CLOSING REMARKS ON ESLAB36 SYMPOSIUM ON
‘EARTH-LIKE PLANETS AND MOONS’

Bernard H. Foing* and the organisers of ESLAB36**

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ABSTRACT
We give a summary of ESLAB36 symposium on ‘Earth-like Planets and Moons’ that took place at ESTEC, Noordwijk on 3-7 June 2002. The different sessions included:
- A family portrait of Earth-like Planets and Moons
- The contribution of space missions for understanding Earth-like Planets and Moons
- Earth as a planet
- Methods for comparative planetology
- Interiors, surfaces, exospheres and impact processes
- Comparing atmospheres and fluids
- Earth-Like Planets and Moons in the galaxy
- Habitable Earth-like Planets and Moons
- ESLAB Symposium summary and roundtable discussion
- Robotic and Human exploration
- Young Planetary Explorers (YPE) special session

2. HIGHLIGHTS FROM ESLAB36 SESSIONS
We summarise some key points from the ESLAB36 sessions:

2.1 Keynote Lecture
In his talk (also ESTEC Colloquium), ‘A family portrait of Earth-like Planets and Moons: similarities and differences’, J. Head discussed how Earth-like planets form, work and evolve. He compared the various physical and evolutionary parameters that shape each Earth-like planet in the Solar System. It is important to learn from these comparisons, also to understand the conditions on these planetary bodies relevant to the origin and evolution of life.

2.2 The contribution of space missions for understanding Earth-like Planets and Moons
(session chaired by J. Head)
E.A. Herland described ESA Missions to study planet Earth, including Earth-watch and Earth explorers.
B.H. Foing described the heritage from Apollo, Luna, Clementine and Lunar Prospector, and the perspectives with SMART-1, Lunar-A, Selene and future lunar missions.
D. Titov gave the rationale and history for missions to Venus, and the rationale for further studies.
A. Chicarro reviewed the results of recent missions to Mars, and the potential of Mars Express, to be launched in 2003.
R. Grard emphasised how Mercury is a key to understanding terrestrial planets, and how the US Messenger mission can help to prepare for ESA’s Bepi Colombo cornerstone, which will have global surface coverage, higher and uniform spatial resolution, long integration times and 50 times more telemetry capability.
J.P. Lebreton described ‘Missions to outer moons’ with emphasis on Galileo results on Jupiter’s moons, and

1. ESLAB36 ORGANISING COMMITTEES
**The ESLAB36 organisers included:

Scientific Organising Committee: B.H. Foing (chair), A. Chicarro, M. Fridlund, R. Grard, J.P. Lebreton (ESA RSSD)
+ A. Herland (ESA Earth Science Division), C. Barbieri (I), T. Encrenaz (F), G. Neukum (D), J. Perez-Mercader (E), T. Spohn, (D), J. Head, T. Johnson (US), A. Basilevsky, E. Galimov (Russia), H. Mizutani (J)


(see http://ssd.esa.int/resources/conferences/eslab36/)

perspectives for the future exploration of Europa, and the upcoming studies of Titan with Cassini/Huygens. M. Fridlund described ‘Missions to Earth-like exoplanets’, including indirect photometric detection methods that will be used by COROT, Eddington and Kepler. He presented the Darwin infrared Space Interferometer for the direct characterisation of Earth-like exoplanets and for investigating their capability to sustain life as we know it. Synergies between all these space missions were discussed in the area of remote-sensing, in-situ instruments, miniaturised technologies, and the challenge of large and complex global data sets from multi-missions.

2.3 Earth as a planet
(session chaired by E.A Herland and M. Rast).

H. Paulsen showed what is known about the Earth interior through seismology. She uses seismic ray path reconstruction, enabling velocity derivation leading to shear velocity models and different speeds in the upper mantle. Seismic tomography distinguishes higher velocity and lower velocity regions, which are correlated with surface tectonics. There is strong potential for collaboration here in the future not only with SAR (Synthetic Aperture Radar) interferometer, but also gravity missions such as GOCE (Gravity Field and Steady-State Ocean Circulation) and of course CHAMP (Changing Minisatellite Payload for Geophysical Research and Applications) and GRACE (Gravity Recovery and Climate Experiment).

