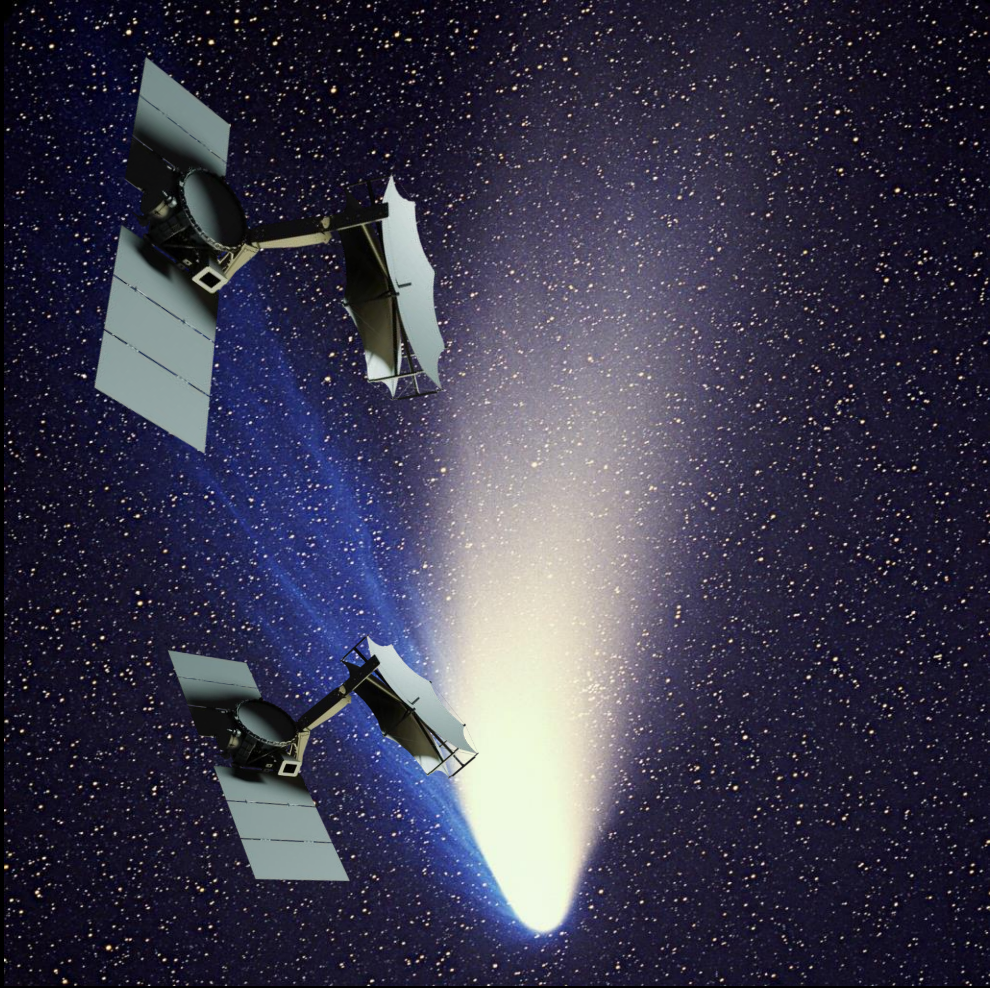
Xenia

SmallSat Rapid Response Flyby to Oort Cloud Comets and Interstellar Objects

Presenter: Benjamin Donitz

Jet Propulsion Laboratory,
California Institute of Technology

Interplanetary SmallSat Conference
May 12th, 2020



Jet Propulsion Laboratory
California Institute of Technology

Authors

- Benjamin Donitz[1]
- Steve Matousek[1]
- Julie Castillo-Rogez[1]
- Tibor Balint[1]
- Robert Miller[1]
- David Tuman[1]
- Matt Kowalkowski[1]
- Roger Klemm[1]
- John Mann[1]
- Aadil Rizvi[1]
- Kevin Ortega[1]
- Mark Wagner[1]
- Autumn Lui[1]
- Anne Marinan[1]
- Diana Chu[2]
- Cassandra Smith[3]
- Taylor Sun[4]
- Lauren St. Hilaire[1]
- Kyle Waters[1]
- Eric Lundgren[5]
- Zubin Olikara[1]
- Stewart Sherrit[1]

