Title: In-Space Outgassing Laboratory Distant From Earth (ISOLDE)

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Need

Outgassing is the phenomenon of the release of gasses enclosed within the materials. This occurrence affect the measurements made with the optical lenses and decrease the reliability of the electronics. Hence, the outgassing rate and characteristics of the contaminants are needed to know in order to understand its effects on spacecraft materials. Although the outgassing experiments are commonly made on the ground in vacuum tanks within the clean rooms, the lower vacuum than ultra high vacuum (UHV, which is the range of pressure between 10^{-6} and 10^{-10} Pa in Europe [1]) is costly to obtain. Extra high vacuum (XHV, which is the range of pressure below 10^{-10} Pa [1]) conditions are the vacuum levels of the spacecraft usually come across and outgassing levels in this conditions are not yet investigated in detail. ISOLDE is the microsatellite contains outgassing laboratories as payload to measure outgassing rate and contaminants from a sample material of copper. The similar studies have been conducted by the instruments of the several spacecraft which orbits in heliocentric distances. ISOLDE is going to cost efficiently carry out the outgassing experiments in standard fashion by baking the substance materials to 125°C for 24 hours in XHV within the chambers whilst orbiting in LEO. Furthermore, zeolite, which is a material to absorb the contaminants, is also used in the laboratories to understand its effect to the outgassing characterization of the copper sample.

Mission Objectives

1. To conduct the standard outgassing measurement processes in the laboratory units with XHV conditions,
2. To test the contamination reliability when the payload operations are going on,
3. To measure the effect of gas absorbing material, zeolite,
4. To provide precise data of a common spacecraft material for improving the prevention techniques of return flux hazards.

Concept of Operations

The launch of ISOLDE is planned from Vandenberg Air Force Station, which is located in state of California, USA, in the first quarter of 2017 by Minotaur IV of Orbital Sciences Corporation. Communication link is going to be built up between ISOLDE's telecommunication subsystem and ground station of Istanbul Technical University's Faculty of Aeronautics and Aeronautics. After successful launch and orbit insertion phases, ground station is going to uplink the signal to start firstly the solar cell deployment and secondly the pressure and temperature detection within the payload. When the desired pressure and

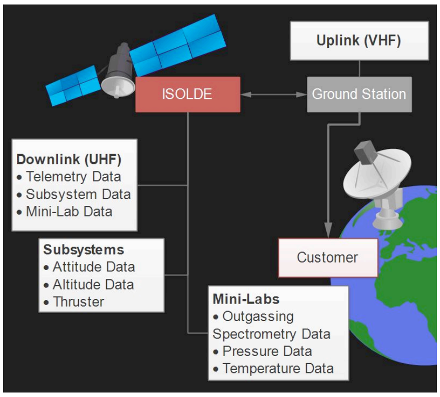


Figure 1: Concept of Operations of ISOLDE.

temperature values of the two laboratory units are obtained equally, mission phase is going to be initialized. Attitude and altitude data with the sensor data coming from the instrument are going to be sent by ISOLDE to the ground station. Experiments will commenced once the related sensors confirm XHV conditions. Sample material can be changed by the customer's needs. Lifetime of the mission is going to be limited after completion of the experiments and successful transfer of downlink data. Experiments are going to end in a week. Finally, de-orbiting phase is going to be held for atmospheric reentry.

Key Performance Parameters

1. Attitude control system to provide the three-axis stabilization and to point the spacecraft to sun in order to keep the laboratory units at the same temperature
2. Successful heating to 0°C the subsystem carrier segment that is shadowed during all mission
3. Achieving the data storage from sensors with 16-bit microcontroller platform
4. Successful data transfer of 2400 bps to the ground station
5. Activating thruster successfully for de-orbiting phase

Space Segment Description

Payload: ISOLDE is going to carry out the outgassing experiments with two square shaped laboratory units. The units are both linked to each other and the outer space directly by the XHV chamber adapted arm configurations. Chambers are going to get vacuumed to 10^{-6} Pa before the launch and get sealed with the moving parts of the arms. The material of the units is chosen to be Aluminum for obtaining mass efficiency. Two COTS Residual Gas Analyzers (RGAs) are going to be used for ionized particle count, thus the mass spectrometry of the contaminants within the lab units. Sample material is chosen to be 1 g Copper for the demonstrations and it is covered with the spring-closed doors in both lab units. Experiments have 3 phases: At the initial phase, the outgassing data from the lab material is going to be obtained from Lab-N while the Lab-Z that has a zeolite-covered area inside collecting the data from the same sample material, which is not going to operate in this case. After the first 24 hours passes with the first phase, seals are going to be closed again for decreasing the pressure to the XHV levels. In the second phase of the experiment, the outgassing rates of the released gasses are calculated through locking/closing the outer XHV valve of the lab-N and opening the connector valve between the lab units. By sampling two RGAs in another 24 hours, second phase of the experiment is going to be finalized. At the end of the second phase, both lab units are prepared for the next experiment by opening valves and closing up once more and closing the connector valve. Final phase is going to start when the zeolite-covered sample is opened up for the experiment. Each of the experiments lasts a day, and after completion of two

