4#Discover Life on Mars With a Rover

4.1 Didactic commentary

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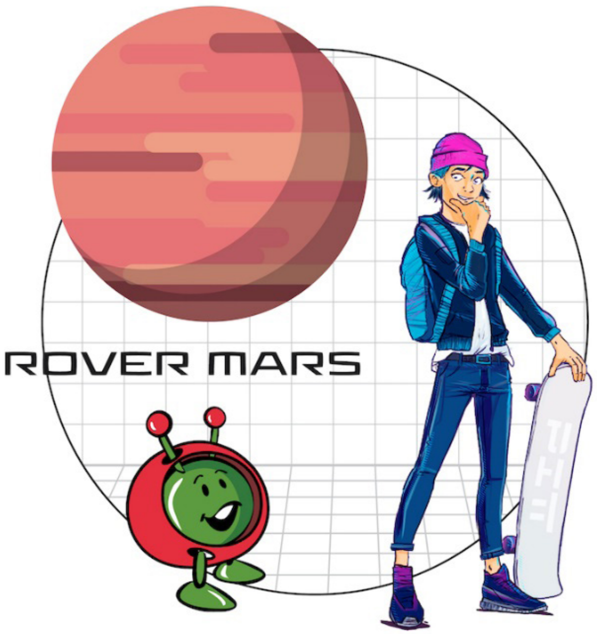
The module #Discover Life on Mars with A Rover was developed in collaboration with ESERO Luxembourg (European Space Education Resource Office). ESERO designs pedagogic material for primary and secondary schools, which is adapted to the Luxembourg school curricula for STEM subjects (Science Technology, Engineering and Mathematics), and which is always linked to the theme of space. As part of the University of Luxembourg's Bachelor in Education Sciences (BScE), ESERO also supports future primary school teachers in developing general scientific knowledge. For example, pupils work on resources developed by ESERO within the framework of the "Teach with Space" project, on the topic of climate change (Andersen et al., 2021).



The current teaching unit *#Discover Life on Mars with a Rover* deals with the topic of robots and has been integrated into the space learn setting. The objective is to bring the fascination with space into the classroom, and to use this topic to encourage young people to learn and work independently and to develop their motivation for the learning process: the multifaceted topic of space is a topic that young people find very interesting – particularly when it's related to the search for extra-terrestrial life. This module draws on the pupils' imagination and arouses their curiosity and enthusiasm. Furthermore, space supports the topic of robots, and takes programming from a theoretical context to a very applied context.

In an interview conducted at the Esero UK Secondary Space Conference, Tim Peake, an ESA astronaut, highlights the pedagogic potential of the topic of space. Peake is convinced that the fascination with space can be transferred to a lot of areas of learning and scientific subjects within the framework of education. He believes that space and the work of the ESA can be used as unique platforms to interest children and young people in the topics of space and space exploration, as well as to stimulate their interest in the work of astronauts, engineers and scientists. Peake sees a clear advantage in the fact that, when learning about space, the content is relevant to and meaningful for children and adolescents: abstract ideas from mathematics, physics, chemistry or biology thus become concrete and tangible. This is what Peake calls "space as an educational outreach tool" (UK ESERO, n.d.). The module *#Discover Life on Mars with a Rover* similarly does not aim to integrate coding into a purely virtual environment, where the programmes created by the pupils simply produce a response on the screen (such as programming images that move, sound effects etc.).

Because the command instructions that pupils have programmed are tested on a robot, they get a response that instantly reflects their efficacy, successes and failures. Here, robotisation adds another level by allowing the algorithms the pupils have designed to produce "spatial feedback" – a tangible aspect that enables learner(s) to look for solutions within a less traditional school environment (INRIA, 2020).

In this way, programming allows them to address their error, in class, within the framework of learning through experimentation (Kapur, 2011). "From a neuroscientific perspective, the error is primarily treated as a diversion from an attempt, and therefore constitutes precious information that allows a person to readjust their design and thus to learn." (INRIA, 2020) Thanks to programming, pupils can experiment with a positive approach to mistakes, because the error message is immediate: an IT programme does not pass judgement, it simply detects the error and flags it up. It gives the pupil the opportunity to keep having another try, until their work achieves the desired result. Consequently, even those pupils with lower attainment levels have the potential to complete their task successfully.

The programme also helps pupils to develop a more in-depth work method, because a programme only works if it is programmed 100% correctly. In this way, it differs from an educational approach in which pupils strive to be "good enough" rather than "good". For example, a learner's aim is often to pass a test, but not necessarily to get full marks. This cannot be the case with programming: whereas an exam can be passed with 50%, a programme that has only been halfconfigured is unusable and cannot work (INRIA, 2020).

In addition to the response provided by spatial feedback, dealing with errors in a way that is conducive to learning, and learning a more in-depth way of working, the module ultimately enables the formation of critical thinking. Here, by "critical thinking", we mean specifically:

the ability to form hypotheses, to confirm them and/or to prove them – or to reject them. Mathematics and science can play a fundamental role in the development of this ability in pupils because the hypotheses, the cause-and-effect relationships and the theories are essential elements of modelling within mathematical and scientific frameworks. The awareness that it is possible to change one's mind plays an equally important role in this. This trial-error loop is not usually achievable within a traditional one-hour lesson because this type of process often takes much more time in a laboratory. However, the trial-error loop is much shorter in information-technology, because a programme flags up an error on the very first attempt. Pupils therefore quickly learn to say, "I thought that…, but I have discovered that…, I am going to try something else" (INRIA, 2020) and can practise a positive error culture.

In the *#Discover Life on Mars with a Rover* module, robotised vehicles like Opportunity and Curiosity (NASA, 2022) leave for a mission on the planet Mars. For a Martian rover like this to know what it must do, a programmer has to write a series of instructions that the robot carries out, one after the other (for example "deploy the solar panels", "deploy the wheels" or "turn on the camera"). However, it is not possible to control the rover from Earth because the radio signal takes between 4 and 20 minutes depending on the position of the Earth in relation to Mars. A remote-controlled robot would therefore only work with a long time-delay. This is why the Martian rover must be programmed in advance, so that it can function independently.

In this unit, pupils are therefore given four different and successive programming missions of increasing complexity. Parts of the basic missions can be reused for the more complex tasks. Since the unit is an introduction to programming, pupils don't need to program all of the missions from scratch. To make the task easier, parts of the programming are given to them in the form of tasks. This also corresponds to the tasks outlined in the ICILS study (International Computer and Information Literacy Study 2018), which was conducted with 6e pupils (Fraillon et al. 2019). The robots used are mBots from the company MakeBlock. These robots are specially designed for beginners and make it possible to teach and learn robotic programming in a simple and fun way. The programming itself is done using MakeBlock software, a blockbased programming environment based on Scratch.

The *#Discover Life on Mars with a Rover* module focuses on the development of a specific skill set, which was modelled in the recent ICILS study under the name of Computational Thinking (CT). It refers to a person's ability to "identify those aspects of real-world problems that lend themselves to IT modelling, to evaluate algorithmic solutions to these problems and to develop their own solutions in such a way that they can be implemented by a computer" (Boualam et al., 2021). The skill set therefore comprises the two key skills "conceptualising problems" and "implementing solutions" (ibid.)[1]. 6e pupils in Luxembourg are currently below the international average in the area of computational thinking as well as in general computing and IT-related skills (see ibid.).

Access to programming via Scratch within the context of the #Discover Life on Mars with a Rover module gives pupils the opportunity to gain some initial experience with IT systems and lends itself very well to teaching beginners. The programming activity is limited to adapting an existing programming environment to the demands of successive programming tasks, and thus offers an opportunity to create effective products, with very little prior programming knowledge (Schubert & Schwill, 2011). Thanks to these step-by-step instructions, learners become familiar with the basic principles of block-based programming and develop basic CT skills, which can be linked to any experiences they have already had with coding, in the way that it has been designed for primary education.

[1] For a critique of the Computational-Thinking model, see for example Nardelli (2019) and Tedre & Denning (2016). From the perspectives of psychology/psychology of learning and epistemology, it is in fact unlikely that CT can define a way of thinking (even a new one) that can be taught. The various skill sets that this comprises are also developed in other disciplines, such as maths and natural sciences, as well as in philosophy and formal logic. For this PITT module, CT is therefore considered to be a group of characteristics, as it is conceptualised within the context of the ICILS 2018 and applied by Boualam et al. 2021. The skills that are grouped together here under the heading of CT, are therefore used in a descriptive rather than a normative way.

References:

Andersen, Katia N., Cornrotte, Fréderic, Trap, Guillaume & Bettelo, Nadia. (2021). Le projet ESERO Luxembourg : conséquences pour la professionnalisation des enseignants sur le thème de l'éducation au développement durable. Rapport national sur l'éducation 2021. https://doi.org/10.48746/bb2021lu-fr-19

Boualam, Rachid, Lomos, Catalina & Fischbach, Antoine. (2021). Compétences en informatique et en information (CIL) et compétences en raisonnement informatique (CT) des élèves de 8e année. Principaux résultats de l'ICILS 2018. Rapport national sur l'éducation 2021. https://doi.org/10.48746/bb2021lu-fr-26

Institut national de recherche en sciences et technologies du numérique (INRIA). (2020). Éducation et Numérique : enjeux et défis. Livre Blanc N 04. https://hal.inria.fr/hal-03051329v2/document

Fraillon, Julian, Ainley, John, Schulz, Wolfram, Friedman, Tim & Duckworth, Daniel. (2019). *IEA International Computer and Information Literacy Study 2018. Assessment Framework*. IEA.

