10 February 2023

English only

Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
Sixtieth session
Vienna, 6–17 February 2023
Item 7 of the provisional agenda*
Space debris

Research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris

The present document has been prepared by the Secretariat on the basis of information provided by Japan on 20 October 2022, by Mexico on 28 October 2022 and by Portugal on 22 November 2022, and contains figures and pictures related to space debris, not included in A/AC.105/C.1/123. The document is issued without formal editing.

* A/AC.105/C.1/L.405.

Replies received from Member States

[Original: English]

Japan

1. Overview

Corresponding to request from the United Nations Office for Outer Space Affairs, Japan reports the debris relating activities mainly conducted by the Japan Aerospace Exploration Agency (JAXA).

The following debris related research and developments are conducted as of October 2022. Further information is introduced in the next section.

(1) Active Debris Removal (ADR)

(2) Status of debris avoidance manoeuvres and research on core technology for Space Situational Awareness (SSA)

(3) Research on technology to observe low Earth orbit and Geostationary orbit (geosynchronous Earth orbit) objects and determine their orbits

(4) In-situ micro-debris measurement system

(5) Development of composite propellant tank

(6) Space debris observation using satellite laser ranging (SLR) and development of a general-purpose SLR reflector

2. Status

2.1 Active debris removal

JAXA has organized and structured a research programme which is aimed at realizing low-cost ADR missions. As shown in Fig.-1, the research and development of key technology for active debris removal has three major themes: non-cooperative rendezvous, capture technology for non-cooperative targets and de-orbiting technology to remove massive intact space debris. JAXA is cooperating with Japanese private companies to realize low-cost ADR on a commercial basis and working to provide these essential key technologies for that purpose.

JAXA is also leading the Commercial Removal of Debris Demonstration (CRD2) program. As shown in Fig.-2, this program comprises of two phases aimed at conducting ADR in partnership with private enterprises. During the first phase of this program, demonstration of key technologies such as non-cooperative rendezvous, proximity operation, and inspection of the H-IIA second stage are planned for Japanese fiscal year (JFY) 2022. During the second phase, demonstration of active debris removal and re-entry of the H-IIA second stage is planned after JFY 2025. Astroscale Japan Inc. was selected through an open competition in February 2020 as a partner company for phase one.

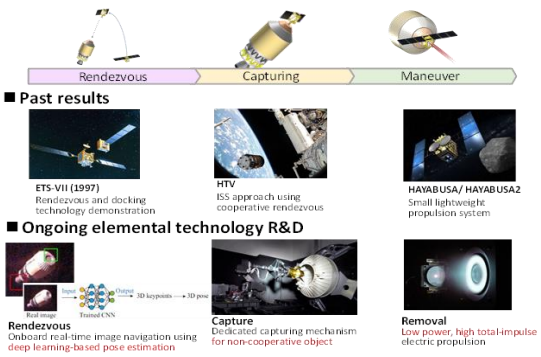


Fig.-1 Active Debris Removal research activities

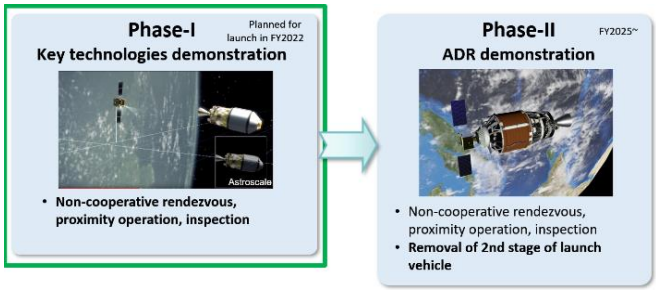


Fig.-2 Demonstration of the removal of large-sized debris in two phases

2.2 Status of debris avoidance manoeuvres and research on core technology for Space Situational Awareness (SSA)

JAXA regularly receives conjunction notifications from the Combined Space Operations Center (CSpOC). In 2021, JAXA executed two debris avoidance manoeuvres (DAM) for low Earth orbit spacecraft. As a satellite operator, JAXA has recognized that the conjunction risk posed by space debris remains high, as the space environment deteriorates year after year.

