NEMO Science Museum

With the support of the Erasmus+ Programme of the European Union

Content

1. O2-SPACE PROGRAMME FOR SCIENCE CENTERS AND NGO'S – 1: BUILD A ROBOTIC ARM

1.1 Activity Description

In this activity the participants make a robotic arm to move an object at 1.5 meters distance. The object must be put in a marked compartment.

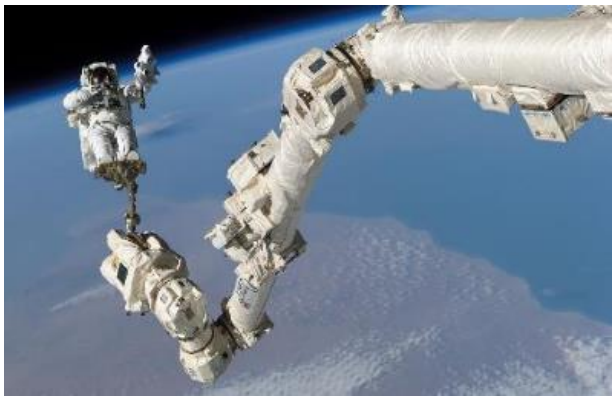
In NEMO science museum this activity is deployed as an unguided standalone activity. Visitors can enter the workshop area and do this activity independently with their own group.

This activity is designed, tested and deployed during the Covid-19 pandemic of 2020-2022. Therefore there is also an extensive guideline and protocol for disinfecting the materials and working hygienically. The activity is based on the tinkering philosophy (Appendix 4.1) where the emphasis is more on the learning process than the final result.

The learning objectives for the students are to:

- learn why a Robotic arm is useful in Space and which robotic arms are being deployed at the ISS;
- research, design and test a robotic arm to grab something (i.e. a moon rock) and move it (i.e. into a collector);
- test their ideas and improve their designs by tinkering;
- learn to use and combine different materials, find solutions for moving parts and use different techniques to assemble the components.

1.2 Context



Robotic Arms are widespread in the Space Industry. Mars Rover Perseverance has one to collect and inspect rocks on the surface of Mars. The Canadian Arm catches manned and unmanned space vehicles when they approach the ISS for docking. The ISS has since 2021 a new European Robotic Arm (ERA), that will help moving parts, transferring payloads in and out the ISS and assisting the astronauts as they work at the outside of the ISS. The ISS has three robotic arms. The function of robotic arms are similar of that of human arms. They are used to grab or hold an object and move it to somewhere else. The context of this activity is versatile and can be adjusted to current affairs. Currently this activity is deployed in NEMO as: give a present to someone at 1,5 meters distance.

1.3 Guideline for educators

This is an unaccompanied activity, visitors can get started independently in the workshop space. Museum Educators can go in the workshop space and guide a little. When guiding, it is important that they know what the visitor is doing, and can make an estimation of what he/she feels, experiences and when he/she gets stuck (and why). It is therefore important to **observe** the participants when they are working. See what they're doing, what materials they're using and how they're responding.

Guidelines for the Museum Educators:

- **Sit on your hands** – suppress the tendency to do something for the visitor yourself. By asking questions and possibly giving hints or directions, try to help the visitor.
- Give **encouragement** and **appreciation.** Compliments can work very well, but try to be specific. "What a smart way to fasten this." Compliment original ideas or innovative use of materials.
- If visitors are unsure if something is **succeeding,** encourage them to just **try** it.
- Also focus on the **process** 'How good that you have persevered!'.
- Let the visitors **put into words** what they are up to or what they are doing. Ask questions about what they plan to make or why they chose to do things a certain way. This way you encourage them to talk about their ideas and reasoning and give you the opportunity to ask a **specific** question or compliment.
- **Challenge the visitor** to further develop the system, for example 'How far do you get?' "Can you lift the present?"
- Point out **aspects** or material **that the visitor may not have noticed yet.** 'This might make it longer'
- If**:** visitors get stuck - encourage them **to** take a good look at what the problem is.
- Point to similar **examples** that are in display.
- **Celebrate successes.**

Learn more about Tinkering in Appendix 4.1

1.4 Hygiene measures (due to the Covid-19 pandemic)

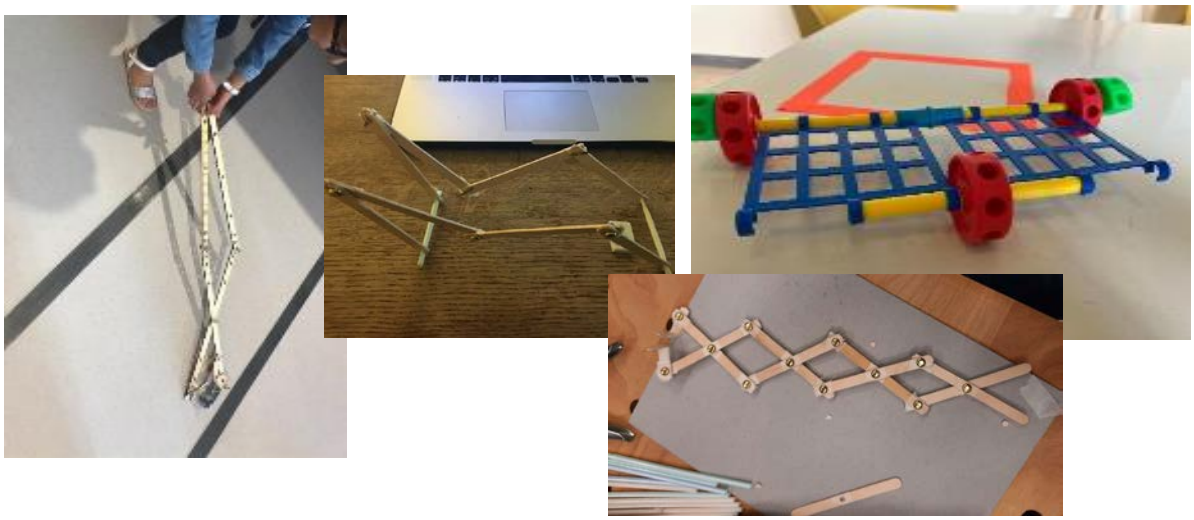
Outside of the measures already in force (keeping your distance, disinfecting hands on each floor, extra cleaning). Are there additional measures for workshops:

- When entering the workshop area the visitors clean their hands with disinfecting fluid;
- The activity starts with the disinfection of the materials using the UVC cabinet by the visitors;
- The doors of the workshop area remains open;
- Additional cleaning of the materials used, in this case with the UVC cabinet. Irradiation with UVC light causes disintegration of the molecules of the virus and all other organisms. (see Appendix 4.3 in the document for more information).