Kapur, Manu. (2011). A further Study of productive failure in mathematical problem solving : *unpacking the design components. Instructional Science*, 34(4), 561-579.

Nardelli, Enrico. (2019). Do we really need computational thinking? Communications of the ACM, 62(2), 32-35. https://doi.org/10.1145/3231587.

NASA. (2022). Mars Exploration Rovers. https://mars.nasa.gov/mer/mission/overview/

Schubert, Sigrid & Schwill, Andreas. (2011). *Didaktik der Informatik*. Spektrum Akademischer Verlag.

Tedre, Matti & Denning, Peter J. (2016). The long quest for computational thinking. *Proceedings of the 16th Koli Calling Conference on Computing Education Research*, 120–129.

UK Esero. The benefits of bringing Space to the classroom. The Esero UK Secondary Space Conference. https://www.esa.int/ESA_Multimedia/Videos/2014/11/ESERO_UK_Secondary_Conference_at_Farnborough_with_Tim_Peake/(lang)/en

4.2 Lesson planning

01 Theme of the lesson in the overall structure of the axes

Module	Axes	Focus	Interdisciplinary ideas and link with other subjects
#Involution	Topic 1 My digital world and me!	• Games and algorithms • Algorithm of the shortest path	• Mathematics • Geography
#Climate Killer Internet	Topic 2 Understanding the internet: the World Wide Web and me	• Internet and climate • Judgement skills	• VIESO (Life and Society) • Geography • German • French
#Data Viz Superpowers	Topic 3 Do you speak Informatique?	• Different types of data visualisation • Manipulation of graphics	• Artistic education • Mathematics
#Discover Life on Mars with a Rover	Topic 5 Robots, partners for better or worse?	• Programmation en Scratch • Educational Robotics	• VIESO
#Pupils vs Machine	Topic 6 Is there a machine as intelligent as I am?	• Basic functioning of AI	• Mathematics • VIESO

Since the modules are independent from each other, it is not necessary to be acquainted with the previous modules to tackle this one. If multiple modules will be completed, it is recommended that the #Involution module is scheduled before the *#Discover Life on Mars with a Rover* module.

This module was designed in collaboration with Frederic Cornrotte from ESERO Luxembourg. ESERO is the education branch of the ESA (European Space Agency). It takes space into classrooms by developing new, interactive, pedagogic media, by organising competitions and by offering regular training to teachers.

02 Conditions of unit

1. Target audience: 7e – 5e
2. Room: With the option to present it using a video projector.
3. Equipment required: free floorspace of 6 m² : 3 m x 2 m

In groups of 2 pupils:

- a laptop or PC with Windows or macOS
- an internet connection
- one available USB port
- mBlock software installed

The rest of the equipment is provided by ESERO (contact ESERO for this: contact@esero.lu or +352 621 96 90 19)

- A map of Mars
- The decoration equipment required for the challenges:
  - 3 photos for decoration
  - fixings to hold the photos
  - a cave
  - a soft toy tardigrade
  - a heat source
  - a Paxi soft toy, which is ESERO's mascot
  - Paxi stickers
- 10 mBots fitted with all of the necessary sensors, for a class of 20 pupils maximum.

4. No prior programming knowledge is necessary.
5. Duration: 100 minutes – 2 hours of teaching or 200 minutes – 4 hours of teaching

03 Contextualisation of knowledge

In February 2020, the Ministry of Education, presented the "einfach digital – Zukunftskompetenze fir staark Kanner" [Simply digital – Future skills for strong children] strategy, the objective of which is to prepare children and adolescents for the demands of the future, to help them navigate their way through an increasingly digital world and to enable them to acquire the necessary skills to do so. The new subject Digital Sciences was introduced within the framework of this strategy. Digital Sciences fits in with the coding taught in primary schools and focuses on six main themes: algorithms, the Internet, computing language, games, robots and artificial intelligence (Ministry of Education, 2020).

The *#Discover Life on Mars with a Rover* module follows on from the emphasis placed on coding and includes it in the themes of Space Education and Educational Robotics. On the one hand, this makes it possible to maintain the learning environments introduced in primary education with the Kniwwelino® micro controller, the Ozobot® educational robot, or even the Lux-Robo Modikit: the mBot robot used in this PITT module has corresponding sensors and (like the Ozobot®) it can be controlled through a block-programming environment. This means the previously-acquired coding knowledge can be reactivated and adapted (Ministry of Education, 2021).

Furthermore, the practical application and the scientific contextualisation within the framework of learning about space, allow pupils to make a real-world connection. The didactic feedback loops encourage an independent approach to learning programming languages.

04 Didactic transposition

a. Learning objectives and target skills

Pupils know the basics of block coding and have tested and adapted them according to the application. They have therefore cooperatively developed solution strategies and used metacognitive reflection through independent research.

Competences from the *Media Compass*[1]

Competences 1 – Information and data: 1.2 Analysing and assessing data, information and digital content

Competences 2 – Communication and collaboration: 2:1 Working with others

Competences 3 – Creating content: 3.3 Modelling, structuring and coding

Competences 5 – Digital world: 5.1 Resolving simple technical problems

[1] https://www.edumedia.lu/medienkompass/medienkompass/

b. Didactic justification

To ensure coding education and training is provided across primary and secondary education in line with *digital sciences* and to build up the level of skill detailed in the *Media Compass*, this module provides more complex tasks based on block coding. The objective is "to identify aspects of real-world problems that lend themselves to IT modelling, to evaluate algorithmic solutions to these problems and to develop them in such a way that these solutions can be implemented by a computer" (Boualam et al., 2021). *#Discover Life on Mars with a Rover* therefore focuses on content for learning computational thinking and provides sample methods and tools to acquire the fundamental and essential skills to further develop their IT knowledge in future.

C. Didactic reduction

This module favours and supports abstraction skills and the ability to recognise the models required by computer modelling of real-world problems through the integration of educational robotics in the learning environment. In addition to increasing motivation for learning through fun coding missions and cooperative problem-solving methods, the responsiveness and clarity offered by robotic programming plays an essential role:

> *Numerous studies [...] have shown that poor engagement and retention statistics in courses such as Introduction to Programming [...] often arise from students' inability to see how the skills they learn can have a concrete impact on what they care about: their physical world; their friends and family. Physical robot programming projects can cast coding problems into the real world, making those skills push back on one's world and thereby achieve a level of significance and engagement that, for instance, computation of the Fibonacci Sequence on a computer screen cannot inspire. (Miller & Nourbakhsh, 2016)*

The didactic principle of constructivist learning is thus transformed into constructionist learning, as Eguchi underlines, in line with Papert & Harrel (1991): "With constructionist learning, the object to think with is built or made, and what is physically constructed can be publicly shared – shown, discussed, examined, and admired" (Eguchi, 2017, 11). The possibility of using a robot to instantly check the coherence and function of blocks of code constructed independently using discrete and predefined programming instructions, facilitates self-directed learning, in which the feedback loops are given directly by the learning material used. The verification, discussion and adaptation of programming instructions in pairs aims to train the pupils' metacognitive skills to consolidate the results of their learning.

05 Over the course of the lesson

The function and use of the mBlock user interface are studied by pupils at home before the next double lesson. This "flipped classroom" approach leaves more time to achieve the individual missions during the phase in school, and allows pupils to gain practical experience of using block coding before the lesson.

The lesson begins by a pilot training in pairs of pilots: at the start of the lesson, the pupils are divided into groups of two per prepared mBot kit. The pilot exercise is assigned and explained on a whiteboard and/or worksheets (in printed form or on tablets). Questions can be discussed, and responses given directly in group. As soon as all pupils have successfully completed their pilot training, the teacher can recap on the learning objectives of the pilots' training then explain the next mission.

According to the level of knowledge, the group dynamic and the degree of internal differentiation required, it is possible to complete up to four missions per double lesson in the elaboration phase. It is equally possible to replace the last two missions with an assessment during which pupils will write a programme themselves, to achieve an objective they have thought up independently, using the mBot. If three to four lessons can be devoted to the module, there should be time to complete all of the missions and end them with an assessment.

All of the missions are constructed following the same blueprint and are explained in worksheets (in printed form or on tablets). For each mission you can download a sheet that contains part of the code. Consequently, pupils don't have to program the entire mission, which allows those who are not familiar with Scratch to complete the module.

As soon as a mission has been completed, the next mission can be assigned. Take particular care to ensure that pupils comment on the codes used during the programming and experimentation with the mBot and reflect on their own work process.