R. Wortel described deformation processes at various scales, in relation to Earth mantle structure and processes. He showed detailed evidence on the plate motions which are not in steady state, on the sea-floor spreading, on the subduction zone in the Adriatic (Mediterranean tear migration), and how sediment basins and their change may be used as indicators, with potential for remote sensing.

H. Laakso gave information on solar winds as a primary source of energy and momentum to the Earth plasma environment. He discussed solar proton episodes and Sun-Earth connection, the ionosphere's formation and layers, as well as the ionosphere-thermosphere coupling. He presented magnetospheric results from Cluster. A synergy with the future SWARM mission can be nicely constructed and be relevant to inter-disciplinary research (planetary/Earth sciences).

S. Bakał described his talk ‘Global atmosphere and climate studies’, the energy balance in the atmosphere which shows anthropogenic effects. Scenarios of CO2 emission predict temperature rises of 2-4 degrees, and global sea level rises up to 1 m. He described the relevance of these results for the International Panel on Climate Change. Problems are in the description of water fluxes overland (evaporation), the importance of freshwater flux for thermo-haline circulation, and the relevance of the hydrological cycle for our climate.

H. van Leeuwen in his talk on ‘Ocean, ice and fluid envelope’, described difficulties to make accurate measurements in-situ. He described the oceanic circulation and energy transport, properties of seawater and interior dynamics (salinity, internal waves, Rossby vs. Kelvin waves, etc). Moon tidal relationships, tidal winds and thermo-haline forcing needed to explain present day ocean dynamics. Remote sensing can help a lot (Scat, SAR, SMOS, GOCE) and better inverse models are desperately needed.

M. Rast gave a talk on ENVISAT’s first highlights with an overview of its status and performance, illustrated with lots of spectacular data.

In summary for the session on Earth as a planet: Earth sciences can help us to further our understanding of planetary phenomena (interior and exterior dynamics); Remote sensing is one of the tools that can enable quantum leaps in gaining knowledge; Earth is probably a good testbed to develop and test sophisticated observation techniques; Planetary and Earth sciences have also in common the permanent battle for better understanding and thus improvement of our models.

2.4 Methods for comparative planetology
(session chaired by H. Waenke and A. Chicarro)

P. Martin’s talk on ‘Surface Mineralogy’, discussed the signature of the crust and mantle on the Moon and Mercury, the effects of weathering and alteration on minerals, and the comparison between basaltic and andesitic spectral features on Mars. He also addressed spectral features from icy outer moons.

S. Maurice reviewed ‘Methods for Remote Sensing of Elemental Composition’, with emphasis on neutron, X-ray, gamma-ray techniques, and recent results obtained with Lunar Prospector.

L. Colangeli’s talk on ‘Laboratory and simulation studies’ described the small-scale processing (such as activation, hydrogenation, radiation) and the new techniques used for study of extraterrestrial samples (IR microscopy, X-ray, Field Emission Scanning Electron Microscopes).

D. Koschny’s talk on ‘Science operations of ESA planetary missions’, and A. Marini’s companion SMART-1 paper, described comprehensive tasks and planning for planetary missions such as Rosetta, SMART-1 and Mars-Express. A number of flash presentations of posters on related topics were given.
2.5 Interiors, surfaces, exospheres and impact processes
(chaired by R. Grard)

H. Wanke described the 'Geochemistry of Mars from in-situ and meteorite analysis', showing the presence of 2 main components (A highly reduced, B fully oxidized) with different mixing ratios for the Earth (A=85%) and Mars (A=60%).