1.5 Outcome of the activity

The activity is deployed from June 2021 onwards in NEMO and is very popular with the visitors.

Example of outcomes of the activity



Additional information

Detailed instruction for museum educators (4.2), argumentation for using UVC as disinfectant and (4.3) a product list (4.4) and instructions for the visitors (4.5) are put in the appendices.

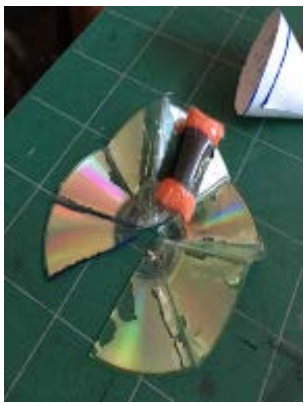
2. O2-SPACE PROGRAMME FOR SCIENCE CENTERS AND NGO'S – 2: ORIGAMI WITH SOLAR PANELS

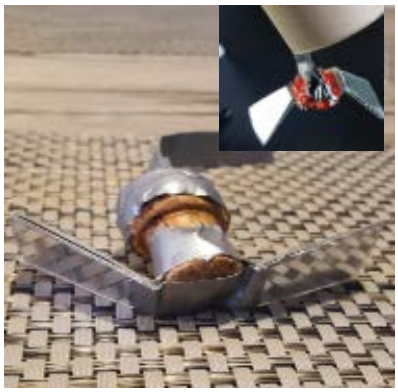
2.1 Activity description

During the development of the O2 activities, the Covid-19 pandemic started and NEMO Science Museum closed its doors to the public. So the criteria for an activity changed. We started to develop an activity that could be tested online. People who participate in these activities had to collect materials in there house to do this activity. The most commonly used objects were things like toilet rolls, that everyone has in their homes during a lockdown.

This activity was prototyped with colleagues that also worked from home. This worked very well and the outcomes were very different every time. An additional advantage for this subject was that the expert in the career video we made for output 3, is a test engineer of foldable solar panels.



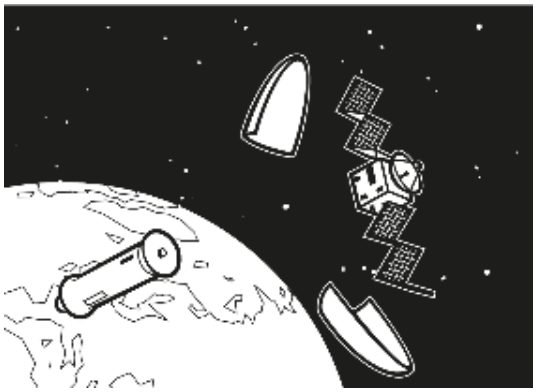



As our museum decided to further develop the criteria for workshops, more awareness for sustainability in the museum was also on the list. That meant no disposables in workshops any more, only reusable materials. This activity was therefore temporarily abandoned for use in NEMO. We developed the robotic arm instead.

But because this activity was a success and in a far stadium, we decided to further develop it into a lesson for the classroom. It was tested online on two different classes of 20 children from the ages 12-14 and the outcomes of the evaluations were that teachers were very enthusiastic about it.

2.2 Teacher Manual - Overview



Spacecrafts need solar panels for their energy supply. Those solar panels are large and flat, but a rocket is round and has little cargo space. The designers and technicians must therefore take into account not only the conditions in space and the mission of the spacecraft, but also the journey to it. In this lesson, students are introduced to the challenges of a designer and also solve such a practical problem.

Age students: 12-14 years

Lesson goals

The students:

- can explain which factors a space mission designer should take into account and why;
- design and create a satellite with solar panels and fold it into the cargo area of a rocket, taking into account the design requirements;
- learn to design, apply and improve solutions for spatial problems and moving constructions.

Lesson structure

The lesson begins with the requirements that a space mission designer must take into account. Afterwards, the students do a practical assignment in which they devise and execute a design of a flat solar panel in a round rocket nose. The lesson ends with the re-examining of the different solutions and the problems that the students have encountered. They also look at how space agencies are working on solutions to these problems.

Preparation 30 minutes

Read the lesson and background information and determine at what level the students will work out the assignment. Try out the assignment yourself and prepare any footage and videos. Collect the materials or ask the students to do this themselves.

Necessities per person or pair

- sharp scissors
- adhesive tape or painter's tape
- CD(-ROM) that can be broken*
- cork (or something else in that shape, for example, a lip balm)
- toilet roll

Duration of lesson: 45-60 minutes

Core objectives: Mathematics, physics and engineering.

Material costs: low

*The CD is just like the solar panel in the real situation difficult material. A CD-ROM breaks down into several layers when you cut it. The challenge is to keep the specular part anyway. A printed music CD does not have this problem. As an alternative to a CD, the students can also use thick cardboard.

2.3 Lesson description – for Teachers

Origami with solar panels

Introduction 10 minutes

Introduce the lesson to the students. Each space mission has a specific purpose, such as making measurements of substances in the Earth's atmosphere, studying the sun's radiation or the surface of Mars. Each mission has very different design requirements. That's why every space mission looks different.

Space mission

Satellites orbiting the Earth are part of a space mission– just like space explorers (probes) that travel to other planets in our solar system. Each satellite or probe has a different size and shape and these depend on a number of factors:

- the measuring instrument that will carry out the mission; this has a size, shape and energy requirement;
- the communication equipment for contact with the earth;
- the size of the solar panels; these depend on the energy needs of the equipment, the orbit around the earth and/or the route to the target and closeness to the sun. The larger the solar panel, the more energy it can provide;
- the construction that holds everything together firmly and ensures that everything works: the bus and service module;
- the dimensions of the cargo space of the rocket with which the mission is launched.

