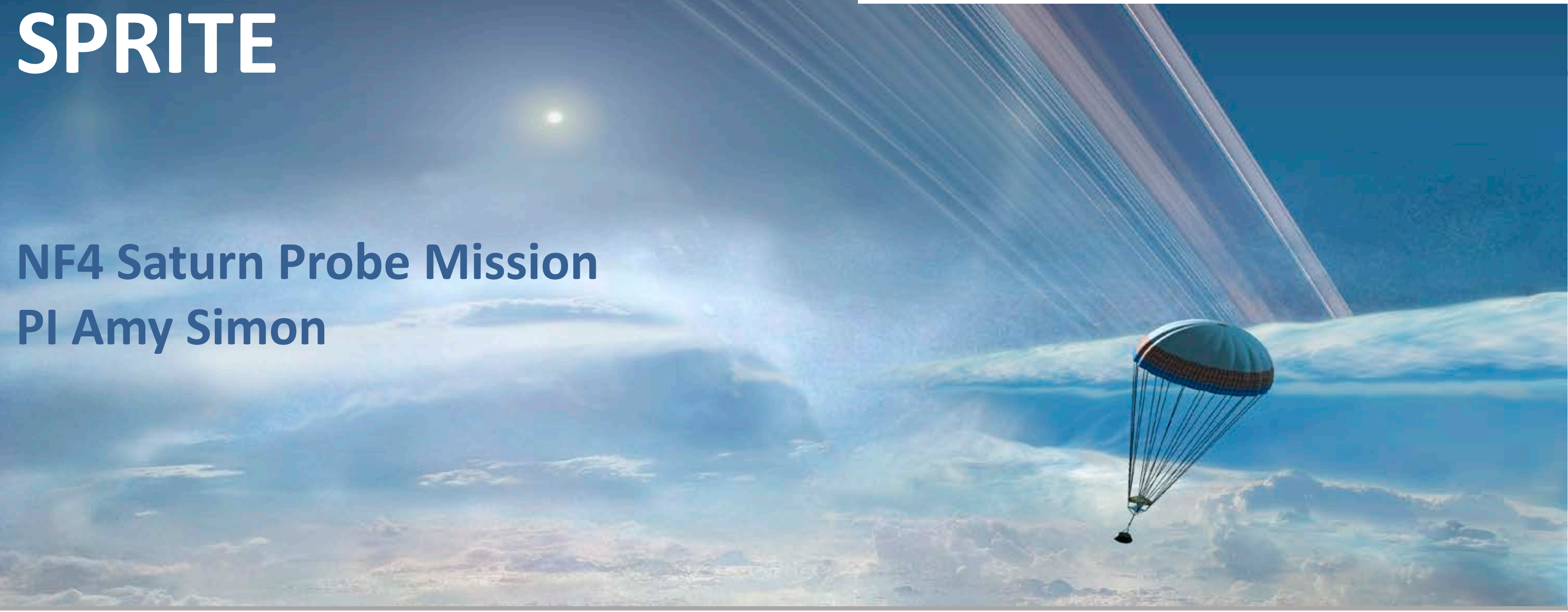
SPRITE

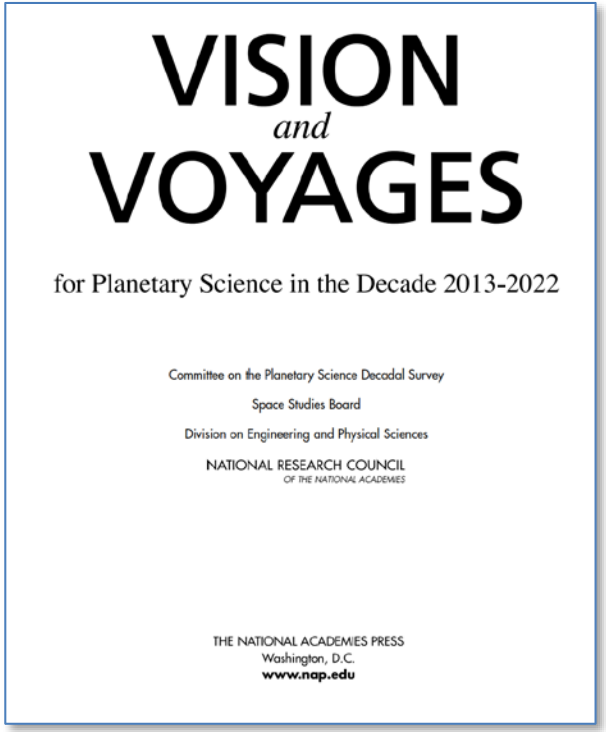


NF4 Saturn Probe Mission
PI Amy Simon

Kim Reh (JPL), Don Banfield (Cornell), Amy Simon (GSFC), Rolf Danner, Dave Atkinson (JPL)

