sampling brines of an evolved ocean world

CERES

planetary mission concept study

Major Findings

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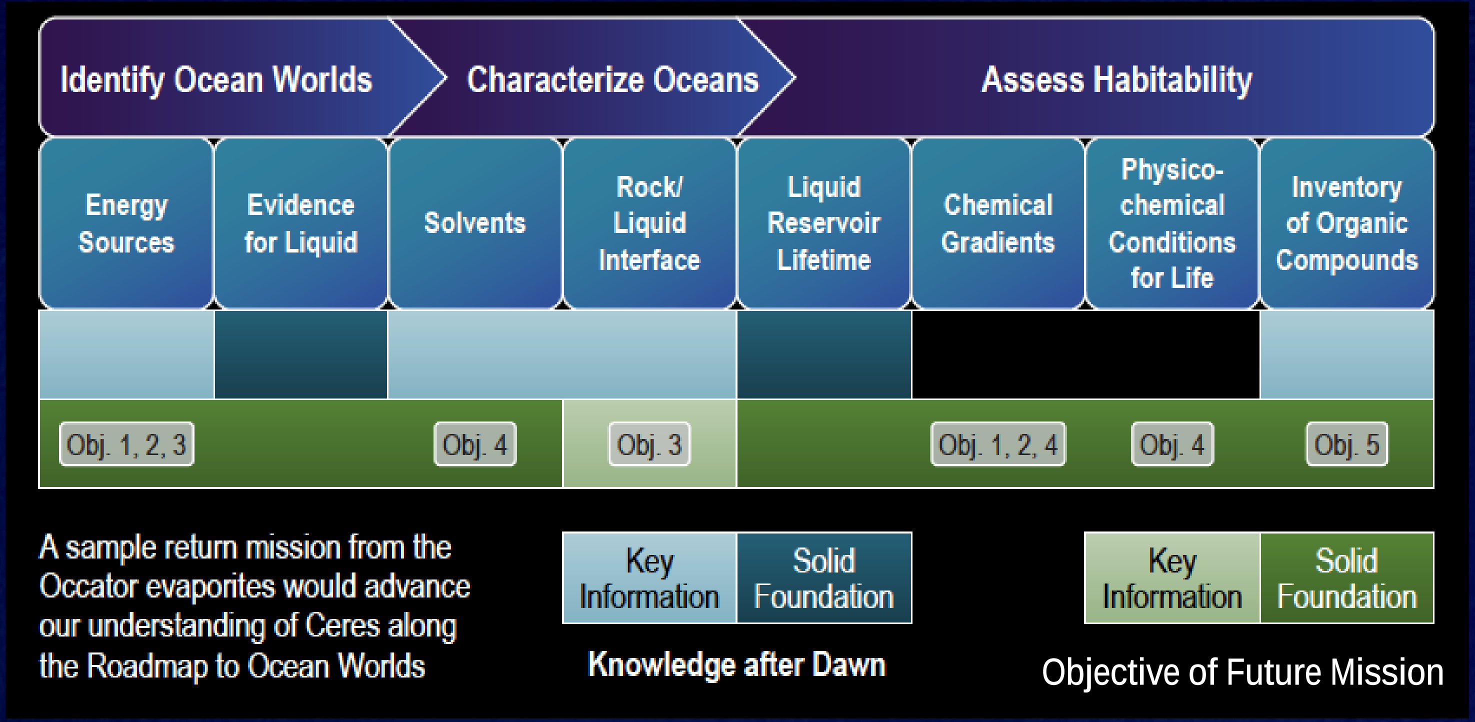
Presentation to Planetary Science and Astrobiology Decadal Survey

