UCL DEPARTMENT OF SPACE & CLIMATE PHYSICS
MULLARD SPACE SCIENCE LABORATORY

June 5, 2016

A Letter of Intent in response to ESA's M5 Call for Mission Proposals

Dear Prof. Colangeli,
This letter provides notification of our intent to submit to ESA a proposal in response to the above call.

Proposal title: **Akon Europa Penetrator Mission**

Name and contact information of Lead Proposer: Dr. Geraint H. Jones
Mullard Space Science Laboratory, University College London, Holmbury St. Mary, Dorking, Surrey RH5 6NT, United Kingdom. Email: g.h.jones@ucl.ac.uk Tel: +44 (0)1483 204100

Core Team Members:
Co-Lead: Dr. Zita Martins, Imperial College London, UK
U. S. Correspondent: Dr. Ralph Lorenz, Johns Hopkins University Applied Physics Laboratory, USA.

Michel Blanc, IRAP, FR	Bruce Bills, Jet Propulsion Laboratory, USA
Veerle Sterken, ISSI, CH	Gael Choblet, LPG, Univ. Nantes, FR
Olga Prieto-Ballesteros, CAB-CSIC-INTA, ES	Geoff Collins, Wheaton College, USA
Jérémie Lasue, IRAP, FR	Frances Westall, CBM, FR
Javier Gomez-Elvira, INTA-CAB, ES	Philippe Garnier, IRAP, FR
David Mimoun, ISAE, FR	Kevin Hand, Jet Propulsion Laboratory, USA
Adam Masters, Imperial College London, UK	Paul Hartogh, MPS, DE
Sascha Kempf, LASP, Univ. Colorado, USA	Krishan Khurana, UCLA, USA
Luciano Iess, Univ. Roma La Sapienza, IT	Katrin Stephan, DLR, DE
John Cooper, Goddard Space Flight Center, USA	Federico Tosi, INAF-IAPS, Roma, IT
Nicolas André, IRAP, FR	Steve Vance, Jet Propulsion Laboratory, USA
Martin Volwerk, IWF, AT	Tim van Hoolst, ROB, Belgium
Roland Wagner, DLR, DE	Andrea Longobardo, INAF-IAPS, IT
Marcello Coradini, JPL associate and former ESA, USA	Jean-Pierre Lebreton, LPC2E, FR
Tilman Spohn, DLR, DE	Luisa Lara, IAA, ES
Emma Bunce, Univ. Leicester, UK	Leonid Gurvits, JIVE, NL

Introductory Note This letter of intent is submitted under the coordination of the Europa Initiative (EI), a group of planetary scientists who believe that Europa is the next priority destination for the assessment of habitability and the search for life in the Solar System. This highly challenging and inspiring goal both deserves and justifies an ambitious joint mission by NASA and ESA, as exemplified by the *Cassini-Huygens*. The selection of three proposals to be submitted by EI (Jones et al., this letter of intent; Blanc et al, JEM; André et al., ESO) is the result of a six-month comprehensive study by our team of the scientific and technical parameter space of potential ESA contributions to a joint mission to Europa, during which we analysed six themes and five "vehicle options". They have carefully selected the most promising set of mission scenarios for consideration by ESA and NASA.

Scientific Goals of Mission

The four key science objectives of Akon (Ἄκων) will be the following:
1. Determination of the internal structure of Europa and its dynamics.
2. Determination of the existence and characteristics of a subsurface ocean.
3. Search for biosignatures in near-surface material.
4. Characterization of the physical (e.g. radiation, thermal, magnetic, electrical, mechanical) and chemical environment of the near-surface region.

ESA's Cosmic Vision strategic document clearly identifies the exploration of the Jupiter system, and within it the search for life at Europa, as one of its top priorities. Indeed the study of Europa as a habitable and potentially life-bearing moon addresses two of the Cosmic Vision science themes:

- Theme 1, "How does the Solar System work?" is directly addressed through the study of Europa as a complex system generating and maintaining the conditions for habitability;
- Theme 2, "What are the conditions for planet formation and the emergence of life?" challenges us to understand how the history of Europa connects its formation scenario to the search for extant Europan life.

