The *Plume Chaser* Mission:

Two-Spacecraft Search for Organics on the Dwarf Planet Ceres

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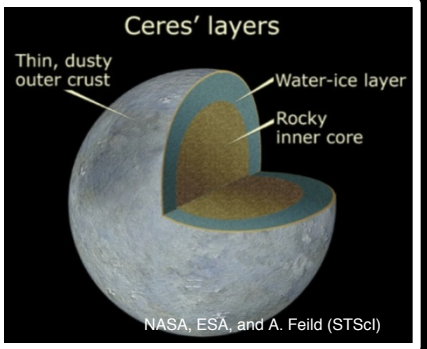
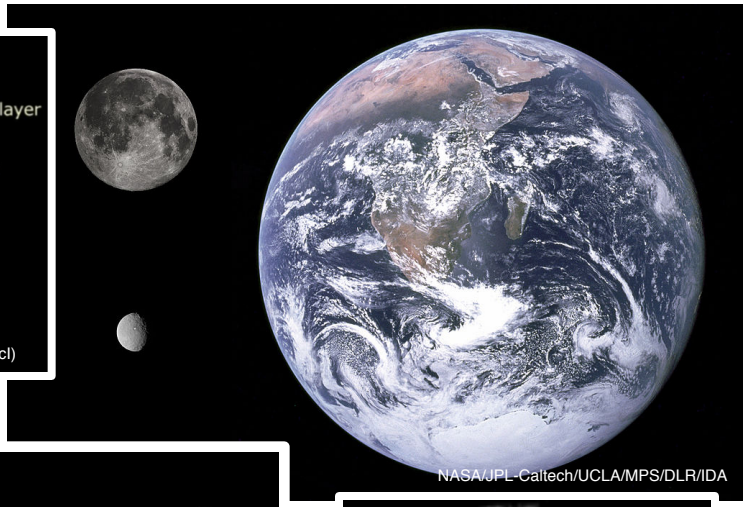
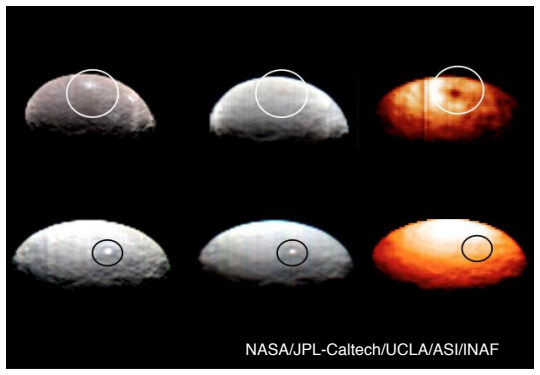
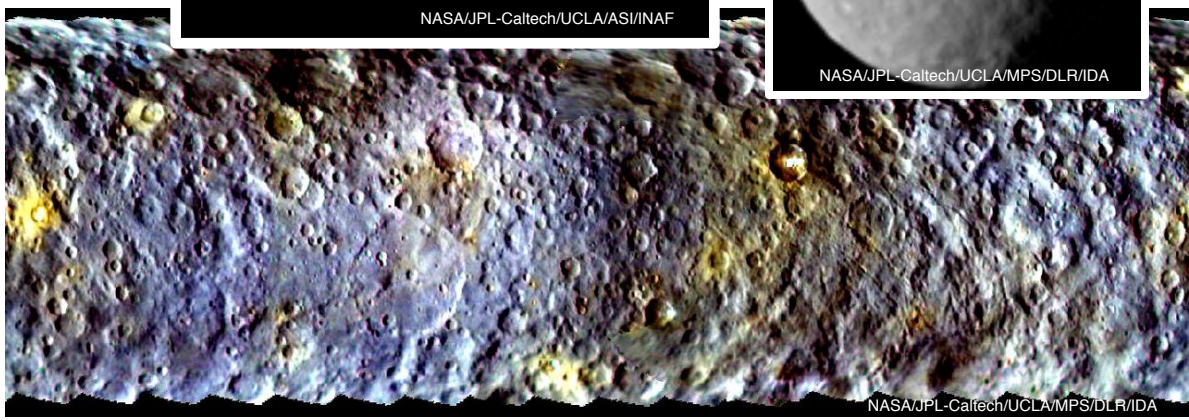
Ceres

- **Aphelion: 2.9773 AU**
- **Perihelion: 2.5577 AU**
- **Orbital period: 4.60 yr**
- **Avg. orbital speed: 17.905 km/s**
- **Mean radius: 476.2±1.7 km**
- **Mean density: 2.077±0.036 g/cm3**
- **Surface gravity: 0.28 m/s2**
- **Escape velocity: 0.51 km/s**
- **Mean surf. Temp.: 168 K**
- **Max surf. Temp.: 235 K**









Why is Ceres so interesting?

