SAMPLE RETURN FROM DWARF PLANET CERES' TO ASSESS PAST AND PRESENT HABITABILITY POTENTIAL. J. C. Castillo-Rogez[1], K. E. Miller[2], J. Brophy[1], R. E. Grimm[3], J. E. C. Scully[1], M. Zolensky[4], L.C. Quick[5], M. M. Sori[6], M. T. Bland[7], D. L. Buczkowski[8], A. R. Hendrix[9], T. H. Prettyman[9], Y. Sekine[10], T. Titus[7], D. A. Williams[11], C. A. Raymond[1], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA. [2]Southwest Research Institute, San Antonio, TX. [3]Southwest Research Institute, Boulder, CO. [4]Astromaterials Research and Exploration Science, NASA Johnson Space Center, Houston, TX. [5]NASA Goddard Space Flight Center, Greenbelt, MD. [6]Purdue University, West Lafayette, IN. [7]United States Geological Survey, Flagstaff, AZ. [8]John Hopkins University, Applied Physics Laboratory, Laurel, MD. [9]Planetary Science Institute. [10]Earth-Life Science Institute, Tokyo Institute of Technology, Tokyo, Japan. [11]School of Earth and Space Exploration, Arizona State University, Phoenix, AZ.

Background: Dwarf planet Ceres is the largest object in the main belt and the most water-rich object in the inner solar system after Earth. Ceres had sufficient water and silicates (i.e., radioisotopes) to host a deep ocean in its history, leading to a layered interior structure with a high degree of aqueous alteration [1]. Dawn revealed evidence for recent and possibly ongoing geologic activity on Ceres [2,3], the potential presence of liquid below an ice-rich crust [3], and high concentrations of organic matter (locally) and carbon (globally) in the shallow subsurface [4, 5]. Ceres could have been active throughout its history [6]. Following a Planetary Mission Concept Study [7], the 2023-2032 Planetary Science and Astrobiology Decadal Survey [8] included a Ceres Sample return mission that would address the following objectives:

1. *Characterize the depth and extent of potential deep brine layer(s) to determine whether liquid exists beneath Ceres today near hypothesized brine extrusion zones*
2. *Characterize the nature of Ceres' brines from salt deposits to determine the chemistry of waters and their potential habitability*
3. *Determine the composition, structure, and isotopic composition of Ceres' organics to understand processes of abiotic organic synthesis and evolution*
4. *Determine the elemental abundances and isotopic ratios of Ceres' materials via measurements on returned samples to determine its accretional environment*

We identified that samples from the Vinalia Facula evaporites in Occator crater are of highest scientific value because of their recent emplacement [3]. Additional objectives considered in [7] could include testing if endogenic activity is ongoing at Occator and if activity recently occurred outside of Occator crater. A high-level possible concept of operations is presented in Figure 1, based on [7].

Mission Architecture: This mission is enabled by electric propulsion and assumes the roll out solar arrays (ROSA) from Deployable Space Systems flown on the