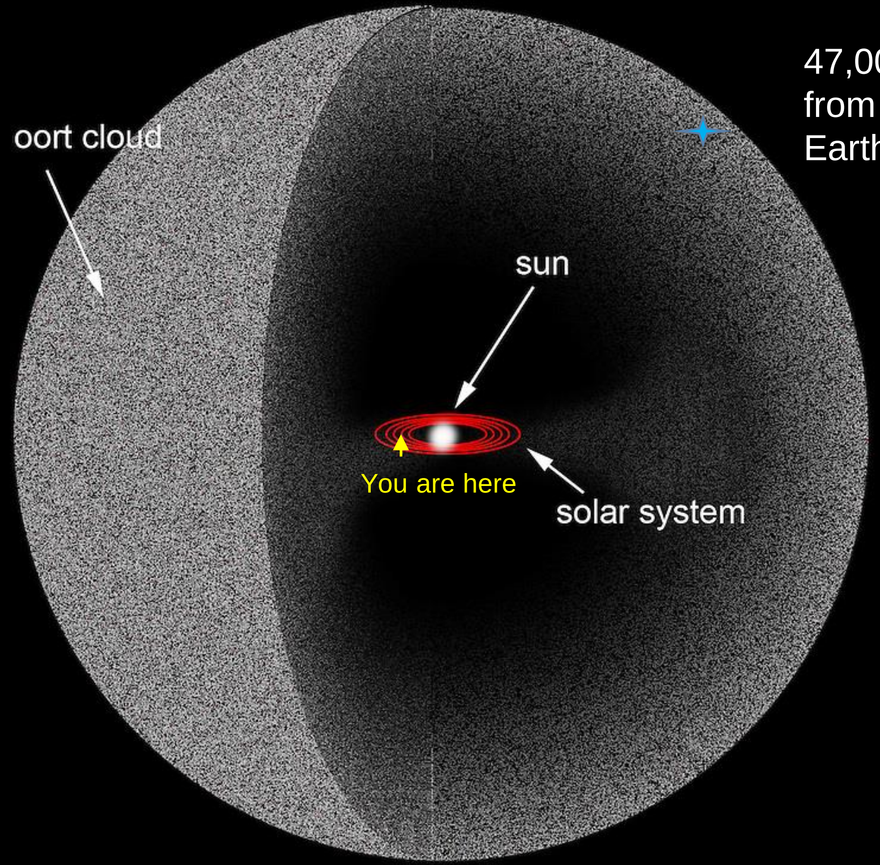
- [1]Jet Propulsion Laboratory, California Institute of Technology
- [2]Cornell University
- [3]Rensselear Polytechnic University
- [4]University of Michigan
- [5]Aerospace Corporation

Note on Terminology

- Oort Cloud Comet (OCC) – Comet that originated in the Oort Cloud, a region of the solar system ~2,000-200,000 AU characterized by the abundance of icy small bodies

- Long Period Comet (LPC) - Comet that originated in the Oort Cloud and eventually developed a shorter period through interaction with the giant planets. An OCC is a “fresh” LPC.

- Interstellar Object (ISO) – A small body that originated from outside our solar system, i.e. on a hyperbolic solar trajectory. Can be actively outgassing (like 2I/Borisov) or asteroid-like (like 1I/Oumuamua)