Small Bodies Panel – November 2, 2020

CERES : Compelling Ocean World Science Close to Home

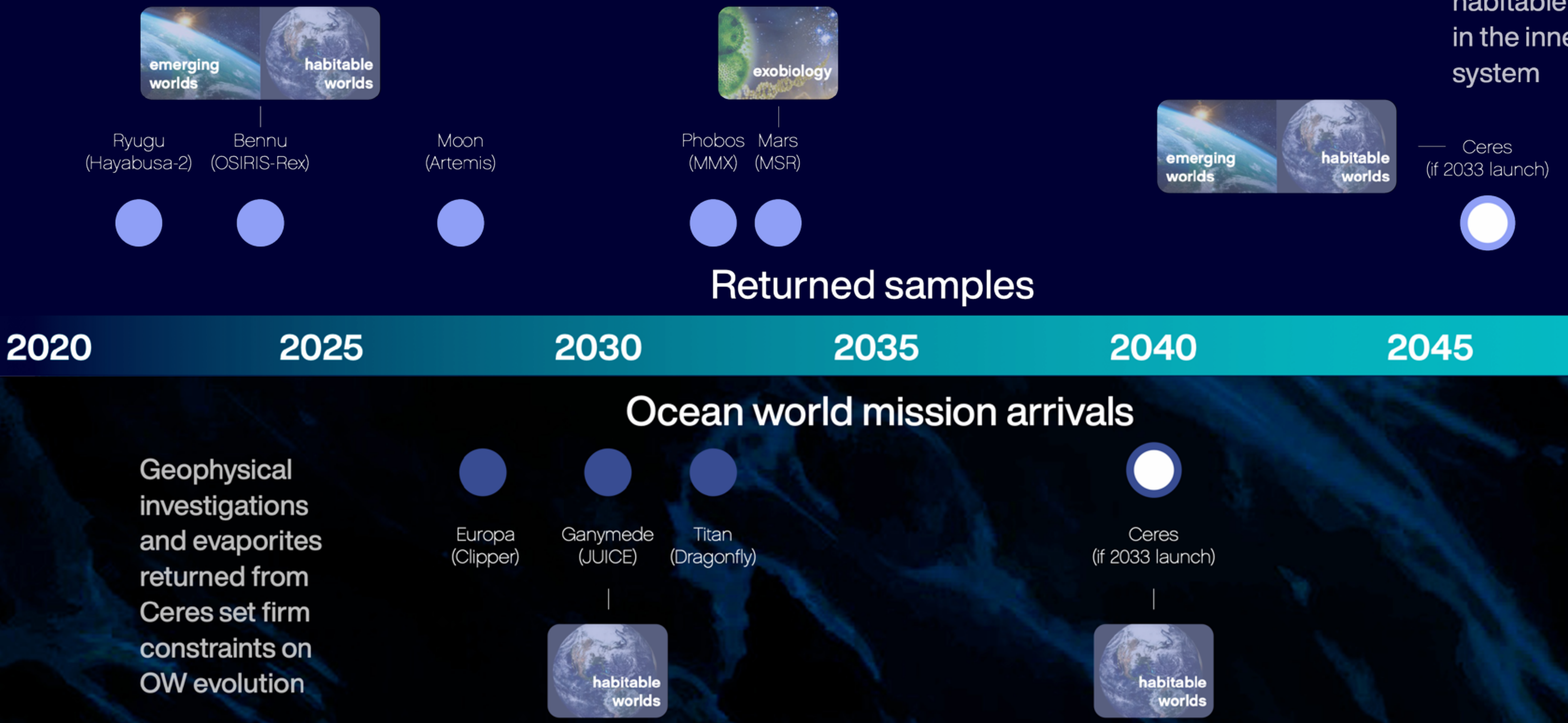
PMCS Science Objectives - Summary



- Major Dawn discoveries:
  - Water-rich body
  - Abundant organics
  - Geologically active within 2 Ma
  - Possible origin in outer solar system
- Key open questions:
  - Are deep brines habitable?
  - What drives Ceres' activity?
  - Where did Ceres form?

Future Ceres Mission is Synergistic with Near-Term Landscape

Organics and volatiles from Ceres retire gaps on the origin of habitable worlds in the inner solar system



Geophysical investigations and evaporites returned from Ceres set firm constraints on OW evolution

CERES HOPPING MISSION

Lander explores multiple sites by "hopping" around Occator Crater.

