CubeSat Deployment System Concept for Interplanetary Missions

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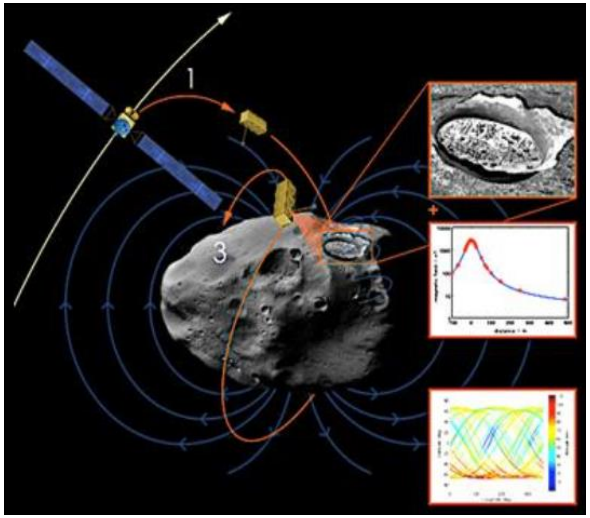
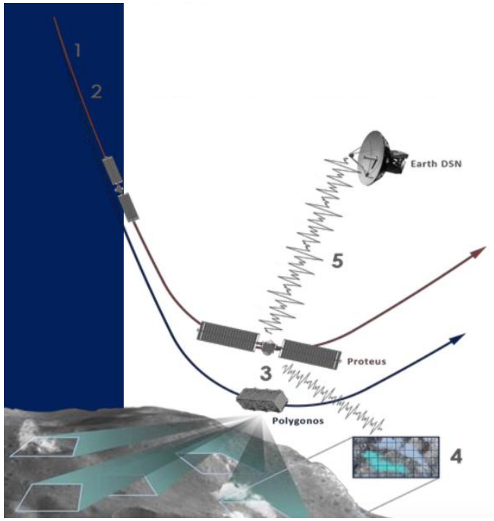
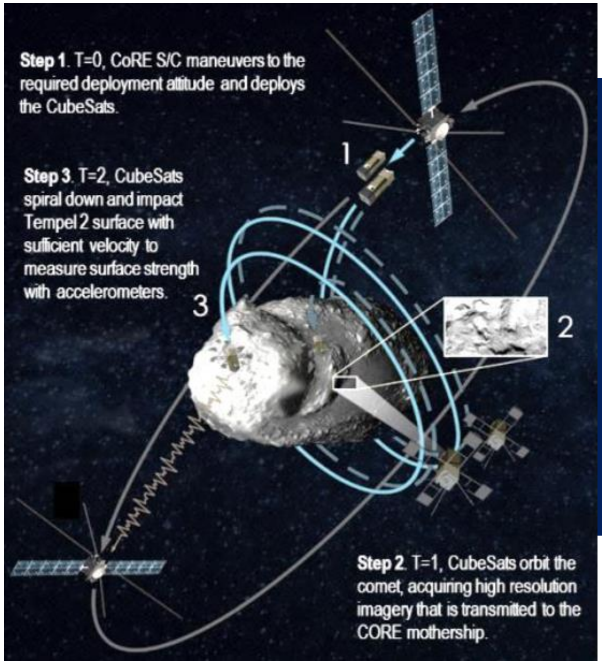
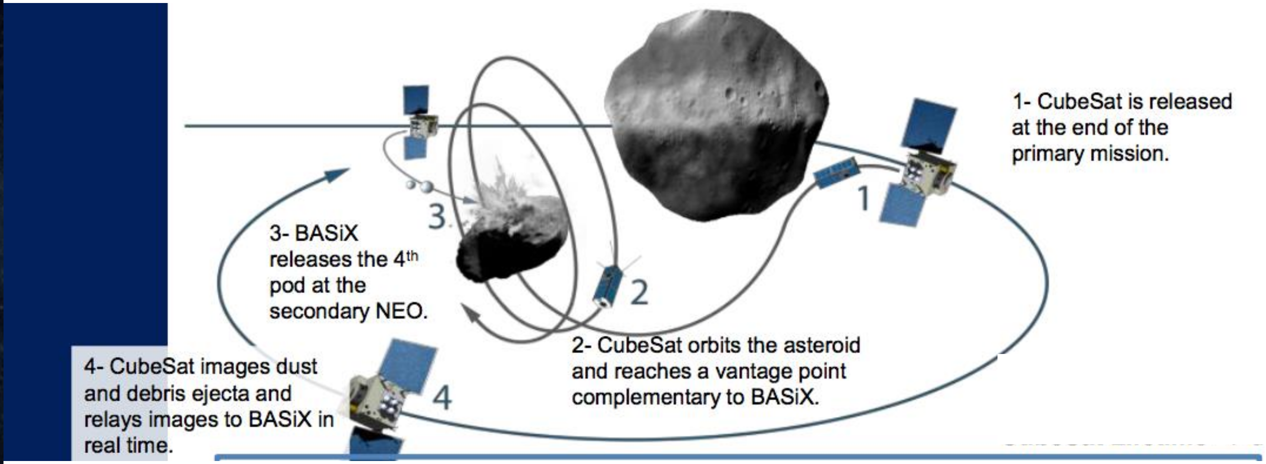
Deep Space CubeSat Mission Concepts