Saturn Probe science theme – Decadal Survey

- Planetary Sciences Decadal Survey
  - Saturn Probe mission one of several recommended Medium-class missions for NASA's New Frontiers program
- Objectives
  - 1: Determine Saturn's Role in Solar System Formation and Evolution
    - Measure noble gas abundances and isotopic ratios of H, C, N, O in Saturn's atmosphere
  - 2: Characterize Saturn's atmosphere structure and composition
    - Measure atmospheric structure and cloud properties at Probe descent location



SPRITE was proposed as a New Frontiers candidate mission to address these high-priority Decadal Survey objectives

Science overview

- The giant planets in our solar system contain clues to the origin of the planets and the conditions that set up terrestrial planet formation
  - These will be key to also understanding exoplanet systems

- Comparative study of Giant Planet composition and structure maps gradients in time and space in our protoplanetary disk
  - Jupiter will be well studied after Galileo/Juno, but which of its features (core size, circulation, etc.) are unique vs universal?
  - Cassini will leave remaining knowledge gaps about Saturn that require in situ sampling and are needed to fit into the puzzle of solar system formation

SPRITE science objectives

Goal I. Collect and analyze evidence of Saturn's formation and early evolution

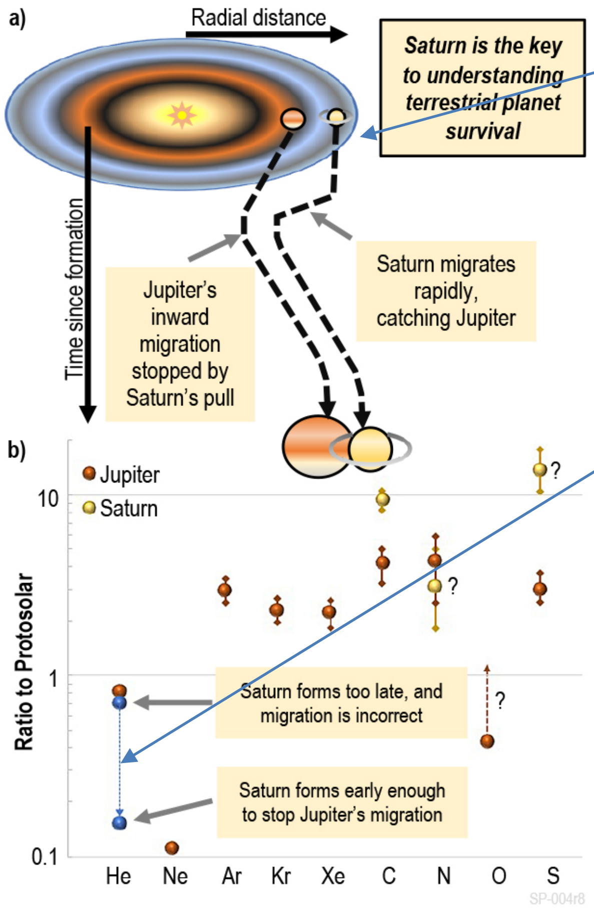
1. Obtain a chemical inventory of Saturn's troposphere to distinguish between competing models of planet formation and extent of migration in the early solar system.
2. Constrain Saturn's He depletion to reconcile observed temperatures with thermal evolution models.

Goal II. Reveal the truth beneath Saturn's clouds – what is really going on?

3. Measure Saturn's *in situ* atmospheric chemistry to confirm condensation models and to interpret remotely observed composition.
4. Perform *in situ* characterization of Saturn's tropospheric cloud structure to provide the ground truth basis for cloud retrieval models.
5. Determine Saturn's *in situ* 3-D atmospheric dynamics along the probe descent path to bound global circulation and analytical models of the time-variable cloud top motions.