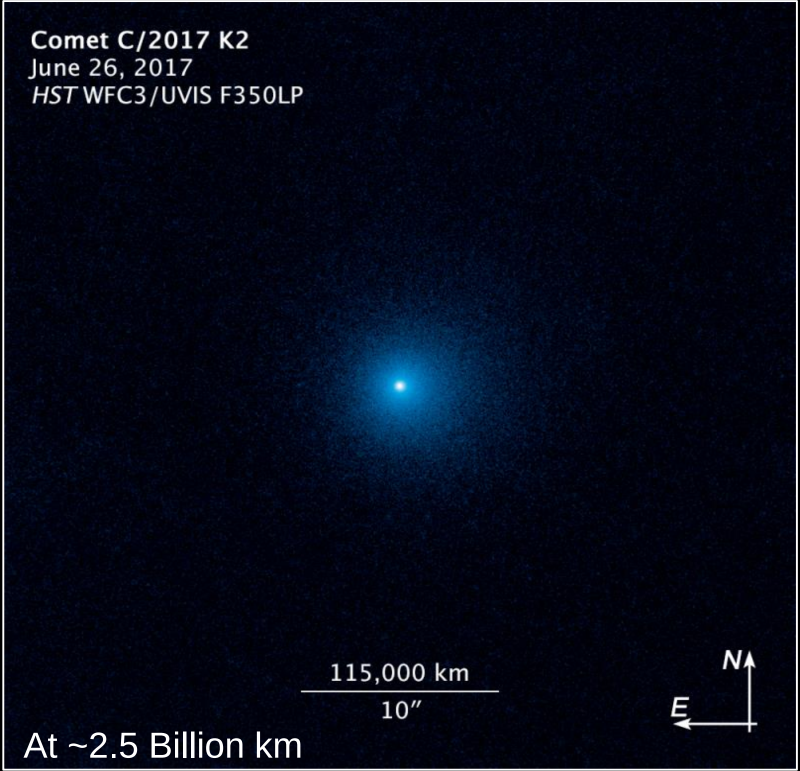
47,000 times farther from the Sun than Earth

Why do we Want to Explore OCCs?

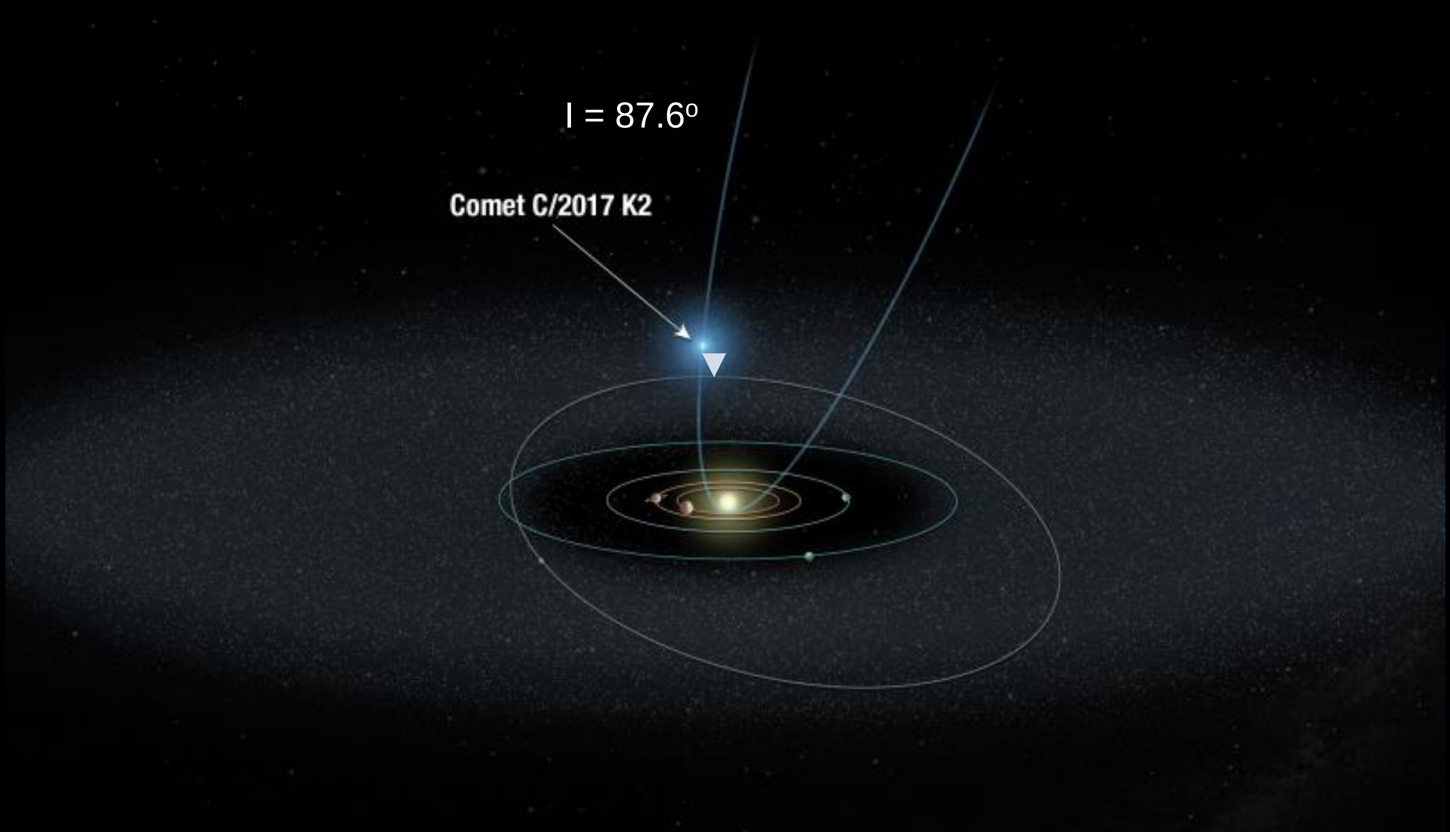
- Bound the temperature of the protoplanetary disk from volatile isotope markers and noble gasses
- Determine the makeup of the early solar system including volatiles, organics, and refractory material
- Understand the nature of the diversity among comets

