27th Satellite Design Contest Mission Overview

DISCERN (Deimos In-Situ Cubesat-based Economical RecoNnaissance)

The University of Tokyo / Waseda University

2. Outline of the satellite (approx. 200 words)

DISCERN — Deimos In-Situ Cubesat-based Economical RecoNnaissance — is a CubeSat lander mission to Deimos, one of the moons of Mars, planned for launch in 2024 as a secondary payload with JAXA's Martian Moons eXploration (MMX) mission to Phobos. Although investigating the origin and evolution of the Martian moons is crucial to understanding the solar system's evolution, Deimos remains unexplored by a dedicated mission. Being a 27-U CubeSat, the DISCERN spacecraft can be developed, built, and launched at a lower cost and conduct riskier operation than a conventional space probe. The mission will help us understand Deimos's history by detecting regolith composition and surface topography with onboard science instruments.. After launch into a Mars Transfer Orbit (MTO) on the same launch vehicle as MMX, a 9-month travel in MTO, Mars orbit insertion, and rendezvous with Deimos, the spacecraft will conduct 78 days of orbital remote sensing observation, and then land on the surface using crushable structures and a self-orienting mechanism. On the surface, the science instruments will perform more detailed analyses. DISCERN will be the first mission to land on Deimos and to perform in-situ analysis of the surface material. It will also be the first CubeSat to orbit another planet and to land on a celestial body outside the Earth system, making it a pioneer of low-cost interplanetary exploration.

3. Aims and significance (Purpose, importance, technical or social significance etc)

(a) Aims

The primary purposes of the DISCERN mission are (1) to collect scientific data of Deimos and (2) to demonstrate an interplanetary exploration by a CubeSat.

(1) Due to Deimos's small size, distance from the Earth, and the interference by Mars and Phobos, the scientific data we can obtain from the ground and the orbiters around Mars are very limited. Therefore, we choose Deimos as our mission target to investigate it close-up. The CubeSat will observe the surface with a camera and spectrometers onboard. High-resolution images with near-global coverage taken by an optical camera will reveal the surface topography including craters and boulders that the images currently available have not shown clearly. The surface composition will be analyzed with infrared and x-ray spectrometers, which will investigate the mineral composition and elemental abundance of the regolith. With the data, we wish to give constraints on the origin of Deimos and to identify potential material resources that can be useful for future explorations of the Mars system.

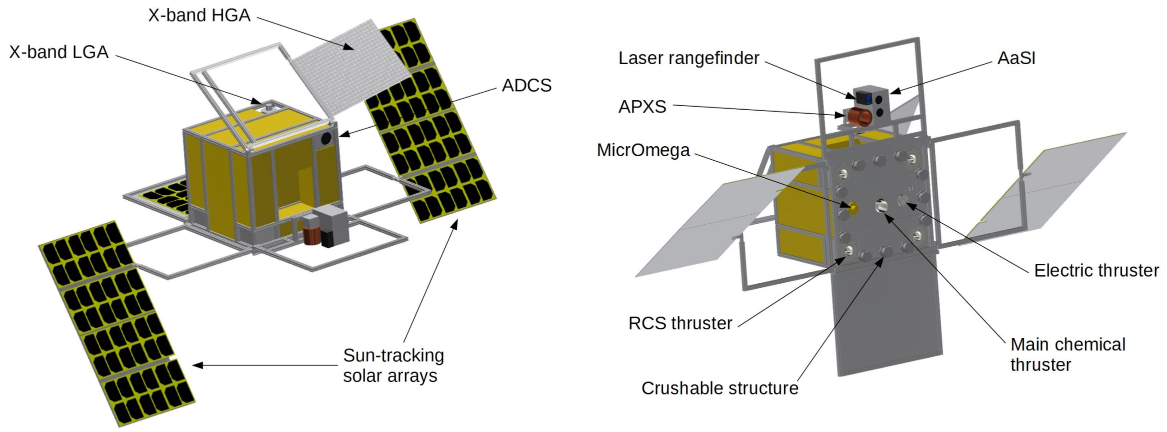
(2) The engineering aim is to prove the possibility of deep space exploration by CubeSats through the demonstration of several innovative technologies and methods such as self-righting landing system for low-gravity bodies, interplanetary communication for a CubeSat through another spacecraft, and a mission profile using both electric and chemical propulsion systems.

