Sylph – A SmallSat Probe Concept Engineered to Answer Europa's Big Question

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ABSTRACT

Europa, the Galilean satellite second from Jupiter, contains a vast, subsurface ocean of liquid water. Recent observations indicate possible plume activity. If such a plume expels ocean water into space as at Enceladus, a spacecraft could directly sample the ocean by analyzing the plume's water vapor, ice, and grains. Due to Europa's strong gravity, such sampling would have to be done within 5 km of the surface to sample ice grains larger than 5 µm, expected to be frozen ocean spray and thus to contain non-volatile species critical to a biosignature-detection mission. By contrast, the planned Europa Multiple Flyby Mission's closest planned flyby altitude is 25 km. Sylph is a concept for a SmallSat free-flyer probe that, deployed from the planned Europa Mission, would directly sample the large grains by executing a single ~2-km altitude plume pass. The 40-kg probe would be deployed by the Europa mission just before it executes a plume fly-through. Within the probe's 16-hour lifespan, it would autonomously navigate to perform a parallel, simultaneous pass at the lower altitude. The Sylph flight system design concept combines SmallSat technologies with robust traditional components and advanced manufacturing technologies. Its payload would comprise Mini-SUDA (SUrface Dust Mass Analyzer), a dual-channel, miniature impact ionization mass spectrometer. Sylph represents a novel type of SmallSat concept: purpose-built configuration, optimized for the harsh environment at Europa and for planetary-protection requirements, and hybridized from both mainstream and SmallSat components.

INTRODUCTION

Sylph (pronounced *silf)* is an investigation and SmallSat flight-system concept named after a supernatural entity of the air that never touches the ground. It was proposed to NASA in January 2016 to augment the planned Europa Multiple Flyby Mission (called EMFM herein) by a joint team: Principal Investigator Jonathan Lunine (Cornell University); science team from the University of Colorado at Boulder and Southwest Research Institute; and engineering and project leadership by the Jet Propulsion Laboratory. The concept was matured from idea to CML 5 (the concept maturity level designating an integrated point design proposed for a Phase A award) in five months by a small team with access to three concurrent-engineering capabilities at JPL: A-Team, Team Xc and the engineering directorate's design atelier.

Sylph's only purpose would be to sample the chemistry of large ice grains in a Europan plume, should EMFM discover and target one for fly-through. Together with higher-altitude mass spectrometry measurements made simultaneously by EMFM, data from its particle analyzer would allow sufficient inferences about Europa's ocean chemistry to determine whether there is life is present.

The size of a home propane tank, the Sylph probe design (Figure 1) reconciles a tough set of mutually competing constraints for a SmallSat subsatellite: challenging, fast science measurement operations in deep space, autonomous navigation, closest flyby ever attempted, miniaturized instrument, low-impact host interface on a flagship mission, Jovian radiation environment, Category-IV planetary protection, mature technology, and competitive cost.

Figure 1. The Sylph probe concept is a small, low-cost free flyer with one purpose: to make a plume measurement that the Europa Multiple Flyby Mission cannot.

This paper summarizes the science objective, then describes the flight system concept and its rapid development, highlighting some of the innovations required for small spacecraft to conduct game-changing science in deep space. Companion papers detail the science context [1] and provisions for planetary protection [2].

SCIENCE REQUIREMENTS

Of the solar system's ocean worlds, Europa and Enceladus are primary targets for exploration: Europa because it appears to be most intrinsically capable of hosting an extant alien ecology, and Enceladus because Cassini has determined that the ocean water it expresses into space is habitable and hosts organics. NASA is currently developing EMFM to characterize Europa's surface, ice shell, and ocean – and reconnoiter potential landing sites for the future – using a suite of nine science instruments. From Jupiter orbit, the EMFM mission design would conduct 45 flybys of Europa, some as low as 25 km in altitude [3].

Among the science operations EMFM might conduct would be plume fly-throughs. Cassini demonstrated at Enceladus how revealing such measurements can be. Europan plume activity is suggested by a singular telescopic observation (Figure 2) [4]. Hypothetical Europan ocean plume behavior is modeled based on this observation and comparison to detailed ocean-plume observations at Enceladus [5]. Two driving requirements emerge: 1) ice grains larger than 5 µm are frozen ocean spray rather than condensed vapor, so analyzing them is tantamount to direct analysis of ocean material; 2) at Europa, unlike at Enceladus, grains this large cannot reach above about 5-km altitude.