Request a classroom intervention:

You can also contact us so that we can support you with this module in your class.

06 | Differentiation possibilities

The option to graduate the missions individually allows for internal differentiation in the level of difficulty and performance. Each group determines the time it needs to complete the mission. Once a mission has been completed, they can move on to the next mission, which is more difficult. If more differentiation is required, teachers can allow pupils to program the missions from scratch. Instead of downloading the sheet that contains part of the solution, pupils can simply program on an empty sheet in mBlock.

07 | Further criteria to be met as part of the lesson series

a. **The Luxembourgish context:** The module is the result of a cooperation between ESERO Luxembourg (the European Space Education Research Office) and PITT. The learning objectives and target skills have been taken from the *Media Compass* and from axis 5 in the subject area of Digital Sciences.
b. **Differentiation:** self-directed learning as well as graduation of the preparatory tasks according to the level of difficulty allows for multiple levels of differentiation.
c. **Media Compass:** see the target learning objectives in the framework for education on media within the didactic transposition section in this document.
d. **The 4Cs model:** Critical Thinking, Creativity, Cooperation, Communication. The 4Cs model is taken into account in various ways through the different social forms and teaching activities.
e. **Relation to current research:** the design of rovers capable of navigating on the Moon or on Mars is a very current research subject in preparation for the next missions to the Moon and to Mars.
f. **Relation to current research in Luxembourg:** the space industry and research in the field of space are being developed in Luxembourg. The University of Luxembourg's role in space research is mentioned in the interview with Miguel Olivares-Mendez.

References:
Eguchi, Amy. (2017). Bringing Robotics in Classrooms. In: Myint Swe Khine (Ed.), *Robotics in STEM Education: Redesigning the Learning Experience.* Cham: Springer, 3-31.
Miller, David P. & Nourbakhsh, Illah. (2016): Robotics for Education. In: Khatib, Oussama & Siciliano, Bruno (Eds.), Springer Handbook of Robotics. Second edition. Berlin/Heidelberg, 2115-2134.
Ministère de l`Education nationale. (2020). Dossier de presse du 06 février 2020: einfach digital – Zukunftskompetenze fir staark Kanner.
https://men.public.lu/content/dam/men/catalogue-publications/dossiers-de-presse/2019-2020/einfach-digital.pdf
Ministère de l`Education nationale. (2021). EDI. Infomagazin fir Elteren 2, 23-26.
https://men.public.lu/dam-assets/catalogue-publications/edi-infomagazin-fir-elteren/2021/02-2021-edi-infomagazin-elteren.pdf
Papert, Seymour., & Harel, Idit. (1991). Constructionism . New York, NY: Ablex Publishing Corporation.

08 | Detailed planning of the lesson

Theme of the lesson: Programming and educational robotics

Learning objectives and skills to be developed during the lesson: Pupils know the basics of block programming and have tested and adapted these basics on real objects. They have thus developed problem-solving strategies cooperatively and have used metacognitive reflection based on independent documentation.

Option for evaluation (if planned): Two options for evaluation are suggested in 4.5 Evaluation ideas.

Duration	Phases	Focus	Social forms/Methods	Materials and media	Learning processes
0min	Homework	**To learn how blockprogramming works with mBlock**	• Autonomous work	• Worksheets with active learning mission, using mBlock	Pupils ... **understand** the concept and basic function of mBlock and have tested it on a concrete example.
20min	Introduction	**Pilot training**	• Groups of two • Classroom lecture • Practice on a practical case	• mBot-Kits (1 Kit per group) • Computer (1 computer per group) • Worksheets or tablets containing instructions	Pupils ... **write** an initial simple programme. ... **experiment** with the interaction between their code and the mBot robot. ...can **understand** and explain in their own words the effects of the different block codes on how the mBot functions.
10min	Transition and instructions	**Recap of pilot training and instruction on the new missions**	• Classroom lecture	• Whiteboard or worksheets for each pupil	Pupils ...**apply the results** of the homework and the pilot training to the mission for the following elaboration phase. ... **identify problems** and verbalise the difficulties with comprehension and application problems.
20-30min	Elaboration I	**Elaboration of mission 1**	• Groups of two	• mBot-Kits (1 Kit per group) • Computer (1 computer per group) • Worksheets or tablets containing instructions	Pupils ...**program** a block code to complete the mission given. ...**experiment** with the block code programmed on the mBot and **check and evaluate** their success or failure. ... can **understand and explain** in their own words the effects of the different block codes on how the mBot functions.
20-30min	Elaboration II	**Elaboration of mission 2**	• Groups of two	• mBot-Kits (1 Kit per group) • Computer (1 computer per group) • Worksheets or tablets containing instructions	Pupils ...**program** a block code to complete the mission given. ...**experiment** with the block code programmed on the mBot and **check and evaluate** their success or failure. ... can **understand and explain** in their own words the effects of the different block codes on how the mBot functions.
20-30min	Analogue: Elaboration III and Elaboration IV				
10-30min	Evaluation and conclusion	**Mission for self-assessment**	• Groups of two	• mBot-Kits (1 Kit per group) • Computer (1 computer per group) • Worksheets or tablets containing instructions	Pupils ... **independently think up** a command to be carried out by the mBot. ...**program** the mBot according to their objective. ... **evaluate** the coherence of their programming after a successful experiment.

4.3 Teaching materials

M1 | M1 Instructions for teachers

Introduction to the mBot rover

The mBot is a robot for beginners created by the company MakeBlock, which makes teaching and learning how to code a robot simple and fun. With the step-by-step instructions, pupils can familiarise themselves with the basic principles of block programming, develop their logic reasoning and their design skills.

Like any robot, the mBot interacts with its environment based on the instructions it is asked to carry out.

It is therefore capable of collecting information using its sensors and to carry out actions using its actuators.

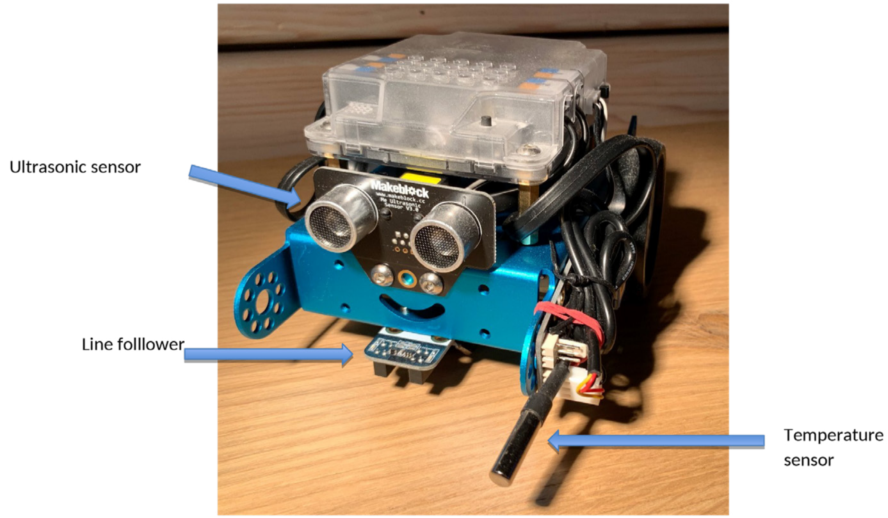
Actions

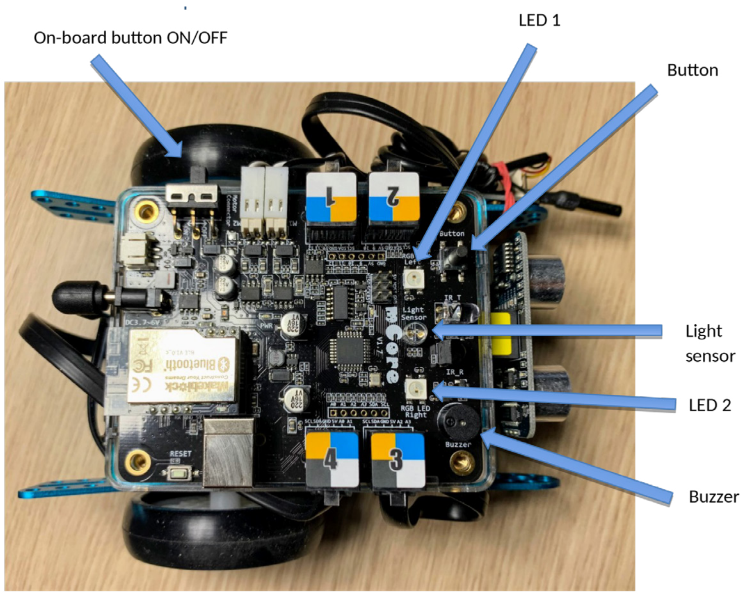
The robot is able to move using its two independent motors, each of which controls one drive-wheel.