- **Differentiated structure with a anhydrous silicate core with water-rich mantle**
- **The relatively rare CM chondrites are thought to originate from here**
- **Spared from the effects of the Late Heavy Bombardment (LHB)**
- **HST detected up to 8 features releasing 10^26 molecules (~6 kg) of material / s**
- **HSO found water vapor in the vicinity of 2 mid-latitude dark regions**
- **Thermal models suggest liquid water below the surface**
- **Could there be cryovolcanism and liquid water bodies under the frozen crust?**

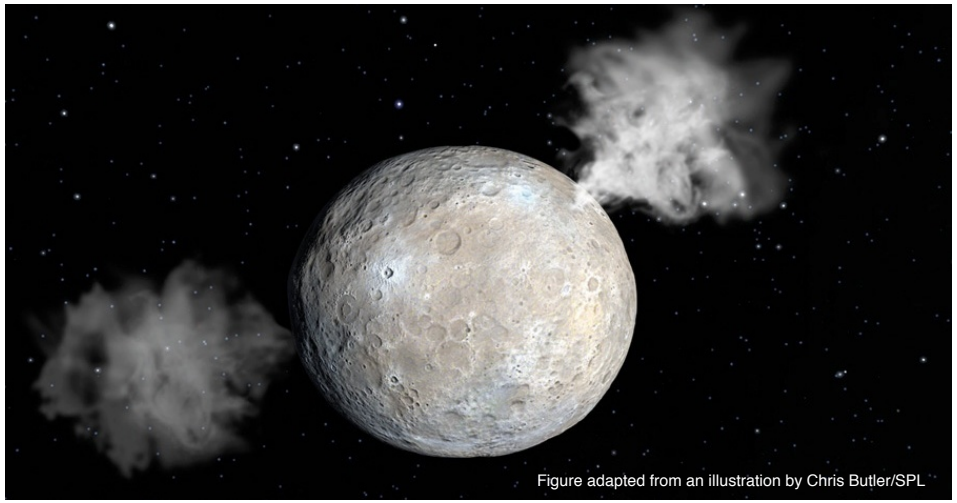
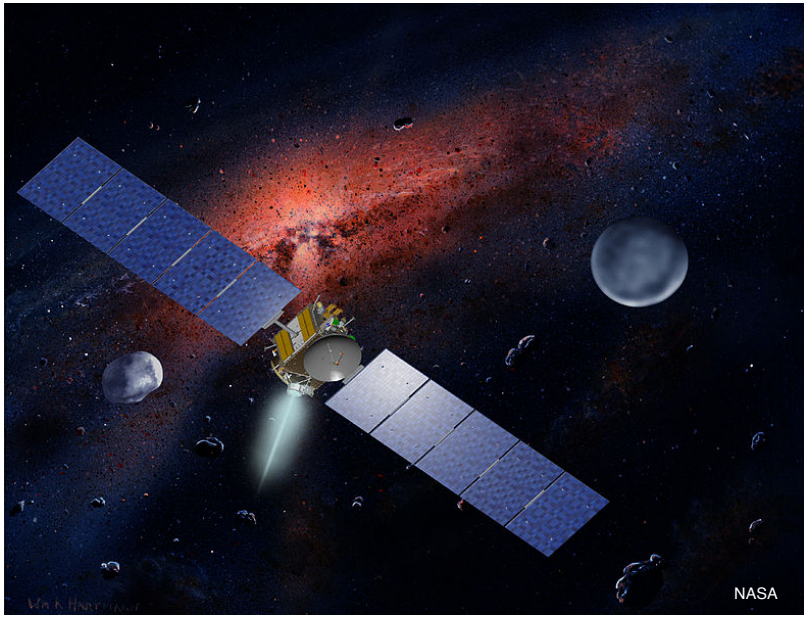


Figure adapted from an illustration by Chris Butler/SPL

Why another mission to Ceres?