This entry probe mission, with a 90-min. descent to 10 bars, completes the gas giant puzzle framed by the Galileo, Cassini, and Juno missions

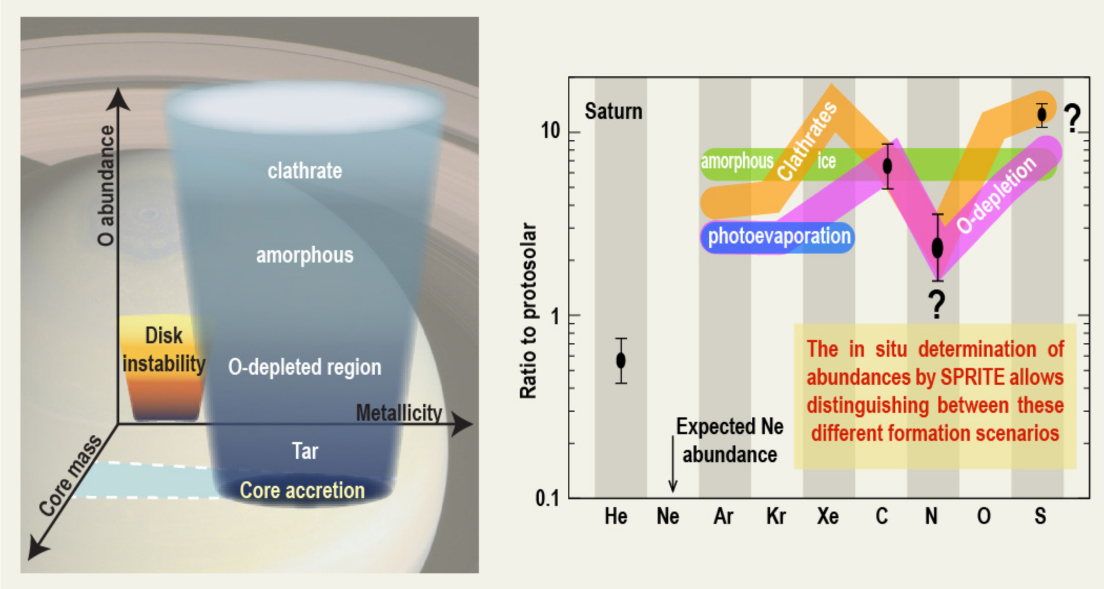
Giant planets key to understanding Solar System formation

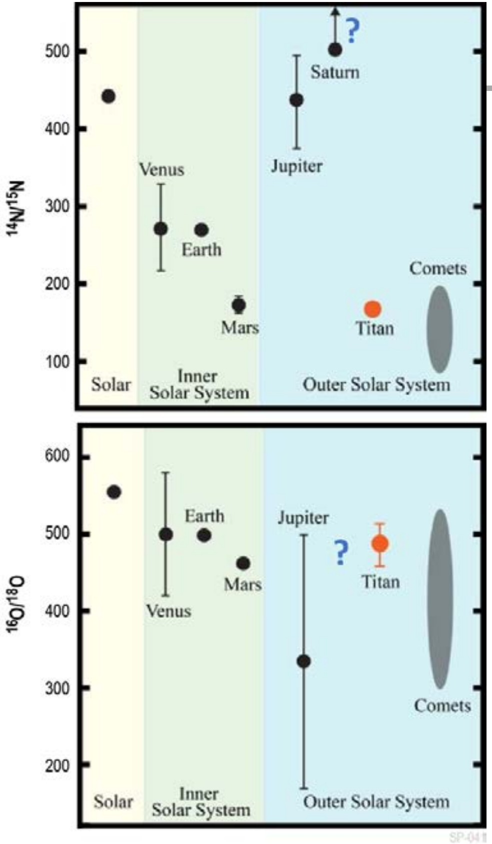


- **WHERE Saturn formed?** Formation models (a), indicate Jupiter alone would have swept up the terrestrial planets leaving the habitable zone barren; was Saturn close enough to put the breaks on Jupiter's inward migration?
- **WHEN Saturn formed?** Saturn is warmer than expected if it were formed in Jupiter timeframe (b); measuring He and Ne abundances would constrain thermal evolution models
- **Elemental abundances similar to Jupiter would indicate it formed close in time and space**
  - Current data sets are insufficient to resolve this