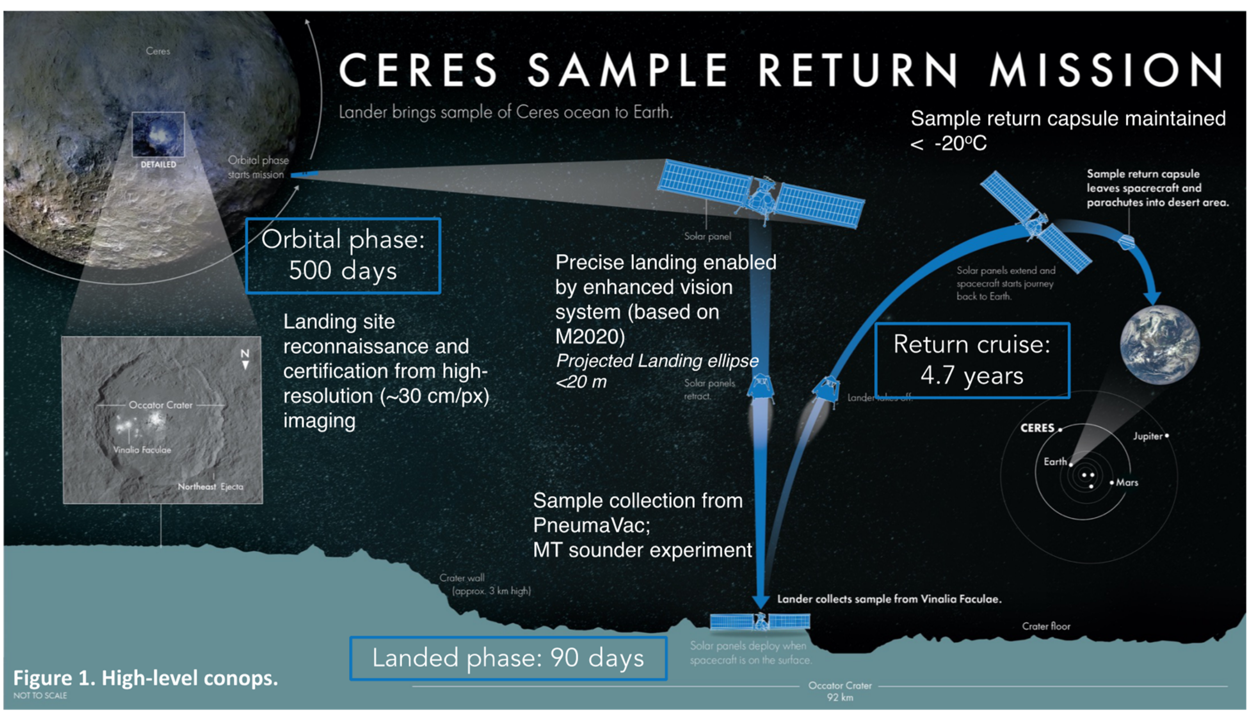

Figure 1. High-level conops.

DART mission [9]. The arrays would need to be stowed for landing, and then redeployed to power a three-week in situ phase, which includes keeping chemical thrusters warm for later take-off. At this time, deployment of ROSA in Ceres' gravity conditions has not been demonstrated. Alternative power solutions could be envisioned, for example using energy-dense batteries combined with advanced on-board resource and fault management for optimizing operations. Use of the Mars 2020 enhanced vision system would enable landing within a projected landing ellipse < 20 m. On the surface, the sample would be collected via the PneumaVac technology from Honeybee Robotics [10] (Figure 2), and Objective 1 would be addressed with the magnetotelluric (MT) sounder experiment. The use of PneumaVac through the lander legs was chosen because it would decrease operational complexity and is planned to fly with the Dragonfly and Mars Moons eXplorer missions. After the completion of the MT sounding experiment, the spacecraft would take off and initiate the 4.7 year return cruise. During this time, the sample capsule would be maintained at < -20 °C to prevent alteration of the sample during cruise.

Payload elements are listed in Table 1. The SRC was conceptually based off of designs utilized for the Stardust and OSIRIS-REx sample return missions. The capsule would be carried by the lander element during the return cruise, and detach in near Earth space with a hyperbolic excess velocity of < 6 km/s. It would utilize a parachute to slow descent to the Utah Test and Training Range. Curation facilities that can maintain sample integrity (low-temperature, controlled atmosphere) and potentially deal with planetary protection concerns due to the return of extraterrestrial organics evolved in a long-lived ocean also need to be carefully considered.

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Table 1. *Summary of mission concept payload, from [7]. Additional instruments to obtain context of the lander working area may be considered.*

Investigation	Science target	Notes
Radio science	Gravity measurements	X-band sufficient
Narrow Angle Camera	Landing site mapping and change detection	Based on the Lunar Reconnaissance Orbiter Malin Space Science Systems; TRL 9 but augmentation with color filters required
Magnetotelluric sounder	Brine depth and geometry characterization	Based on CLPS 19D and CP12 Lunar Magnetotelluric Sounders, TRL 8.
Sample return capsule	Returned sample analyses	Based on Stardust and OSIRIS-REx concepts

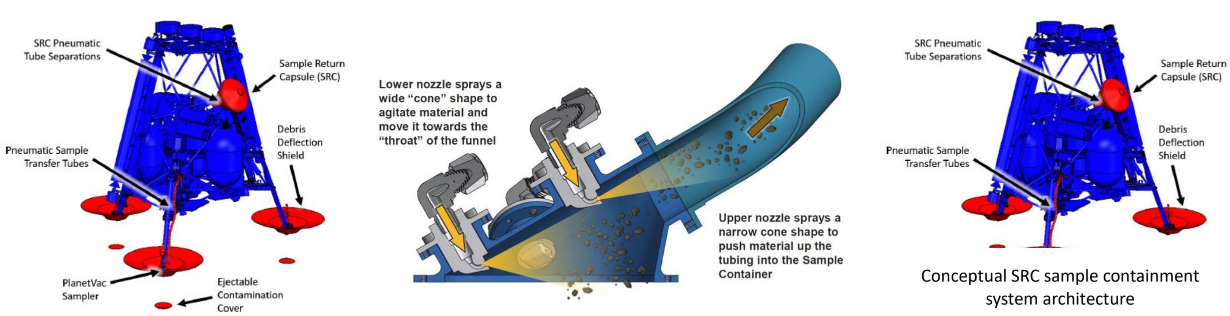

Figure 2. Sample acquisition would use PneumaVac technology in the lander footpads. Compressed gas would move the loose sample material to the SRC. Addition of a drill was considered as a way to mitigate the risk posed by consolidated material.