ABSTRACT BOOK

INTERNATIONAL WORKSHOP

EUROPA LANDER:
SCIENCE GOALS
AND EXPERIMENTS

9-13 FEBRUARY 2009

ИКИ

SPACE RESEARCH INSTITUTE (IKI)
MOSCOW, RUSSIA

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NAVIGATION AND CONTROL PROBLEMS DURING LOW-THRUST TRANSFER FROM EARTH TO JUPITER

E.L.Akim[1], V.V.Sasonov[1], V.A. Stepanyants[1], A.G. Tuchin[1], [1]*Russian Science Academy, Keldysh Institute of Applied Mathematics.*

The study is performed for the benefit of the project “Landing in Europa”. The possibilities of the mission navigation support are investigated in the interplanetary trajectory Earth – Jupiter including determination of spacecraft motion parameters (position and velocity) and parameters of low-thrust engines (LTE) (direction and magnitude of the thrust).

Navigation problem are considered in the long-term parts of the trajectory during LTE operating and in the coasting arcs. Russian ground-based radio systems performing rage, range rate, and 3-way Doppler are considered as a source of the tracking measurements.

Deviations of the acceleration vector from the nominal values arise due to errors of the thrust when the LTE operates. The orientation errors are negligible compared with errors due to LTE works. LTE execution errors are divided into the errors in the module of thrust vector and its direction. Error of the module does not exceed 6% of its value and in the direction it lies at the cone with the semi-angle of 1°. The execution errors were represented as a sum of systematic and noise components in order to estimate the accuracy of the spacecraft’s motion parameters determination. The systematic components are approximated by the linear functions of time in the interval of correlation. Their parameters are determined together with the spacecraft state vector using trajectory measurements.

As a result conducted investigations were obtained the dependences of the errors in determination and prediction of the spacecraft motion parameters and determination of value and direction of thrust vector from the duration of the intervals of the correlation of systematic errors, relationship of the values of systematic and noise components of errors, and from the frequency of trajectory measurements performing. The estimation is obtained of the addition fuel expense in order to thrust operation errors compensate. It is shown that the errors of navigation can be significantly reduced with the presence of onboard accelerometers with the accuracy not worse than 10-7 mm/s^2

JOVIAN MAGNETOSPHERE MAGNETOSPHERIC MAGNETIC FIELD AT EUROPA ORBIT AND USING MAGNETOMETER DATA TO STUDY OF THE EUROPA INTERIOR

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The electrodynamic interaction of the rotating Jupiter’s magnetospheric plasma with Europa leads to formation of the Alfven wings. An induced magnetic dipole Europa moment is driven by the external magnetic field of Jupiter. This induced dipole significantly exceeds the possible intrinsic magnetic dipole of Europa. The maximum magnetic field at the Europa’s equator is less than 25 nT, while the measured magnetic disturbance is greater than 100 nT. Inductive response is mostly significant. The field increases upstream and decreases downstream of the moon. At the center of the magnetospheric disc current sheet, large perturbations due to strong pickups are found by Galileo. An induced response depends on the external inducing field, the time varying part of Jupiter’s magnetic field at Europa’s location. The dominant variation is in the radial component.

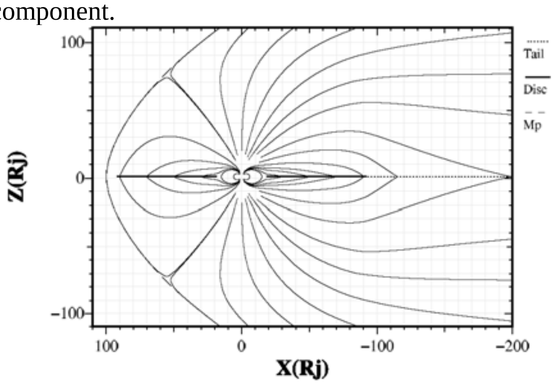

Fig. 1. Noon-midnight meridional cross-section. Total magnetic field from all magnetospheric sources screened by the magnetopause currents. Dashed line marks the magnetotail current sheet. Northward (southward) from the equatorial plane, the magnetic field is directed from (to) Jupiter. The transition from dipole like to stretched tail-like field lines in Jupiter magnetosphere near Ganymede orbit is shown (Alexeev and Belenkaya, 2005).

Our personal contributions on the Jupiter system study is in construction of the magnetospheric models which opposite to other model used now (Connerney or Khurana models) to take into account the outer magnetosphere global current systems (magnetopause and tail current) and give possibility to study the solar wind and IMF effects on the Jupiter magnetosphere. In results we will forecast the total magnetic field vector at spacecraft orbit inside Jupiter system as well as the contribution of the different sources (dipole, higher multypoles, plasma disk, magnetopause current, and tail current). We can take to account the different states of the Jovian magnetosphere. The effects Europa-magnetospheric plasma interaction near the jovian moon can be estimated also. The most significant scientific output in the sense of the Europa interior structure can be received by using simultaneous magnetic measurements on Europa lander and Europa orbiter spacecrafts.

EUROPA'S SURFACE COMPOSITION AND MORPHOLOGY - IMPLICATIONS TO INSITU TARGET DEFINITIONS

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Introduction:

Tides have created the two types of surface features on Europa: cracks/ridges and chaotic areas. The ridges are thought to be built over thousands of years by water seeping up the edges of cracks and refreezing. The cracks and grooves likely result from the flexions of the moon's crust due to the tidal interactions with Jupiter and the neighboring moons. The chaotic areas show evidence of the melt-through and exposure of a subsurface ocean. Housing such a global subsurface ocean, the surface of Europa can be decoupled from its rocky interior. Avery small number of craters on Europa suggests a young surface age (1).

Surface composition and morphology:

With an average density of 3.04 grams per cubic centimeter, Europa is predominantly a rocky object. The gravity data indicate that the rock is sandwiched between a central iron core and an outer crust of H_2O. The water layer is about 100 km thick (2). At surface temperatures between 110 and 50 K, the water at Europa's surface occurs in its solid state (3). Convective motions from subsurface regions may force the restructuring of the moon's surface. Whether the subsurface water is solid or quasi fluidal (slushy) is not known. Galileo observations (fig. 1) show dark spots in the northern hemisphere of the moon, so called lenticulaes. They are interpreted as an indicator for warmer ice moving upward from the bottom of the ice shell while colder ice sinks downward.

Fig.1: Surface structures on Europa's northern hemisphere; Credits: NASA/JPL/University of Arizona/University of Colorado, high res-data combined with colored.

Reddish-brown spots in fig. 1 indicate where liquid water probably melted through Europa's surface, hence giving hints of a subsurface ocean. Bright plains consist mainly of water ice as indicated by NIMS spectral data. The reddish material matches the laboratory spectrum of magnesium sulfate (3). The thickness of the ice crust is currently not known. Today's water environment on Europa depends on the hydrogen/oxygen depletion rate in the history of the moon (4). The examination of the subsurface water cycle on Europa requires robotic in-situ studies including melting technologies to penetrate the icy shell of the upper crust.

Surface target areas for insitu studies:

In order to better understand Europa's water/ice crust, future missions will focus on in-situ and subsurface studies. Planning these analyses requires the development of a detailed target definition strategy. The target definition of such studies has to include different surface areas with different tidal stresses, the local heat transportation mechanisms through buoyant and negatively buoyant diapirs, as well as seasonal dynamics in respect to the Sun and Jupiter. Multiple and alternative strategies have to be developed. The presentation deals with first steps for these target definition studies.

References:

1Sullivan, R ; Greeley, R ; Homan, K ; Klemaszewski,; Belton, M J ; Carr, M H ; Chapman, C R; Tufts, R ; Head, J W ; Pappalardo, R ; Moore, J ; Thomas, P ***Episodic plate separation and fracture infill on the surface of Europa. Galileo Imaging Team,*** Nature **391**, No. 6665, 371-3 (1998).

2 Pappalardo R T; Head J W; Greeley R . ***The hidden ocean of Europa, Scientific*** American , 64-73 (1999).

3Williams, K.K.; Greeley R ***Estimates of Ice Thickness in the Conamara Caos Region of Europa, Geophysical*** Res. Let.,**25**, 4273–4276 (1998).

4 Greeley R. et al. ***Europa: Initial Galileo Geological Observations***, Icarus **135**, 4-24 (1998).

SOLAR WIND - JOVIAN MAGNETOSPHERE COUPLING

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A paraboloid model of the Jovian magnetosphere is presented. The magnetopause is approximated by a paraboloid of revolution. The magnetospheric magnetic field consists of the planet dipole field, the field of the magnetotail current sheet, the magnetodisc field, and the portion of interplanetary magnetic field which penetrates into the magnetosphere. All magnetic fields of the magnetospheric origin are screened by the magnetopause currents. This model allows us to study the electric fields and plasma motions caused by the unipolar Jupiter's inductor and the solar wind MHD generator. Jupiter’s auroral emission demonstrates the electrodynamic coupling between the ionosphere and magnetosphere. The paraboloid model provides mapping along highly-conducting magnetic field lines and is also applied for consideration of the stability of the background plasma disk in the rotating Jupiter magnetosphere with respect to the flute perturbations.

IMPACT-PRODUCED EXOSPHERE OF EUROPA

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Introduction:

Atoms of several elements were detected in the exosphere of Europa, including oxygen (Hall et al., 1995), sodium (Brown and Hill, 1996) and potassium (Brown, 2001). Study of thin atmosphere of this Jupiter's moon can be useful for understanding the chemical composition of its surface.

Photon-stimulated sputtering and decomposition of Europa's surface produce this atmosphere (Leblanc et al., 2002). However, meteoroid impacts can be also considered as minor source of Europa's atmosphere, especially during collision of the comet Shoemaker-Levy 9 with Jupiter (Shulman, 2002). In this paper we study chemical composition of impact-produced exosphere and photolysis of impact-generated Na- containing species.

Chemistry of impact-produced fireballs: Jupiter-family comets strike Europa with velocities between 20 and 30 km/s (Zahnle et al., 1998). The elemental composition of the impact-produced fireball was taken to be that of a mixture of 4 wt% of CI chondrites taken as impactors and 10 % of the lunar ferroan anorthosites, 78 wt% H_2O, 5 wt% CO_2, 0.9 wt% SO_2 ices, 2 wt% Na_2SO_4, and 0.1 wt% K_2SO_4 modeling the elemental composition of Europa's surface. Target-to-impactor mass ratio in the expanding hot cloud is taken from (Cintala, 1992).

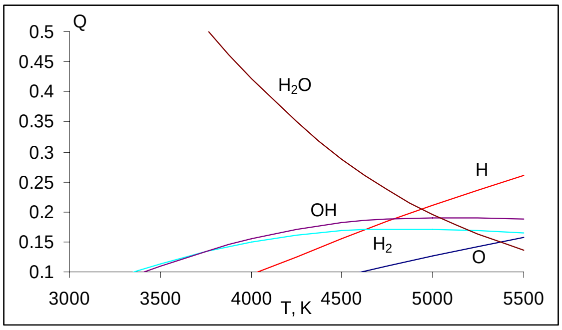

Figure 1. Equilibrium content of main species in the impact-produced fireball.

Thermodynamic calculations based on quenching theory [3] were conducted in order to estimate the chemical composition of the fireball as it adiabatically cooled to the point where chemical reactions effectively stopped. The initial fireball temperatures and pressures were set equal to 10^4 K and 10^3 bars, respectively. It was assumed that chemical reactions end when the chemical and hydrodynamic time scales became comparable. For a typical meteoroid size of about 0.1 mm, the hydrodynamic time scale is 10 ns at the assumed fireball expansion speed of about 10 km/s. Quenching of the main reactions in the fireball occurs at about 3000-4000 K and 30-100 bars for 0.1 mm impactors (Berezhnoy et al., 2003) and at about 2500 K, 3 bars for 10-m impactors typical for the case of SL9-Jupiter collision.

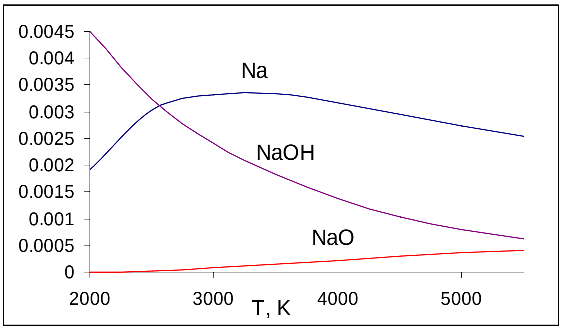

Figure 2. Equilibrium content of Na-containing species in the impact-produced fireball.

Thermodynamic calculations of the chemical composition of expanding hot cloud were performed for different temperatures and pressures. If equilibrium condensation takes place than the main H-, S-, Na-, K- bearing species are H_2O, OH, H_2, SO_2, SO, Na, NaOH, KOH, and K, respectively (see Fig. 1 and 2). Due to high O/C ratio in the expanding hot cloud, the main C-bearing species are CO and CO_2 (see Fig. 3) while the content of impact-generated hydrocarbons is very low. Thus, complex organic compounds which can be formed on the Europa's surface during irradiation of ices are destroyed by impact processes. Deuterium exchange between main O, H- bearing species in the expanding hot cloud leads to enrichment of impact-produced water ice grains by deuterium on about 20 ‰, additional enrichment is achieved due to preferred loss of lighter H-bearing species to the space by gravitational escape.

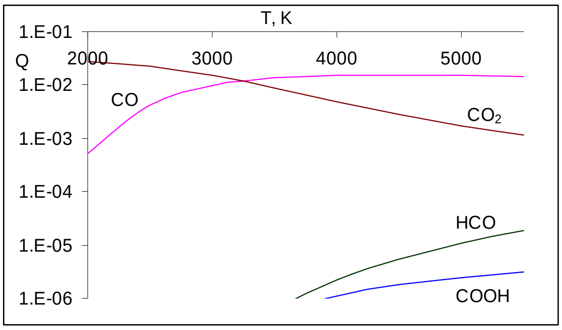

Figure 3. Equilibrium content of C-containing species in the impact-produced fireball.

Properties of impact-produced exosphere: Sodium is primarily sputtered as Na atoms with a small molecular component, NaX where X could be oxygen or sulfur (Wiens et al., 1997). NaO and NaOH are abundant in the impact-produced fireballs (see Fig. 2). Due to significance of formation of molecules in the Europa's exosphere photolysis lifetimes of molecules and velocity distribution of photolysis-generated atoms are important parameters for modeling the properties of this exosphere. Lifetime for electron-impact dissociation of NaX is assumed to be 10 hours, a receiving additional energy of each atom after photolysis is assumed to be between 0.5 and 1 eV by (Leblanc et al., 2002). However, NaOH and NaO photolysis lifetimes at 300 K are estimated to be 10 and 40 s on Earth (Self and Plane, 2002) or 4 and 16 min on Europa, respectively. Typical temperature of impact-produced cloud after termination of chemical reactions is about 3000 K. NaOH and NaO photolysis lifetimes decrease with increasing temperature due to additional population of excited energy levels. It means that NaO and NaOH photolysis lifetimes are even lower than several minutes and dissociation rates of Na-containing molecules on Europa are determined by photolysis, not by electron impact.

Based on energy and momentum conservation laws, the velocity distributions of photolysis-generated Na atoms are estimated from the solar flux (Huebner et al., 1992) and NaOH, NaO photolysis cross sections (Self and Plane, 2002). Average excess energies of Na atoms produced through NaOH and NaO photolysis are 0.3 and 0.4 eV, respectively. Width at half-maximum is 0.1 eV for both cases; velocity distribution functions have narrower maxima than that of Maxwellian distribution at corresponding temperatures. If during NaOH photolysis NaO and H species are formed than the majority of excess energy is transformed to the kinetic energy of lighter component, hydrogen atom.

During collision of the comet Shoemaker-Levy 9 with Jupiter lines of Fe, bands of MgO, CO, and CN were detected in the vicinity of Europa (Shulman, 2002). These species represent cometary coma because we expect quite different chemical composition of impact-produced fireballs. For example, very bright Na lines were not detected during Shoemaker-Levy 9 - Jupiter collision while we expect strong sodium emission during collisions between comets and Europa. The CN content in the impact-generated fireballs is very low, about 10^{-11}, while CN lines are very bright in cometary spectra and in the vicinity of Europa during the collision between the comet and Jupiter. If detected lines have cometary origin than estimation of mass ($7*10^{12}$ kg) of bodies collided with Europa (Shulman, 2002) comparable to the mass of biggest Shoemaker-Levy 9 fragments and required for explanation of the intensity of detected variable lines and bands can be reduced to a reasonable value.

Conclusions: Chemical composition of impact-produced fireballs on Europa is estimated. Properties of photolysis-generated Na atoms are considered. Meteoroid bombardment leads to enrichment of D/H ratio in water ice and destruction of complex organic compounds on Europa. Previous possible detection of cometary impacts on Europa is still very tentative. Micrometeoroid source of Europa's exosphere can be studied by mass spectrometers on board future Europa landers.

References:

Berezhnoy, A. A. et al. (2003) *PASJ 55,* 859-870.
Brown, M. E., Hill, R.E. (1996) *Nature 380,* 229–231.
Brown, M. E. (2001) *Icarus 151,* 190–195.
Cintala, M. (1992) *JGR 97,* 947-973.
Hall, D. T. et al. (1995) *Nature 373,* 677.
Huebner, W. F. et al. (1992) *Astrophys. Space Sci. 195,* 1-289, 291-294.
Leblanc, F. et al. (2002) *Icarus 159,* 132-144.
Self, D. E., Plane, J. M. C. (2002) *Phys. Chem. Chem. Phys. 4*, 16-23.
Shulman, L. M. (2002) *Proceedings of Asteroid, Comet, Meteors Conference, p. 289-292,* July 29 – August 2, 2002, Berlin, Germany.
Wiens, R. C. et al. (1997) *Icarus 128,* 386–397.
Zahnle, K. et al. (1998) *Icarus 136*, 202-222.

IN-SITU ANALYSIS OF EUROPA ICES BY MELTING PROBES

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Introduction:

A key aspect for understanding the astrobiological potential of planets and moons in the Solar system is the analysis of material embedded in or underneath icy layers on the surface. In particular in case of the icy crust of Jupiters moon Europa such investigation would be of greatest interest.

Technique:

The most obvious technique to penetrate ice layers with small and reliable probes which do not require the heavy and expensive equipment of a drilling rig is by melting. Since the energy demand is high, in case of an extraterrestrial application (Europa), only heating with radioactive material seems feasible to reach significant depth, in particular the postulated ocean below an ice crust tens of km thick. In case of Europa such a probe needs to allow in-situ analysis. Data transmission to the surface element would be performed with long wave RF technology.
The necessary power is driven by the desired penetration velocity (almost linearly) and the dimensions of the probe (third potency).

Tests:

While melting probes have successfully been used for terrestrial applications e.g. in Antarctic ice, their behaviour in vacuum is different and theory needs confirmation by tests. The planetary simulation chamber at DLR in Cologne has been used to perform a series of melting tests in cold (LN2-cooled) water ice samples. The feasibility of the method could be demonstrated and the energy demand for a space mission was estimated.

Results:

The paper will explain the results of tests in vacuum and underline technological areas where further development is needed. In order to understand the physical and chemical nature of the ice layers, as well as for analysing underlying water, a melting probe needs to be equipped with a suite of scientific instruments that are capable e.g. of determining the chemical and isotopic composition of the embedded or dissolved materials. An overview of potential instrumentation (like miniaturized spectrometers) will be given.

Short range melting probe for a Europa Lander:

While the long-term goal is to penetrate thick ice crusts and explore the ocean beneath, in the short run (e.g., to equip an Europa Lander for ESA’s Cosmic Vision!) a simple melting probe to access the uppermost meters of Europa’s crusts (where radiation levels are already low enough to permit the long term survival of organic matter) appears to be feasible. Variants with radioisotope and electrical heating and both sampling and in-situ probes will be presented.

THE EUROPA-JUPITER SYSTEM MISSION: STUDY RESULTS AND PROSPECTS

Michel Blanc *(CESR and EcolePolytechnique)*, **Bob Pappalardo** *(JPL)*, **Ron Greeley** *(ASU)*, **Karla Clark** *(JPL)*, **Jean-Pierre Lebreton** *(ESA/ESTEC)*, **Anamarija Stankov** *(ESA/ESTEC)*, **Paula Grunthaner** *(JPL)*, **Peter Falkner** *(ESA/ESTEC)*, **Masaki Fujimoto** *(JAXA)*, **Lev Zelenyi** *(IKI) and the EJSM team*

The Jovian System is one of the most interesting scientific targets in the Solar System. It is a small planetary system in its own right, built-up out of the mixture of gas and icy material that was present in the external regions of the solar nebula. Through a complex history of accretion, internal differentiation and dynamic interaction, a very unique satellite system formed, in which three of the four Galilean satellites are locked in the so-called Laplace resonance. The energy and angular momentum they exchange contribute to various degrees to the internal heating sources of the satellites. Unique among them, Europa is believed to shelter an ocean between its active icy crust and its silicate mantle, where the main conditions for habitability may be fulfilled.

Building on the heritage of the LAPLACE proposal to ESA and of the NASA SDT studies of a Europa Orbiter and of a Jupiter System Observer, ESA and NASA have now completed a joint study of the the Europa Jupiter System Mission (EJSM), an ambitious international mission to explore in depth the Jovian system and its Galilean satellites. EJSM/Laplace addresses one overarching goal: to study the reality and the conditions of the emergence of life in the icy worlds of giant planets. More specifically, the mission will address three inter-related themes concerning the Jupiter system and its evolution: How was it formed? What are its relevant processes? Does it harbour habitable worlds?

To achieve its goals, EJSM will focus on Europa and Ganymede as the key pair of Galilean satellites whose detailed comparison will shed light on their formation, internal structures and habitability. EJSM will also provide the basis for a detailed understanding of the Galilean satellite system and its coupling to the whole Jovian system: Jupiter’s atmosphere and interior, Jupiter’s magnetosphere and magnetodisk. From its different components and themes, EJSM will allow an integrated understanding of the Jupiter System to emerge for the first time.

EJSM will deploy in the Jovian system two orbiting platforms to perform coordinated observations of its main components. The Jupiter-Europa Orbiter (JEO), to be provided by NASA, will perform a tour of the Jupiter system before going into Europan orbit for a multi-month study of this moon. Similarly, the Jupiter- Ganymede Orbiter (JGO), to be provided by ESA, will perform a different tour of the Jupiter system, then will move into a resonant orbit with Callisto, the fourth Galilean satellite and the only one outside the Laplace resonance. Finally, JGO will go into Ganymede orbit to study this moon and its magnetosphere. During their orbital tours, JEO and JGO will also perform synergistic and coordinated observations of a host of different targets in the Jupiter system.

In addition, JAXA is studying an additional ambitious stand-alone mission that would deliver a Jupiter Magnetosphere Orbiter (JMO), a spinning platform with a suite of instruments tailored to the objectives of magnetospheric science, and a probe that would fly by one or several of the Trojan asteroids, a family of small bodies which might be remnants of the population of icy planetesimals from which Jupiter’s core formed. This JAXA contribution, if it materializes, will contribute very significantly to the “Origins” and “Magnetosphere” themes of EJSM.

Both JGO and JEO will perform during their moon orbit phases a full mapping of the surfaces, sub-surfaces, interiors and planetary fields. This full cartography performed at high resolution will provide the necessary basis for the selection and analysis of potential landing sites for a follow-on lander.

Thus the EJSM mission can serve as the precursor of the Europa lander mission under study by RosCosmos and IKI, whose science and payload definition are the subject of the present workshop.

We will summarize the results of the assessment study of EJSM by ESA and NASA,, the capabilities of the planned payloads, and the outstanding opportunity that EJSM offers to produce a new view of the Jovian system and particularly its Galilean satellites just four centuries after their discovery by Galileo Galilei, and to prepare for the next major step forward: land on Europa’s surface.

SURFACE ENHANCED RAMAN SPECTROSCOPY (SERS) AS A LOW RESOURCE ANALYTICAL MEASUREMENT FOR DIRECT LIFE DETECTION ON ICY MOONS

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Key life detection/astrobiology experiments on the surface of an icy-moon will involve image acquisition, chemical measurements and/or measures for metabolic activity. Useful support experiments would seek to characterise environmental parameters, assess habitability and elucidate the geology and mineralogy of the surface. Analytical instruments utilising Raman spectroscopy could be used for many of the support measurements. The addition of microfluidic devices (designed to process samples and facilitate SERS) to Raman instrumentation primarily intended for support measurements could allow it to perform direct life detection. The focus of this paper is on using such an instrument to measure trace quantities of organic compounds, biological or non-biological in origin. But we note that the use of a Raman active substrate in experiments seeking to stimulate and then record metabolic activity, would effectively yield an instrument package capable of all three types of life detection experiments in addition to support measurements.

Raman spectroscopy has widely been adopted as a “first responder tool” for characterising an unknown material. Unfortunately Raman signals are inherently weak, and while this doesn’t impact the characterisation of an unknown material, it severely limits the detection of trace quantities of organic molecules in an inorganic sample matrix. In the laboratory this is routinely overcome by performing measurements with a microscope, and focusing a beam onto a point of interest. In this way the small quantities (> 0.5 %) of organic carbon present in a rock can be isolated and characterised. Such an approach would be hard to replicate remotely over a great distance with two way light times in excess of 80 minutes. To overcome the generic issue of low concentrations of a dispersed analyte, analytical chemists typically use an organic solvents to dissolve and isolate (or extract) an organic component from a sample, and performing measurements on the analyte dissolved in the solvent, possibly after reducing the volume of the solvent to boost the intensity of the analyte’s signal. This procedure can be automated and extremely rapid. However, for Raman spectroscopy this approach frequently fails because the resulting spectra reflect only the organic solvent, and not the small quantity of analyte.

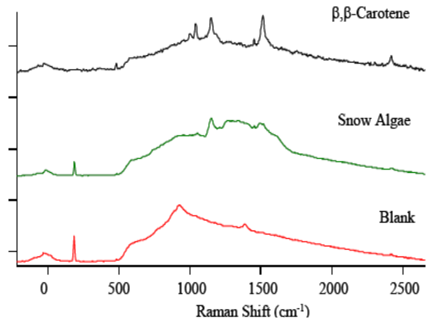

Figure 1. Left image of snow algae. SERS spectra obtained using a 514 nm light source and silver substrate. Measurements performed on the solvent extracts of melted snow.

Surface enhanced Raman spectroscopy (SERS) is Raman spectroscopy performed to take advantage of the enhancement in Raman signal observed when an analyte is adsorbed onto a metal surface. It facilitates the analysis of trace organic compounds in an organic solvent by increasing the signal generated by an organic compound over that of the solvent (typically by a factor of 10^6 or more). Shown in the Fig. 1 are the spectra obtained for a sample of snow impregnated with snow algae, (although such a life mode is unlikely to find a viable habitat on the surface of any currently known icy moon). Such spectra differ slightly from conventional Raman spectra, but can usually be interpreted in a similar way.

Microfluidic devices for sample processing can have smaller footprints, typically a lower mass (although their support systems must also be accounted for) and additional functionality over their bench-top counterparts. We have used microfluidic devices to prepare samples for SERS analysis and to process and extract organic matter from sample matrices. An example is shown in Fig. 2. A microfluidic device was used to extract and concentrate . -carotene from a magnesium sulphate crystal that contained small intracrystalline quantities of the compound. The concentration of carotene in the crystal is approximately 10-50 ppm by mass. Such a low concentration (while probably optimistic) better represents the likely concentration in materials solidified from aqueous geothermal fluids at areas of up-welling on an icy moon, than the snow algae in fig. 1.

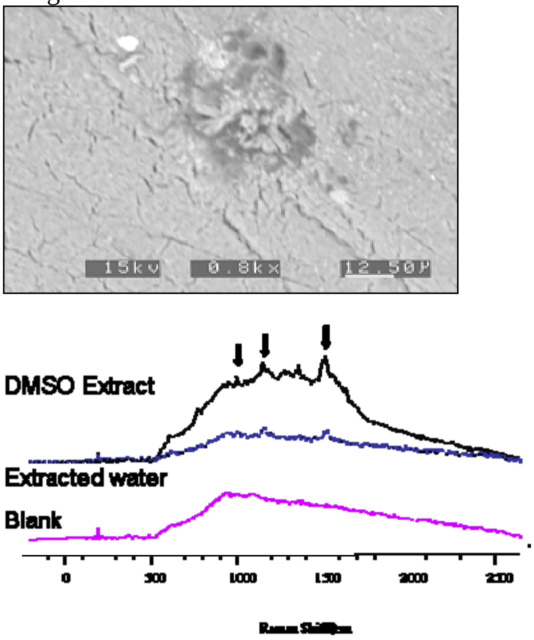

Figure 2. SEM image of organic compound encased in a sulphate mineral, and SERS spectra obtained for the organic compound (carotene), after its extraction and concentration in a microfluidic device (a combination H-cell).

The presence of a single strongly responding SERS compound is still unlikely, more probable is a mixture of compound types with a predominance of chemically resistant structures such as high ring number PAH. SERS spectra for the solvent extract of a mineral deposit formed by a high temperature thermal spring is shown in fig. 3. Its main spectral features are comparable to the spectra obtained for traces of solid organic matter present in ancient rocks on Earth (the D1 and D2 peaks characteristic of insoluble polymeric organic matter). In this instance the spectra is not proof of any biogenicity, but indicates that large molecular weight carbon based molecules are present (although on Earth these result from the natural pyrolysis of biological organic matter).

Given the limited resources (mass and power) available for astrobiology instrumentation on an icy moons lander within Jupiter's radiation belt, a combination Raman/SERS instrument could be an extremely attractive way of performing high risk but crucial analysis for direct life detection. By sharing resources with instruments designed for less risky surface measurements such as mineralogy, a SERS facility on an icy moons lander could provide an economic analytical window for low concentrations of biologically important organic compounds.

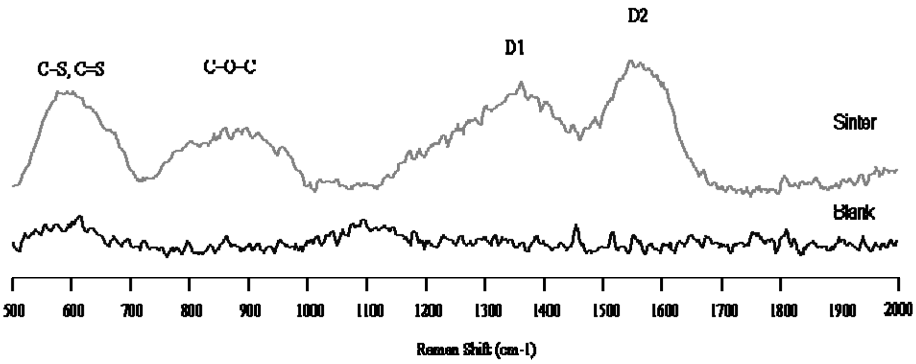

Fig. 3. SERS spectra of trace quantities of organic matter present in a high temperature spring mineral-deposit.

CONCEPT MAGNETOMETER DESIGN FOR A EUROPA LANDER

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In order to define both the time variable inducing magnetic field at Europa and the resulting induction signal, simultaneous measurements from a Europa orbiter, and platform lander are desirable. Multi-frequency sounding at frequencies which enable probing of the interior is necessary in order to constrain the location and thickness of any subsurface ocean.

A Europa lander poses considerable engineering challenges for payload developers. Instrumentation and sensors need to be low volume, low mass, low power, highly tolerant to ionizing radiation and capable of science grade measurement in a low ambient temperature (50K-110K). We present a conceptual design for a DC vector magnetometer compatible with these constraints. The instrument is composed of an ultra low mass sensor based on magneto-resistance together with associated electronics. The baseline arrangement utilizes two spatially separated sensors operating as a gradiometer fitted to a rigid boom in order to separate the ambient field from the lander disturbance field. Multiple sensor arrangements can also be envisaged depending on magnetic cleanliness and boom constraints and combinations wit a compact fluxgate are also possible if resources permit. Digital implementation of the sensor control loop facilitates fast and flexible migration into radiation hardened power optimized FPGAs or ASICs making such a magnetometer attractive for instrumentation suites featuring centralized control and processing likely to be utilized on a compact lander.