Example Comet:
C/2017 K2 – A Gift from the Sky

- C/2017 K2 (C2K2) is a "great" comet with nucleus between 50-80 km
- Perihelion in Dec. 2022 at 2.1 AU from Earth, 2.3 AU from Sun
- C2K2 will visit once in our lifetime but there will be more comets like C2K2
  - No guarantee those would be accessible
  - C/2010 U3, another record comet had perihelion at 8 AU (Feb 2019)
- All comets are interesting!
  - Concept discussed today can be applied to many future targets



At ~2.5 Billion km



Qualifies as “Great” comet (50-80 km large)
~1-3 million year orbit (inbound)

Future Visitor Exploration

C2K2, 2017

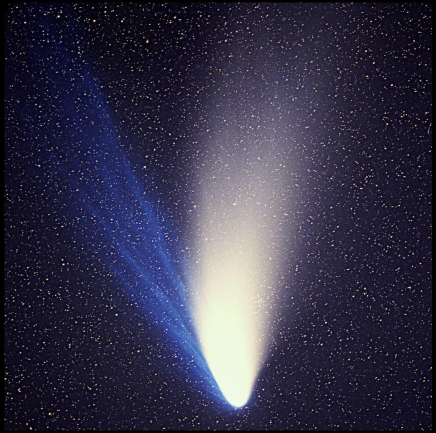
Image credit: Jewitt, 2017

Borisov, 2019

Image credit: Jewitt, 2019

Ouamouamoua, 2017

Image credit: Meech, 2017



Hale-Bopp, 1995

Image credit: Kolmhofer, 1997

Xenia Mission Concept

- Scientists and engineers at JPL worked to develop the Xenia mission concept
    - Rapidly build, test, and launch mission to encounter C2K2
    - <18 months from project start to ATLO
- Conclusion: technically, development is feasible but requires new technology development and parts availability
    - MarCO demonstrated rapid development process
    - Availability of COTS parts streamlines the design and build process
    - Enabling technology is actively in development, if not yet flown
- Programmatically, there was no place for a rapid response mission
    - Too large for SIMPLEx and cadence is not conducive to reactivity

Xenia Scientific and Programmatic Goals

- Science
  - Explore a long-period comet up close and understand the nature of the diversity among comets
  - Constrain the temperature of the edge of the protoplanetary disk