(b) Importance, technical or social significance

There are multiple hypotheses regarding the origin of the Martian moons. By orbiting close to and landing on Deimos, this mission will provide tremendously precious scientific data on the surface topography and composition, which will greatly contribute to our knowledge of the solar system evolution. Due to its lower cost and shorter development time, a CubeSat has the ability to carry out more risky missions than a conventional interplanetary probe. DISCERN will therefore have a chance to demonstrate some new technologies for more complex CubeSat missions of interplanetary exploration, which is crucial to expand the possibilities of future CubeSat mission.

4. Specific content of the Mission

(a) System (overall configuration, shape, mass, function, orbit, data acquisition etc, including ground station and satellite/mission device)



Dimensions	366 × 353 × 336 (Stowed) 1590 × 952 × 652 (Orbital) 1003 × 952 × 652 (Landed)	Wet Mass	40 kg
Orbit	Earth-Mars transfer orbit → Mars orbit → G-3D orbit near Deimos → Deimos surface	Propulsion	- Main chemical thruster: Ariane Group 10N bipropellant thruster × 1 (Isp=300s) - Main electric thruster: Enpulsion IFM Nano Thruster × 1 (Isp=3000s, thrust =0.45mN, power usage=30W) - RCS thrusters: IPROS 0.5N hydrazine thruster × 4 (Isp=180s)
Scientific Instruments	- Optical camera: Aalto-1 Spectral Imager (AaSI) - Infrared spectrometer: MicrOmega - X-ray spectrometer: Alpha Particle X-ray Spectrometer (APXS)	ADCS	- Blue Canyon Technologies XACT (including a star tracker, three reaction wheels, an inertial measurement unit, and sun sensors) - Jenoptik DLEM 20 laser rangefinder module
Structure	- 27U CubeSat standard - 6061 Aluminum Alloy	Communication	PROCYON X-band HGA, LGA (Data uplink and downlink via MMX spacecraft, or other Mars orbiters if MMX is not available.)
Landing System	- Crushable structure for soft landing - Deployable side panels for self-orienting	C&DH	ISIS On Board Computer with custom daughterboard
Thermal Control	- Passive heat pipes - Heater: Hakko Electronics Satellite Heater × 4 - Multi-layer insulation	Electrical Power	- Power generation: DHV-CS-10 CubeSat solar panel × 59 (maximum output: 59W) - Solar array drive assembly: custom assembly based on the Honeybee Robotics CubeSat SADA - Energy storage: EXA BA0x Pegasus Class BA01/S High

			Energy Density Battery Array (capacity: 22.2Wh)

(b) Concrete achievement methods or necessary tasks and/or items to be developed

DISCERN is a CubeSat with a strict volume limitation, restricting fuel option and the landing system design. Regarding the fuel option, as a large delta-V (>1,500 m/s) is required to reach Deimos while the volume should be kept small, DISCERN will use electric propulsion as well as chemical propulsion systems. Electric propulsion, which has a high specific impulse, will be used where the spacecraft doesn't require sudden deceleration, and chemical propulsion will be used to enter orbit around Mars from MTO, which requires sudden velocity change. Those thrusters are all COTS parts, which can save developing cost and time and have less uncertainty of performances. For the landing system, since no purpose-designed lander has ever landed on Deimos or similarly sized bodies before, it needs to be developed. By referencing previous lander designs for other bodies and the properties of Deimos, we designed a landing system using crushable structure and deployable panels that is simple, compact, and robust. Crushable structures are a mature technology, being used and planned to be used on many landers with similar touchdown velocity as that of DISCERN, including the MMX spacecraft, the Venera landers, the Schiaparelli EDM, and the planned ExoMars Kazachok surface platform. Regarding the self-righting system, similar systems with deployable panels have been used on Mars landers such as Mars Pathfinder and the Mars Exploration Rovers. Thus we chose to apply this technology to our CubeSat mission.