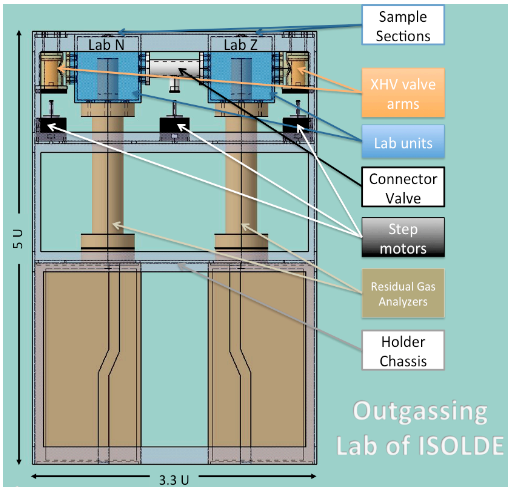


Figure 2: Payload of ISOLDE.

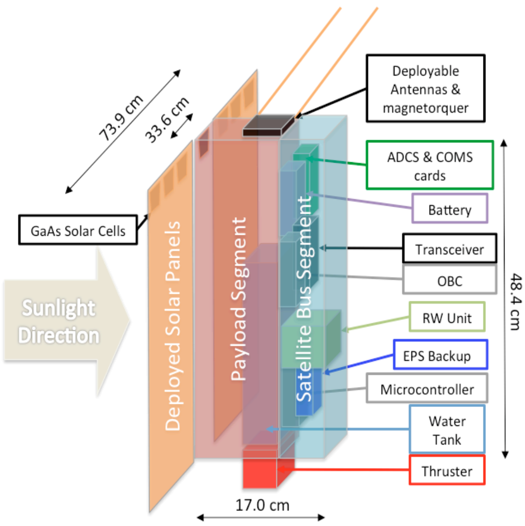


Figure 3: Subsystems and allocations.

successive rounds of experiments the mission will be completed. RGAs are the compact measurement instruments that each has its own AC/DC adapter works with 24 V.

ADCS: Maintaining necessary pointing accuracy for the healthy communication with the ground station is the first concern of the attitude determination and control system. Furthermore, the system needs to be effective and small considering respectively the limited power and mass budgets. In order to generate necessary power for the payload and to neglect the eclipse time in LEO, ISOLDE will open deployable cell panels when orbiting its 6-6 Sun-synchronous orbit (SSO). Hence, sun-pointing vector is needed to stabilize in the normal axis direction of solar panels by a magnetorquer. Attitude determination system consists of 6 sun sensors (5 coarse, 1 fine), a magnetometer and 2 gyroscopes.

EPS: For the power generation, 32 GaAs solar cells are going to be used from the deployed solar panel of ISOLDE. A commercial Lithium-polymer battery is selected for the power supply.

C&DH: The control system of the spacecraft relies on the received data decoding and transmitted data encoding without bit errors. COTS CubeSat computer is selected by trade-off studies as OBC that is radiation hardened and precaution techniques implemented in order to prevent SEUs and SELs. A commercial 16-bit microcontroller platform has been chosen for the subsystem housekeeping. Power consumption and complexity factors are minimized and the performance reliance is thought to be improved by software solutions. Reed-Solomon coding is going to be used and the transmitted data is going to be encrypted.

Propulsion: Propulsion subsystem is considered for de-orbiting phase, to prevent adding the number of on-orbit debris collection. A commercial CubeSat propulsion unit that performs on-orbit electrolysis of water to generate oxygen and hydrogen propellants to feed its bipropellant thruster is considered. [2] Water amount to be produced the propellants is determined as 2.266 kg in order to achieve necessary ΔV to de-orbit spacecraft. The water tank is placed between the RGAs of the payload to balance the spacecraft more effectively by ACS.