There is clearly the potential for a huge science return from Akon, enhancing and complementing through synergy the science return from NASA's Europa missions and JUICE. The delivery of a miniaturised, rugged, instrument suite to Europa's subsurface allows potentially ground-breaking science in several fields of research. The mission will obtain measurements of the Europan environment at the same or even better precision as JUICE will do for Ganymede. To achieve the four key science objectives, data would be gathered during three mission phases. Example of observations from each phase are as follows:

Descent science:

- Multispectral and polarimetric imaging of surface at ever increasing spatial resolution; changing viewpoint yields three dimensional topographic information for landing site surroundings for geomorphology. This closes the resolution gap between orbiter and lander/penetrator science and provides the geological/topographical context of penetrator sites. Enables geological characterization of small and geologically young regions at up to cm-scale. This is complementary to orbiter science and helps understand endogenic processes on a local scale and to characterize the regolith structure and surface age in detail. Images taken during descent at a different altitude could reveal exchange processes between surface materials and an exosphere and/or changes caused by geologic activity.
- Measurement of magnetic field during descent, giving two-point measurements with other magnetometers on the NASA lander and other penetrator.
- Sampling and *in-situ* measurements during descent allow discrimination between water-ice and clathrate hydrates and measure abundance of volatiles in the near-surface environment.

Impact science

- Accelerometer/seismometer yields information on surface strength.
- Detection of impact echoes of penetrator & delivery module for information on ice crust.

Sub-surface science

- Long-term seismological investigation of the subsurface and deeper interior, including Europa's differentiation, the occurrence of water in the ice shell, and determination of the location and depth of subsurface ocean.
- Study of density, size, rigidity, electrical conductivity and viscosity of the ice shell and ocean by determining tidal quantities at the rotational period and the induced magnetic field during multiple Jovian days and Europa orbits, and by characterizing the rotation of Europa.
- A study of flow in the ocean by magnetic measurements and rotation variations.
- A study of a possible core dynamo.
- Determination of the local ice properties, including elastic parameters, thermal conductivity, rheology, and local heat flow.
- Sampling of subsurface material to ascertain composition and habitability *in situ*; search for biomarkers (this can be further broken down into determination of multiple parameters);
- Detection of signatures of life potentially present in the subsurface material, and encaged in salty ice grains or clathrate hydrates in the near-surface environment.

- Identification and characterization of non-water-ice materials, including organic compounds, constraining the surface age, discrimination between water ice and clathrate hydrates, and determination of volatile compounds amount in the near-surface environment.
- A cross-scale link between remote observations and sample analyses by *in-situ* surface information. Highest resolution images of regolith and studied samples.
- Changes in composition (ice components and salts), physical, radiation effects, thermal and mechanical properties with varying depth.
- Examination of local geologic processes, such as the processes responsible for the formation of salts and any organic material, but also the erosion and degradation of small-scale surface features and surface materials (size distribution of blocky material, regolith properties (albedo, color, grain size). *In-situ* measurements could revolutionize our knowledge of the exchange between surface and subsurface materials and the habitability of Europa's crust/ocean.

Possible Mission Configuration

Mission profile: The proposal will be for one or two penetrators to be delivered to Europa by the NASA Europa Lander mission. Several delivery options are possible; in almost all cases, a modest carrier spacecraft would be required to decelerate the probe. Options include a standalone penetrator delivery element that separates from the NASA lander and carrier soon after Jupiter Orbit Insertion, a later separation from the NASA craft, separation from the NASA lander during its landing descent, and a combination of these to allow large spatial separation between two penetrator landing sites and the NASA lander. The Akon proposal team will work together with the other Europa Initiative proposal teams to discuss with NASA the various options for the mission elements and their delivery.

The penetrator(s) would be delivered to the surface of Europa at a speed of ~300m/s, and would be buried up to several metres in the subsurface of the moon. Samples would be gathered from the subsurface material adjacent to the penetrator, and studied on-board by a suite of instruments. Other instruments would image the surface material, and geophysics instruments would take long-term measurements of the magnetic, gravity, and radiation environments, and take seismic measurements. These measurements would complement data from the NASA lander, and these multi-point observations, forming a geophysical network with that lander, would greatly enhance the combined scientific return from the NASA and ESA missions.