5. Originality and/or social effects

(a) Originality of the mission

The Martian moons Phobos and Deimos have never been landed by a spacecraft to conduct in-situ analyses of the surface material. Thus their history and chemical properties remain very unclear. In order to provide information on Deimos, we will take high-resolution images of the nearly-entire surface, and in-situ infrared and x-ray spectral data that are not obtainable by MMX alone to reveal the surface composition.

Currently, the only interplanetary CubeSat mission ever flown is MarCO, which flew by Mars without entering orbit. Using a combined electric and chemical propulsion system to provide high delta-V in a small volume, DISCERN will be the first CubeSat to enter orbit around another planet (Mars), and the first to land on a body (Deimos) outside the Earth system. Several unflown low-cost mission concepts for exploration of the Martian moons had been proposed in the past, but none of them are both CubeSat-based and include orbital and surface investigation. DISCERN aims to obtain data both from orbit and from the surface while keeping the cost low with a CubeSat architecture, and by doing so increase the chance of being funded and launched.

(b) Anticipated results, effects, intended users

The scientific data obtained by this mission will be able to provide constraints on the formation of Deimos, making significant progress in the solar system sciences. Combination of our results and the information of Phobos' surface, expected to be collected by MMX, will reveal whether the two Martian moons originated from the same source and share the same history. Further questions that arise after the mission will lead to future exploration missions to the Mars system. Surface material found on Deimos could be used as fuel, providing resources to future missions. As an engineering demonstration mission, DISCERN can provide useful data for researchers to develop future deep space exploration by CubeSats. For example, DISCERN's landing system design can inform future lander missions to the Martian moons and similarly-sized asteroids.

Socially, DISCERN will provide many benefits to all members of humanity. The results from the mission will provide new knowledge about our solar system to the general public. Collaboration with researchers from all over the world on the scientific instruments will facilitate international cooperation. By demonstrating the viability of a low-cost, risk-taking interplanetary mission, DISCERN will accelerate future space exploration and the development of related technologies, which will also provide benefits on Earth. Finally, if DISCERN, as a mission conceived and designed by students, is successfully launched, it would be an inspiration for other students to engage in space exploration.

DISCERN - Deimos In-Situ Cubesat-based Economical RecoNnaissance

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Abstract

DISCERN — Deimos In-Situ Cubesat-based Economical RecoNnaissance — is a CubeSat mission to land on one of the Martian moons Deimos, for launch in 2024 as a secondary payload with Martian Moons eXploration (MMX), JAXA's sample return mission to Phobos. The mission will reveal regolith composition and surface topography with an optical camera, a near-infrared spectrometer, and an X-ray spectrometer onboard to explore the origin and the evolution of Deimos. The spacecraft will be a 27U CubeSat to keep the cost low. The DISCERN spacecraft will be launched into a Mars Transfer Orbit (MTO) with MMX, enter Mars orbit with chemical propulsion, and then transfer to an orbit near Deimos by electric propulsion. Over 78 days in orbit near Deimos, remote sensing observations will be performed. The spacecraft will then land using crushable structures and reorient itself with side panels under microgravity. After landing, more detailed scientific analyses will be conducted with all the instruments. A successful operation will allow the spacecraft to be the first CubeSat to orbit another planet and to land on a celestial body outside the Earth system.

1. Introduction

DISCERN — Deimos In-Situ Cubesat-based Economical RecoNnaissance — is an interplanetary CubeSat lander mission designed to explore Deimos. Deimos is the smaller Martian moon (the larger one is Phobos), which has a size of 15.0 x 12.2 x 10.4 km^3, an orbital period of 30.3 hours (in 1:1 resonance with Mars), and a distance of ~20,000 km away from Mars[1,2]. Currently, our knowledge of the Martian moons is very limited. Although some remote observational data are available, both moons have many unknowns regarding their history. To date, multiple hypotheses for their origin have been suggested: formation by giant impacts on Mars[3], captured primitive asteroids or comets[4], or co-accretion with Mars[5]. Understanding the Martian moons may help future exploration of the Mars system, since the moons' surface materials are considered to be potentially useful as a source of water or hydrogen[6]. Unlike Phobos, which had been the target of several previous missions and will be explored by JAXA's Martian Moon eXploration (MMX) sample return mission, Deimos has never been targeted by a dedicated mission. A reason MMX chose Phobos over Deimos is that there are more existing data on Phobos to help select landing sites[7]. Therefore, to pave the way for Deimos exploration, the DISCERN mission will obtain precious scientific/engineering data on Deimos with a CubeSat that costs much less and can tolerate more uncertainty than a conventional interplanetary mission.