LIFE DETECTION STRATEGY FOR SUBGLACIAL LAKE VOSTOK, ANTARCTICA: LESSONS FOR BIOEXPLORATION OF THE JUPITER MOON EUROPA

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Introduction:
Bacterial 16S ribosomal gene analysis guarded by criteria for trace DNA analysis and Ancient DNA research testifies for the very low biomass in lake ice (Fig. 1) from giant subglacial Lake Vostok buried beneath 4-km thick East Antarctic ice sheet.

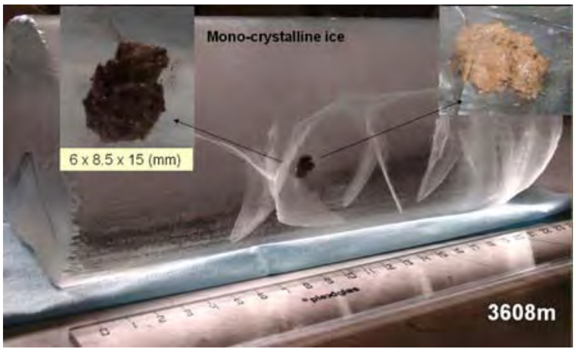

Fig. 1. Lake ice sample ‘Big Kamina’ (3608 m depth) as analogue of an extraterrestrial sample

The lake ice seems to be essentially germ-free indicating that the water body should also be hosting a highly sparse life, if any (Fig. 2).

Ice species	Sample (m)	Bacteria (cells/ml) (Flow cytometry)
Vostok glacier	Snow V5	0
	Snow V14	0
	122 (dry coring)	1.9
	2005	2.4
	2054	3 - 24
	3489 – sediments	0
Vostok accretion 1	3561	4 – 9
Vostok accretion 2	3622	0.6
	3613	3 (2.4 – 3.1 SR)
	3621	2 (2.4 – 4.4 SR)

S Rogers 2008
3501
2.3 ± 0.3 - 12.3 ± 9.6
3610
Microscopy
Bulat et al (2008) Unpublished

Fig. 2. Cell counts in Vostok ice core

Therefore the life detection strategy for Lake Vostok must consider a high chance of contamination similar to forward-contamination upon searching for extraterrestrial life.

Contamination Issues: For Lake Vostok and similar icy environments a special set of indexing contaminant criteria were developed which allowed recognizing most findings as contaminants. The current way to avoid contamination appears to use stringent chemistry-based decontamination procedures and clean (dust-free) room facilities (Fig. 3) along with comprehensive biological controls including establishment of contemporary contaminant database (Fig. 4) as a prerequisite to identify and categorize sources of contaminants.

Fig. 3. Working on lake Vostok ice biocontent in clean (dust-free) room facilities

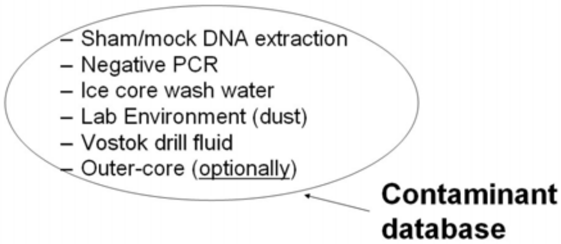

Fig. 4. Comprehensive biological controls

More challenge would be to advance cleanliness and sterilization approaches and procedures in order to achieve and measure the level of cleanliness appropriate for tools exploring icy environments like Lake Vostok.

Life Detection Strategy: The life detection strategy for (sub)glacial environments on Earth or Jovian’s Europa should be based on: (i) stringent ice decontamination procedures to meet chemistry and trace DNA analysis standards, (ii) certification of various environments in contact with ice samples for biological contents, (iii) appropriate methods to uncover not only Earthly known life, (iv) verification of findings through their possible metabolic profiles as can be deduced from physical and chemical features of an icy environment and (v) repetition at an independent laboratory.

MATHEMATICAL SIMULATION OF CRYOBOT MOVEMENT

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Introduction

The idea of penetrating of Jovian moon's Europa ice shell leads to design the suitable equipment, namely cryobot.

The cryobot motion through the ice shell can be realized by means of ice thaw in its vicinity using the heating of its surface till the necessary temperature.

We suppose that the suitable equipment must be of maximum compactness and effectiveness. It is clear that the problem of transportation of any mass to the surface of a planet on its moon is a main one for the weight and dimension limits for equipment.

Analysis of the problem

The relation connecting the stress and strain tensors, well known from the elasto-plastic theory, is usable for description of the ice structures physical condition. The thaw process of the ice shell is steady state and quite slaw, and the equilibrium equations must exist on every step of solution. The temperature field in the vicinity of the object being under consideration must be determined in order to obtain the stress-strain field.

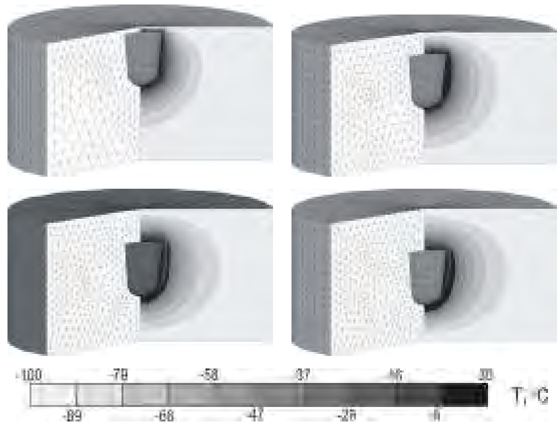
We suppose in order to obtain the approximate solution of the problem that the external medium is isotropic one and homogeneous and its properties are the functions of the temperature only. We use for the solution of the problem the heat conductivity equation.

It must be undersigned that the boundaries determining the boundary value problems for the stress-strain and the temperature fields are variable. They are determined by the physical condition of the medium external to cryobot and defined from its position.

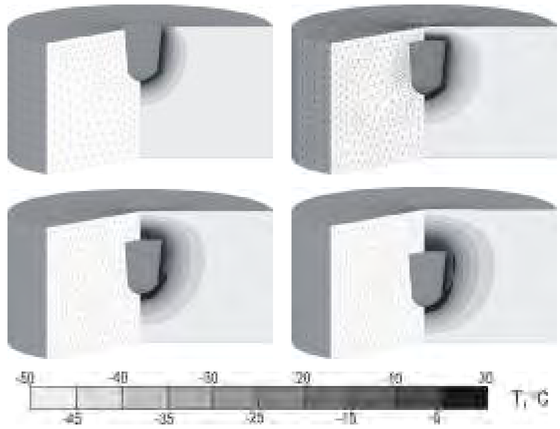
Let us consider a small-dimensional object with the surface having a constant temperature greater then the melting temperature of external ice.

One can calculate the stress-strain and the temperature fields of the medium external to such object considering the different positions of the object during its slaw movement.

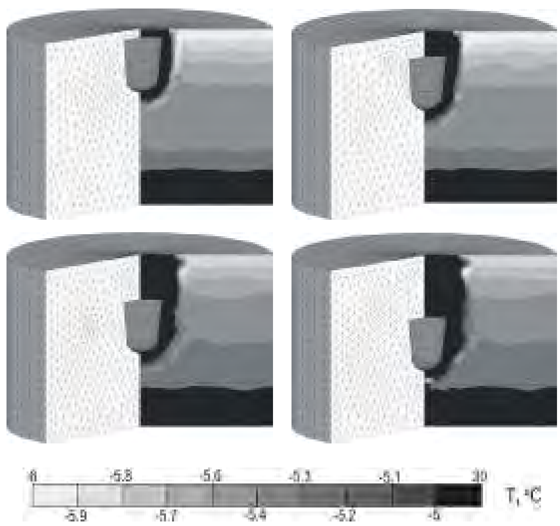
The approximate solution of the boundary-value problems has been obtained using the finite-element method in the cylindrical coordinate system. The triangle finite elements of ring shape were used.



(*a*)

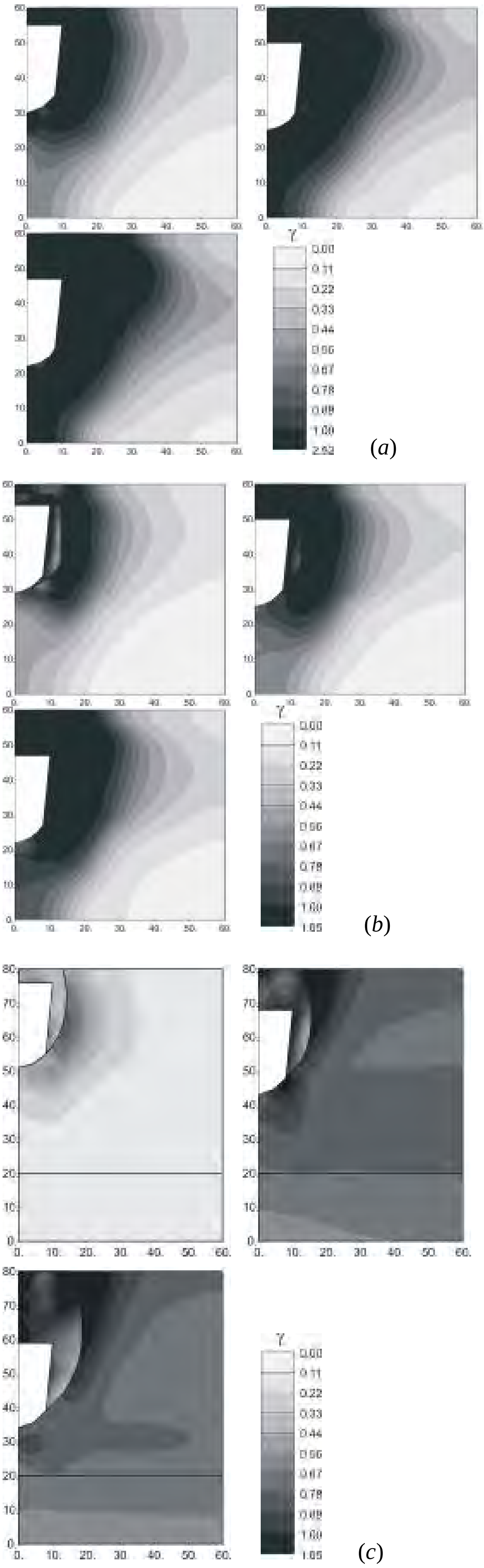


(*b*)



(*c*)

Fig 1. The temperature fields in the ice structure by the temperatures: 100ºC (*a*), 50ºC (*b*), 6ºC (*c*)



(*a*)

(*b*)

(*c*)

Fig 2. Random regions of the fractures of the ice structure by the temperatures: 100ºC (*a*), 50ºC (*b*), 6ºC (*c*)

The fast of vital importance for more exact solution is that the properties of the medium being under consideration are different relatively to the tension and compression. The ultimate strength of compression is greater then ultimate strength of tension.

One take this regularity into account if suppose that the ultimate strength of shearing stresses is dependent from the ultimate strength of the normal stresses in the same plane.

The fracture theory of Schleicher-Naday based on this phenomena give the possibility to determine the stress-strain condition of the medium in the moment of fracture.

Conclusion

The numerical estimation of the stress-strain state of the ice structures during the thaw process give the information concerning the problems one must solve for cryobot design.

It is of vital importance the generating of the ice medley in the vicinity of cryobot.

Continuous changing of the pressure, density ad viscosity of the ice near cryobot leads to nonlinearity of the problem relatively to all parameters.

The medley generation makes the penetrating process through the ice shell faster or slower. It depends of the boring technology.

The new investigation of all these problems is strictly necessary for study of the ice shell of Jovian moon Europa by means of special probes equipped with cryobots.

CURRENT STATUS OF THE EJSM JUPITER EUROPA ORBITER FLAGSHIP MISSION DESIGN

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NASA and ESA have embarked on a joint study of a mission to Europa and the Jupiter system with orbiters developed by NASA, ESA, and possibly JAXA. An international Joint Jupiter Science Definition Team (JJSDT) is defining the science content for the Jupiter Europa Orbiter (JEO) mission study run by NASA and for the Jupiter Ganymede Orbiter (JGO) mission study run by ESA. Engineering teams for both missions are working closely with the JJSDT to define mission concepts that optimize science, cost, and risk. The NASA-led JEO mission would address a scientifically rich subset of the complete EJSM science goals and would be designed to stand alone or in conjunction with the ESA-led JGO. This paper focuses on the NASA-led JEO mission and will describe the concept in the context of a standalone mission.

An orbital mission to Europa is driven by the desire to investigate an astrobiological archetype for icy satellite habitability, with a putative warm, salty, water ocean with plausible energy sources. Additionally, JEO would explore the Jupiter system to better understand how Europa’s possible habitability is related to the formation scenario of the other Jovian satellites. The JEO mission would perform 2.5–3 years of Jupiter system science, including encounters with Io, Ganymede and Callisto, before insertion into orbit around Europa for a comprehensive set of science campaigns lasting for up to one year. This paper will highlight the JEO mission design and implementation concept. The work reported was sponsored by the National Aeronautics and Space Administration.

THE SURFACE COMPOSITION OF EUROPA AND IMPLICATIONS FOR A LANDED MISSION.

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Introduction: The materials which make up the surface of Europa are of serious concern to the design of a landed mission. Spectral observations from ground-based telescopes and spacecraft missions have provided a window into understanding the surface composition. While water ice (in both crystalline and amorphous states) is known to be the primary surface compound, other materials are present, particularly in the dark and disrupted terrains. These are expected to include acids, bases, alkaline salts, and volatile compounds, and may even include biogenic materials. The possibility of biological materials in the near-surface, or detritus resulting from destruction of biological material, cannot be ruled out on the basis of available data.

Radiation effects: The unique conditions of temperature and radiation at the surface have led to the creation of compounds not generally found on the surface of the Earth. Radiolysis driven by magnetospheric charged particles, as well as ultraviolet photolysis, directly affect the upper surface layer [1,2]. The Io torus and the Jovian magnetosphere are believed to be an important source for elemental hydrogen, oxygen, sulfur, chlorine, potassium and sodium; less abundant elements are likely to be present below current detection limits as well. This material is mixed into the regolith to a depth of 1-2 meters by micrometeorite impact gardening [3]. Chemistry resulting from charged particle irradiation is most pronounced on the trailing hemisphere, where the flux is highest, and grows progressively weaker toward the north and south poles. The bulk of the energy is deposited by electrons in the 20-80 keV range [1,3]. Large molecules, having larger radiation cross-sections, are most susceptible to destruction by charged particle bombardment, but high bond strengths may provide a measure of resistance to destruction [4]. Free radicals produced in radiolysis are involved in further chemical reactions [1]. Destruction of H_2O also produces hydrogen and oxygen, which scavenge electrons from surface materials and promote additional chemical reactions [1,3,5].

Volatile compounds: Carbon dioxide (CO_2), hydrogen peroxide (H_2O_2) and sulfur dioxide (SO_2) have been detected in Galileo Near-Infrared Mapping Spectrometer (NIMS) observations [5,6,7]. These are believed to be products of radiolysis involving simple volatiles, and it is likely that equilibrium between creation and destruction of these compounds is being maintained over geologic time. Other expected volatile ices include hydrogen sulfide (H_2S), sulfur monoxide (SO), carbon monoxide (CO), molecular oxygen (O_2), ozone (O_3) and formaldehyde (H_2CO) [8,9,10,11].

Hydrates: While water ice was identified from ground-based telescopic spectra [12] in the 1970's, it was apparent that not all of the water was in a pure state. Asymmetric and distorted water absorption features in Europa's spectrum indicate the presence of water in a bound state which does not permit all of the vibrational modes occurring in pure crystalline and/or amorphous water ices [13,14,15]. Galileo observations indicate that these asymmetric absorption features are strongest in the dark, disrupted terrains, such as linea, chaos and lenticulae [16,17]. The strength of these features is anticorrelated with the visual albedo, which is darkest on the trailing hemisphere and brightens towards the pole as well as toward the leading hemisphere [16,17]. This indicates a relationship to charged particle bombardment, yet the correlation with geologic features also indicates a degree of endogenic control [18,19,20].

Infrared spectral behavior. A number of hydrated compounds exhibit such spectral absorption features, and in particular, the family of sulfate hydrates tend to have absorption features quite close to the observed vibrational frequencies [16,21]. The magnesium sulfate hydrates ($MgSO_4 \bullet nH_2O$, n=1,1.5,2,3,4,5,6,7,11), sodium sulfate hydrates ($Na_2SO_4 \bullet _n H_2O$, n=10; $Na_2Mg(SO_4)_2 \bullet 4H_2O$), and sulfuric acid hydrate ($H_2SO_4 \bullet nH_2O$, n=4,6,8) have the most similar spectral structure and vibrational frequencies to those observed by Galileo NIMS, but no single compound yet proposed matches the observations exactly [20, 21]. Cryogenic laboratory spectroscopy of these compounds has shown that, at Europan surface temperatures of 80 to 120 K, hydrated sulfates exhibit spectral fine structure that can be used to distinguish between these compounds [21,22]. These spectral features range from 5 to 40 nm in width [21,22]. Linear mixture modeling of Galileo NIMS observations using cryogenic laboratory spectra of water ice and sulfate hydrates suggests that the surface may be comprised of a mixture of compounds [16,17,20,21]. Model results suggest a surface of approximately 60% sulfuric acid hydrate, with the remainder a mixture of the hydrated sulfate salts epsomite ($MgSO_4 \bullet 7H_2O$), hexahydrite ($MgSO_4 \bullet 6H_2O$) and bloedite ($Na_2Mg(SO_4)_2 \bullet 4H_2O$) [20].

Endogenic vs. exogenic processes. The origins of these materials are not well understood and debate over the relative importance of exogenic (radiolytic and photolytic chemistry) and endogenic (aqueous geochemistry and interior transport) processes has been lively [16,17,18,19,20]. Sulfuric acid hydrate is easily produced by radiolysis of sulfur and water [8]; the sulfur could have originated from Io and been implanted into Europa's surface [18,19]. This model requires no endogenic inputs. In contrast, it is more challenging (while not impossible) to construct a model in which the hydrated sulfate salts are generated solely by radiolysis of implanted elemental Mg and Na in H_2O. Several lines of reasoning suggest that sulfate brines have been produced in Europa's ocean, and made their way to the surface by way of interior convection [23,24]. This could provide hydrated sulfate salts in disrupted surface features [25]. Radiolytic processing of this material, or implanted sulfur, or both, could produce hydrated sulfuric acid [8,18]. It should be noted that all of the hydrated sulfates proposed are white in color, though radiolysis of sulfur can create polymers with reddish tints [26]. A satisfying explanation may require a combination of processes and compounds.

Surface Texture: Estimates of porosity from Voyager, Galileo and ground-based photometry indicate a highly porous surface suggestive of a vapor-deposited frost, or extremely fine-grained regolith [27,28,29,30,31]. Yet some models of infrared spectral absorption in icy regions are best matched using large water-ice grain sizes [13,17]. This could be due to very long infrared path lengths in a highly scattering, porous medium. Engineering considerations for a lander should include possibilities ranging from thin frost deposits on ice slabs, to deep terrestrial snow with probable large-grained ice (1 cm and possibly even up to 50 cm at depth). While these are extreme limits, they are within the range of various models proposed to explain the observations [17,29].

Reactivity: Any surface lander must be prepared to operate not only under extreme temperature conditions, but in an environment containing highly reactive compounds. While reaction rates are far lower in solids than in liquid states, and lower at Europa surface temperatures than under terrestrial conditions, they are not necessarily zero. Melting of the surface ice, either during landing operations or due to lander activities, will create a potent chemical stew. There is no reason to assume that such a melt will be in thermodynamic equilibrium. Acids of sulfur, carbon, and chlorine are to be expected, as are alkaline salts of $MgSO_4$, Na_2SO_4, $NaHCO_3$ and other bases, including NaOH. Abundances for many of these compounds are poorly constrained, and their production by melting of surface ice should be considered in any lander design.

Scientific Questions: A number of outstanding scientific questions about the Europa surface composition could be addressed by a landed mission. The possibility of in-situ analysis could do much to answer questions raised by remote sensing, while enabling future remote sensing to better characterize the surface areas inaccessible to a lander. The chemical makeup and origin of the dark material is of paramount concern. Identification of the hydrate phase should be a primary objective of surface experiments. The possible presence of organic compounds and even extant or extinct microorganisms (or at least their radiation-processed remnants) cannot be ruled out on the basis of Voyager and Galileo observations [32]. Infrared remote sensing has detected weak spectral features suggestive of C-N, C-H, and $-NH_2$ (amide) bonds [16,32]. Confirmation or falsification of these results would be valuable. The relative influences of exogenic and endogenic processes on the surface chemistry needs to be worked out – remote observations of disrupted terrain such as linea on the less-irradiated leading hemisphere could assist with this, but were not obtained by Voyager or Galileo. This brings up the subject of lander mobility: it would be unfortunate were a lander to arrive in bright, white icy terrain and have no way of sampling the dark material; similarly, access to less-radiation processed material (such as in the subsurface) would greatly enhance the scientific value of a lander.

Conclusions: Europa's surface is expected to contain reactive acids, bases, salts and a number of volatile compounds. These present both hazards and opportunities for a landed mission. Quantification of material abundances and detection/falsification of organic and biogenic compounds are of high priority to understanding the surface composition. Access to radiation products at the surface and relatively unprocessed material from well below the surface (>2 m) would be of great value. A lander component to a prospective mission to Europa could contribute significantly to assessment of Europa's formation, subsequent evolution, habitability, astrobiological potential, and space environment.

References: [1] Johnson, R.E. *et al.*, in *Jupiter: The planet, satellites and magnetosphere*, eds. Bagenal, F., Dowling, T.E. and McKinnon, W.B., 2004. [2] Hudson, R.L. and Moore, M.H., *J. Geophys. Res.* 2001. [3] Cooper, J.F. *et al., Icarus* 2001.[4] McCord, T.B. *et al., J. Geophys. Res*. 2001. [5] Carlson, R.W. *et al., Science*, 1999a. [6] Carlson R.W. *et al., Science* 1999b. [7] Noll, K.S. *et al., J. Geophys. Res.* 1995. [8] Moore, M.H. *et al., Icarus* 2007. [9] Delitsky, M.L. and Lane, A.L., *J. Geophys. Res.* 1997. [10] Delitsky, M.L. and Lane, A.L., *J. Geophys. Res.* 1998. [11] Spencer, J.R. and Calvin, W.M., *Astron. J.* 2002. [12] Pilcher C.B. *et al., Science* 1972. [13] Clark R.N. and McCord T.B., *Icarus* 1980. [14] Clark R.N., *J. Geophys. Res.* 1981. [15] Hansen G.B. and McCord T.B., *J. Geophys Res.* 2004. [16] McCord, T.B. *et al., Science* 1998. [17] Dalton, J.B., *Ph.D. Thesis, Univ. of Colorado*, 2000. [18] Carlson, R.W., *et al., J. Geophys. Res.* 1999c. [19] Carlson, R.W., *et al., Icarus* 2002. [20] Dalton, J.B., *Geophys. Res. Let.*, 2007. [21] Dalton, J.B. *et al., Icarus* 2005. [22] Dalton, J.B. *Astrobiology* 2003b. [23] Kargel, J.S., *Icarus* 1991. [24] Pappalardo, R.T. and Barr, A.C., *Geophys. Res. Let.*, 1999. [25] Pappalardo, R.T. et al., *J. Geophys. Res.*, 1999. [26] Carlson, R.W. et al., *Icarus* 2005. [27] Buratti, B.J., *Icarus* 1985. [28] Nelson, R.M. *et al.*, 1987. [29] Domingue, D.L., *Ph.D. Thesis, Pittsburgh Univ.*, 1990. [30] Domingue, D.L. *et al., Icarus* 1991. [31] Domigue, D.L., and Verbiscer, A., *Icarus*, 1997. [32] Dalton, J.B. et al., *Astrobiology* 2003a.

MODELS OF THE RADIATION ENVIRONMENT IN THE JUPITER SYSTEM: THE CASE OF EUROPA.

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Introduction:

The radiation protection is one of the two NASA highest concerns priorities. In view of the renewed interest in missions targeted to the Jupiter system, for which radiation exposure is one of the greatest challenges, it is fundamental to be able to evaluate particle fluxes and doses at any time and at any location and elevation on and around Jupiter and any of its moons. With this goal in mind, a 3-D radiation environmental model for the Jupiter system has been developed, to be used in radiation analysis for sake of science as well as for studies and analyses for missions to the Jovian system.

Methods:

The work is described as models of incoming galactic cosmic rays and solar events primary particles rescaled for Jupiter conditions, coupled with the Jupiter trapped particle environment. All incoming particles are then transported into the Jupiter satellites environments, with surface structure, compositions, topography and backscattering taken into account, then through the subsurface layers, again with backscattering taken into account. The JPL models for the Jupiter trapped belts have been used to evaluate the particle flux (protons, electrons, ions) at various distances from the planet as a function of latitude, longitude, and incoming direction. Models for both incoming GCR and SPE particles are those used in previous analyses as well as in NASA radiation analysis engineering applications, rescaled at Jupiter conditions. Physical data for the Jupiter satellites have been obtained from the most updated results from space missions. In order to correctly assess the filtering effects of the Jupiter magnetic fields on incoming particles, a 3-D magnetic cutoff model for the Jupiter system has been developed. Various models for the Jupiter magnetic field have been used to compute the Jupiter cutoff rigidity grids. Solar modulated GCR primary particles are filtered with the fully angular dependent cut-off rigidity model, as a function of latitude, longitude, incoming direction, and distance from the planet.

Results:

Particle transport computations were performed with deterministic codes (HZETRN for baryons and ELTRN for electrons and photons) adapted for planetary surfaces geometry and human body dose evaluations. Fluxes and spectra for most kinds of particles, namely protons, neutrons, alpha particles, heavy ions, pions, electrons etc. have been obtained. Results have been obtained for different surface compositions, mostly water ice with some silicatic (and not only) impurities. Radiation environments for the Galilean satellites are shown as examples of application of the model to the computation of radiation analysis boundary conditions. This Jupiter Radiation Environment Model will be possibly tested against spacecraft data from Europa landers.

Acknowledgements:

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A CONCEPT OF A PROBE FOR PARTICLE ANALYSIS AND LIFE DETECTION IN ICY ENVIRONMENTS

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Introduction:

Reliable methods for the rapid in-situ detection, quantification and identification of microscopic organisms in water and glacial environments are of major importance in many research areas from microbial biotechnology and biosafety to environmental monitoring and astrobiological space exploration.

Natural water habitats typically consist of many different microbial groups. The detection and identification of bacteria in such highly heterogeneous suspensions is a real challenge for in-situ real-time analysis. Nowadays, the common technique for biological characterization is probe sampling and subsequent culturing. This method has many obvious drawbacks such as necessity of taking a big amount of probes and keeping them in appropriate conditions before and during analysis, long waiting times, difficulties or impossibility to culture some bacterial, fungal and algal species in the laboratory, etc. According to existing reports, the density of microbial cells in ice is in average 10^4-10^7 cells per cm³ with approximately 99% of the cells not cultivable using traditional microbiological methods.

Driven by environmental, occupational, and methodological concerns, there has been growing interest in methods that offer the potential of analyzing and characterizing water-borne particles in-situ and in real-time. Of particular interest would be to differentiate between different kinds of particles. Ideally, biological particles should then be differentiated into individual species. We are working on new concepts and approaches detecting and measuring the microorganisms without the drawbacks of currently available biochemical methods that tend to be destructive, slow and laborious.

We propose a concept for the development and construction of a melting probe equipped with quick and accurate reagentless autofluorescence detection systems combined with light-scattering microsystems and, optionally, microarray chips integrated into the melting probe. This combination of methods may provide sensitivity high enough for detecting very low levels (~10-100 cells/cm^3) of microbes within seconds. In the proposed setup, water from melted ice is aspirated into the device and is pre-analyzed in a laser light gate, determining particle properties like size; shape, biological/non-biological nature, live/dead analysis, etc. This is followed by a either fluorescence or FET (field-effect transistor)-based microarray which contains individual array units stamped with various antibodies for specific detection of antigenic determinants. For example, reliable biofilm detection can be accomplished by detecting biomarker chemical species unique to biofilms. Some biofilm markers are tryptophan and exopolysaccharides (EPS), which indicate the presence of living bacteria. Specific antigen-antibody interaction will be further transformed into a fluorescence- or a FET signal, respectively, denoted as a "recognition event", and further analyzed using software that implements neural networks.

Detection of Intrinsic Autofluorescence of Living Organisms

Fluorescent microscopy in combination with a light-scattering approach aims at detecting microorganisms based on their intrinsic fluorescence. Essentially, we determine characteristic parameters of fluorescence spectral profiles after specific excitations. This approach is expected to be viability-sensitive and should be able to detect and identify single cells as well as other particles.

Autofluorescence in biological tissues is a common and useful phenomenon arising from a variety of endogenous biomolecules that absorb light in many regions of the near-ultraviolet and visible light spectrum. All living cells have some intrinsic level of autofluorescence, which is most commonly caused by NADH, riboflavins, porphyrins, and flavin coenzymes. One of the primary contributors of plant autofluorescence is chlorophyll, though lignins, carotenes, and xanthophylls also produce a significant level of fluorescence emission when stimulated with the proper wavelengths.

These molecules are excitable over a broad range of wavelengths including the blue region of the spectrum. The emission wavelengths of these autofluorescent molecules when excited in the blue is broad (500–700 nm) and overlaps emission spectra of commonly used fluorescent dyes. The peak autofluorescence emission after 488 nm excitation is in the green region of the spectrum.

Fluorescence methods such as flow-cytometry have long been a favored choice for particle-counting and size-monitoring as they offer close to real-time response and operate continuously. Two further aspects, namely sensitivity and specificity must be addressed. For the discrimination of biological particles, their intrinsic fluorescence offers significant potential, and several systems have been developed, that incorporate particle fluorescence measurement in conjunction with the measurement of other particle parameters in order to optimize cell discrimination.

In 1995, Pinnick *et al*. described a laser-based particle counter that detected fluorescence and elastic scattering from individual airborne particles as they traversed the beam from a 488-nm argon-ion laser. The low levels of intrinsic fluorescence observed from kaolin, hematite, and polystyrene particles in comparison with that observed from several types of biological particles suggested that the instrument would be useful in discriminating biological from non-biological particles. In an effort to enhance particle discrimination, the same researchers went on to extend the capabilities of the system to record the spectrum of fluorescence from a particle rather than simply the fluorescence magnitude.

More recently this approach has been further developed using two UV excitation frequencies in place of the 488-nm beam. The fluorescence spectra obtained from individual 2–5-mm biological aerosol particles excited by either 266- or 351-nm radiation from a *Q*-switched laser Nd:YAG and Nd:YLF, respectively, illustrated the differences in fluorescence spectra obtained from different biological particles.

Several different fluorescence spectra can be recorded simultaneously. L. Leblanc and E. Dufour performed experiments in which excitation at 250 nm (aromatic amino acids+nucleic acids), 270 nm (tryptophan residues) and 316 nm (NADH) has been used for 25 strains of bacteria in dilute suspensions. Evaluation of the spectra using principal component analysis and hierarchical clustering showed a good reproducibility from culture to culture and a good discrimination of the bacteria. Applying the method of Mahalanobis distances to the spectra would enable the classification and validation of microbial groups. Moreover, advanced signal processing algorithms would allow individual quantification of various bacterial/fungal groups and calculation of heterogeneity (biological diversity) index of the natural suspensions.

Quick and accurate detection of microbial contamination is possible by a combination of fluorescence technologies. H. Mason and co-workers have reported that microbe capture chips, used with a prototype fluorescence detector, are capable of statistically sampling the environment for pathogens (including spores), identifying the specific pathogens/exotoxins, and determining cell viability where appropriate. The technology is sensitive enough to detect very low levels (approximately 20 cells/ cm^3 of microbes in seconds).