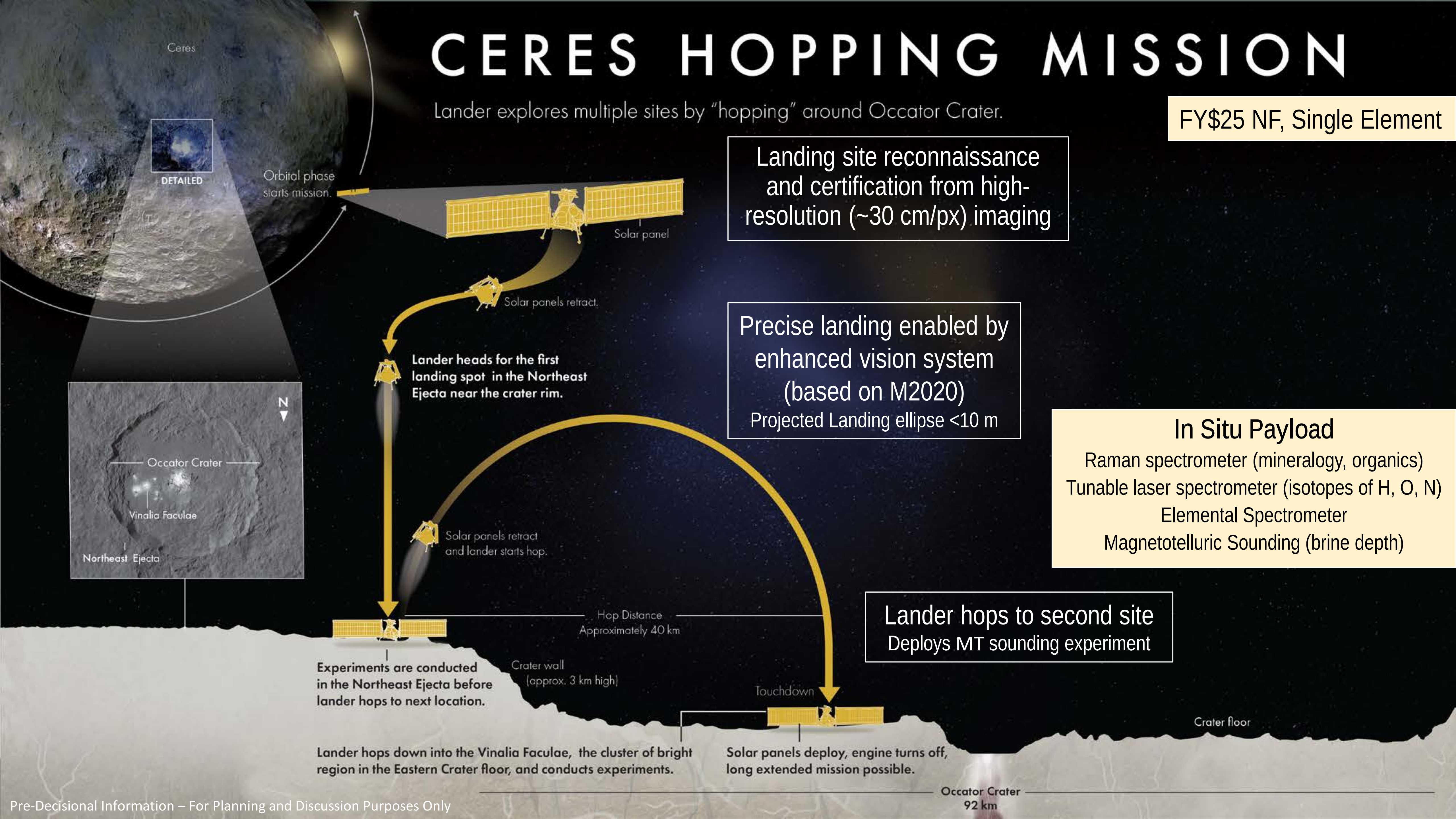
FY$25 NF, Single Element

Landing site reconnaissance and certification from high-resolution (~30 cm/px) imaging

Precise landing enabled by enhanced vision system (based on M2020)
Projected Landing ellipse <10 m

In Situ Payload
Raman spectrometer (mineralogy, organics)
Tunable laser spectrometer (isotopes of H, O, N)
Elemental Spectrometer
Magnetotelluric Sounding (brine depth)

