Prospector-1:
A Low-Cost Commercial Asteroid Mission
Grant Bonin | SmallSat 2016
About DSI

• A space technology and resources company
  • Vision to enable the human space development by harvesting asteroid materials

• Water is key enabler of cis-lunar economy
  • Growth of annual space product by 5-10x over next few decades

• Headquarters in Mountain View, California
  • NASA Ames Research Park
  • Actively hiring engineering and business development
The Silicon Valley of Space Resources

First Look
Luxembourg woos would-be asteroid miners with $223-million program
The Grand Duchy of Luxembourg allocated 200 million euros for asteroid mining operations that could eventually provide a stream of resources from space.

By Ben Thompson, Staff | JUNE 6, 2016

Luxembourg invests to become the ‘Silicon Valley of space resource mining’
by Peter B. de Selding — June 3, 2016

The Luxembourg government’s backing for space mining ventures includes an initial $225 million in seed money for R&D and co-financing. One early investment will be in Deep Space Industries’ Prospector-X nano-satellite to test space-mining technologies. Credit: Deep Space Industries

Mark A. Garlick/Harvard-Smithsonian Center for Astrophysics/AP | View Caption
DSI Business Model

- DSI asteroid prospecting technologies enable commercial missions
  - Every key technology for smallsat asteroid missions enhances LEO satellites and applications
  - Focus on technology instead of applications

- Collaborative approach
  - Track technology roadmap closely
  - Partner with leading providers to complete solution
  - Example: HawkEye 360, Space Flight Laboratory
Example: Water Propulsion

SmallSat Chemical Propulsion - Cost vs. Performance

Monoprop

Resistojets

Cold Gas

A gap in the market...
DSI Water Propulsion

SmallSat Chemical Propulsion - Cost vs. Performance

- Monoprop
- DSI Water
- Resistojets
- Cold Gas

Comet-1 1U and 2U Systems
Asteroid Prospecting
Proving space resources with low-cost spacecraft
Why prospect?

- **Asteroid Mathilde (50 km)**: 1.3 g/cm³, C-type, low albedo (<0.1)
- **Asteroid Itokawa (350 m)**: 1.9 g/cm³, S-type
- **Asteroid Eros (23 km)**: 2.7 g/cm³, S-type, high albedo (>0.15)

Two bodies of same spectral type can be very different:

- Dark type never observed up close
- Bulk density seems to be smaller for dark objects

Courtesy ESA
Prospector-1

• DSI’s first micro-spacecraft asteroid mission

• Primary (science) objective: to survey target of interest for extractable water

• Launched to low-Earth Orbit as secondary payload

• Injected to asteroid using chemical Earth departure stage

• Careful target down-selection for relatively short cruise, close range operations

• DSI-developed *Comet* water thrusters for cruise, rendezvous and proxops

• X-band TT&C for absolute navigation, far infrared / optical relative navigation
Water Mapping

• Science campaign begins at first holdpoint, incrementally closer station-keeping distance

• VIS/MWIR imagery for pictures and surface water mapping (hydrated salts and –OH bearing silicates in regolith)

• Neutron spectrometry for measuring subsurface hydrogen abundance

• Asteroid rotation and north-south station-keeping used to achieve latitude / longitude hydrogen map

• Co-registration of imagery and neutron measurements at increasingly close range to identify regions of interest
Landing Attempt

• At end-of-life, Prospector-1 will attempt to land at site of interest

• Will use instrumented landing legs to evaluate geotechnical characteristics of regolith (“diggability”)

• Will use high-accuracy gravimeter payload to evaluate bulk geophysical characteristics (nano-g-level accuracy)

Lastly:

• Will assert a commercial presence at the asteroid, validating policy regime for private companies to harvest space resources
Prospector Summary

• Prospector-1 in detailed design phase
  • Development and qualification of propulsion, interplanetary avionics stack

• Announcing now to identify mission partners
  • Multiple vendors of all candidate instruments
  • Ensure best possible partners and vendors

• Flight demonstration of propulsion, avionics, and GNC in 2017
  • Prospector-X tech demonstrator
  • Three HawkEye 360 microsatellites
  • Additional mission TBA
Selling bottled water in space...

• DSI is developing a private asteroid mission, propelled by water thrusters, to prove water abundance at a target asteroid

• DSI is building and flying commercial and R&D missions using water propulsion

• DSI is working to develop next-gen solar thermal and water electric thrusters

• DSI is studying cis-Lunar transportation architectures using water and water-derived propellants

The Goal:

• To create an ecosystem of spacecraft products and missions today that can be supplied by space resources tomorrow
...So where would you like to go?
With gratitude to friends and partners...
## Prospector-1 System Summary

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<th>Characteristic</th>
<th>Specification / Description</th>
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| Spacecraft mass (post injection)      | 29 kg dry mass  
|                                       | 49 kg wet mass                                                                                                                                         |
| Spacecraft Size                       | Hexagonal form factor  
|                                       | 54 cm x 47 cm x 50 cm (27 cm wide faces)                                                                                                               |
| Cruise Propulsion                     | Water electrothermal propulsion (DSI Comet thrusters)  
|                                       | 200 s specific impulse  
|                                       | 1000 m/s delta-V on-board                                                                                                                                |
| Power generation                      | Three deployed and three body-mounted solar arrays  
|                                       | 120 W nominal (main solar panels at 1AU solar distance)                                                                                             |
| Tracking, telemetry and command      | Scanning X-band antenna system  
|                                       | DSN-compatible ranging transponder  
|                                       | Minimum 3.1 dB link margin at worst-case range / orientation                                                                                           |
|                                       | Minimum 1 kbps at worst case range / orientation                                                                                                          |
| Attitude determination and control   | Dual star tracker configuration  
|                                       | Three reaction wheels  
|                                       | RCS propulsion shared with primary propulsion                                                                                                          |
|                                       | Arcminute-level attitude control                                                                                                                           |
| Guidance and navigation              | Ranging transponder for absolute navigation                                                                                                               |
|                                       | Optical (IR) navigation for relative navigation                                                                                                          |
|                                       | Stereo optical navigation for proximity operations                                                                                                         |
| Command and data handling             | Distributed network CAN architecture  
|                                       | Single computer and high-speed data recorder                                                                                                               |
| Payloads                              | VIS/MWIR Camera (0.5 m spatial resolution @ 10 km range)                                                                                                 |
|                                       | Neutron spectrometer                                                                                                                                     |
|                                       | Instrumented landing legs, magnetometer, gravimeter                                                                                                       |
The inaugural mission of the Luxembourg and Deep Space Industries partnership, Prospector-X™ is a 3U spacecraft that will operate in low Earth orbit, testing critical innovations engineered for future missions in deep space.

**PROPULSION**
The Deep Space Comet-1™ electrothermal thruster uses the most abundant resource in the solar system — water — as propellant. It is intrinsically inert, launch safe, and cost-effective.

**DEEP SPACE AVIONICS**
Modular, scalable, and intrinsically radiation-tolerant avionics combine the best of commercial technologies with rigorous screening and innovative design approaches to enable cost-effective, yet radiation-robust subsystems for deep space.

**OPTICAL NAVIGATION**
A two-camera optical navigation system enables proximity operations at asteroids or at close range to other targets. This vision system is developed jointly between Deep Space and the University of Luxembourg's SnT.