Université de Liège
Le Recteur

February, 11th 2016

Mrs Elke Sleurs
Secretary of State for Scientific Policy
North Galaxy
Bd du Roi Albert II 33/1
1030 Brussels

Dear Madam Secretary of State,

OUFTI-1 is the educational nanosatellite developed, built, and tested at the University of Liège (ULg) by several generations of students. The project was initiated on 18 September 2007 by Prof. Jacques Verly from our School of Engineering. At the end of 2013, the European Space Agency (ESA) selected OUFTI for inclusion in its new, pioneering, educational "Fly Your Satellite!" (FYS) program, together with a handful of other European nanosatellites. We learned today that ESA conditionally cleared OUFTI-1 for imminent launch, together with two other educational satellites (from Danemark and Italy). The project is followed closely by Belspo.

OUFTI-1 is, first and foremost, an educational project. About forty-five (45) students designed and built this advanced satellite from scratch, providing them invaluable hands-on experience in a complex, multidisciplinary project. OUFTI-1 is a CubeSat (a concept initiated at Stanford University in the USA), i.e. satellite of 1 dm3 and 1 kg, powered with a few watts. The OUFTI-1 main payload is a D-STAR repeater operating on amateur radio frequency bands. D-STAR is one of the most sophisticated amateur radio digital communication protocols, capable of transmitting voice and date simultaneously. OUFTI-1 will be the first satellite to feature D-STAR in space.

OUFTI-1 will operate in the amateur-satellite service. The frequency bands were chosen in conformity with the Table of Frequency Allocations of the Radio Regulations.

Downlink is in the [144-146] MHz band, where amateur-satellite service has a primary status worldwide. Frequencies have been coordinated with regard to other amateur and amateur-satellite services by IARU.

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Uplink is in the [435-438] MHz band, where amateur-satellite service has a secondary status worldwide. Uplink will be sporadic (with a probable maximum of four times fifteen minutes per day), directional (towards OUFTI-1 when visible from the ground station), and within an amateur band (435 MHz).

In accordance with the law of 17 September 2005 about launch activities, flight operations, and space objects guidance, the University of Liège hereby requests to be allowed to fly and operate in space the OUFTI-1 CubeSat under Belgian jurisdiction.

We would appreciate it if you could start, as soon as possible, all the necessary administrative and legal procedures so that OUFTI-1 can be launched on the date that will be specified by ESA. According to ESA planning, the launch could take place on 12 April 2016, i.e. in about two (2) months. This date should remain confidential.

We trust that you will give your full, timely support to this new phase and last phase of the OUFTI-1 project (i.e. launch and operation in space), so that generations of students can finally see their dream becoming very a reality!

Sincerely yours,

Pr. Albert CORHAY

OUFTI-1 Environmental Impact Assessment

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RECORD OF REVISIONS

Iss/Rev	Date	Author	Section/page	Change description
1/0	11/02/2016	X.Werner, S. De Dijcker	All	Initial issue

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1. ACTIVITIES AND OBJECTIVES

1.1. PROJECT DESCRIPTION

OUFTI-1 is the first Belgian student satellite. It has been developed at the Université de Liège (ULg), in collaboration with four other institutions of higher learning, i.e. two industrial engineering schools (HEPL-ISIL and HELMO-Gramme), one computer-science school (HEPL – INPRES), and the University of Louvain (UCL). The aim of this educational project is to provide hands-on experience to students in the design, construction, test, and operation of complete satellite systems.

OUFTI-1 is a CubeSat, which is a cube-shaped satellite with a size of 10x10x10 cm^3 and a weight of about one kilogram. The key, innovative feature of OUFTI-1 is its payload: the D-STAR digital radio communication (sub)system. OUFTI-1 consists of a single spacecraft. The satellite launch mass is less than 1 kg. The mission lifetime is one year from the launch date.

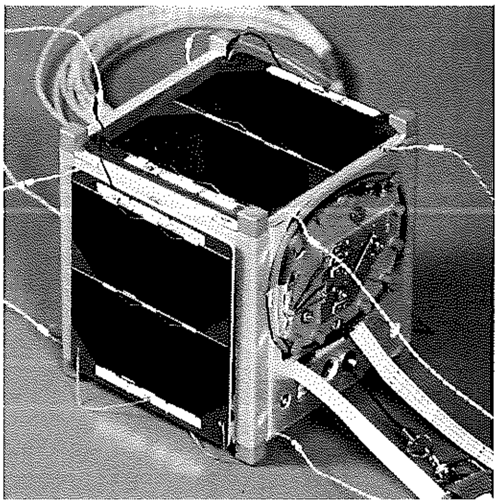

Figure 1-1: OUFTI-1 CubeSat.after integration (not in its flight configuration)
(© ULg - Jean-Louis Wertz 2013.)

