Biosignature Explorer for Europa (BEE) Probe – The Concept for Directly Searching for Life Evidence on Europa at Lower Cost and Risk . Michael J. Amato[1], P. Spidaliere[1], P. Mahaffy[1], C. Schiff[1], O. Hsu[1], T. Hurford[1], M. Benha[1], W. Brinckerhoff[1], J. Garvin[1], J. Downing[1], T. Errigo[1], D. Glavin[1], M. Sarantos[2], R. Lorenz[3], T. Hoehler[4], et al. [1]NASA Goddard Space Flight Center (GSFC), Greenbelt MD. [2] University of Maryland Baltimore County/NASA Goddard Space Flight Center, [3] JHU Applied Physics Laboratory, [4] NASA Ames Research Center,

Introduction:

Europa exploration has revealed a dynamic icy world, rich with complexity suggestive of deeper secrets. Europa's substantial sub crustal water ocean results in the pressing question of if the ocean is habitable and if it harbors life.

The tantalizing possibility of hydrothermal activity below its ice crust shell has placed Europa as one of the highest priority targets in the search for habitable environments – and potentially extant life – in our Solar System [NRC, 2011]. Although, the NASA Europa mission is planned to study various aspects of the surface/exosphere interaction, the compositional analysis of potential plumes is a high-value objective. Sporadic eruptive plumes at Europa have been observed [Roth et al., 2013], and analysis shows plume activity is likely at lower intensities The plumes represent an opportunity to uniquely-probe the chemistry of the subsurface ocean and assess Europa's potential to sustain life by looking for bio signatures. Freshly-ejected ocean material would represent a relatively unaltered sample of the subsurface chemistry, as compared to sputtered surface materials exposed to high energy radiation that will destroy organic compounds. In addition to the detection of more pristine organic molecules, the composition of the salts in the ocean has important implications for the source of ocean materials [e.g., Brown and Hand, 2013].

The potential changing intensity of the plumes at Europa calls for a versatile measurements strategy that can accommodate a wide range of geographical locations and outgassing intensities. While the NASA Europa mission spacecraft is well equipped for Europa studies, which include plume detection and characterization, it is limited in its ability to fully analyze Europa plumes. The recently selected instrument suite likely lacks the ability to achieve the highly desirable and difficult detection of direct biosignatures or life evidence. In addition, the Clipper mission may not be able to easily modify its orbital trajectory or altitude to fly through plumes or remotely study plume events that may be short lived or highly diffuse. Thus, a smaller Probe equipped with the focused set of instruments and navigation capabilities is better suited to target detection of bio signatures and can target denser plumes and lower altitudes that might be otherwise inaccessible to the Europa Clipper spacecraft.

The BEE plume probe:

A small plume probe would have more flexibility to perform the critical science investigations in support of the goal of exploring Europa plumes for evidence of past or current life on Europa. Objectives to meet this goal could include: 1) Characterizing the building blocks of life within the plumes, 2) investigating plume source regions to assess them as a biological niche environment and 3) further assess plume source regions for future landed missions.

Our team has designed a Biosignature Explorer for Europa (BEE) Probe concept to 'taste' the ocean by in situ analysis of plume sample for biosignatures, which provide the most science and most programmatically robust way to determine if the Europa ocean harbors life evidence. By flying directly through a plume, the BEE is able to sample freshly released ocean water and search for evidence of extant life. BEE does this by using newly matured collection approaches and mass spectrometer designs based leveraging heritage approaches. The search for direct in situ molecular biosignatures is the clearest path toward to definitive identification of signatures of life as we know it at Europa.

The BEE will search for molecular signatures of life by capturing material soon after it is released from a subsurface reservoir, and conduct chemical analysis with experiments optimized for detection of molecular biosignatures. Plume fly-through with sampling and out-of-radiation zone molecular analysis is akin to "landerless landing" in an ocean (or fresh ocean deposit) in the quest for Europa ocean biosignatures

The BEE fly-through approach may offer many advantages over static landings. BEE plume sampling collects intact biomarker material before their inevitable destruction by radiation after release from the ocean. BEE offers better targetability of plumes or active targets (2-9 km fly through corridor vs. lander Braking-Descent-Landing (BDL) uncertainty of at least 75-100km or worse). BEE is less sensitive to radiation damage and effects on sensitive instrumentation. BEE has no landing loads on sensitive bio-molecule sensors.