Different forms of Earth observation satellites

Figure 1 Left to Right: Sentinel-5P TROPOMI, AEOLUS and Sentinel-6. Source: ESA

Figure 1 shows examples of three Earth observation satellites, each with completely different shapes and sizes. TROPOMI, the measuring instrument on the Sentinel-5P satellite, measures reflected light from Earth with an advanced prism. Its purpose is to make measurements of various substances in the Earth's atmosphere. To measure the wind directions, the instrument on the satellite AEOLUS uses a special kind of laser (LIDAR) and has a different orbit around the earth than Sentinel 5P-TROPOMI. Sentinel-6 satellite, measures earth's sea level with radar technology and also looks very different.

Rocket journey

Satellites are brought to space by rockets. Each rocket has its own specific characteristics. The cargo space wherein the satellite has to fit, is always in the nose, but the dimensions differ per rocket. The type of rocket also affects the maximum weight that the charge may have. When designing, it is important to take this into account.

Because the cargo space is limited, the solar panels are folded during launch. Only in space they unfold. At launch, they are exposed to great forces and vibrations, so they have to be able to withstand that. All these things must be properly tested before launch, because once the satellite is launched, the technicians can no longer access it for maintenance or repairs. That is why it is also important to test in advance whether the solar panel can withstand large temperature differences and whether it also functions well in the vacuum of space.

Figure 2 Vega rocket, with cargo space at the top. Source: ESA

Assignment 30 minutes

The students will now get to work on the design assignment: origami with solar panels. The assignment is to make a design in which a CD (the solar panel) and a cork (the satellite) fit together in a toilet roll (the nose of the rocket). A number of design requirements have been drawn up. Those are also the criteria for evaluating the design of the students.

The students can perform this assignment in a number of ways:

- In class: the students carry out the design assignment in class. They can therefore look together and be inspired by other people's problem solving.
- At home: the students design and make the design assignment at home. They then take their design to class and present it. Or they can hand in a few photos or short video of the folding and unfolding (for example, of up to 10 seconds), in which they show that the design meets the requirements.
- Digital at home: this assignment lends itself well to online. Make sure that students have collected the materials in advance, otherwise it will take a lot of lesson time.
- In pairs or individually:
    - In the classroom there is the possibility to do the assignment in pairs. This stimulates thinking about the design in advance, because the students then have to make a plan together and explain their ideas to each other.
    - An individual assignment results in more trial and testing. They also learn to invent and implement solutions to technical problems directly on their own. It is then useful to schedule a feedback moment in between to encourage stalled students to continue. Students can exchange their solved problems at such a time.

Tip: With a whiteboard marker you can draw well on smooth surfaces. The students can start drawing a cutting plan on the CD before cutting.

Design requirements

The design requirements for the design are also the evaluation criteria. These can be expanded to make the assignment more challenging. The worksheet contains only the basic requirements:

- Solar panel: use the entire reflective surface of the CD. The reflective side must remain uncovered as much as possible. Adhesive tape stops sunlight.
- Construction: the solar panel must be attached to the satellite.
- Packing: the satellite and the entire solar panel must fit in the nose of the rocket. Unfold after launch: the entire reflective surface of the solar panel must point in the same direction (the sun) after unfolding. The reflective side is the working side of the panel.

This lesson has a number of expansion possibilities:

Materials

Limiting materials stimulates the creative process of coming up with better solutions. Also, it makes the comparison of different solutions based on exactly the same materials more interesting. But sometimes it is not possible to offer everyone the same materials. The option to use more and different materials gives the students more influence on their own process and also offers opportunities for more diversity in the types of solutions. For example, the satellite can be a piece of clay, students can use iron wire in the construction, paper as a support material for the solar panel and so on. Make clear agreements about the design requirements. The satellite must remain a contiguous structure. And if students use cardboard as an alternative to a CD, make sure that the properties remain the same, because that the solar panel is a fragile, rigid material is an important part of the assignment. Because a CD cannot bend, the alternative material is not allowed to do so either. A possible addition is to set a maximum weight for the whole structure.

Applied mathematics

In the assignment, students practice with their spatial insight and geometry. Even more math can be added by asking students to mathematically substantiate that the CD or material they have used still has the same surface area as the basic material. The same can be done with the volume of the cork.

Folding mechanism

Adding a fold-out mechanism makes the assignment technically and conceptually more difficult. When you fold a material by hand, you use all possible folding directions. In space travel, unfolding often only happens in one direction. More directions makes it more complicated and the folding mechanism also has to come along in the rocket, and that means less weight and size for the satellite itself. That is why solar panels from satellites often have a z-profile that is folded under tension. When it is at its destination, the tension is released and the solar panel unfolds. Other solutions are also possible. With this extension, make sure you have more materials, such as wooden sticks, paper and rubber bands.

Evaluation 10 minutes

Discuss the different solutions the students have created. Invite a few students to present their designs. Do they meet the design requirements?

Discuss similarities and differences between the solutions. What are common folding profiles? Where are the panels usually mounted? What was the biggest design problem they encountered? How did the design process go?

Design problems and solutions

- Hinges need space to move: if you tape the pieces together too tightly, they can no longer move. Apparently, a hinge needs space to move.
- CD's that fall apart: when tapping the different layers of the CD together, you have to take into account that you are not allowed to tape over the reflective part, so you only do the edges. And not to use pieces of the CD that are too small.
- Solar panel and satellite together: the challenge seems to be mainly folding the panel. But at the end of the day, it all has to be tied together and fit into the toilet roll together. The widest part of the toilet roll, the middle, you can only use once.
- What are the advantages and disadvantages of different solutions? Do you think your solution will survive the space?

Process questions

- The order of the design process: how did you get started? Design first or try directly? What are the advantages and disadvantages of both approaches?
- Design: did you make a cutting plan with a whiteboard pen? Did you stick to it? Did your idea make sense in the execution?
- Group work: how did the collaboration go? Did you do everything the same, or was there a division of the thinking and the executive work?

Closing 5 minutes

Complete the assignment and discuss with the students that they have thought like an engineer about the problems that a satellite builder and designer encounter. They have solved real problems and shown in pilot situation that their solution works. The space industry also works with dummies and scale models for tests. In the practical assignment, they applied mathematics skills such as spatial awareness and geometry, devised and tried out technical solutions and tested them endlessly. This is also how it works in the space industry: engineers are constantly looking for smart solutions. They are often inspired by solutions from other crafts and by nature. For example, NASA has an origami department for this purpose (duration 3.20 minutes): https://bit.ly/2YgAdrN.