- **Dawn arrives close to aphelion, while plume activity was observed at perihelion**
- **Dawn instruments are not capable of measuring needed critical isotopic composition of volatiles**
- **Dawn has no impactor to enable**
  - **the release subsurface volatiles**
  - **imaging before and after an impact event**



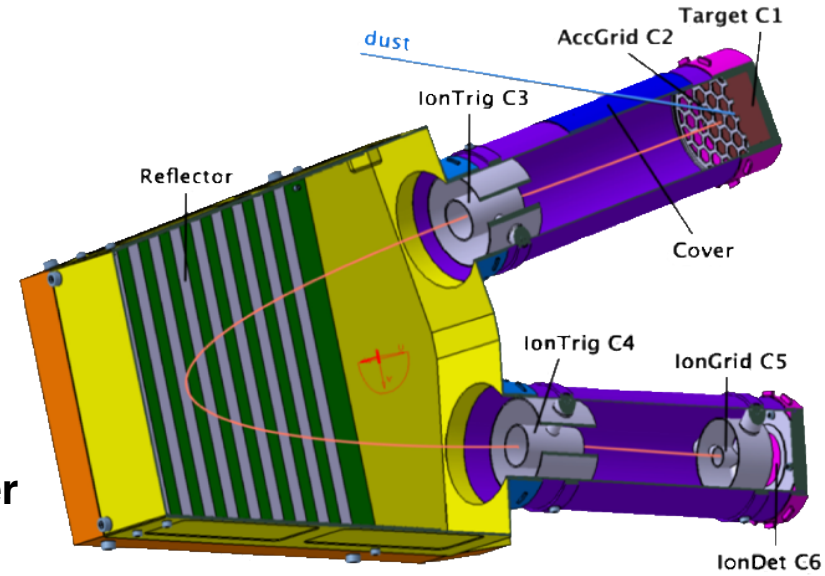
→ **Plume Chaser has a different, but complementary mission concept to Dawn**

Science Objectives

Primary Science Objectives	
A.1	Search for evidence of organics in the Ceres water vapor/plume
A.2	Determine the column water content and location of highest density
A.3	Determine the elemental composition (C, H, O, N) of any carbon rich plume particles
A.4	Characterize the particles in the plume for dissolved salts
Secondary Science Objectives	
B.1	Characterize the silicate dust in the plume and relate it to other solar system objects, such as meteorites and comets
B.2	Characterize the mechanical, chemical and geological properties of the crust by observing the impact site before and after impact
B.3	Look for surface compositional changes on the surface associated with venting; characterize composition differences involving water or possible organics

Instrumentation

- **ENIJA Mass Spectrometer**
  - **TRL 4**
  - **Particle size: 10 nm – 100 um**
  - **Particle mass: 1 – 2000 amu**
- **NASA ARC/Draper Lab. NIR spectrometer**
  - **TRL 4**
  - **Range: 1.6 – 3.4 um**
  - **Resolution: 0.15 um**
- **GomSpace NanoCam C1U camera**
  - **TRL 9**
  - **Spectrum: 400 – 1000 nm**
  - **FOV: 9.22 deg**
  - **Resolution: < 80 m/pixel from 650 km**