Quantifying the range of grain sizes and column densities that could be intercepted at various altitudes in a Europan plume allows a mass-spectrometry science investigation to be defined, including flow down from questions to observables to measurements, and estimates of margin between the instrument performance needed and the capabilities that a mission design could deliver. The Sylph STM (science traceability matrix) for these conditions is derived directly from the STM of ELF, the Enceladus Life Finder mission concept proposed to NASA in 2015.

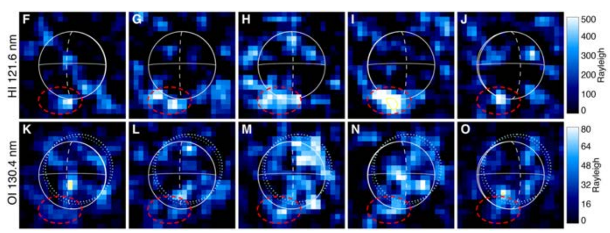

Figure 2. Possibility of plume activity at Europa may justify Sylph as a low-cost, high-payoff enhancement for EMFM. [4]

The Sylph STM requires compositional analysis of a wide range of both vapor-phase and solid-phase constituents. In the Sylph investigation, EMFM itself would measure the plume composition using both of the mass spectrometers already on its payload: MASPEX for the vapor, and SUDA for the tiny grains. Making these measurements would be the principal motivator for EMFM to target a plume, with or without Sylph.

However, the Sylph STM would combine these EMFM measurements with additional mass spectra of the large, low-altitude ice grains, collected by a miniature version of SUDA on the probe as it skims over the surface ~20 km below EMFM and transmitted back to EMFM. Making this single measurement in a 3-second plume pass could enable EMFM to detect biosignatures if

Europa has ocean plumes. It would also create a focused, well-bounded set of mission traceability requirements for a small probe: deploy from EMFM, auto-navigate using a terrain map provided by EMFM to a 4.5-km/s pass 2-5 km above the plume source, aim Mini-SUDA's aperture into the velocity vector, and transmit mass spectra and contextual navigation camera images to EMFM multiple times before expiring.

PROBE INSTRUMENT PAYLOAD

The conceptual payload for Sylph is a miniaturized version of the SUDA instrument. SUDA is an impact-ionization mass spectrometer that relies on high encounter velocity to fragment impinging dust or ice grains, fingerprinting the ionized impact products in a time-of-flight mass spectrometer. On EMFM, its primary purpose is to measure the velocity and composition of dust grains sputtered off the surface of the airless Europa by the micrometeoroid flux, and back-propagate their trajectories to surface source locations, thereby generating a map of surface composition.

Mini-SUDA carries instrument electronics identical to SUDA, connected to two miniaturized sensor heads (Figure 3). Two heads enable simultaneous acquisition of both cation and anion spectra, necessary for identifying plume grain constituents in a single pass. The Mini-SUDA impact targets are quite small (4 cm^2 total) compared to SUDA's 220 cm^2 aperture; at the high particle column-density encountered low enough in the plume to catch frozen ocean spray, small targets preclude saturation of the instrument electronics by small-grain impacts that would overwhelm the large-grain signal. To account for a priori uncertainty about particle column-density, the target area is selectable in flight (1, 2, 3, or 4 cm^2), and uploaded into the probe by EMFM before deployment. A key mission-traceability requirement is that the instrument functions optimally at encounter velocities above 4 km/s, consistent with EMFM's flyby speed without imposing a velocity change on Sylph.

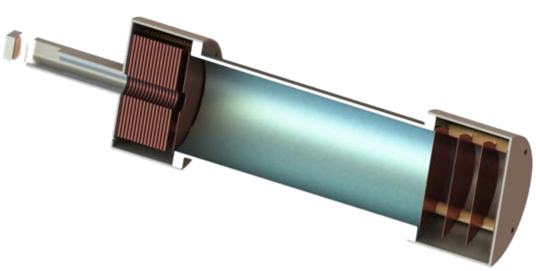

Figure 3. The Mini-SUDA concept is a small version of EMFM's particle analyzer instrument. Sensor head (shown) integrates area-selectable target (at left), reflectron time-of-flight ion optics, and detector stack.

FORMULATION PROCESS

Sylph's small size and simple payload are enabled by an investigation strategy that combines its measurements with those of EMFM itself, rather than forcing a duplicative instrument suite. Specifics about potential Europan plumes will not be answered until EMFM arrives at Europa, so the probe would remain quiescent, stowed in its shielded biobarrier dispenser for activation and release only upon EMFM's best plume pass, analogous to the way CubeSats remain stowed until a primary payload is deployed.