- Psyche
- Proteus
- BASiX
- CoRE
- Many others!









All Image Credit: NASA JPL ("JPL's Advanced CubeSat Concepts for Deep Space Exploration", CubeSat Workshop, August 2015)

Deep Space CubeSat dispenser Motivation

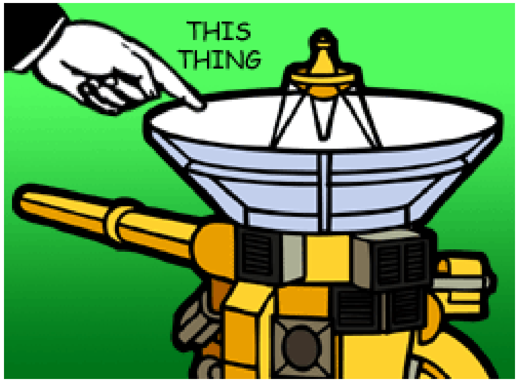
- Current CubeSat deployment systems are designed to deploy CubeSats near Earth
- MarCO – deployed near Earth, makes transit to Mars outside of dispenser
  - Dispensers for MarCO did not need to perform in a capacity beyond typical Earth orbiting CubeSat deployment systems
- Potential design challenges for long term interplanetary missions:
  - Communications: Dispenser may need to participate in data transfer from CubeSat to Earth
  - Thermal: Maintaining operational/survival temperatures
  - Radiation: Minimizing dose to both CubeSat and Dispenser electronics
  - Deployment accuracy and predictability
  - Cold welding between CubeSat and dispenser interfaces
- A standard platform with flight heritage is a critical piece in making interplanetary mission architectures involving secondary payloads (CubeSats) truly practical

Assumed Dispenser Functions

- Pre-launch/Launch
  - No change from typical CubeSat missions
- Post separation from Launch Vehicle/Transit
  - Power on, thermal control, CubeSat/Dispenser diagnostics, communicate any health concerns to primary
- Upon receiving deployment signal
  - Deploy CubeSat, verify deployment, and communicate to primary
- Post deployment
  - Receive CubeSat data and transfer to primary spacecraft to relay to Earth

Communications System

- Deep space communications hardware is very large
- CubeSat data must get back to Earth
  - Primary spacecraft high gain antenna (HGA) can be used to send data in order to make use of the large antenna that is available
- In order to minimize any operational requirements on the primary, the dispenser can have its own low power communications system
  - Send/receive data from the CubeSat
  - Onboard dispenser avionics can then transfer the data to the primary spacecraft through a wired interface
- Above solution makes use of deep space communications systems already in place for the primary mission



HGA Antenna Example
Credit: NASA JPL

Earth Deep Space Antenna Example
Credit: NASA

Thermal System (1)

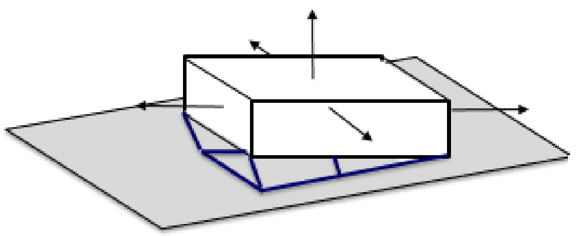
- Thermal system control objective:
  - Maintain temperatures between -10° C to 40° C
- Utilize heaters to maintain minimum temperature in shaded/cold conditions
- Select insulation properties for optimal temperature range
  - Balancing act between minimize power required in cold case to maintain temperature range and minimizing temperature in the hot case
- 3 different MLI configurations were examined:
  - $\alpha = 0.12$, $\varepsilon = 0.11$ (COTS)
  - $\alpha = 0.14$, $\varepsilon = 0.07$ (COTS)
  - $\alpha = 0.04$, $\varepsilon = 0.04$ (theoretical)