Payload/instrument configuration. The instruments are split into two groups: those mounted on the delivery module to make measurements during the descent to the surface of Europa, and those included in the penetrator itself, to operate under the moon's surface. Penetrator instruments will be in two groups – thermally-isolated short-term instruments for the in situ analysis of subsurface material, and backend-mounted geophysics instruments for long-term observations and regolith imaging. Planetary protection is clearly a key issue to be addressed. The Akon team are very aware of these tight restrictions on sterilization that would need to be carried out on all components

Technology. The proposal will benefit from very successful ESA-funded technology development studies into the feasibility of delivering instrumented penetrators into the subsurface of icy moons such as Europa. These studies have led to a mature design that allows the operation of instruments at relatively high temperatures while thermally insulated from the ~80K subsurface material, and the long-term survivability of penetrators in this environment through the application of advanced battery technology. The studies have included very successful live tests of this design and already demonstrated the survivability of several relevant instruments at ~300m/s impact speeds.

Potential Payload Consortium/Consortia Composition

Below are listed instruments currently under consideration for inclusion on the proposed penetrator(s), to address several key scientific areas including habitability, astrobiology, and geophysics. If two penetrators are proposed, both payloads could consist of some common sensors plus experiments unique to each penetrator. Other instruments, such as a gravimeter, could also be added. A common digital processing unit could also be provided at a national level by a consortium of countries not listed here, and active targeting studies are of interest to Universität der Bundeswehr München (DE). Collaboration with US-based groups, including possible leadership of experiments, is anticipated.

Name	Possible leading institution(s)	Nation	Heritage or related instruments
Descent Imager	Osservatorio Astronomico di Padova/ UCL Mullard Space Science Laboratory	IT/UK/ DE	JUICE JANUS, ExoMars PanCam
Accelerometer	Institut für Weltraumforschung	AT	Rosetta Philae; penetrator trials
Energetic particle detector	Christian-Albrechts-Universitaet zu Kiel/ UCL Mullard Space Science Lab	DE/ UK	MSL Radiation Assessment Detector, JUICE PEP
Habitability Conditions Package	Centro de Astrobiologia	ES	Phoenix MECA Wet Chemistry Laboratory
Magnetometer	Imperial College London	UK	CINEMA
Mass spectrometer for volatile characterization	Open University	UK	Rosetta Philae PTOLEMY
Mechanical sensors	Institut für Weltraumforschung	AT	HP3 mole
Nanopore-based detector	Zürcher Hochschule für Angewandte Wissenschaften/ Universitaet Heidelberg	CH/ DE	MinION terrestrial applications
Permittivity probe	Institut für Weltraumforschung	AT	ExoMars Humboldt station
Radio transponder for geophysics	Koninklijke Sterrenwacht van België	BE	VEX VeRa, MEX MaRs, ExoMars LaRa
Regolith Imager & IR spectrometer	CNRS Centre de Biophysique Moléculaire/ UCL Mullard Space Science Laboratory	FR/ UK	ExoMars CLUPI and PanCam
Silicon Seismic Package	Imperial College London	UK	InSight
Temperature & thermal conductivity	Institut für Weltraumforschung	AT	Rosetta-Philae MUPUS
VISTA micro-thermogravimeter	Istituto di Astrofisica e Planetologia Spaziali	IT	Scientific package of MarcoPolo-R; Penetrator for JUICE
Wet Chemistry Package	University of Leicester	UK	Beagle 2 & Life Marker Chip.
(Earth-based) Radio detection for VLBI	Joint Institute for VLBI, Dwingeloo	NL	Huygens

Expected main funding agencies involved in the payload provision

The payload will be provided by instrument consortia primarily funded by the national agencies of the countries listed above, in addition to collaborating institutions in other countries, including Hungary.