BEE's broad regional context can be established with simple imaging systems.

BEE can be more agile and responsive to activity on Europa when we arrive with the Europa mission, allowing easier targeting to the "the action". BEE has no BDL lander systems and cost, uses less resources, has less complexity, has fewer mission constraints and no landing risks that will drive additional costs. BEE also has better means for employing next-gen molecular biosignature sensing techniques already proven to be high value science by NASA Europa Peer Panel.

BEE has an advanced mass spectrometer with a large area collection approach that leverages past designs while enabling new direct biosignature science. The sensitive mass spectrometer is combined with gas chromatograph separation for definitive identification of biosignatures. It also carries the BEE UV plume targeting camera as well as visible and IR cameras to image the active region with better resolution than the Europa mother ships instruments.

The BEE team has refined its cadence of prerelease survey, probe release, refined targeting, sample collection, analysis and transmit operations. BEE is released from the mother ship ~ 8 hours before closest approach to Europa. Initial targeting is done using plume data from the Europa mission instrument suite. Refined targeting on a plume is aided by BEEs unique near UV camera that finds water from electron generated OH emissions night or day. The BEE probe flies thru at 2-10 km altitude and collects material. The probe images the surface in visible and infrared at process-diagnostic scales. After exiting the intense radiation environment, it uses proven mass spectrometer technology to analyze the material for biosignatures. The BEE then transmits the data back to the Europa mission mother spacecraft. The BEE can be released during a large number of the baselined flybys. The BEE uses its refined targeting and propulsion system to enable targeted access a majority of Europa's surface.

The small BEE probe attaches to the Clipper mission, currently on its NADIR viewing side. The BEE team has worked with the Europa mission project engineering team to work out initial mechanical, load, electrical, communications and operations details that have low cost and resources impact on the main mission. BEE employs a modular mechanical design and a carefully designed internal radiation protection vault to protect sensitive electronics from radiation effects and is under 250 Kg.

The BEE probe ACS and propulsion system are designed to enable targeting and post sample collection maneuvers. BEE is three axis stabilized and utilizes acceleration measurement systems, star sensors and gyro packages. The propulsions system is a hybrid system combining a basic bi-propellant design with a simple hydrogen driven three axis cold gas system that is compatible for use just before and during sample collection.

The BEE's avionics utilize a selectively redundant design that leverages multiple NASA Goddard Space Flight Center (GSFC) systems designed for far from earth applications. The design has high performance processor and memory units combined with a number of interfaces cards. These interfaces include power and data interfaces, propulsion and actuator interfaces, refined targeting sensor interfaces and redundant X-band transponder. The BEE's power system is currently a heritage Lithium-Thionyl Chloride primary battery designed with multiple battery cell strings.

The BEEs thermal system utilizes blanketing and four thermal zones as well as survival heaters. The battery system is isolated from the electronics vault to minimize heating requirements but the propulsion tanks are thermally linked to the vault. A separate thermal interface will be linked to the mother spacecraft thermal system during cruise.

The initial planetary protection plan has impacts on design and Integration and test. The approach uses a combination of solutions that include Dry Heat Microbial Reduction (DHMR), possible bio barriers, radiation exposure and options for a 'controlled end of life high speed impact heating event'.

The BEE probe is a feasible way to achieve critical biosignature and life evidence goals with less risk and lower cost than other options. The BEE team has shown this approach to be feasible approach to be considered.

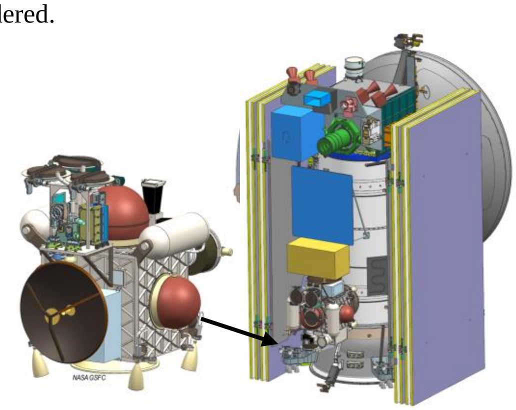

Figure 1 – The BEE probe design and its current location on the Europa mission spacecraft.

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References - [1] NRC, 2011, [2] Roth et al., 2013 [3] Brown and Hand, 2013