Xenia Scientific and Programmatic Goals

- Science
  - Explore a long-period comet up close and understand the nature of the diversity among comets
  - Constrain the temperature of the edge of the protoplanetary disk
- Pathfinding
  - First close approach of a long period comet
  - First “reactive” mission, with many applications down the line
  - Scout is important for assessing risk (~38 km/s, 10^5 kg/s dust ejected)

Xenia Scientific and Programmatic Goals

- Science
  - Explore a long-period comet up close and understand the nature of the diversity among comets
  - Constrain the temperature of the edge of the protoplanetary disk
- Pathfinding
  - First close approach of a long period comet
  - First “reactive” mission, with many applications down the line
  - Scout is important for assessing risk (~38 km/s, 10^5 kg/s dust ejected)
- Outreach!
  - Public will see the comet with their naked eye from Earth and up close from Xenia

Credit: Cherie Benoit at Flickr


Credit: Wally Pacholka

Credit: Paul Sutherland

Credit: Philipp Salzgeber

Xenia Scientific and Programmatic Goals

- Science
  - Explore a long-period comet up close and understand the nature of the diversity among comets
  - Constrain the temperature of the edge of the protoplanetary disk
- Pathfinding
  - First close approach of a long period comet
  - First “reactive” mission, with many applications down the line
  - Scout is important for assessing risk (~38 km/s, 10^5 kg/s dust ejected)
- Outreach!
  - Public will see the comet with their naked eye from Earth and up close from Xenia
- Technology demonstration opportunity
  - Autonomous science data return
  - Deep-space SmallSat propulsion