Multi-layer Insulation in use
Credit: ESA

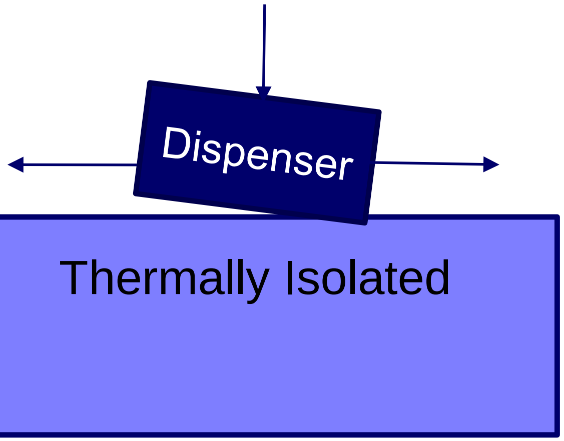
Thermal System (2)

- Cold Case Assumptions:
  - Dispenser shaded by Primary spacecraft (no thermal interaction)
  - All other surfaces radiate to space
  - No view factors with sun, distance from the sun is not relevant
- Hot Case Assumptions
  - Solar radiation incident on largest panel at 0.89 AU
  - No thermal interaction with primary

Config	α	ε	Max Temperature	Heater Power Required
1	0.12	0.11	42.8 °C	11 Watts
2	0.14	0.07	94.0 °C	7 Watts
3	0.04	0.04	36.0 °C	4 Watts



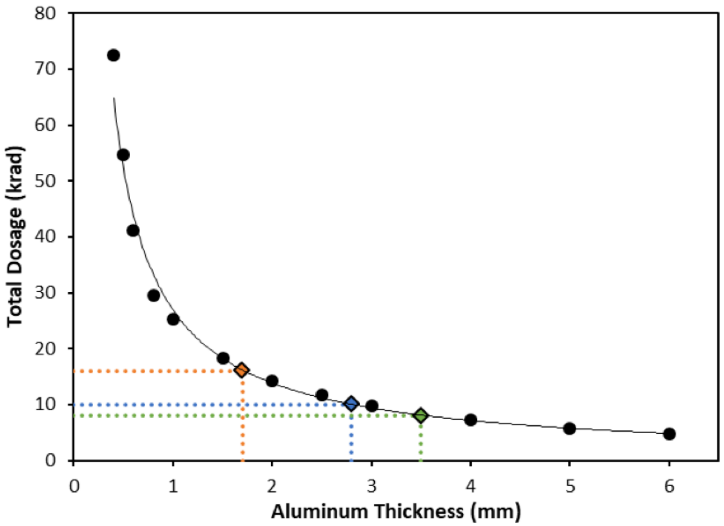
Dispenser Thermal Model (Cold Case)



Dispenser Thermal Model (Hot Case)

Radiation Concerns

- 16 krad typical allowable ionizing dose of radiation for CubeSat components[1]
  - Targeted 10 krad and 8 krad for factor of safety
- Shielding entire CubeSat with Dispenser vs just Dispenser components
  - CubeSat can shield itself where necessary to save mass
- Assuming Aluminum dispenser body:
  - 16 krad: 1.7 mm wall thickness (similar to thickness of existing dispensers)
  - 10 krad: 2.8 mm wall thickness
  - 8 krad: 3.5 mm wall thickness



Data from SPENVIS model

[1]Byrne, James, and K. Cahoy, Resource-Constrained Avionics Design for CubeSats, 2016.