Core technology for space situational awareness (SSA)

JAXA has developed a new SSA system, which is currently in trial operation to check its performance before it goes into full operation in April 2023.

(1) Radar: JAXA has developed a new radar for low Earth orbit, which can observe 10cm class objects at 650 km altitude.

(2) Telescope: JAXA has refurbished its 1m and 50cm class telescopes to increase their capability to observe space debris in high orbit including geostationary orbit.

(3) Analysis system: JAXA has developed a new system to analyze observation data from the radar and telescope facilities, which is then used for conducting risk assessment and making a collision avoidance plan in the case of space debris approaching JAXA's satellites.

JAXA has also developed a tool to support DAM planning upon receiving a conjunction data message from CSpOC and, has made it available free of charge to all satellite operators on JAXA's website since March 2021.

This tool is expected to simplify the DAM procedure and reduce workload. JAXA will continue this activity.

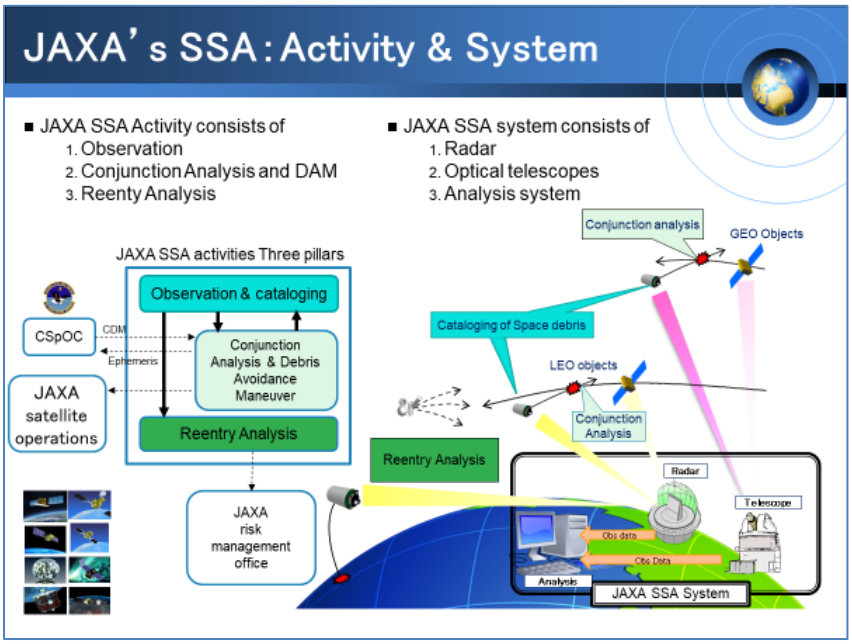


Fig.-3 Activity for SSA in JAXA

2.3 Research on technology to observe objects in low Earth and geostationary (geosynchronous) orbits and determine their orbits

Generally, the observation of objects in low Earth orbit is conducted mainly by radar system, but JAXA has been working to develop an optical system to reduce the cost for both construction and operation. A large complementary metal-oxide semiconductor (CMOS) sensor for low Earth orbit observation has been developed (Fig.-4). Analyzing the data from the CMOS sensor with field programmable gate array-based image-processing technologies enable the detection of objects in low Earth orbit measuring 10 cm or less. In order to increase the observation opportunities in relation to objects in low Earth and geosynchronous Earth orbits, two remote observation sites have been established in Australia (Fig.-5), one at the Zadko observatory (western Australia) and another one with an installation of four 18 cm telescopes at the Siding Spring observatory, in addition to the Mt. Nyukasa observatory in Japan. These observation sites will make it possible to carry out precise orbital determinations and altitude estimation of objects in low Earth orbit using the data from both sites in Australia.