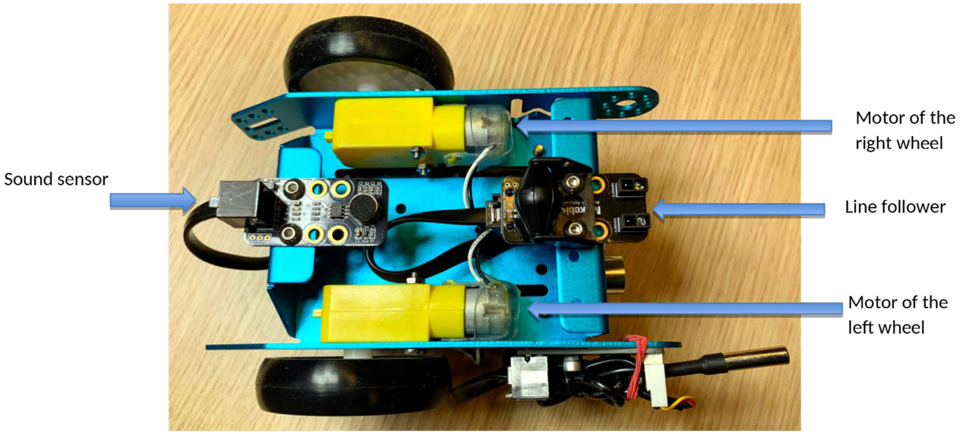
- It can make sounds with a buzzer.
- It can emit light with its LED lamps on which the colour can be adjusted.
- To interact with its environment and to gather information, on the robot there is:
    - an ON/OFF button,
    - a launch-programme button,
    - a "line-tracking" module for following a line on the ground,
    - an ultrasound module that enables it to "see" obstacles in-front of it and know its distance from them,
    - a light sensor which provides it with information on the amount of ambient light,
    - a sound sensor which provides it with information on the level of ambient noise,
    - a temperature sensor that measures the temperature in the ambient air,
    - a line-tracking sensor.

Fitted to the front of the mBot, the line tracker has two sensors capable of detecting a white surface (within a range of 1 to 2 cm), by emitting an infrared light and by recording the quantity of reflected light.If a large amount of light is reflected, it can be deduced that it is near to a white surface. If the reflection is weak, it can be deduced that the surface is black or that the sensor is not near to a surface.

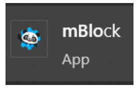
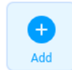
To identify the buttons and sensors:



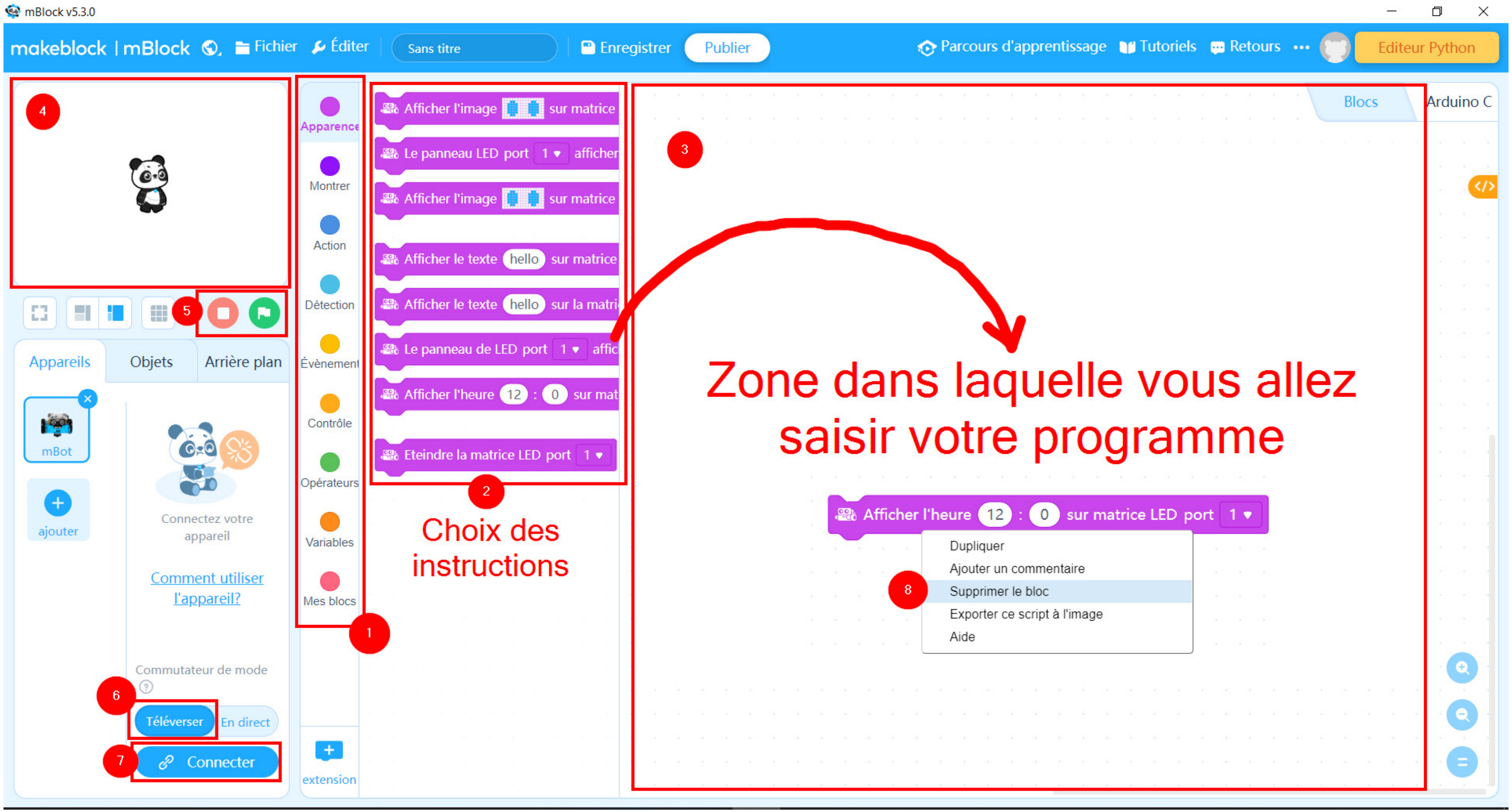




The mBot robot is programmed using mBlock software. This software can be downloaded on PCs (Windows or Mac) or as an app version (for Android or iOS). It is also possible to use the web version of the software. This is particularly useful for the homework that pupils have to do before the lesson.

How to use the programming software	
1. Open the mBlock programme.	
2. In the top left of the screen, choose your language by clicking on	
3. In the "Devices" tab on the left, delete the CyberPi device by clicking on the cross.	
4. Still in the "Devices" tab, click on "Add".	
5. Select the mBot and click on "OK".	
6. At the bottom of the screen, click on „Extension".	
7. Add the extension "Sensing Gizmos".	

Description of the user interface

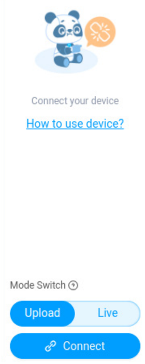


To create the programme, all you have to do is drag the elements from the library into the program-me-creation zone.
Please note, you sometimes have to place them in there carefully to make it interlock.

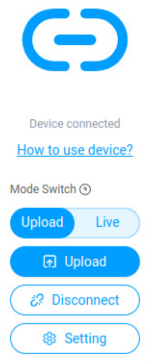
(1) Zone for selecting an instructions library	(5) Start/stop the programme when you're programming an image
(2) Zone for choosing an instruction to drag and drop into the zone	(6) Button to select to download your programme to the mBot
(3) Zone where you enter your programme	(7) Button to click to connect to the mBot
(4) Test zone for programming an image instead of the mBot	(8) To delete an instruction, right click – > delete the block

Procedure for sending the programme to the mBot

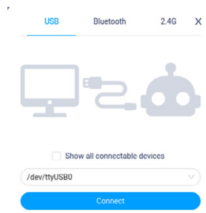
1. Place the robot on a surface, plug it into the computer.
2. Check that the robot's switch is on "ON"
3. Make sure the "Upload" button is selected.
4. Click on the "Connect" button.



5. When the connection is established, click on the "Download" button.



6. In the next screen, click on "Connect".

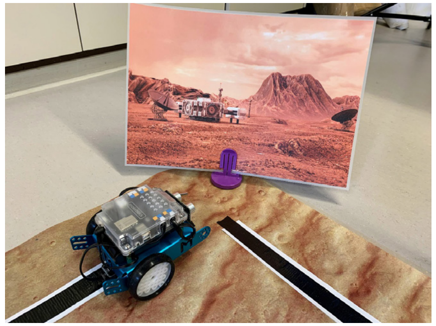


Presentation of the map of Mars

The map is a real satellite image that was taken by the ESA's Mars Express satellite in November 2018.
It is divided into 9 zones which will be mentioned during the description of each mission.