2. Mission Objectives

2.1 Science Objectives

The primary purpose of the DISCERN mission is to perform in-situ scientific measurements around/on Deimos and provide constraints to its origin, contributing to the understanding of the solar system's formation. In order to achieve this goal, the spacecraft will obtain (1) high-resolution images, (2) near-infrared spectra, and (3) X-ray spectral data. (1) The mission will clarify the topography and shape of Deimos in more detail by obtaining near-global, high-resolution images in orbit, and close-up images on the surface after landing. (2) The mission will reveal the mineral composition of the surface with near-infrared spectral data. The spectrometer on board is capable of detecting mineral phases, ices, and organics, which are critical clues to give insights into the history of Deimos. (3) The X-ray spectrometer will measure the elemental abundance of the surface, which will inform us about the chemical history of Deimos through comparison with that of meteorites. The results will have a large effect on one of the hypotheses for the origin, the captured asteroid hypothesis.

2.2 Engineering Objectives

The engineering objective of the DISCERN mission is to demonstrate several enabling technologies for low-cost, CubeSat-based interplanetary exploration, including the combined use of chemical and electric propulsion for achieving high ΔV in limited volume, interplanetary communication by a CubeSat via other spacecraft to avoid the need to carry large antennas, and a self-orienting system for reliable landing on low-gravity bodies.

3. Achievement Methods

3.1 Mission Architecture

3.1.1 Orbit

As a secondary payload with MMX, we chose an orbit similar to that of MMX for smaller ΔV, shorter mission duration, and more stability against a change in the launch date. Also, our orbit design allows DISCERN to complete the mission while MMX is in the Mars system for signal relay.

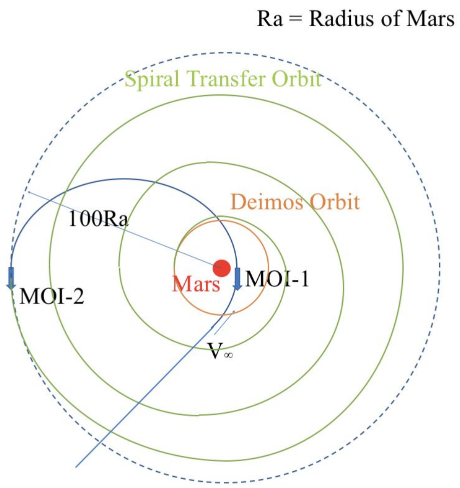

Fig. 3.1 The orbit in the Mars system

The orbit is visualized in Fig. 3.1. Mars Orbit Insertion (MOI) -1 will be done by chemical propulsion with a ΔV of 720 m/s. After MOI-1, the DISCERN spacecraft will be in a Hohmann transfer orbit, until MOI-2 changes the inclination and circularizes the orbit. MOI-2 will be done by chemical propulsion with a ΔV of 97 m/s. After MOI-2, the spacecraft will be inserted into a spiral transfer orbit to Deimos, requiring a ΔV of 643 m/s, which will be provided by electric propulsion. After rendezvous with Deimos, DISCERN will circulate around the target in a general 3-dimensional (G-3D) orbit[8] for 78 days to collect scientific data. This orbit requires an additional ΔV of 38 m/s. This leads to a total ΔV of 1,488 m/s. 855 m/s of which will be generated by chemical propulsion and the remaining 643 m/s by electric propulsion.