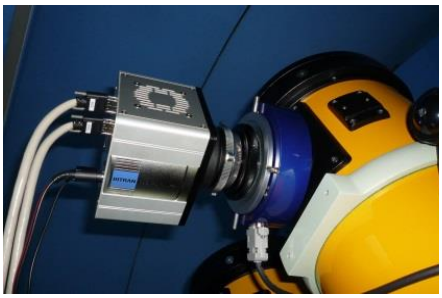


Fig.-4 The CMOS sensor manufactured by Bitran which can detect 10cm LEO objects analyzing the data with FPGA-based image-processing technologies.

Fig.-5 The remote observation sites in Australia. The left figure shows the telescope install at the Zadko Observatory (western side of Australia). The right one is four 18cm telescopes install at the Siding Spring Observatory (eastern side of Australia).

2.4 In-situ microdebris measurement system

The space debris monitor (SDM) is an in-situ micro-debris sensor focusing on micro to milli sized debris in orbit. The latest flight experiment was conducted by H-II Transfer Vehicle Kounotori 5 (HTV-5). Information based on actual measurements of those small debris is essential to properly understand the vast amount of small debris orbiting near the Earth, especially since they are becoming a dominant risk factor in orbit.

The unique properties of the SDM are its simple detection system, which does not need any special calibration before flight, and the potential to collaborate easily with other sensors. The SDM consists of a debris-detection area and circuit areas. The debris-detection area is made of very thin polyimide film and there are thousands of 50 µm-wide conductive grid lines capable of detecting the diameter of collided debris measuring from 100 µm to millimetres.

JAXA jointly collaborates with the NASA Orbital Debris Program Office to develop a new in-situ microdebris measurement system in order to understand the number of small debris objects orbiting at under 1,000 km. Series of hyper velocity impact tests are underway using a breadboard model in a cooperation between NASA and JAXA.

This composite propellant tank has a shorter delivery period and lower cost compared to a titanium propellant tank. About the demisability during atmospheric re-entry, experimental and analytical evaluation is ongoing.