Light Scattering-Based Microbial Detection

In case of lower numbers of cells, their identification can be a serious problem because of the low intensity of optical signals. Any monitoring system must aim for a minimum level of false positives. In an attempt to further reduce the occurrence of false positives, such as may occur when non-biological particles are present with similar size and fluorescence signature to biological particles, additional characteristics must be determined from the scattering particle. One method of achieving this is to examine the spatial pattern of light scattered elastically from the particle, from which both particle size and shape information can be deduced.

Light-scattering-based instruments such as optical particle counters have long been a favored choice for suspended particle count and size monitoring as they offer near-real-time response and can operate continuously without the need for reagents, etc.

The manner in which a particle spatially scatters incident light is a complex function of the size, shape, structure, and orientation of the particle, as well as of the properties of the illuminating radiation wavelength, such as polarization state. With suitable control of some of these variables it is possible to determine parameters related to the shape and structure of the scatterer. This spatial light-scattering analysis, also known as two-dimensional angular optical scattering, has therefore been attracting considerable attention. Dick *et al*. have used multi-angle azimuthal measurements to determine spherical and non-spherical fractions of different systems of particles.

The potential of spatial light scattering analysis can be exploited for particle shape characterization, and the research in this field will result in a number of real-time monitoring systems for application in, for example, particle detection and characterization in water systems.

Summarizing, the very attractive approach would be to create an instrument that similarly records simultaneously an estimate of particle size based on elastic scatter together with intrinsic particle fluorescence detection. Existing successful attempts to produce plots of fluorescent intensity against a scattered light signal in laboratory has illustrated the potential of such dual-parameter measurements in the achievement of precise discrimination of living microorganisms.

In our opinion, a melting probe equipped with autofluorescence-based detection system combined with a light scattering unit, and, optionally, with a microarray chip would be ideally suited to probe icy environments like Europa’s ice layer as well as the polar ice layers of Earth and Mars for recent and extinct live.

GRAVITATION-ELASTIC WAVES IN THE SYSTEM HIDDEN OCEAN OF THE JOVIAN MOON EUROPA – ICE SHELL

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Introduction:

There are numerous publications in the scientifically journals [1-6] and communications on the Internet concerning the existence of the water ocean on the Galilean moons of Jupiter. The most sensational results were obtained in the year 2000 by the Galileo probe being launched in 1995 to the orbit of the artificial Jovian satellite and by the Cassini probes flyby on its way toward Saturn. The photographs of the Galilean moons` surface from the distances equal to 800, 351, and 123 km confirmed the presence of a solid ice cover. The valuable information was obtained by magnetometers of the Galileo probe. The magnetic field of Europa turned always by the same side to Jupiter varies in time periodically having a period of approximately 10 h. This period is very close to the period of Jovian's rotation around its axis, the northern and southern poles changing two times their places during period. The only physical factor capable to generate the magnetic field of such kind is the eddy current in a spherical layer of conducting fluid.

Let us consider the partial characteristics of hydroelastic and gravity oscillations of the system ocean–ice shell, neglecting the Coriolice and ponder motive forces. The physical model of Europa may be presented taking into consideration the available experimental data in the following way. The core of Europa is a perfectly hard sphere. It is covered by a spherical layer of conducting ideal incompressible liquid interacting with a thin ice elastic shell on its surface.

The solution of the boundary value problems is sought in the form of expansions into series of the associated Legendre polynomials.

It is noted that there are at least three tones of natural vibrations of the "shell-spherical liquid layer" system, whose periods lie in the vicinity of the ten-hour period of Jovian rotation. Figure 2 shows the variations of the period value as a function of the tone number *j*. Curve 1 corresponds to partial characteristics of purely elastic oscillations of the "ice-liquid" system in the absence of gravity. Curves 2-4 correspond to gravitationally perturbed elastic waves at different values of the dimensionless meaning respectively different ratio of gravity forces and elastic forces. .The curve corresponding to the period of hydro-elastic and gravitational vibrations of the unfrozen ocean almost coincide with the curve 3. Curve 5 shows the constant period of Europa’s magnetic field oscillations equal to period of Jovian rotation around its axis. Curve 6 corresponds to the dry shell oscillations.

Fig. 2. The eigen value spectrum of the system ocean - ice shell (*j* – eigen value number). Logarithmic are plotted on the ordinate.

Thus, it is seen from the figure that, considering electromagnetic effects, one should take into account also hydroelastic effects, since the corresponding frequency spectra are in the close vicinity.

References:

1. *Cassen, P., Reynolds, P., and Peale, S.J.*, Is There Liquid Water on Europa? // *Geophys. Res. Lett.* 1978, vol. 6, pp. 731-734.
2. *Williams, K.K. and Greeley, R.*, Estimates of Ice Thickness in the Conamara Chaos Region of Europa // *Geophys. Rev. Lett.,* 1998, vol. 25, pp. 4273^276.
3. *Pappalardo, R.R., Head, J.W., and Greeley, R.* The Hidden Ocean of Europa // *Sci. American,* October, 1999, vol. 281, no. 4. pp. 54-63.
4. *Greenberg, R., Hoppa, G.V., Tufts, B.R., et al.,* Chaos on Europa // *Icarus,* 1999, vol. 141, pp. 263-286.
5. *Kivelson, M.G., Khurana, K.K., Russel, C.T., et al.* Galileo Magnetometer Measurements. A Stronger Case for a Subsurface Ocean of Europa // *Science,* 2000.
6. *Kovach, R.L. and Chyba, C.F*., Seismic Detect ability of a Subsurface Ocean on Europa // *Icarus,* 2001, vol. 150, no. 2, pp. 279-287.
7. *Dokuchaev, L.V.*, Spectrum of Natural Vibrations of the Ice Ocean of Jupiter's Moon Europa // *Kosm. Issled.* 2003, vol. 41, no. 3, pp. 277-284.
8. *Dokuchaev, L.V*., Gravitational and Hydroelastic Waves in the Ice Ocean of Jupiter's Moon Europa // *Cosmonautical i Raketostroenie,* 2003, no. 4 (33), pp. 99-110.
9. *Vlasov, V.Z., Izbrannye Trudy* (Selected Papers), M.: AN SSSR, 1962, Vol. 1.

LANDING SITE CANDIDATES FOR A EUROPA LANDER FROM THE GALILEO SSI AND NIMS INSTRUMENTS: A GEOLOGIC AND ENGINEERING PERSPECTIVE.

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Introduction: The jovian satellite Europa represents one of the most intriguing planetary bodies within our solar system. Scientific planetary missions to Europa would seek to ascertain the composition of its frozen surface, confirm the hypothesis of an underlying liquid ocean, and crucially, search for past or even present traces of life. Ideally, a lander would be to carry out geochemical and biological investigations on the satellite surface. In this case, careful choice of suitable landing sites would be critical to both the fulfillment of its scientific objectives and engineering constraints. This work aims at proposing suitable locations that meet these criteria.

Available datasets: The site candidates are chosen through the analysis of high (less than 100m/pixel) and medium resolution (100-300 m/pixel) images of the Galileo solid state imager (SSI), and spectral data from the near-infrared mapping spectrometer (NIMS). The aim of this approach is to combine the knowledge of the terrain geology and morphology [1] with spectral data of areas of chemical significance [cf. 2, 3]. Due to lack of high resolution images from high latitudes, all the site candidates are proposed in the mid latitudes, i.e. ±50 degrees from the equator.

Geological considerations: A thorough and detailed description of the various geologic units and history of Europa's geologic evolution has been carried out by several authors [cf. 1, 4, 5]. The relevant part to this work is that a candidate landing site should be chosen with the aim of analyzing material that has been ejected recently in geologic terms, i.e., mottled terrain and Chaos regions (see the references above for details). Consequently, we have chosen sites that are mostly located in Chaos regions, pull-apart bands, and regions that show evidence of material ejected from the surface recently, ex., Fig. 1(c, d, h, i, and k). In addition, large impact craters with central peaks are targets of high scientific values regardless of their age. Large craters should contain material excavated by the impact process that otherwise would not be available for analyzing. For that reason, we included two prime targets to the candidate sites: Pwyll crater (fig. 1a) and an unnamed crater north of Manannán crater lying in old rough terrain (fig. 1b). Both craters are more than 25 km in diameter and display central peak features.

Geochemical considerations: Spectra of Europa were acquired by the NIMS instrument during the Galileo mission. The most interesting spectra collected were those for regions showing what came to be called "Non-icy" material which are characterized by distorted and asymmetric adsorption features near 1.5 and 2 μm [6]. Many candidates were chosen to explain these features, but the two most prominent candidates have been hydrated salts [2], hydrated sulfuric acid [3], or a combination of both [7]. It is clear that one of the main objectives of any upcoming lander mission would be not only the in-situ analysis of ice, but also that of these "non-icy" materials. Consequently, we have taken into account spatial distribution of this material in choosing our candidate landing sites in order to maximize the scientific gains of the mission (Fig. 2). Consequently, most of the candidate sites fall in regions that show high concentrations of non-icy material as shown in fig. 2

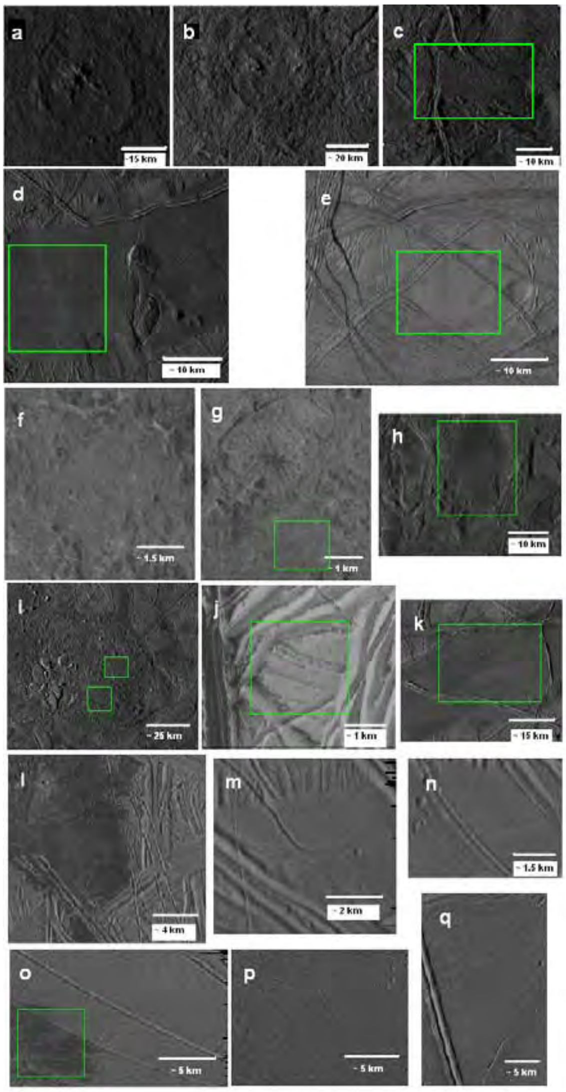

Fig. 1. Candidate landing sites; (a) Pwyll crater; (b) Unnamed crater north of Manannán crater lying in old rough terrain ; (c) Small dark area south of Belus linea, highly indicative of recent material that has been injected into the surface disrupting the previous terrain; (d) Dark pull-apart band south of (c) of material that has cut through and separated the older ridges on either side of the band; (e) A remarkably "smooth" inter-banded region between several small ridges lying in region full of small unnamed lineae between Cadmus Linea in the north and Belus linea in the south; (f) A rather smooth region within the Dyfed Regio east of Manannán crater; (g) A smooth region just south of Manannán crater which appears in the upper part of the image; (h) A smooth

plain in a chaotic terrain south of Belus Linea; (i) A chaotic-like terrain southeast of Manannán crater, similar in appearance and mode of formation to (c) but on a larger scale. No higher resolution images exist for this region to asses it fully in terms of its suitability for a lander; (j) One of the highly resolved sites on the eastern edge of Yelland Linea in Argadnel Regio; (k) A pull-apart dark band similar to (d) west of Castalia Macula in the Argadnel Regio; (l) A highly resolved area in the Thrace Macula. Note the contrast between the Macula and the surrounding terrains in terms of color and texture; (m) and (n) Both taken from the same high resolution image for terrain around Thrace Macula. Should prove as excellent targets for “older” terrains; (o) Another site in the terrain around Thrace Macula which seems to show a transition between the darker and lighter colored terrains (appears more clearly in the parent image); (p) and (q) High-latitude targets around an unnamed Macula-like terrain around Libya Linea. The area shows features similar to the pull-apart bands of (d) and (k).

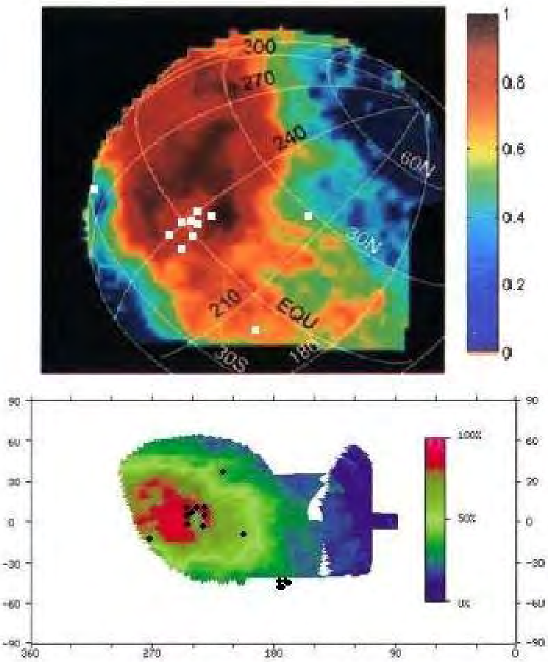

Fig. 2. Global distribution of “non ice-mixtures” as measured by NIMS onboard Galileo. White squares (upper panel)and black dots (lower panel) represent approximates locations of the candidate landing sites; **(a)** Spatial distribution of what McCord et al., assumed to be hydrated salts; **(b)** Similar distribution fractions reported by Carlson et al., assuming the non-ice mixtures to be those of hydrated sulfuric acid mixtures.

Engineering considerations: Due to the limitations in our knowledge of the satellite’s surface morphology, it is assumed that the final choice for a landing spot would be based on high-resolution data acquired beforehand by the orbiting “mothership” carrying the lander. It is assumed that the lander will be separated from the orbiter when it has arrived, maintained a closed orbit (circular or otherwise), and has collected more data that can help in constraining a candidate site. Consequently, this removes any restrictions on having definite landing ellipses that would, in that case, be dependent on a hyperbolic trajectory of a direct interplanetary arrival [8]. This makes the orbiter’s orbit around Europa the defining factor, which is beyond the scope of this work. However, a near equatorial site should be favored due to the differences in average temperatures between the poles and the equator. The energy from solar irradiance (~50 W/m2 on average) , will, for most practical cases, be insufficient to power all the lander’s subsystems, rendering the reliance on other sources of energy (ex. radioactive substances) necessary, which means that putting the lander in an environment with the highest possible ambient temperatures is of prime importance for the mission’s energy budget.

Summary: These candidate sites should only act as preliminary targets for further investigation. More information is needed to constrain the optimum site. While the sites suggested here are all in the mid-latitudes, this should not rule out the possibility of a near polar site if indeed, future observations show it to be of a higher scientific value. Rather, it is hoped that these sites can act as primary targets of interest from which a suitable site can be finally chosen once more data is in hand.

Fig.#	Image ID*	Lat*	Lon*
2a	11E0012	5.7	240.5
2b	E6E0031	-25.3	274.6
2c	11E0014	-0.1	240.2
2d	11E0016	-5.9	240.1
2e	15E0007	29.8	220.1
2f	14E0006	3.3	238.8
2g	14E0007	3.3	239.4
2h	11E0011	5.8	234.3
2i	11E0013	0.0	234.0
2j	12E0067	-16.7	196.0
2k	11E0015	-5.8	233.9
2l	17E0056	-47.0	173.5
2m	17E0057	-47.7	172.1
2n	17E0057	-47.7	172.1
2o	17E0058	-48.4	170.6
2p	17E0059	-52.7	177.6
2q	17E0060	-51.7	177.2

Table 1. Source images in the PDS library for the images displayed in Fig. 3. Latitude and longitude values are the central coordinates of the parent image, so the actual coordinates of the small sub-images may differ slightly. Longitude values are counted from the local East. Latitude values are counted from the local equator with negative values indicating locations in the southern hemisphere. ***** Image ID, Intercept point latitude, and intercept point longitude are the official header descriptions in the PDS library for Galileo images

References: [1] Papalardo R. T., et al., (1999), JGR, 104, 24,015-24055. [2] McCord, T.B., et al., (1999), JGR, 104, 11827-11,851. [3] Carlson R. W., et al, (2005), Icarus, 177, 461-471. [4] Carr, M.H., et al., (1998) Nature, 391, 363-365. [5] Procketer L. M., et al., (1999), JGR, 104, 16,531-16540. [6] Dalton J. B., et al., (2005), Icarus, 177, 472-490. [7] Orlando T.M. et al., (2005), Icarus, 177, 528-533. [8] Ball A. J, Garry R. C., Lorenz R. D., and Kerzhanovich V. V., (2007), Planetary Landers and Entry Probes, ISBN 978.5218200028, Cambridge University Press.

CRYPTOLIFE AND CRYPTOBIOSPHERE: TRIADS OF EXISTENCE CONDITIONS

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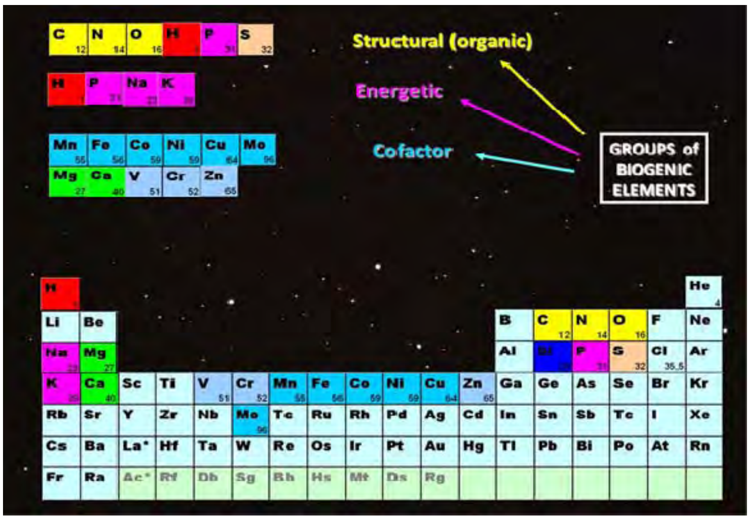
On Earth, evolution of Life is based on MATTER, rather than energy fields, since, unlike these fields, matter remains spatially and temporarily stable and is extremely diverse and energy-rich. Only carbon-based life forms have yet been found. The results of analysis of the capacity of elements for maintaining Life (to one extent or another) indicate that their role as biogenic elements is not incidental and is governed by certain distribution patterns within the periodic table. In fact, the list of biogenic elements includes only 20 elements and ends with the 65th element, zinc. Molybdenum (96th element), which play a significant role in the enzyme systems of photosynthesis, is an exception. All of these elements are distributed between the following three GROUPS OF BIOGENIC ELEMENTS (Fig. 1): (1) structural or organic group C, O, H, N, P, S; (2) energy group H, P, Na, K; and (3) cofactor or metal group Fe, Mg, Ca, Cu, Co, Ni, Zn, Mo, V, Cr.

For the origination and existence of life, certain environmental conditions are required. Life is material; a material basis—a PLANET—is therefore required for its origination and evolution. Above all else, it depends on the presence of spheres (litho-, hydro- and/or atmosphere), moderate and stable environmental conditions, and long-lasting temporality of the planet (at least 0.5–1 years), i.e., on the PLANET LEVEL TRIAD.

Secondly, it depends on the presence of liquid water and carbon and energy sources, i.e., the LIFE LEVEL TRIAD. Why? WATER is the most abundant simple compound in the Universe; the temperature range of its transition from one state to another is
moderate; it is a universal non-aggressive solvent and consists of the structural and energy biogenic elements (*oxygen* and *hydrogen*). CARBON is the most abundant light element in the Universe; it forms stable and labile polycarbons and associates with other light elements; it forms stable compounds in its three aggregate states under moderate conditions and an infinite variety of labile compounds. Carbon compounds are water-soluble under moderate conditions. Nuclear ENERGY is not suitable for the existence of Life, since penetrating radiation destroys its material matrix quite easily. Due to its nonquantized state, dissipative heat flux is incapable for vector-mediated transfer in matter. Only the moderate quantum energy of stellar radiation and chemical bonds can combine with labile organic molecules.

Finally, the presence of water-soluble mineral compounds and the temperature ranging from -8 to +117°C (–18 – +180–250°C ???) form the TRIAD OF ENVIRONEMNTAL CONDITIONS. As to the pressure range, it is quite uncertain, since many living objects on Earth are resistant to a pressure ranging from ~0 to 1100 atm.

Life cannot survive in deep space; it should be always protected by 1-3 planetary spheres. The term CRYPTOLIFE and its derivative CRYPTOBIOSPHERE are more suitable for living objects that inhabit the deep horizons of the lithosphere or hydrosphere (which can be covered with a thick ice shield as on Europa), rather than the planet surface. Most likely, Cryptolife is represented by microorganisms.



GEOPHYSICAL INVESTIGATIONS FOR A LANDED MISSION TO EUROPA

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Introduction: Almost all of our knowledge of Europa's interior derives from indirect inferences drawn from geological interpretation of the surface morphology. Galileo images revealed intriguing surface features that present tantalizing hints about the subsurface structure of the satellite, but there is disagreement as to their meaning because interpretations of the surface features vary. Fundamental questions remain about the existence of a subsurface liquid ocean, the thickness of the solid ice shell, and the mechanisms that produce specific surface features. Orbital measurements will help resolve some of these questions, but may yield ambiguous results about the shallow subsurface and provide little insight about the deep interior of Europa. Geophysical measurements made at Europa's surface can directly test interpretations of orbital observations and provide unique information about the depth and temperature of the subsurface sea, the state and composition of the silicate crust, and the existence of a metallic core.

Seismology: Much of our knowledge of Earth's interior comes from seismology. Propagation of sound waves from distant earthquakes is recorded by a dense network of seismic stations in order to pinpoint the sources and reveal the structure of the crust, mantle and core of our planet. Challenges for applying a similar approach on Europa arise from the lack of coverage by a network of seismometers and from possibly high levels of seismic noise.

Passive Seismology. Europa is likely to be a noisy place if models of ridge formation are accurate. Current models for the origin of the double ridges invoke diurnal tidal stresses that subject the brittle surface to extension, compression and shear. These alternating stresses are assumed to fracture the crust and force motion along the fractures to build ridges. This process, if active today, could provide a natural sound source for seismic studies and may generate substantial noise if active in many different locations.

An ideal seismic investigation would deploy a network of seismometers across the surface of Europa to identify specific source locations and derive velocity profiles along multiple ray paths. A 3-axis seismometer should be included on a landed mission at a minimum to ascertain the seismicity of Europa's ice shell and how it varies on diurnal time scales. Information about the average thickness of the ice shell and depth of an underlying liquid layer can be obtained from a single station, by analyzing arrival times of multiple guided waves assumed to come from the same source (Lee et al., *Icarus*, 2003).

Active Seismology. The most direct means of determining the ice shell thickness and the depth of a subsurface sea is simple echo-sounding using a well characterized artificial sound source. Many of the ambiguities in seismic data interpretation are removed when an artificial sound source is available. Both ice and water are excellent conductors of sound with little acoustic attenuation. An impulsive source should be easily distinguished from the ambient noise, with most of the energy partitioned into compressional rather than shear waves. A cost-effective seismic energy source might be a kinetic impactor deployed by the delivery spacecraft, but small explosive devices launched by the lander may suffice.

Radar: Radio echo sounding may provide the most detailed information about the structure of the solid ice shell. Radar sounding of Europa is likely to be carried out by orbiting spacecraft, but reflections from the surface ("clutter") will likely limit the sensitivity of the measurements. A ground-penetrating radar on a landed spacecraft would complement a seismic investigation, provide a reference point for interpretation of orbital observations, and present the best opportunity to detect a warm, convective sublayer of ice beneath the conductive ice shell.

Gravity and Magnetics: Future orbital missions will rely upon measurements of Europa's response to tides to determine whether or not the solid surface is underlain by a layer of liquid water. Central to these measurements is an understanding of the diurnal changes in gravitational acceleration experienced at the surface of Europa. Orbiting spacecraft can detect these variations indirectly, through analyses of deflections in their orbits, but a landed gravimeter would provide a record of diurnal changes of acceleration at a fixed location which could serve as an essential reference point for interpreting orbital observations.

Among the most compelling indications of a subsurface sea on Europa are the perturbations of the magnetic field that were detected by the Galileo spacecraft during close encounters with the moon. A landed magnetometer could monitor variations in Europa's magnetic field at a fixed location on the surface, that are possibly produced by electrical currents induced in a buried briny ocean by the periodic changes in the external Jovian field.

Summary: The proposed investigations use existing technology to address fundamental questions about Europa's interior. The results will provide a crucial context for evaluating whether or not Europa is a habitable world.

SCIENTIFIC TASKS OF THE GAS ANALYTIC PACKAGE FOR THE EUROPA LANDER.

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Introduction: Europa is an icy Jovian satellite with possible close to its surface ocean. Fast recycle of Europa’s surface “ocean” ices (proved by low density of impact craters) exclude the presence of significant silicate component in ice other than contamination by falling meteorites. Presence of liquid water provides the possibility for biological activity if any life could originated in Europa’s history. The search for life is one of the most intriguing goals of planetary research and Europa here is one of the most interesting planetary bodies in the Solar system together with Mars and Titan. The task of evaluation of possible Europa’s habitability (especially in its ocean) is also an important issue for astrobiology, if no life still originated on Europa. There are several circumstances which are favorable for Europa’s habitability such as: possible ocean and moderate temperatures in its depth, sufficient concentration of volatile components, which can form different biologically valid components including organics and nutrients, a source of energy in the from of energetic ionized particles bombarding surface ices, the last being a source of volatile elements and also a “cold traps” for reaction products, etc. As well there are circumstances which are unfavorable for habitability such as: the same flux of energetic ionized particles which can in turn ruin complex organics, no sunlight at ocean depths, unknown pH, salinity and toxicity of water, etc. The knowledge of physical-chemical conditions at Europa’s surface and depths is very important for understanding of habitability issues.

Description of the Gas Analytic Package (GAP): GAP converts ices into gases and uses method of gas analysis. GAP uses two methods of gas analysis: gas chromatograph combined with mass spectrometer (GC/MS) and tunable diode laser absorption spectrometer (TDLAS). The necessary sensitivity of analysis is provided due to accumulation of components of interest in adsorption traps.

General scheme of GAP is presented on Fig.1. A portion of ice can go two paths: in the first case ice goes to a vaporizer; and in the second case it goes to a melting device. The aim of the vaporizer is to convert main components (H_2O, CO_2, sulfuric components, etc.) into gaseous phase for analysis using GC/MS and TDLAS. GC/MS here identifies and measures the quantity of main components. TDLAS mainly is aimed to measure precisely $^{13}C/^{12}C$, D/H, $^{17}O/^{16}O$, $^{18}O/^{16}O$ isotopic ratios in H_2O and CO_2. Ice, which passes to the melting device, is heated to a liquid phase. Occluded in ice gases (e.g. NH_3, N_2, CO, CH_4, noble gases (NG), etc.) are released and collected in adsorption traps for further analysis using GC/MS. The obtained liquid is directed to adsorption trap for extraction and accumulation of refractory components. By melting of ~100 cm^{3}of ice and extraction of organics into ~10 μl of sample we can increase the sensitivity of analysis by order of 3, what helps to achieve ppt level. The concentrated sample of refractory components goes to pyrolytic device for conversion of sample into gaseous phase. Evolved gases are analyzed using GC/MS. Heavy organics, which are stable for high-temperature heating, will be converted into H_2O and CO_2 by combustion in O_2 containing atmosphere. Measurement of these H_2O and CO_2 in TDLAS will provide important information about isotopic ratios of H, and C in organics.

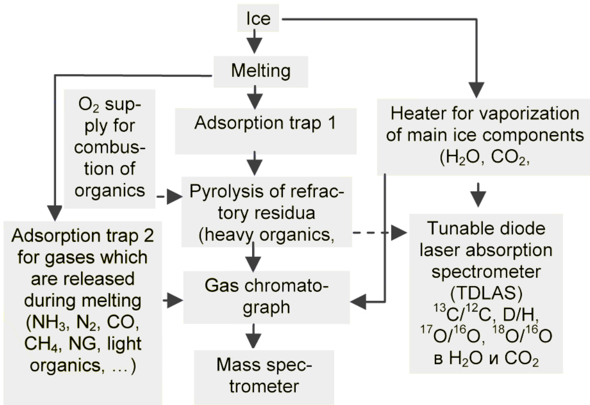

Fig. 1. General scheme of the gas analytic package for the Europa lander.

Tasks for the GAP: Chemical analysis of surface ices is the main aim of the GAP. Detailed analysis “in situ” of surface ices can give important information about physical-chemical conditions at Europa’s surface, which is valid for evaluation of habitability and search for life.

Ices are the mixture of components built mainly from biologically significant volatile elements C, H, N, O, S, P, Cl, while salts can contain some rock-forming elements Na, K, Fe, Ca, etc. It is expected that water ice is the main component of ices. There can be various species formed from cited elements which can be a significant or trace admixtures in water ice. One of the tasks of the GAP is to measure significant and trace volatile components of ice.

Organic species representing a vide range of different classes are possible components of ices. The measurement and identification of individual organic components is one of the main tasks of the GAP. Organic components if abundant are measured during the measurement of the main components of ice. Trace organic components are measured using both adsorptive traps for their accumulation from large ice volumes. Specific measurement of organics is performed using combustion in an atmosphere that contains O_2. Produced H_2O and CO_2 can be used for evaluation of quantity of refractory organic material and for precise measurement of $^{13}C/^{12}C$ and D/H ratios what is important for interpretation whether this organics is of biogenic or abiogenic origin.

One of indirect methods of detection of biological activity is the measurement of products of metabolism. Microorganisms release biogenic gases during their life cycle. These gases are: CO_2, N_2O, N_2, SO_x, H_2S, H_2, CH_4, (hydrates). Important indication of their biogenic origin is isotopic shift of C, N, and S elements. These gases can be trapped in ices after their migration from ocean depths. The measurement of such gases in ice together with isotopic ratios of C, N, and S elements is also must be a task for the GAP.

AN ARCTIC ANALOG TO EUROPA: SIGNS OF LIFE ON THE ICE

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Non-ice materials on the surface of Jupiter's moon Europa are often concentrated along geologic features and may represent sites of communication with the subsurface ocean. Dalton et al (2003) have suggested that biosignatures from this ocean could become entrained in mobile ice and carried to the surface. The best spectral matches to date for the non-ice materials are sulfur-rich hydrated minerals (Carlson et al., 1999, McCord et al, 1999). Identifying these materials is a priority for future missions (Clark et al, 2007)) and may help to constrain the habitability of Europa's ocean.

Borup Fiord Pass, located at a Lat/Lon of 81° N, 81° W on the Canadian Arctic Island of Ellesmere, represents the only known site on Earth where sulfur minerals and glacial ice are found in intimate association. Alkaline spring waters high in sulfide and sulfate access the surface of the ice during the melt season each year, depositing elemental sulfur, gypsum and calcite and exsolving H_2S (Grasby et al, 2003). The sulfur signature of the spring deposits is extensive enough to be detected and monitored from orbital satellite observations collected by the hyperspectral Hyperion instrument aboard EO-1 (Castano et al, 2008) and these data can provide temporal coverage of spring activity.

Diverse microbial communities are active within the deposits and are thought to be mediating the geochemistry of the deposits by the sulfur redox transformations from which they gain energy. Cultivation experiments targeting sulfide-oxidizing members of the microbial community have successfully isolated microorganisms from the spring deposits, which are producing sulfur in culture.