3.1.2 Mission Profile

The DISCERN spacecraft will be launched as a secondary payload with MMX in 2024. The mission after launch can be divided into four phases. *Phase 1* — MTO Phase — will begin after separation from the upper stage in MTO. The spacecraft will travel on the same orbit with MMX for 9 months. In *Phase 2* — Mars Orbital Phase — the spacecraft will use its own thrusters to conduct MOI-1, MOI-2, and spiral orbital transfer to rendezvous with Deimos in Mars orbit. This phase will take 800 days, during which the spacecraft obtains its location data by communicating with the ground via MMX. After arriving in a G-3D orbit near Deimos, *Phase 3* — Orbital Science Phase — will begin, where the spacecraft circles around Deimos at progressively closer distances and conduct remote sensing measurements for 78 days. During this phase, the spacecraft will send scientific data as well as its location data to Earth via MMX. Finally, in *Phase 4* — Landed Science Phase, DISCERN will land on the Mars-facing side of Deimos (in order to maintain line-of-sight with MMX at Phobos) and conduct in-situ analysis on the surface. The spacecraft will land just after local sunrise and all scientific data will be acquired and transmitted within 15 hours (before sunset) due to the low nighttime surface temperature that is not survivable for onboard instruments.

3.2 Satellite System Architecture

3.2.1 Science Instruments

Key to achieving the science objectives is a set of fundamental scientific data from the surface of Deimos obtained by a suite of instruments specially chosen from previous space missions to fit the CubeSat. These include an optical camera (AaSI), a near-infrared spectrometer (MicrOmega), and an X-ray spectrometer (APXS). Basic specifications of the instruments are shown in Table 3.1.

Aalto-1 Spectral Imager (AaSI)

Aalto-1 Spectral Imager (AaSI)[9] is a spectral imager designed for a nanosatellite mission, Aalto-1[10]. The instrument includes a spectral imager, a visible RGB-camera, and control electronics for them. The size, mass, and power consumption are low (Table 3.1), which fit the severe constraints of this CubeSat mission. Currently, the resolution of images for the global surface of Deimos is not uniform[11]. Especially, high-resolution images are lacking in the trailing hemisphere, which leads to uncertainty in the

Table 3.1 Science Instruments

Instrument	Dimension (mm^3)	Mass (kg)	Power Consumption (W)
AaSI	97 x 97 x 48	0.60	4.0
MicrOmega	184.5 x 117.5 x 98.0	1.9	5.0
APXS	84 x 52 x 52	0.64	1.5

volume and shape[2]. Therefore, in the vicinity of Deimos, AaSI aims to obtain high-resolution (>4.3 m/pix) images for nearly the entire surface. After landing, it will take close-up images (~50 µm/pix) of the surface, which will help to define characteristics of the sites analyzed by MicrOmega and APXS.

MicrOmega

MicrOmega (flown on MASCOT/ Hayabusa2) is a near-infrared hyperspectral microscope designed to characterize the texture and composition of the surface materials of the Hayabusa2's target asteroid Ryugu[12]. A spectrometer designed for a pristine small body such as Ryugu is suitable for this mission because previous spectral analyses suggest that Deimos resembles primitive asteroids[13]. One of the characteristic spectral features of Deimos is absorption at 2.8 µm detected by the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM). The absorption feature indicates a metal-OH combination on the surface[14]. Spectral analysis by MicrOmega is expected to be at the highest resolution ever done and obtain new findings on the composition. If interlayer water or hydroxyl bonding in minerals is detected on Deimos, it can serve as a source of water for future missions. The spectrometer has a spectral range of 0.99-3.65 µm and a spectral sampling of 20 cm^{-1}, which enables it to identify potential constituent minerals (primary and altered, oxides, salts, and hydrated phases) within each 25 µm pixel of the 3.2 x 3.2 mm^2 FOV[12].

Alpha Particle X-ray Spectrometer (APXS)

APXS (flown on Mars Pathfinder, Philae/Rosetta, and Mars Exploration Rovers) is a small instrument that is capable of determining all elements from carbon to nickel on the landing site[15]. It measures in-situ concentrations of elements from sodium to nickel by bombarding the surface sample with X-rays with an energy of about 14 KeV, and light elements such as carbon and oxygen by alpha particles at about 5.5 MeV.