In situ composition measurements are the only way to distinguish between models

Formation models must be further constrained

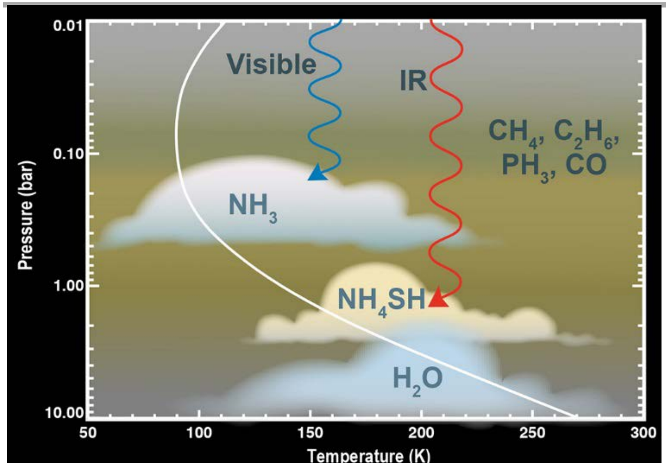


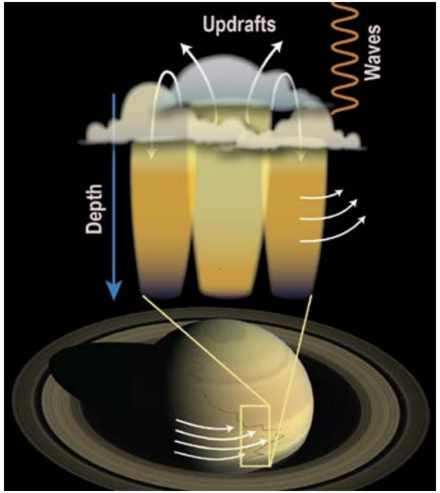


After initial formation, different nebular conditions and planetesimal trapping mechanisms determined Saturn's ultimate elemental composition and isotopic ratios. Competing models exist.

Distinguishing between models requires measurements of He, Ne, Ar, Kr, Xe, C, N, O, and S abundance and their isotope ratios.