Lander hops to second site
Deploys MT sounding experiment



CERES SAMPLE RETURN MISSION

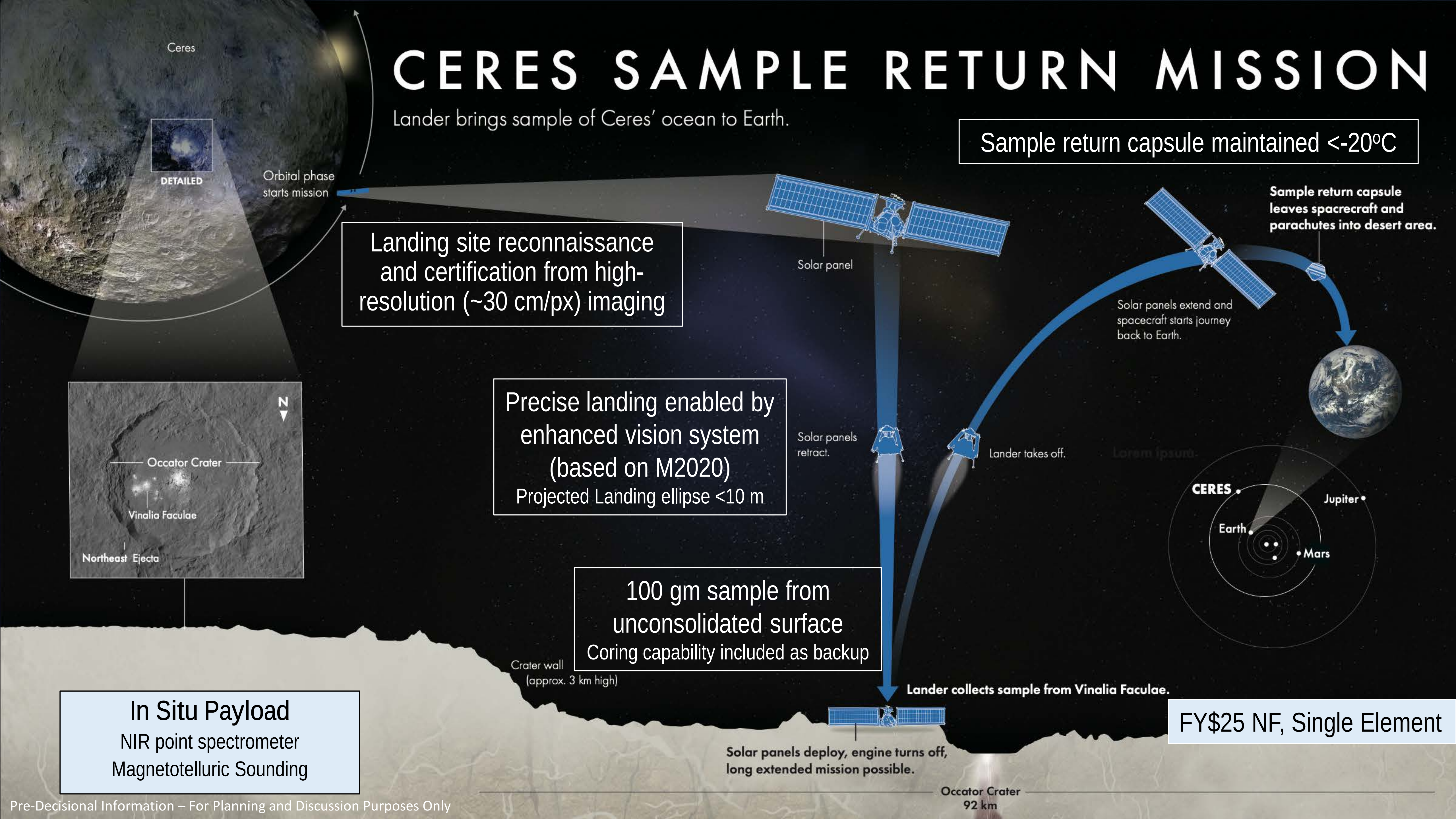
Lander brings sample of Ceres' ocean to Earth.