Eventual Proposed International Collaboration Elements for the Mission

This proposed mission will be a close collaboration with NASA. We foresee that delivery of the Akon penetrator(s) to the Jovian system, and possibly to the near vicinity of Europa itself, will be provided by elements of the US agency's Europa soft lander mission. In the near-term, we also propose to approach NASA to establish the possibility of a data relay being provided by ESA for the NASA 2022 Europa Multiple Flyby Mission as part of the Akon project. This would allow the use of this NASA spacecraft for data relay from the Akon penetrator(s), if it will be available. Collaboration with additional international partners may be possible.

Our consortium looks forward to presenting to ESA our proposal for this high scientific return mission.

Yours sincerely,

Dr. Geraint H. Jones
on behalf of the Akon team

List of Additional Supporters of the Akon Europa Penetrator Mission & Europa Initiative

Name	Institution	Country
Allthorpe-Mullis, Elise	UCL	UK
Belenguer Davila, Tomas	Instituto Nacional de Técnica Aeroespacial (INTA), Madrid	ES
Bentley, Mark	IWF/ÖAW	AT
Bernelli, Franco	Politecnico di Milano	IT
Bowles, Neil	U. of Oxford	UK
Bridges, John	U. of Leicester	UK
Brown, Patrick	Imperial College London	UK
Cann, George	UCL	UK
Carr, Chris	Imperial College London	UK
Chide, Baptiste	ISAE	FR
Church, Phillip	Qinetiq	UK
Coates, Andrew	MSSL, University College London	UK
Cook, Tony	Aberystwyth	UK
Coustenis, Athena	Observatoire de Paris, Meudon	FR
Cowman, Joseph	UCL	UK
Crawford, Ian	Birkbeck, U. of London/CPS	UK
Dehant, Veronique	Royal Observatory of Belgium	BE
Desprats, William	ISAE	FR
Desai, Ravindra	MSSL, University College London	UK
Fabio Rezzonico	Zurich University of Applied Sciences	CH
Fernandez Remolar, David C.	British Geological Survey	UK
Flores Martinez, Claudio L.	University of Heidelberg	DE
Foerstner, Roger	Bundeswehr University, Munich	DE
Gao, Yang	Surrey Space Centre, U. of Surrey	UK
Gladstone, Randy	SWRI	USA
Greathouse, Thomas	SWRI	USA

Grindrod, Pete	Birkbeck, U. of London/CPS	UK
Grodent, Denis	STAR, Université de Liège	BE
Heredero, Raquel López	Optical Space Instrumentation Laboratory in INTA, Madrid	ES
Horbury, Tim	Imperial College London	UK
Humphries, Tim	Qinetiq	UK
Irfan, Huma	Birkbeck, U. of London/CPS	UK
Javaux, Emmanuelle	LPAP - Université de Liège	BE
John Holt	Uni of Leicester	UK
Joy, Katie	University of Manchester	UK
Kargl, Günter	IWF/ÖAW	AT
Kereszturi, Akos	Research Centre for Astronomy and Earth Sciences	HU
Konstantinidis, Kostas	Bundeswehr University, Munich	DE
Krupp, Norbert	MPS	DE
Lucchetti, Alice	OAPD, INAF	IT
Martins, Philippe	Telecom ParisTech	FR
Mepsted, Gary	Qinetiq	UK
Palomba, Ernesto	Istituto di Astrofisica e Planetologia Spaziali-INAF, Roma	IT
Perkinson, Marie-Claire	Airbus	UK
Pike, Tom	Imperial College London	UK
Polaine, Yves	Telecom ParisTech	FR
Radiot,i Aikaterini	Université de Liège	BE
Regoli, Leonardo	MPS/UCL	DE/UK
Retherford, Kurt	SWRI	USA
Rizzi, Francesco	Finmeccanica - Leonardo	IT
Sheridan, Simon	Open University	UK
Simamora, Ondi	UCL	UK
Sims, Mark	Space Research Centre, U. of Leicester	UK

Smith, Alan	MSSL, UCL	UK
Teanby, Nicholas	University of Bristol	UK
Timoney, Ryan	University of Glasgow	UK
Wellbrock, Anne	UCL	UK
Whiteside, Barry	Imperial College London	UK