The OUFTI-1 project has been selected by ESA to be part of the 'Fly Your Satellite!' Program. Therefore, the spacecraft design has been reviewed and successfully tested in collaboration with ESA experts.

Fly Your Satellite! (FYS) is an educational program whose main, but not only, focus is the verification campaign of CubeSats built by university students – a phase with high learning value for the students. The program was kicked off with the help of six CubeSat teams selected in June 2013. The program aims at offering students the opportunity to benefit from the transfer of technical competence and experience from ESA specialists. In addition, by teaching best practices for spacecraft design, development and verification, the program aims at increasing the CubeSats' chances for mission success. From the 6 selected teams, only 3 are still in the program: e-st@r-II from the Politecnico di Torino in Italy, AAUSAT4 from the Aalborg University in Demark and OUFTI-1 from the Université de Liège in Belgium.

ESA has selected a launch opportunity: it will take place along SENTINEL-1B(ESA) and MICROSCOPE(CNES) using a Soyuz rocket on 22 April 2016, operated by the launch service provider Arianespace. The launch base is located in Kourou, French Guiana.

1.2. SOYUZ LAUNCH VEHICLE

1.2.1. General overview

The Soyuz LV operated at CSG is the most recent of a long line of Soyuz family vehicles that taken together, are acknowledged to be the most frequently rockets launched in the world. Vehicles of this family, that launched both the first satellite (Sputnik, 1957) and the first man (Yuri Gagarin, 1961) into space, have been credited with more than 1780 launches to date. As the primary manned launch vehicle in Russia and the former Soviet Union and as one of the primary transport to the International Space Station, the Soyuz has benefited from these standards in both reliability and robustness. The addition of the flexible, restartable Fregat upper stage in 2000 allows the Soyuz launch vehicle to perform a full range of missions (LEO, SSO, MEO, GTO, GEO, and escape).

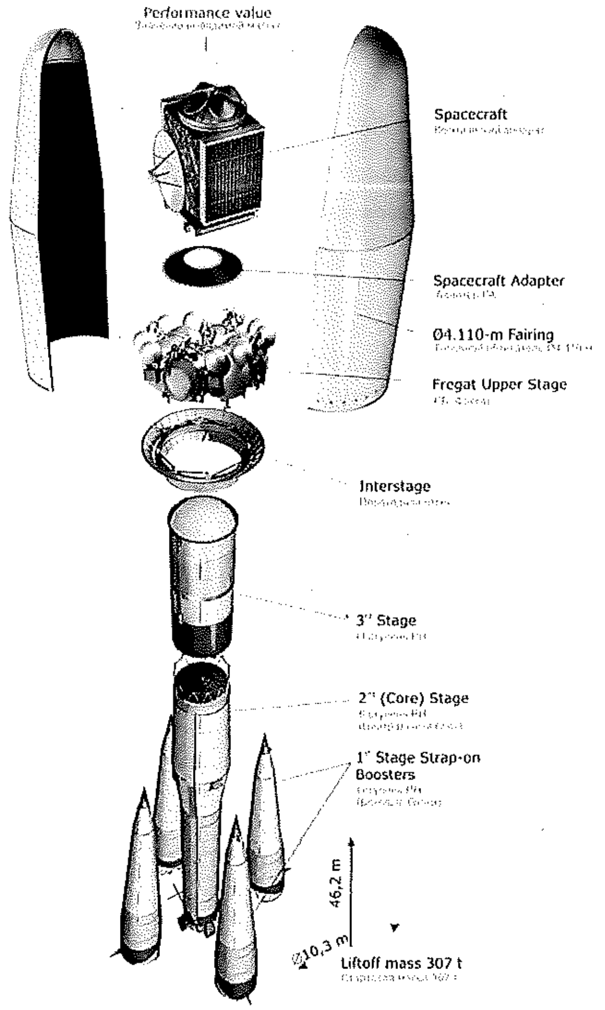

Figure 1-2: Soyuz Launch Vehicle

The Soyuz LV consists primarily of the following components:

- A lower composite consisting of four liquid-fueled boosters (first stage), a core (second) stage and a third stage;
- A restartable Fregat upper stage;
- A payload fairing and intermediate bay; and
- A payload adapter/dispenser with separation system(s). Depending on the mission requirements, a variety of different adapters/dispensers or carrying structures may be used.

The Soyuz configuration and relevant vehicle data are shown in Figure 1-2.