3.2.2 Landing System

In order to land on Deimos safely, give the size of DISCERN of approximately 30 cm, an appropriate landing site with boulders and cobbles smaller than 20 cm, needs to be detected. In addition, the thrusters should not be fired toward the surface at low altitude to avoid contaminating the surface. Therefore, the landing sequence will be conducted as the following. After the end of the orbital science phase, the spacecraft will leave the G-3D orbit and enter a trajectory that intercepts Deimos' surface. Starting from this point, the spacecraft will be under autonomous operation and measuring altitude by a COTS laser rangefinder. When the spacecraft is within 200 m of the surface, it will start searching for an ideal landing site by analyzing AaSI images to identify obstacles. Once a suitable site is found, the spacecraft will use its thrusters to cancel horizontal velocity and begin free fall toward the site. Regardless of whether an ideal landing site is found, the spacecraft will continue to image the surface with the AaSI, which is pointed toward the surface by opening the side panel it is mounted on, until 10 m above the surface, when the panel will be retracted for the touchdown.

Compared to small bodies that have been landed on before like Itokawa and Ryugu, Deimos's gravity is much stronger, so a mechanism to cushion the impact is required[16], but our calculation showed that the initial touchdown speed is much lower than the escape velocity of Deimos, so anchoring is not required. In order to avoid contamination the surface by propellants, a passive landing system is preferred to avoid a hard landing in case of a loss of control. Comparison of the touchdown velocities and softlanding methods of previous lander designs showed that the most suitable softlanding method for DISCERN, which is expected to touchdown at less than 1.1 m/s, is either crushable structures or dampers. Crushable structures were chosen over dampers due to their simplicity and compactness that are suitable for a CubeSat mission. DISCERN will utilize the crushable structure similar to that of the MMX mission.[17]

Due to the possibility of bouncing on the surface and landing in an incorrect orientation, DISCERN should be able to reorient itself upright from any orientation. Deployable panels, including one top panel and four side panels, will therefore be attached to five faces of the CubeSat structure except for the bottom face with the crushable structures, and these panels will be utilized to orient the spacecraft. The panels, deployed in orbit to expose solar panels to sunlight, will be retracted before landing. After initial touchdown on the bottom face, the spacecraft will bounce and finally come to rest in any orientation (Fig. 3.2.1). As soon as the spacecraft is at rest on the surface, the top panel will first deploy automatically (Fig. 3.2.2), followed by the side panels (Fig. 3.2.3). After the process, the spacecraft will be upright regardless of its original orientation. A JVL MST082A03 Mini Stepper Motor[18] will be used on each panel to provide enough torque (0.03Nm) to flip the spacecraft on the surface of Deimos.

The deployable panels also have other functions. The top panel also serves as a rotatable mount for the high gain antenna, and the side panels hold solar panels and science instruments that can be deployed near the surface after landing.

3.2.3 Propulsion System

To save the propellant volume, high specific impulse and high density propellant is preferred.

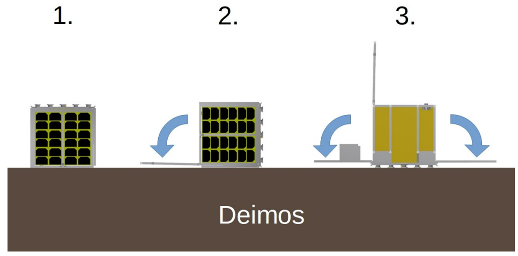

Fig. 3.2 The self-orienting mechanism

For this reason, DISCERN will use hydrazine and MON3 bipropellant chemical thruster, which can achieve specific impulse of 300 s, and has a fuel density of 1.2 g/cm^3, and a iodine ion thruster as main engines, along with 4 hydrazine monopropellant RCS thrusters. The thruster configuration is shown in Table 3.2. The propulsion system, including tanks, valves, thruster modules, and propellant for ΔV, altitude control, and unloading weighs about 25.3 kg and takes up 15.1 U in total.

3.2.4 Communication System

The distance between DISCERN and MMX will be 3.3×10^7 m. In order to send and receive scientific, tracking, and command data, DISCERN will use an x-band high gain antenna similar to the one on PROCYON, a 50 kg-class deep space exploration satellite built by the University of Tokyo[19]. Our calculation based on the sizes of the antennas and the distance between them showed that it is possible to communicate with MMX at 32 kbps using the same antenna.

