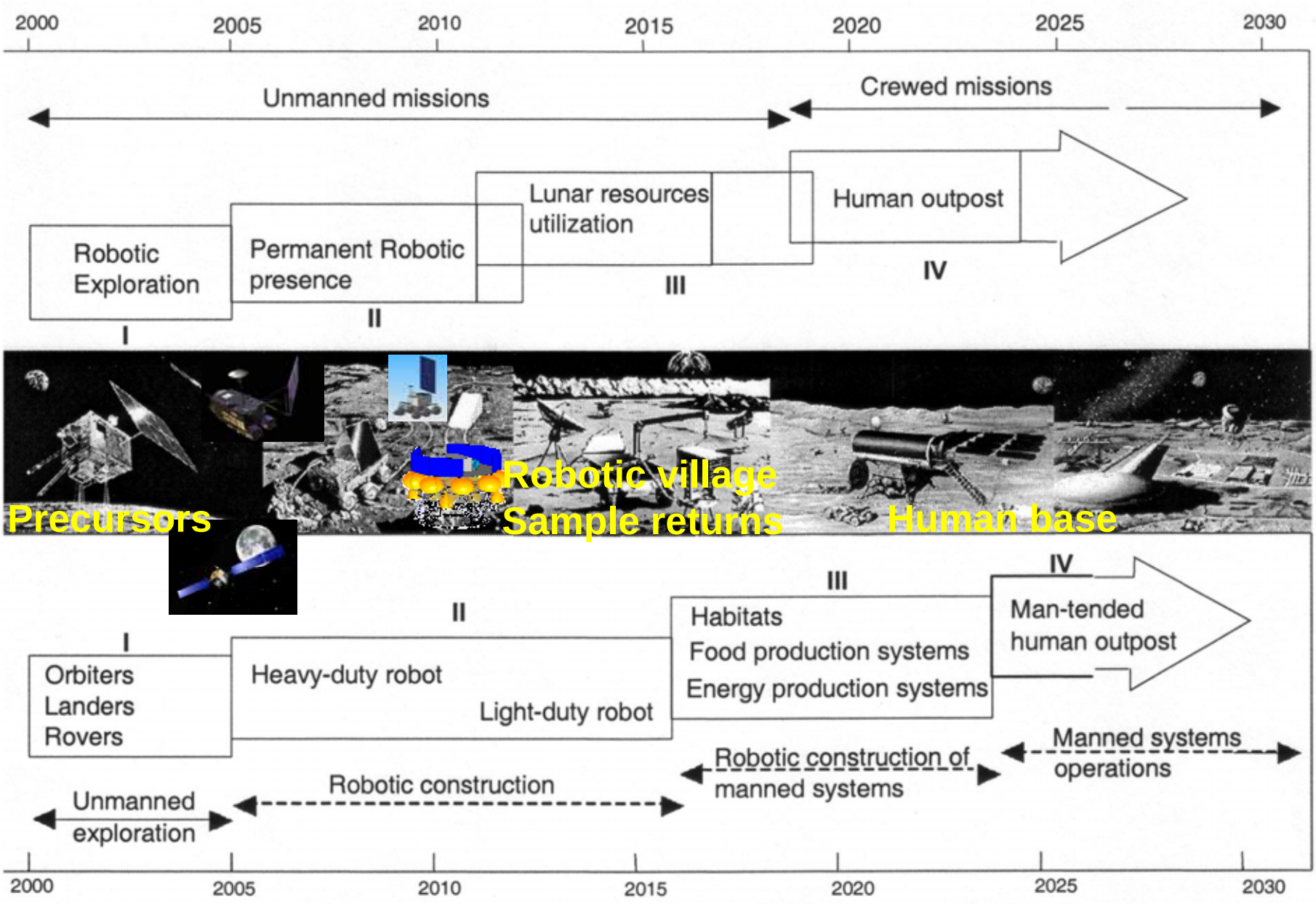
Roadmap: International Lunar Exploration Working Group (sci.esa.int/ilewg)



ICEUM/ILEWG: global village and international network

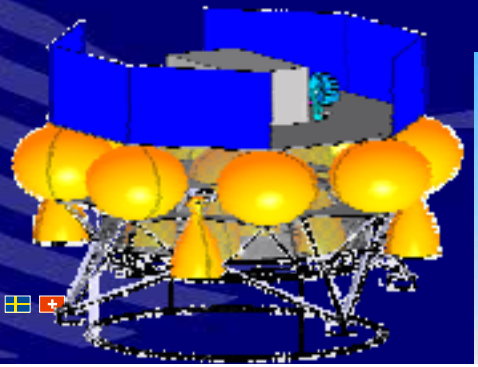
- ***Udaipur 2004:*** The participants endorse the ILEWG stepwise approach, starting with joint science analysis from ongoing precursor missions (Smart-1, Lunar-A, Selene, Chang'E, Chandrayaan-1, Lunar Reconnaissance Orbiter, Moonrise), continuing with lunar landers cooperating into an international **lunar robotic village before 2014**, **evolving technologies for man-tended missions** and preparing the ground for an effective, affordable human lunar exploration and **permanent presence by 2024**.
- ***Toronto 2005:*** We advocate **robotic engineering precursors** for geophysical characterization, life sciences, in-situ resource utilization and the deployment of infrastructures in preparation for human-tended operations.
- ***Beijing 2006:*** Recognizing the importance of the **geophysical studies of the interior of the Moon** for understanding its formation and evolution, the necessity for a better monitoring of all natural hazards (radiation, meteorites impacts and shallow moonquakes) on the surface, and the series of landers planned by agencies in the period 2010-2015 as an unique opportunity for setting up a **geophysical network on the Moon, we recommend the creation of an international scientific working group for definition of a common standard** for future Moon network instruments, in a way comparable to Earth seismology and magnetism networks.
- ***Sorrento 2007:*** We need now to exchange information and coordinate the studies of national lunar missions that could lead to **complementary elements of a global robotic village**