In the fall of 2015 when NASA first invited EMFM enhancement concepts for free-flyer investigation of putative Europan plumes, the team's initial trade space included the full range of biosignature measurement techniques and implementation architectures. The JPL Innovation Foundry A-Team was deployed to sift through the feasibility, benefits, and costs of the various combinations. Based primarily on the plume model, TRL of the instrument options, propulsive requirements of the mission-design options, and EMFM's intrinsic ground-track placement flexibility, the team rapidly converged on a design seed: ELF-derived STM, large grains, low altitude, single instrument, no velocity change, small probe, single pass, sacrificial. This approach yielded the collateral benefits of using scientists already on the EMFM team, requiring only mature technologies, facilitating sterilization, yielding low development cost, and fitting up to three copies in the EMFM mass allocation.

The decisions to make the probe small and sacrificial were essential. At one end of the option spectrum would be a large spacecraft, with impressive capability but significant complexity. At the other would be a small, single-string satellite embracing the CubeSat philosophy of low-cost at higher risk. If a plume were detected by EMFM, but were to lie outside the range of ground tracks EMFM could reach, the free-flying plume probe would have to be a fully capable spacecraft. This would significantly drive system and mission complexity, requiring high-impulse propulsion for orbital maneuvers and plane changes, heavier radiation protection for extended operations in the Jovian environment, and redundant subsystems to assure performance life. The proof-of-feasibility concept for this option was a spacecraft more similar to EMFM itself than to a SmallSat, tough to fit within the mass allocation and stretching credulity for being selectable. Because the EMFM orbit tour design in fact has extensive flexibility over both short and long timescales, and because the primary mission would be likely to prioritize plume passes itself, the option of a less-capable, slaved-trajectory, single-function, and sacrificial SmallSat won the trade.

Once the architecture was decided, JPL stood up a core Sylph formulation team led by SmallSat experts, and supported it with three simultaneous design teams. The first comprised senior experts in traditional deep-space flight-system design. They acted as the technical conscience for key design decisions by injecting lessons learned from prior flight projects. The second support team was Team Xc, which routinely conducts model-based concurrent-engineering design studies of SmallSats. The third support team was the Engineering and Science Directorate design atelier, a deep-design team that uses implementation models in a concurrent-engineering environment to resolve complex, coupled challenges in configuration, structures, thermal, and integration.

Team Xc is a core service of the JPL Innovation Foundry. It extends the 20-year heritage of Team X into the SmallSat realm, convening large- and small-satellite experts from across the Lab for focused concurrent design sessions that rapidly develop spacecraft architecture solutions. The subsystem chairs use inter-linked models that exchange key parameters, allowing rapid iteration and optimization. In three 3-hour design sessions, Team Xc developed a Sylph architecture for attitude control, navigation, and propulsion, traded primary vs. secondary power options, and developed radiation-mitigation strategies.

The design atelier then shaped the mission's core requirements into the configuration presented to NASA via integrated digital solid models, a mission-operations animation, and a full-size 3D-printed take-apart model. The atelier validated the configuration design with key Phase B-level performance analyses including FEM structures and thermal performance models of the probe and dispenser, high-fidelity assembly and integration flow, complete parts list, and high-accuracy mass estimate.

An option space ranging from proven methodologies to contemporary innovations like additively manufactured metal structures was investigated by the concurrent process, enabling a matched set of features consistent with the core team's design philosophy to be infused into the design in an expedited manner. Three configuration innovations detailed below – lightening voids achievable only by additive manufacturing, multi-functionality elements, and modular integration to facilitate multiple sterilization techniques – drove down mass and cost without sacrificing technical maturity. What resulted was a tightly coupled, detailed design that implemented the strategy, met the requirements, and identified areas needing refinement.

CONCEPT OF OPERATIONS

The Sylph operations concept is based on a 16-hour life. Sylph is ejected on approach to an EMFM periapsis targeted for a 25-km altitude plume fly-through. On final approach, DSN tracking passes provide final navigation and commanding. At T-9 hours, EMFM powers up Sylph, performs its final systems check, uploads the terrain map for its autonomous navigation, and selects the Mini-SUDA target area. It ejects Sylph one hour later; Sylph detumbles, then acquires Europa for autonomous navigation. It executes a <10-m/s lateral thrust maneuver to reduce flyby altitude to a keyhole between 2-5 km. For the next few hours, Sylph cruises ballistically toward encounter, with just a few navigation imaging and corrective maneuvers. A few minutes out from plume contact, Sylph powers on Mini-SUDA and begins collecting data. Traveling at 4.5 km/s relative to the moon, the actual encounter lasts about three seconds. Data collection ceases seconds after exiting the plume, and data uplink begins immediately. The probe transmits Mini-SUDA spectra and selected OpNav (optical navigation) images to EMFM at least four times before exhausting battery power. It expires in the flyby orbit, and eventually impacts the surface of Europa.