Borup Fiord Pass provides us with the opportunity to investigate sulfur-on-ice mineralogy in the field for the first time and gain understanding of how the spectral signatures of these kinds of materials vary from field to orbital scales. We are investigating how microbes present at the site are cycling sulfur through different redox states in this cold environment, and how the geochemical macrosignature of the springs and their associated deposits is being influenced as a result of metabolic activities of the microcommunity. This work will inform the search for biosignatures at icy moons like Europa.

References

Carlson, R. W., Johnson, R.E., and Anderson, M.S. (1999), Sulfuric acid on Europa and the radiolytic sulfur cycle, *Science* 286: 97-99.

Castano, R., K. Wagstaff, D. Gleeson, R. Pappalardo, S. Chien, D. Tran, L. Scharenbroich, B. Tang, B. Bue, and T. Doggett (2008). Onboard detection of active Canadian sulfur springs: A Europa analogue, *9th International Symposium on Artificial Intelligence, Robotics and Automation for Space (i-SAIRAS 2008)*, in press.

Clark, K., R. Greeley, R. Pappalardo, and C. Jones (2007). *Europa Explorer Mission Study: Final Report*, JPL D-38502.

Dalton, J.B., Mogul, R., Kagawa, H.K., Chan, S.L., and Jamieson, C.S. (2003) Near-Infrared Detection of Potential Evidence for Microscopic Organisms on Europa. *Astrobiology Vol 3, No. 3*

Grasby, S.E., C.C. Allen, T.G. Longazo, J.T. Lisle, D.W. Griffin, and B. Beauchamp (2003) Supraglacial Sulfur Springs and Associated Biological Activity in the Canadian High Arctic—Signs of Life Beneath the Ice *Astrobiology Vol 3, No. 3*

McCord, T. B., G. B. Hansen, F. P. Fanale, R. W. Carlson, D. L. Matson, T. V. Johnson, W. D. Smythe, J. K. Crowley, P. D. Martin, A. Ocampo, C. A. Hibbitts, J. C. Granahan, and the NIMS Team (1998). Salts on Europa's surface detected by Galileo's Near Infrared Mapping Spectrometer, *Science*,

MICRO-PENETRATORS FOR IN-SITU SUB-SURFACE INVESTIGATIONS OF EUROPA

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Abstract:
In-situ elements are essential to significantly extend orbital observations to justify the large mission costs. They can provide ground truth, and new exploration capabilities, particularly for astrobiological goals, including capability for direct astrobiological material detection and indirect habitability determination. They can also provide interior body structure investigation using seismometers, and sub-surface material chemistry via a package which includes a mass spectrometer. Targeted landing at a site of upwelled material could provide access to potential biological material originating from deep beneath the ice.

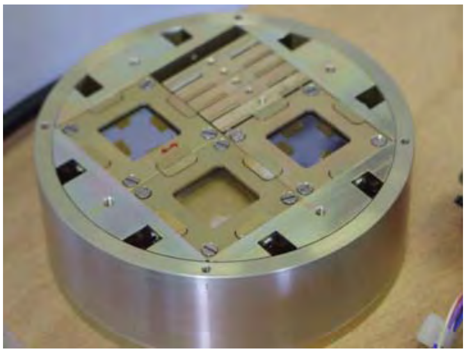
Current UK developments for lunar penetrators are aiming for a similar scientific payload of around 2kg within a total penetrator mass of around 13kg, though a comparatively short in-situ Europa mission could allow a significant mass reduction, potentially down to 5Kg. A spacecraft attachment and ejection system, and rocket based delivery system for the penetrator, is estimated to require an additional mass of around 2.6 times that of the penetrator. A two penetrator system could provide redundancy without carrying dead mass, to allow landing at different sites, and improved seismic capability.

In May 2008 the UK penetrator consortium successfully fired 3 full scale penetrators into a dry sand target at ~310 m/s impact velocities which are also proposed for Europa. This demonstrated survival of the penetrator shell, power system, accelerometers, micro-seismometer sensor; mass spectrometer, drill, magnetometer, and radiation detector assemblies. We are currently planning to complete impact ruggedisation of all components with 2 years.

For Europa, we recognise that additional developments are required which include demonstration of successful impact into ice, and survival in the radiation environment. Existing defence sector experience with impact into concrete and steel indicate that impact survival is feasible, and initial studies of radiation environment below the icy surface are very encouraging. Both the temperature environment at Europa and communications from beneath the surface will be covered by the lunar developments, which include impact into the permanently shadowed craters, and trailing antennae options.

Penetrator shell

Inner stack



Micro-seismometer bay

Penetrator hardware elements for May 2008 impact trials

SEARCH FOR SIGNS OF LIFE BY MEANS OF ATR SPECTROSCOPY (EXPERIMENT "MATROS")

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Abstract:
We propose for Europa lander an IR spectroscopic experiment able to detect bio-molecules (proteins, DNA/RNA, carbohydrates, lipids) in both viable and anabiotic cells. The spectral range is about 2.5–25 micron, spectral resolution 5–10 cm^{-1}, mass required is about 2 kg (mass of sample delivery system is not included).

The technique is based on Attenuated Total Reflection (ATR) spectroscopy, widely used in laboratories but so far never applied in planetary missions. ATR-spectra are absorption spectra of a sample contacting an ATR-prism. Simplicity of specimen preparation is an advantage of this methodic: one just needs to put the specimen in contact with ATR-prism.

Only thin layer of the sample (about one λ thin) contributes to ATR-spectrum. However, it is possible to vary depth of ATR-sampling with factor 2–3 (e.g., by changing angle of incidence inside the ATR-prism). This allows a kind of layer-by-layer analysis of the sample.

Bio-molecules have characteristic absorption bands in IR part of the spectrum (see fig.1).

By varying the penetration depth we can detect presence of DNA/RNA at some distance from ATR-prism surface – in the central part of a bio-cell. Fig. 1 shows results of such measurements with spore Clostridium pectinofermentans. Blue curve corresponds to a shallow penetration (0.25 micron) so only cell membrane is sampled and DNA/RNA band is absent. Deeper penetration (red curve) samples also the central parts of the cell, where DNA/RNA are located, and consequently the respective band appears.

Another way to make sure that the bands result from bio-cells (but not from a mixture of some minerals) is culturing of bacteria directly on the ATR-prism surface. Bacteria propagation will result in progressive deepening of bio-bands. We did such experiments in laboratory, with positive result.

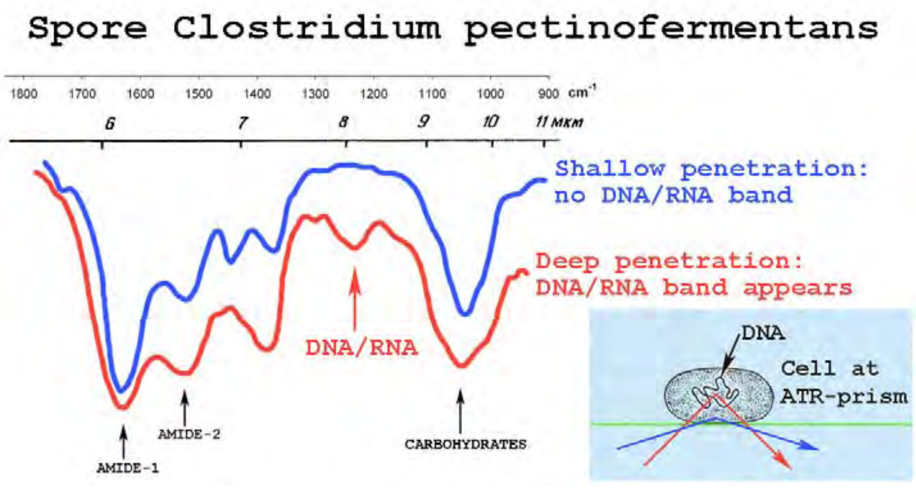

Fig. 1. Bio-molecules have characteristic IR bands, e.g. all proteins show «Amide-1» & «Amide-2» bands.
Different AIO inside ATR-prism provides sampling depth varying.
Blue curve: only cell membrane is sampled and DNA/RNA band is absent.
Red curve: central part (DNA/RNA are there) is also sampled – respective band appears.

PLANETARY RADIO INTERFEROMETRY AND DOPPLER EXPERIMENT FOR A MISSION TO EUROPA.

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We present a concept of the Planetary Radio Interferometry and Doppler Experiment for a mission to Europa (PRIDE-E). In this experiment, a network of Earth-based radio telescope will observe all radio-transmitting spacecraft of the mission (surface and orbital elements). The experiment poses minimal requirements to the on-board instrumentation beyond standard characteristics of the data down-link system. The outcome of the experiment will consist of estimates of the state vector of the transmitting spacecraft. These data will be used for evaluation of gravimetric and geometric parameters of Europa and will serve as input into diagnostics of the structure of Europa and ultimately can help to confirm or rule out the existence of a large deposit of water. An optimal configuration of PRIDE-E is expected to yield the accuracy of position determination of a lander or orbital vehicle at the level of tens of metres.

PRIDE-E will exploit radio link channels “Europa/Jupiter – Earth” at any standard deep space frequency. Inclusion of the Square Kilometre Array (SKA) into the suite of Earth-based assets of PRIDE-E will at frequencies lower than 8.5 GHz will offer an additional bonus in the form of Direct-to-Earth (DtE) realy of science data from the lander with the data rate at the level of tens of bits per second. This data transmission regime might be considered as a backup to the standard communication scheme, especially in critical phases of the mission.

‘STOP AND DROP’ HARD LANDER ARCHITECTURES FOR EUROPA ASTROBIOLOGY INVESTIGATIONS.

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Introduction: Several mission architectures for an orbiter-deployed surface payload were considered in our study: 1) a probe that functions as a sub-satellite, making several low altitude passes, but which does not necessarily function on Europa’s surface; 2) a high-velocity (>1000 m s^{-1}) penetrator that performs sub-surface science; 3) a mid- to high-velocity (>200 m s^{-1}) impactor that excavates material into a plume to be observed by an orbiter; and 4) a range of lander options, from a ‘soft’ landing (<10 m s^{-1}), to ‘hard’ (10-50 m s^{-1}) and ‘very hard’ (<200 m s^{-1}) landings. In an effort to optimize science return while minimizing mass and the risk of failure, we chose the ‘hard’ and ‘very hard’ lander configurations for additional study. Spacecraft and science payload heritage for such a lander is provided by the Deep Space 2 mission (< 200 m s^{-1}) and to some extent by the Pathfinder and Mars Exploration Rover missions (10-50 m s^{-1}).

A ‘hard’ or ‘very hard’ lander allows for a ‘stop and drop’ de-orbit sequence. After an initial burn to release the probe from the parent spacecraft, the lander package executes a Hohmann transfer and upon reaching periapse a second burn cancels the tangential velocity and the probe drops to the surface, accelerating at Europa’s 1.3 m s^{-2}. The altitude at which the second burn occurs determines the impact velocity. For de-orbit altitudes less than 15 km, the impact velocity is < 200 m s^{-1}. The time until impact from 15 km is ~150 s, while that from 5 km is ~90 s.

The total change in velocity (Δv) needed to achieve a hard landing is the sum of the deployment Δv and the periapse ‘stop and drop’ Δv. To satisfy the Δv range, the propellant mass and engine specific impulse (ISP) needed for a 100 kg probe is 35-55 kg and 200-360 s, respectively. These are reasonable ranges for flight-proven engines. As an example case, a drop from 5 km would impact Europa’s surface at only ~100 m s^{-1} and would require a total Δv of 1470 m s^{-1} or 1510 m s^{-1} for 100 km and 200 km orbits, respectively.

The 200 km orbit requires a higher Δv than the 100 km orbit, but the higher orbit enables longer communication with the lander from an orbiter during decent and while on the surface. For a direct Hohmann transfer, the orbiter will be in contact throughout the entire 1.06 hour decent, and will be in contact for an additional ~15 minutes after landing. After ~110 minutes the orbiter comes back into view, permitting another ~20 minutes of communication. On the next orbit, the rotation of Europa reduces the communication time to ~16 minutes. The above model assumes a landing near the equator and a flat horizon. For a lander that survives for a total of 6 hours, and is in communication with the orbiter at 200 km, the total contact time is 1.90 hours, 0.84 hrs of which is when the probe is on the surface of Europa. If the orbiter is in a 100 km orbit, total contact time is 1.5 hrs, 0.48 hrs of which is time on the surface.

Assuming the 8 kilobit per second data rate that Huygen’s had with Cassini, this short-lived lander could return 30.5 Mbits during decent and 24.2 Mbits from the surface to a 200 km orbiter. For a 100 km orbiter this reduces to 29.4 Mbits during decent and 13.8 Mbits from the surface.

The trade-off between mass and power (e.g. batteries and radioisotopes systems) was not examined in detail, but clearly increasing the lifetime of the lander on the surface increases the data return. For a 200 km orbit, the parent craft and the lander can communicate for three orbits until the lander rotates out of view. It then takes approximately 8.5 hours until the lander comes back into view, at which point communications can proceed for each of the 6 to 7 orbits that take place as the lander moves across the field of view of the orbiter. The lifetime of the lander should thus be designed for one of the following: 1) a ~7 hour lifetime (first phase of orbits); 2) a ~30 hour lifetime (first phase, plus blackout period, plus 13 hours for the next full phase of communications orbits); or 3) a lifetime that increases in increments of 21.5 hours beyond the initial 7 hour period, thus allowing for several blackout and communication periods.

To capture a full europan day (85.2 hours), the lander should survive for approximately 93 hours in order to communicate the data back to the orbiter.

Science Value: The NASA Decadal Survey details several recommendations and science goals that are greatly advanced by the addition of a surface science package. Specifically,

Goal 2.1: Characterize the surface composition, especially compounds of interest to prebiotic chemistry.

Theme 2.1: What is the chemical composition of the water-rich phase?

Theme 2.4: Can and does life exist in the internal ocean of an icy satellite?

Theme 4.2.1: Is there extant life in the outer solar system?

These goals are directly parallel to goals and questions fundamental to astrobiology, as detailed in the NASA Astrobiology Roadmap (2008).

Investigations from orbit will not be sufficient to fully address these goals. Though orbiter payloads can be well-optimized for determining the habitability of Europa from orbit, the above goals reflect the need to understand the detailed chemistry of Europa's ocean and the need to detect possible biosignatures in the ice of Europa. Surface science investigations with a lander will permit a direct search for biosignatures, and will provide a much needed 'ground truth' of orbital spectroscopic measurements. Detection of compounds from orbit is limited by surface concentrations in the upper ~100 µm of the ice. A lander, however, can investigate much deeper, possibly accessing material beneath the radiolytically processed and gardened layer. Furthermore, a lander greatly increases detection limits and may serve to concentrate important chemical, molecular, and biological components [Chyba and Phillips, 2001].

The primary objective for the deployable probe/lander is to perform a direct, in-situ search for chemical indicators of past or present life on Europa. Life detection experiments, however, should yield useful information even if no life is detected [NRC 2000]. Furthermore, if mass and power constraints allow for only one life detection experiment, biochemical investigations should rank above all others [NRC 2000]. For these reasons the notional payload for the probe considered here consists of cameras for decent and landed imagery, an accelerometer for surface regolith assessment, and a mass spectrometer capable of interrogating surface chemistry. Depending on design limitations, the mass spectrometer will also measure the composition of Europa's thin atmosphere during decent. Thus, while astrobiology will serve as the motivating science for the lander package, the above payload will provide the following information regardless of the life-detection results:

1. Capture sub-meter scale imagery needed for future landed missions.

2. Determine regolith depth via accelerometry data upon impact. This is important for assessing geological processes, space weathering, and future sub-surface sample acquisition parameters.

3. Obtaining 'ground truth' of chemical species mapped from orbit.

4. Measure minor species in the ice that are not detectable via orbital spectroscopy.

Astrobiology and surface composition science will be greatly aided by the ability to perform mass spectrometry of surface samples. Mass spectrometry serves as a very useful and complimentary technique to the UV/Vis/IR spectroscopic techniques employed from orbit. Additionally, mass spectrometry prioritizes the biochemical approach to the search for biosignatures, i.e. the detection of large and highly specific organic structures provides a critical step toward life detection [Chyba and Phillips, 2001; McKay 2004]. Mass spectrometery will comprise the bulk of the payload mass, utilizing some 3-10 kg depending on the complexity of the instrument.

Estimates based on a range of missions and studies indicate that the total science payload mass can be 2-10% of the total probe mass (wet). For a 50-100 kg probe, this limits the science instruments to 1-10 kg, with conservative estimates weighted toward to low end of this range. This implies that our notional payload of cameras, accelerometers, and a mass spectrometer will fit onboard the spacecraft, but little to no margin for any other instruments remains.

For maximum science return, lander deployment should occur after significant mapping of the surface has been conducted from orbit. Identification of regions both rich in surface chemistry (e.g. C-H, C-C, and C-N bonds) and young in surface age will be critical. If regions younger than ~105 years can be identified and targeted, then it is likely that a lander impacting the surface with a velocity greater than a few tens of meters per second could excavate beneath the radiation processed and gardened surface layer without additional drilling. This is important for the astrobiological investigation of possible biosignatures on the europan surface.

Conclusions: A landed surface package will greatly advance our understanding of Europa. Importantly, the science return of a lander cannot simply be accommodated by improving the payload of the orbiter; new investigations and new discoveries become possible with in-situ science.

An additional ~100 kg payload available on an orbiting craft may be sufficient to permit a conservative, relatively low risk, hard lander capable of performing a limited but very useful set of science investigations. Imagery and mass spectrometry will provide a ground truth for orbital measurements while also greatly improving the detection limits for minor compounds of geochemical and astrobiological interest.

Along with the specific science objectives to be addressed, the inclusion of a lander element as part of a mission greatly improves the exploration and discovery value of the mission as a whole. Much of planetary science involves exploration as a means for discovering new and important phenomena. Landing on the surface of Europa presents a great opportunity to advance the science, exploration, and discovery agenda detailed in NASA's Decadal Survey, and central to NASA's overall mission.

Chyba, C. F. & Phillips, C. B. (2001) Possible Ecosystems and the Search for Life on Europa. Proc. Natl. Acad. Sci. U.S.A. 98: 801-804.

McKay, CP (2004) What Is Life—and How Do We Search for It in Other Worlds. PLoS Biol. 2:9, e302.

NASA Astrobiology Roadmap 2008. http://astrobiology.arc.nasa.gov/roadmap/

NRC (2000) National Research Council Committee on Astrobiology. Report from Workshop on Life Detection, April 2000.

TIDAL DEFORMATION AND THE INTERIOR STRUCTURE OF EUROPA.

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Important clues on Europa's interior can be gained by monitoring tidally-induced surface deformations from orbiting and landed spacecraft. Such observations could provide constraints on the thickness and rheology of Europa's ice and liquid water layer, being thus an important tool to characterize basic physical properties of the satellite's putative ocean. A higher temporal resolution and precision than with space techniques alone can be achieved by additionally emplacing a lander on Europa's surface. We will present relations between key tidal parameters that can be retrieved from an instrument suite monitoring tidally-induced changes of local gravity, tilt, latitude and strain at the surface and the interior of Europa, focusing on implications for the outermost ice and water layer. A most promising approach would involve laser altimetry and gravitational field observations from an orbiting spacecraft combined with monitoring of tidally-induced gravity changes at the surface. However, tidal measurements at the surface may be affected by instrumental drift, insufficient instrument coupling to the surface, local sources of noise and the presumably short life-time of the instruments due to the harsh radiation environment.

GENTNER – A MINIATURISED LASER INSTRUMENT FOR PLANETARY *IN-SITU* ANALYSIS.

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Jupiter's moon Europa is the second body in the Solar System where extraterrestrial life seems possible to have existed in the past or to exist even now. This and the Earth-like nature Europa makes it a promising, though challenging target for *in-situ* space exploration. Europa's probably young (<1 Gy) surface that shows signs of active tectonism will yield clues on its interior materials and processes. Europa has sampled cometary material adding to its scientific attractiveness. Europa's distance from Earth asks for autonomous analytical tools that maximize the scientific return but require minimal resources, demanding new experimental concepts.

We propose a novel instrument for the almost complete elemental analysis of Europa's surface materials as far as within reach of a robotic arm or a similar device onboard the lander. It makes use of Laser Induced Breakdown Spectrometry (LIBS), the spectroscopy of laser generated plasmas in the visible. We suggest to name it GENTNER after Wolfgang Gentner (1906 – 1980), the discoverer of the nuclear photo effect, Director of CERN, founder of the Max-Planck-Institute for Nucelar Physics in Heidelberg and of its Department of Cosmophysics.

Essential components of the instrument are presently developed for implementation into a Mars mission. Moreover, these tasks are accompanied by in-depth methodical investigations to adapt LIBS to non-terrestrial environmental conditions[1,2,3].

The basic components of GENTNER are (a) the ***instrument module*** with pump laser, optical spectrometer and electronic units housed in the main body of the Lander, which are connected via optical fibres to (b) close to the sample light-weight external ***sensor head***(s) containing the laser and light sampling optics mounted on robotics arm(s) (Fig.1).

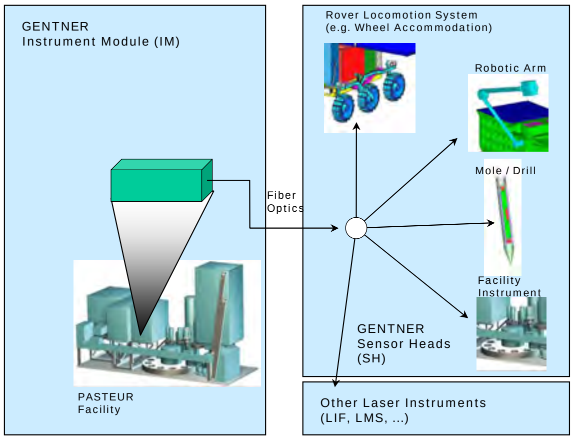

Figure 1: *Schematic of the GENTNER instrument as originally proposed*[4] *for ESA's Mars payload Pasteur. It easily can be adapted to the* in-situ *operation on Europa's surface and to various lander designs.*

GENTNER provides almost complete, quantitative and (rather) non-destructive elemental abundances by (a) fast – a matter of seconds and (b) as many analyses as desired – thousands, with (c) adequate sensitivity – down to 10 ppm, (d) high lateral resolution – upwards 50 µm, (e) independently of sample properties – ice, dust, rock, and with (f) the capacity of depth profiling – up to 2 mm. Moreover, the GENTNER instrument can easily be augmented by Raman-spectroscopy for mineral identification as well as for the detection of organic materials related to the presence of traces of primitive life forms.

The advantage that one instrument module can serve several sensor heads allows for a highly flexible implementation of GENTNER: The light-weight sensor heads may be operative on a robotic arm or in a mole, and they might be installed near the import gate of drill cores or rake samples for their effective routine exploratory geochemical analysis.

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[1] I. Rauschenbach, V.Lazic, S. Jovicevic, E. K. Jessberger, R. Fantoni (2007) LIBS in the cold: Laser induced breakdown spectroscopy of soils, rocks and ice under simulated Martian conditions. *Lunar Planet. Sci*. **38**, #1284

[2] V. Lazic, V., I. Rauschenbach, S. Jovicevic, E.K. Jessberger, R. Fantoni, M. Di Fino (2007) Laser induced breakdown spectroscopy of soils, rocks and ice at subzero temperatures in simulated martian conditions. *Spectrochimica Acta Part B*, **62**, 1546 – 1556

[3] I. Rauschenbach, V. Lazic, S.G. Pavlov, H.-W. Hübers, E.K. Jessberger (2008) Laser induced breakdown spectroscopy on soils and rocks: Influence of the sample temperature, moisture and roughness. *Spectrochimica Acta Part B*, **63**, 1205-1215

[4] E.K. Jessberger and the International GENTNER Team (2003) GENTNER Idea Proposal to ESA

EUROPA: SEISMIC GEOPHYSICS

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Europa has a rich content of geophysical tasks. Some of them are: geomorphology, nonlinear seismology, knowledge of extreme state of the Europa ice crust. In accordance with geomorphology search the ice crust is homogeneous matter, natural seismicity is absent or very weak, fault are straight and formed by tidal forces; core is small. Exogenous seismicity has a level compared with the Earth. Simultaneously search of Antarctic polar station seismograms show that the ice crust thickness can be defined by seismic methods during one day recording of seismic waves fields by seismometers. Properties of Europa ice have peculiarity which determines few borders into the inner crust massif which has a nature of the phase change of the second genre. The other main property of the ice crust is that all phase changes of the ice and water near the ice generate high frequency acoustic, seismic noises and electro-magnetic radiation which are a source information too.

THE DIFFRACTION CAMERA FOR HUNTING UP THE MICROORGANISMS’ TRACES

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Introduction:

The proposed experiment “Diffraction Camera” is, by our opinion, a way to avoid a contradiction between a lot of useless data and only few bits of important information, when looking for microorganisms with the microscopic method. On the one hand, the idea is of importance for a narrow band telemetry system. On the other hand, it has all the advantages of detecting the microorganisms by an unambiguous interpretation.

Advantage:

If microorganisms exit (or existed) on Europa, even in non-active or probably latent form, their traces should inevitably be present in the surface rocks (or ices), since the water states on Europa are in constant exchange. If microorganisms are observed with microscope, it gives a direct, “visual” answer allowing no ambiguous interpretation. The proposed experiment combines the advantage of the visual method and the limited data transmission requirements.

The potential of the diffraction camera:

The proposed experiment “Diffraction Camera” includes the diffraction camera with a laser and the microscope with a program unit for coding (compressing) the image to be transferred. The diffraction camera works as a detector of the objects, the concentration of which is low, and determines their sizes. With the chosen optics parameters (D/F=1.25, D=4 mm), the diffraction scattering characteristics allow the objects with sizes ranging from 0.9 to 28 μm to be detected and measured. This size range roughly corresponds to the mean sizes of the terrestrial bacteria.

Figure 1 presents the main idea of the camera. If the scanning laser beam meets a small obstacle in the droplet on the object glass, the corresponding diffraction pattern appears in the CCD. For the first diffraction ring of a radius R, the angle $\Phi=1.22\lambda/\delta$, and $\Phi\approx R/L$ (since R is much smaller than the magnification distance L) Then, for L=50 mm and the size of the object $\delta=28$ μm, we obtain the radius of the first diffraction ring R=1.9 mm, which can be definitely resolved with the CCD having 7-μm pixels. The smaller objects naturally produce a larger diffraction pattern.

The coding microscope:

When the diffraction pattern appears in the CCD, the instrument switches to the microscope mode. The principle scheme of the instrument is shown in Fig. 2.

If only 0.6 kB is allotted for one image, the compression software will produce a satisfactory picture of the microscope field of view. Moreover, the available methods of the data compression can replace the video shapes by their symbols with any compression degree. If the uncompressed image of the microscope field of view occupies 2.5 kB, in the code mode it can be presented, in extreme case, only by 10-12 bits, if the possible cases of the objects’ shapes, size ranges, mobility, etc expected in the droplet on the object glass are coded in the transferred bytes. For this, the instrument is provided with a special logic unit.

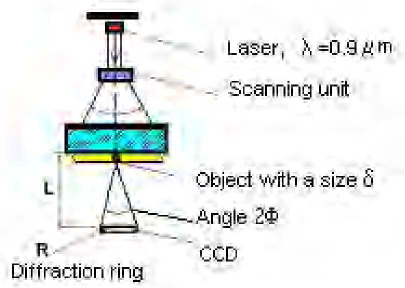

Fig. 1 The diffraction camera scheme

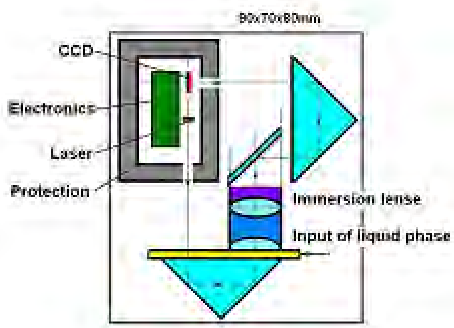

Fig. 2. The principle scheme of the instrument

Technical details:

The mass of the instrument is about 0.6 kg, the power consumption is 2 W, and the telemetry requirement is 10 kB/session. The CCD, the laser, and the electronic unit are in the protected chamber. Almost a half of the mass of the instrument is allotted to the protection from the radiation.

INTERNAL STRUCTURE OF ICY SATELLITES OF JUPITER

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Introduction:

The purpose of this study is to reproduce characteristic features of the internal structure of icy satellites of Jupiter. The mass and mean moment of inertia are used as input data for determination of the thickness and phase state of an outer water-ice shell, and the core sizes and masses. Various compositional models are considered for a satellite core: γ-iron core (ρ=8.1 g cm^{-3}), Fe-10 wt%S core (5.7 g cm^{-3}), a eutectic Fe-FeS core (5.15 g cm^{-3}), and troilitic FeS core (4.7 g cm^{-3}). The phase compositions and mantle densities are modelled within the system Na_2O-TiO_2-CaO-FeO-MgO-Al_2O_3-SiO_2-H_2O-Fe-FeS including the solid solutions. The equilibrium phase assemblages were calculated using the technique of free energy minimization. The density variations in the mantle and core radii and masses are found by the Monte-Carlo method.

Europa:

The results show that Europa is differentiated into a water-ice shell, anhydrous mantle and iron-sulfide core. Both L/LL and CM chondrite compositions match the total mass and moment of inertia value of Europa and can be regarded either as the primary material of Europa (carbonaceous chondrites) or as a reasonable analogue for its anhydrous rock-iron core (ordinary chondrites). The amounts of iron and iron sulfide, and the (Fe_{tot}/Si) ratio of Europa's anhydrous rock-iron core are not consistent with the bulk compositions of the most oxidized CI chondrites and the most reduced H chondrites. It is likely that Europa inherited a significantly higher proportion of material close to the moderately oxidized L/LL type chondrites rather than to the carbonaceous chondrites. The allowed thickness of Europa's H_2O layer (whether liquid or ice) ranges from 115±10 km (6.8±0.6% of total mass) for a differentiated L/LL-type chondritic mantle with a crust to 135±10 km (7.9±0.5%) for an undifferentiated L/LL chondritic mantle (Fig. 1).

Ganymede:

Two alternative density models of an outer shell are considered. Model (A) - an outer shell is completely composed of the high-pressure ice phases (no water is present), resulting in a maximum in the density of an outer shell. Model (B) - in the three-layer model of an outer water-ice shell, we assume that below a shell of ice-I (30-120 km thick), a liquid layer of 230-140 km thick may exist, resulting in a minimum density of an outer shell. The ice-V + ice-VI + water triple point lies at 273 K and 0.64 GPa. We adopted a "conductive" model where a mixed layer of water and high-pressure polymorphs of ice may coexist at depths between 260 km and an ice-rock interface. Our calculations show that the ice thickness of the outer shell in model (A) is about 890-920 km and in model (B) is 780-850 km (Fig. 2). The content of H_2O in Ganymede's icy envelope is 46-48% of the total mass.

Callisto:

We show that Callisto must only be partially differentiated into an outer ice-I layer, a water ocean, a rock-ice mantle, and a rock-iron core free of ice (mixture of anhydrous silicates and/or hydrous silicates + Fe-FeS alloy, $3150 < \rho < 3620$ kg m^{-3}). Assuming conductive heat transfer through the ice-I crust, heat flows were estimated and the possibility of the existence of a water ocean in Callisto was evaluated. The liquid phase is stable (not freezing) beneath the ice crust, if the heat flow is between 3.3 and 3.7 mW m^{-2}, which corresponds to the heat flow form radiogenic sources. The thickness of the ice-I crust is 135-150 km, and that of the underlying water layer, 120-180 km. The allowed total (maximum) thickness of the outer water-ice shell is up to 270-315 km. The results of modeling support the hypothesis that Callisto may have an internal liquid-water ocean (Fig. 3). The total amount of H_2O in Callisto is in the range from 49 to 55 wt%,

Conclusion:

Models of the internal structure of completely differentiated Europa and Ganymede, and partially differentiated Callisto have been constructed on the basis of Galileo gravity measurements, geochemical constraints on composition of ordinary and carbonaceous chondrites, and thermodynamic data on the equations of state of water, high-pressure ices, and meteoritic material. Comparison of the internal structure of the Galilean satellites and Titan has been made. Schematic Fe_{tot}/Si atomic ratios for the terrestrial planets, meteorites and Galilean satellites are shown in Fig. 4. Geophysical and geochemical constraints show that the bulk compositions of the rock-iron cores of the Galilean satellites are similar and may be described by the composition close to the L/LL chondrites. The atomic Fe_{tot}/Si ratio for C-chondrites is ~0.89. These results indicate that the jovian satellites did not form from C-chondritic material.

