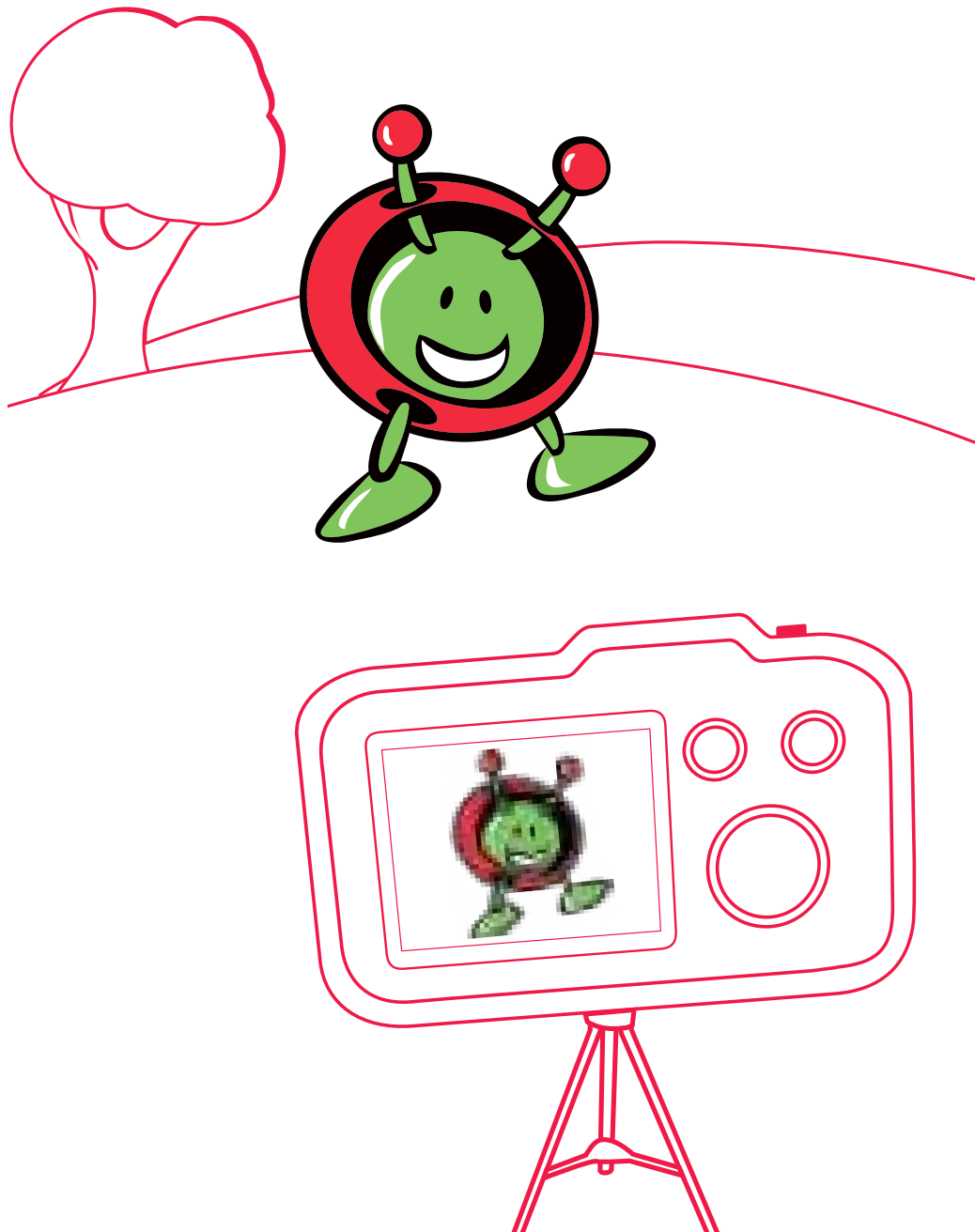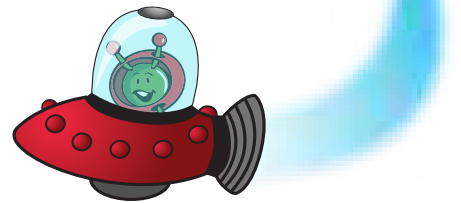esa **kids**

teach with space

→ PIXEL YOUR SPACE

Geometry behind science and art images

→ INTRODUCTION

If you compare old astronomy images, or even videogame graphics, you will probably notice a large difference in the level of detail that you can see. Have you ever wondered why? To answer this, we need to introduce the concept of 'pixels', which are used to create such images.