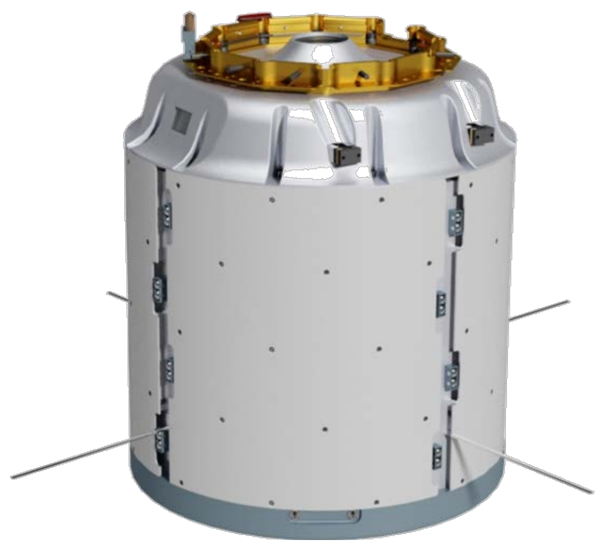

Figure 4. The Sylph probe concept is the size of a home propane tank. View shows OpNav camera (center top), twin instrument apertures (top right side), and UHF antennas.

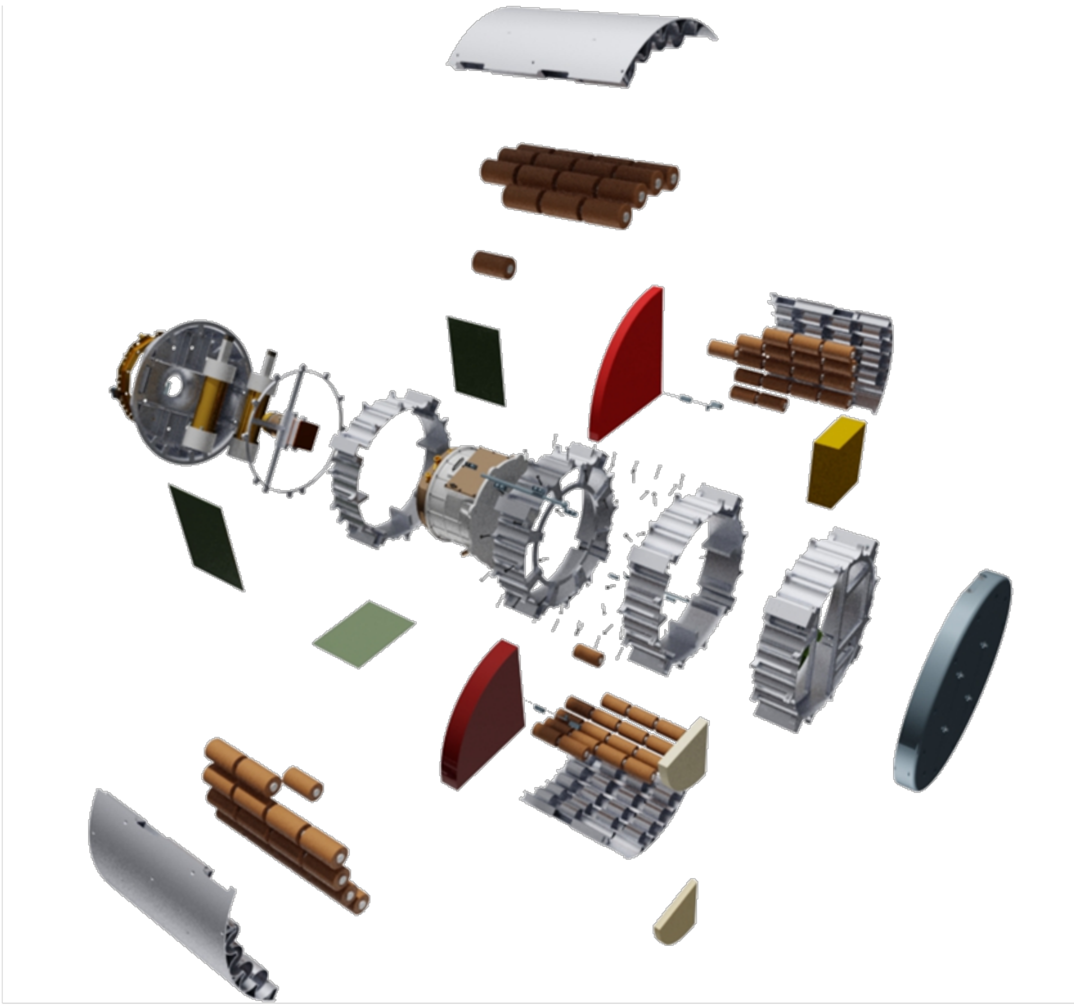

Figure 5. Sylph's small size and low parts count would make it a pathfinder for multi-technique sterilization procedures for future in situ ocean-world probes.

DRIVING DESIGN REQUIREMENTS

The Sylph concept is subject to a diverse, complex set of requirements and constraints quite different from Earth-orbiting SmallSats or even the most advanced CubeSats planned for the Moon, near-Earth asteroids, Mars, or deep space. The probe must survive nearly a decade of storage in flight onboard EMFM, yet impose minimal accommodation impact. The system must shield against the high-radiation environment of the Jovian system and survive hypervelocity impacts of plume particles. As a planetary protection Category-IV mission, it must assure $\leq 10^{-4}$ probability of any viable terrestrial organism being deposited onto the Europan surface.

A fundamental requirement for any EMFM-hosted free-flyer is to minimize its impact on the host spacecraft and mission. This is analogous to requirements levied on CubeSats launched as secondaries: resource burdens for mass, volume, and power are designed to be minimized, and safety is paramount. NASA allocated a study mass envelope of 250 kg for Sylph.

Analogous to a PPOD dispenser for CubeSats, a multi-function dispenser meets the key EMFM accommodations requirements for Sylph, and is thus an integral part of the overall flight system design. The Sylph dispenser could be mounted in multiple locations on the EMFM spacecraft; the reference location is on the external surface of the aft skirt. The principal operations requirements assumed are minimal heat leak (to minimize EMFM parasitic power), digital interface (for occasional health checks during cruise, to upload targeting data, and to command deployment), safe ejection (to avoid re-contact damage to EMFM), and no re-orientation by EMFM to deploy the probe.