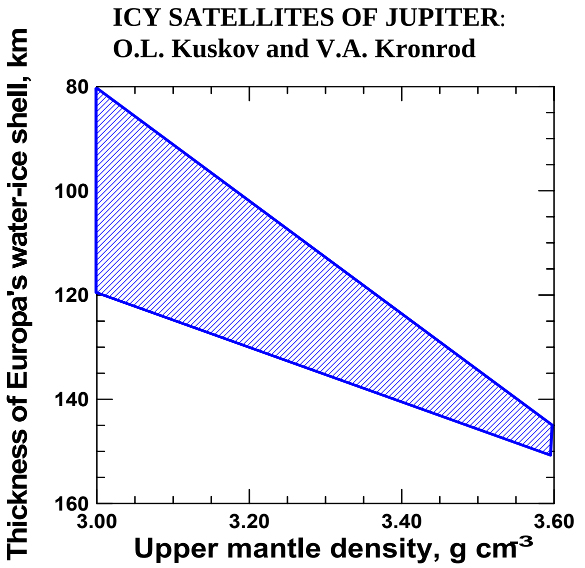

Fig. 1. Thickness of the water-ice shell of Europa.

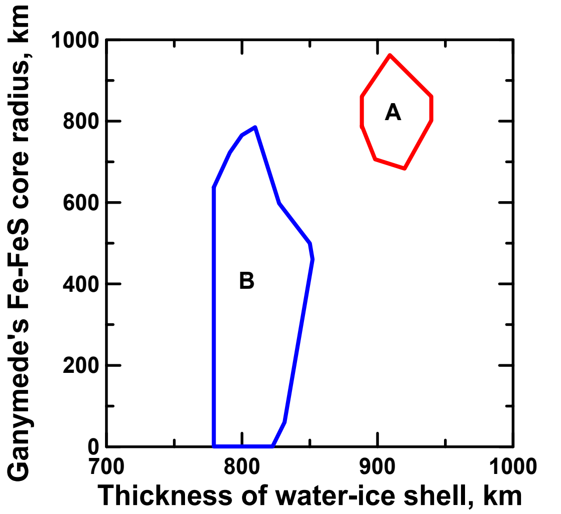

Fig. 2. Thickness of the water-ice shell of Ganymede.

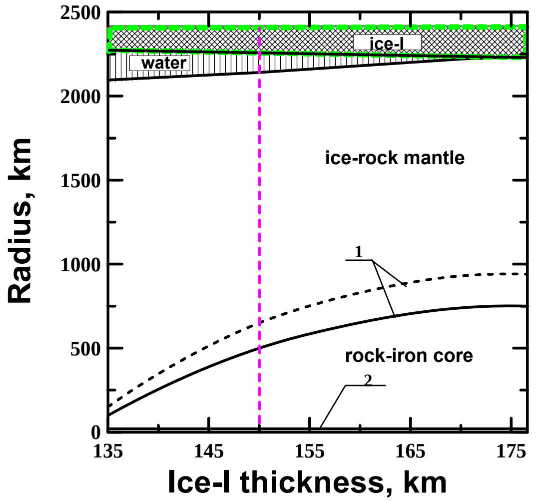

Fig.3. Internal structure of Callisto with a subsurface ocean. Because Callisto is only partially differentiated, a layer of a mixture of high-pressure ices and rock-iron material (rock-ice mantle) must exist between the outer ice-water shell and the rock-iron core. The vertical line corresponds to the thickness of ice-I crust of 150 km. The maximum radius of the rock-iron core is 950 km.

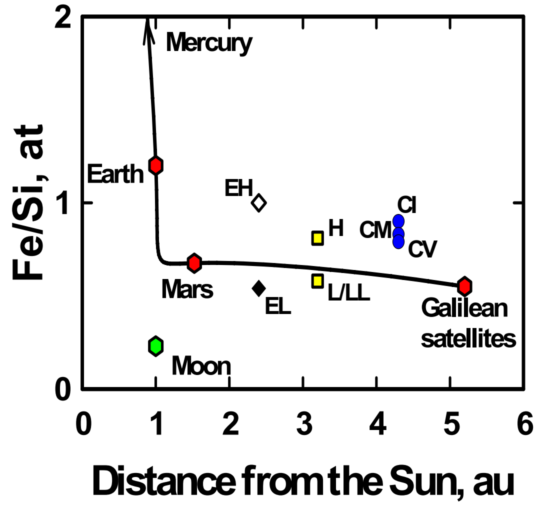

Fig. 4. Schematic Fe_{tot}/Si atomic ratios for the terrestrial planets, meteorites and Galilean satellites.

ESA COSMIC VISION PROGRAMME: OUTER PLANET MISSION STUDIES

Jean-Pierre Lebreton, *ESA/ESTEC, Research and Scientific Support Department, Postbus 299, 2200 AG, Noordwijk, The Netherlands.* jean-pierre.lebreton@esa.int

Abstract:
ESA’s Cosmic Vision plan concerns space science missions that would be developed for launch in the timeframe 2015-2025. It addresses the following four big science questions:

- What are the conditions for planet formation and the emergence of life?
- How does the Solar System work?
- What are the fundamental physical laws of the Universe?
- How did the Universe originate and what is it made of?

Following a call for missions issued by ESA science programme directorate, the international science community responded in mid-2007 with more than 50 proposals. ESA selected, in late 2007, two candidate outer planet missions that were proposed to be jointly studied in international cooperation: Laplace, a mission to the Jupiter System and TandEM a mission to the Saturn System. In February 2008, ESA and NASA initiated joint studies of two missions to the outer planets: the Europa Jupiter System Mission (EJSM) and the Titan Saturn System Mission (TSSM). Two Joint Science Definition Teams (JSDTs) were formed with US and European membership to guide the study activities that were conducted collaboratively by engineering teams on both side of the Atlantic with Japanese science participation in EJSM.

EJSM comprises the Jupiter Europa Orbiter (JEO) that would be provided by NASA and the Jupiter Ganymede Orbiter (JGO) that would be provided by ESA. Both spacecraft would be launched independently in 2020, and arrive 6 years later for a 3-4 year mission within the Jupiter System. Both orbiters would explore Jupiter’s system on trajectories that include flybys of Io (JEO only), Europa (JEO only), Ganymede and Callisto. The operation of JEO would culminate in orbit around Europa while that of JGO would culminate in orbit around Ganymede. Synergistic and coordinated observations would be planned. JAXA continues to study ways to complement the NASA and ESA spacecraft by providing a third platform, a Jupiter Magnetospheric Orbiter (JMO). Interest was also shown by the Russian Space Agency to provide a Europa Lander, the subject of this workshop.

The Titan Saturn System Mission (TSSM) comprises a Titan Orbiter provided by NASA that would carry two Titan in situ elements provided by ESA: a montgolfière and a lake lander. The mission would launch in 2020 and arrive 9 years later for a 4-year duration in the Saturn system. Following delivery of the ESA in situ elements to Titan, the Titan Orbiter would explore the Saturn system via a 2-year tour that includes Enceladus and Titan flybys. The montgolfière would last at least 6-12 months at Titan and the lake lander 8-10 hours. Following the Saturn system tour, the Titan Orbiter would culminate in a ~2-year orbit around Titan. Synergistic and coordinated observations would be planned between the orbiter and in situ elements.

The ESA contribution to this joint endeavor will be implemented as the first Cosmic Vision Large-class (L1) mission; the NASA contribution will be implemented as the Outer Planet Flagship Mission. The contribution to each mission is being reviewed and evaluated by each agency between November 2008 and January 2009, and a joint decision as to which destination has been selected is expected to be announced in February 2009.

TILTMETER FOR EUROPA LANDER : TIDAL DISTORTION OF THE ICE CRUST AND LONG-PERIOD SEISMOMETRY. Ralph D. Lorenz, Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA. Ralph.lorenz@jhuapl.edu

Introduction – Tidal Tilt

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A Europa Lander offers the prospect of making a novel geophysical measurement that provides information on the rigidity (and thus thickness) of the ice crust. This measurement is simply one of the tilt of the ground (or equivalently, the changing orientation of the local gravitational vector to the surface) which can be made with quite simple and robust instrumentation which complements other proposed measurements.

In essence, the horizontal component of the changing tidal acceleration on a satellite in an elliptical orbit is expressed in a tilt of the local gravity relative to an inertial frame. A lander on a perfectly rigid satellite would measure this changing tilt (see figure 1). However, if the surface of the satellite itself distorts in phase in response to the changing tide, then the tilt measured on the surface is reduced.

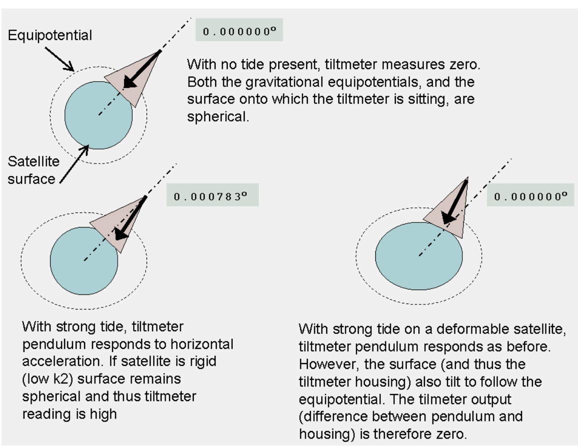

Figure 1. Changing tilt on a tidally-excited satellite.

In formal terms, the tilt measurement measures the difference in tidal parameters (h-k-1) whereas orbital measurements such as laser altimetry and Doppler tracking measure these terms separately [1,2]. An in-situ measurement of the lander tilt in this way is strongly complementary to orbital measurements, although in principle can infer the crustal rigidity independently (conversely from the individual orbital measurements, the tilt sensed on the surface is a MINIMUM when the crust is least rigid). Figure 2 shows the amplitude of the expected tidal tilts on Europa with a thick crust, and that for a fully rigid Europa : for an arbitrarily thin crust, the tilt is zero. However, the expected tilts for a moderately thin crust are well above the expected measurement resolution of a few nanoradians.

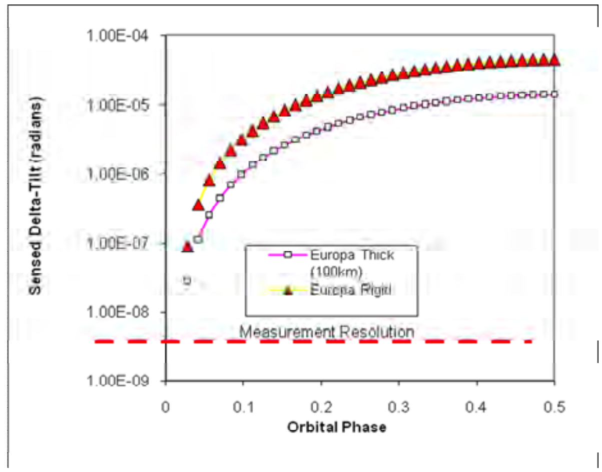

Figure 2 : Tidal tilt as a function of orbital phase.

Long-Period Seismology

The tidal tilt history shown in figure 2 is perfectly analytical, and corresponds to a uniform crust responding with no phase lag. In reality, there may be some phase lag which could be detected through an asymmetry of the curve. Furthermore, a real brittle crust is unlikely to deform in a perfectly smooth fashion, but will suffer discontinuous slips along faults, notably the cycloidal cracks. This will therefore cause discontinuous jumps in tilt, as well as seismic waves to be radiated away from these sites.

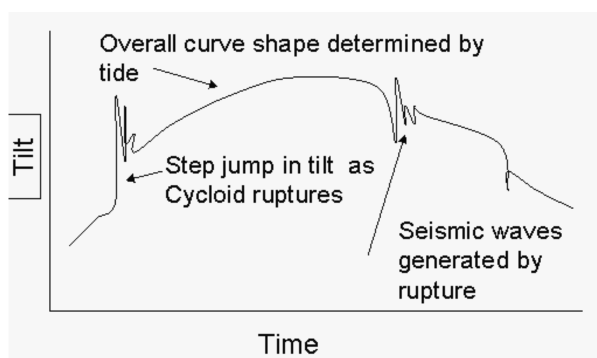

Figure 3. Schematic of the tilt history likely on the surface of a brittle crust.

A pendulum tilt meter acts as a long-period seismometer (indeed, responding to DC signals) and thus a tiltmeter can augment or replace other seismic instrumentation. For a pendulum a few tens of cm in length, the angular resolution acheivable corresponds to ~10 nanometers, amply sensitive to detect teleseismic events.

Instrumentation and Requirements

A tiltmeter is an intrinsically simple instrument. A variety of sensing techniques is possible – a common approach is to use a conductive fluid in a vial (e.g. figure 4) – comparable tilt sensors were used on the Huygens probe to Titan [3]

Figure 4. Commercial fluid-bubble geophysical tiltmeter, able to achieve <10 nanoradian precision.

For a lander application a simple pendulum sensor may be better (e.g. figure 5). Modern optical or capacitive position sensing techniques can be used – the best approach to use should be considered taking the lander radiation environment into account.

A tiltmeter on a lander needs to incorporate a leveling mechanism. Preventing large temperature changes nearby is important to avoid thermally-induced tilts via differential expansion.

Data over two tidal periods (7 days) would be desirable to reliably characterize the tidal cycle. For that measurement, only a few tens of measurements, at ~2 axes x 24 bits each – say 5000 bits total – is adequate. Measuring seismic activity obviously demands a larger dataset, perhaps exploiting event-driven sampling and data compression.

The mass of the pendulum structure and position sensors can be quite small (<1 kg) : the leveling mechanism may entail ~0.25kg, although these values depend strongly on the impact decelerations expected on the lander and on the range of angles that the leveling mechanism must accommodate. Instantaneous power of the order of 0.5W is ample, although the instrument can be operated at a low duty cycle if this is considered prohibitive.

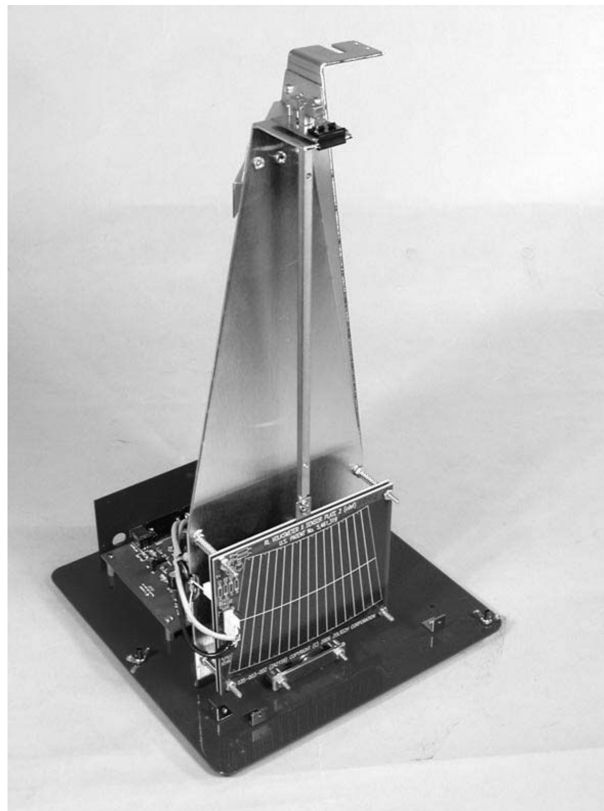

Figure 5. A Commercial capacitive-sensing tiltmeter, also able to achieve nanoradian precision.

References:

[1] Wahr, J., M. T. Zuber, D. E. Smith and J. I. Lunine, Tides on Europa, and the thickness of Europa's Icy Shell, Journal of Geophysical reszearch, 111, E12005, doi:10.10129/2006JE002729, 2006

[2] Wu, X., Y. E. bar-Sever, W. M. Folkner, J. G. Williams and J. F. Zumbruge, Probing Europa's hidden ocean from tidal effects on orbital dynamics, Geophysical research Letters, 28, 2245-2248, 2000

[3] Lorenz, R. D. et al., Descent Motions of the Huygens Probe as Measured by the Surface Science Package (SSP) : Turbulent Evidence for A Cloud Layer, Planetary and Space Science, 55, 1936-1948, 2007.

ORIGIN OF JUPITER’S AND SATURN’S REGULAR SATELLITES IN CIRCUMPANETARY DISKS.

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Introduction:

The main features of the constitution of the Jupiter’s and Saturn’s regular satellites should be reflected in the models of their formation. The models should not contradict the experimental data on the composition of atmospheres of these giant planets. We have constructed such models, consistent with the models of the internal structure of the Galilean satellites [1], [2] and with the data on the Titan’s atmosphere composition [3]. Models of formation of the regular satellites are of several types. All of them suggest formation of the satellites in circumplanetary disks (planetary subnebulae) . Most of authors including us, prefer the model of the protosatellite disk as gas-dust accretion disk [4], [5]. The model is similar to the model of formation of planets in the circumstellar protoplanetary disks. The protosatellite disks contained solid material not only in dust particles, but also in larger bodies. Formation of planetesimals in the disks through the disk’s gravitational instability is highly improbable due to the disk’s disturbance by large protoplanetary bodies approaching Jupiter and Saturn. At the same time some of these bodies in the vicinity of the planet could be captured by the disk after the pairwise collisions. Evaluation [6] showed that during the time interval of satellite formation ~10^5 yr several large (10-100 km) planetesimals could be captured into the subnebula from heliocentric orbits. Small bodies were held by gravity of these planetesimals at their surfaces. Hence the captured planetesimals played the role of seeds (embryos) in the process of satellite formation, which proceeded by accretion of subnebula’s solid material onto these seeds. The main income of solid material into the subnebulae from the feeding zones of the planets presumably resulted from the capture of dust particles and small bodies (< 20 m in size) through gas drag and these particles and bodies brought the basic contribution to the mass of satellites during their formation [5], [6], [7].

As the small particles and bodies due to the gas drag moved in the protosatellite disks with gas (and additionally relative to the gas) towards the central planets, they lost their volatiles according to the T-P conditions in the disks. In such a way in Saturn’s subnebula the particles imported from the solar nebula, had lost noble gases, CO and methane due to very low temperature of stability thresholds of their clathrates. In the case of Jupiter’s disk the particles during their drift to the planet had lost even H_2O in the inner region of disk.

For both planets we consider the models of low-mass gas-starved protosatellite accretion disks, which accumulate the mass of solid material contained in the regular satellites, during the whole period of their formation [4]. Arguments for the gas-starved disk models were clearly demonstrated in [7], [8].

Main Features of Constructed Models of Jupiter’s and Saturn’s Protosatellite Disks:

1) The Jupiter’s and Saturn’s subnebulae are considered as gas-dust accretion disks with accumulation of solid material on the surfaces of the growing satellite embryos. (2) The disks are considered as open systems with parameters depending on the rate of mass accretion onto the disks from the surrounding regions of the solar nebula and the composition of the capturing nebula’s solid material. (3) Four sources of the disk heating are included: viscous dissipation of turbulence in the disks, infall of material onto the disks from, radiation of the young central planet, and the thermal radiation from the surrounding region of the solar nebula. (4) The cosmochemical restrictions on the temperature and composition of solids in the disks of Jupiter and Saturn are considered in the computations. (5) The dependence of opacity of the disk material on temperature, chemical composition, enrichment and size of dust particles is allowed for. (6) The growth of dust particles is taken into account through the opacity variation. (7) The models constructed are two-dimensional: the calculations are made for not only radial, but also vertical T-P structure of the disks.

The equations and methods of computer simulations we have presented earlier for the protosatellite disk of Saturn [5]. Here for the first time we present the results of comparative modeling of Jupiter’s and Saturn’s disks. It is important that input parameters for models of both disks are considered in concordance with the modern data on the evolution of disks around the young solar-type stars and the solar nebula.

Results and Discussion:

We have constructed the models of protosatellite disks of Jupiter and Saturn, which satisfy the complex of cosmochemical and physical constraints. The cosmochemical data impose restrictions on the temperature distribution in the midplane of the disks. For the disk of Jupiter these data concern the abundance of water in each of the Galilean satellites; for the disk of Saturn the data on the Titan’s atmosphere were obtained by means of the Huygens probe and

Earth-based observations. One more cosmochemical constraint originates from the data on the enrichment of atmospheres of Jupiter and Saturn in volatile substances heavier than hydrogen and helium relative to the cosmic abundance. The physical constraints include modern data on the lifetime and evolution rate of the protoplanetary disks around young solar-type stars and the solar nebula. These data yield the lifetime of the gas-dust solar nebula $<\sim 10^7$ yr. The accretion of the giant planets ceased owing to photoevaporation of the gas from the solar nebula by the UV emission of the young sun. As the formation of satellites in the circumplanetary disks should occur at the late stage of planet accretion only, it could not proceed for more than $\sim 10^6$ yr. Any satellite formed in the disk earlier, should drift to the planet and fall on it [7].

We obtained restrictions on the turbulent viscosity and opacity of the disks of Jupiter and Saturn. Too high or too low values of these parameters yield too high or too low temperatures in the disk, which are not consistent with the cosmochemical constraints. Too high opacities do not also fit the rather low enrichment of planetary atmospheres in heavy volatiles. The opacity is strongly dependent on size of the dust particles in the disk. The models that better than others fit cosmochemical restrictions on temperature and astrophysical data on protoplanetary disks around young stars yield opacity of the order of $\kappa \sim 10^{-2}$cm^2/g and particle size of about $a \sim 1$ cm and $a \sim 0.1$ cm in the disks of Jupiter and Saturn correspondingly.

This size is also consistent with the models of formation of Jupiter [9], which require this rather large size of dust particles in order to obtain sufficiently high accretion rate of the planet. The protosatellite disks with lower opacity due to higher sizes of particles appear to be transparent for the powerful radiation of the young giant planets and hence too hot to satisfy chemical constraints. The duration of satellite accretion $\sim 10^6$ yr shown above would decrease to $\tau_a \sim 2\times 10^5$ yr if to consider satellite migration of the first type [7]. The best models we have constructed to fit this timescale show the accretion rate of gas-dust material onto the disk and from the disk onto the planet of about 10^{-7} M_{Jup}/year and 10^{-7} M_{Sat}/year for Jupiter and Saturn. These models better than others also fit the cosmochemical temperature constraints. The accretion rates shown above are consistent with the accretion rate of material in the solar nebula in the region of giant-planet formation of about 10^{-10} M_{Sun}/year, characteristic of the late phase of the solar nebula evolution before its dispersal through photoevaporation [10]. The dispersal timescale would be much shorter than satellite accretion timescale τ_a.

It follows from our estimates that material of large icy satellites Ganymede, Callisto and Titan initially had contained, probably, the whole cosmic abundance of water, but at mutual collisions of presatellite bodies the growing satellites had lost up to 60% of this most abundant component. Though Europa is less abundant in water, its parent material could be almost as much enriched in water as that of the above icy satellites. If the primitive material of these satellites also contained refractory organic compounds (CHON), which had (at least partially) entered the composition of these satellites, then the loss of water would be higher.

Acknowledgments: This research was supported by the Russian Foundation for Basic Research (RFBR grant 08-05-01070).

References: [1] Kuskov O.L and Kronrod V. A. (2001) *Icarus, 151,* 204–227. [2] Kuskov O.L and Kronrod V. A. (2005) *Icarus, 177,* 550–569. [3] Niemann H. B. et al. (2005) *Nature, 438,* 77779-784. [4] Makalkin A. B. et al. (1999) *Solar Syst. Res., 33,* 456-463. [5] Makalkin A. B. and Dorofeeva V. A. (2006) *Solar Syst. Res., 40,* 441-455. [6] Ruskol E. L. (2006) *Solar Syst. Res., 40,* 456-461. [7] Canup R. M. and Ward W. R. (2002) *Ap.J., 124,* 3404-3423. [8] Makalkin A. B. and Ruskol E. L. (2003) *Solar Syst. Res., 37,* 545-554. [9] Hubickyj, O. et al. (2005) *Icarus, 179,* 415–431. [10] Alexander R. D. et al. (2006) *MNRAS, 369,* 229-239.

MODEL OF EUROPA AND A POSSIBILITY OF ORGANIC COMPOUNDS SYNTHESIS IN AN UNDERWATER TORCH

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In the work are presented experimental results, showing that in the process of the meteoric impact penetrating through the surface ice armour of Europa, the undersurface ocean can be considerably enriched with organic compounds (OC) formed in a plasma torch. For this to happen, it is required that in the meteorite composition is present carbon or other elements, containing in the OC.

It is shown that during penetrating impact are generated two torches - direct and reverse in relation to the direction of the meteorite motion. Thus approximately half of OC formed as a result of impact, penetrate into ocean of Europa.

Estimations on concentration of OC delivered at meteorite bombardment of Europa ice armor by planetesimals or nuclea of comets into subsurface ocean during the first 200-500 years of Jupiter's satellite are also presented.

For the verification of the hypothesis on OC synthesis in the plasma torch, the modeling experiment simulating synthesis of OC in an underwater torch has been conducted. Impact was modeled by laser influence on the tablet of the super pure carbon placed in the sample unit with saturated nitrate ammonium water solution. Methods of sample and experiment preparation were ensured sufficient purity of the test. The following comparative mass analysis of the substance at the MALDI TOF - TOF BRUKER's instrument has shown presence of high weights compounds only in the experimental solution whereas the control substance remained pure.

The obtained results showed that together with the "background" OC in the underwater torch could have been also synthesized amino acids and may be polypeptides with masses up to ~2000 a.m.u.

MASS SPECTROMETRIC MEASURING COMPLEX FOR THE DETECTION OF THE SIGNS OF LIFE IN THE ICE SURFACE OF EUROPA

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Providing the presence of simplest forms of life in the ocean of Europa, the biomass of these organisms that have remained in an ice matrix is supposed to be detected also in the surface layer of ice. For the investigation of sings of life is proposed the measuring complex of two time-of-flight mass spectrometers (TOF MS): laser and gas, and the system for the biomass extraction from the water obtained from ice sample.

Signs of life can be detected by measurements of:

- element composition of the biomass sample with the help of laser TOF MS, by ratio of mass peaks of C, O, N, H, also K, Ca, P, S and some microelements;
- masses of molecular ions obtained from the biomass sample after its thermal evaporation and ionization in the gas phase by electron impact, with the help of gas TOF MS;
- molecular mass of secondary ions located in the ice matrix, emitted under the influence of the primary energetic particles beams on the surface of Europa in the processes of similar fast atom bombardment , with the help of gas TOF MS operating in a mode of external ions registration.

The joint comparative analysis of these results will give the information about the possibility of presence of life on Europa and its similarity with Earth form. The instrument complex can be created after considerable modernization of the new generation onboard instruments LASMA and MANAGA developed for Phobos – Soil Mission. Onboard system of biomass extraction will be created for the first time.

INHABITED EUROPA (How plasma torch of the meteorite impact could have promoted arising of the extraterrestrial form of living matter)

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New concept according to which the processes of SHV-impacts of meteorites can contribute to the origin of the primary forms of living matter was proposed. These processes can start in the plasma torch of meteorite impact and stop in the meteorite impact crater.

It is generally accepted that planets are the optimal place for the life origin and evolution. In the process of forming the planetary systems the meteorites, space bodies feeding the planet growth, appear around stars. In the process of forming the Earth meteorites sizes ranged up to hundreds and thousands of kilometers. These space bodies consisted mainly of planetazimali and comet nucleus. During acceleration in the earth’s gravitational field they reached SHV and, hitting the Earth's surface, generated powerful blowout of hot plasma in the form of a torch. They also created giant-size craters and dense dust clouds. These bodies were composed of all elements needed for synthesis of organic compounds (OC) with the carbon content up to 5 – 15%.

A new idea of possible synthesis of the complex OC in SHVI-generated plasma torch were proposed and experimentally confirmed. Previously unknown and found experimentally new feature of impact generated plasma torch has allowed to developing the original concept of the prehistory of life. According to this concept the intensive synthesis of complex OC arose during meteoritic bombardment in first 0.5 billion years at the stage of the planets formation. This the most powerful and destructive action in the Earth history could play the decisive role and prepare the conditions for origin of the life. In the interstellar gas-dust clouds the synthesis of simple OC may be explained by identical process occurring in the plasma torch of SHV-collisions between the dust particles.

Experimental evidences indicate that during the plasma torch fly away make it possible to advance a hypothesis according to which the plasma-generated unbalanced asymmetric electric and magnetic fields may lead to the initial insignificant breaking of the mirror symmetry in processes of enantiomer’s synthesis. These processes hypothetically could determine the «sign» of asymmetry of bioorganic world.

It is assumed that the processes occurring in the highly unbalanced hot plasma simultaneously with the synthesis of simple and complicated OC were capable to ensure their ordering and self assembling. Due to spontaneous mirror symmetry breaking they were also capable produce the homochiralic macromolecular structures needed for origin of the first simplest living organisms.

It has been shown experimentally that the plasma-chemical processes in the torch have high catalytic properties and assure the rise of the chemical reactions rates by 10-100 millions times. In the process of the plasma fly-away this in turn can assure fast forming the simple and complicated OC including highly forked polymers. One may assume that predominantly inorganic substances from meteorites were used for synthesis of complicated OC on the early Earth.

Laboratory experiment with modeling the SHV-impact plasma torch by the laser working in Q-switch regime has shown the possibility of synthesis of high-molecular, ~4000 a.m.u, OC by impact of micrometeorite with effective diameter 100 mkm. The target was composed of only H, C, N and O in inorganic form. The obtained of mass-spectra evidence to the high velocity of chemical reactions due to plasma catalytic processes. Some signs of self - assembly and ordering were observed. This allows to concluding that the plasma torch with huge local density of energy and matter may be the optimal medium for synthesis of complex OC needed for the origin of the primary form of living matter.

Having the giant energy, the meteorite impact is capable to inject the new-created complicated OC deep inside the space body surfaces, including subsurface water reservoirs, such as, for example, on Europa, Encilade and Titan. In this case the meteorite impact has no natural alternative in creation the initial conditions for origin of extraterrestrial life. Such a possibility was confirmed by laboratory impact modeling experiment, in which the plasma torch was created under the water surface.

The important feature of this new concept is the possibility of its experimental verification. This could be done in experiment with collision of two body’s, projectile and target, launched from counter-flying satellites. Such configuration provides the overcritical velocity (~16 km/s) impact and simultaneous measuring the mass of the synthesized OC by remote onboard TOF – MS.

The proposed concept is based on real physical processes occurring in the nature and on experimental results of study the problem in impact experiments and modeling its analogues in laboratory conditions. Thus, the realizability and survivability of this concept should be taken as well grounded due to the simplicity and clarity of physical processes.

References:

1. Managadze. G. G.A novel scenario of prebiotic stage of evolution of life and universal mechanism of its realization in the meteorite impact. Intern. Jour. of Imp. Eng. (2008)

2. Managadze G. G. A new universal mechanism of organic compounds synthesis during prebiotic evolution // Planetary and Space Science, Volume 55, Issues 1-2, Pages 134-140 January (2007).

3. Managadze G.G. Brinckerhoff W.B.Chumikov A.E. Managadze N. G. Synthesis of high-molecular organic compounds in plasma torch modeling SHV-impact torch. Pr-2132. Preprint of Space Research Institute Russian Academy of Sciences. Moscow. (2007).