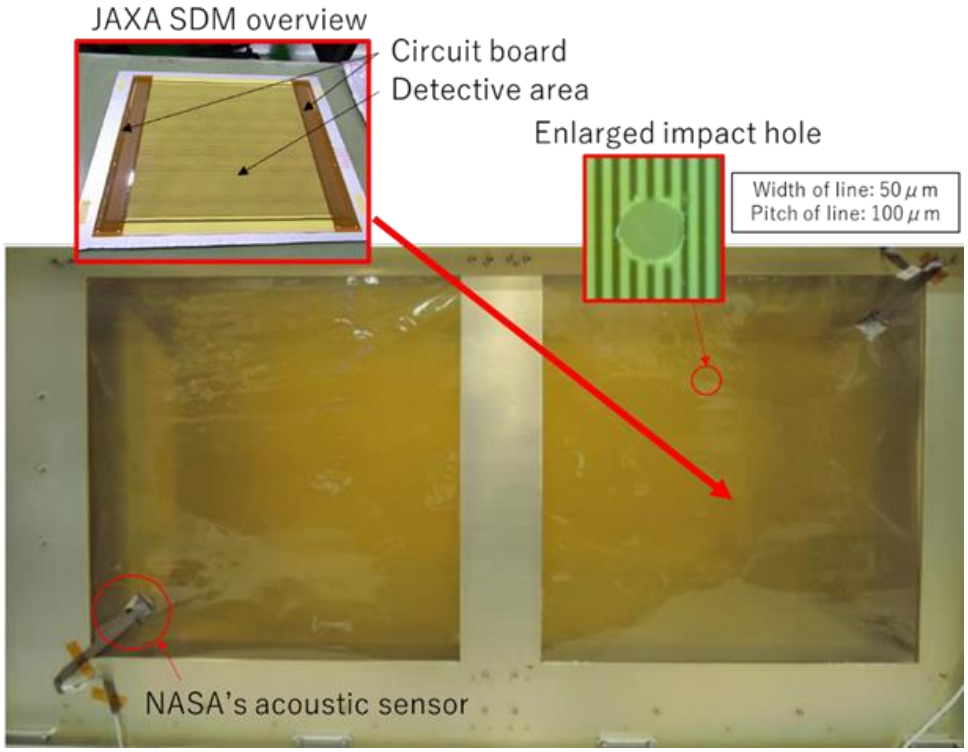


Fig.-6 JAXA SDM mounted on the test frame for HVIT

2.5 Development of a composite propellant tank

A propellant tank is usually made of titanium alloy, which is superior because of its light weight and good chemical compatibility with the propellant. However, its melting point is so high that such a propellant tank would not demise during re-entry and would pose a risk to people on the ground.

For several years, JAXA conducted research to develop an aluminium-lined, carbon-composite overwrapped tank with a lower melting temperature. As a feasibility study, JAXA conducted fundamental tests, including a liner material aluminium compatibility test with hydrazine propellant and an arc heating test.

After the manufacturing and test of a shorter sized EM-1 tank, JAXA manufactured a full-sized EM-2 tank. The shape of the EM-2 tank is identical to that of the nominal tank, which includes a propellant management device. Using the EM-2 tank, a proof pressure test, vibration test (for wet and dry conditions), an external leak test, a pressure cycle test, and a burst pressure test were conducted, and all showed good results. Subsequently, the critical design review was completed.

This composite propellant tank has a shorter delivery period and lower cost than a titanium propellant tank. Experimental and analytical evaluation of demisability during re-entry is ongoing.

Fig.-7 EM#2 tank

Fig.-8 Evaluation tests by arc heating wind tunnel

2.6 Space debris observation using Satellite Laser Ranging and development of a general-purpose SLR reflector

JAXA is focusing on SLR as the third space debris observation method after radar and telescope.

The SLR Tsukuba station is scheduled to enter into operation in April 2023.

In recent years, it has become increasingly important to improve the visibility of orbiting objects. JAXA has developed an affordable and compact SLR reflector (named Mt. FUJI) that can be universally used in low Earth orbit. JAXA will promote its application internationally to improve the trackability of on-orbit objects, thereby contributing to the sustainable use of outer space.

Fig.-9 JAXA SLR Tsukuba station and SLR Reflector (Mt. Fuji)

Mexico

[Original: Spanish]

The amount of space debris in orbit continues to grow as a result of new launches and the fragmentation of existing objects, and most potentially harmful orbital debris is not regularly monitored. Although compliance with existing space debris mitigation guidelines has improved to some extent, current compliance rates (between 40 and 60 per cent, depending on the orbital regime) are far from those needed to prevent the steady increase in debris collisions.

The growing number of small satellites, the decreasing lifetime of satellites and the possibility of creating large commercial constellations of thousands of satellites are posing new challenges. At the same time, the increase in commercial options for space situational awareness, on-orbit servicing of satellites and active debris removal could bring some benefits, although these activities present their own political and legal challenges.

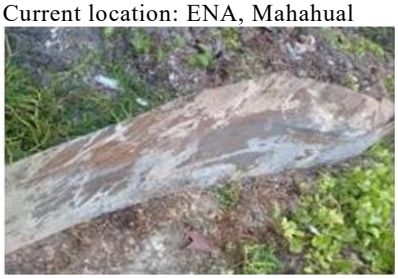
Mexico supported the initiative of Canada, Germany and the Czech Republic to create a compendium of actions to mitigate such debris, which was submitted for consideration by the Legal Subcommittee of the Committee on the Peaceful Uses of Outer Space at its fifty-third session and was the first-ever document to contain first-hand information from Member States regarding the regulatory measures they have taken to reduce and remove space debris[1].