Sample return capsule maintained $<-20^{o}$C

Landing site reconnaissance and certification from high-resolution (~30 cm/px) imaging

Precise landing enabled by enhanced vision system (based on M2020)
Projected Landing ellipse <10 m

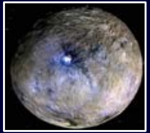
100 gm sample from unconsolidated surface
Coring capability included as backup



In Situ Payload
NIR point spectrometer
Magnetotelluric Sounding

FY$25 NF, Single Element

SCOPE: KEY FINDINGS WITH APPLICATION TO OTHER MAIN BELT ASTEROIDS



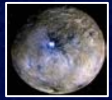
Ceres / PMCS specific / Other large, water-rich bodies

Applies to all main belt asteroids (independent of size and distance)

Size dependent

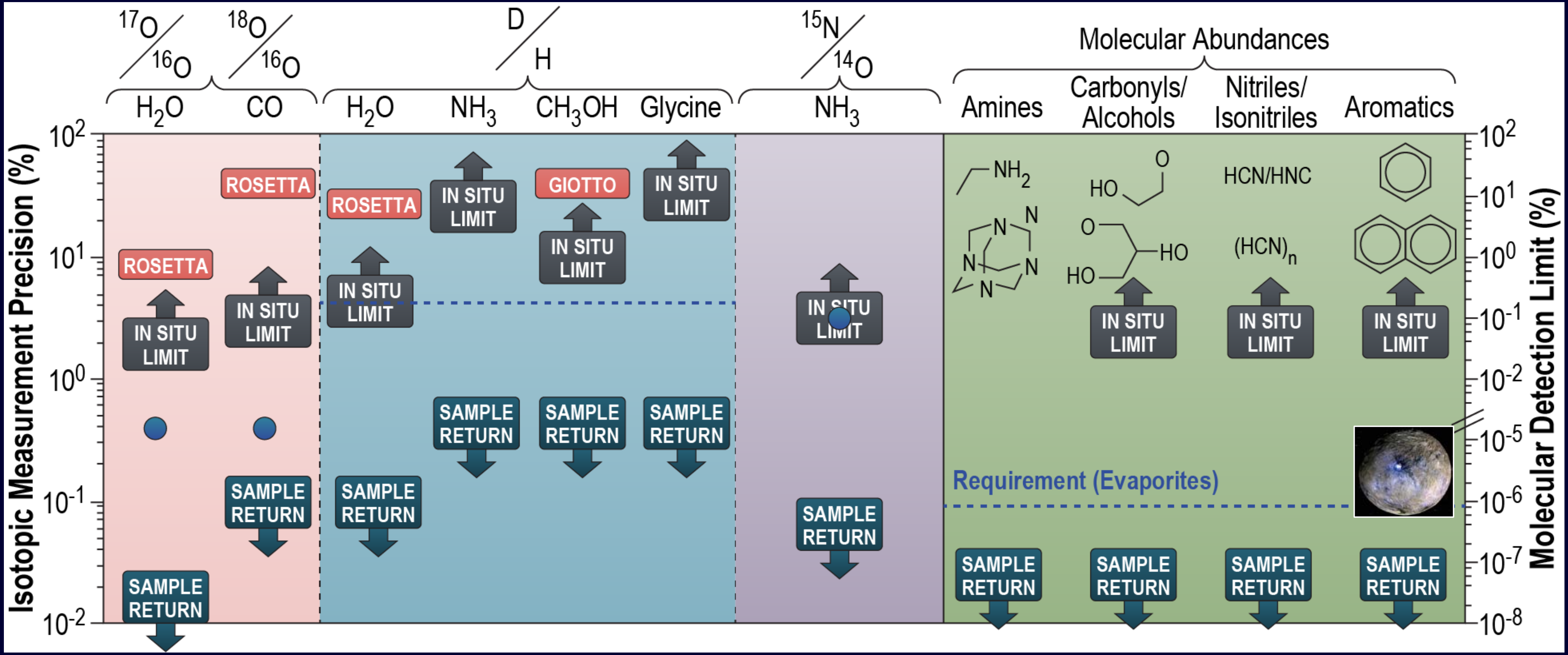
Supporting slides in backup package

Key Findings – Science

- *In situ* exploration for habitability and origin science is challenging under New Frontiers budget
  - Contamination control for the study of organic matter is major cost driver ➔ requires protocols developed for Mars 2020 
  - Complexity of origin science, e.g., lack of reference framework ➔ requires multiple analysis techniques, high sensitivity and spatial resolution
  - *S*urface contamination and weathering ➔ requires sample cherry picking or high-spatial resolution in situ remote sensing instruments
  - Mobility is prohibitive on large body and for targeted science
- In situ phase great for deployment of geophysical sounding experiment

Vesta fragments on Bennu
Credits: NASA/Goddard/University of Arizona

In Situ Exploration Could not Address Origin and Organics Science at Ceres



Based after Milam et al. (2020) Volatile sample return in the solar system, White Paper submitted to the Planetary Science Decadal Survey 2023-2032. .