4. Managadze G.G. Universal mechanism of abiogenous synthesis of organic compounds in the processes of super-high-velocity impact at the stage of prebiotic evolution. Journal of automation and information science. V37. p.34.(2005).

5. Managadze, G.G. Possibility of asymmetric organic compounds synthesis in the plasma torch generated in SHV-. impact. Pr-2107. Preprint of Space Research Institute, Russian Academy of Sciences, Moscow. (2005).

6. Managadze, G.G. The synthesis of organic molecules in a laser plasma similar to the plasma that emerges in hypervelocity collisions of matter at the early evolutionary stage of the earth and in interstellar clouds. J. Exp. Theor. Phys. 97 (1), 49–60,(2003).

7. Managadze, G.G., Brinckerhoff, W.B., Chumikov, A.E., Molecular synthesis in hypervelocity impact plasmas on the primitive Earth and in interstellar clouds. Geophys. Res. Lett. 30 (5), 1247, (2003).

8. Managadze, G.G., Brinckerhoff, W.B., Chumikov, A.E. Possible synthesis of organic molecular ions in plasmas similar to those generated in hypervelocity Impacts. Int. J. Impact. Eng. 29, 449–458, (2003).

9. Managadze G.G. .Molecular synthesis in recombinating impact plasma. In proceedings of 27 General assembly of the European . Geophysical Society. Abstract EGS.02-A-06871. Nice (2002).

10. Managadze, G.G. Organic compound synthesis in experiments modeling high-speed meteor impact. In: Proceedings of the 26th General Assembly of the European Geophysical Society. Geophys. Res. Abstr. 3, 7595,Nice (2001).

THE CONCEPT OF EXPEDITION TO EUROPA, THE JUPITER’S SATELLITE

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The annotation:
Europa is one of satellite of Jupiter, the smallest Galileo moon. Europa is considered as one of few objects in the Solar system (apart Mars and Titan) that may host extraterrestrial life making it a very attractive research target. The surface of Europa is an ice crust overlaying an ocean of liquid water. Therefore, it is essential to complement remote sensing of this satellite from its orbit with contact studies on its surface by means of a various kind of landing stations.

The proposed space mission to Europa will include following basic stages:

- Interplanetary flight to Jupiter;
- Flight in the Jupiter-dominated zone ;
- Insertion into an orbit around Europa and landing.

Two variants of the interplanetary cruise are possible. First, we considered the chemical propulsion including gravitational maneuvers around Venus and the Earth. Alternatively, electric propulsion system can be applied application during the heliocentric section of the cruise coupled with single gravitational maneuver around the Earth.

Launch vehicle "Proton" with upper stage booster "Breeze-M" is necessary to carry out the spacecraft (SC) to the escape trajectory.

In the vicinity of Jupiter a series of gravitational maneuvers near Galileo satellites is conducted in order to save propellant mass during the insertion into the orbit around Europa. Extremely strong radiating belts of Jupiter have to be taken into account. Lengthy approach to the planet is unacceptable due to enormous cumulative radiation dose, destroying the electronics of the spacecraft. Therefore, the trajectory in the vicinity of Jupiter should be chosen in order to minimize the duration the parts of the trajectory within Europa orbit, and to exclude whenever possible entering within Io.

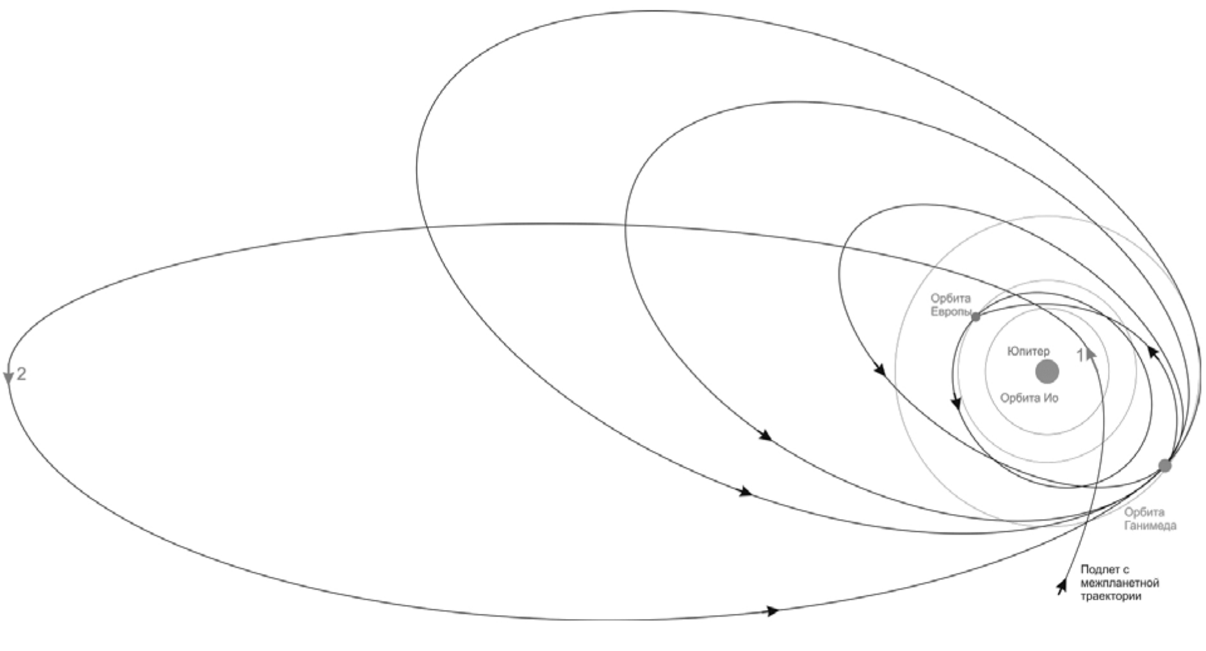
With these assumptions, we choose the sequence of gravitational maneuvers within less than two years. This stage is completed with insertion of the SC into a circular polar orbit round Europa.

From this orbit remote studies of the surface will be conducted, and the landing site meeting certain topography conditions will be chosen. The landing module is separated, and performs an active landing. The orbital module remains on the orbit and serves as a relay for the lander.

Preliminary ballistic estimations have shown, that the complete structure of a space vehicle including the orbital and landing devices can be realized only with application of electrorocket engines.

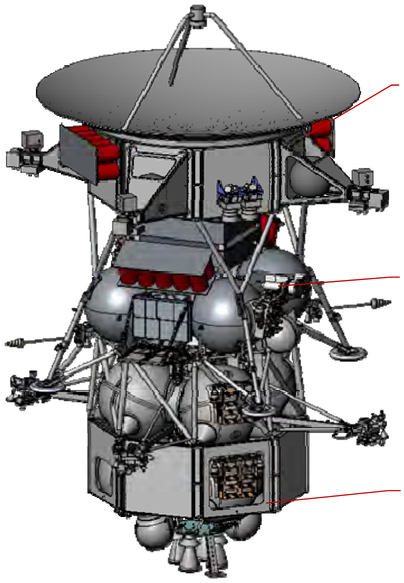
Thus, considering scientific goals of the mission and the ballistic limitations we propose the following mission elements:

- The electrorocket transport module;



- The orbital module;
- The landing module;
- Propulsion system.

The electrorocket transport module is intended for creation of momentum at the heliocentric stage of flight.



The orbital module is the basic structural element of the space vehicle and provides the control of the SC at all stages of flight. At the orbit around Europa it serves for research experiments and relaying.

The landing device provides ΔV to quit the orbit around Europa, soft landing on its surface, and realization of science experiments. The distinct feature of Europa lander (w.r.t. e.g., Lunar landers) is the use for the main brake engine of the monocomponent fuel on the base of hydrazine. It allows to minimize the pollution on the surface.

The propulsion system provides corrections during the cruise, and also braking impulses in the vicinity of Jupiter when forming the orbit around Europa.
Preliminary estimations show that the mass allocation for scientific equipment on the orbital module is about 50 kg, and on the landing device – about 60 kg.

Considering the overall complexity of mission, the expedition concept, and the spacecraft design include considerable margins.

The landing approach and the elements of the landing module will be testes during Lunar mission "Luna-Resource" which is planned for launch in 2012.

The electrorocket transport module is being developed, and it designing and tests will be finalized during various space expeditions of Roscosmos.

Propulsion system and many of the elements of the orbital module already developed and are the part of the "Phobos-Soil" mission.

PROJECT “EUROPA LANDER-SOUNDING”: EXPERIMENTAL POSSIBILITIES FOR COMPLEX SOUNDING OF THE SUBSURFACE-ELECTRICAL STRUCTURE OF EUROPA MOON.

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The primary goal of the ”Europa lander ” mission is an investigation of the Europa moon and particularly its internal structure. These studies are based on the following measurements which are performed by various instruments carried by the spacecraft:

- gravitational field variations caused by librations fluctuations of Europa moon and tidal effects;
- seismic noise at frequencies between 0,1 and 100 Hz for revealing how their intensity and spectral structure depends on thermoelastic effects, artificial and natural influences on the Europa moon surface (P- and S-waves from working GZU (manipulator for automated testing for soil and rock properties); dust and gas fluxes from the torus around the Europa moon orbit, impacts of small meteoroides et etc);
- magnetic (3 components) and electric (2 components) field fluctuations in the frequency range from 0.1 to 1000 Hz which allows to determine an impedance on a surface of the Europa moon (magnetotelluric sounding) and to investigate electrodynamic properties of rocks from which the Europa moon is made;

The available photometric data gathered earlier show rather complex character of both Europa moon surface and it’s subsurface structure.

The complex sounding of the Europa moon provides not only the information about its structure (important for understanding of the origin of the Jupiter system) but also an outstanding experience of sounding at surface of celestial body. This experience is of particular importance for further investigation of subsurface structures of Europa and its geological history which will be carried out in the future space missions.

References:

[1] Clifford S.M. (1993) *JGR, 98,* 10973–11016. [2] Toulmin P.,*et al*, (1977) *JGR,82*,4624-4634 [3] Fanale F.P. (1986) *Icarus, 67,*1-18.[4] Ozorovich Y.R., Linkin V.M., Smythe W., “ Mars Electromagnetic Sounding Experiment – MARSES ”, Proceedings of LPI Conference, Houston, 1999.

UNDERSTANDING EUROPA'S RADIATION ENVIRONMENT AND HOW IT INFLUENCES LANDING SITE CHARACTERIZATION. G.W. Patterson, L.M. Prockter, C. Paranicas, Space Department, Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD 20723, Wes.Patterson@jhuapl.edu

Introduction: The surface of Europa is eroded and altered chemically by irradiation from Jovian magnetospheric particles, UV photons, and particles associated with Io's plasma torus [1]. It has been shown that this process can have important astrobiological consequences [2,3] and both NASA and ESA have suggested that the exploration of Europa's surface should be a high priority. However, the high radiation environment around Europa also presents a significant hazard to the lifetimes of chemically altered species [4] and potential missions to the satellite.

It has recently been demonstrated that radiolytic processes across the surface of Europa are not uniform with respect to location and depth [5]. Further, several surface processes (e.g., micrometeorite bombardment and nonsynchronous rotation) have an influence on how radiolytic products are distributed [1,6]. We have begun an effort to characterize the variability of radiolytic processes and integrate the influence of related surface processes with location and depth globally for Europa. With this information, we can identify regions on Europa that provide greater protection against the harsh Jovian radiation environment and have high science value (e.g., locations where relatively unaltered subsurface organic material may be found at or near the surface).

Radiolytic Processes: Close to Europa, electrons and ions spanning a wide range of energies coexist with the moon and bombard its surface. Interactions with theses charged particles primarily affects the top few cm of Europa's icy shell [1] (although high-energy electrons can penetrate up to a meter [7]), leading both to erosion of the surface via sputtering and the production of molecular oxygen, hydrogen peroxide, and other oxidants (Fig. 1). Energetic ions can also be implanted into the surface and subsequently incorporated into the ice [8]. Ions in Jupiter's magnetosphere that can be incorporated into new molecules include H, O, S and components of the solar wind (90-95% protons, 5% He++, and traces of C, O, Si, and others). Recent modeling suggests that electrons in the hundreds of keV to tens of MeV range, which dominate the radiation dose at Europa, preferentially get deposited into the satellite's trailing hemisphere and systematically decrease across the reamainder of the satellite as a function of longitude and latitude [7] (Fig. 2). This suggests that Europa's leading hemisphere is effectively shielded from a significant fraction of the radiation present at the body.

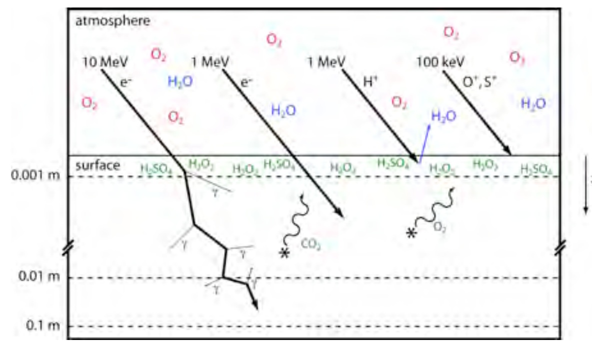

Fig. 1. Various ions and electrons are continuously bombarding Europa's surface and depositing their energy at different depths. Protons and heavy ions are stopped almost immediately upon contact with the ice. These deposit energy into a layer, which leads to the sputtering off of new molecules. Electrons deposit their energy deeper into the ice and as they slow down produce photons nearly isotropically. These photons can then re-ionize other molecules in the ice at much greater depths. Some products, such as O_2 and CO_2, appear to form in the ice due to the action of electrons.

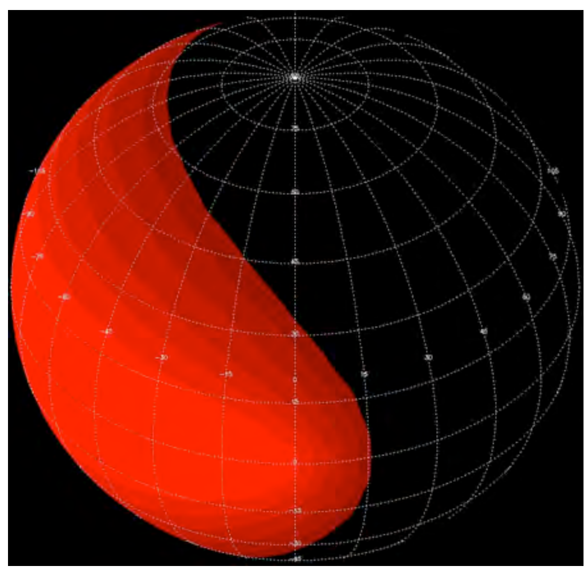

Fig. 2. Sketch of preferential bombardment of Europa by energetic electrons in tens of keV to few MeV energy range.

Surface Processes: Impact gardening by micrometeorite bombardment results in vertical mixing of the surface of Europa. Because the satellite is in nearly synchronous rotation about Jupiter, heliocentric impactors are expected to preferentially affect the leading hemisphere [9]. Given a mean surface age for Europa of ~10^7 yr [10], gardening should extend to a depth of 1.3 m [1]. Mixing rates at Europa can be as high as 1.2 μm/yr for a fresh surface while it has been suggested that the sputtering rate due to radiolytic processes is more than an order of magnitude less at ~0.02 μm/yr [1]. This indicates that gardening can bury oxidants produced in the radiation environment surrounding Europa, protecting them from loss by sputtering [6].

Modeling suggests that the decoupled outer shell of Europa should undergo nonsynchronous rotation due to torques imposed by tidal forces [11,12]. Comparisons of Voyager and Galileo images [13] suggest that this mechanism would lead to rotations of 1° in longitude over timescales >10^3 yr. Such a process would lead to a 'smearing' of the distribution of the highest energy electrons, which are generally confined to the trailing hemisphere of the satellite. It would also 'smear' the affects of impact gardening, increasing the volume of oxidants that can be buried and preserved from breakdown due to continous irradiation.

Landing Site Characterization: The radiolytic and surface processes we have described are regional in nature. Radiolytic processing of Europa's surface is strongest at the satellite's trailing hemisphere. The effects of micrometeorite bombardment are strongest at the satellite's leading hemisphere. Nonsynchronous rotation of Europa's ice shell 'smears' both of these effects over time. These processes are ongoing and interact with each other to produce a complex and global cycle of chemical alteration and surface erosion. Understanding how this cycle works can provide essential information for assessing the science value and risk associated with potential landing sites.

References: [1] Cooper et al. (2001), Icarus, 149, 133-159; [2] Chyba (2000), Nature 403, 381-382; [3] Irwin and Schulze-Makuch (2001), Astrobiology, 1(2), 143-160; [4] Delitsky and Lane (1997), J. Geophys. Res., 102, 16,385-16,390; [5] Paranicas et al. (2007), Geophys. Res. Lett., 34; [6] Chyba and Phillips (2001), P. Natl. Acad. Sci. USA 98(3), 801-804; [7] Paranicas et al. (2002), Geophys. Res. Lett., 29; [8] Johnson (1990), Springer-Verlag.; [9] Schenk et al. (2004), Cambridge University Press, Cambridge, 427-456; [10] Zahnle et al. (1998), Icarus, 136, 202-222; [11] Greenberg and Weidenshilling (1984) Icarus 58, 186-196; [12] Ojakangas and Stevenson (1989), Icarus 81, 220-241; [13] Hoppa et al. (1999), Icarus, 137, 341-347.

PLASMA ENVIRONMENT OF EUROPA.

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We review the environmental plasma conditions at the Europa location, including Jovian magnetosphere structure and dynamics, mass and energy plasma composition, which will affect Europa lander sophisticated measurements targeted at organic analysis, as well as spacecraft systems in general. Jupiter magnetosphere is relatively well studied by the spacecraft in comparison with other outer planets, but still the description is in many aspects qualitative and lacks dynamical details as well as some specification models.

The Jupiter magnetosphere is different from the Earth's one in a number of ways. The proper magnetic field is much larger, the rotation is faster and the solar wind effect is relatively weaker. The second feature is presence of Io-genic plasmas. Thus the powerful magnetosphere is created, which is dominated by rotation. It is also a very efficient accelerator of particles. The Europa environment is physically equivalent to that in the outer radiation belt of Earth's magnetosphere but typical particle energies and fluxes are higher by the factor of 10-100. An important aspect is substantial presence of heavy Iogenic ions, specifically sulfur.

Corotation creates an azimuthal plasma motion with velocity of about 100 km/s at 10 Rj (much larger than Europa's orbital velocity) and therefore the sides of Europa are differently affected by plasma particles. Another effect of corotation is presence of electric field, immediately accelerating newly born ions to corotation velocity, and thus moving them away from the satellite and the spacecraft.

Radial plasma dynamics includes interchange instability (scale of minutes), rapid injections (hours) and global discharges of Io-genic plasma disk (days). Thus plasma motion around Europa is not purely azimuthal. It should be noted that “radiation safe” zones are computed assuming the stable flux tube rotation.

The satellite also moves vertically relative to plasma, due to the difference between the orbital plane and centrifugal equator (plasma disk). As a result local thermal plasma density (100 eV) varies by a factor up to 10.

The weak Europa exosphere allows direct interaction of plasma with the surface. The surface is strongly affected by sputtering, ion implantation, radiogenic changes etc.

Extremely strong radiation (particles with energies higher than 1 MeV) affect spacecraft in a number of ways. Protons and heavy ions affect primarily open electronic elements, such as SSD. Energetic electrons penetrate much deeper and in addition to radiation damage may create substantial internal charging. Strong surface charging is also quite feasible. A substantial experience on this aspect was acquired in the course of Galileo mission.

Therefore a special policy on mediating of environmental effects on the spacecraft in general and on sensitive measurements in particular should be pursued in the project.

CHARGED PARTICLE FLUXES AND RADIATION DOSES IN EARTH-JUPITER-EUROPA SPACECRAFT’S TRAJECTORY

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Space research mission to the system of Jupiter and its satellite Europa is connected with considerable radiation hazard. In the current study estimations of charged particle fluxes and radiation doses under various shielding in different parts of the trajectory are made, using different empirical models at each stage of the computations.

The worst radiation hazard during the mission will originate from the powerful Jupiter’s radiation belts. In particular, during 2 months in Europa orbit and on its surface the absorbed dose under 2.2 g/cm^2 (the equivalent of “Galileo” spacecraft shielding) will amount to several hundreds of kilorads.

Additionally the dose of several tens of kilorads will be absorbed during the gravity assists near Jupiter. We have examined different variants of the trajectory and concluded, that the optimal path should probably include the first fly-by with nonzero inclination and the pericenter inside Io orbit, and then several gravity assists using Ganymede.

Also estimates of the charged particle fluxes and radiation doses near Earth and in the interplanetary part of the trajectory are given.

The results are compared with the publications by other researchers.

Finally proposals are made on the monitoring of the radiation environment during the mission.

ASTROBIOLOGY OF EUROPA.

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Introduction:

Europa satellite is a priority object of exploration for the Space Agencies. The main reason of its high interest is the evidences of the presence of harbor liquid water reservoirs below the icy crust. Liquid water is one of the pre-requisite for potential habitability searching. Other conditions that have been recognized as necessary for the life as we know are biogenic elements and free energy.

From the Astrobiology point of view, the object for exploration should be potential habitable environments. But the direct study of the deep aqueous reservoirs is not currently feasible because of its inaccessibility and the uncertainties about the location or the extension of the aqueous reservoirs. However, some important information could be obtained if some connection between the liquid reservoirs and the surface exists. Actually, some features of the surface seems to have been associated with materials that have been fluid during the ascent stage to the surface, such as the chaotic areas or some confined cryovolcanic materials. These areas are good candidates for future in situ exploration from the astrobiological point of view.

Remote sensing observations from an orbiter are very valuable to characterize some geological geochemical and geophysical properties of the surface. These observations are essential to be prepared for a landing, including the selection of the appropriated site. However, searching for biosignatures do not seems to be easy from remote sensing. It would be useful just in the case the detection is absolutely clear and definitive, and this only occurs if the biosignatures are in high abundance or they are explicitly biological.

Endogenous materials could be affected and/or destroyed by the high radiation environment in the surface environment. Therefore, it would be more remarkable to be able to access to the subsurface to analyze fresh materials. This is only possible if some in situ element reaches the surface.

Search for life:

The option of having a lander for a future Europa mission will provide more reasonable opportunities in searching for life, extant or extinct. Usually, detection of biosignatures needs direct sampling, and concentration of materials. In addition, it is always preferable the detection of more than one biosignature to be conclusive in the results.

Studies of astrobiological interest could be:

1) Measurements to characterize the properties of the surface/subsurface environment.

Taking into account that the potential habitable environment is at different physical conditions (pressure, temperature, radiation) than the samples that can be measured at surface or subsurface, it is essential to characterize the landing site context from where the materials are taken (e.g. mineralogy, physico-chemical properties like redox or pH, radiation doses). It would be mandatory to be able to sample the subsurface materials, as deeper as possible, in order to avoid the radiation environment. These measurements would provide the setting on the state of potential biosignatures. Simple sensors packaged in an environmental station as part of the lander payload would be very useful.

2) Measurements for the detection of potential biosignatures.

It includes the organic molecules characterization, volatiles and isotope ratios analysis or the examination of potential biological structures. Some techniques are relevant for these purposes such as raman, infrared and fluorescence spectroscopy, GCMS, and optical microscopy. Imaging of the context from where the chemical analysis is made and the comparison between data from the orbiter and the lander are mandatory.

3) Biological measurements

A lander for Europa should include biological measurements of potential extant life. Interesting techniques to have into account are the “inmuno arrays”. These techniques have been already considered for future missions to Mars. In the case of Europa they should be developed properly due to the duration of the trip to the Jupiter system and extreme radiation environment of the surface. Immuno arrays is a biochemical test that is able to state the presence as well as concentration of certain compounds, by using the reaction of antibodies to its corresponding antigens. This essay takes advantage of the specific binding of an antibody (typically monoclonal) to its antigen. An instrument based on this technique is SOLID (by Centro de Astrobiologia), which has been designed and built for the detection and identification of biochemical compounds by in situ analysis of samples.

Other biological techniques will be included in the talk.

LIFE DETECTION ON EUROPA FROM AL LANDER: METABOLIC SIGNATURES

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All living forms on Earth are organized on a cellular base. A cell is an entity, separated from its environment by a membrane which encloses all cell components. These cell components constitute the "cell computering centre" (nucleic acid machinery) and the "cell chemical plan". The chemical plan has a double role: 1. to synthesize all molecules and particularly macromolecules (lipids, sugars, proteins, nucleic acids) of cell components from nutrients taken from the environment; 2. to produce energy for biosynthesis, nutrient uptake and waste elimination. Roles 1 and 2 are named anabolism and catabolism respectively, that together constitute the cell metabolism.

Cell energy is produced from light (photosynthesis) or chemistry (chemosynthesis). Energy obtained is stored in high energy bond molecules such as ATP (adenosine tri-phosphate). Chemosynthesis functions through oxido-reduction reactions which require electron donnors (inorganic or organic reduced molecules) and electron acceptors (inorganic or organic oxidized molecules). Products of these reacions are reduced electron acceptors, that could be used as metabolic signatures. For instance, when sulphate plays as an electron acceptor, it is reduced to hydrogen sulphide, which is an indicator of sulphate reducing organisms.

When the electron donnor is an organic molecule (sugar for instance) and no electron acceptor is available, energy may be produced through fermentative reactions. In these cases, the electron acceptor is an internal intermediate compound, and fermentation products are released. These fermentative products (organics, carbon dioxide, hydrogen…) could also be used as metabolic signatures.

When the electron donnor is an organic molecule, it is used as a carbon source for biosynthesis. If the electron donnor is inorganic, cells (autotrophy) often synthesize organic compounds from carbon dioxide. For these reactions, carbon (from carbon dioxide) must be reduced. This occurrs thanks to a reducing power coming from the electron donnor, if it is well located on the red-ox scale, or through a reversed electron flow.

A similar situation exists in the case of photosynthetic organisms. Most of phototrophs utilize their energy to convert carbon dioxide into organics. Anoxic photosynthetic organisms utilize a reduced compound from the environment to reduce carbon dioxide (for instance hydrogen). Oxygenic phototrophs can photolyze water into hydrogen (reducing power) and oxygen whic constitutes a metabolic signature.

In this review, a variety of compounds resulting from oxido-reduction, fermentation or photosynthetic reactions will be presented as potential metabolic signatures for life detection.

SELECTING LANDING SITES ON EUROPA: CONSIDERATIONS BASED ON AGE, TOPOGRAPHY, MORPHOLOGY AND ALBEDO.

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Exploration of Europa by the Galileo spacecraft revealed that the surface of this moon of Jupiter is geologically young (~60 Ma; *Schenk et al., 2004*). Europa's surface is crisscrossed and disrupted by features primarily formed through lateral and vertical tectonics, possibly with associated icy volcanism. Such observations, combined with Galileo magnetometer observations, and theoretical and earlier spacecraft studies, strongly suggest that there is an ocean underlying Europa's icy shell (e.g., *Greeley et al., 2000, 2004*).

There is uncertainty about the thickness of the ice shell overlying the proposed ocean, although evidence increasingly points towards a depth of more than several kilometers (e.g., *Pappalardo et al., 1999; Turtle and Pierazzo, 2001*) and perhaps at least 20 km (*Schenk, 2004*). Because of the difficulty of getting through the ice shell to the ocean beneath, prime targets for future exploration include regions in which the ocean may have been transported up to the surface, through the formation of geological features.

Geological mapping of Europa's surface has revealed a variety of surface features, some of which are unique to Europa (*Greeley et al., 2000*). Lineaments include cracks, double and multiple ridges, whose origin is still uncertain, as well as bands formed when the lithosphere pulled apart along cracks, allowing subsurface material to fill the newly formed gap. Some of the youngest features comprise disrupted plates of preexisting terrain surrounded by finer-textured matrix material, collectively termed chaos. Chaos regions may cover many hundreds of square kilometers of the surface. Smaller chaos-like areas with subcircular planforms several kilometers in diameter, are termed lenticulae. Chaos areas are commonly associated with smooth low albedo plains material, which commonly shows signs of embayment of the surrounding terrain and was apparently inviscid during emplacement. Although the origins of these features are still not well understood, it is likely that some of them – especially bands and chaos material – are associated with subsurface material, possibly from the ocean itself (e.g., *Greeley et al., 2004*). As such, they are prime targets for exploration by a future lander

Many of the features on Europa have dark material associated with them, and appear to have brightened with age, possibly because of frost deposition or chemical alteration (*Squyres et al., 1986; Geissler et al., 1998*). Thus low albedo features appear to be relatively young. Mapping of features on Europa shows that bright features are the oldest, and while low albedo features are youngest (e.g., *Prockter et al., 1999; Figueredo and Greeley, 2000; 2004*). Landing sites within low albedo material are likely to be able to sample some of Europa's youngest material. In addition, Figueredo et al. (*2003*) evaluated the astrobiological potential of the major classes of geologic units on Europa with respect to possible biosignatures preservation on the basis of surface geology observations. They concluded that smooth plains, smooth bands, and chaos regions would have the highest astrobiological potential.

In this paper we will review the characteristics of a site that will provide the highest science return from a lander. These include, but are not limited to:

- Evidence of likely communication with subsurface ocean, and hence high astrobiological potential
- Relative youth, and hence minimally affected by radiation
- Relatively flat, smooth area large enough for an achievable landing ellipse.

One of the most promising sites that meets these criteria is the Castalia Macula region of Europa, which was studied by Prockter and Schenk (*1995*). This region was comprehensively imaged by the Galileo spacecraft on several orbits, at both local and regional resolutions (Fig. 1) and with different illumination geometries, and is one of the best-studied regions on Europa. Castalia Macula consists of unusually dark and reddish material (Fig. 2), most of which is confined to a broad topographic depression 350 m deep. This depression is located between two large uplifted domes 900 and 750 m high, to the north and south, respectively. The low albedo of the Macula along with mapping of the stratigraphy of the region suggest that this is a relatively young area on Europa, and would therefore be an excellent target for a future lander.

References

Geissler, P.E. and 14 others, (1998). Evidence for non-synchronous rotation of Europa. *Nature 391*, 368-370.

Greeley, R., and 17 others (2000). Geologic mapping of Europa, *J. Geophys. Res.*, 105, 22,559 - 22,578.

Greeley, R., C.F. Chyba, J.W. Head III, T.B. McCord, W.B. McKinnon, R.T. Pappalardo, and P. Figueredo, Geology of Europa, in *Jupiter: The Planet, Satellites and Magnetosphere*, ed. F. Bagenal, Cambridge University Press, 2004.

Prockter, L.M., A.M. Antman, R.T. Pappalardo, J.W. Head and G.C. Collins (1999a). Europa: Stratigraphy and geological history of the anti-Jovian region from Galileo E14 solid-state imaging data, *J. Geophys. Res., 104,* 16531-16540,

Figueredo, P.H. and R. Greeley (2000). Geologic mapping of the northern leading hemisphere of Europa from Galileo solid-state imaging data, *J. Geophys. Res., 105,* 22,629 – 22, 646.

Figueredo, P.H. and R. Greeley (2004). Resurfacing history of Europa from pole-to-pole geological mapping, *Icarus*, 167, 287-312.

Figueredo, P.H., R. Greeley, S. Neuer, L. Irwin, and D. Schulze-Makuch, Locating Potential Biosignatures on Europa from Surface Geology Observations (2003), *Astrobiology, Vol 3.,* 851-861.

Pappalardo, R.T. and R.J. Sullivan (1996). Evidence for separation across a gray band on Europa, *Icarus, 123,* 557-567.

Pappalardo R.T., and 31 others (1999). Does Europa have a subsurface ocean? Evaluation of the geological evidence, *J. Geophys. Res., 104*, 24015-24056.

Prockter L.M. and P.M. Schenk, The origin and evolution of Castalia Macula, Europa, an anomalously young depression, Icarus, 177, 305-326, 2005.