1.2.2. Mission profile

A typical Soyuz mission includes the following three phases:

- Ascent of the Soyuz three-stage;
- Fregat upper stage flight profile for payload(s) delivery to final orbit(s); and
- Fregat deorbitation or orbit disposal maneuvers.

A typical ascent profile is depicted on Figure 1-3.

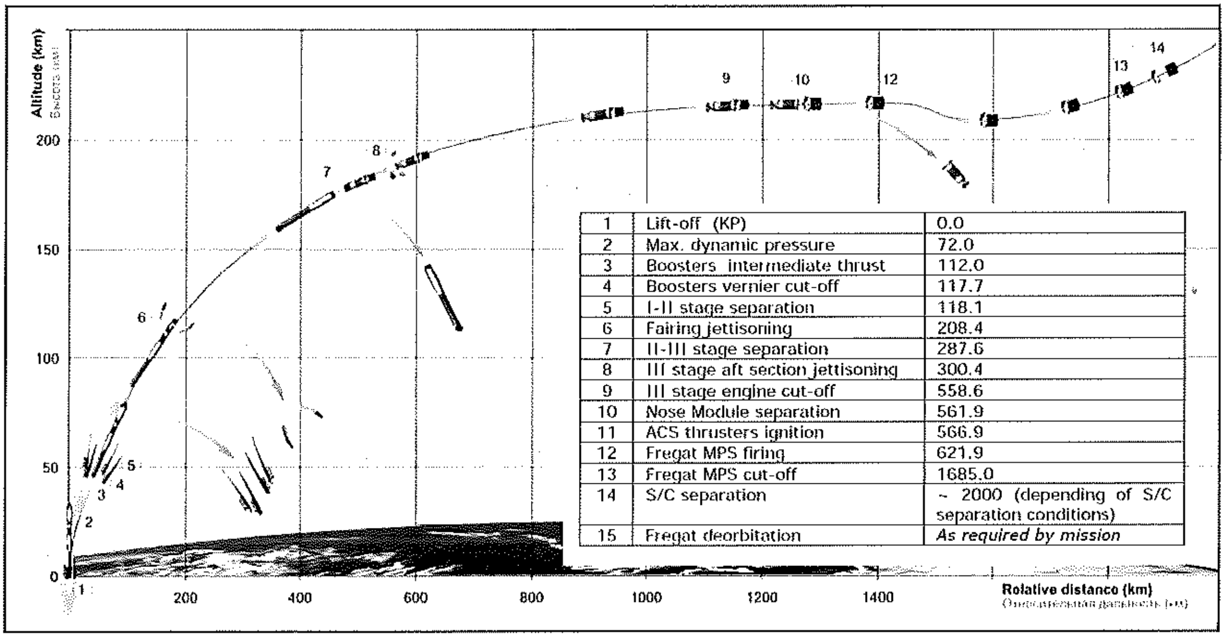

Figure 1-3: Soyuz typical ascent profile

1.2.1. Soyuz reliability

The table hereunder shows the information on Soyuz reliability. Reliability figures are presented individually for the lower three stages of the vehicle and for the Fregat upper stage. To provide the most relevant data, these reliability figures correspond to the flights performed in the past 20 years with Soyuz U, Soyuz FG and Soyuz 2 as these configurations have the same heritage.

COMPONENT/VEHICLE	SOYUZ	FREGAT UPPER STAGE
TIME FRAME	1991-2011	2000-2011
NUMBER OF FLIGHTS	261	28
NUMBER OF FAILURES	5	0
FLIGHT SUCCESS RATE (%)	98.1	100

1.3. ARIANESPACE

Arianespace is a French joint stock company ("Société Anonyme") which was incorporated on 26 March 1980 as the first commercial space transportation company.

Arianespace is the international leader in commercial launch services and today holds an important part of the world market for satellites launched to the geostationary transfer orbit. From its creation in 1980 up to end 2011, Arianespace has successfully performed over 204 Ariane launches. In 2011, Arianespace performed successfully the two first Soyuz launches at the Guiana Space Center. In parallel, Arianespace continues the Soyuz commercial operations started in 1999 at Baikonur by its affiliate Starsem holding as of end 2011 a record of 24 successful launches. Arianespace signed contracts for more than 300 payloads with some 80 operators/Customers. Arianespace provides each Customer a true end-to-end service, from manufacture of the launch vehicle to mission preparation at the Guiana Space Centre and successful in-orbit delivery of payloads for a broad range of mission.

1.4. CONCLUSION

The Soyuz launch vehicle has an excellent technical success rate and a proven track record with an excellent launch reliability. The launch service provider Arianespace has a credible customer oriented reputation. For these reasons, the ESA and the Université de Liège are confident that the launch of OUFTI-1 will be a success.