D. Breuer showed computer simulations for the modelling of the interiors and evolution of Earth-like Planets and Moons.

L. Wilson and J. Head discussed the 'History of volcanism on Earth-like Planets and Moons'. They showed the different styles of volcanism on Earth. They compared early Moon volcanism, Venus volcanic resurfacing over 100 Myr, and Mars extensive Hesperian volcanism and recent flows.

G. Cremonese's talk on 'Exospheres of Earth-like Planets and Moons' described the sodium and potassium exospheric detections for the Moon, Mercury and Europa, and discussed the sources and processes needed to sustain them.

M. Grande gave a tutorial on 'Magnetospheres in the Solar System', showing the different cases pending on the existence of an atmosphere, the magnetisation or the rotation properties of the body.

H. Hoffmann & G. Neukum, in their talk 'The Cratering Record on Planets & Moons in the Solar System' presented the new standard crater frequency distribution on the Moon, on Mars (including the effects of eolian resurfacing), and on outer bodies in the Solar System.

2.6 Impacts interaction with Planets and Moons
(session chaired by L. Colangeli, and G. Schwehm)

Talks by Ph. Claeyts on 'The Earth impact cratering record' and A. Ocampo on 'Large impact cratering processes and their stratigraphy' discussed Earth crater impact structures and processes, and in particular the in-situ studies of Chicxulub layers in relation to the Cretaceous-Tertiary KT event.

O. Botta's talk on 'Exogenous material delivery to Earth-like Planets and Moons' discussed the volatile and organics inventory contribution by asteroids, comets, meteorites and Interplanetary Dust Particles. Some of these components might have been important ingredients for prebiotic chemistry on the Early Earth and Mars.

2.7 Comparing atmospheres and fluids (with emphasis on Earth, Mars, Venus, Titan, Europa)
(chaired by J.P. Lebreton, L. Becker, T. Encrenaz)

T. Encrenaz's talk on 'Atmospheric structure, composition, and diagnostics' reviewed atmospheric properties of terrestrial planets and outer satellites. Infrared spectra are used to derive elemental abundances. She discussed reservoirs of volatiles (chemical elements and D/H) in the Solar System nebula, and limits to rocky big Earths in the context of exoplanets. She discussed the case of Titan's special chemistry. She showed the specific case of the Earth's composition indicating departure from thermal equilibrium, and the rise of biogenic oxygen.

C. Sotin showed how, as a result of diverse sources of heat (accretion, radiogenic, tidal heating) large rocky planets can sustain an ocean.

C. d'Uston presented 'Preliminary results on the chemical composition of the Mars surface as observed by Mars Odyssey Gamma Ray Spectrometer' showing evidence of near-surface water.

2.8 Earth-Like Planets and Moons in the galaxy
(session chaired by S. Volonté)

Some 100 exo-Jupiters detected with the velocity technique have been reported. The next steps for detection of Earth-size exoplanets will make use of high accuracy photometry of transits: this is the goal of space missions such as Corot, Eddington and Kepler.

Visible coronography and IR nulling interferometry will follow, as complementary techniques to detect and characterize terrestrial atmospheres through spectroscopy of CO₂, water, CH₄, O₂ and O₃. The rise of terrestrial oxygen in the last billion years has led to life-searching strategies using O₂ or O₃ absorption bands. Hypertelescopes with baselines of 100 km, as proposed by A. Labeyrie and colleagues would allow us to resolve well the surface of terrestrial exoplanets.

2.9 Habitable Earth-like Planets and Moons
(session chaired by B.H. Foing)

P. Ehrenfreund's talk on 'Complex organics and prebiotic chemistry in space and on planets' reviewed the abundances of ices and organics in the interstellar medium and in comets. She showed the ingredients necessary for life, exogenous delivery, and the earliest fingerprints of life on Earth through the ¹³C record and stromatolites. She argued whether life is a cosmic imperative: how "easy" is it to start it and what are the prospects for life elsewhere?