Schenk, P.M., C.R. Chapman, K. Zahnle, and J.M. Moore (2004). Ages and Interiors: the Cratering Record of the Galilean Satellites, in *Jupiter: The Planet, Satellites and Magnetosphere*, edited by F. Bagenal, T. Dowling, and W. McKinnon, pp. 427-456, Cambridge University Press, Cambridge.

Squyres, S.W., R. T. Reynolds, and P. M. Cassen, Liquid water and active resurfacing on Europa, *Nature*, 301, 225, 1983.

Turtle, E. P. and E. Pierazzo, Thickness of a Europan ice shell from impact crater simulations, *Science* 294, 1326–1328, 2001.

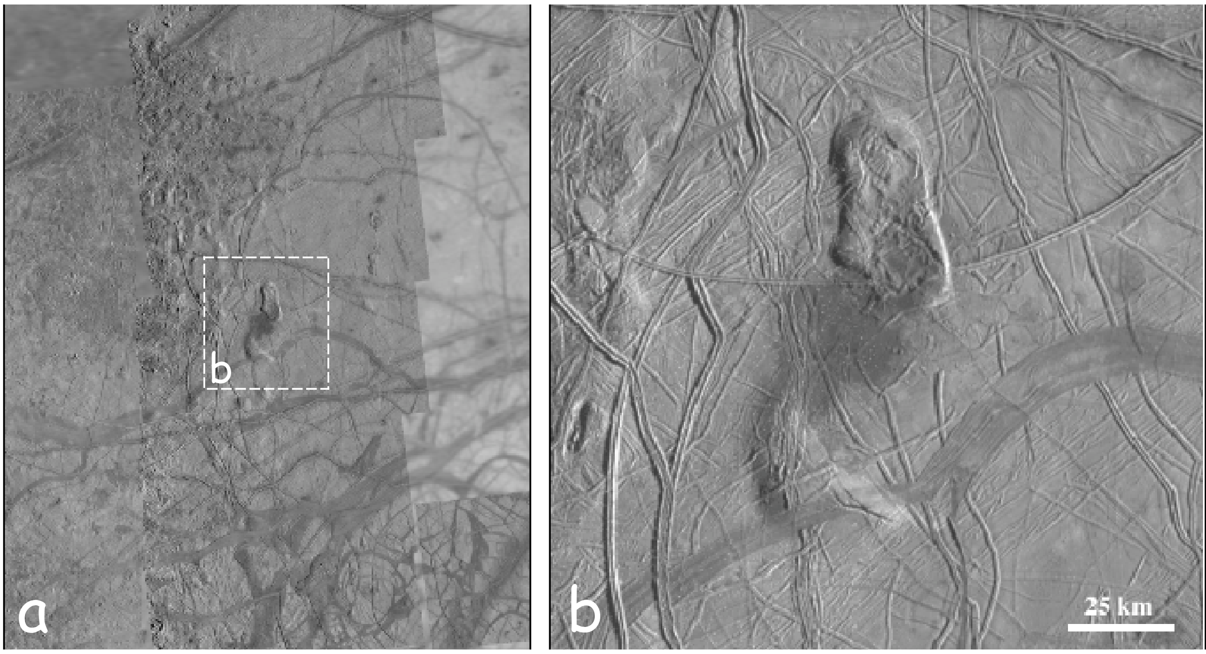

Figure 1: (a) Regional view of Castalia Macula region showing relationship to chaos regions to the west and bands to the southeast. (b) Local view showing the Castalia Macula dark plains deposit and domes to the north and south.

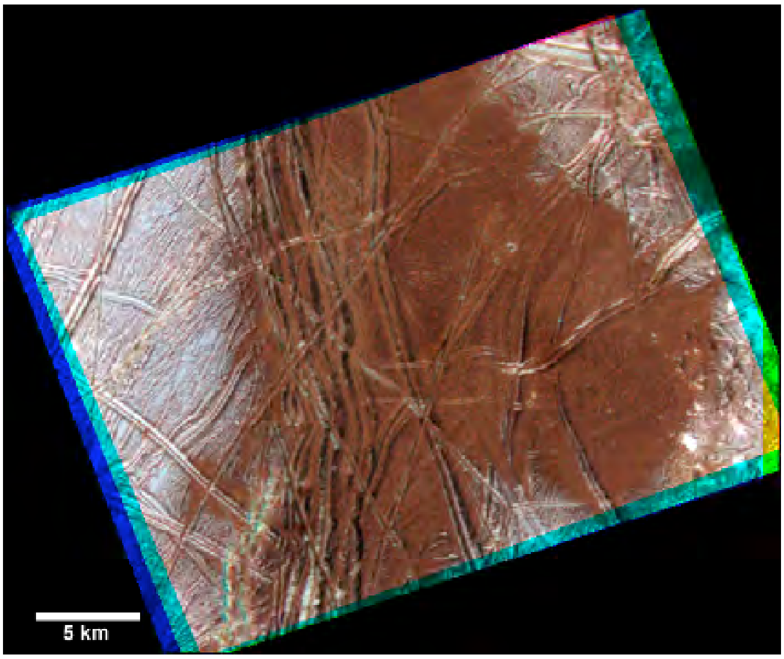

Figure 2: Color imaging of the Castalia Macula deposit shows it to have the reddish brown color shared by dark features elsewhere on Europa. Color ratio images using 9680 and red filter Galileo data show that Castalia may one of the reddest units on Europa. Such deposits are inferred to be sites of non-ice materials, particularly hydrated minerals.

ABOUT THE EVIDENCE OF EXISTENCE OF AN OCEAN AT THE JOVIAN MOON EUROPA BASED ON THE STUDY OF ITS ICE COVER’S ROTATION

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Introduction:

The investigation of Jupiter and its Galileo moons being fulfilled by *Galileo* and *Cassini* missions (fly bay of the first one on Jan. 30, 2000) gave the information of vital importance concerning magnetic field of Jovian moon Europa induced by rotating magnetic field connected with Jupiter. This information leads to conclusion of existence of liquid oceans at the Jovian moons Europa and Callisto covered completely by the ice shell. The main results of these investigations were published during last years (see [1 – 10]).

The principal possibility of direct evidence of oceans existence at the Jovian moon Europa by means of landing probes equipped by the angular velocity sensors of high precision are under consideration. This conception is based on the theoretical solution of the problem concerning Europa ocean and its ice shell rotation induced by magnetic field.

The inclination to the Jovian rotating axis of its magnetic dipole induces the self magnetic field of Europa rotating relatively to the moon with the angular velocityω. The relative liquid motion excited by this field is characterized by great values of hydrodynamic and magnetic Reynolds numbers.

The rotation of Europa ocean and of its shell. Theory and experiment:

The physical model for describing the rotation of the ocean and its ice shell may be represented as a solid, absolutely rigid spherical no electro conductive kernel closed by spherical layer of ideal, non compressible electro conductive liquid, closed by a thin, no electro conductive elastic shell. The liquid layer has in accordance to last information a thickness approximately 100 km, and the ice shell – of 10 km.

We suppose that the kernel is rotating synchronous with the moon’s orbital motion. The ocean is rotating together with the ice shell having in the contrary a velocity relatively to the kernel equal to zero in the moment t = 0 only. We describe this motion by integral-differential equation with singular kernel of Abel type.

The analytical solution of this equation has been obtained by Laplacian transformation method. The quality analysis of this solution was fulfilled as well as the comparison with the results of special experiments [11].The main results of our investigation are as follows.

The initial state of the ocean – ice shell system (the synchronous rotation) is non stable. The system has a tendency to transform in the steady state one, having the partial co rotation. This means the relative rotation of the ocean together with its ice shell with very slow constant angular velocity Ω^0 in the direction of magnetic field’s rotation. The asymptotic state of the system is stable relatively to the angular velocity: the breaking moment will be greater then the twisting one while increasing of the angular velocity, and the system will come back to the non disturbed state.

The effect of ice shell rotation may be used for direct evidence of liquid ocean at Europa by means of landing probe equipped with angular velocity sensor. The angular velocity Ω^0, measured by this sensor, is greater then synchronous one and smaller then co rotation’s angular velocity: $10^{-5}\,s^{-1} < \Omega^0 < 10^{-4}\,s^{-1}$.

Such accuracy is of course very high but, as the Russian speak in such case, «*The play is worth of candles*».

References:

1. *Young, R.E.* The Galileo probe mission to Jupiter: Science overview // J. Geophysics Res. 1998. V. 103. No E10 pp. 22.775–22.790.
2. *Anderson, J.D., G. Shubert, R.A. Jacobson et al.* Europa‘s differential internal structure. Inferences from four Galileo encounters // Science, 1998. 281, pp. 2019–2022.
3. *Carr, M.H., M.J.S. Belton, C.R. Chapman et al.* Evidence for a subsurface ocean on *Europa* // Nature, 1998. 391, pp. 363–365.
4. *Showman, A.P., and R. Malhorta,* The Galilean satellites // Science, 1999. 286, pp. 77–84.
5. *Belton M.J.S.* Galileo: On to Io and Cassini // The Planetary report, 1999. V. XIX. No 4. pp.12–17.
6. *Pappalardo, R.R., J.W. Head, and R. Greeley,* The hidden ocean of Europa. //Sci. Am., October 1999. pp. 54–63.
7. *Stevenson, D.J.* An ocean in Callisto? // The Planetary report, 1999. V. XIX. No 3. pp. 7–11.
8. *Saur, J., D.F. Strobel*, and *F.M. Neuburer*, Interaction of the Jovian magnetosphere with *Europa*. Constraints on the neutral atmosphere // J. Geophys. Res., 1998. 103, pp. 19, 947–19.
9. *Zimmer, C., K.K. Khurana, and M.G. Kivelson.* Subsurface oceans on Europa and Callisto. Constraints from Galileo magnetometer observations // Icarus, 2000. Vol. 147. p. 329.
10. *Kivelson, M.G., K.K. Khurana, C.T. Russe et al.* Galileo magnetometer measurements. A stronger case for a subsurface ocean at Europa // Science, 2000. 289, pp. 1340–1343.
11. *Rabinovich B.I.* About the principle possibility to prove the existence of the ocean at the Jovian moon Europa using a landing probe. Preprint IKI RAN Pr-2146. Moscow, 2008.

SEARCH FOR COMPLEX ORGANIC MATTER AND SOUNDING OF EUROPA' SURFACE AND NEAR-SURFACE ATMOSPHERE BY MEANS OF FAR IR & TERAHERTZ SPECTROSCOPY

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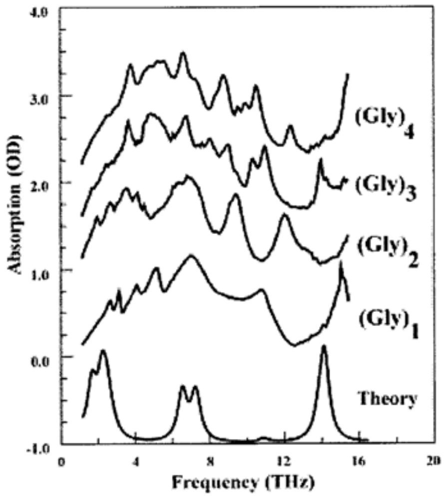
Scientific background:
Terahertz, or submillimeter, spectroscopy is a powerful, quickly developing method highly demanded in numerous applications from material science to security and remote sensing. Spectral range from 1 to 10 THz, corresponding to vibration modes of large molecules and intermolecular bonds in solids and liquids, is particularly encouraging for future missions to Europa due to its potential efficiency for detection of organic matter. To date, no specific experiments have been accomplished in THz range onboard interplanetary spacecraft, mainly because of technological limitations.



THz spectra of polypeptide powder of glycine, (Gly)n (n = 1 – 4). As the chain length increases, distinct and new absorption features are produced. From M. R. Kutteruf, C. M. Brown, L. K. Iwaki, M. B. Campbell, T. M. Korter, and E. J. Heilweil, *Chem. Phys. Lett.*, **2003**, *375*, 337

However, sustaining demand on commercial security equipment focused on complex organic species, along with biotech industry, has driven a dramatic boost in terahertz technology for last 5 years.
Cheap and reliable sources and detectors appear on the market, allowing for planning a set of spacecraft experiments related to this range.
Scientific goals that may be achieved include search for volatile organic matter and other studies of surface material by *in situ* analysis of gas extracted from surface samples, as well as global studies of Europa' surface structure and composition based on passive sounding from the orbiter. To meet these goals, two types of measurements are proposed.
A **far-IR & THz channel** as a part of **TDLAS** instrument is capable to detect organic matter specific for life, such as amino-acids, as well as to perform search and comprehensive analysis of abiogenic organics (tholin-like polymers, PAHs etc), and precise measurement of water ice spin-isomers ratio. A THz spectrometer for identification of molecules using vibration-rotational spectroscopy could be developed with the spectral resolution of 10^6 and the minimal registered change of power NEP~10^{-14} Wt·Hz$^{-0.5}$ (for bolometer) and NEP~10^{-18} Wt·Hz$^{-0.5}$ (for homodyne receiver), that allows to detect minor components at the sub-ppb level.
As gas-phase transmission spectroscopy provides highest detection capability, it may suffer from non-volatility of some condensed organics, such as tholins, or molecule destruction during sample heating. Thus other techniques, including ice thin film transmittance of reflection spectroscopy of material extracted from ice samples on a filter, need to be considered. These techniques are capable to detect organic inclusions in raw ice sample at ppm level. Preliminary, recommended spectral ranges are:
7-12 µm - search for simple organic volatiles (gas phase transmission)
25-30 µm - search for condensed organics in filter (solid-state reflection)
70-90 µm - search for condensed organics in ice; trapper ions; ice inner structure (solid-state transmission.
A **passive THz sounder onboard orbiting satellite** could provide critical data on ice structure and composition with global coverage. Being sensitive to micron- and submillimeter-scale structures, emission phase function and polarization of outging terahertz radiaton provides information on cryotectonical processes forming Europa surface, its interactions with Jupiter plasma environment and possible extinct atmosphere. Passive sounding of outgoing THz radiations allows also for chemical and isotopic analysis of Europa' near-surface exosphere produced by the ice crust gas emission.
In order to estimate potential efficiency of terahertz spectroscopy for the planned mission, we calculated synthetic spectra of some life-specific

and abiogenic organic molecules for conditions related to TDLAS experiment, including gas-phase cell transmittance, ice thin film transmittance and ice reflectance measurements. Synthetic spectra of Europa outgoing terahertz radiation was calculated using DDA technique simulating irregular surface with inclusion of mineral and organic material. Such an experiment may help to address a question of the existence of tholin-like material on the surface of Jovian satellites.

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RAMAN SPECTROMETER FOR *IN SITU* MEASUREMENTS ON EUROPA’S SURFACE.

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Introduction:

Raman spectroscopy is a commonly used technique that provides useful information about the vibrational, rotational and other low-frequency modes of the systems under study, based on the inelastic scattering of the monochromatic light used as excitation. This vibrational information turns out to be specific for the chemical bonds in the system, providing a particular fingerprint by which the compounds in the system can be identified.

In that context, Raman spectroscopy is one of the most useful tools as contact instrument needed for exploration and characterization of planetary surfaces, such as Europa’s surface. Those aspects, exploration and characterization of the surface, are critical if one of the main goals of the possible mission to Europa still is to characterize this moon as a planetary object and its potential habitability from the astrobiological point of view [*Prieto-Ballesteros et al., same issue*]. Analyzing the surface environment by this or any other technique is the only way to get a high-science return on that field.

This work also suggests an instrument based on Raman spectroscopy as a needed tool for taking *in situ* measurements on the Europa’s surface. These measurements will not only provide useful inputs on the characterization of the environment, but also valuable contributions on the definition of the key *habitability* parameters (from the physical and chemical point of view).

Surface characterization:

It will be discussed how Raman spectra may contribute to determine the nature and distribution of the surface constituents on the surface of Europa, providing relevant inputs on the determination of the surface composition at an excellent spatial and spectral resolution.

As far as the technical aspects of the mission allow, it is also possible to get depth profiles of the shallow superficial ices, by characterizing the minerals and potential organic molecules in there.

However, it is worth to mention that, given the aggressive environment on the surface of that moon, the plausible compounds expectable to be found on there will be extremely simple. Based on the analysis of data from the orbiters, it is interesting to remark that there may exist some kind of similarities between some IR spectra of the Europa’s surface and some others gotten in laboratory conditions from organic compounds of astrobiological interest.

Raman spectroscopy is a valuable tool that will turns out to be of great interest in analyzing and detecting those elements as well as providing complementary information about the environmental conditions of the surface. In that sense, Raman spectra will be an important contribution to the measurements of the key habitability parameters, such as temperature, pH, electrical conductivity, radiation conditions and redox couples, among others.

On the other hand, these spectra may also be useful in stating what organic molecules are present and directly related to plausible past and/or present forms of life. This point is based on the capability of the Raman spectroscopy to discriminate and characterize the possible inclusions of CHONPS elemental compounds in those ices.

Some technical aspects:

As mentioned, it is well known that the surface environment of Europa is quite extreme because of the radiation and temperature, as well as the landing determinants: volume, mass, plausible power consumption, etc.

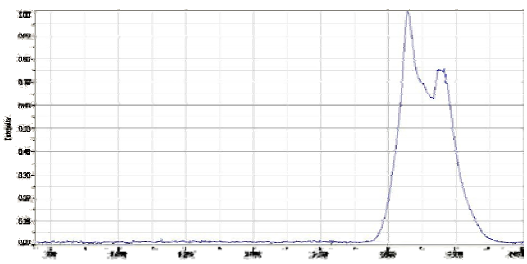

Figure 1. Raman spectrum of ice taken at ~279 K.

Under those premises, the opto-electro-mechanical design of the spectrometer requires to be as simple as possible in order to comply with those mentioned constraints. That aspect will have direct implications, mainly, as for spectral resolution and excitation energy, what will condition the kind of science that may be carried out from the measured data.

However, the identification of the mentioned compounds on the Raman spectra is robust enough even to be done in those *non-optimal* conditions.

This aspect reinforces the idea of the Raman spectrometer as a valuable instrument on board a lander for Europa.

Potential work methodology:

One of the biggest advantages of the Raman spectrometry over other techniques is that it doesn't need to pre-process the sample under analysis before taking the spectra as well as to take measurements of samples in any phase. These features allow Raman spectrometer to work as a micro probe to analyze sublimed samples in detail; as a contact instrument to get spectra from the surrounding minerals; or even as a remote sensing instrument, by using an external optics to focus the target at the distance. It will be discussed how the instrument is able to accommodate all these different alternatives.

This versatility in its usage makes the Raman spectrometer cover a wide measurement range: from micro to macro as well as from local to extensive areas.

It is also worth to mention how the added value of this technique is improved by combining this instrument together with other complementary techniques, such as IR and fluorescence spectrometers. It will be discussed how it is possible to take advantage of the synergy provided by the three different techniques. This fact is the concept behind the instrument called *Tri-spec* (by Centro de Astrobiologia, Spain).

Under that consideration, Raman spectrometer is able to provide quick results in a non-destructive way. Therefore, it may be used as a first approach technique to be followed by other more complex ones on the basis of the Raman outcomes.

EUROPA REGIONAL-SCALE GEOLOGY, STRATIGRAPHY AND IMPLICATIONS FOR FUTURE LANDERS

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Introduction: A global-scale (~1-km/pixel) view of Europa derived from Voyager and Galileo data show a world made up of widespread regions of high albedo, relatively old, materials and darker, mottled, terrains (known to be areas of chaos from high-resolution data) (1,2). On a regional-scale (~100-m/pixel) a surface is revealed that is characterized by complex tectonic and cryovolcanic interactions (3,4,5). The paucity of impact craters demonstrates that the surface of this icy world is geologically young and potentially still active today. From an astrobiological perspective, the recent geology and the interpretation that a subsurface ocean is present makes Europa a significant target for future, direct, surface exploration. To identify landing sites that provide access to the most geologically recent materials, the detailed stratigraphy of surface units must be established. In the analysis presented here, we perform regional-scale (~100 m/pixel) geologic mapping of the area in the vicinity of Manannán crater to identify units and structures that correspond to the most recent episodes of geologic activity and evaluate implications for *in situ* science.

Geology of the Manannán Region of Europa: Geologic terrains on Europa are broadly classified as either cryovolcanic or tectonic in origin. Significant outcrops of cryovolcanic materials are found throughout the Manannán region. Local (10s of km^2 in extent) cryovolcanic activity is dominated by smooth deposits that appear to embay adjacent terrains, suggesting the eruption of low-viscosity fluids onto the surface. In comparison, large-scale (100s of km^2 in extent) cryovolcanic activity is characterized by the presence of blocky deposits with limited occurrences of smooth low-albedo materials. These volcanic provinces, which have a mottled texture in low-resolution data, often show evidence of multiple eruptive centers. In some places multiple sites of upwelling are identified, an observation that suggests crustal thinning, "melt through" and extrusion, rapid refreezing and significant foundering of older plains-related "rafts." In some locations, upwelling and lateral motion has resulted in the piling up of rafts with distal fracturing and faulting possibly associated with subsurface return flow.

Tectonic activity on this part of Europa is manifested by both compressional and extensional structures. A broad, low, rise that is surmounted by en echelon segments of sinuous fractures cuts across the area. We interpret this rise to have formed under regional compression with the fractures being sites of tensile failure at the crest of the folds. Extension-related features are manifested by a variety of morphologies ranging from single and double ridges to ridge and broad "band" complexes. Tectonic reconstruction of some of the band materials suggests processes associated with simple lateral crustal displacement to more complex activity associated with multiple episodes of activity and reactivation of older structures. Sites of most recent tectonic activity are associated with extensive, narrow, single, through-going fractures.

Conclusions: Mapping of the Manannán region has identified numerous sites of relatively recent geologic activity. The identification of a wide range of cryovolcanic features bodes well for being able to constrain potential landing sites to sample material from either the shallow or deep interior. To reach deposits of local extent, those that appear to have been emplaced as a fluid, necessitates precision landing. The extreme blockiness of most surfaces requires significant lander robustness to a range landing conditions. To reach features associated with most recent tectonic activity (sites that are of very limited lateral extent) also calls for precision landing. These tectonic features may ultimately become the highest priority landing targets, as they are mapped as the geologically youngest features. Like the fractures on Enceladus, these may also be locations of venting (plumes?) of material from the interior; a hypothesis to be tested with the Europa Orbiter.

A revolutionary advancement in the understanding of icy satellites will be achieved by direct access to the surface of Europa. Sampling of features of the highest scientific priority requires a very robust landing system and the ability to target places on the surface that are of limited areal extent.

References: (1) Greeley, R. *et al*., Geologic Mapping of Europa, 2000, *J. Geophys. Res.*, 105, 22559-22598. (2) Senske, D. *et al.*, Geologic Mapping of Europa: Unit identification and stratigraphy at global and local scales, 1998, LPSC 29, Lunar & Planetary Institute. Abstract 1743. (3) Spaun, N., *et al.,* Geologic History, surface morphology and deformation sequence in an area near Conamara Chaos, Europa, 1998, LPSC 29, Lunar & Planetary Institute. Abstract 1899,. (4) Prockter, L. M., *et al.,* Europa: stratigraphy and geologic history of an anti-jovian region from Galileo E14 SSI data, 1999, *J. Geophys. Res*., 104 16531-16540. (5) Figueredo, P. H. and Greeley, R., Resurfacing history of Europa from pole-to-pole geologic mapping, 2004, *Icarus*, 167, 287-312.

NEAR-SURFACE ATMOSPHERE OF EUROPA

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Introduction:

Europa's atmosphere, which consists mostly of molecular oxygen, was discovered as a result of observations made with the *Hubble Space Telescope* (HST) (Hall *et al.*, 1995). The very tenuous oxygen atmosphere of Europa originates from a balance between sources from irradiation of the icy satellite surface by solar UV photons and magnetospheric plasma and losses from pick-up ionization and ejection following dissociation or collisions with the low energy plasma ions. Since the incident plasma is primarily responsible for both the supply and loss of oxygen, a dense atmosphere does not accumulate (Johnson *et al.* 1982). Recent observations of Jupiter's inner magnetosphere made onboard the *Galileo* (Lagg *et al.*, 2003) and *Cassini* (Mauk *et al.*, 2003) spacecraft discovered a neutral-gas torus along the orbit of Europa formed as a result of the loss of neutral gas from Europa's atmosphere.

The very tenuous atmosphere of the Jovian satellite Europa provides an example of the near-surface (or boundary-layer) atmosphere of a celestial body. Saur *et al.* (1998) published a detailed description of the interaction between the plasma and ionosphere of Europa. Shematovich and Johnson (2001) developed a collisional stochastic model of Europa's atmosphere. It was shown that the main process responsible for the loss of oxygen is its ionization by magnetospheric electrons and that the secondary loss process - the escape of atomic oxygen - is the source of neutral gas for the neutral torus. Shematovich *et al.* (2005) suggested a modified model of the formation of Europa's hot corona by thermal and nonthermal sources of molecules, which are products of radiolysis of Europa's icy surface. This model included the processes of dissociation and ionization of parent H_2O, H_2, and O_2 molecules by magnetospheric electrons and solar UV radiation and the collisional ejection of oxygen from the atmosphere under the action of low-energy plasma. The spatial distribution of the near-surface oxygen atmosphere and its thermal structure were determined. In particular, it was shown that the near-surface atmosphere is populated mostly by oxygen molecules. This near-surface molecular envelope of Europa is surrounded by an extended, albeit very tenuous, atomic oxygen corona (Shematovich, 2006).

Theoretical predictions of the composition and chemical evolution of Europa's near-surface atmosphere are of great importance for assessing the biological potential of this satellite. This atmosphere is expected to contain complex, possibly prebiologic, molecules sputtered by plasma from the surface of the body.

Modeling:

The flow of the atmospheric gas in the near-surface boundary layer of Europa is non-equilibrium for the following reasons:

(1) parent O_2, H_2, and H_2O molecules are sputtered out from the surface as a result of both thermal and nonthermal surface sources - thermal evaporation and nonthermal sputtering of the icy satellite surface by high-energy magnetospheric plasma;

(2) products of dissociation of parent molecules - H, O, and OH - are formed with an excess of kinetic energy, i.e., with suprathermal energies;

(3) atmospheric gas is lost to the inner Jovian magnetosphere due to the atmospheric sputtering.

Therefore, the gas state in Europa's near-surface atmosphere can be described by the kinetic Boltzmann equations for all atmospheric components (Shematovich *et al.*, 2005; Shematovich, 2006). Such set of the Boltzmann kinetic equations is nonlinear, and its stationary solutions can be obtained via numerical stochastic simulations (Shematovich, 2004). The essence of the method is that model particles representing atoms and molecules of the atmospheric gas are ejected from the surface or are formed in dissociation reactions, and the trajectories of these particles are followed between collisions. The method also uses a weighted stochastic procedure for choosing the time, place, type, and yield of the next collision. Such a numerical model was used to compute, at the molecular level, the distribution functions of atmospheric components by kinetic energies and internal excitation levels and, consequently, to estimate the distributions of density, temperature, and particle fluxes in the atmosphere.

Results of Calculations and Comparison with Observations:

Europan atmosphere is found to be a very tenuous and surface-bounded gaseous envelope with O_2 molecules being the main constituent. This is supplemented by an admixture of H_2O, OH and O (Fig.1). The light H_2 molecules are easily lost to the Europan neutral torus. The heavier H_2O and O_2 molecules are lost mainly through the non-thermal mechanisms: dissociation and ionization, atmospheric sputtering by the low-energy magnetospheric plasma and non-thermal surface ejection. Returning molecules have species-dependent behavior on contact with Europa's surface. The O_2 molecules stick with very low efficiency and are immediately desorbed thermally, but returning H_2O, OH, and O stick to the grains in the icy regolith with unit efficiency.

It follows from the computations that the oxygen density in the near-surface atmosphere is determined by a number of processes at different heights and, consequently, cannot be described by a simple exponential dependence for the model of outflowing atmosphere (Saur *et al.*, 1998). In the lowermost atmospheric layers (<10 km) the distribution of oxygen is determined by the combined effect of nonthermal surface sputtering and thermal desorption of oxygen molecules from the surface. The near-surface atmosphere is populated mostly by thermal oxygen molecules, which, after their collision with the surface, almost immediately return to the gaseous phase as a result of thermal desorption. The transition region between 10 and 100 km is mostly populated by molecules with kinetic energies below 0.1 eV, which were either injected with such suprathermal energies during surface sputtering or acquired suprathermal energies as a result of momentum and energy transfer in collisions with hot oxygen atoms that form via dissociation. The neutral atmosphere is, on the average, dynamically stable in these near-surface layers. The upper layers (>100 km) of the atmosphere demonstrate increasing heating of molecular oxygen as a result of collisions with magnetospheric ions and suprathermal oxygen atoms, which leads to the formation of the escaping (evaporating) exosphere of Europa.

Molecular oxygen column densities estimated from HST observations (Hall *et al.*, 1995) of oxygen emissions in Europa's atmosphere lie in the interval $(1.4\text{--}14)\times10^{14}$ cm^{-2}. Correspondingly, the integration of the distributions of molecular oxygen shown in Fig. 1 over height demonstrates that these column densities accumulate predominantly in the lowermost atmospheric layers, owing mostly to multiple acts of thermal adsorption--desorption of oxygen molecules on the icy surface of the satellite. The thermal state of this near-surface layer is, correspondingly, to a large degree determined by the temperature of the icy surface of the satellite.

The surface-bounded atmosphere of Europa is characterized by a diffuse and extended hot corona of atomic oxygen formed due to atmospheric sputtering and dissociation (Shematovich, 2006), by suprathermal radicals entering the regolith that can drive radiolytic chemistry (Johnson *et al.*, 2003), by a supply of pick-up ions to the plasma torus, and by a supply of neutrals to the Jovian inner magnetosphere producing a neutral gas torus along the Europa's orbit. The calculations show that the chemical composition and structure of the atmosphere is determined by both the water and oxygen photochemistry in the near-surface region and the adsorption-desorption exchange by radiolytic water products with the satellite surface.

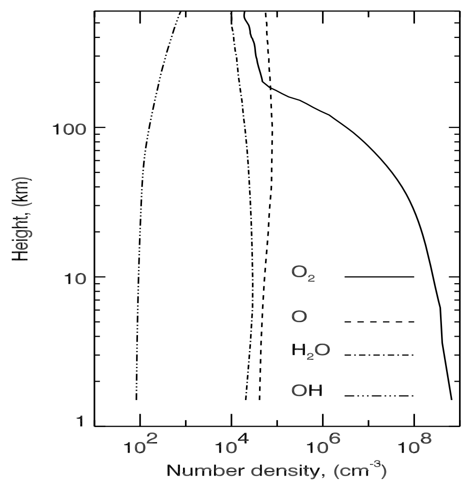

Figure 1. Height profiles of the main neutral constituents of the near-surface atmosphere at Europa.

There is a need for reference models of the European atmosphere to aid in planning of future missions to Europa. Johnson *et al.* (1998) noted that Europa surface composition, among the prime science objectives for such missions, could be inferred in part from orbital measurements of sputtering products comprising the atmosphere. Modeling of ionization chemistry (Shematovich, 2008) allows us to quantify pick-up ion densities and fluxes in the near-surface atmosphere, and because ion composition measurements are far more sensitive, so that even trace species could be measured in the pick-up ion populations downstream from Europa.

This study is supported by Russian Foundation for Basic Research (Project 08-02-00263).

Hall D.T., Strobel D.F., Feldman P.D., *et al. Nature*, 1995, **373**, 677

Johnson R.E., Lanzerotti L.J., Brown W.L. *Nucl. Instrum. Meth.*, 1982, **198**, 390

Johnson, R. E., Killen, R. M., Waite, J. H., Lewis, W. S. *Geophys. Res. Lett.*, 1998, **25**, 3257.