Interpreting remote observations is not enough to solve this

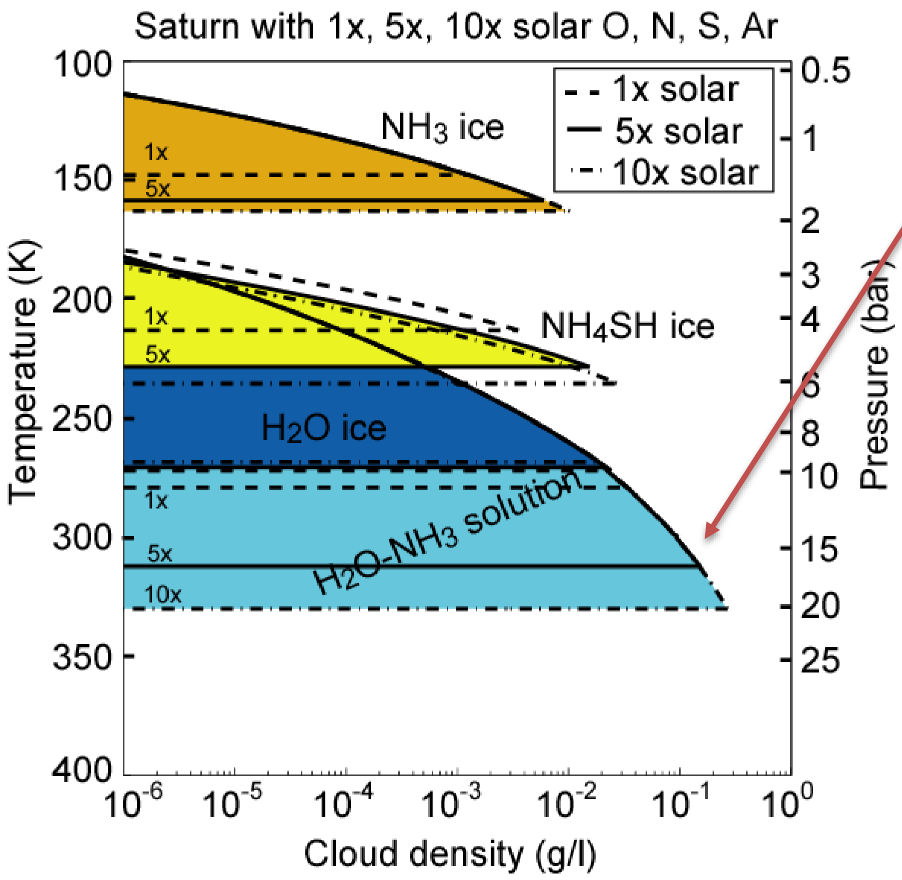




- We can't infer a giant planet's chemistry, clouds, and circulation from a view outside its opaque clouds
  - Remote imaging / spectral observations limited to cloud tops and above
  - Spectral data do not reveal the actual cloud composition
- Can't accurately model circulation
  - Chemistry, thermal structure, deep winds, and vertical motions drive the weather, and climate, at the visible cloud tops
- Interpretation of remote sensing data (including exoplanets) relies on many assumptions
  - SPRITE can serve that role for Saturn.

In situ data anchor these models, unlocking the full potential of remote sensing data.

Deep water abundance necessary for Objective 1



- Water at upper levels appears depleted, while disequilibrium species CH_4, PH_3 etc., are enhanced over solar values
- Implies water is enhanced at deep levels
- A 10 or 20-bar probe won't get to well-mixed H_2O region

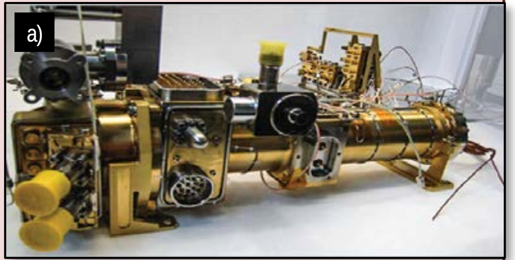
Measurement of disequilibrium species CO, C2H6, and PH3, constrains the deep water abundance

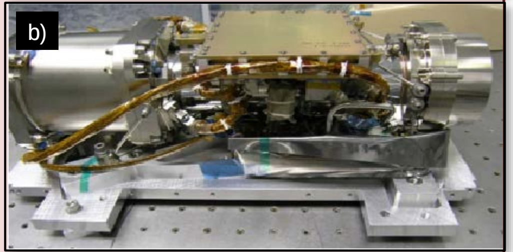
SPRITE has a focused payload of 4-instruments

- QMS – Quadrupole Mass Spectrometer (GSFC)
  - Measure noble gas and elemental abundances; key isotopic ratios

- TLS - Tunable Laser Spectrometer (JPL)
  - Measure noble gas and key elemental abundances of C, S, O, and N species; abundance profiles of disequilibrium and condensable species (PH_3, C_2H_6, NH_3, CO)

- ASI - Atmospheric Structure Instrument (ARC)
  - Measure *g*-loads during entry, and pressure/temperature during descent
  - Determine atmospheric structure to 10-bar pressure, including vertical profile of horizontal and vertical winds
  - Determine cloud altitudes and measure optical depth