2. POTENTIAL IMPACT OF THE ACTIVITIES ON THE TERRESTRIAL ENVIRONMENT, THE ATMOSPHERE AND THE NATURAL AND HUMAN ENVIRONMENT OF THE PLACE OF LAUNCHING

The environmental monitoring program of Soyuz of Centre National d'Etudes Spatiales - Centre Spatial Guyanais (CNES/CSG) defines the environmental study monitoring points. Throughout the text hereunder, the different monitoring points will be highlighted, together with an assessment of the potential impact of the launch activity and the measures taken to minimize the eventual impact on the environment.

2.1. ON THE GROUND

Continuous environmental monitoring of all the environment components is performed at Kourou launch base but also in the cities of Kourou and Sinnamary during the Soyuz launch vehicle pre-launch preparation.

The environment impact assessment is made with respect to the following factors:

- Emission of harmful chemical substances;
- Electromagnetic effect;
- Ozone-depleting effect;
- Acoustic effect;
- Mechanical contamination of the Earth's surface.

The most serious problems that may arise during the Soyuz launch vehicle operation and launch are related to emission of harmful chemical substances. Based on the previous assessments and operating experience, the electromagnetic and acoustic effects, mechanical contamination of the Earth's surface and near-earth outer space pose much lower environmental risks.

Samples are taken continuously before, during and after the launch to verify that no toxic agents that may be created due to the launch, are found in the air.

2.2. ON THE LAUNCH SITE

The Soyuz launch site for OUFTI-1 flight is located at the CSG in French Guiana near the city of Kourou. This spaceport is managed by CNES and ESA. In the framework of the environmental monitoring program, the following environmental samples are taken:

- Measurements of air quality: monitoring the impact of all products of combustion (passive sensors, adaptive air analyzers to revenue from Soyuz, etc.),
- Measures of Soil Quality: monitoring the penetration of pollutants in the soil, study of deposits on the ground, monitoring of fauna and flora,
- Measuring the water quality of nearby creeks (automatic samplers, piezometers),
- Vibration and acoustic measurements,
- Monitoring of the vegetation,
- Monitoring of birds, fish fauna and aquatic invertebrates.

The facility is in compliance with the ISO Standards ISO 14001 and ISO 9001. ISO 14001 is a globally recognized management system standard for environmental impact assessment. It is an instrument to identify and control the effects of a company and its activities on the environment. It consists of an environmental policy, an environmental plan, an implementation plan, corrective and monitoring actions and management review. By applying a policy based on the continuous protection of the ecosystem around the space center, each launch are ensure to have only a limited impact on the environment.

More information about the environment impact are available on the CSG, Arianespace and CNES websites.

3. Potential impact on outer space

Since the Fregat conducts a deorbitation or orbit disposal maneuver, no adverse effect of the Soyuz launch vehicle on the outer space occurs because of the launch profile.

Analyses show that OUFTI-1 will re-enter the atmosphere within the 25-years limit and that no fragment will survive, thus, there is no impact on outer space either.

4. CONCLUSION

As shown in this document, Arianespace uses an environmental monitoring program ensuring both the safety and the security of the launch activity and reducing, to the maximum extend, the potential negative impact of the launches on the environment

Nevertheless, launching space objects into outer space is never without risks and especially potential negative impact on the environment can never be completely excluded. We think however the environmental impact has been assessed and has been analyzed.

For the OUFTI-1 project, which has limited budget, this launch opportunity that the European Space Agency offers us, is a hope for all the students (48) that have been involved in the project to see their achievement be placed in orbit!

ANNEX 1: FYS CUBESAT ORBIT PARAMETERS

semi-major axis, km	a G(Γ)	6936.9
eccentricity	e G(Γ)	0.01523
inclination of the orbit plane, deg	I G(Γ)	98.22
longitude of the ascending node, deg	Ω G(Γ)	314.58
argument of perigee, deg	ω G(Γ)	242.33
true anomaly, deg	υ G(Γ)	358.48

Annex 2: OUFTI-1 Testing and Documentation Overview

1 Functional & Mission Tests

After assembly and integration, several Functional Tests (November 2013) and a Mission Test (December 2013) were performed at system level to verify the good functionality and performance of OUFTI-1 in laboratory conditions. The tests were performed at the University premise by the students and reported to the ESA Education Office.

After the review of the delivered documentation and test results, at the end of January 2014, the ESA CubeSat Evaluation Board, consisting of ESA specialists, decided to accept OUFTI-1 to the second Phase of the Fly Your Satellite! (FYS) programme.

2 Environmental Testing Campaign

As part of the Phase 2 of the Fly-Your-Satellite! programme, environmental tests were performed on the CubeSat to verify its functionality in launch and space representative conditions.