Sylph is designed to handle the highest expected radiation environment. Total dose begins with the multi-year cruise to the Jovian system. Once orbiting Jupiter, EMFM executes a year of orbit-phasing operations, then about 45 flybys of Europa. In the worst case, Sylph would not be deployed until after this primary mission is complete. For these long intervals before Sylph's mission, its dispenser is designed with thick walls to provide adequate shielding. Upon ejection however, Sylph is no longer protected and receives a large, final dose. Based on EMFM's Jovian radiation environment model, Sylph's expected total mission dose is less than 150 krad. A radiation design factor of two drives internal components to be specified for up to 300-krad TID.

Based on the plume model, Sylph would encounter plume particles head-on at 4.5 km/s. While the Mini-SUDA targets depend on these conditions, other frontal areas must protect internal components from damage. Ultimately the requirement is easily met because the critical shielding thickness for the largest expected plume particles is 3 mm of aluminum – much less than what is required anyway for radiation shielding. Facing forward, the OpNav camera lens could be damaged, but it is not needed in the plume or thereafter. Impacts could impose disturbance torques, but the resulting slow tumble would not affect the telecomm link for data transfer to EMFM.

The probability of impacting Europa is assumed to be unity, after some indeterminate time following Sylph's mission. Thus the entire flight system must be sterilized during integration, and the dispenser must also provide a biobarrier function throughout launch processing and launch operations. The three accepted methods of sterilization are vapor hydrogen peroxide (VHP), dry heat microbial reduction (DHMR), and irradiation. VHP cleans surfaces, allowing aseptic assembly, but cannot penetrate inside packaged components like batteries or integrated circuits. DHMR bakes hardware for extended periods at or above 125°C. Irradiation requires special handling in reactor facilities, but is useful for materials that degrade with high heat, such as batteries. To avoid pushing technology, Sylph uses all three techniques in parallel and series, as appropriate during integration. The mission assumes no microbial reduction credit for radiation received after launch; exposure in Jupiter space constitutes significant design margin.