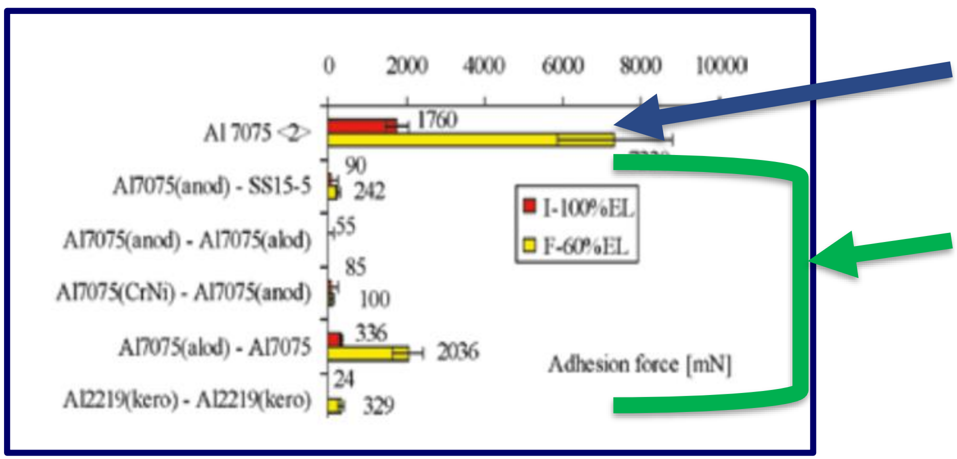
Deployment Accuracy

- Mechanical springs are a popular method of deployment for CubeSat dispensers
  - Very reliable compared to other options
  - Long-term stowed state raises concerns of spring relaxation
    - Spring relaxation can cause a loss of spring stiffness of at least 1-2%
- Spring relaxation can be mitigated using a process called heat setting
  - Holding the spring under high stress at elevated temperatures
- Spring will undergo its relaxation on the ground where it can be measured
  - Ensures accurate deployment velocity

P-POD with Coil Spring

Cold Welding Concerns

- CubeSat deployment systems typically have a metal on metal interface between CubeSat and dispenser
  - This raises concerns about cold welding
  - Long-term contact raises chances of cold welding between two similar, flat, materials
- Using different material coatings greatly mitigates the adhesion forces



- Uncoated materials see large adhesion force
- Coated materials see small adhesion forces

Different adhesion forces under impact and fretting for a selection of materials. Credit: ESA[3]

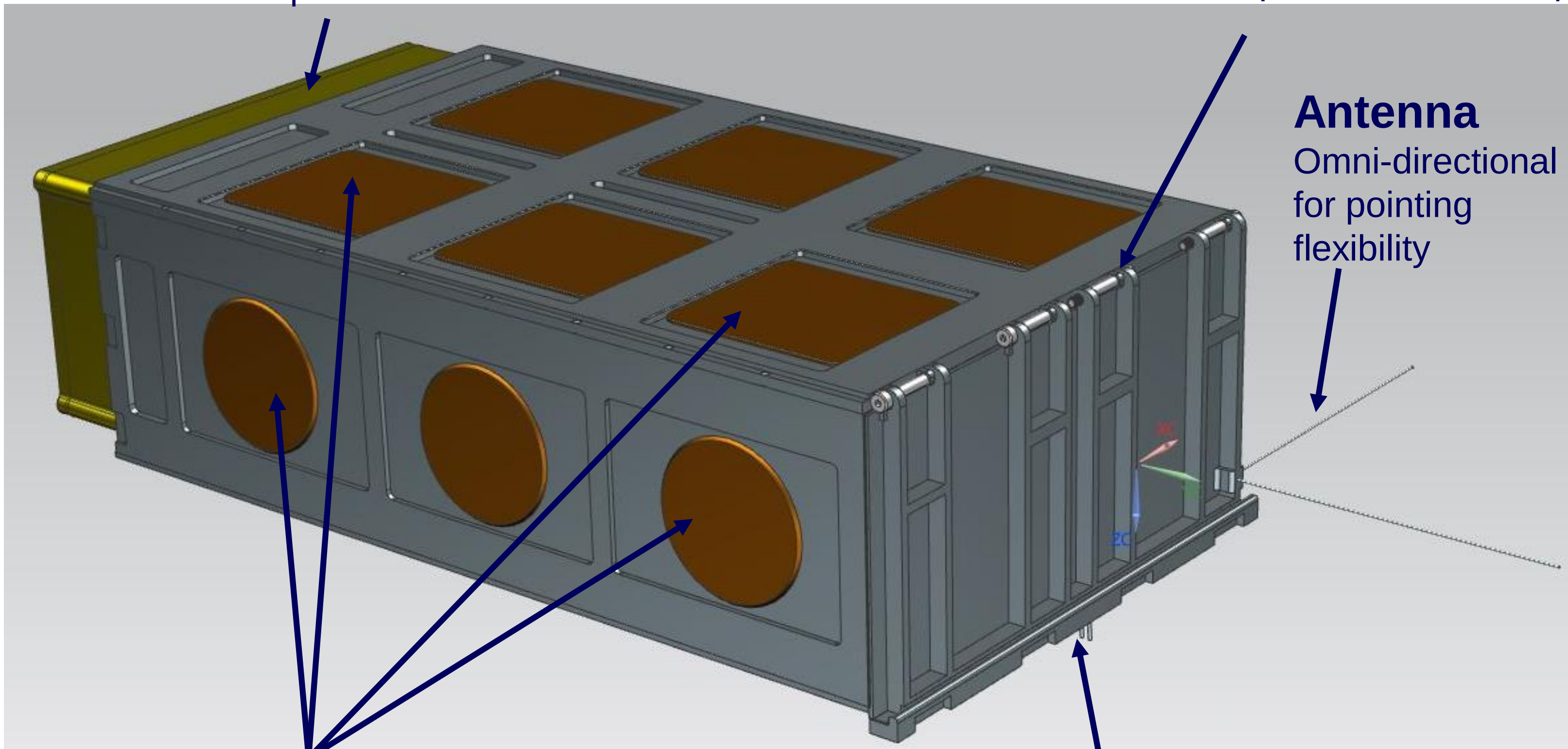
[3]A. Merstallinger, M. Sales, E. Sermerad, B.D. Dunn, Assessment of Cold Welding between Separable Contact Surfaces Due to Impact and Fretting under Vacuum (ESA STM-279 November 2009), ESA Communications Production Office, 2009.