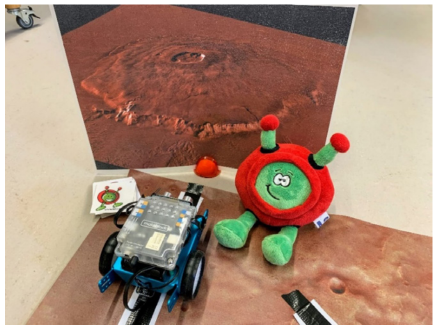
Positioning

1. Place the photo of the Martian base in the corner of zone 3.

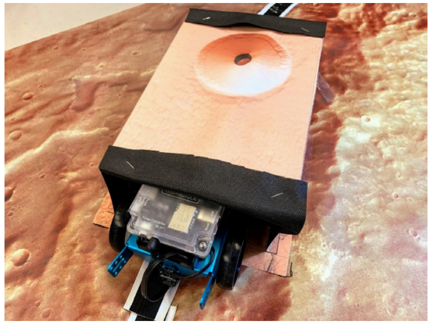


2. Place the photo of the Mars landscape just outside the map, next to zone 6.

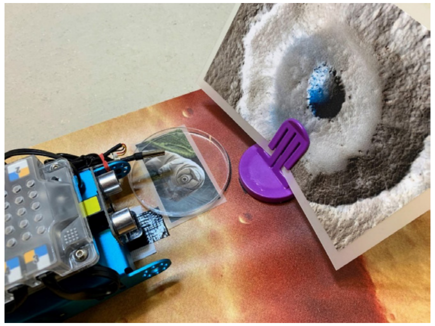
3. Place the image of Olympus Mons vertically at the end of the road, below zone 9 on the map. Place Paxi (the ESERO mascot) and the Paxi stickers next to Olympus Mons.



4. Place the Mars cave on zone 8, stick it to the map with sticky tape, put a piece of black road going across the cave and stick this to map as well.



5. On zone 1, place the image of the Mars impact crater vertically at the end of the road. Place a heat source to the left of the road, just in front of the Mars impact crater. Place the image of the tardigrade under the heat source and place the tardigrade soft toy next to the heat source.



Lesson preparation

1. To ensure you are comfortable using the equipment, we strongly advise you read, understand and test the solutions to the 4 missions before starting the lesson with the pupils.
2. Ensure a lithium battery or AA batteries are loaded into the mBot.
3. Connect the rover to your PC using a USB cable.
4. Press the ON button.

Reading your first programme

To familiarise themselves with the mBlock programme, pupils should do an initial exercise at home to prepare for the lesson. This exercise can be done on the web version of the mBlock programme. That way, they don't have to install anything. Ask the pupils to carry out the following operations:

- In the Tutorials menu go to -> Example Programs.
- Select the scene -> Happy Panda.
- Click on "OK".

Check that the pupils have understood:

- how the Panda is controlled by the coloured blocks. The coloured blocks represent the instructions to follow. There is no need for you to explain all the blocks in detail. Pupils should find out for themselves what they can do with each block.
- the function of the green flag and the red square.

Next, ask the pupils to change the Chinese message in the "say" block and to demonstrate what changes when the programme runs. Encourage them to play with the programme and to find out about the functions by themselves.

And they're off!

The lesson can begin. The programming game is divided into 4 missions, preceded by "pilot training" – a test challenge to complete by programming the mBot to make it carry out specific tasks.

Since this module will constitute most pupils' first experience with block programming, the pupils don't have to program each exercise from scratch. Files containing part of the solution are given at the end of each mission. Pupils therefore only have to complete them to reach the final solution. To do this, pupils must save the files on their computer, then open them, still on their computer, through the mBlock interface.

For classes of pupils who have already worked on Scratch or another block-programming language, you could choose not to use these files and let the pupils program the entire mission.

The missions have been designed to be of increasing difficulty: first, pupils are asked to focus on variable values (mission 1), then on programme logic (mission 2), and then to combine the 2 aspects (missions 3 and 4).

Write your first programme: pilot training

For this first exercise, the mission consists of:

- making the mBot drive in a straight line across the table.
- stopping the mBot as soon as it is less than 10 cm from an obstacle by using the ultrasound sensor. The obstacle could be the pupil's hand, a book or any other object.

Mission 1

Context:

The rover is in the centre of the map, in a dry valley, and receives the order to return to its original base to receive a new mission.

Mission:

Pupils must return to the zone 3 base, by following the black line with the line-tracking sensor.

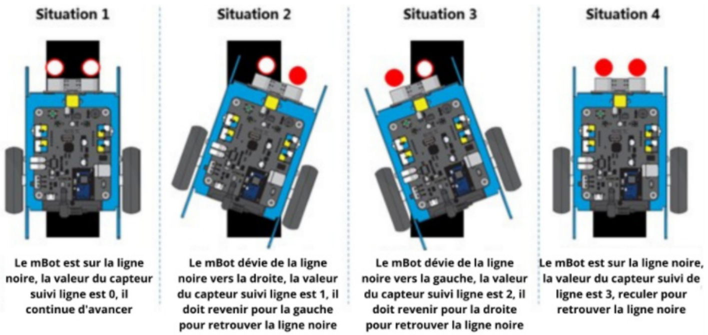
In the "Sensing" instructions library, there are **2 blocks** associated with the line tracker:

This first block will send back a number between 0 and 3 based on the following values:

Chapter 1 (Left)	Chapter 2 (Right)	Return value
		0
		1
		2
		3

The second block then sends back either true or false.

Programming:



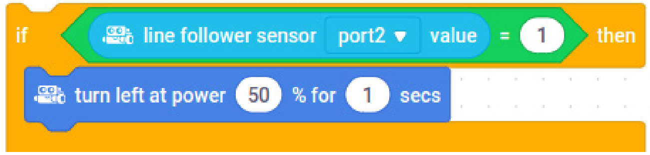
○ Indique que le capteur ne peut pas recevoir le signal infrarouge
● Indique que le capteur peut recevoir le signal infrarouge

Pupils must download the exercise to be completed.
https://drive.google.com/file/d/19URJN5cICsLO5O_mEGmUU76QIgQyjlw-/view

Important note: In general, for line tracking, pupils intuitively tend to program using time commands for turning left or right, which makes it very difficult to stay on the line. The notion of time depends on the motor's power at that point in time. Furthermore, we have noticed that pupils (and adults alike) underestimate the length of a second.

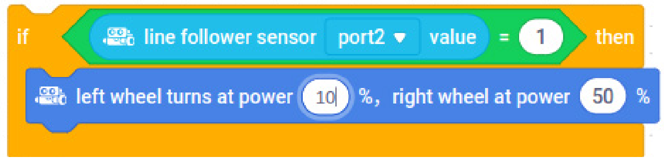
Instead of programming this,

it is much more reliable to use the line-tracker's reaction time and to reduce the motors'



power.

Unfortunately for the "reverse" command, seconds have to be used. Here, make sure pupils



do not choose a duration that is too long (not more than 1 second).

T Mission Control: so that the pupils can learn from their errors – resulting from incorrect judgements and programming – it is necessary to document these trial-and-error learning processes. Pupils are therefore tasked with commenting on mBlock on the coding and reasons why they coded in one way or another. To comment on a line of code, you must right-click on the line of code and click on "Add Comment" (see the description of the programming interface above.)

Mission 2

Context:

The rover has returned to its base and receives the order to try to find life on Mars.

The ExoMars satellite has found some potentially interesting places and has given some GPS points to visit.

The base has also received an urgent message from Paxi, who has encountered some technical problems with the spacecraft not far from Olympus Mons, the highest mountain on Mars.

The pupils must first rescue Paxi who will be a great help for our mission since Paxi has great knowledge of the Mars landscape.

Mission:

Pupils must:

- follow the black line from zone 3 to zone 9.
- stop in front of Olympus Mons using the ultrasound sensor.
- produce a light signal using the mBot's LED lamps to inform Paxi of their arrival.
- get Paxi to "come aboard" by giving the pupil a Paxi sticker.

Programming:

The pupils must download the exercise to carry out.:
https://drive.google.com/file/d/19TXcB3dyFwFN0wUumda3ZEWG0WK2OuFK/view

IT Mission Control : pupils are tasked with commenting on their lines of code on mBlock.

Mission 3

Context:

The ExoMars satellite has shown the location of a Martian cave to explore, which could contain life. Pupils must enter the cave and scan it.

Mission:

The pupils must:

- follow the black line from zone 9 to zone 8.
- stop inside the cave when the light sensor detects a low light intensity.
- produce a sound signal simulating a laser scanning the inside of the cave.

Programming:

The pupils must download the exercise to complete.
https://drive.google.com/file/d/19TTVN_k1Y4e6DVhRrDgSpAw_A_8Hp1Ue/view

IT Mission Control : pupils are tasked with commenting on their lines of code on mBlock.

Mission 4

Context:

The pupils have not found life inside the Mars cave, but there is another promising location.

Suddenly, we hear the sound of a meteorite crashing not far from the entrance to the cave. The pupils must go to the crash site to look for traces of life.

Mission:

The sound of the meteorite crashing is simulated by clapping.

Using the sound sensor, the mBot must:

- hear the sound of the meteorite's crash using its sound sensor.
- stop in front of the meteorite impact crater.
- measure the temperature to detect a source of hot water of above 30 °C that contains life.
- play a "victory song", composed on the mBot, if the temperature is over 30 °C!