2.1 Thermal Vacuum Test

A thermal vacuum test campaign was performed at ESTEC from 18 to 30 September 2014.

- Four cycles of alternating hot and cold temperatures were performed with the target temperatures as per Table 1 and shown in Figure 1
- Test operator: ESA personnel
- The test was executed by two experienced students from the OUFTI-1 student team, under direct supervision of ESA specialists
- Test preparation, execution and reporting following procedures in ESA Education Fly-Your-Satellite! programme, tailored from ECSS standard
- Functional tests were performed before, during and after the Thermal Vacuum test to assess the good functionality of the satellite
- Thermal Vacuum Test Report and Minutes of Post Test Review can be provided upon request

Cycle	Number of Cycles performed	Low Target Temperature (EPS)	High Target Temperature (EPS)
Non-operational	1	-28 °C	-28 °C
Operational	3	+63 °C	+63 °C

Table 1: Target Temperatures TV/TC OUFTI-1 (EPS = Electrical Power System)

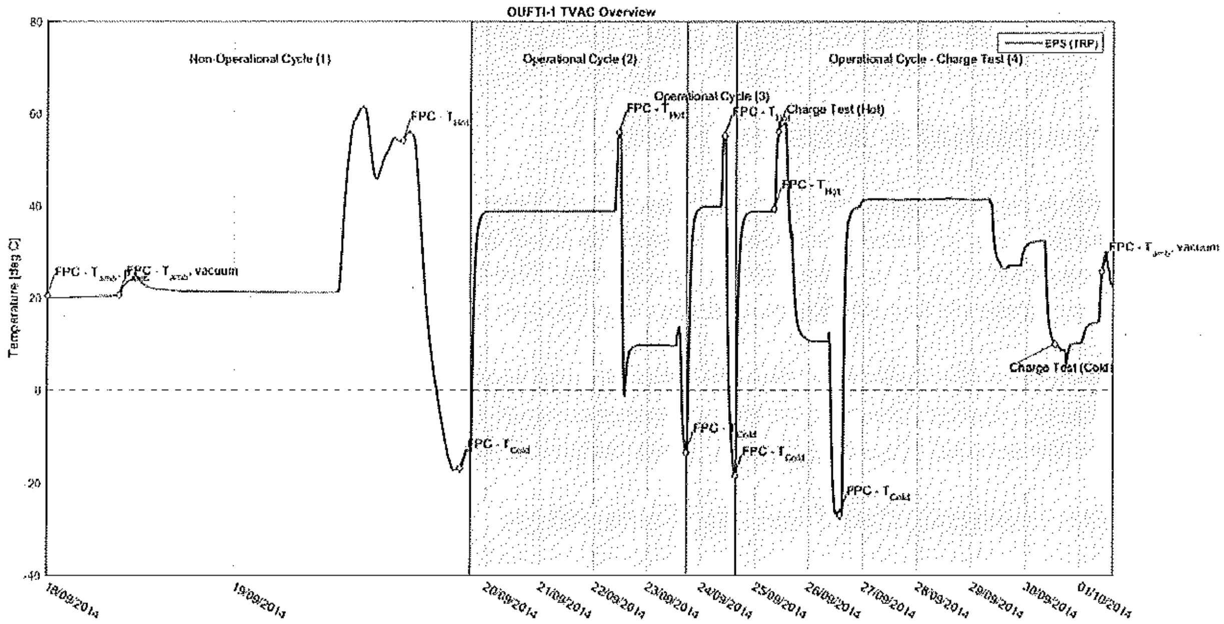

Figure 1: OUFTI-1 Thermal Vacuum/Thermal Cycling Overview

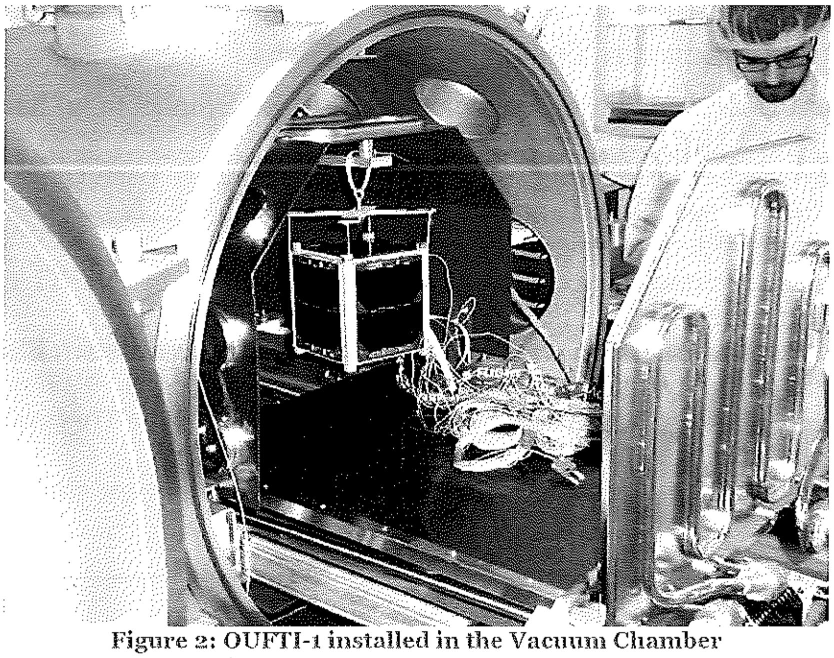

Figure 2: OUFTI-1 installed in the Vacuum Chamber

2.2 Vibration Test

The Vibration Test campaign was performed in two parts. The first part included only the Random Vibration Test and was performed at ESTEC from 10 to 12 March. The second part included the High Level Sine and Quasi-static Acceleration tests and was performed at V2I in Liege.