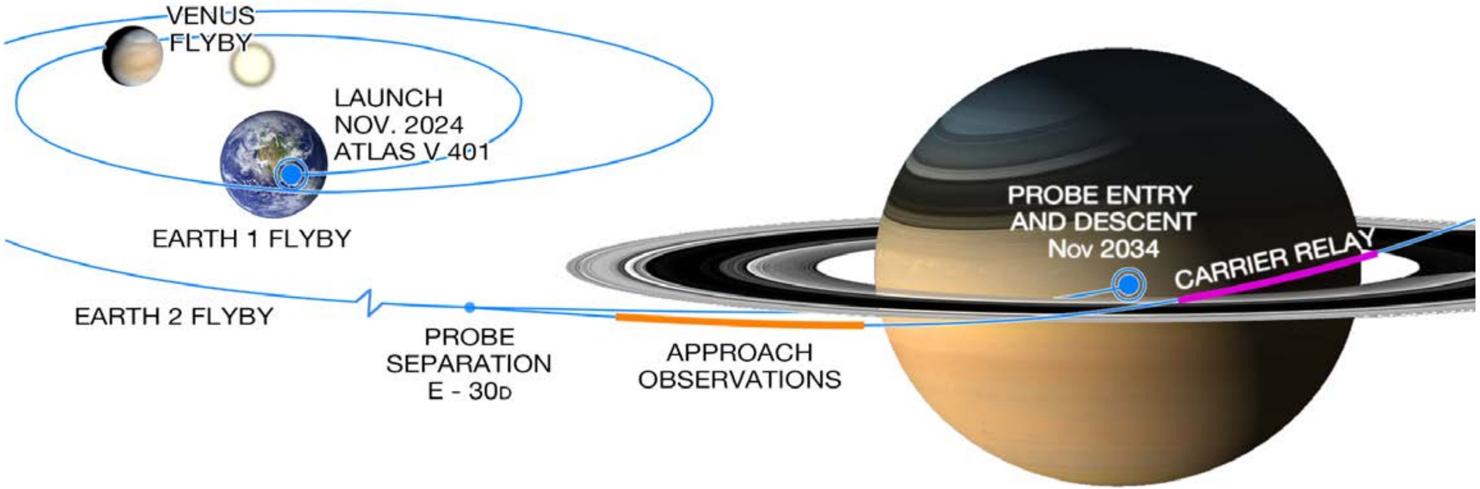
PROBE INSTRUMENTS

CARRIER SPACECRAFT INSTRUMENTS

- MCI – Multi-Channel Imager
  - Provide context imaging for in situ measurements prior to entry

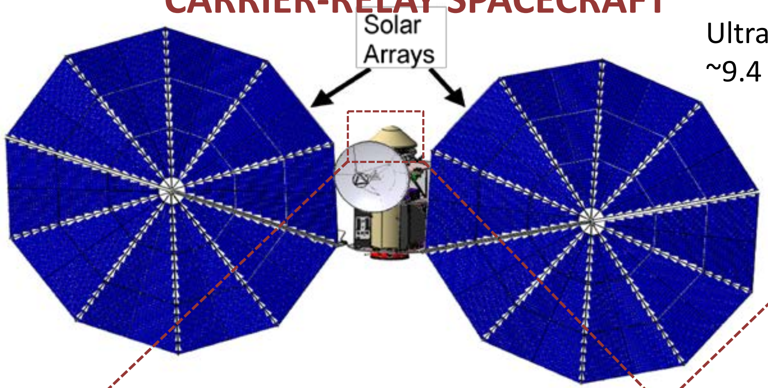
SPRITE mission design

- 10-year mission
  - Launch in 2024
  - Gravity assists of Venus, Earth, Earth
  - Saturn flyby in 2034
- Solar-powered Carrier Relay Spacecraft (CRSC) carries atmospheric probe
  - Probe released at entry T-30 days on battery power
  - Remote observations from carrier relay spacecraft 5 days prior to probe entry
  - ~26 km/s probe entry; relay for 90 min satisfies all objectives + 30 min science margin
  - Carrier relay tracks probe, records data; relays back to Earth after flyby