Space debris has already fallen to Earth in Mexico, so far without causing harm to people but nonetheless posing a major risk, which the Mexican Space Agency (AEM) has begun working to address. The most recent such incident was on 25 April 2016, when space debris from the Russian spacecraft Soyuz-2-1A fell in Mahahual, Quintana Roo. In the same year and in the same place, fragments of the European spacecraft Ariane 5 were found. The necessary measures were made possible by the Quintana Roo State Civil Protection Unit and local residents[2].

[1] https://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html.
[2] https://elquintanaroo.mx/cae-basura-espacial-en-mahahual/.

Fragment No. 1
Dimensions 3 x 1 metres
Approximate weight 60 kg
Current location: ENA, Mahahual

Fragment No. 2
Dimensions 3 x 1.5 metres
Approximate weight 80 kg
Current location: ENA, Mahahual



Fragment No. 3
Dimensions 3 x 1.5 metres
Approximate weight 80 kg
Current location: ENA, Mahahual

Fragment No. 4
Dimensions 3 x 2 metres
Approximate weight 100 kg
Current location: ENA, Mahahual

Falling space debris is a reality not only in Mexico but also worldwide. A solution must be therefore sought in order to address the situation before serious consequences occur.

Accordingly, and given the importance of the issue, Mexico, through AEM, has taken steps to become a member of the IADC, and has also begun to coordinate, at the national level, activities relating to the problems of space debris.

With a view to coordinating the experience of Mexico at the national level, public and private universities have likewise undertaken the task of developing models for the identification of debris and monitoring space debris and satellite damage through observatories to ensure the safety of space infrastructure, as well as activities, research and methods that have proven effective in reducing the generation of space debris.

One such activity is the recent Colibri Mission, which is a university project aimed at helping to mitigate space debris by means of a cube satellite capable of locating, with exact coordinates, the position of space debris, to be complemented by a series of models based on gravity, atmosphere, velocity and many other variables[3].

The Colibri Mission satellite will remain in orbit for one year. It is currently in the design phase, during which the mission has been technically defined, and the implementation process is now under way.

Lastly, an indicative table showing the main activities and research being carried out by public and private universities in Mexico in relation to space debris is included in an annex at the end of the document

Portugal

[Original: English]

With space becoming more and more an important asset in many sectors, it is crucial to take care of space infrastructures in order not to compromise the operation of satellites and the services dependent on these. Space debris is one of the biggest and most serious challenges space exploration and space activities are facing, being the

[3] https://www.colibrimission.com/.

sustainability of space operations one of the Portuguese priorities, Portugal is concentrating efforts in this problem.

Through the Portuguese participation in the European Space Agency, the Portuguese industry and research centres are actively integrated in several space debris mitigation related activities. The ADRIOS – Active Debris Removal/In-Orbit Servicing programme is executed through the ClearSpace-1 mission.

The ClearSpace-1 mission, is an active debris removal mission aiming at removing a large debris from orbit in which the Portuguese industry has a major role, leading the Guidance, Navigation and Control system and the On-Board Flight Software, putting the Portuguese industry at the forefront of the in-orbit servicing technological developments.

Aiming at a zero-debris policy, Portugal is also involved, at ESA level, in the Deorbiting Kit that can be used to de-orbit satellites at the end of life as well as launcher adaptors, addressing the necessary functionalities for controlled re-entry that is now a required for numerous systems under development.

When collisions or other fragmentation events occur, more debris are created, and the problem is aggravated. To ensure continuity of space operations and access to space, space debris mitigation is imperative. ESA's CREAM – Collision Risk Estimation and Automated Mitigation programme focus on the development of techniques for automated avoidance manoeuvre decisions with Portugal developing state of the art machine and deep learning techniques enabling automated avoidance manoeuvre decisions.