Xenia mission goals are enabled by using small spacecraft

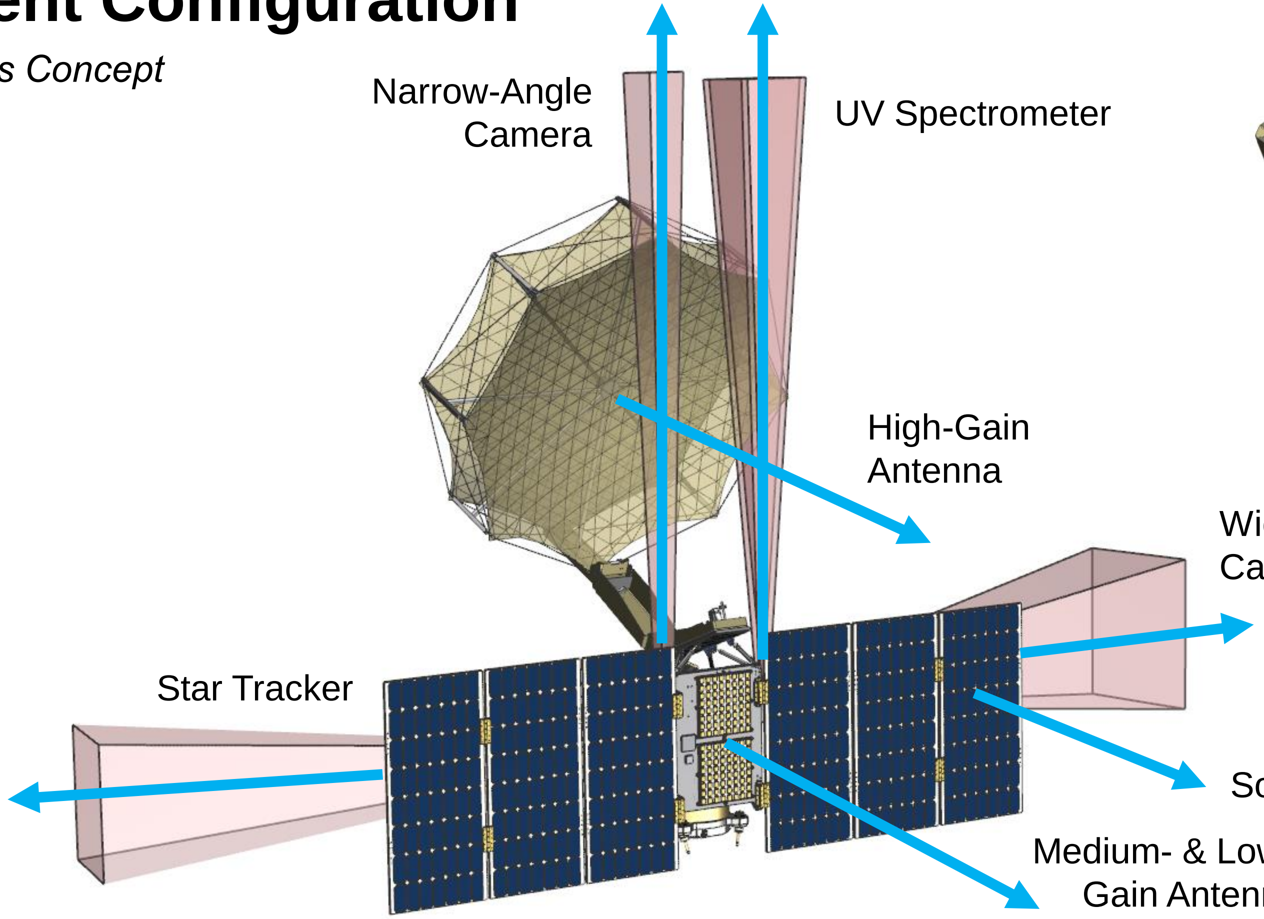
Driving Requirements

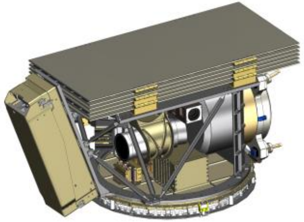
SmallSat

Short Name	Requirement	Drives
Mass	The mass of each spacecraft shall not exceed **75 kg (150 kg total)**	Flight system and payload
Launch Energy	The launch vehicle shall directly inject the two spacecraft on an intercept trajectory with an energy of **>57 km^2/s^2**	Flight system and navigation
Launch Date	The spacecraft shall launch no later than **February 2022**	Schedule (all)
Post-Encounter Data Return	The spacecraft shall return at least **1 Gb** of data from the encounter before end of mission	Flight and ground systems

Current Configuration

Artist's Concept





Stowed

Paradigm Shift in SmallSat Exploration | Constraints

- Extremely rapid turn-around time (~24-month project from start to launch)
  - Need all subsystems to be ready for integration
- Large amounts of launch energy required to encounter (C_3 of >57 km^2/s^2)
  - These types of opportunities almost never land in launch energy-friendly places
- High-risk, high-reward exploration to time-limited visiting body
  - Schedule slip means missing the opportunity!

Enabling Capabilities for Rapid SmallSat Exploration

- Efficient SmallSat deep space propulsion (Isp > 200)
  - Several companies and institutions who are trying, but no existing, flight proven systems
- Flight-proven, stowable HGAs and autonomous data return
  - Need capability to return science data after fast fly-by
- Rapid turnout for COTS subsystems and components capable of use in deep space
  - E.g. SDL IRIS radio
- **No programmatic opportunity for rapid response missions**
  - **Existing AO scheme does not allow for missions to take advantage of fleeting opportunities like visiting a passing by comet**

Summary (1)

- OCCs and ISOs hold some of the most pressing secrets about the formation of our solar system but are not easy to get to
- Missions of opportunity are often characterized by high energy and inclination orbits and quick time to respond
- Need the capability to respond to incredible science opportunities

- **We are eager for our first flyby of an OCC or ISO!**

Summary (2)

- Need to leverage commercial parts and rapid development cycles to respond to infrequent, fleeting opportunities with great science potential
- Reactive mission to OCC is technically feasible; design can be adapted for other far-away visitors like OCCs and ISOs
- Programmatic elements are not in place to quickly mobilize to respond to an opportunity like a passing OCC or ISO

- **We need to get ready to respond to an approaching OCC or ISO!**

Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov