

# The First Akon Europa Penetrator Workshop



**Thursday, January 21, 2016, from 10:00 to 17:00 GMT**

The Royal Astronomical Society  
Burlington House  
Piccadilly  
LONDON W1J 0BQ  
United Kingdom

(Nearest Underground stations: Piccadilly Circus, Green Park)

*Note that unfortunately, no refreshments will be available at the venue, but there are several coffee shops and cafes very close by for lunch and our afternoon break.*

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## **10:00 Welcome and Brief Overview of the NASA Europa Mission**

### **10:10 A Europa Initiative for ESA's M5 call**

Michel Blanc (IRAF, FR & ISSI, CH)

### **10:30 The Akon penetrator concept and how we got here**

Geraint Jones (MSSL-University College London, UK)

### **10:55 Penetrator studies at Qinetiq**

P. Church (Qinetiq, UK)

*We shall describe previous penetrator studies in brief and focus on the current phase III programme.*

### **11:15 High landing accuracy penetrators for Europa**

Konstantinos Konstantinidis (Bundeswehr University, DE)

*Europa is hypothesized to contain a potentially habitable global ocean. Possible recent transport of ocean material to the surface is marked by certain terrain features (chaotic terrain, impact craters, linear tectonic features, etc.) ranging in size from 10s of km to under 1 km. Such areas would be interesting targets for a penetrator aiming to sample this surfaced ocean material. However, the recently studied CLipper ESA Penetrator (CLEP) concept has an accuracy requirement of only 300 km, insufficient to target any specific area of interest. In this work we investigate ways to increase the targeting accuracy of a Europa penetrator delivered by the NASA Europa Mission/Europa Clipper. First we investigate interesting landing areas on Europa and deduce the landing accuracy required to target them. Using the CLEP concept as a basis we investigate how modifications in operations, propulsion system, and navigation methods affect accuracy. We also discuss the merits of adding guidance & control (G&C) and hazard detection and avoidance (HDA) functions. Based on this analysis we discuss possible modifications to the CLEP system and operations for increased landing accuracy, so that more interesting and/or safer areas can be targeted on Europa.*

### **11:35 Drilling, Sampling and Sample Handling Technologies to Support Europa In-situ Science**

Francesco Rizzi (Finmeccanica, IT)

*Finmeccanica (formerly Selex ES), in cooperation with Politecnico di Milano, is willing to give an overview of the drilling, sampling and sample handling technologies developed in the frame of ESA robotic exploration projects. These technologies and concepts can be considered as a starting point for conceiving a dedicated sampling tool for the Akon Europa Penetrator mission. Such a tool, on the basis of the specific scientific objectives, needs and constraints, would be installed in the Penetrator and would be aimed to: - collect a local subsoil sample outside the Penetrator (after penetration), - retrieve the sample inside the Penetrator, - deliver the sample to a scientific instrument (e.g. the Mass Spectrometer mentioned in the CDF Assessment) for in-situ analysis. Finmeccanica will shortly present their capabilities and background experiences, summarized here below: - Rosetta SD2 equipment, landed and operated on the Churyumov-Gerasimenko comet in Nov-2014; - ExoMars drill subsystem, currently under qualification for the ExoMars-2018 mission; - Fast sampling devices developed for missions on low gravity bodies (e.g. Marco Polo); - Sample handling, encapsulation and sealing mechanisms for Mars Sample Return; - Lunar (roto-hammering) Drill for Luna Resource Lander, conceived to collect soils at polar latitudes preserving the volatile content.*

### **11:55 Ultra low payload with maximum sensors designs for Penetrator & Mini Lander**

T. C. Ng (via Webex) (HK)

*I participated in Beagle 2 Mars Mission involved with virtually all the sampling tools developments on board. For Europa exploration, I believe in ultra low payload with maximum sensors on board within 50 kg for "Penetrator + Mini Lander + retro rocket + airbag" all inclusive. The rest of 200 kg for Orbiter.*

*Penetrator 10 kg > 1/ no motor 2/ sensor on surface 3/ open inlets for samples influx 4/ front and side impact triggers to switch on control box & to deploy sensors / solar panel at tail 5/ oval cross section 6/ fish tail shaped counter sink 7/ heating coil to melt ice to liquid form 8/ smaller diameter of 6-8 cm 9/ aerial panoramic camera 10/ bouncing camera ball*

*Mini Lander ( 15-20 kg) > 1/ 3 cover partitions as 3 robotic arms 2/ melting probe without motor 3/ panoramic camera viewing horizon of planet 4/ GCMS to analysis melted ice / atmosphere / plumes 5/ radiation protection by tungsten copper and aluminum lining 6/ seismometer needle sensors to detect earthquake 7/ a dozen of sensors & spectrometers 8/ pendulum automatic erection 9/ multiple sensing sites 10/ real time imaging of melting probe in operation with depth marking I believe we should lower the payload of both landing devices, more payload should be allocated to retrorocket and airbag mechanism for descend and landing. A lesson learned from bitter experience of Beagle 2.*

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**12:15 - 13:15 Lunch**

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### **13:15 A Low-Resource Magnetometer for the Akon Europa Penetrator**

Adam Masters (Imperial College London, UK)

*Magnetic field measurements at Jupiter's moon Europa underpin consensus that there is a global subsurface ocean of liquid water. Galileo magnetometer data shows clear evidence for induced magnetic fields resulting from electric currents in this conducting liquid layer below the ice crust. Magnetic field observations thus allow electromagnetic sounding of Europa's interior, central to assessing ocean habitability. NASA's Europa mission will carry a magnetometer package (ICEMAG) that will infer ocean location, thickness, and salinity. Here we present the significant additional science return that would result from a low-resource magnetometer on the proposed Akon Europa penetrator. We outline an instrument design based on robust solid-state anisotropic magnetoresistance developed from an Imperial College instrument that flew on the three CINEMA CubeSats in 2012/2013, further improved with increased radiation tolerance and reliability for the Sunjammer mission. The proposed instrument mass is less than 150 g and is sensitive to <1 nT field variations. We outline the science objectives that could be achieved with magnetic field measurements made by such an instrument inside the penetrator, highlighting not only synergistic science with ICEMAG but also unique penetrator MAG science. A penetrator MAG would determine the extent of Europa's magnetic dynamo, and potentially discover ocean flows.*

### **13:35 A miniaturised Ion and Neutral Mass Spectrometer for the Akon Penetrator delivery module**

Ravindra Desai (MSSL-University College London, UK)

*Galileo magnetometer observations showed evidence for the outflow of a number of ion species at Europa which the Galileo Plasma Spectrometer was unable to measure. Strong wave power was observed at the gyrofrequencies of, Sodium/Calcium, Potassium/Magnesium, and Chlorine, indicating the pickup of these species in appreciable quantities. These species have all been observed to, or suggested to, be present in the European ice and would therefore likely be present in the moon's exosphere. Some of the lighter species would be present at altitudes detectable by the Europa orbiter, while others are heavier/shorter lived species and would only exist closer to the surface. In this presentation we show hybrid simulation results where we are able to place the first constraints on the abundances of these species as observed by Galileo, and consequently show how important it is for these species to be taken into account within Europa exploration endeavours. We put forward the idea that a miniaturised INMS instrument would add significant science return in its ability to characterise processes occurring within the European exosphere and possibly plumes, being able to achieve measurements which both the Europa orbiter and Penetrator wouldn't.*

### **13:55 VISTA, a thermogravimeter to detect water ice, clathrate hydrates and organics**

Andrea Longobardo (IAPS-INAF, IT)

*VISTA is a thermogravimeter developed by an Italian consortium and selected in the scientific payload of the ESA mission study MarcoPolo-R. The total sensor mass is about 100g, whereas the volume is lower than  $5 \times 5 \times 5 \text{ cm}^3$ . The core is a Piezoelectric Crystal Microbalance (PCM), oscillating at a resonant frequency linearly related to the mass deposited on its sensible area. The VISTA main challenge consists in two resistors built-in on the crystal, acting as heater and temperature sensor, respectively. The heater allows the desorption of most volatile compounds, and thus to infer their abundance as mass difference. The temperature sensor measures the actual temperature of the crystal, not possible with commercial PCM sensors. VISTA could perform crucial measurements in an in-situ mission on Europa, namely: - Discrimination between water ice and clathrate hydrates, difficult to perform spectrally (due to their similar spectral features), but possible by means of VISTA due to their different sublimation temperatures (i.e. 160-200 K of water ice, 60-140 K for most of clathrate hydrates); - Determination of composition of non-ice materials (e.g. epsomite, meridianite, mirabilite), characterized by different dehydration temperatures (from 220K to 320K); - Detection of organics, expected to desorb at temperature larger than 234 K.*

#### 14:15 Habitability Conditions Package for Akon Penetrator

Olga Prieto-Ballesteros, Javier Gomez-Elvira (CAB, ES)

Besides the direct detection of biosignatures, important measurements for Astrobiology are those related to physical-chemical environmental constraints of the aqueous. Characterization of liquids may be performed by melting the ice of the studied area. The instrument is conceived to measure pH, conductivity and redox, which condition the state of the water solution that is potentially available for life. Extreme values of these parameters would be problematic to some biological processes. On the other hand, specific anomalous values could be due to life presence. The Habitability Package is based on the multiparametric probes used in the laboratory and field campaigns to measure the physicochemical conditions of natural waters. Heritage from martian soft landing oriented instrument prototypes also exists. They are usually solid-state electrodes made of different metals. The instrument is conceived as a receptacle(s) or pipe(s) where the electrodes are accommodated, recording the magnitudes of the liquefied sample. Modularity and simplicity of the design are the most significant features of the instrument, highly restricted by the mission and the environment. The adaptation to the space conditions at the penetrator context implies some restrictions of mass and power.

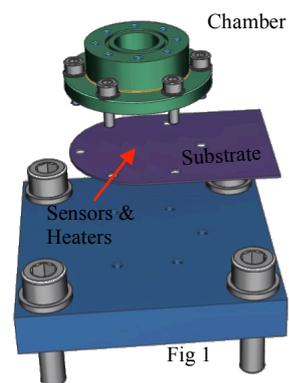
#### 14:35 Icy Moons Penetrator Science Package: A Proposal for the AKON Europa Penetrator

John Bridges, Mark Sims, John Holt (University of Leicester, UK)

A landed or penetrator mission to the Jovian icy moon Europa enables direct access to the surface and immediate sub-surface of its ice and the only means of assessing potential habitable environments, evidence of biosignatures and provide ground truth for orbital observations. Icy material in the outermost microns of Europa has been heavily processed by micrometeorite gardening, solar UV and radiation [1] and may have broken down any organics at the surface of this moon. It is expected that the effects of radiolysis will be reduced as a function of depth to a point where less modified ice may inform the bulk composition of Europa's ocean, particularly if the mission is targeted at geologically young areas. Thus characterisation of deeper layers via a penetrator is needed to analyse more pristine organic material, other compounds, trapped/dissolved gases and particulate lithologies that may have been delivered to the near surface. Transmission IR through melted ice is a key analytical technique for such a mission and could identify a wide range of dissolved and solid compounds. For instance, between  $6000\text{--}400\text{ cm}^{-1}$  ( $1.7\text{--}25\text{ }\mu\text{m}$ ) identification of  $\text{H}_2\text{O}$ ,  $\text{H}_2\text{O}_2$ ,  $\text{NH}_3$  and its hydrates, and solid mineral phases including clays, and igneous minerals are possible. In addition, large organic molecules such as tholins have spectral features at 4.57 and 3.4 microns [2].

The proposed Icy Moons Penetrator Science (IMPS) instrument is a multi-chamber astrochemistry and astrobiology analysis package that enables a range of "wet chemistry" analyses, including transmission IR, of a fluidic sample using a suite of custom sensors. Underlying the proposed concept design is a configurable substrate technology currently being developed by the Space Research Centre, University of Leicester in collaboration with the NASA Ames Research Center, where the analyte chamber environment is controlled by embedded heaters and an array of parylene protected transducers. A laboratory model of a single chamber is shown here (Fig 1) such that the basic principle is more readily understood, where an ice sample

is delivered to the chamber, processed and analysed (this is not as built for IMPS). It is proposed that lateral quartz windows on the analyte chamber will facilitate both excitation light sources and diametrically positioned UV, visible and IR sensors to monitor the light transmitted through the melted ice and enable the near IR absorption peaks of dissolved compounds within the liquid to be identified. Temperature, electrical conductivity, pH and redox are also essential measurements to characterise the Europa hydrous/icy environment and its habitability and these sensors are positioned on the chamber substrate base.



Until recently, mission architectures that include soft landing modules have been favoured above hard landing and penetrator concepts, perhaps because of their familiar and tested engineering systems. This tendency has led to typical instrument payload masses of between 4 kg and 24 kg being proposed [3]. Such payloads will not be possible with the mass, volume and power constraints of a penetrator delivery system where instruments will be limited to a few hundred grams [4]. A novel aspect of the proposed IMPS instrument is to provide an adjunct interface such that other instruments, a microscope camera for example, could be integrated with one or more IMPS chambers. A CCD or active pixel detector could be accommodated on the chamber substrate (protected by parylene) and a micro-lens array used to focus the device for the observation of suspended particles (organic or mineral; size, shape, roughness & colour) that are illuminated by RGB or

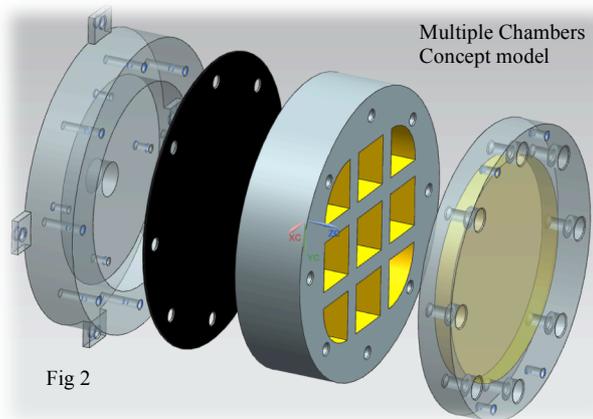


Fig 2

UV LED's. However, mass may be minimised if a high TRL camera module is mounted laterally by the adjunct interface.

It is proposed that IMPS is a modular design such that the number of experimental chambers is matched to the probe resources, science requirements and sampling regime. Typical chamber size will accommodate between 0.1 cc and 1 cc of ice sample and subsequent reduced volume of liquid. Embedded heaters are used to melt the ice, exposing the liquid to the substrate sensors. As a minimum, the sensor substrate will include differential ISFET's to measure pH (similar to the Dutch LioniX sensors used in LMC [5]), platinum conductivity detectors and temperature monitoring. The substrate may also include a redox sensor depending on selection of appropriate electrode TBD and photo diodes to measure optical density and UV fluorescence.

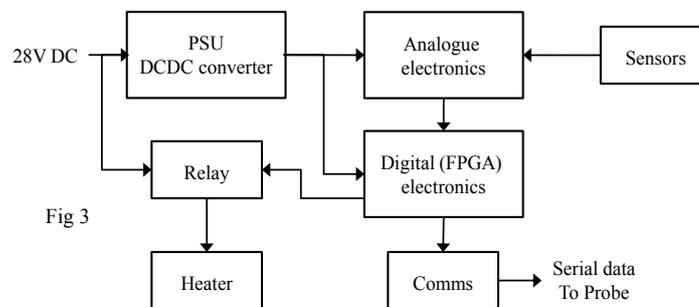


Fig 3

IMPS Instrument Summary Table		
<b>Science Capability</b>	<ul style="list-style-type: none"> <li>○ Habitability (within ice)</li> <li>○ Astrobiological materials</li> <li>○ Lifeforms</li> </ul>	Transmission IR spectroscopy Suspended particulate morphology (0.1 mm to 1.0 mm scale) Physical & chemical analyses of melted ice Bulk & particulate organic fluorescence (using uv LED's)
<b>Mass</b>	250 g (estimated from CAD) inc electronics and standard spacecraft interfaces	
<b>Power</b>	1 W to 3W	
<b>Size</b>	Typically 100 mm diameter / 55 mm	
<b>Heritage</b>	Beagle 2, Life Marker Chip	

Table 1

A multiple chamber concept model (used to estimate mass) is shown in fig 2; sample chain interface not shown (solid lid used to account for mass). Electronics are accommodated in the base of the instrument. A basic block diagram is shown in fig 3.

1. Hudson, R.L. and M.H. Moore, *Infrared spectra and radiation stability of H<sub>2</sub>O<sub>2</sub> ices relevant to Europa*. *Astrobiology*, 2006. **6**(3): p. 483-489.
2. Gowen, R.A., et al., *Penetrators for in situ subsurface investigations of Europa*. *Advances in Space Research*, 2011. **48**(4): p. 725-742.
3. Korablev, O., et al., *Methods and measurements to assess physical and geochemical conditions at the surface of Europa*. *Advances in Space Research*, 2011. **48**(4): p. 702-717.
4. ESA, *Assessment of a Europa Penetrator Mission as Part of NASA Clipper Mission*. CDF STUDY REPORT, 2015.
5. Sims, M.R., D.C. Cullen, and J.M.C. Holt, *Development status of the life marker chip instrument for ExoMars*. *Planetary and Space Science*, 2012.

