EVALUATION OF INSTRUMENTS FOR COMING EUROPA MISSIONS TO CONDUCT RESEARCH ON ASTROBIOLOGY.

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Introduction: This work is to summarize discusssions about mission payloads, which were undertaken as an interdisciplinary activity under the COST TD1308 action to analyze the astrobiology potential of Europa, the satellite of Jupiter. Various observations underline the astrobiology relevance of the satellite, such as its magnetic field [1], various surface structures [2], plume observations [3] and theoretical argumentations [4], which indicate that a liquid subsurface ocean is below the ice crust. Tidal heat generating geothermal centers may be found at the bottom of this ocean at the rocke-water interface [5]. The ice crust covering this ocean could also give astrobiologically relevant information, including the existence of various clathrates [6], signs of material recirculation, and radiation driven chemistry [7]. Below, the main instrument types are compared and their possible synergy in astrobiology analyzed.

Methods: Based on interdisciplinary discussions at the former meetings of the COST TD1308 action, possibilities for various observations were reviewed and compared. The aim was partly to evaluate the expected information by astrobiology-relevant instrument types and also to outline possibilities for synergy, e.g. which information provided by one instrument would be relevant for another one. Such synergic aspects might be important not only for the planning of the scientific payload but also for the planning of relevant Earth based laboratory tests and analogue research work.

Results: The main instrument types, their observational methods, expected results and astrobiology relevance are listed in Table 1. The instruments were classified according to mission goals and objectives of the lander concepts (Hand et al. 2017. Report on Europa Lander Science Definition Team), but here applied to orbiter based instruments too, and grouped to 1: search for biosignatures, signs of life (organic, textural and inorganic indicators of past life), 2: characterize habitability (non-ice components and proximity to liqud water), 3: determine surface properties and dynamics.

The group of instruments listed here covers the main types that are already planned, however specific subtypes are not indicated. They were designed for the identification of the depth of the ocean below the ice crust (1, 3, 4, 5, 12), for the composition of the ice by remote sensing (2, 6, 7, 8, 9, 10) and in-situ methods too (11, 12, 13, 14, 15, 16, 17, 18, 19).

Discussion: Connections between instruments support an increase in scientific return and also to improve planning the payload in advance:

Goals 2,3: The plume-related observations (9) around Europa should be correlated to the plasma environment (2) to better understand the sublimated and ejected components including their fate.

Goals 1, 2: Any re-deposition of plume material or identification of related surface changes around possible vents (6, 7, 8), including thermal effects (5), support the estimation both of the mass and composition of plume (9) materials.

Goals 1,2: The composition estimation of the ocean requires further modelling than the simple compositional analysis of the non-ice material on the surface (6, 8) and possible plumes (9). In these cases the magnetometer (1) related data on the estimation of solved electrolyte content range might be narrowed down by remote sensing and in-situ compositional data. Drill supported (12) data on the near surface radiation driven chemical alterations should also be taken into account for spectral interpretation (6, 7, 8) especially point to the role of subsurface and surface driven contributions.

Goals 1,2: Connecting local microscopic imaging (13) at different depth values (12) to the distribution of the ice contaminants from remote sensing spectral observations (8) together help in the estimation of source of these contaminants and the possible role of surface radiation effects driven alterations.

Goals: 2: The seismic and penetrating radar observations (11, 4) could show subsurface regions inside the ice crust where clathrates or condensed salts provide specific behavior in the reaction of radar signals.

Conclusion: Evaluating the connections between instruments supports payload definition and gain of results relevant for astrobiology. While most proposed instruments of the already accepted missions provide information on the surface physical and chemical properties, the information provided regarding habitability, and identification of biosignatures, is low.