2.4 Extra information for the teacher

Types of satellites

Every space mission is different and every mission has its own requirements. This lesson uses the example of earth observation satellites. ESA's Copernicus program has Earth observation satellites with the Sentinel satellites that measure the state of our Earth. They keep an eye on air pollution, sea levels and other indicators. Each satellite looks different. Figure 3 shows the satellites. For more information about the Copernicus programme, please visit: http://bit.ly/copernicus_satellieten.

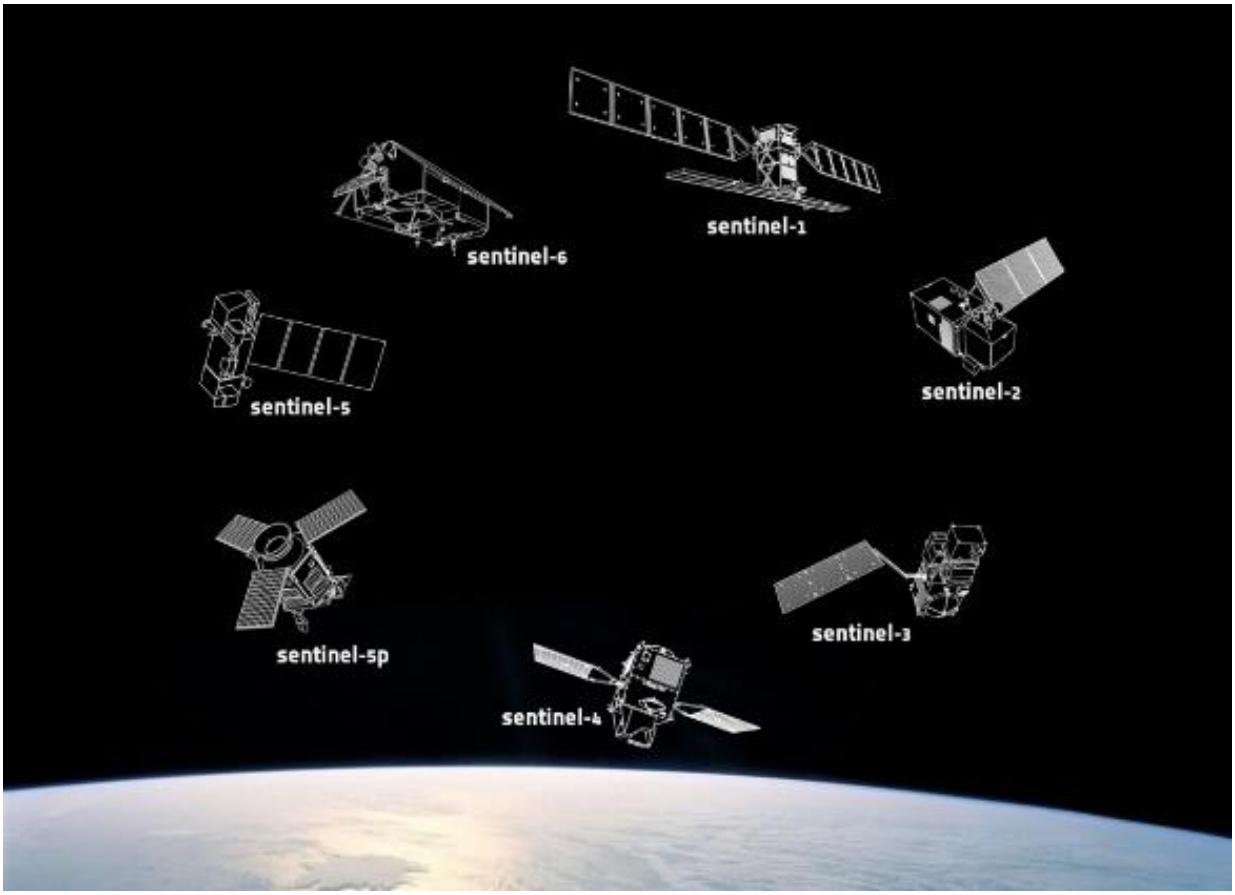


Figure 3 ESA Copernicus Earth observation programme with all the different satellites. Source: ESA

Cargo and launch

A lot of energy is needed to detach from the earth's gravity. Rockets therefore take a lot of fuel with them. The bigger and heavier their load is, the more fuel they have to carry and the bigger they have to be themselves. That's why designers of satellites do their best to keep them as small and light as possible.

VEGA

The smallest rocket of the European Space Agency (ESA) is the VEGA. It is 30 meters high, has a diameter of 3 meters and weighs 137,000 kilos including cargo and fuel.

The VEGA can transport a total of 1500 kilos to space to an orbit of 700 kilometers above the Earth. This rocket puts Earth observation satellites into orbit.

The load (or *payload)* must fit into the cargo space in the nose. More satellites can also be taken along, as long as the maximum weight is not exceeded. The maximum volume of the load is 20 $m^{3,}$ the external dimension of the nose is 7.13 meters high and the diameter 2.3 meters.

The VEGA has four stages, or rocket engines, that are used in successive launch phases. The lower engine is the largest and turns on first. When the fuel of this stage is finished, it is released and the next stage turns on and so on. The fourth stage is usually attached to the load at the VEGA. For example, it can take the cargo to just the right orbit or ensure that small satellites are released at different times.

Packing and unfolding

The satellites are folded before launch to fit into the nose of the rocket. Once in space, they should automatically unfold. Figures 6 and 7 show the packing and unfolding of the Earth observation satellite AEOLUS, which was launched into orbit with a VEGA rocket on 22 August 2018.