- The campaign consisted in a High Level Sine test (levels/durations in Table 2), a Quasi-Static Acceleration test (Table 3) and Random Vibration test (Table 4). All the tests were alternated with Low Level Sine tests to verify no changes in

eigenfrequencies occurred. The tests were performed on all three axes of the CubeSat.
- Test operator: ESTEC personnel in the first part of the campaign and V2I staff in the second part of the campaign
- Test executed by OUFTI-1 student team members under direct supervision of ESA specialists
- Test preparation, execution and reporting following procedures in ESA Education Fly-Your-Satellite! programme, tailored from ECSS standard
- Functional tests were performed before the start and after the ending of the Vibration Test campaign to assess the good functionality of the satellite
- Vibration Test Report and Minutes of Post Test Review can be provided upon request

Frequency [Hz]	Amplitude [g]
5 – 6	1.5
7 - 100	2.5
100 – 125	1.25
Sweep rate	**4 oct/min**

Table 2: OUFTI-1 - Sine Vibration

Quasi-static	Protoflight
Direction	X, Y, Z
Amplitude	10.8 g
Method	Test

Table 3: OUFTI-1 - Quasi-static Acceleration

Frequency [Hz]	Levels [g^2/Hz]
20	0.0113
50	0.0113
100	0.0225
200	0.0563
500	0.0563
1000	0.0225
2000*	0.0113 → notched to: 0.00003*
G_{RMS}*	**7.42 → after notching: 6.48**
Duration	**2 min/axis**

Table 4: OUFTI-1 Random Vibration

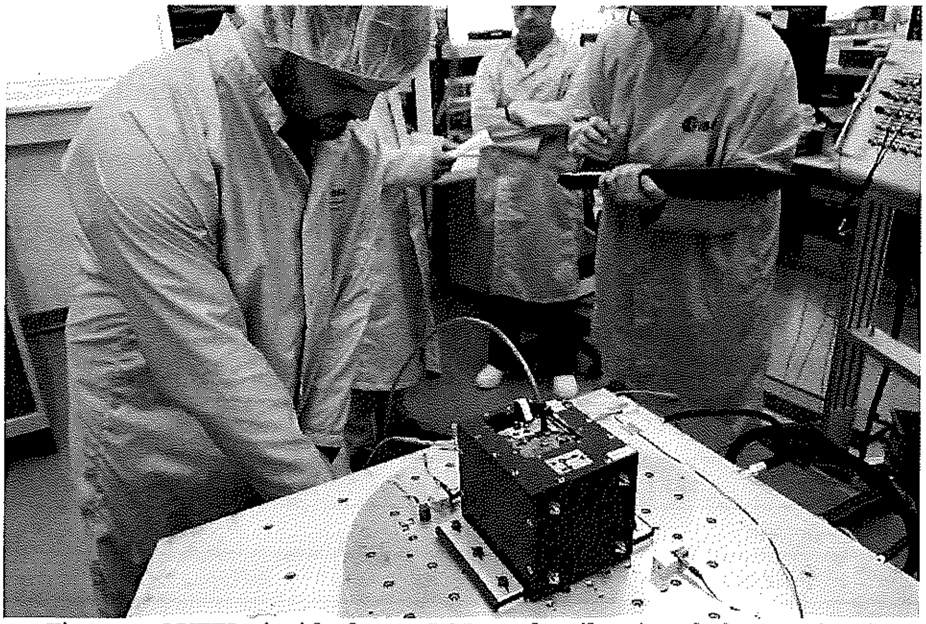

Figure 3: OUFTI-1 inside the testPOD on the vibration shaker at ESTEC

3 Documentation Overview

The following data package, tailored from the ECSS standard, were submitted and regularly updated by the team and reviewed by ESA specialists.