Lunar science and exploration missions

- Data analysis & Interpretation
- Science and Technology Lessons Learned
- Preparation for human lunar missions

- **International collaborations**

  2003 SMART-1 mission and exploitation
  2007 JAXA Selene Kaguya (science exchange)
  2007 Chinese Chang'e 1 (ground station)
  2008 ISRO Chandrayaan-1 (ESA SIR2, C1XS, SARA; NASA M3, miniS
  2009 LRO & LCROSS (planning, impact, outreach)
  2011- Orbiters (GRAIL+LADEE, LEO, ESMO, BW, ASI)
  2011- Landers, Rovers & Robotic village (GLXP, Chang'e2, Selene2, India, Lunaglob, UK Moon Lite)
  2013-2016 International Lunar Network, ESA Moon-NEXT
  2017- ESA Logistics lander, Sample return: Chang'e 3, Selene3
  2019- Human missions



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Sorrento lunar declaration (sci.esa.int/ilewg)

- 9th ILEWG Conference on Exploration and Utilisation of the Moon (ICEUM9)
- >250 participants, time STS120 launch & docking
- SMART-1 , Kaguya , launch of Chang'E 1
- Preparation Chandrayaan-1, LRO/LCROSS
- Space Agencies Exploration Coordination Group to benefit from ILEWG
- Integration and analysis of data and results from historical and new missions
- Cooperation at all levels (agency, mission, instrument, science, subsystem, ops)
- Outstanding lunar science questions remaining
- ICEUM unique gatherings, moving to a workshop mode
- More emphasis on the human aspects
- Lunar data dissemination via modern free web-based
- Establish an informal ILEWG Lunar Surface Operations Working Group
- Support Young Lunar Explorers and student lunar projects
- Initiate discussion (political and legal) on exploration and the use of the Moon
- Lunar Odyssey: engage the public (and youth) in science and technology
- Science analysis of current precursor robotic missions, to the global robotic village, and the preparation of international human settlements on the Moon.

Other ILEWG related events:

- 14-18 Jul. 08 COSPAR B0.1 Moon session, Montreal
- 20-23 Jul. Lunar Science Institute Workshop, Ames RC
- 15-18 Sep. Moon and beyond III, DGLR, Bremen
- 22-26 Sep. Europlanet Conference, Munster
- 29 Sep-3 Oct IAC Space Exploration Symposium, Glasgow
- 27-31 Oct 10th ILEWG conference on Exploration and Utilisation of the Moon
  - Port Canaveral Florida, ILEWG/ NASA LEAG / Space Resources Roundtable

- 20-24 April 09 European Geoscience Union, Vienna
- 13-18 Sep. 09 Europlanet Conference, Potsdam
- 12-16 Oct 2009 IAC Space Exploration Symposium, Korea
- 2009 11th ILEWG CEUM

- May 2010 IAF Global Lunar Conference, Beijing
- COSPAR2010 Moon science and exploration symposium, incl. session on International Lunar Base (COSPAR B, F, PEX, ILEWG) , Bremen

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ILEWG ROAD MAP TO THE MOON VILLAGE, MARS AND BEYOND
(Europe, robotic, life sciences/Manned)

- MOON TECHNOLOGIES MARS

Setting an International Lunar robotic village and Mars robotic outpost

- 2010 Chang'E 1 orbiter II
- 2011 GRAIL+LADEE, Phobos Grunt
- 2012 LEO, Chang'e 2, Moon-LITE , Selene-2, Chandrayaan2 lander
- 2013 IL Network , Maggia, ESMO ExoMars , Mars Scout
- 2014 Infrastructures, energy, ISRU Network science
- 2015 Intl Lunar Robotic Global Village Scouts?
- CEV Crew Exploration Vehicle, ACTS
- 2016 ILN, Moon-NEXT point land, life sciences, biology lab Mars-NEXT

2018 ESA Logistics lander demo, Chang'E 3 sample return Astrobiology Field Lab?

International Lunar Exploration Base and Mars Exploration

- 2019 Chinese mission to the Moon?
- 2020 ESA Logistics lander , US human on Moon
- 2021 Early Earth Sample Return?, European, Indian, Japanese on the Moon ?
  Lab, Infrastructures, energy, ISRU, green house
- 2022 EMCRV Crew Return Vehicle ? Mars Sample Return
- 2023 Long Term Lunar Base >2030

Humans to NEO/Phobos

Humans to Mars