University of Stuttgart

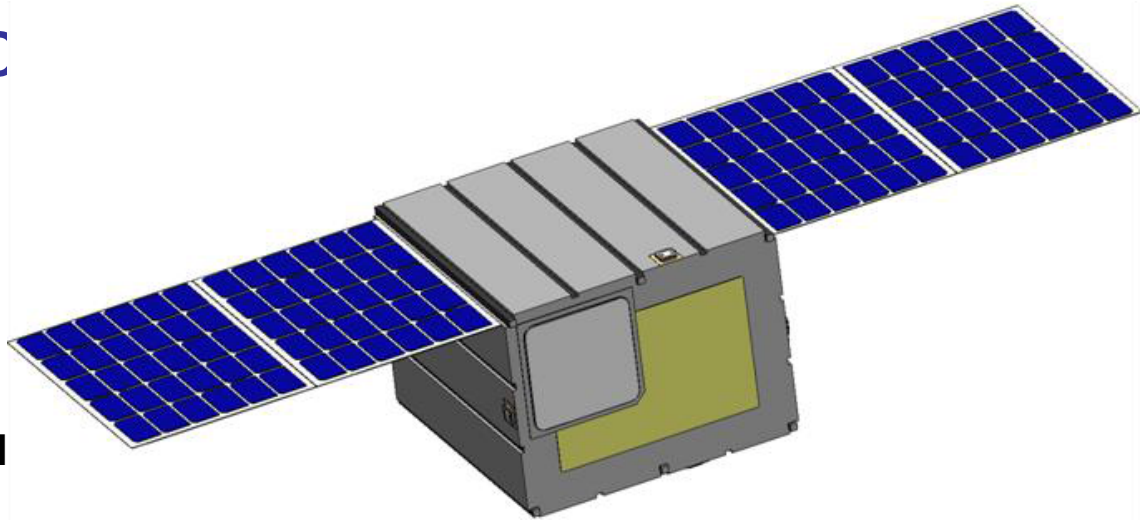

NASA Ames


GomSpace

Mission Concept: *Sniff*, *Wait*, and *Impact*

- **Sniff**
  - **Venting from the surface of Ceres is common**
  - **Permanent exosphere**
  - **Densest parts will be localized and studied**
- **Wait**
  - **Venting is not common on Ceres, but likely at perihelion**
  - **S/C must remain in orbit until a plume event occurs and can subsequently be maneuvered through it**
- **Impact**
  - **Venting is rare on Ceres**
  - **Sporadic occurrences under extremely favorable conditions**
  - **Trace exosphere might be beyond detection limits**
  - **To guarantee scientific return, impactor will create a plume to fly through**

The Two Spacec

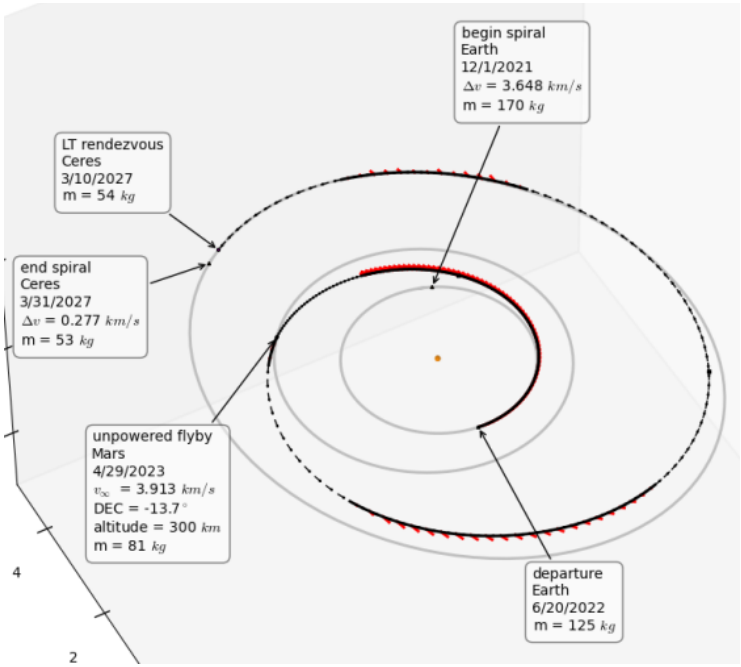


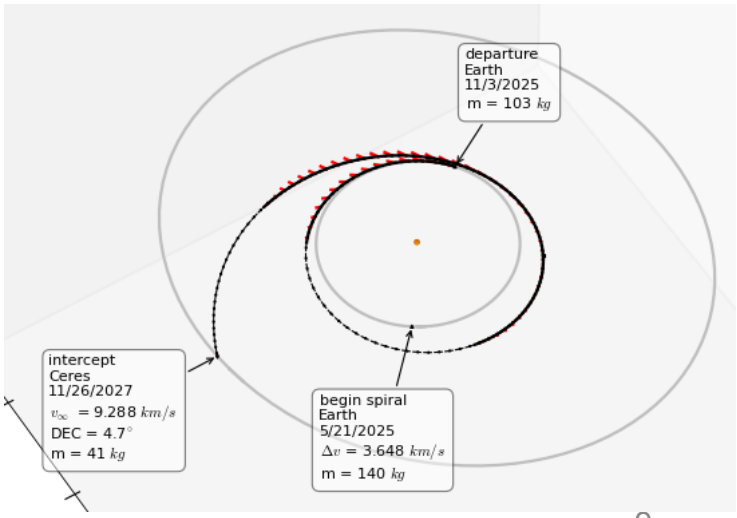
- **Same design for both S/C**
  - **Size: 40x40x30 cm^3**
  - **Dry mass: 40 kg**
  - **Wet mass: <190 kg**
  - **Fit within ESPA Grand frame**
- **3D printed Ti tank/structure**
- **MMA Design solar array**
  - **200 W EOL**
- **Propulsion**
  - **CubeSat Ambipolar Thruster (CAT)**
  - **ISP: 1200**
  - **Size: 1U**
  - **Propellant: Iodine**