Telecommunication: Due to the polar orbit of the ISOLDE within the LEO altitude limits, data relay communication architecture is preferred. UHF band is selected for the uplink VHF band is selected for the downlink. Only the Istanbul Technical University's ground station is going to be used, hence point-to-point data relay communication architecture needs a transmitter, a receiver and an antenna that can be found in the market for CubeSats. For the pointing omnidirectional cable antenna, it is possible to integrate magnetorquer. Hence the antenna base is

Table 2: Link budget of ISOLDE.

Link Budget of ISOLDE	*UHF band downlink*	*VHF band uplink*
Frequency [GHz]	**0,44**	**0,125**
EIRP [dbW]	2,36	14,02
Transmitter Power [W]	1,50	2,20
[dBW]	1,76	13,42
Transmit Antenna Gain [dBi]	0,00	0,60
Transmitter Line Loss [dB]	-1,00	-1,00
Transmit Antenna Pointing Loss [dB]	0,00	-9,26E-07
Free Space Path Loss [dB]	**-142,21**	**-131,28**
Atmosphere Absoption Loss [dB]	**-0,17**	**-1,00**
Polarization Loss [dB]	**0,00**	**0,00**
Other Loss [dB]	**0,00**	**0,00**
G/T	**-22,81**	**-23,41**
Receive Antenna Gain [dBi]	0,60	0,00
Receiver Line Loss [dB]	0,01	0,01
Receiver Antenna Pointing Loss [dB]	-9,26E-07	0,00
System Noise Temperature [dBK]	-23,42	-23,42
Carrier-to-Noise Density Ratio	**64,51**	**86,28**
Required Carrier-to-Noise Density Ratio [dB]	**56,82**	**56,82**
Required E_b/N_0 [dB]	5,50	5,50
Implementation Loss [dB]	3,00	3,00
Data Rate [kbps]	2,40	2,40
[dB-Hz]	36,81	36,81
Margin [dB]	**1,64**	**23,40**

Table 1: Temperature ranges of ISOLDE.

Subsystem	Min. Temperature (°C)	Max. Temperature (°C)
Payload	+125	+125
ADCS	-20	+50
Battery(s)	-10	+40
Antenna(s)	-30	+70
Receiver	-20	+50
Transmitter	-20	+50
OBC	-40	+85

going to be put on the top of the ISOLDE originating the center of mass. Link budget of ISOLDE is given in table 1.

Thermal Control: 6-6 SSO with three-axis stabilization is a challenge for the thermal control subsystem as the solar panel section continuously illuminated and shadowed parts of the structure will lack the radiation heating during the whole mission. The sample material within the payload tank is going to be heated up to 125°C and the temperature is going to be stabilized during the experiments. Therefore, flexible Kapton® flexible

heaters are going to be used for heating up the colder sides of both payload and spacecraft. Temperature ranges of the subsystems and payload are given in table 2.

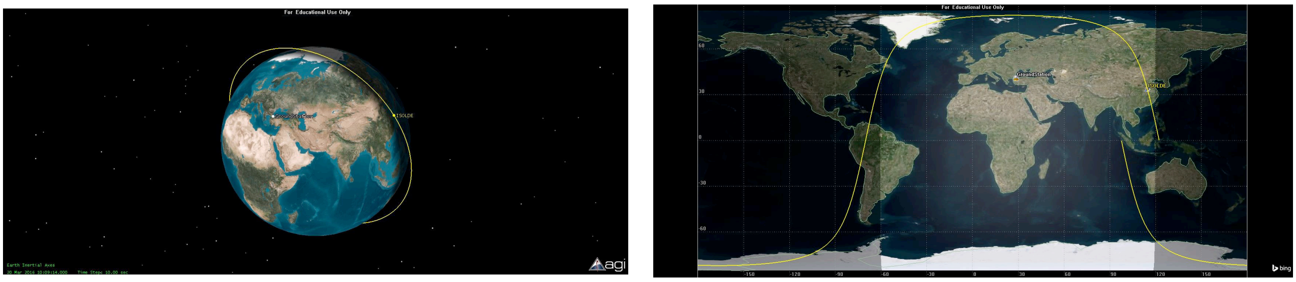
Structure & Mechanisms: As a microsatellite, ISOLDE, has got 33.6 x 48.4 x 17 cm dimensions and weighs 29 kg. Structure of ISOLDE is designed with two segments: Payload segment is going to hold the payload chassis and has deployable solar cell plates on it, and the bus segment which is 0.6 U prolonged version of the spacecraft is going to carry the subsystem units.