SYLPH FLIGHT SYSTEM

The Sylph spacecraft design (Figure 5) is enabled by several deep-space SmallSat technologies being developed currently for CubeSats and NanoSats. Where SmallSat subsystems are not available or have too-low TRL, the design incorporates traditional components. This strategy led the Sylph design to converge with healthy resource and performance margins (Table 1).

Table 1. Sylph concept is designed with large margins.

Functional Requirement	Driving Requirement	Design Value	Margin
Launch Mass (kg)	250 (allocation)	85 (probe + dispenser)	165 (194%)
Stored Energy (Whr)	1250	1800	550 (44%)
Data Storage (Mb)	215	1024	809 (376%)
Uplink Time (min)	4	30	26 (650%)
ΔV (m/s)	12	23	11 (91%)

Sylph is battery-powered. The spacecraft uses an IMU (Inertial Measurement Unit), optical imager, and cold-gas propulsion system for autonomous navigation and targeting. The IMU selected is the only extant solution to meet the stringent radiation and other performance requirements. Because of its size and mass, it ultimately drove the overall configuration (the design team referred to Sylph as a "flying IMU", seen in Figure 6). Spectra from Mini-SUDA are transmitted via UHF radio link to EMFM. Core avionics are based on JPL's deep-space electronics for small-satellite platforms.

Figure 6. Cold gas propulsion (bottom), avionics boards (lower), MIMU (middle), and OpNav camera (top) would dominate the interior volume

Leveraged Technologies

Sylph is conceived as a science mission, not a technology demonstration mission. The design focus is on instrument accommodation and science data sufficiency rather than on infusing immature technologies. However, the unprecedented form factor and environmental constraints drove Sylph to look beyond traditional solutions. In the end, the spacecraft concept incorporates a diverse set of components that draw on sources ranging from MSL heritage, to the MarCO CubeSats (to be launched with InSight), and SmallSat technologies in advanced development at JPL. The resulting design is single-string, a risk posture consistent with its extremely short mission duration.

Instrument Accommodation

Mini-SUDA would use the same instrument electronics as EMFM's SUDA instrument. High particle column-density at low altitudes allows the ion dispersion paths to be contained within a single, narrow tube. Two targets, each with ion optics and detector, simultaneously generate both anion and cation spectra on a single pass. The sensor heads fit into the top cap of the probe (Figure 7). Only the impact targets are exposed outside the spacecraft (Figure 8). The nominal flyby orientation is canted 45 degrees off-axis, so that Mini-SUDA's impact targets face "into the wind" at the optimal angle for ionization products to enter the ion optics.

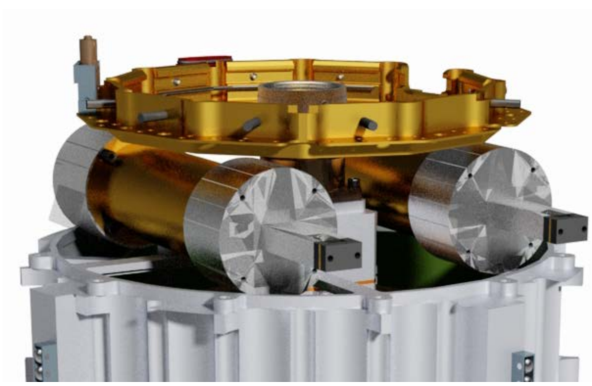

Figure 7. Two side-by-side Mini-SUDA sensor heads would generate a full set of ion spectra simultaneously. Impact targets (near end) are sized for low-altitude plume pass.

Multifunctional Structure

Structure and power components fulfill multiple functions. Sylph is 40 cm high and 35 cm in diameter, similar in size to a water-cooler bottle or home propane tank. The dense, radiation-tolerant batteries line the shell, helping to mitigate the large radiation dose encountered after ejection from the dispenser at the start of the 16-hour plume mission (Figure 8). The battery mass contributes the equivalent of 1 cm of aluminum shielding for the avionics in the interior, avoiding kilograms of otherwise purposeless mass. The design is well-margined: shielding capability of 150 krad, but with expected internal dose just over 100 krad from launch through end of mission.