Programming:

The pupils must download the exercise to complete:
https://drive.google.com/file/d/19Rp5qXX6illEKTe5U5OoUm25J9RfGaWq/view

Important notes:

Prepare the heat source just before starting this mission.

IT Mission Control : pupils are tasked with commenting on their lines of code on mBlock.

Read your first programme (to do at home)

M2 | Instructions for pupils (homework)

- Go into the Tutorials menu on Example Programs.
- Select the Happy Panda scene.
- Press "OK"

Do the following tasks:

- The blocks of colour give the panda instructions. Try to find out what you can do with each block.
- Work out what action the panda is made to do by which coloured block in the programme and write it on a list. Take this list to your next lesson.
- Try to understand the function of the green flag and the red square.
- Change the Chinese message in the "say" block and write down what this changes when you run the programme.

Write your first programme: pilot training

M3 | Instructions for pupils: the missions

Here is your first exercise:

- Make the mBot drive straight ahead on the table in front of you.
- Stop the mBot as soon as it is 10 cm away from an obstacle, using the ultrasound sensor. The obstacle could be your hand, for example.

Missions

IT Mission Control : You are in charge of IT Mission Control. If the rover does not carry out the order requested and causes an accident for example, the mission is a failure. It is therefore important to analyse the errors to improve the code. This is why IT Mission Control makes comments on the codes on mBlock [right-click on the mouse -> comment].

Mission 1

Context:

The rover is in the centre of the map, in a dry valley, and receives the order to return to its original base to receive a new mission.

Mission:

Return to the base in zone 3 by following the black line, using the line-tracking sensor.

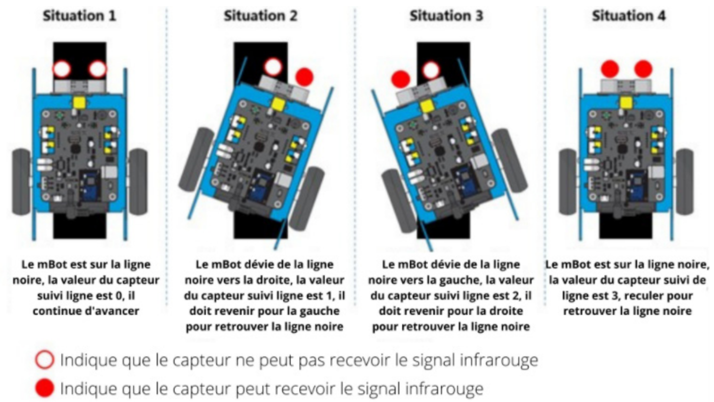
Help:

In the "Sensing" instructions library, there are **2 blocks** associated with line tracking:

This first block will send back a number between 0 and 3 based on the following values:

Chapter 1 (Left)	Chapter 2 (Right)	Return value
		0
		1
		2
		3

The second block will send back either "true" or "false".



Programmation :

Download the exercise to be completed: **Return to base**
https://drive.google.com/file/d/19URJN5cICsLO5O_mEGmUU76QIgQyjlw-/view

Mission 2

Context:

The rover has returned to its base and receives the order to try to discover life on Mars!

The ExoMars satellite has found some potentially interesting places and has given some GPS points to visit.

The base has also received an urgent message from Paxi, who has encountered some technical problems with the spacecraft not far from Olympus Mons, the highest mountain on Mars.

The pupils must first rescue Paxi who will be a great help for our mission since Paxi has great knowledge of the Mars landscape.

Mission:

- *Follow the black line from zone 3 to zone 9.*
- *Stop in front of Olympus Mons using the ultrasound sensor.*
- *Produce a light signal using the mBot's LED lights to notify Paxi (the ESERO mascot) of your arrival.*
- *Get Paxi to "climb aboard" by taking a Paxi sticker.*

Programming:
Download the exercise to be completed: **Rescue Paxi on Olympus Mons**
https://drive.google.com/file/d/19TXcB3dyFwFN0wUumda3ZEWG0WK2OuFK/view

Mission 3

Context:

The ExoMars satellite has indicated the location of a Martian cave to explore, which could contain life. You must enter the cave and scan it.

Mission:

- *Follow the black line from zone 9 to zone 8.*
- *Stop inside the cave when the light sensor detects low light intensity.*
- *Produce a sound signal simulating a laser scanning the interior of the cave.*

Programming:

Download the exercise to be completed: **Explore a Martian cave**
https://drive.google.com/file/d/19TTVN_k1Y4e6DVhRrDgSpAw_A_8Hp1Ue/view

Mission 4

Context:

You haven't found life inside the Mars cave, but there is still another promising location.

Suddenly, we hear the noise of a meteorite crashing not far from the cave. You must go to the crash site to look for signs of life.

Mission:

- *Simulate the meteorite crash by clapping your hands.*
- *Hear the sound of the meteorite crash (simulated by clapping) using the mBot's sound sensor.*
- *Measure whether the temperature inside the cave is positive to test the temperature sensor.*
- *Stop in front of the meteorite's impact site.*
- *Measure the temperature to detect a heat source of above 30 °C, containing life.*
- *If the temperature is above 30 °C, play a "victory song" that you have composed on mBot!*

Programming:

Download the exercise to be completed: **Find life on Mars**
https://drive.google.com/file/d/19Rp5qXX6illEKTe5U5OoUm25J9RfGaWq/view

4.4 Interdisciplinary ideas

VIESO (Vie et Société)

The module can be combined with the subject VIESO. The question "Where does human life start", which is part of the topic "Man, nature and technology" can also be approached by talking about what life is. Please refer to point *4.6 More on this topic* in which the question "What is life?" is discussed from a scientific and philosophical perspective.

4.5 Evaluation ideas

Write a short programme from start to finish.

Once the pupils have become familiar with the way the block codes work and how to apply them for a purpose using the mBot, they can carry out an assessment/self-assessment, either by writing a programme that fulfils their own objective, or a programme for a mission that is given to them but they are not given a code model for it.

Two different tasks are suggested: one involves programming the mBot, the other involves programming without mBot. The mBot programming task is more complex whereas programming without mBot is easier.

A mission for the mBot

The pupils are asked to think up their own mission for the mBot and to write down the different processes that the robot must execute in succession. The different work steps must then be produced on the mBlock programme using the blocks of code that are already available. To solve this task, it is useful for pupils to look back over the scripts they commented on during their first missions to remind themselves of the function of the different codes.

It is then possible to work out together, in group, whether the written code corresponds to the objective of their chosen mission.

A mission for Paxi (can also be done as homework)

In this task, pupils give a series of instructions to an image, for example the image of Paxi, or another image of their choice.

Preparation:

1. Download the image of Paxi onto your computer.
1. Open the "mBlock" programme.
1. In the "Sprites" tab on the left, delete the image of the panda.
1. Still in the "Sprites" tab, click on the "Add" button, then "Upload" and select the image of Paxi that you downloaded previously.
1. Click on "OK".
1. Still in the "Sprites" tab, reduce the size of the image of Paxi from 100 to 30.

Exercise

Create a new programme where Paxi follows your mouse pointer continuously, without ever touching it.

4.6 More on this topic

01 | Discovering the planet Mars

Humans have been undertaking missions to explore the planet Mars since the 1960s. Following its launch on 28 November 1964, NASA's Mariner 4 probe was the first to fly by Mars on 14 July 1965. To this day, four space agencies have completed missions to investigate the red planet: NASA (the National Aeronautics and Space Administration), ISRO (the Indian Space Research Organisation), the Soviet Union and Russia's space programme and the ESA (European Space Agency).

During the 1960s and at the start of the 1970s, several probes were sent to fly by Mars. The most successful mission was that of NASA's Mariner 9 probe, launched at the end of 1971. Mariner 9 remained in orbit around Mars for almost one year and was able to take over 7,000 photos of Mars, which radically changed our perception of this planet.

Finally, in 1975, NASA sent two pairs of orbiters and landers. An orbiter is a space probe that orbits a celestial body whereas a lander refers to a spacecraft intended to touch down on the surface of a celestial body. Viking 1 and Viking 2 touched down on Mars and remained there for several years. Unfortunately, they did not find any clear sign of life on Mars.

At the end of the 1990s, a complete map of Mars, from the north to the south pole, was established by Mars Global Surveyor, a NASA orbiter. Almost simultaneously, NASA launched the Mars Pathfinder, which consisted of a lander and a rover, the famous Sojourner. This is the first rover to have functioned outside of the Earth or the Moon. A rover is a motorised vehicle designed to move around on the surface of a planet or a moon (contrary to a lander which remains immobile once it has landed on a celestial body.) For a complete classification of the different spacecraft, please consult this explanatory page provided by the NASA: https://www.nasa.gov/audience/forstudents/postsecondary/features/F_Spacecraft_Classification.html

The Mars Odyssey orbiter, which is still in orbit around Mars, was launched by NASA in 2001. In 2003, the ESA sent a mission to Mars that consisted of an orbiter and a lander, called Mars Express and Beagle. The lander was unfortunately lost during the landing, but the orbiter is still on its mission.