Table 3: Mass and power allocations of ISOLDE. [3, 4]

Subsystem on-orbit dry mass allocation	Percentage	Allocated mass [kg]	Percentage	Allocated power [W]
Structure and Mechanisms	20	5.81	5	1.95
Thermal Control System	8	2.32	33	12.87
Attitude Determination and Control System	9	2.61	11	4.29
Power System	16	4.65	2	0.78
Cabling	3	0.87	-	-
Propulsion System	5	1.45	4	1.56
Telecommunication System	4	1.16	30	11.70
Command and Data Handling	4	1.16	15	5.85
Payload	31	9.00	-	120
Total	**29.03 kg**		**39.01 W (Without payload)**	
Margin	**14.52 kg**		**31.21 W**	
Maximum	**50 kg**		**138.48 W**	

Orbit/Constellation Description

Sun-synchronous orbit allows the continuous absorption of the sunlight in which the dependability of the satellite on battery decreases, consequently S/C mass decreases as well. Apart from power access, the de-orbit phase is the most prominent factor that should have taken into account.



(a) (b)

Figure 4: Sun-synchronous polar LEO of ISOLDE. (a) 3D view of the orbit, (b) World map view.

Primarily, the orbit is chosen at a higher altitude to test the materials in a XHV environment. However, due to excessive fuel consumption and lack of a comprehensive de-orbit plan, a high altitude orbit was discarded. In this way, the mass of S/C has kept at lowest level to reduce the final cost by preserving XHV condition that is applicable for the altitudes higher than 640 km. The resulting circular orbital parameters are 98.18° of inclination, 90.4° of RAAN and 700 km of altitude.

Implementation Plan

Design of the project ISOLDE will be held by Aeronautical Engineering students, and Metallurgy Engineering students will accompany with the payload design. Space Systems Test and Integration Lab. of ITU has the capability to design and to conduct tests of a microsatellite. Thermal vacuum chamber tests can be demonstrated in the same facility, and other tests such as impact and vibration tests can be completed by various engineering laboratories of ITU. The sensors used as subsystem devices can be found COTS. As the need for astronomical observations in deep space increases, the more sensitive optical materials are going to be needed. Moreover, the performance of sensors and electronics are needed to manufacture out of the outgassing limits, which currently stops the further developments. Hence, the companies are going to demand the material improvement techniques like zeolite usage and its in-situ data so as to provide deep space missions in the near future. The project will be sponsored by such high-technology developing companies and institutions in co-operation.

Table 4: Project timeline.

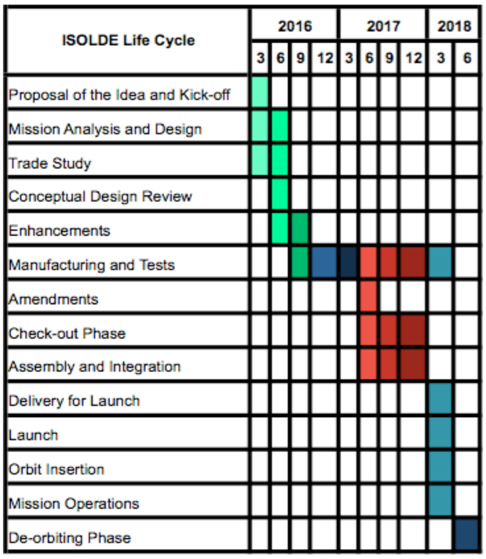


Table 5: Estimated costs of the project.

Component	Estimated Cost [$]	Remarks
Equipment	**305,000**	**Including margin**
Structure & Mechanism	15,000	
Thermal Control System	5,000	
Attitude Determination and Control System	15,000	
Power System	120,000	
Propulsion System	35,000	
Telecommunication System	22,000	
Command and Data Handling	7,000	
Payload	25,000	
Manufacture	**100,000**	**3 models to manufacture**
Tests	**100,000**	**Held in ITU**
Personnel	**888,000**	**20Stu,x800$ + 6Prof,x3500$ for 24m**
Operations	**30,000**	**May increase by other GS usage**
Utilities	**100,000**	**For back-up utilities**
Other	**200,000**	**For unpredictable costs**
Total	**1,723,000**	
Total with Launch	**3,723,000**	**Approximate (transfer costs included)**

Project Risks

1. Any malfunction of ADCS system can be resulted in telecommunication loss or experiment failure due to lack of power generation.
2. Any possible leakage from the water tank can be hazardous for the payload electronics and spacecraft hardware.
3. X-ray emissions in space are negatively affecting the quality of the mass spectrometry experiments.
4. Any launch delay can increase the cost of the project.

Two times sampling and radiation studies before the lunch would provide to minimize the x-ray risk affecting the mission's qualification. Stringent outgassing procedures at the ground tests would increase the experiment efficiency and decrease the leakage risks.

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