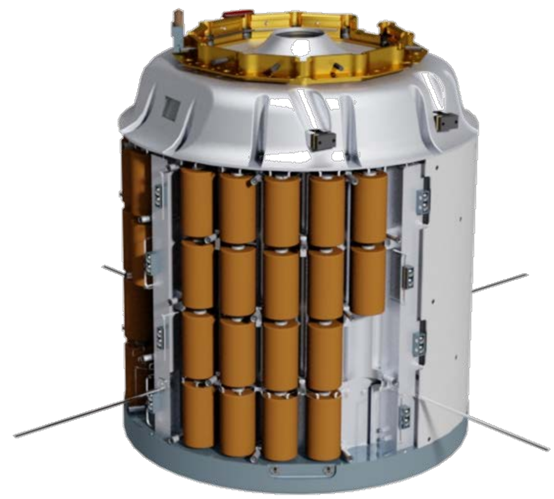

Figure 8. Multifunctional configuration design takes full advantage of necessary mass. Inside outer skin (right), batteries provide a layer of radiation shielding (left).

The Sylph interior structure is configured into modular layers that are integrated and tested in parallel, and then stacked together for final testing (Figure 9). The aft segment contains avionics and the instrument interface. A central segment contains the largest single component, the IMU. The forward segment contains OpNav camera and instrument sensor heads. The cold-gas propulsion subsystem is self-contained in a caboose segment that also acts as the aft radiation shield. A shielded front cap closes out the structure and contains the mounting-ring of the ejection interface.

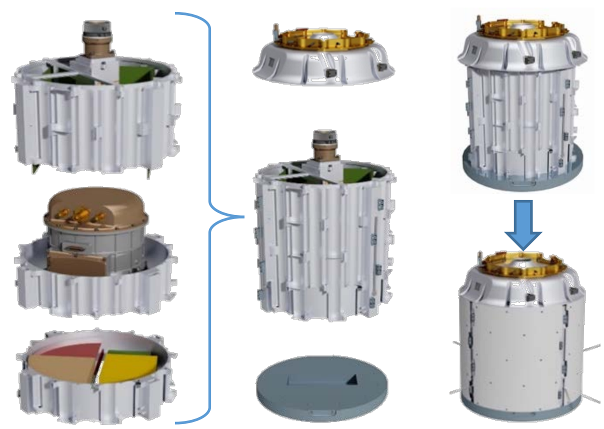

Figure 9. Flight system modularity facilitates assembly, test, and sterilization.

Power and Avionics

Sylph's power source is 72 D-cell-sized Li-ion primary batteries. Primary batteries are better than rechargeable batteries for this application because of their higher energy density and because they degrade less than secondary cells after years of storage. The power system is sized for a 28V spacecraft bus, with enough energy for a 16-hour mission, with margin, after accommodating decrements for storage losses and depth-of-discharge limitations.

The avionics use the deep-space hardware being developed by JPL for planetary CubeSat applications. Sylph baselines a UHF, transmit-only version of the Iris transponder. No receiver is needed; the probe is designed for "fire and forget" operations, so no commanding occurs after deployment; nor would tracking be useful (explained below). UHF is adequate because the separation between probe and EMFM remains under 1000 km even for several hours after the plume pass. Four dipole antennas, held down by burn wires until after ejection, provide omnidirectional coverage. The command and data handling system architecture is based on a further-hardened version of JPL's Sphinx CubeSat product. Custom memory-storage and interface cards interface the Sphinx to the other avionics, OpNav camera, and Mini-SUDA.

Guidance, Navigation, and Control

The GNC subsystem architecture is based on only two sensors, the IMU and OpNav camera. Alignment between these two sensors is critical, so they are hard-mounted to each other to maintain required tolerance (Figure 6). A coupled cold-gas propellant system provides control. This architecture yields multiple benefits. The first is compatibility with accepted sterilization techniques. Although reaction wheels are available for this size of spacecraft, there are no performance data about whether they could be sterilized, stored for years in a harsh environment, and then still function. Second, Sylph navigation must be autonomous due to separation from Earth; in any case, Sylph could not carry the technical resources to talk directly with Earth, and EMFM would have no scheduled passes until after its close flyby.

Sylph navigation cannot rely on ranging from EMFM; with differential ranging, the error could be no better than EMFM itself. While EMFM's position errors are small enough for it to execute close flybys at 25-km altitude, they are not small enough for Sylph at just 2-km altitude. Rather, the worst-case error ellipses overlap the surface of Europa (allowing impact), and are wider than the plume near its source (allowing a null pass altogether) (Figure 10). Thus Sylph must autonomously navigate with accuracy better than EMFM itself.