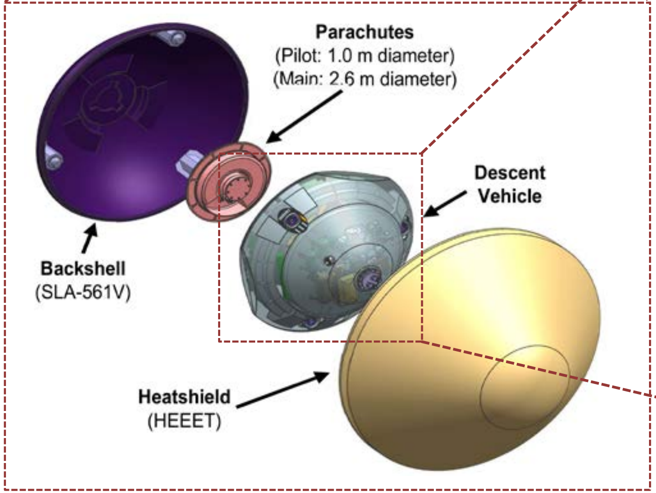
SPRITE flight elements

CARRIER-RELAY SPACECRAFT

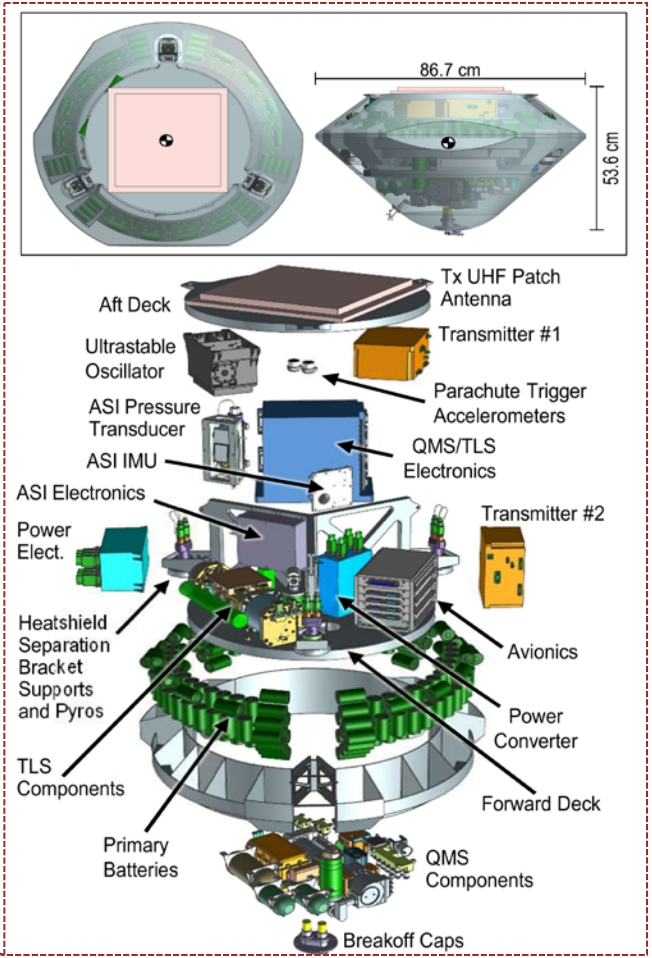


UltraFlex with LILT cells
~9.4 m dia; 98 m^2

AEROSHELL



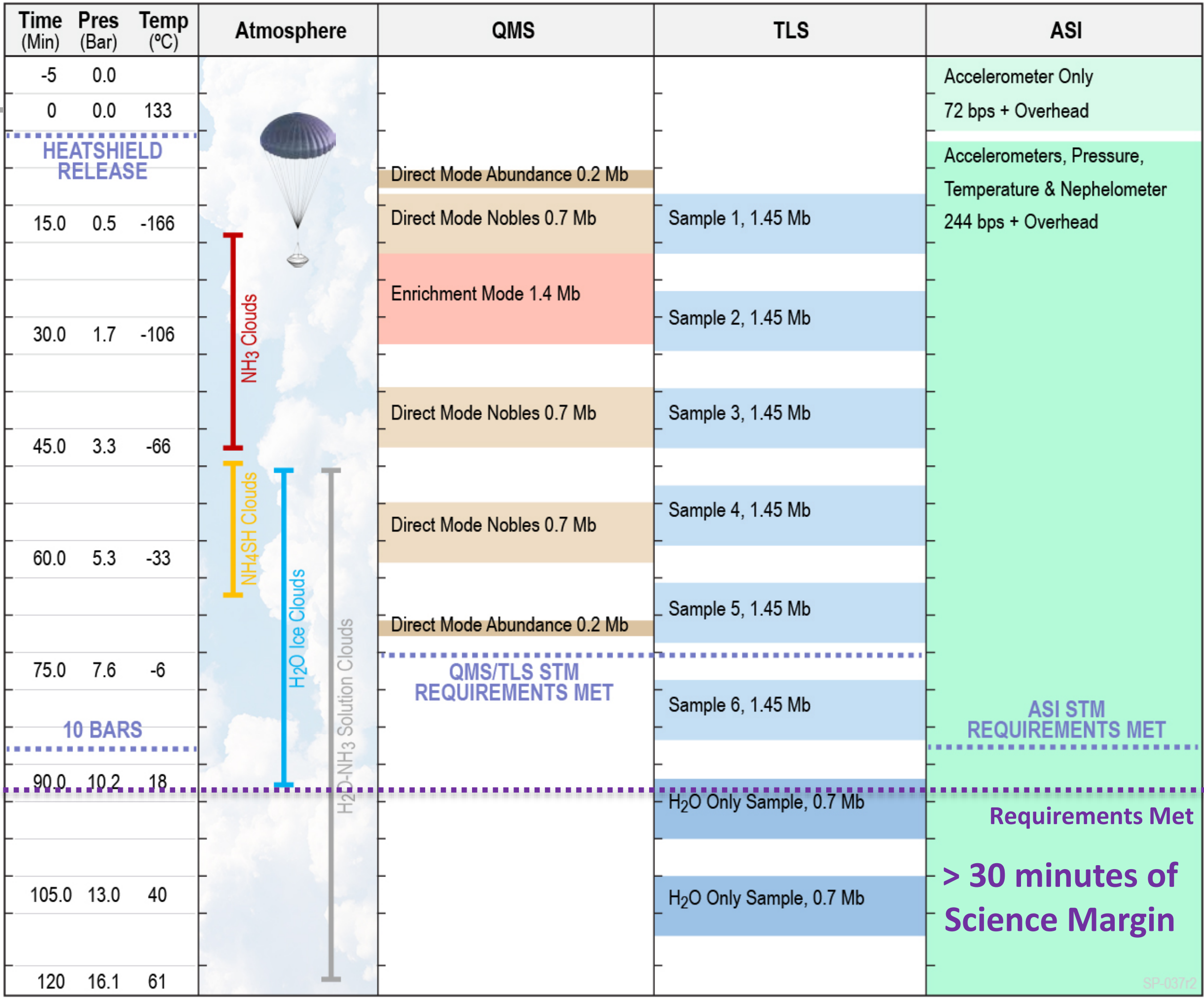
DESCENT VEHICLE



Descent operations

SPRITE measurements are interleaved throughout the descent to 10 bars, through the upper two cloud decks and deep into the postulated H_2O-NH_3 solution cloud.

The carrier will receive data from the Descent Vehicle > 30 minutes past 10 bars, while we focus on direct measurements of H_2O that exceed the STM requirements.



Descent includes 30 minutes of unallocated science time & data volume

SPRITE provides missing puzzle piece for Giant Planets

Jupiter: well-characterized

Juno
--Internal Structure
--O abundance

Cassini Proximal Orbits
--Internal Structure/Core

Saturn: incomplete

Galileo Probe
-- Elemental Composition, except O
-- Isotopes

Saturn Probe
-- Elemental Composition
-- Isotopes

Will help interpret Exoplanet systems

SPRITE – Key Facts


Science Times

Tuesday, December 12, 2034

The New York Times

Saturn Mission Unlocks Planet's Role in Solar System Formation

By Miranda Tyson