In 2004, NASA sent two other rovers to Mars: Spirit and Opportunity. Spirit broke in a sand dune in 2010, whereas Opportunity survived until 2018, when it stopped functioning during a sand storm.

In 2006, another NASA orbiter, the Mars Renaissance Orbiter, was put into orbit. Since then, it has sent us more data about Mars than all of the other missions combined. One year later, NASA sent the Mars Phoenix, another stationary lander. Unfortunately, NASA lost contact with it after a few months and declared it dead in 2010.

A new NASA rover, much more powerful than all the others, the Curiosity, arrived on Mars in 2012. The design of Curiosity inspired the development of the rover Perseverance, which landed on Mars in February 2021. One of Perseverance's main missions is to collect samples from the surface of Mars. It is expected to bring these samples back to Earth in 2031, as part of a joined mission between NASA and the ESA. The latest news from Perseverance is available on the following page: https://mars.nasa.gov/mars2020/

Finally, let's not forget the ExoMars mission, a collaboration between the ESA and the Russian space agency Roscosmos. The mission contains a lander, called Schiaparelli, which was sent to Mars in 2016 but broke during the landing, and an orbiter, called Trace Gas Orbiter, sent in the same year and which is still there. This same mission also planned to send a rover in 2022, named Rosalind Franklin. For the ESA, research and science are aspects that are central to the human condition, as name sponsorship should remind us (ESA, 2019a). Unfortunately, due to the current situation, the ESA has completely cancelled the ExoMars mission (Science.lu, 2022).

Other countries are also developing missions to Mars:

- India's Mars Orbiter Mission, arrived in orbit in 2016,
- The United Arab Emirates' Hope Probe mission, sent to Mars in 2020,
- China's Tianwen-1 mission, arrived in orbit and on Mars in 2021,
- Japan's Mars Moons Exploration Mission, planned for 2024.

Finally, we note that this summary gives the impression that Mars exploration consists solely of successful missions. In reality, several missions have failed. A summary of all of the missions is available on Space.com (n.d.). This provides a good illustration of how scientific research works: History often only remembers the successes, whereas every discovery, invention or scientific breakthrough is and always will be preceded by several failures, which are not mentioned and are forgotten afterwards.

02 | Why explore Mars?

Of course, the discovery of the universe and the challenge of going further have always interested humans. The purely scientific reasons for exploring Mars are as follows:

- the search for life on Mars,
- characterisation of the climate and the geology of the red planet,
- preparation of the terrain with a view to future human exploration.

Understanding whether there is life outside Earth is a fundamental question. Since Mars is the planet most similar to our own, it is a favourite place to investigate this question.

Understanding the geology of Mars is important for understanding the planet's history. Studying the atmosphere on Mars can help to understand the evolution of this atmosphere and why Mars currently has much less atmosphere than Earth. In the long term, these studies will help us to understand our Earth and the other planets in the solar system better.

Finally, one of the ultimate goals is human exploration. To pave the way, it is necessary to study the risks in advance. This is why robots are currently exploring and categorising the surface of Mars.

In the following video, Joel Levine, a planetary science expert, gives a great explanation of why missions to Mars are important from a scientific perspective.

Why we need to go back to Mars

The video is part of a series of eight talks on Mars (TED, n.d.).

03 | Is there life on Mars?

The most exciting question of all of the missions to Mars is probably to discover whether there is life on Mars, in fossil form or even living.

One Martian day is close to the terrestrial 24 hours, and the planet has a similar inclination, so there are Martian seasons and even climatic regimes that correspond more or less to our own. There are lots of indications that Mars was once much more similar to our planet Earth. The photos and data that we have obtained from the various obiters and space probes that study Mars, indicate that even if Mars is a dry planet today, water once flowed on Mars. And where there's water there's life, because water is the main element required for life to develop.

The first probes, Viking 1 and Viking 2, which touched down on Mars in the 1970s, didn't find life on Mars. This is not proof that there is no life. On the contrary, the microbes that NASA found at the bottom of frozen lakes in Antarctica give us hope of finding life on Mars, because the Antarctic climate resembles that of Mars today. On Earth, microbes were found in sedimentary rocks over 1,000 metres below the ground, but also in salt deposits and deep-sea chimneys (Alonso & Szostak, 2019). These findings indicate that our robots may not yet have looked in the right places on Mars.

The Viking mission had actually done four different experiments to see if there were bacteria in the Martian ground. At the time, the results of the four experiments seemed to eliminate the possibility of the presence of life. But today, almost 40 years later, scientists are able to explain the failure of the Viking experiments and the quest for Martian life remains open.

Today, scientists have also developed much more sophisticated and discrete techniques for detecting the presence of current or past life. The most well-known is based on the detection and sequencing of DNA. Nonetheless, this method is still problematic: even if DNA is common to all terrestrial life, it is not certain that extra-terrestrial life has a DNA. Research that is even more meticulous therefore focuses on different types of proteins and amino acids to search for extraterrestrial life forms (McKay & Parro García, 2014).

NASA's rover Curiosity, and the future rover Rosalind Franklin are fitted with measuring instruments that make it possible to perform experiments based on these new technologies to search for traces of past or present life. The choice of landing spot for the rovers is one strategic aspect.

Finally, the detection of a biosignature gas in the atmosphere of planets and exoplanets is another method of searching for life. This is one of the missions of the new James Webb Space Telescope (Wolchover, 2021).

The Fermi Paradox: Where are they?

The question of the existence of life in the universe and outside our Earth is called the Fermi Paradox. In 1950, the physician Enrico Fermi (1938 Nobel Prize) is having lunch with his colleagues in Los Alamos. They are discussing a cartoon on extra-terrestrials which appeared in the New Yorker, when suddenly Fermi says: "Where are they?". His colleagues instantly understand that Fermi is referring to the fact that the sun is a relatively young star in our galaxy. Consequently, civilisations more advanced than our own should have appeared in the older planetary systems and have therefore colonised our galaxy in one way or another and thus have shown themselves to us. Please note, however that Fermi probably did not doubt the existence of other civilisations. The more likely explanations for the paradox are that interstellar travel is simply not possible, that the trip was not worth the effort, or that civilisations do not survive long enough to develop the necessary technologies (Gray, 2015).

04 | What is life?

We have seen in the previous paragraphs that one of the problems in the search for extra-terrestrial life is the fact that we don't know exactly what life outside our planet might look like. This question is only the start of a much deeper question: what is life? This rather philosophical question seems simple, but it is actually far from having a clear answer, even from a purely scientific point of view.

First of all, it seems easy to decide whether something is living or not. Unfortunately, the world is full of borderline examples. Therefore, some things are alive according to one definition, whereas they are not according to another definition. In everyday life, this doesn't pose a major problem. However, it's catastrophic in the field of science, as the microbiologist Radu Popa from NASA explains: "This is intolerable for any science [...] But a science in which the most important object has no definition? That's absolutely unacceptable. How are we going to discuss it if you believe that the definition of life has something to do with DNA, and I think it has something to do with dynamic systems? [...] We cannot find life on Mars because we cannot agree what life represents." (Zimmer, 2021).

Finding a definition of life that satisfies everyone is proving very complicated. But that is what the molecular biologist Edward Trifonov tried to do in 2011. He examined 123 current definitions of life and tried to find a common sub-definition among them. The final result was that life is an "auto-reproduction with variation". However, this definition was quickly dismissed: a computer virus reproduces with variation, but no one would say it is alive.

Then the philosophers have tried to find an answer by adopting different perspectives. One philosophical trend follows the principal of operationalism, according to which it is not absolutely necessary to find a universal definition for life. Each area of scientific research works with the definition best suited to it. Therefore the definition that NASA uses to look for life outside our planet differs from the one that doctors use to distinguish between alive and dead. But this doesn't matter, the important thing is that the definition works for its own field of research.

Another trend goes more in the direction of family resemblance, which is a philosophical idea according to which we classify objects into different groups. The objects in the same group can be linked by their similarities without necessarily all sharing a common similarity. For example, to illustrate this idea: if we asked one person to give a definition of the word "game", they would probably not be able to do it. A game can be played with two people, more or even alone. A game can have a winner and a loser, but it doesn't' necessarily have to fulfil this criterion. A game can be for children, but there are also games for adults. To find a clear, succinct definition for the term "game" is evidently not simple. However, if we were asked to identify, among different objects, which of them are games, we would probably have no difficulty in doing so. Intuitively, we know how to recognise a game, without having an exact definition. A game satisfies a certain number of criteria within a list of criteria, but without necessarily having to satisfy all of these criteria. And what if it was the same with the term "life"? In (Abbott & Persson, 2021), some researchers from the University of Lund have classified a long list of things into various categories, hoping to find the category that defines life. They have tried to establish a list of properties that are associated with life, without each living object necessarily having to satisfy all of these criteria. Unfortunately, this approach also poses a problem. One of the properties of living things was order (living things have coordinated and organised structures), as do snowflakes (which we cannot class in the living things category). Another property was that of DNA. However, red blood cells do not have DNA, whereas we would like to class them in the category of living things.