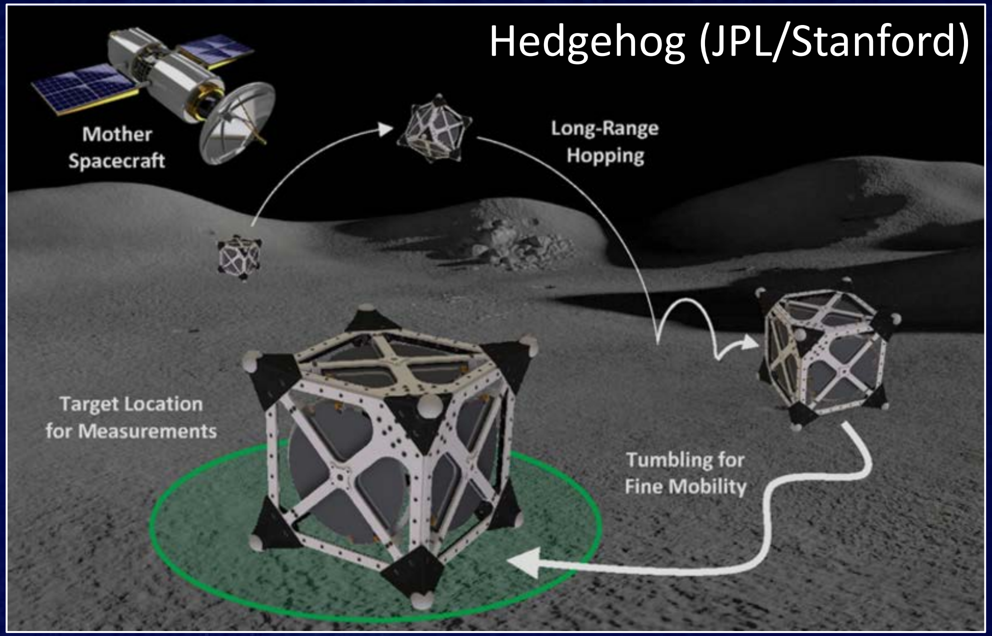
Key Findings – Getting There

- ➢ Electric propulsion offers significant launch flexibility ❈
  - Launch opportunity every year, about same travel time ✢
  - Delivers more mass into target orbit in shorter travel times than chemical propulsion ✢
- ➢ Landing/sampling site reconnaissance required ➔ orbital phase ❈
- ➢ Retractable/redeployable solar panels required ❈
  - Technology demonstrated on ISS (Deep Space Systems); lunar gravity demo in progress
  - Landed phase on battery only might be possible depending on science concept
- ➢ LiDAR not required for landing after deorbiting, feature tracking with Landing Vision System is sufficient ❈
  - Demonstrated on OSIRIS-REx, soon on Mars 2020
  - Facilitated by low velocity in low gravity environment

Key Findings – Mobility

- Mobility: Wheeled rovers do not have enough traction
  - Designing a dedicated mobility system was found expensive and low maturity
    - Solutions exist for low-gravity targets, depending on science focus
- Hopping is energy intensive and risky
  - Keeping thrusters warm drives surface power
  - Only two sites in close proximity under New Frontiers cost cap and Category IV vehicle

  - Dust is major source of risk
  - Solutions exists depending on object size and science objectives



Summary

- In situ exploration and sample return at Ceres both at New Frontiers cost cap [$FY25] with 50% reserves
  - Proximity and low-gravity ➔ Single element architectures with orbital and landed phases + sample return ❇ (Caveat: dust and μ–**gravity** might require different strategy)
  - *In situ*: Science risk (origins and organics) and challenging mobility ❇
  - Could be << NF cost cap for smaller bodies depending on science; e.g., if landing is required vs. Touch and Go; thruster- vs. reaction wheel-based hopping; attitude control requirements
- Concepts were found feasible with existing technologies ✢
  - Retractable/redeployable solar arrays need further demonstration in relevant environment
  - Additional engineering of sampling system and transfer to return scapsule needed
  - **Investing in lighter, multi-functional structures could significantly reduce cost**

Back-up

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