→ PIXEL YOUR SPACE

Geometry behind science and art images

FAST FACTS

Age range: 8–11 years old

Type: pupil activity

Complexity: easy

Teacher preparation time: 30 minutes

Lesson time required: 1.5–2 hours

Cost per kit: low (less than 10 euro)

Location: indoor (any classroom)

Includes the use of: printed photos, craft material, the internet

Outline

In this activity, pupils will understand the basics of geometric components of images, including pixels, and their scientific and artistic relevance. Pupils will work with an image and produce a processed 'pixelated' copy and compare his/her artwork with the original image to draw conclusions from the artistic and scientific perspective. Pupils will explore how basic geometric shapes can create a more complex image, understand that more pixels will give more detail and discover stylization as an artistic process.

Pupils will learn

1. To process and stylize an image.
2. About innovative artistic styles.
3. To draw parallel lines, grids and squares.
4. What pixels are.
5. The basics of imaging.

Curriculum relevance

Mathematics
- Use geometric tools to draw two-dimensional shapes
- Perform basic multiplication and division

Science and technology
- Understand the basic principles of a technological process

Art & design
- Explore different artistic processes (abstraction, composing an image with basic geometric shapes)
- Develop a wide range of art and design techniques in using colour, patterns, textures, lines, shapes, different forms and space
- Discover the work of a range of artists

→ BACKGROUND

Over the past decades, space probes have benefitted from huge advances in technology, which have enabled the inclusion of cameras of many different types capable of recording data at unprecedented levels of detail. Digital cameras on spacecraft use sensors called charge-coupled devices (CCDs) that turn light into electric signals. Each CCD is made up of a grid of tiny little pieces – pixels – that collect the incoming light (see Figure 1).

Figure 1

object → lens → CCD → image
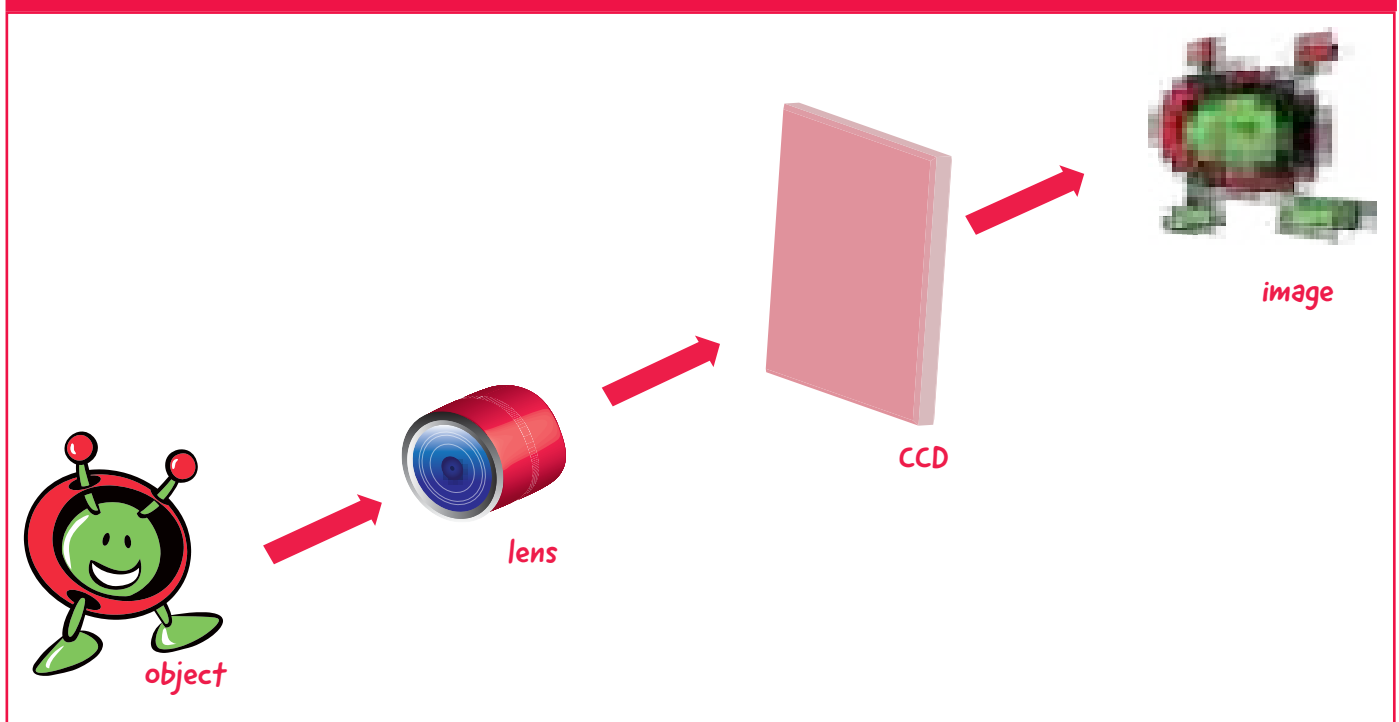
↑ How objects are digitally imaged using charge-coupled devices (CCDs)