University of Michigan

Trajectory Design

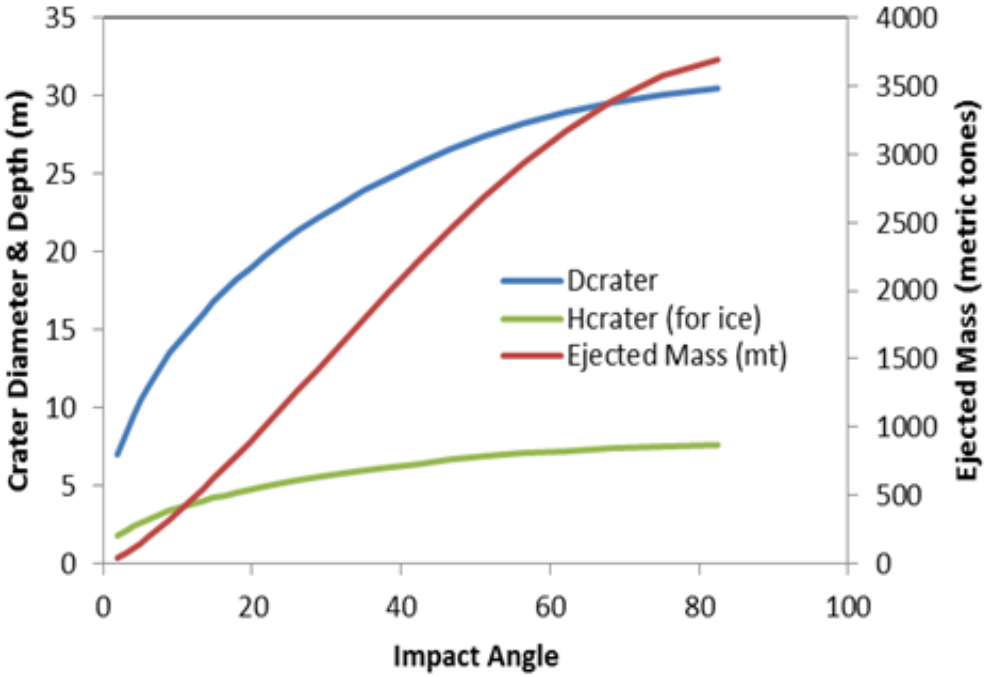
- **Starting from GTO**
- **Plume Chaser**
  - **Dry mass: 43 kg**
  - **Propellant: 120 kg**
  - **Overall duration: 4.8 yrs**
  - **Delta-V: 14.4 km/s**
  - **1 year science orbit before decommision**
- **Plume Maker**
  - **Impact mass: 41 kg**
  - **Propellant: 99 kg**
  - **Overall duration: 2.1 yrs**
  - **Delta-V: 14.5 km/s**
  - **Impact speed: 9.3 km/s**

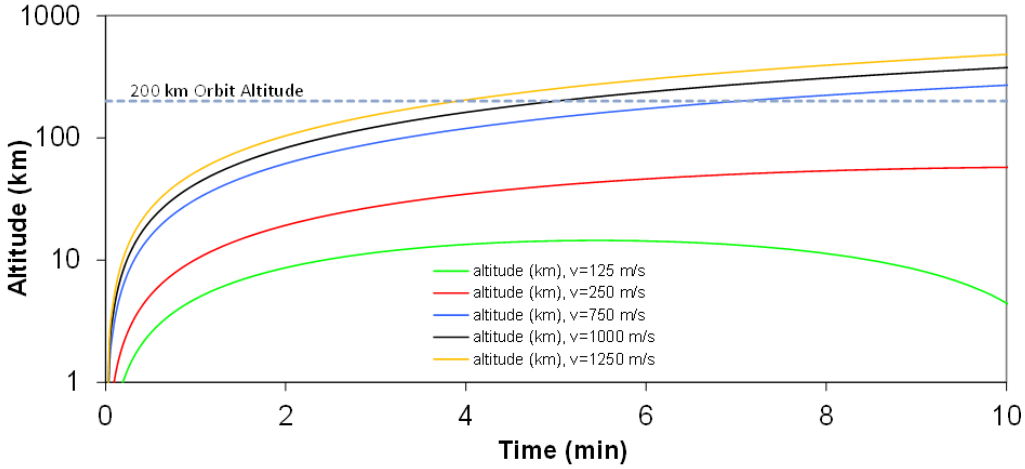




Impacting

- To create a crater
  - Speed: 9.3 km/s
  - Mass: 40.9 kg
  - Energy: 1764.5 MJ
  - Crater
    - > 10 m wide
    - > 3 m deep
- To create a plume
  - Reach above 200 km
  - With particle velocity 750-2000 m/s





Conclusions

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