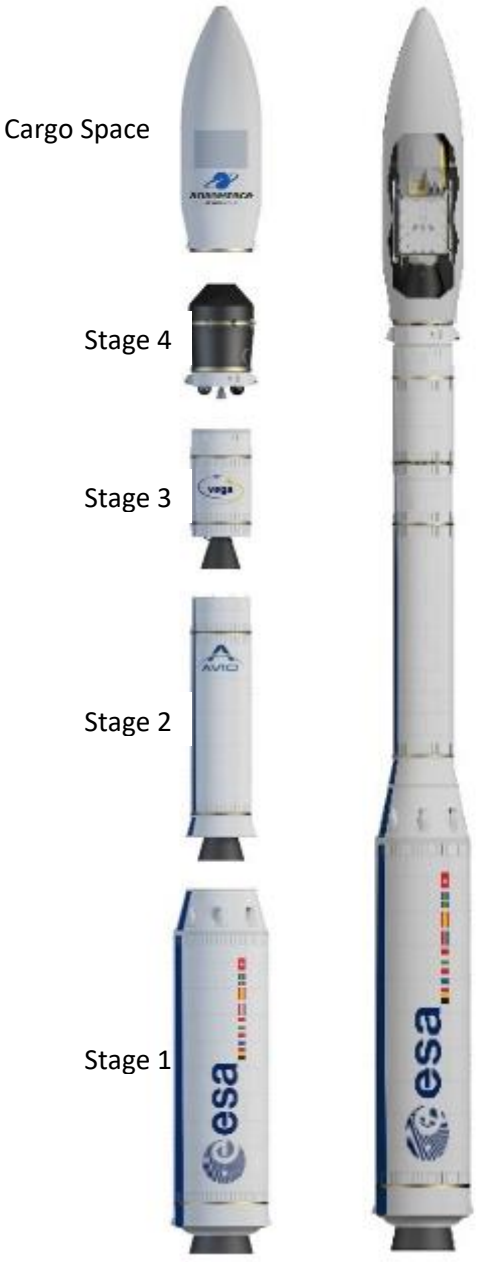


Figure 3 VEGA-four stage rocket, With cargo space in the nose. Source: ESA

Figure 5 The packing of earth observation satellite AEOLUS in the nose of the VEGA. Source: ESA

Watch a time-lapse video of packing the AEOLUS in the nose of the VEGA rocket through launch (duration 3.28 minutes): https://bit.ly/3cggG35

Animations of expanding AEOLUS in space:

- Aeolus in Vega, stage 4, fold out nose (duration 0.20 minutes): http://bit.ly/2KRG18a
- Stage 4 separation (0.20): http://bit.ly/39m7kRk
- Fold-out solar panels (0.20): http://bit.ly/3qVgvhF

Figure 4 Animation, of launch, release and deployment of AEOLUS. Source: ESA

There are also space missions that leave earth's environment. For example, they will observe the Sun (Solar Orbiter), to Mars (ExoMars) or to Mercury (BepiColombo). Because of the amount of radiation and heat, a probe in orbit around the sun requires a different kind of solar panel than a probe that travels to Mars or Mercury. These explorers also have to fold out in the right place, and for such a long journey that is often a bit more complicated and more steps are needed.

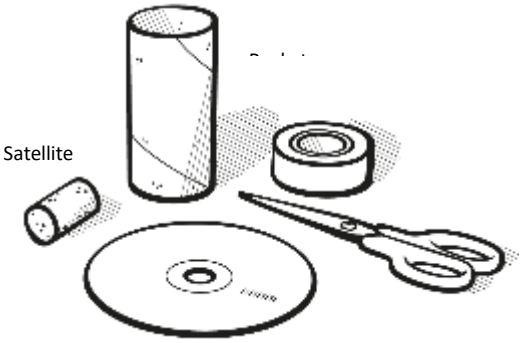
- Video about ExoMars (duration 2.34 minutes): https://bit.ly/3sXZvt1
- Video about Solar Orbiter (2.40): https://bit.ly/39jU7Zp
- Video about BepiColombo (3.27): https://bit.ly/3pkSmkj

2.5 Worksheet - Students

Origami with solar panels

Assignment

Design and create a satellite with solar panels and fold it into the nose of a rocket.



Materials

- Solar panel: CD that can be broken
- Satellite: cork, or anything else of that size and shape, like a lip balm
- Rocket nose: toilet roll
- Sharp scissors
- Adhesive tape or painter's tape

Your design must meet these design requirements:

- Solar panel

  You need to use the entire reflective surface of the CD. You should leave the reflective side uncovered, because adhesive tape stops the sunlight.

- Construction

  The solar panel must be attached to the satellite.

- Pack

  The satellite and the entire solar panel must fit into the nose (the cargo area) of the rocket.

- Deploy after launch

  The entire reflective part of the solar panel must, after unfolding, point in the same direction (towards the sun). The reflective side is the working side of the panel.

  Complete this assignment in consultation with your teacher.

3. OUTCOME 3-CAREER MOVIES AND PODCAST

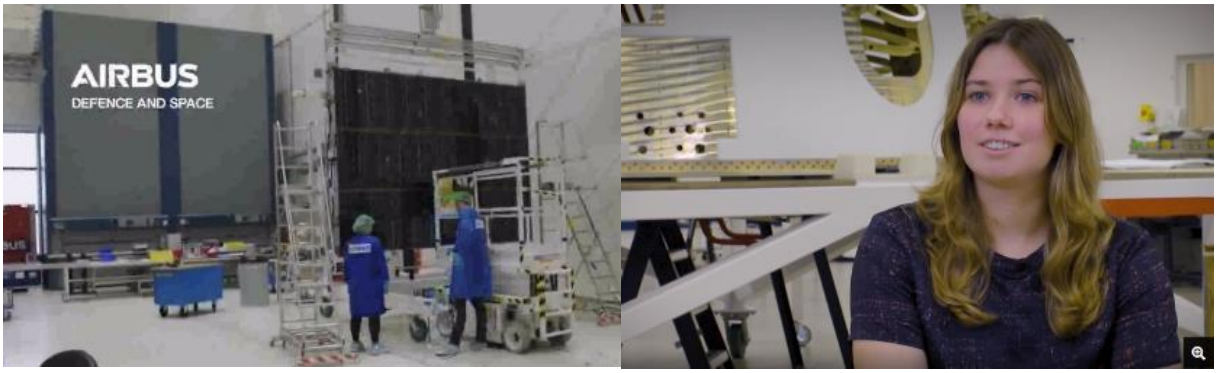
Description

To inform students what it is like to work in the space industry, we've recorded Career video's. Two Dutch role models tell in this video about their work, their passion and their choices in educations to become a space industry professional.