SAN FRANCISCO - Scientists from NASA's Jet Propulsion Laboratory and Goddard Space Flight Center unveiled exciting discoveries today on the formation of the Solar System. Dr. Amy Simon, Principal Investigator of the SPRITE Mission which successfully flew by Saturn last month, made the announcement

NOAA Studies of Sea Level Rise Needed into Next Decade for Disaster Support

By DENNIS OVERBYE, Jr.

Researchers at the National Oceanic and Atmospheric Administration have concluded that the exchange of water stored on land with polar glaciers and ice sheets has reached stable equilibrium. The announcement comes amidst continued catastrophic flooding of the Maldives.

Science Goals

- Reveal the story of Saturn's formation, migration and early evolution
- Gain knowledge of the properties and processes hidden beneath Saturn's clouds

4 Instruments

- Quadrupole Mass spectrometer (GSFC)
- Tunable Laser Spectrometer (JPL)
- Atmospheric Structure Instrument (ARC)
- Multi-Channel Imager (BATC)

Mission

- Launch Nov 2024
- Solar powered, chemical propulsion
- E-V-E-E-S cruise trajectory
- Probe entry & Saturn flyby, Nov. 2034
- Context imaging during 6 days prior to entry
- 2-hour probe descent and data relay
- HEEET Thermal Protection System

Team

- Principal Investigator: Amy Simon (GSFC)
- Deputy PI: Don Banfield (Cornell)
- PS: David Atkinson, PM: Rick Nybakken, PSE: John Day (JPL)
- JPL: Mission Management, Descent Vehicle
- LM: Carrier Relay S/C & Aeroshell