Johnson R.E., Quickenden T.I., Cooper P.D., *et al. Astrobiology*, 2003, **3**, 823

Johnson R.E., Carlson R.W., Cooper J.F., *et al.* In *Jupiter : Satellites, Atmosphere, Magnetosphere*. Cambridge, Univ. Cambridge Press, 2004, 485

Lagg A., Krupp N., Woch J., Williams D.J. *Geophys. Res. Lett.*, 2003, **30**, 1556

Mauk B.H., Mitchell D.G., Krimigis S.M., *et al. Nature*, 2003, **421**, 920

Saur J., Strobel D.F., Neubauer F.M. *J. Geophys. Res.*, 1998, **103**, 19947

Shematovich V.I., and Johnson R.E. *Adv. Space Res.*, 2001, **27**, 1881

Shematovich V.I., Johnson R.E., Copper J.F., Wong M.C. *Icarus,* 2005, **173**, 480

Shematovich V.I. *Sol. Syst. Res.*, 2004, **38**, 27

Shematovich V.I. *Sol. Syst. Res.*, 2006, **40**, 195

Shematovich V.I. *Sol. Syst. Res.*, 2008, **42**, 507

A Laser-Ablation Mass Spectrometer For the Space Research

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Introduction:
The performance of a laser ablation mass spectrometer (LMS) developed in our group will be demonstrated. The instrument is a small size reflectron-type time-of-flight mass spectrometer specifically developed for its application to space research [Rohner et al., 2003]. It has been carefully designed by taking into account the results achieved from detailed simulation of ion trajectories and extensively tested in laboratory. The system is capable of measuring the elemental and isotopic composition of solid samples such like metals or minerals. The measurements can be prepared with a high spatial resolution and are suitable for analysis of grain size regolith, thus allowing an accurate picture of the modal mineralogy of the investigated regolith. The high dynamic range of the measuring signal and high sensitivity combined with a high mass resolution permits possibility of determination of isotopic composition for any solid material with the potential for age dating. Furthermore, the instrument offers opportunity of studying molecules of high masses. Molecular composition of sample can be investigated over a large mass range and it can be used to investigate carbonaceous samples or bio-related materials. The latter are of particular interest for exo-biology and in search for life.

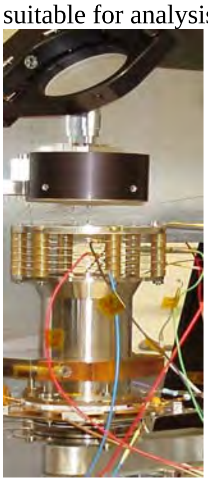

Figure 1. Laser ablation mass spectrometer

The construction details of the instrument were described[1, 2]. Here, it will only be briefly reviewed the underlying concept of the measurement. The instrument consists of a highly optimized axially symmetric reflectron time-of-flight mass spectrometer (Figure 1). The Reflectron is built from a set of potential rings (top), the flight tube with the MCP detector below and ion optical elements for collecting and focusing the ions removed from the target. A pulsed Nd:YAG 1064 nm laser of 3 ns pulse duration is used for the ablation process. The laser beam passes from the top and is focused using lens to the spot size of ~15 μm on the sample. This corresponds to a laser fluence of few GW/cm^2. A careful control of the laser fluence and the laser beam profile provide means to minimize elemental fractionation effects in ablation process. It also allows the mass spectrometric investigations of any kind of surfaces with a high spatial resolution. Our studies show that the mass spectra can be measured with the mass resolution of ~500 or better. Trace elements can typically be determined with a high sensitivity of few ppm Figure 2 depicts the spectrum obtained by ablating PbS sample. The largest cluster detected in this process possesses mass of ~ 828 amu. Detection of even larger species (of several thousands amu) is feasible using time of flight mass spectrometers which opens unique opportunity for sensitive detection of large complex molecules in space environment.

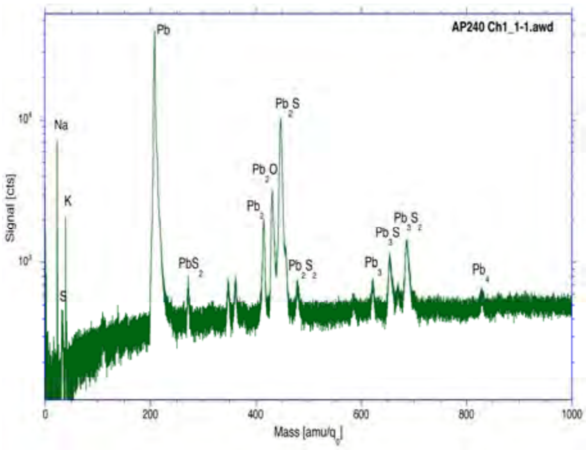

Figure 2. The mass spectrummeasured by laser ablation of PbS. Note that the detection of of molecular species possessing large masses can sensitively be performed with LMS.

Literature

1. U. Rohner, J.A. Whitby, P. Wurz, A miniature laser ablation time of flight mass spectrometer for in situ planetary exploration. *Meas. Sci. Tech.*, 14:2159-2164, 2003
2. U. Rohner, J.A. Whitby, P. Wurz, and S. Barabash, A highly miniaturized laser ablation time of flight mass spectrometer for a planetary rover. *Rev. Sci. Instrum.*, 75:1314-1322, 2004

SCOUT- Europa Terrestrial Lander (ETL)

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Introduction:
The scenario of Search for Extra-Terrestrial Intelligence (SETI) got a lot of emphasis on Jupiter's moon EUROPA[1]. A Lander mission is required to conduct scientific analysis and to dig out the real condition of Europa. Here, a new type of Europa exploration Lander being developed, called ***SCOUT-Europa Terrestrial Lander (ETL).*** The Lander is designed to satisfy the conditions like extreme radiation & temperature exposure, soft landing, stabilization within a short period of time after impact, room for sample storage and scientific analysis. As this is going to be very expensive mission, it should be utilized to the maximum. SCOUT-ETL is designed to give platform for various scientific instruments. The raw mass of scout (without any scientific payload) including the Thruster Bag Landing System [TBLS], Radioisotope Thermoelectric Generator [RTG][2] and robotic manipulator is about 135 Kg and possible to hold scientific payload ranging about 125-175 Kg. SCOUT-ETL uses Electro-Parachuting [EPC] for its descent entry and Field Conversion Radiation Protection [FCRP] system for protection from the magnetic and cosmic radiations.

Structural Mechanism:
SCOUT-ETL structure (without any payload and instruments) is in the form of a cuboid supported and balanced by four independent landing gears. Structure of SCOUT-ETL is developed from redundant frames. The system is designed to transform the point load acting upon the main frame into uniformly distributed load, so as to increase the DESIGN FACTOR. The structural members are made from carbon fiber rich material for its light weight and high strength[3].

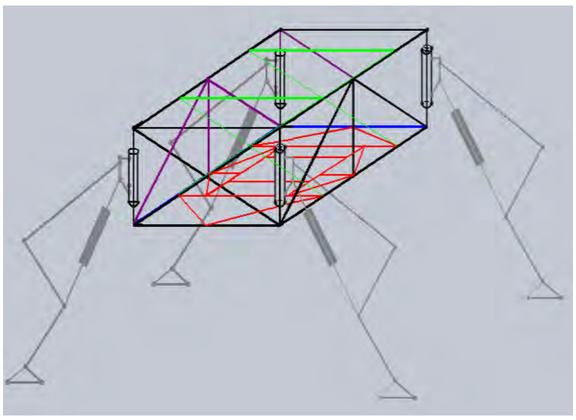

Figure1: Line diagram of SCOUT-ETL, with landing gears and dampers.

The Lander structure is designed to accommodate a carbon fiber compressed air tank, mini RTG of 73W electrical output and 1480W heat, robotic manipulators and Thruster Bag Landing System. A volume of 378×10^6 mm^3 is allocated for scientific instruments. Platforms for drilling machine, video camera and robotic manipulators are developed along with the main structure of SCOUT-ETL in some extrusion. From the force balance equation[5] of the system, it is inferred that the system would remain rigid even with impact at a velocity of about 20 m/s.

Safe landing and stabilization mechanisms: If the Lander is ejected from the launch vehicle at a known distance from the surface of Europa, then the governing force balance equation from force balance is given by,

Assumptions: drag force has been neglected when the thrusters have been switched on.(but Electro-Parachuting, EPC will produce some considerable drag)

taken, acceleration due to gravity= 1.314 m/s^2
height above the ground = 200Km
(ejection from the launch vehicle)
atmospheric pressure =1×10^{-6}Pa

m → mass of the body just before thruster has been turned on
a → mass discharge rate from the nozzle of the thruster;
b → product of (Axρ)
Where, ρ is density of oxygen in Europa atmosphere
A is area of cross section the nozzle

$$g = \{ x''(t) - [x'(t)a/(m-at)] + [a(x'(t) - (a/b)/(m-at)] \}$$
were x'(1000)=0 and x''(0)=0

$$x(t) = \frac{2at + 2000bt + bgt^2 - 2m\log(m) + 2at\log(bm) + 2m\log(m-at) - 2at\log[b(m-at)]}{2b}$$

x'(0)→initial velocity when thruster are switched on
x(t) →variation of position with time.

From this equation the impact velocity is approximated; the Thruster Bag Landing System [TBLS] and Damping, balancing mechanism are designed based on the above equation.

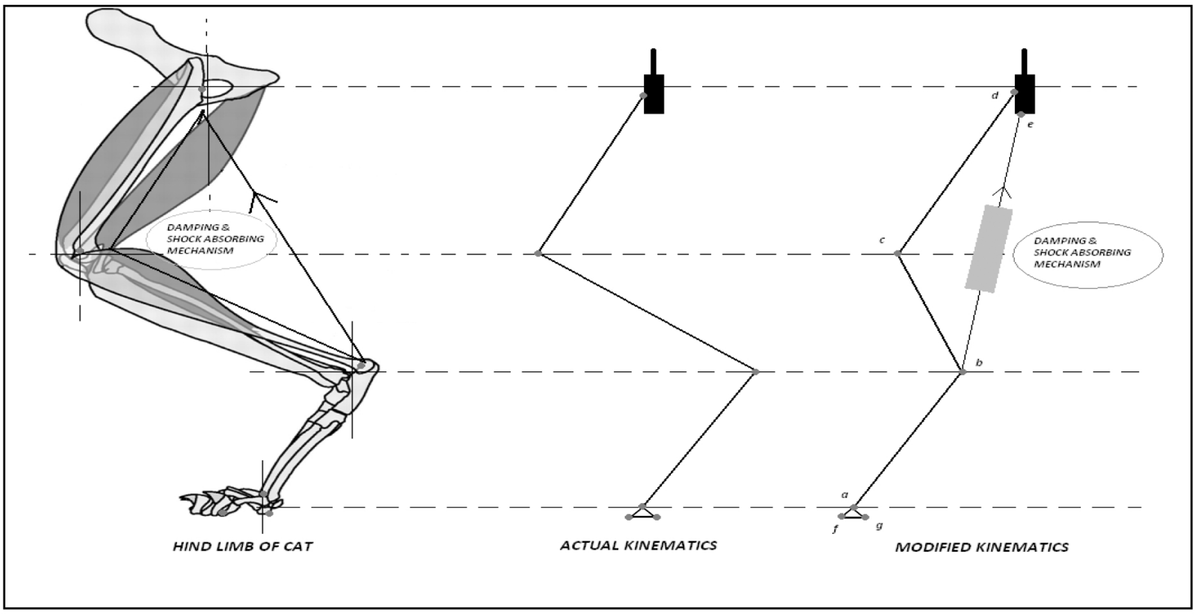

Figure2: Damping and balancing extracted from the bio- mechanics of hind limb of cat.

Damping and balancing mechanism: As the system is subjected to land at a velocity of 4m/s, a high efficient shock absorbing system should be incorporated with the landing gears. For safe and smooth landing of SCOUT-ETL, the damping and vibration control mechanism is extracted from the hind limb of cat. Cat has the ability to land stabilize safely from a free fall condition. The kinematics and dynamics of the femur, tibia, metatarsals bones and vastus lateralis, semimembranosus, lateral gastrocnemius muscles are studied and with some modification, the same mechanism is adapted for the safe landing, vibration damping[6] and stabilization.

Electro-Parachuting [EPC]: After ejection from the launch vehicle, SCOUT-ETL starts descent towards Europa surface. The initial stabilization of the Lander is provided by the fly wheel and then it is subjected to free fall. The aerodynamic design of SCOUT-ETL radiation shield allows the Lander to follow a defined trajectory. At some distance, were the electron density of Europa[7] is measured to be 10,000 electron/cc; Electro-Parachuting [EPC] is deployed. It's a kind of drag parachute, but the drag is produced by the electrostatic force of repulsion. Anode is placed at the center of parachute and positive charge is fed to the anode at a pulse less than a nanosecond. The inner layer of the parachute is made of substrate capable of retaining a lot of negative charge. By the principle of electrostatic force of repulsion, the like charge repels each other. The positive charge will attract the nearby electrons and in turn increases the electron density. This repulsive force will decelerate the velocity of the descending Lander combined with the wind drag.

Thruster Bag Landing System [TBLS]: This system act as a thruster to decelerate the speed of SCOUT-ETL. It's an air bag like system, which is capable of producing both upward thrust (to avoid rebounding after impact) and downward thrust (for deceleration). From the governing force balance equation, the amount of discharge of the high dense air and the time for which it should be actuated can be known. As this acts like an air bag, the payloads remains unaffected after impact.

Field Conversion Radiation Protection [FCRP]: Radiation protection shield is made of mu-metal (Nickel+Iron) combination, which has high permeability. The electric field is passed through the radiation shield; this field will convert the incoming magnetic field into electromotive force (emf). So some of the entering magnetic field from strong magnetosphere of Jupiter will be converted into emf. This shield act as the protection from electromagnetic radiation and thermal radiation.

Reference:

1. Tritt, Charles S. (2002). "Possibility of Life on Europa". Milwaukee School of Engineering. Retrieved on 2007-08-10.

2. "Space Nuclear Power" G.L.Bennett, 2006.

3. Michael Thomas Hicks Stanford Linear Accelerator Center Stanford University Stanford, CA

4. SNAP-19: Pioneer F & G, Final Report, Teledyne Isotopes, 1973

5. "Vector mechanics" Ferdinand P. Beer & E. Russell Johnston Jr.with the collaboration of Elliot R. Eisenberg and Robert G. Sarubbi.

6. "Vibration – Fundamental and Practice" Clarence W. de Silva 2007.

7. Surface-bounded atmosphere of EuropaV.I. Shematovich a, J.F. Cooper c, M.C. Wong da Institute of Astronomy, Russian Academy of Sciences, 48 Pyatnitskaya Street, Moscow, 119017 Russia

PLANETARY PROTECTION AND THE ICY MOONS OF THE GIANT PLANETS.

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The former exploratory missions in the Jovian and Saturnian systems revealed the diversity of the icy moons of these giant planets. From the data gathered, it also appears that some of them have active surface and could have, beneath an icy crust, oceans or pocket reservoirs containing mixtures of liquid water. Based on the increasing knowledge about the microbial diversity of terrestrial micro-organisms, it seems that the presence of indigenous life forms in the liquid water tanks of these worlds cannot be ruled out as well as for some terrestrial organisms to find there an environment allowing them to proliferate.

Since several space agencies are committing themselves to explore those Icy moons and that the possibility to export the terrestrial biosphere is possible, States ruling these agencies and party of the so called Outer Space treaty (*Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies* (U.N. document 6347 January 1967)) have the responsibility to protect the visited bodies against terrestrial contamination.

The Committee for Space Research (COSPAR) on the statement of the article 9 of this treaty, is recommending a planetary protection policy which applies to the activities towards these bodies. These policy is regularly updated, taking in account the most recent knowledge and the most advance technologies. The present level of planetary protection of such bodies and ways to implement it will be presented and discussed. A special emphasis will be given for probes landing on Europa the largest icy moon of Jupiter.

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A THERMAL DRILL HEAD FOR THE EXPLORATION OF SUBSURFACE ICE LAYERS ON EUROPA

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Introduction:

The planned Europa Jupiter System Mission (EJSM) will bear the unique opportunity to bring a landing probe onto the surface of Jupiter’s moon Europa in the late 2020s. After Galileo, this would be a long awaited chance to have a close glimpse into some of the mysteries of this moon. Care must be given at the choice of in-situ science instruments that will be brought to the surface. We present a novel approach to deliver scientific instruments into subsurface layers of planetary ices: A thermal drill head, using heat and mechanical drill in combination to penetrate the ice, is proposed[1]. The objective of such an instrument would be to penetrate the upper layers of Europa’s surface to reach zones, where space weathering and Jupiter’s heavy radiation have not altered the material that might have been brought to the surface from the deep.

The combination of two locomotion mechanisms, gravity-assisted melting and mechanical drilling, brings advantages in terms of penetration performance, sample acquisition and mission security. The vibration and rotation of the blades assure a good contact to the walls of the borehole and might bear advantages in terms of surface contact even in the case of sublimation. Such a system can sample liquid water (once the borehole has refrozen on the top) which can be transported into the instrument by the use of a micro-pump. A system of filters can retain biogenic material, if present, for further analysis by optical microscope, chemical micro lab or spectrometry. Gases, as indicator of biological activity, can be acquired by a combination of heating and drilling. Finally, such system bears the possibility to overcome layers of non-melting material, such as regolith or rock.

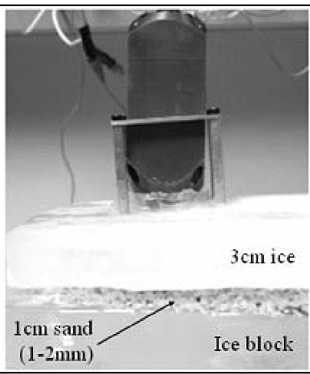

Fig. 1 Thermal drill head penetrating a layer of ice and sand.

A prototype of such hybrid melting-drill system was developed through a cooperation between Chinese and Austrian partners. It underwent preliminary tests in normal atmospheric conditions and showed a good performance in terms of penetration speed. Based on this performance analysis, a mathematical model of such penetration mechanism was established and will be presented. Test of the system in a cooled vacuum chamber, similar to Europan surface conditions, are planned for early 2009. The results will allow the comparison to planetary drilling technologies in terms of penetration speed, power budget and operational constrains.

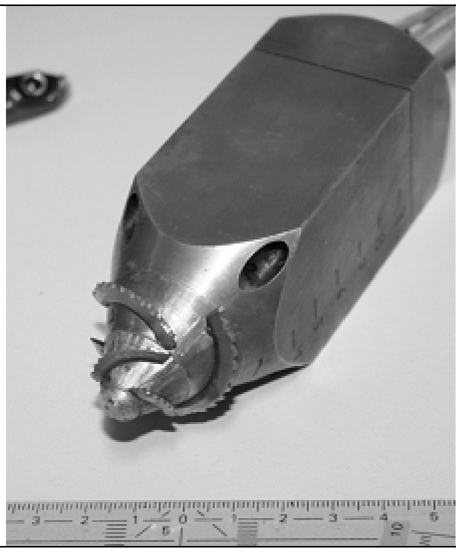

Fig. 2 The cross-section of the thermal drill prototype is 40mm x 40mm. Its final length will depend on the integrated payload.

The weakness of systems that use melting as unique locomotion lies in the necessary trade-off between the power consumption and the penetration speed. Current mission proposals solve this problem by the use of radioisotope thermoelectric generators. But the power budget which is invested to penetrate into the surface depends on the depth in which in-situ analysis is to be performed: As a mission to Europa will have a strong astrobiological character, its objective will most probably be to penetrate beyond the sterilized surface zone where radiation, sputtering and meteoritic gardening alter or dissociate complex molecules or other imbedded biologic indicators[2]. While heavy ions are already stopped in the sub-millimeter range of Europa’s surface, energetic electrons can penetrate depths of centimeters. Meteoritic impact can furthermore bury by radiation affected material into one meter depth or even deeper[3]. A safe assumption for the system design might therefore be a minimal operation range beyond one meter. This will be a challenging operation requirement for a classical drill tool that requires a rigid connection to the surface under these conditions. Ice at the environmental condition of the Europan surface is expected to have a Young's Modulus between 0.06GPa to 6GPa[4].

The maximal operation depth of a melting probe or thermal drill is obviously limited by the energy budget and penetration time that a lander can spend on the subsurface investigation. Furthermore, there are technical constrains, such as the maximal cable length which the probe can carry: Since it can be expected that the channel behind the probe will refreeze, all necessary cable needs to be hosted inside the penetration unit and paid out by a Tether Management System (TMS) while progressing through the ice[5]. The current design allows the storage of ten meters of cable. The same cable is also used to determine the length of the performed trajectory through the readouts of an optical encoder that is integrated in the TMS.

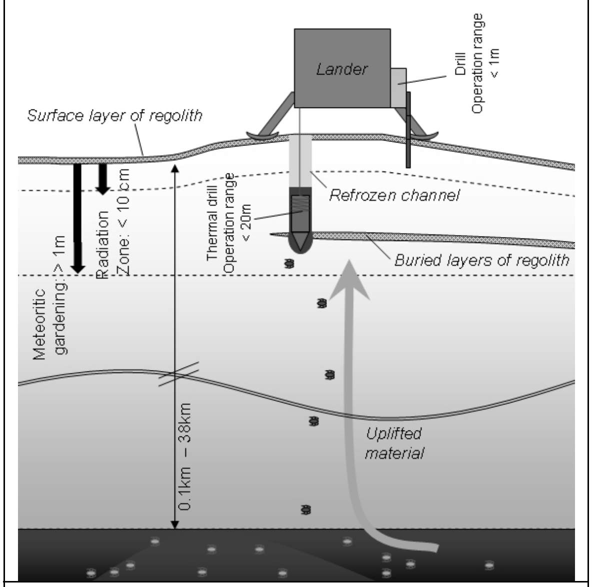

Fig. 3: Operational ranges of a surface drill and a melting probe put into the context of an Europa exploration scenario. The total ice sheet depth estimation varies for 100m to 38km[7].

The coming step in this development will be tests of this system in a cyro-vaccum-chamber to evaluate its performance in sublimation environment. This will then be followed by a study of possible instrument payloads, which such a system could carry into the ices of Jupiter moon Europa.

References:

[1] Weiss P., Yung K.L., Ng T.C., Kömle N., Kargl G. and Kaufmann E., Study of a melting drill head for the exploration of subsurface planetary ice layers, Planetary and Space Science, 56, pp. 1280-1292, 2008.

[2] Greenberg, R., Europa the ocean moon - Search for an alien biosphere, Springer Verlag, 2005.

[3] Cooper, J.F., Johnson, R.E., Mauk, B.H., Garret, H.B., and Gehrels, N., Energetic ion and electron radiation of the icy Galilean satellites, Icarus, Volume 149, 1, pp. 133-159, 2001.

[4] Williams K.K., and Greeley, R., Estimates of ice thickness in the Conamara Chaos region of Europa, Geophys. Res. Lett., 25(23), pp. 4273–4276, 1998.

[5] Treffer M., Kömle N., Kargl G., Kaufmann E., Ulamec S., Biele J., Ivanov A. and Funke O., 2006. Preliminary studies concerning subsurface probes for the exploration of icy planetary bodies, Planetary and Space Science, vol 54, pp. 621-634, 2006.

[7] Billings, S.E., and Kattenhorn, S.A., The great thickness debate: Ice shell thickness models for Europa and comparisons with estimates based on flexure at ridges, Icarus, 177, pp. 397-412, 2005.

IN SITU COMPOSITION ANALYSIS OF PLANETARY SURFACES BY LASER-BASED MASS SPECTROMETRY.

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Introduction:

Knowing the chemical, elemental, and isotopic composition of planetary objects allows the study of their origin and evolution within the context of our solar system. Exploration plans in planetary research of several space agencies consider landing spacecraft for future missions. Although there have been successful landers in the past, more landers are foreseen for Mars and its moons, Venus, the moons of Jupiter and Saturn, and asteroids. Furthermore, a mass spectrometer on a landed spacecraft can assist in the sample selection in a sample-return mission and provide mineralogical context, or identify possible toxic soils on Mars for manned Mars exploration. With an optimised mass spectrometer also biosignatures can be investigated, e.g. the isotopes of C, N, S, O and others, or the products of metabolism present or past of organisms.

Instrumentation:

For compositional analysis of solid surfaces Laser Mass Spectrometers (LMS) are very well suited and are used in laboratory research for decades (Vertes et al., 1993). Laser ablation was chosen as a sample introduction technique principally because of its high spatial resolution and the lack of any need for sample preparation [Becker and Dietze, 2003]. Ions for analysis are generated directly from the surface under investigation by short, intense laser pulses. The formation of a laser-induced plasma out of nearly every solid material can be used to bring material from the solid into the ion phase, which then can be easily analysed by mass spectrometric means to measure the surface composition itself. Once a critical power density of approximately 10^9 W/cm^2 is exceeded during the laser pulse the ionisation of released surface material is more or less independent of the element, i.e., minimal inter-element fractionation in the ionization process occurs (Managadze and Shutyaev, 1993; Vertes et al., 1993; Berger and Dietze, 2003).

Advantages of laser ablation/ionisation include simplicity of the resulting instrument design, speed of measurement, and the ability to do depth profiling (potentially important for a regolith in which mineral grains are coated with impact produced glass). Time-of-Flight mass spectrometers (TOF-MS) are a natural match to the pulsed laser ablation/ionisation because they couple well to a pulsed ion source such as that produced by laser ablation. In laboratory instrumentation the detection limit for LMS is normally between 10 ppb and 1 ppm depending on element, and fractionation is less than in the often used spark source mass spectrometry (Dietze and Becker, 1993).

Given the resources available on landed spacecraft mass spectrometers, as well as any other instrument, have to be highly miniaturised. In recent years highly miniaturised laser mass spectrometers for planetary research have been developed by two groups for various planetary missions. A compact LMS prototype based on an earlier Russian design (Managadze and Shutyaev, 1993) has been demonstrated for mineralogical studies of meteorites (Brinkerhoff et al., 2000). An adapted version of this instrument, the LASMA instrument will be part of the Phobos-Grunt payload. LASMA will study the composition of the soil and rocks on Phobos. In the original design of the BepiColombo mission of ESA to Mercury there was a landing spacecraft. To study the formation and evolution of the planet via composition studies two miniature and highly miniaturised laser ablation time-of-flight mass spectrometers (LMS) were developed and built, suitable for in situ measurements of the elemental and isotopic composition of the surface of airless planetary bodies (Rohner et al., 2003, 2004).

LASMA on Phobos-Grunt. The LASMA instrument to be used for the Phobos-Grunt mission is a typical lander LMS and is based on an earlier development (Managadze, 1992; Managadze and Managadze, 1999; Brinckerhoff et al., 2000). In this instrument a 7 ns laser pulse with 16 mJ power from a flash-lamp pumped Nd:YAG laser (wavelength 1064 nm) is used, which is focussed to a spot of Ø 50 µm on the sample surface. Since the laser repetition rate has to be kept very low to stay within the power limits of the spacecraft, spectra are recorded with a high-dynamic range detector and signal acquisition system, and all spectra are transmitted individually to Earth. The flight instrument will be 220 x 110 x 260 mm^3, will weigh about 1.5 kg, and will be mounted on the outside wall of the lander.

Rover LMS. Automatic paragraph indents are imbedded to appear every time you use a hard return.

Sample of a level-two head. For the rover of the landing spacecraft of the BepiColombo mission, the Mercury Surface Element (MSE), a highly miniaturized LMS was developed [Rohner et al., 2004]. The MSE was canceled later for budgetary reasons. The prototype instrument has a demonstrated mass resolution m/Δm in excess of 180 (FWHM) and a dynamic range of better than five orders of magnitude. The ion-optical system itself has a measured mass resolution of 400, as seen from single shot spectra, which is in good agreement with the ion-optical design. The estimates for the flight instrument are a mass of 280 g (including laser and all electronics) and a total volume of 7 x 4 x 3 cm^3 including all electronics. For full operation only 3 W power will be needed making use of local energy storage to accommodate the short-term power needs of the laser system.

Membrane inlet mass spectrometer. As part of the scientific payload of a melting probe, e.g. for an Europa lander or Mars polar lander, we propose to use a Membrane-Inlet Mass Spectrometer (MIMS). Since melting probes melt their way through water ice, the probe is always immersed in liquid water, at ambient pressures depending on depth. Therefore, a mass spectrometer on a melting probe has to be contained in a sealed vacuum system. The use membranes for sample inlet allow overcoming the large pressure difference, a few bars outside pressure and 10^{-6} mbar at the inside of the mass spectrometer. Membranes have permeability for certain chemical substances, but cannot be penetrated by water. Such membrane inlet systems have been used in a variety of applications (Johnson et al., 2000) in water depths up to 250 m (Wenner et al., 2004). An instrument intended for use on Europa would make measurements similar to an environmental monitoring instrument in a terrestrial ocean: the abundances of dissolved gases (oxygen, nitrogen, carbon dioxide and others) allow to determine the geochemical environment and the abundances of volatile organic compounds that might suggest the presence of life.

MALDI. Matrix-assisted laser desorption/ionization (MALDI) mass spectrometry is widely used in laboratory for mass spectrometric analysis of large, non-volatile biomolecules, in particular peptides, proteins, oligonucleotides, and oligosaccharides (Zenobi and Knochenmuss, 1998). In MALDI the analyte is co-crystallized most frequently with an excess of a solid matrix material. Derivatives of benzoic acid, cinnamic acid, and related aromatic compounds were recognized early on as good MALDI matrices for proteins. MALDI instruments are specialised LMS instruments, in that the laser wavelength is matched to the absorption of the matrix. Thus, during the laser pulse the irradiated matrix volume is volatilised and thus sets free the dissolved molecules, which are ionised in this process and thus available for mass analysis. The mass spectrometer itself has to have the capability for detection of large molecules (in case of biological matter), which is most easily realised with time-of-flight instruments. For Europa, and other planetary bodies with an ice surface, the water ice is the natural matrix and the MALDI technique will allow to identify dissolved bio-molecules, if present.

References:

Becker, J.S. and H.-J. Dietze (2003), State-of-the-art in inorganic mass spectrometry for analysis of high-purity materials, Int. J. Mass Spectr. 228 127–150.

Brinckerhoff, W. B., G. G. Managadze, R. W. McEntire, A. F. Cheng and W. J. Green (2000), Laser time-of-flight mass spectrometry for space, Rev. Sci. Instr. 71(2): 536–545.

Johnson, R.C., R.G. Cooks, T.M. Allen, M.E. Cisper and P.H. Hemberger (2000) Membrane introduction mass spectrometry: trends and applications, Mass Spectr. Rev., 19, 1–37.

Managadze G.G., (1992), Time-Of-Flight Mass Spectrometer. Russian Federation Patent No. 1732396, Priority of invention 29.02.1988, registered in 1992. Bulletin of Inventions, No. 17.

Managadze, G.G., and I. Yu. Shutyaev (1993), in *Laser Ionization Mass Analysis*, Chemical, Analysis Series Vol. 124, Wiley, New York, Chapter 5.

Managadze G.G., and N.G. Managadze. (1999), Quantitative standard less express analysis of some alloys on TOF mass spectrometer. Zh. Tekh. Fiz. 69(10), 138 [Tech. Phys. 44, 1253 (1999)].

Rohner, U., J. Whitby, and P. Wurz (2003), A miniature laser ablation time-of-flight mass spectrometer for in situ planetary exploration, *Meas. Sci. Technol., 14,* 2159–2164.

Rohner, U., J. Whitby, P. Wurz, and S. Barabash (2004), A highly miniaturised laser ablation time-of-flight mass spectrometer for planetary rover, *Rev. Sci. Instr.,* 75(5), 1314–1322.

Vertes, A., R. Gijbels and F. Adams (1993), *Laser Ionisation Mass Analysis*, New York, Wiley.

Wenner, P.G., R.J. Bell, F.H.W. van Amerom, S.K. Toler, J.E. Edkins, M.L. Hall, K. Koehn, R.T. Short and R.H. Byrne (2004), Environmental chemical mapping using an underwater mass spectrometer, Trends Anal. Chem., 23(4), 288–295.

Zenobi, R., and R. Knochenmuss (1998), Ion formation in MALDI mass spectrometry, Mass Spectr. Rev. 17, 337–366.

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