3.1 2020 Charlotte Pouwels – Test engineer at Airbus

Charlotte Pouwels is a Test Engineer at Airbus and an Analogue Astronaut for ESA. At Airbus she performs (non) destructive testing of solar arrays in a cleanroom environment and she also creates 3D models & drawings in this project (SparkWing). At EuroMoonMars, as Head of Logistics, she participates in simulated Astronaut missions on earth to perform research for future space missions. She studied Applied physics with a specialization in Space and radiation. Charlotte has the ambition to be a space astronaut, so she became an advanced diver and she takes flying lessons.

Watch here the Career Video with Charlotte Pouwels



3.2 2021 Sorosh Shoaie – earth observation data scientist at VanderSat

VanderSat is a Dutch remote sensing company that provides the highest spatial resolution data products to clients all around the world. The soil moisture and vegetation optical depth products are acquired through the use of its patented algorithm and inquiries into novice data products are continuously made. Sorosh Shoaie is a Remote Sensing Specialist at VanderSat Dataprovider. He uses Earth observation data, monitor droughts. Why does he like working in the aerospace sector so much? And what was the education path he took, so he could do this work?

Watch here the Career Video with Sorosh Shoaie

3.3 Podcast: Jos de Laat – research earth observation (KNMI)

Jos de Laat is a Senior Scientist at The Royal Netherlands Meteorological Institute (KNMI). The Royal Netherlands Meteorological Institute (KNMI) is the Dutch national weather service. Primary tasks of KNMI are weather forecasting and monitoring of weather, climate, air quality and seismic activity. KNMI is also the national research and information centre for meteorology, climate, air quality, and seismology. As a research scientist, Jos has 15+ years of experience on atmospheric composition research with a focus on remote sensing. In this podcast he is interviewed, along with other European colleagues, on the topic of earth observation.

Listen here to the podcast FUTURE SPACE podcast - Earth Observations

4. APPENDICES

4.1 What is Tinkering?

Tinkering is an innovative method, work form and way of thinking and working. Tinkering activities are hands-on: participants are invited to play and create with tools and inspiring materials. The activities, materials and coaching method together lead to an exciting learning experience.

Creativity, problem-solving ability and personal input of the participant is emphasized. Tinkering encourages the participant to pursue their own project, idea or personal goal that corresponds to their own motivation and interests.

Tinkering activities offer the opportunity to get stuck and get out of it, goals can be continuously adjusted. The end goal is open and there is a lot of room to give creative interpretation to what you make. The making and learning process is more important than the result. Tinkering can help develop 21st century skills such as problem solving, creativity and confidence

Tinkering activities often span multiple subjects and disciplines, which means that participants work interdisciplinary with science, technology, math and visual education. Participants will ask themselves questions such as “I wonder how this works?” or “What would happen if I did this?”

Tinkering activities differ in content and style, but the points below always come up.

1. The activity is hands-on, something is made with materials and tools.

2. The atmosphere is playful, creative and innovative.

3. Participants follow their own interests and create their own learning path.

4. End results are highly variable and sometimes unexpected.

5. Begins with a starting point, throughout the activity participants are encouraged to set and adjust their own goals and use their creativity and a self-chosen way. This makes the activity interesting and meaningful for them.

6. In the activity the participants try a lot. In the beginning this may be improvisational, but during the activity it can go from improvising to designing, testing and improving.

4.2 Preparation of the workshop for Museum Educators

Task museum educator:

- At the beginning of the day make sure everything is ready.
- At the end of the day, complete any missing materials. In storage are ready-made packages and loose elements.
- At the end of the day, all materials are disinfected using the UVC cabinet.
- This is an unmanned activity, if there is time, walk in and see if you can enthuse visitors. See below in this document.
- Write down notable cases in logbook.

Setup the workshop area

- In the Workshop area there are max 3 tables. Around the tables is indicated with tape where visitors can work.
- On each table stickers are indicated where the start line of the activity is and where you can place the gift 1.5 meters away.
- On each table there is am and with material and the worktop.
- The UVC cabinet contains the instruction and safety warning.
- At the entrance there is a disinfection pole and poster with course of events.
- The digital screen contains information about the activity.

Material

- Tables + stools/chairs
- UVC Cabinet
- Disinfectant wipes
  - Documents:
    - Worksheet (on the table)
    - UVC cabinet instruction (on UVC cabinet)
    - Safety warning (in default on UVC cabinet)
  - A basket per table with:
    - 5 x short + 5 long wing nuts + 10 nuts
    - 2 x wooden long stick (42 cm) stick with holes
    - 5 x wooden bar (18 cm) with holes
    - 5 x purple bendable Tinkertoys sticks
    - 5 x yellow hard TinkerToys (TT) sticks
    - 2 x blue TT net
    - 4 x red TT wheels
    - 2 x green TT corner pieces
    - 2 x blue TT connector
    - 2 x blue TT plug
    - 2 x green TT eye connector
    - 2 x piece (+/- 50 cm cm) jumping rope
    - 1 x gift

Course of activity:

At the entrance there is a poster with instruction

- Make a giant arm to give a friend a present remotely.
- One family/household/group can work per table.
- Is there a table available? Come in. On the table is a basket of materials and the assignment.

Per table there is room for a household, they work at the table. Material and instructions are on the table. The activity starts with the disinfection of the materials in the UVC cabinet this takes 1.5 minutes. An adult must operate the UVC cabinet.

After:

- Visitors take the built apart (on the worksheet).
- Put the materials in the basket.

Safety

- UVC light is harmful, as soon as the door is opened, the lamps in the cabinet automatically go out.
- Plexiglass is incorporated into the door of the UVC cabinet, so you can see that the lamps are on. UVC light cannot pass through plexiglass.
- The loose small materials can be dangerous for very young children (when swallowed).
- In case of the UVC cabinet giving an error, switch on and off again. Visitors can't just set the time differently.