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**14:55 - 15:15 Break**

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**15:15 Penetrator Deployed Mass Spectrometers for surface and sub-surface volatile characterization**

Simon Sheridan (Open University, UK)

*Miniature, low-mass, low-power Mass Spectrometer instrumentation and sample processing systems have been developed that are compatible with high-speed penetrator deployment. These working prototypes have flight heritage and are based on the Ptolemy Mass Spectrometer instrument on the Philae lander. We will describe the instrumentation, discuss results from previous impact tests and the issues and opportunities for deployment of such instrument packages at Europa*

**15:35 A Silicon Seismic Package (SSP) for Akon**

Tom Pike, Anisha Mukherjee and John McClean (Imperial College London, UK) Simon Calcutt (Oxford University, UK) Ian Standley (Kinemetrics Inc., USA)

*A seismometer on the surface of Europa is the prime instrument for studying the dynamics of the interior. A micromachined silicon seismometer in a robust and compact package has been developed by Imperial College and Oxford and delivered for the InSight mission. The performance of the InSight microseismometer has been demonstrated at 0.3 ng/rHz, with a bandwidth below 0.6 ng/rHz from 10 s to 10 Hz. We have separately developed technology to armour the seismic sensor for shocks of up to 14,000g, as validated during testing for the MoonLite penetrator development. Low temperature operation of the micromachined suspension has been demonstrated at 77K. The Akon SSP would be operated from within the penetrator with excellent coupling to the Europa surface. Estimated mass based on the InSight hardware would be 600g for the sensors and associated electronics, with a power budget of 500 mW. The Akon SSP would deliver a critical portion of the science deliverable from a mission to the Europa surface.*

**15:50 Abiotic versus biological sources of highly oxidized organic compounds on planetary surfaces**

David Fernández-Remolar (British Geological Survey, UK)

*On planetary surfaces, abiotic and biological compounds exposed to high radiation doses eventually produce analogous associations of highly oxidized compounds. This makes it difficult, when not impossible, to unlock the source of the molecular diversity that can eventually persist in the surface planetary materials. Whatever the origin of the molecules may be, and under these conditions of high radiation rates, the organic compounds follow a degradation pathway that includes fragmentation, dehydration, ionization, oxygenation and aromatization. As a result, the final association of organic compounds that can remain on the planetary surface becomes very similar, when not identical. To this regard, it becomes essential to define a careful and integral strategy for a robust identification of the origin of the organics and, therefore, demonstrate whether or not they were produced by living forms. In this talk, it will be described an example of co-occurrence of highly oxidized organics sourced in biological and abiotic processes that were found in the extreme hyperarid environment of Atacama. Furthermore, it will be discussed the different criteria that are used to evaluate the origin of the oxidized molecules in the extreme system.*

**16:15-16:25 Brief Contributions (<5 minutes each)**

**Lessons learned deploying Penetrators in the Antarctic** - David Jones (Coventry University, UK)

Over the last 5 years the British Antarctic Survey has successfully designed, tested and deployed over 100 penetrators into glaciers from overflying aircraft. Here I will talk about some of the lessons learned managing the project "Aircraft Deployed Ice Observation System" (ADIOS).

**mg to g scale platforms for outer solar system missions** - Michael Johnson (Imperial College London, UK)

*Building on work developing subsystems for very volume and mass constrained interplanetary CubeSats (small spacecraft typically in the 1-10kg range), we have a number of platforms in development that could be of considerable utility for similarly constrained elements of larger missions such as the proposed Akon penetrator: - Thin-Film Spacecraft/Lander/Rovers (TF-SLRs) are very thin (<50um), low mass (<1g) self-sufficient probes able to be deployed in large numbers from small deployment devices. Able to return data to traditional orbiters, the deployment device or each other, these probes provide robust, compatible, yet disposable platforms for making large numbers of high risk high reward multipoint measurements with a minimal power and mass budget and can include a wide range of sensors including imagers. - For embedding in existing instruments and sensors, we are also developing a rad hard process independent Spacecraft-on-Chip (SpoC). Compatible with GaAs, SOI, and other processes, this open source IP core is designed to provide very low power processing, storage, communications and environmental monitoring (e.g. pH, temperature) for hostile environments. Its minimal footprint could be directly integrated into ASICs, MEMS devices, solar cells or as discrete devices for printed circuit boards as required. - PocketRTG is a very small radioisotope thermoelectric generator originally developed for interplanetary CubeSats targeting the outer solar system. With a footprint <5x5x5cm and able to provide electrical power of the order of mW for many decades, this flexibly fuelled power source could dramatically extend the life of some instruments using newly available <0.5g pellets of Americium-241.*

**16:25-17:00 Discussion & Next Steps**

**17:00 (sharp!) End**