One category of organisms has really changed the perspective on what life is: extremophiles. These are organisms whose normal life conditions are fatal for most other organisms.

The tardigrade is one well-known example.

The tardigrade, the cutest of all the extremophiles

The tardigrade, also known as the water bear, is an organism of half a millimetre long (just big enough to be seen by the naked eye) which lives almost everywhere on the planet. It can be found in salty or fresh water, as well as in humid terrestrial environments such as forest mosses. The tardigrade is often referred to as the champion of extremes because it can survive in the most hostile of environments: it can withstand temperatures of -272°C to 150°C and up to 6,000 bars of pressure. It can also be exposed to ultraviolet rays and X-rays. It can go without food or water and put itself in a state of stasis for over 10 years. Once its state of stasis has finished, it can reactivate its metabolism.

In 2007, during the TARDIS experiment (Tardigrades in Space), ESA researchers sent 3,000 tardigrades on a 12-day space mission. "Our principal finding is that the space vacuum, which entails extreme dehydration and cosmic radiation, was not a problem for water bears," the head of the TARDIS project explained (ESA, 2008).

Recently, the ESA kept tardigrades outside the international space station (ISS) for even longer and they survived the space vacuum, extreme temperatures and solar rays. Previously, scientists were convinced that these conditions were incompatible with any life form (ESA, n.d.a).

We also invite you to check out ESERO Luxembourg's *Space Bears activity*.

Meet the tartigrade, the thoughest animal on Earth - Thomas Boothby

Carole Cleland, philosopher at the University of Colorado, suggests an even more radical approach. For years, she has observed, collaborated and discussed with several researchers in different areas and from different institutions (in particular NASA). And the thing they all have in common is that their research is concerned with life. She drew a series of scientific articles from this, which have been collated into a book (Cleland, 2019). Her conclusion: scientists should simply stop looking for a definition of life, because it is one of those undefinable concepts. After all, according to Cleland, "we don't want to know what the word 'life' means to us, we want to know what life is".

For a complete overview of the scientific and philosophical discussions around life, we refer the reader to (Zimmer, 2021) or (Zimmer 2021a).

05 | The importance of robots (and digital sciences) for missions to Mars

Sending robots to Mars offers many advantages. Firstly, it is much easier to ensure a robot's safety than a human's. When humans didn't know any better, they sent animals like dogs or monkeys on space missions to find out what a human needed. Today, we know that it can be very dangerous for humans to go further into space than the ISS (International Space Station). What's more, robotised missions are always less expensive than missions with humans (even if they are clearly less spectacular). From an organisational perspective, robots are less vulnerable than humans and can operate in much more hostile environments. Lastly, there are several tasks that a robot can accomplish better than a human.

However, as we have seen in this module, these robots cannot be programmed from Earth, because a signal coming from Earth would take too long (around 20 minutes) to travel from Earth to Mars. These robots therefore have to be programmed in advance and then function autonomously.

On Mars, the robots collect a lot of information that they have to send to Earth. This represents quite a large flow of data which can't currently be processed in space and has to be sent in the form of raw data. Furthermore, Martian rovers don't have all the laboratories that we have here on Earth. Outside the ISS, we can currently only use computers in space that are about as powerful as the ones we had on Earth 20 years ago. "Without the protection of the Earth's magnetic field or the ISS shield," explains Professor Marcus Völp, researcher at SnT (Interdisciplinary Centre for Security, Reliability and Trust) at the University of Luxembourg, "the computers we use on Earth would make a lot of mistakes and would end up getting fried because of the radiation in space. However, we do need calculating power by the time we want to collect the first matter from asteroids using swarms of robots." This is why research is investing in the development of "supercomputers" which will be capable of working in space and processing raw data directly on location, so that only useful data is sent back.

Of course, we must make the robots and supercomputers secure with regard to sources of natural errors" continues Professor Völp, "but we must also protect them from sabotage. The best way to achieve this is to allow the robot to make mistakes, just like pupils do at school sometimes, without anything terrible happening (for example by allowing pupils to help other pupils and other robots to help other robots)."

The ISS is already welcoming astronauts who will soon be near the Moon and one day on Mars. However, we can't train all astronauts in IT: these supercomputers will therefore have to be as autonomous as possible. That's where artificial intelligence comes into play.

Artificial intelligence will also play an increasingly important role in the robots. The European Space Agency (ESA) and the National Aeronautics and Space Administration (NASA) are planning to send a rover to Mars in 2026. Its mission will be to collect tubes containing samples of Martian ground. These tubes will have been placed on the ground previously by the rover Perseverance (see above). The new rover will be called Fetch (from the verb to fetch). It must be capable of moving around as autonomously as possible, to find the tubes and retrieve them. To do this, the rover Fetch will use artificial intelligence and image-recognition techniques so that it can find the tubes left on the ground autonomously (ESA, 2020).

The University of Luxembourg and the SnT are conducting research in all of these areas: error tolerance, artificial intelligence on robots and many others.

References:

Abbott, Jessica K. & Persson, Eric. (2021). The problem of defining life: a case study using family resemblance. [Preprint]
Alonso, Ricardo. & Szostak, Jack W. (2019). The Origin of Life on Earth. Scientific American, September 2019
Cleland, Carol. (2019). *The Quest for a Universal Theory of Life: Searching for Life As We Don't Know It* (Cambridge Astrobiology). Cambridge: Cambridge University Press.
European Space Agency, ESA. (2008). Tiny animals survive exposure to space.
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Research/Tiny_animals_survive_exposure_to_space
European Space Agency, ESA. (2019). Missions to Mars.
https://www.esa.int/ESA_Multimedia/Images/2019/05/Missions_to_Mars
European Space Agency, ESA. (2019a). ESA's Mars rover has a name: Rosalind Franklin.
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/ExoMars/ESA_s_Mars_rover_has_a_name_Rosalind_Franklin
Euorpean Space Agency, ESA. (2020). Sample Fetch Rover for Mars Sample Return campaign.
https://www.esa.int/ESA_Multimedia/Videos/2020/02/Sample_Fetch_Rover_for_Mars_Sample_Return_campaign
European Space Agency, ESA. (n.d.). Exploring Mars.
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Exploration/Mars
European Space Agency, ESA. (n.d.a). Exposure to space and Mars.
https://www.esa.int/Science_Exploration/Human_and_Robotic_Exploration/Blue_dot/Exposure_to_space_and_Mars
Gray, Robert H. (2015). The fermi paradox is neither Fermi's nor a paradox. Astrobiology, 2015 Mar;15(3):195-9.
McKay, Christopher P. & Parro García, Victor. (2014). Thow to Search for Life on Mars. Scientific American, June 2014
Science.lu. (2022). ESA stoppt gemeinsame Mars-Mission mit Russland.
https://science.lu/de/esa-stoppt-gemeinsame-mars-mission-mit-russland
Space.com (n.d.). Mars missions: A brief history.
https://www.space.com/13558-historic-mars-missions.html
TED (n.d.). What's the big deal about Mars.
https://www.ted.com/playlists/414/what_s_the_big_deal_about_mars
Wolchover, Natalie. (2021). The Webb Space Telescope Will Rewrite Cosmic History. If it Works. Quantamagazine.
https://www.quantamagazine.org/why-nasas-james-webb-space-telescope-matters-so-much-20211203/
Zimmer, Carl. (2021). What is Life ? The Vast Diversity defies easy Definition. Quantamagazine.
https://www.quantamagazine.org/what-is-life-its-vast-diversity-defies-easy-definition-20210309/
Zimmer, Carl. (2021a). Life's Edge. The Search for what it means to be alive. New York, NY : Dutton.

4.7 A word from the scientists: interview with Dr Miguel Olivares-Mendez

Miguel Olivares-Mendez is an assistant professor at the Interdisciplinary Centre for Security, Reliability and Trust (SnT) at the University of Luxembourg. He leads the Space Robotics department.

In 2006, he obtained his Computing Engineer diploma at the University of Malaga (UMA), in Spain, then a master's degree in robotics and automation in 2009 and in 2013 a doctorate in robotics and automation at the faculty of industrial engineering at the Technical University of Madrid (UPM), in Spain. In 2013, he won the prize for the best doctoral thesis awarded by the European Society for Fuzzy Logic and Technology (EUSFLAT).

In May 2013, he joined the SnT at the University of Luxembourg as an associate researcher in the automation and robotics research group. In December 2016, he became a researcher with overall responsibility for research activities into mobile robotics in the Automation & Robotics research group at SnT – University of Luxembourg.

In 2019, he was named professor of space robotics at the University of Luxembourg and in 2020 he founded the research group Space Robotics (SpaceR) at SnT – University of Luxembourg. The SpaceR group, which currently consists of 22 members, has received 3.5 million euros in financed projects and industrial collaborations. Over the course of its first year and a half as the head of the SpaceR group, Miguel Olivares-Mendez imagined, constructed and implemented two facilities linked to space: the LunaLab and the Zero-G Lab.

Luna Lab

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