UVC cabinet

- Irradiation with UVC causes disintegration of the molecules of the virus (and all other organisms). On slippery surfaces it works best, for example a mobile phone, then 1 minute irradiation is enough. The radiation causes a 99.9% reduction in the virus. That's a better disinfection than alcohol with a wipe. Especially since you don't see where you've been and especially when you do it often you become less careful.
- The disinfection is especially suitable for smooth materials and simple shapes the better the disinfection. It is important that material can be irradiated on all sides, so do not lay on top of each other.
- The sensitivity varies from material to material, but a typical plastic/rubber material can last up to 10,000 cycles before there is any visible change. This amounts to 2 disinfection cycles in one day at 220 days a year at least 2.3 years A visible change does not mean that the material is unusable.
- Materials must be offered in aluminum or stainless steel baskets.
- The disinfection time can be set by pressing the start button for 3 seconds and continuing with the arrows to set the time. Confirm the correct time by pressing the start button again.
- The UVC cabinet is supplied by Bioclimatic(https://www.bioclimatic.nl/).

4.3 UVC cabinet

4.3.1 Argumentation for using UVC for disinfecting the materials

There are other ways to disinfect materials for activities then using UVC. Cleaning with ethanol 70% wipes or immersing the materials in disinfecting fluid. We researched those ways extensively and concluded that using the UVC cabinet is very durable and safe.

1. The cabinet we chose is save and easy.
   If the doors of the cabinet are open, the lamps won't switch on. So there is no risk that visitors can be in direct contact with the UVC light. Also the cabinet has a fixed time, visitors cannot change that. So they put the materials in, close the door and push start.
2. The use of the UVC is very thorough.
   When using a lot materials, they all have to be cleaned in between use by visitors. In the cabinet, if you make sure all the materials can receive the UVC light, all materials are cleaned. In contrast to using a disinfecting wipe with ethanol, then it is easy to miss a spot. Because there is no indication of what you've cleaned already and what not. As cleaning all the sides of all the materials is quite a time demanding task, the experience is that people are not doing it that thorough.
3. The use of UVC is save for materials.
   Because the exposure to UVC is very short (1,5 minute per cleaning), materials are not really affected. Electronic devices can also be safely disinfected by the cabinet. In contrast to cleaning materials by immersing them in disinfecting fluid. Wood for example degenerates very fast if you make it wet.
4. The use of UVC is sustainable and cheap in the long run.
   After purchasing a UVC cabinet it can be used endlessly. There is no checking and filling ethanol bottles, wipes or baths. Or buying replacements.

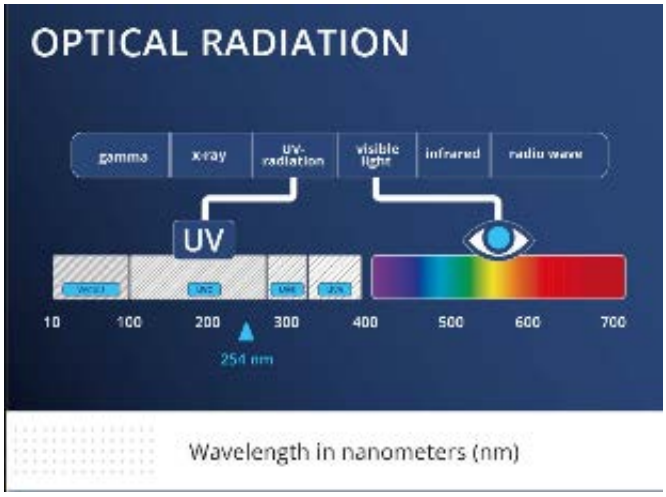
After successful testing with visitors, the UVC cabinet is deployed in the maker space at the museum.

4.3.2 Additional information about the UVC cabinet

(source bioclimatic.nl)

Effect of UVC disinfection

Invisible optical radiation, how can it be disinfecting? UVC as part of the light spectrum ultraviolet light or ultraviolet radiation is part of the light spectrum and has a shorter wavelength than visible light. Other invisible parts of the light spectrum include infrared and X-rays. UV light is divided into UVA, UVB, and UVC. UVC light has a wavelength of 100 to 300 nm, but the 240-280 nm range is particularly is well absorbed by microorganisms. The energy of the UVC light disrupts DNA and prevents microorganisms from multiplying. Professional disinfection bulbs mainly produce UVC light with a wavelength of 254 nm, which has the most powerful disinfecting effect.



Disinfecting effect

UVC damages the DNA of microorganisms and viruses, which keeps them from multiplying.

A photo-chemical effect is created in the cell that causes dimming. Adjoining Cytosine and Thymine molecules bind to each other instead of to the opposite base in the DNA molecule.

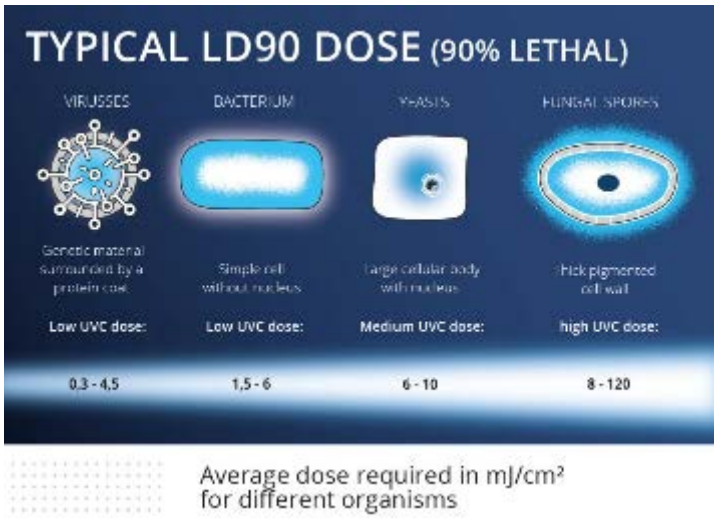
That renders the DNA information useless, and the cell dies and can no longer divide. The effectiveness of UVC light has been extensively researched and published by scientists worldwide, the best known being Wladyslaw Kowalski.

The relationship between dosage and result

For many microorganisms, we know what dosage is necessary for critical damage. We call the dosage needed to deactivate 90% of the population the D90 dose.

Sensitivity to UVC light varies widely between different types of microorganisms. Viruses and bacteria are very sensitive, while yeasts and molds are much more resistant to UVC light.

In practice, that means that molds need a longer exposure time or a more powerful UVC bulb.