Preliminary Design Concept

Electronics Box
Contains system computer, transceiver, thermal controller, data storage, and primary spacecraft interface electronics for power and data transfer

Door Stops in Hinge Assembly
Spring loaded plunger engages in slot to stop and lock door in place

Antenna
Omni-directional for pointing flexibility

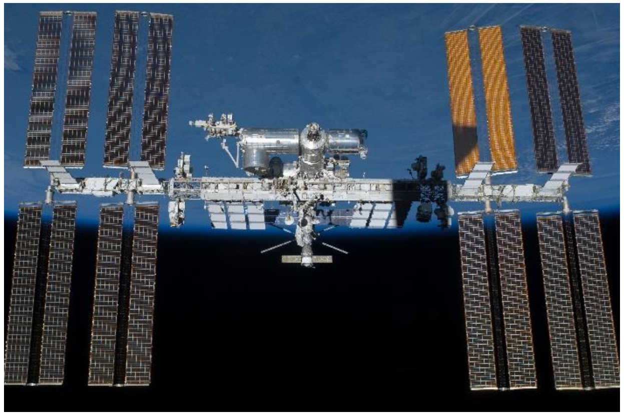


Heaters (Dispenser to be wrapped in MLI)

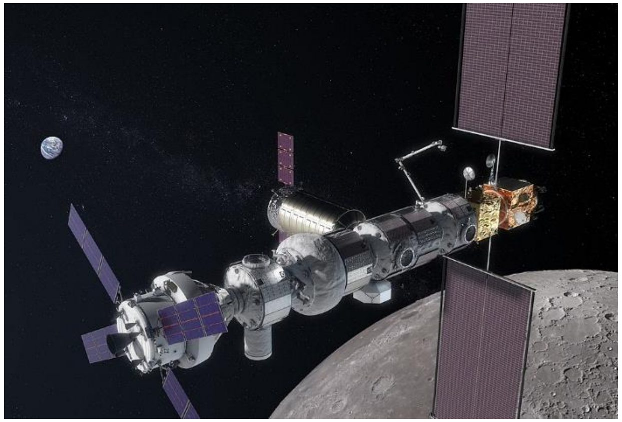
Door Release Mechanism
Pin Puller on underside unlatches door

Testing for Flight Readiness

- Potentially send on EELV launch prior to long term testing to help qualify for longer term tests
- Potential long term test beds include ISS, GEO spacecraft or Lunar Orbital Platform-Gateway
- Develop payload to stimulate CubeSat in various power state modes
  - Allows full thermal system testing to ensure temperature regulation is reliable
  - Allows for full deployment system test to ensure reduced risks of cold welding or other deployment malfunctions
  - Allows for full communication system test to ensure communication architecture behaves as expected
  - Indicates total ionizing dose transmissibility from dispenser exterior to payload



International Space Station
Credit: NASA



Lunar Orbital Platform-Gateway
Credit: NASA

Conclusion

- Proposed functions on a CubeSat deployment system are feasible
  - Individual functions have been in practice for a long time
  - The challenges arise when bringing these functions together in a system that works for a secondary payload interface
- Most significant change from available CubeSat dispensers will be the added avionics package to handle thermal control, communications, command and data handling, etc, to the CubeSat dispenser
- **Special thanks to NASA JPL for funding and support of the preliminary studies to springboard this effort!**

Image Credit: NASA JPL