- Mission Description Document
- CubeSat Design Description
- System Specification Document
- Assembly & Integration Report
- Test Plan (functional and environmental tests)
- Test Specification (functional and environmental tests)
- Test Procedure (functional and environmental tests)
- Test Report (functional and environmental tests)
- Verification Control Documents
- User Manual
- Requests for Deviation
- Requests for Waiver
- Non Conformance Reports
- Space Debris Mitigation Document, incl. re-entry/casualty risk analysis
- Declared Material List
- Limited-Life Item List
- Finite Element Analysis
- Battery Logbook
- Registration Status Report
- Outreach Planning Document

Annex 3: Assessment of the compliance of OUFTI-1 with the Space Debris Mitigation requirements (ESA/ADMIN/IPOL(2014)2)

Req. Id. (see Note 1)	Requirement Text	Compliance Status (see Note 3)	Recommendations for Compliance with the Requirement (see Note 3)
6.1.1.1	*Spacecraft and launch vehicle orbital stages shall be designed so as not to release space debris into Earth orbit during normal operations.*	C	
6.1.1.2	*Space debris released into Earth orbit as part of normal operations, other than as covered by 6.1.2, shall remain outside the GEO Protected Region, and its presence in the LEO Protected Region shall be limited to a maximum of 25 years after release.*	C	
6.1.1.3	*If space debris are released into Earth orbit during normal launch operations, then the number of space debris released, other than those covered by 6.1.2, shall not exceed:* *a. One, for the launch of a single spacecraft.* *b. Two, for the launch of multiple spacecraft.*	C	Note: It is understood that the cubesat will be co-passenger with Sentinel-1B on Soyuz VS14, launched from Kourou, French Guiana. No further information available about the launch phase.
6.1.2.1	*Pyrotechnic devices shall be designed so as to avoid the release into Earth orbit of products larger than 1 mm in their largest dimension.*	NA	Note: No pyrotechnic devices.
6.1.2.2	*Solid rocket motors shall be designed and operated so as to avoid releasing solid combustion products larger than 1 mm into the GEO Protected Region.*	NA	Note: No propulsion systems.
6.1.2.3	*In the design and operation of solid rocket motors, methods to avoid the release of solid combustion products that might contaminate the LEO Protected Region shall be considered.*	NA	Note: No propulsion systems.
6.2.1	*In Earth orbit, intentional break-up of a spacecraft or launch vehicle orbital stage shall be avoided.*	C	Note: No intentional break-ups foreseen.
6.2.2.1	*The probability of accidental break-up of a spacecraft or launch vehicle orbital stage shall be no greater than 10^{-3} until its end of life.*	NV	The Project plans end of life of the cubesat at re-entry epoch (8.5 years from launch). No quantitative assessment of the in-orbit break-up risk is provided. Debris generation due to battery explosion is qualitatively assessed to be unlikely based on: • Use of battery cells from well reputed manufacturer, without manufacture defects. • Battery always in allowed operational temperature range until end of life. • Pouch battery cells have a low burst pressure that is not likely to generate debris. • Cubesat structure able to contain battery debris in the event of cell failure. • Battery cells contained in a metallic box.
6.2.2.2	*The determination of accidental break-up probability shall quantitatively consider all known failure modes for the release of stored energy, excluding those from external sources such as impacts with space debris and meteoroids.*	NV	See 6.2.2.1. No information on battery cell probability of explosion is provided.