Average dose required in mJ/cm² for different organisms

What are the risks?

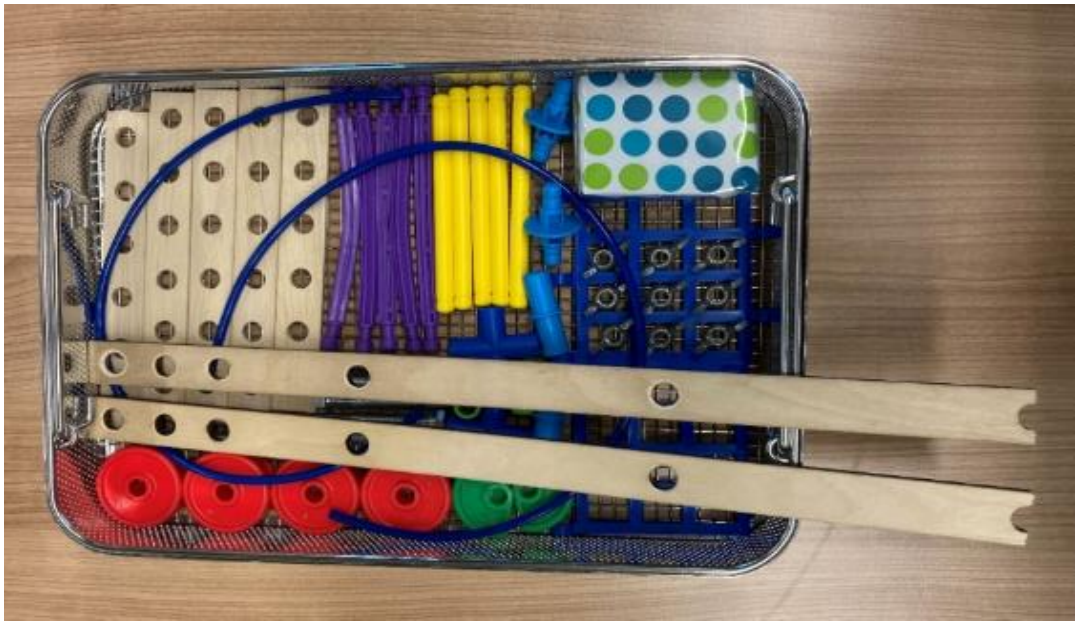
UVC is invisible, but UVC bulbs emit a blue light as a by-product that has no disinfecting effect. It serves a practical function, letting you know that the bulb is switched on.

UVC radiation is dangerous to skin and eyes, so it's best to avoid exposure. All installations should be shielded and proper protective equipment such as a face masks and skin covering should be used during testing and maintenance.

Effect on skin:
Because UVC does not have an infrared component like sunlight, you won't feel its effects, but it can cause redness and a burning sensation on the skin fairly quickly.

Effect on the eyes:
UVC does not penetrate into the eye, but corneal irritation can occur a few hours after exposure. It causes a painful, burning sensation that's also know n as "welder's eye" or "snow blindness".

4.4 List of materials



Material	Supplier	More information
Uvpro – UVC disinfection cabinet	Bioclimatic	Link to: website
Baskets for use in the UVC cabinet	Meekers Medical	Link to: website M-Line instrument net 360x250x60mm article no CIL254703
Wing nuts	Local Hardware store	M8
Screws	Local Hardware store	M8
Wooden bar with holes (42 cm)	Custom made, local laser cutter company	2 x 42 cm, 5 mm. thick multiplex, with holes
Wooden bar with holes (18 cm)	Part of Eichorn constructor set	Link to: product on amazon
Washing line	Local Household goods store	
Plastic box (gift/object to move)	Local Household goods store	15 cm. x 20 cm. x 3 cm. wrapped with gift paper
Purple bendable TT sticks	TinkerToy, Super Building Set	Link to: product on amazon
Yellow hard TT sticks		
Blue TT net		
Red TT wheels		
Green TT corner pieces		
Blue TT connector		
Blue TT plug		
Green TT circular connector		

4.5 Visitor instruction sheets

Welcome sign at the entrance.

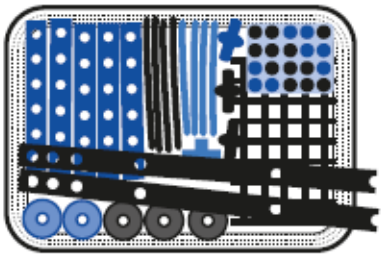
- **Ontsmet je handen**
  Disinfect your hands
- **1 huishouden per tafel**
  One household per table
- **Alle tafels bezet? Wacht even**
  Are all the tables occupied?
  Wait a few minutes
- **Tafel vrij? Kom binnen**
  Is there a table free? Come on in!

Build a giant arm

Work together to build a giant arm so that you can give someone a present from 1.5 metres away.

1 First disinfect the materials in the UV cabinet.

- Place the materials in the basket as shown in the picture: flat and next to each other, with minimum overlap.



- Take the basket over to the UV cabinet and follow the instructions. Please note: only an adult can operate the UV cabinet and only one person at a time is allowed near it.

Did you know?
The UV cabinet destroys viruses and other organisms. The UV light causes molecules to disintegrate.

2 Work together to build a giant arm so that you can give someone a present from 1.5 metres away.

- The gift has to go from START to the marked spot 1.5 metres away.
- Take a look at the materials and try a few things out. Build your giant arm.
- Test the giant arm. Can you use it to give the present from 1.5 metres away?

Here's an extra challenge: can you also lift the present with the giant arm?

3 When you have finished, deconstruct your giant arm and put the materials back on the table.

maker space

You want to do experiments at home?
nemosciencemuseum.nl/explore

Use of UVC Cabinet instruction

UV cabinet

1 Open the door and put the basket of materials in the cabinet.

2 Close the door.

Did you know?
Radiation with UV light causes viruses and other organisms to break down. The molecules disintegrate.

3 The time is already set to 1 minute and 30 seconds. Press the button to switch on the cabinet. Think about what you are going to make with the materials.

4 When 'end' appears on the display, the materials are clean. Open the door and take the basket of materials out of the cabinet. Don't worry, it won't be hot!

5 Take the basket to your table and use the materials to build a giant arm.

maker space

Safety Card on UV Cabinet