Nonetheless, to take advantage of advanced tools, such as AI and machine learning while improving collision risk estimation and automated manoeuvre decisions, such as course corrections, and mitigate the space debris associated risks is necessary to have sufficient and reliable data by surveying and tracking such objects and providing this information to a variety of stakeholders. To ensure Europe's access to these data, and with the support of the European Union, the EUSST – European Space Surveillance and Tracking – has been gradually building on the tracking capabilities. With a consortium currently composed by seven countries, Portugal, through the Ministry of Defence, cooperates to the enhancement of these capabilities integrating the Portuguese sensors on the EUSST network.

Annex

Public and private universities in Mexico engaged in activities and research relating to space debris

Public universities

Projects or observatories affiliated to the International Scientific Optical Network (ISON) project:

The International Scientific Optical Network (ISON) is an international project currently consisting of 30 telescopes at 20 observatories, located in a number of countries, that are used to detect, monitor and track objects in space. The project has a presence in 50 countries and employs approximately 200 researchers.

University or research centre	*Name of institute*	*Project*	*Person responsible*	*Project description*	*Remarks*
Autonomous University of Nuevo León (UANL)	Faculty of Physical and Mathematical Sciences (FCFM)	International Observatory for Space Debris Monitoring – ISON Project	Enrique Pérez León	Under the ISON project, with the support of the UANL Observatory, a space observation network is being established for the monitoring of space debris, asteroids and even gamma ray bursts to improve understanding of the initial conditions of the universe.	The UANL Observatory was inaugurated on 7 March 2017 and has continued to operate to date. The Observatory currently forms part of the master's programme in astrophysics at FCFM, supporting research.
	http://vidauniversitaria.uanl.mx/telescopio-de-la-uanl-importante-para-proyecto-ison/ https://www.milenio.com/cultura/inauguran-observatorio-uanl-monitorear-clima-espacial				
Autonomous University of Sinaloa (UAS)	Astronomy Centre (CA)	UAS Astronomical Observatory – ISON Project	Tatiana Nikolaevna Kokina Yurova	Under the ISON project, with the support of the UAS Astronomical Observatory, a space observation network is being established for monitoring near-Earth asteroids and debris generated by space technology, obtaining images and analysing information.	The UAS observatory was inaugurated on 3 May 2012 and has continued to operate to date. In the case of UAS, monitoring-based research and analysis are conducted in collaboration with the M.V. Keldysh Institute of Applied Mathematics of the Russian Academy of Sciences.
	http://reserva.uas.edu.mx/index.php?p=2 https://www.noroeste.com.mx/buen-vivir/detecta-observatorio-de-la-uas-basura-espacial-KANO451478 https://direcciondecomunicacion.unison.mx/presentan-monitoreo-de-basura-espacial-en-aniversario-del-area-de-astronomia-del-difus/				

Projects with other affiliations

University or research centre	*Name of institute*	*Project*	*Person responsible*	*Project description*	*Remarks*
National Autonomous University of Mexico (UNAM) and Autonomous University of Nuevo León (UANL)	Institute of Astronomy (IA) and Faculty of Physical and Mathematical Sciences (FCFM)	University Programme for the Development of Astrophysics and Space – San Pedro Mártir National Astronomical Observatory (OAN-SPM)	Eduardo Pérez Tijerina	The Observatory will participate in the State Programme of Scientific Tourism, offering guided astronomical observation activities, and, as part of the project of the University Programme on international collaboration, will continue to participate in the monitoring of space debris, gamma ray bursts and space weather.	The OAN-SPM Observatory was inaugurated recently, in 2020, at the height of the COVID-19 pandemic. The observatory is the laboratory used by students of the bachelor's degree programme in physics who are specializing in astronomy and students of the master's degree programme in planetary astrophysics and related technologies, which meets the CONACYT standard of excellence.
	https://puntou.uanl.mx/noti-u/abriria-en-julio-observatorio-astronomico-universitario-uanl/ https://www.astrossp.unam.mx/es/ https://www.planeacion.unam.mx/Memoria/2014/PDF/7.2-IA.pdf				