Table 3.2 Configuration of the propulsion system

Thruster	Thrust	Power Consumption (W)	Volume (U)	Mass (kg)	Specific Impulse(s)
CP	10 N	10	1	0.8	300
EP	0.45 mN	30	1	0.6	3000
4 RCS	0.5 N	1	1	0.4	180

CP = Chemical Propulsion System (10N Bioropellant Thruster Type S10-26 with Dual Seat ArianeGroup Valve).
EP = Electric Propulsion System (IFM Nano Thruster, Enpulsion),
4 RCS = 4 RCS Thrusters as a total (Hydrazine thrusters, Advanced Technology Institute, LLC)

If the MMX spacecraft is not available for communication relay, DISCERN can also transmit data via other Mars orbiters equipped with x-band antenna such as MAVEN[20]. To enable communication when the spacecraft's attitude is fixed after landing, the high gain antenna will be movable, and a low gain antenna will be installed as a backup.

3.2.5 Thermal Control

The thermal control system is required to keep the spacecraft's temperature within operational limit of its components. The worst case for thermal control will be when the spacecraft is orbiting in the shadow of Deimos. If the spacecraft's temperature is maintained at 300K, the blackbody radiation from the satellite's bus to space will be -248 W. By covering the bus with multi-layer insulation (MLI) (heat emissivity = 0.02), the heat flow can be reduced to -5 W. To compensate this heat flow, the spacecraft will be equipped with four satellite heaters manufactured by Hakko Electronics[21]. Passive heat pipes will transfer heat generated by the heaters to other components.

3.2.6 Command & Data Handling (C&DH)

The command and data handling (C&DH) system needs to control all components on the spacecraft, including non-CubeSat and custom-built ones. The system also has to store data collected by the scientific instruments temporarily before transmission because communication relay by the MMX spacecraft will not be constantly available due to MMX's own mission and occultation by Mars and Phobos.

The ISIS On Board Computer[22] is chosen as the C&DH system for DISCERN. A custom daughterboard will be paired with the computer to interface with non-CubeSat and custom-built components. The computer also has up to 32GB of redundant onboard storage that is far more than enough to store all expected scientific data[22].

3.2.7 Attitude Determination and Control System (ADCS)

Being an interplanetary mission to the Mars system, the spacecraft's ADCS needs to reliably function in interplanetary space for a long period of time. Unlike Earth-orbiting CubeSats that use magnetic torques for momentum dumping, the spacecraft operates beyond the Earth's magnetosphere, so thrusters are required for the task.

The ADCS for the spacecraft will be the XACT attitude control system produced by Blue Canyon Technologies[23]. The XACT system is a complete ADCS package including a star tracker, three reaction wheels, an inertial measurement unit, and sun sensors[24]. The system has flight heritage on the MarCO mission, which demonstrated its performance on a mission to Mars[25].

3.2.8 Electric Power System

The power system should provide enough power for each phase of the mission, which is summarized in Table 3.3. The peak power requirement happens during the spiral orbit, when the electric thruster is operating. Assuming an 80% efficiency of the power supply system, 45.2 W of power must be supplied in this phase. The spacecraft has to generate power while firing its electric thruster in a fixed direction, so the solar panels providing power during the phase must be capable of tracking the sun without turning the spacecraft.

DHV-CS-10 CubeSat solar panels will be used on DISCERN[22]. Each solar panel can generate about 1 W of power in Mars orbit. A pair of the deployable side panels will each consist of two sun-tracking arrays that can be folded onto a frame connecting to the spacecraft bus. A total of 48 solar panels will be mounted on these sun-tracking arrays, capable of generating a total of 48W of power regardless of spacecraft attitude in Mars orbit. In the landing phase, the sun-tracking arrays will be folded onto the frame, exposing only 24 solar panels. Another side panel will also be covered in 11 solar panels, providing a total of 35 W of power on the surface of Deimos if the sun is directly overhead. Since the side panels cannot track the sun in landed configuration, power output will decrease as the solar angle decreases.

Storage of electricity for use when the spacecraft is in shadows will be provided by a single EXA Pegasus Class BA01/S battery array with 22.2 Wh of capacity[22], which can power the ADCS, C&DH, and the heaters for 2 hours.