Optimization of measurement and sampling strategies in order to maximize results of future missions is strongly recommended. The JUICE and Europa Clipper missions will characterize the habitability of Europa for the first time. They will provide global and regional remote observations to constrain the inner aqueous reservoirs, and the chemistry of the surface and compounds of potential plumes (including expelled potential biosignatures to the exosphere, as in the case of Europa Clipper). COST members contributed in the recognition that a mission with a lander would permit more ambitious astrobiology goals, searching for biosignatures by using in situ payload on local samples as pristine as possible.

References: [1] Kivelson et al. 2000. *Science* 289, 1340–1343. [2] Carr et al. 1998 *Nature* 391, 363 [3] Sparks et al. 2016 *ApJ* 829, 121 [4] Ross, Schubert 1987 *Nature* 325, 133–134. [5] Goodman, Lenferink, 2009 *AGU Fall Meeting*, #P31B-1251. [6]Prieto-Ballesteros et al. 2005 *Icarus* 177, 491-505. [7]Brown, Hand 2013. AnJ 145, 110.

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Table 1. Overview of various intruments, astrobiology related observational characteristics, and expected results. Note that (*) marks drilling activity, what is a general method that supports various other in-situ instruments.

Instruments	Observational method	Specific targets, ideal results	Astrobiology relevance	Goals		
				1	2	3
Geophysical measurements (exosphere and interior)						
1. Magnetometer	magnetic field analysis	oceanic induced currents, solved electrolyte content	ocean thickness, salt content, currents			■
2. Plasma detector	plasma detection around the satellite	ion and atom types released form the surface	surface and plume material composition			■
3. Ice penetrating radar	radar wave reflection from solid, liquid surfaces and inhomogeneity	ocean/ice crust interface, ice structure below chaos terrains, ice crust growth	existence, depth of ocean		■	■
4. Seismometer	quakes and sounds inside the ice crust	ice thickness, cracks' source, ice characteristics	ocean volume, signs of ocean-ice interaction		■	■
Surface remote characterization						
5. Laser altimeter	ice crust surface reflection	topographic undulation in space and time	ice thickness and structure from tidal response			■
6. Thermal emission imaging	surface temperature recording	elevated temperature areas, fractures	potential signatures of warmer ice/liquid			■
7. Color stereo cameras	optical observation of the ice and components	surface morphology, 3D surface structure	recirculation of ice and signs of internal activity			■
8. Optical imaging in general	optical reflection, albedo, color measurements	dark and contaminated ice, related color pattern	identify internal activity, origin of materials			■
9. VIS-IR Imaging spectrometer	spectral reflection of the ice	identification of contaminants' composition	ocean composition, submarine hydrot. vents, biological materials	■	■	■
10. UV spectrometer	absorption or exited atoms, ions	ions, atoms, molecules including organics	sublimated and plume material composition		■	■
11. Surface dust mass analyzer	near surface dust/ice grain detection	characterizing the near surface dust environment	estimation on the source of solids including plumes			■
In situ sample analysis						
12. Drilling system (in general)*	shallow subsurface ice	ice structure, contaminants, composition	evolution of ice, radiolysis, internal components	■	■	■
13. Microscopic imager	optical observation of the ice and components	crystalline structure and contaminants of the ice	ice processing, biomorpho features	■	■	■
14. Raman spectrometer	lased based Raman excitation of the crust	composition of non-ice and clathrate materia	chemical alterations, mateirals in the ocean	■	■	
15. Mass spectrometer (+ gas chromatogr.)	in-situ sampling and ionization of surface material	identification of the surface ice composition	searching for material from the ocean and rocky crust	■	■	
16. Thermograivmeter	mass loss analysis during sample heating	ice, clatherate, and organics detection	composition of ice and extrapolation to the icean	■	■	■
17. Multiparametric sensor	wet chemistry analysis	pH, salinity, redox parameters	complex habitability and geochemisty	■	■	
18. Fluorescence spectrometer	in-situ UV bean excited analysis of electrons	organic molecule characterization	direct analysis of molecules important for life	■	■	
19. Microarrays	Antibody biosensor	biomolecule detection	biorelevant materials	■		