Earlier projects

University or research centre	*Name of institute*	*Project*	*Person responsible*	*Project description*	*Remarks*
National Autonomous University of Mexico (UNAM)	Advanced Technology Centre (CAT) and Faculty of Engineering (FI), Juriquilla Campus, Querétaro	Strategies for reducing space debris	Saúl Santillán Gutiérrez	Research activities and development of strategies aimed at space debris mitigation, addressing such issues as the detection of space particles, the development of mathematical models of debris generation, measurements and protection plans.	The research and strategy development activities began in 2013 and it is not known if those activities are still being carried out. The research team included researchers, graduate students and undergraduate students in technology and engineering.
	https://www.dgcs.unam.mx/boletin/bdboletin/2013_129.html https://www.zonacentronoticias.com/2013/02/desarrollan-en-la-unam-estrategias-para-reducir-la-basura-espacial/ https://www.equilibriummedicinanatural.com/a-limpiar-el-espacio-sideral/				

Projects focused on research and outreach (current)

University or research centre	*Name of institute*	*Project*	*Person responsible*	*Project description*	*Remarks*
National Polytechnic Institute (IPN)	College of Mechanical and Electrical Engineering (ESIME) and the ESIME Ticomán Aerospace Association (AAET)	General space debris research and outreach	N/A	IPN, through the ESIME Ticomán unit, founded the ESIME Ticomán Aerospace Association, one of the objectives of which is to carry out research on such topics as space debris. These bodies frequently publish articles on that topic, disseminating information within the Institute and among the general public.	Since the inauguration of AAET, these bodies have produced and disseminated information on space debris and other topics. They do not currently have a project as such in this area, as they are in the process of expansion.
	https://www.aaetipn.com/single-post/2017/04/11/basura-espacial https://www.unoosa.org/documents/pdf/copuos/stsc/2020/statements/2020-02-05-PM-Item08-04-MexicoS.pdf https://www.zaragoza.unam.mx/wp-content/Portal2015/ActividadesCulturales/NocheEstrellas/BasuraEspacial.pdf				
National Autonomous University of Mexico (UNAM)	Institute of Astronomy (IA)	General space debris research and outreach	N/A	The objectives of the Institute of Astronomy are, inter alia, to conduct research on astrophysics and develop astronomical instrumentation. The Institute also conducts outreach activities and disseminates information relating to astronomy and science in general, including the topic of space debris (see links).	The Institute has carried out research on space since its establishment, contributing to scientific outreach through the UNAM scientific education journal *Revista de Divulgación de la Ciencia*. Its objective is to provide high-quality training at the bachelor's, master's and doctoral levels.
	http://www.comoves.unam.mx/numeros/articulo/170/basura-espacial http://www.comoves.unam.mx/numeros/retos/261				

Private universities

University or research centre	*Name of institute*	*Project*	*Person responsible*	*Project description*	*Remarks*
Pan-American University (UP)	Faculty of Engineering at the Aguascalientes and Mexico City campuses	Colibri Mission project (Pakal nanosatellite – CubeSat)	Led by the same group of students (see second link for information on the leaders of each area under the project)	The Pakal nanosatellite – CubeSat project is capable of obtaining measurements of atmospheric density in low Earth orbit in order to study atmospheric phenomena and contribute globally to solving the space debris problem.	The Colibri Mission project was inaugurated in 2018 and currently remains under development. The project is being developed with the involvement of more than 50 Pan-American University students from different areas of study and in collaboration with DPL of MIT, through which it has become part of the programme of international science and technology initiatives (MISTI).
	https://www.sinembargo.mx/04-07-2021/3994408 https://www.colibrimission.com/				