Req. Id. (see Note 1)	Requirement Text	Compliance Status (see Note 3)	Recommendations for Compliance with the Requirement (see Note 3)
6.2.2.3	*During the disposal phase, a spacecraft or launch vehicle orbital stage shall permanently deplete or make safe all remaining on-board sources of stored energy in a controlled sequence.*	NV	According to the developer, the cubesat will not have a disposal phase since end of life coincide with atmospheric re-entry. Since there is no disposal phase, there is no need for devices to make safe on board sources of stored energy (batteries).
6.3.1.1	*The probability of successful disposal of a spacecraft or launch vehicle orbital stage shall be at least 0.9 at the time disposal is executed.*	C	Note: No reliability requirement available.
6.3.1.2	*The probability of successful disposal shall be evaluated as conditional probability weighted on the mission success, i.e. P(D|M).*	C	See 6.3.1.1.
6.3.1.3	*The start and end of the disposal phase shall be chosen so that all disposal actions are completed within a period of time that ensures compliance with 6.3.1.1.*	C	Note: No disposal phase (end of life at re-entry epoch).
6.3.2.1	*A spacecraft or launch vehicle orbital stage operating in the GEO Protected Region, with either a permanent or periodic presence shall be maneuvered in a controlled manner during the disposal phase to an orbit that lies entirely outside the GEO Protected Region.*	NA	
6.3.2.2	*A spacecraft operating within the GEO Protected Region shall, after completion of its GEO disposal maneuvers, have an orbital state that satisfies at least one of the following two conditions:* a. *the orbit has an initial eccentricity less than 0.003 and a minimum perigee altitude ΔH (in km) above the geostationary altitude, in accordance with equation (1):* $\Delta H = 235 + (1000 \cdot C_r \cdot A/m)$ (1) *where:* *C_r is the solar radiation pressure coefficient (dimensionless)* *A/m is the ratio of the cross-section area (in m^2) to dry mass (in kg) of the space system* b. *the orbit has a perigee altitude sufficiently above the geostationary altitude that long-term perturbation forces do not cause the spacecraft to enter the GEO Protected Region within 100 years.*	NA	
6.3.3.1	*A spacecraft or launch vehicle orbital stage operating in the LEO Protected Region, with either a permanent or periodic presence, shall limit its post-mission presence in the LEO Protected Region to maximum of 25 years from the end of mission.*	C	Note: Re-entry foreseen in 8.5 years.
6.3.3.2	*After the end of mission, the removal of a spacecraft or launch vehicle orbital stage from the LEO Protected Region shall be accomplished by one of the following means (in order of preference):* a. *retrieving it and performing a controlled re-entry to recover it safely on the Earth, or* b. *manoeuvring it in a controlled manner into a targeted re-entry with a well-defined impact footprint on the surface of the Earth to limit the possibility of human casualty, or* c. *manoeuvring it in a controlled manner to an orbit with a shorter orbital lifetime that is compliant with 6.3.3.1, or* d. *augmenting its orbital decay by deploying a device so that the remaining orbital lifetime is complaint with 6.3.3.1, or* e. *allowing its orbit to decay naturally so that the remaining orbital lifetime is compliant with 6.3.3.1, or* f. *manoeuvring it in a controlled manner to an orbit with a perigee*	C	Note: The current baseline foresees that the spacecraft will be released in an elliptic orbit (453.15 km x 664.44 km, inclination 98.2°), which should allow the spacecraft to re-enter in less than 10 yrs by natural orbital decay.

Req. Id. (see Note 1)	Requirement Text	Compliance Status (see Note 3)	Recommendations for Compliance with the Requirement (see Note 3)
	altitude sufficiently above the LEO Protected Region that long-term perturbation forces do not cause it to re-enter the LEO Protected Region within 100 years.		
6.3.4.1	*For the re-entry of a spacecraft or launch vehicle orbital stage (or any part thereof), the maximum acceptable casualty risk shall be set in accordance with norms issued by approving agents.*	C	
6.3.4.2	*The re-entry of a spacecraft or launch vehicle orbital stage (or any part thereof) shall comply with the maximum acceptable casualty risk according to 6.3.4.1.*	C	

1. Identification of the requirement ECSS-U-AS-10C / ISO 24113:2011 as per ESA/ADMIN/IPOL(2014)2.
2. Status of planned compliance: Compliant (C), Partial Compliant (PC), Not Compliant (NC), Not Applicable (NA), To Be Clarified (TBC), Not Verified (NV).
3. Recommendations from the Technical Autority.

9808

Bureau des radiocommunications (BR)

Genève, le 17 février 2016

Réf.: 09A(SPR)O-2016-000681

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Sujet: **Renseignements pour la publication anticipée concernant les réseaux à satellite OUFTI-1**

Réf.: **Votre courrier électronique [brigitte.wayembergh@bipt.be] daté du 1 février 2016**
Votre télécopie de confirmation (référence N° 16/FRE/2013-000161-2-55054BWM/SAT/203/OUFT) datée du 1 février 2016

Madame, Monsieur,

Le Bureau des radiocommunications a l'honneur d'accuser réception de votre communication mentionnée en référence ci-dessus concernant les renseignements pour la publication anticipée pour ce qui est du réseau à satellite OUFTI-1 et procédera à son traitement. L'API /A section spéciale de ce réseau devrait être publiée dans la BR IFIC 2815 du 15.03.2016.

Veuillez agréer, Madame, Monsieur, l'assurance de ma considération distinguée,

Chuen Chern Loo
Chef a.i., Division de la Publication et de l'Enregistrement des Services Spatiaux
Département des services spatiaux