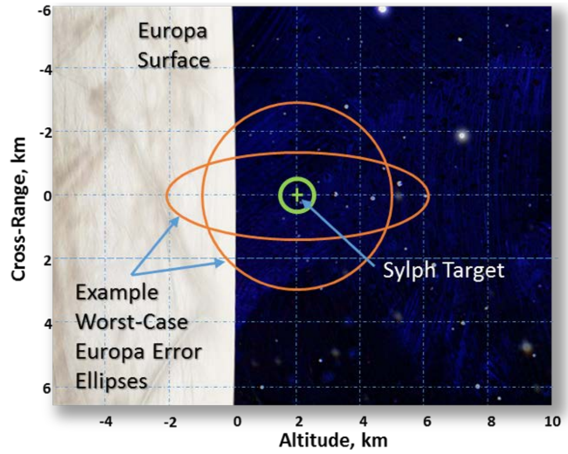

Figure 10. Sylph must auto-navigate to compensate for worst-case EMFM navigation errors.

Sylph's autonomous navigation scheme pairs a JPL imaging system with autonavigation software. To initialize Sylph, EMFM uploads the relevant terrain feature map and navigation keyhole calculated to fly over the plume source on the surface, via the dispenser data interface. After ejection and the detumble maneuver, the probe images a star field and zeroes out IMU rates to set the initial state. After the diver maneuver down toward the surface, and throughout the remainder of the approach, the camera takes recurring images of the moon. The autonav algorithms use Deep Impact heritage; the software uses Europa's limb and surface features to aim for a cross-track coordinate location. Unlike Deep Impact however, which aimed for an impact, Sylph's target lies above the limb. This simple terrain-relative approach avoids having to attempt to image or target the plume itself. Sylph executes one main targeting maneuver, with provisions for up to three more targeting adjustment maneuvers until about 30 min before the plume encounter.

To stay on target throughout the 8-hr approach, Sylph depends on an accurate IMU to measure the dispenser ejection translational rates and subsequently monitor propulsion system performance errors. An early trade led Sylph to select the Honeywell MIMU because of its accuracy, drift characteristics, and radiation tolerance; All other IMU options are either too rad-soft, are subject to unacceptable drift, or have too-low TRL for use today. The MIMU's large relative size (Figure 6) became the main volume and power driver of the system design.

Spacecraft Integration

Meeting planetary protection requirements is a significant driver for in situ probes to ocean worlds. Small size and parts count mean that Sylph would exercise the necessary procedures in preparation for other future systems and missions (Figure 5). This is especially valuable given the multiple techniques that need to be interleaved in the integration flow.

All components except batteries would undergo bake-out at up to 128°C for 10 weeks. The components would then be assembled in a clean room and the system would be baked for an additional 2.5 weeks. In parallel, the batteries would be irradiated with up to 10 Mrad (some battery chemistries can withstand high temperatures, but they experience severely reduced discharge capacity after being baked and stored for years). The core flight-system exterior, batteries, and outer structure components would then be surface-sterilized in a vapor hydrogen peroxide glovebox and final-assembled. Spore-filtered propellant would be aseptically loaded and the spacecraft would be aseptically integrated into its dispenser. Once sealed, the dispenser serves a second function as the biobarrier throughout ground handling, launch processing, and in-flight storage.

Biobarrier Dispenser

An integral part of the Sylph flight-system design is a custom dispenser, analogous to the PPOD used to launch and deploy CubeSats but tailored for this application. Shown mounted on EMFM's aft skirt (Figure 11), the 44-kg dispenser fulfills several key functions: the biobarrier prevents contamination throughout ground and launch processing; nearly 2 cm of aluminum helps mitigate the total radiation dose until deployment; heaters and insulation maintain warmth during the multi-year cruise; an electrical interface provides connectivity for occasional health checks, to initialize the probe, and to upload navigation data before its mission; and deployment.

Figure 11. Biobarrier dispenser would serve multiple functions: controlled interface with EMFM, radiation shielding, deployment, and planetary protection.

The biobarrier prevents recontamination during integration with EMFM or at any time later during launch processing or cruise. A HEPA air filter allows the dispenser volume to vent during ascent. Sylph is secured in the dispenser by a Lightband separation system; a motor-driven door seals the dispenser until deployment, and re-closes afterwards to minimize post-ejection heat loss from EMFM.

CONCLUSION

Sylph would be a low-cost, high-payoff enhancement for the planned Europa Multiple Flyby Mission, that would enable it to detect chemical signs of life if Europa presents it with an ocean plume. In combining SmallSat approaches with flight-qualified components and standards, the Sylph probe design is both innovative and feasible, robust to its mission environment, and appropriate for an ocean-worlds exploration flagship.

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