Table 3.3 Maximum Power Requirement [W] During Different Phases of the Mission

Phase 1	MOI	Phase 3 Data collection	Phase 3 Data transmission	Phase 4 Data collection	Phase 4 Data transmission
17.69	36.1	20.1	26.1	11.05	15.55

3.2.9 Structure

The structure of DISCERN is shown in Fig. 3.3(a) and (b). The structure will be made of 6061 aluminum alloy. In order to comply with the 27U CubeSat standard, the dimensions of the spacecraft with all panels stowed will be 366 x 353 x 339 mm. The structure has a mass of 4.62 kg. The AaSI and the APXS will be mounted on one of the side panels so that they can be deployed near the surface of Deimos for close-up analysis when the panel opens.

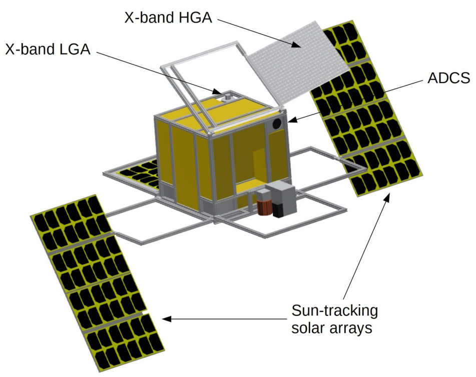

Fig. 3.3(a) DISCERN structure (top side)

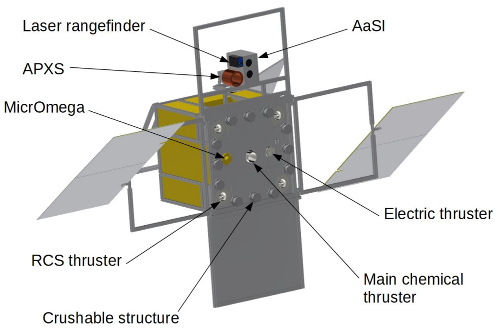

Fig. 3.3(b) DISCERN structure (bottom side)

3.3 Development Tasks and Issues

To reduce development cost, the DISCERN spacecraft use commercial off-the-shelf (COTS) or flight-heritage components whenever possible. However, due to the novelty of the mission to land a CubeSat on a body outside the Earth system, certain components are not available as COTS or flight-heritage parts and thus need to be developed, including the combined chemical and electric propulsion system, and the self-orienting system. Development risk would not be high because individual thrusters in the propulsion system are all COTS and similar self-orienting systems have operated successfully on previous non-CubeSat missions.

4. Anticipated Results

Scientifically, data collected by DISCERN on Deimos's composition will help constraint its formation. By comparing the data to those collected from Phobos by MMX, we can find out whether the two moons have a common history. Knowledge gained from both DISCERN and MMX will significantly improve our understanding of the Martian moons and the solar system as a whole. Data on Deimos's composition can also be used to identify resources that can be utilized in future manned missions to the Mars system.

On the engineering side, data collected from the operation of DISCERN can validate the viability of CubeSat-based interplanetary exploration, and the mission architecture can serve as a basis for future mission designs, especially for next-generation Martian-Moon landers or landers to similarly-sized asteroids.

5. Originality and Social Significance

DISCERN will not only be the first spacecraft to conduct in-situ exploration of Deimos, but also the first CubeSat to ever orbit another planet (Mars) and land on a body (Deimos) outside the Earth system. This innovative mission architecture will allow DISCERN to gain additional data on Deimos that will not be obtainable by MMX alone without adding a large amount of cost.

Besides, providing data to scientists and engineers, the DISCERN mission will greatly benefit society. Knowledge gained from the mission will eventually be shared with the general public and improve our understanding of the solar system we live in. Since the scientific instruments on DISCERN are developed by many different countries, this mission will provide opportunity for more international cooperation. The demonstration of low cost, high risk-tolerance interplanetary exploration will hasten the pace of space exploration and the development of technologies that benefit people on Earth. Being a student-designed mission, DISCERN will be a great inspiration for other students if it is successfully launched.

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