The word **pixel*** was introduced in 1965 in the context of space exploration when an American engineer of the NASA Jet Propulsion Laboratory used the word to describe basic elements of images from space probes to the Moon and Mars.

Imagery is a key field for space exploration and scientists around the world base a lot of their research on images taken during space missions. For example, images of planets, stars, nebulae and galaxies taken by digital cameras in space since the 1990s have greatly changed our view of the Universe, such as those from the ESA/NASA Hubble Space Telescope.

On 19th December 2013, the European Space Agency (ESA) launched the largest digital camera ever to be flown in space. The Gaia telescope has an enormous camera which is made up of 106 CCDs working together. All CCDs combined contain 1.5 billion pixels! The Gaia telescope will use its camera to survey more than a billion stars in the sky, mapping our Milky Way Galaxy in unprecedented detail.

***Pixel:** a pixel is a small picture element in a digital image.

For a simple example of how the number of pixels affects the quality, or **resolution***, of an image, we can turn to a well known videogame character. When the Mario character from Nintendo Super Mario Bros first appeared in 1981, it was composed of only 16 by 12 pixels. Today his image contains around 17 times more pixels! Figure 2 shows how Mario has changed over the years thanks to an increase in the number of pixels – many more details are visible and the image is noticeably smoother.
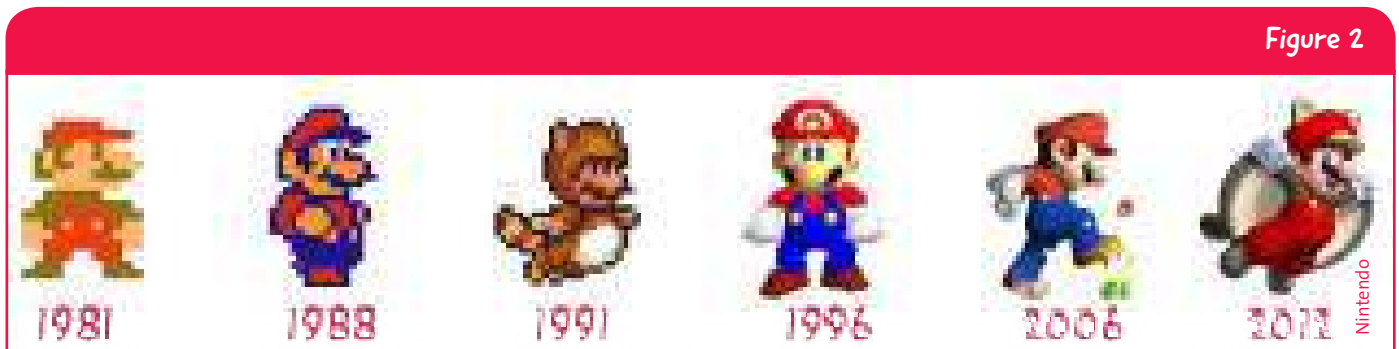
Figure 2

1981 1988 1991 1996 2006 2012

↑ Evolution of the Mario character in the videogame Super Mario Bros through the years showing the increase in the number of pixels and how this relates to an increase in detail. For a larger version of this figure, see Figure X3 in the Appendix.

# Distance versus camera resolution

You can also appreciate the difference in detail of an object when seen from close up compared to far away. When a camera – or your eyes! – move nearer to an object, the object occupies more of the field of view and more data on the object can be collected (see Figure 3). In this case, the increased resolution is the result of the object occupying more pixels on the sensor of the camera. Hence, the resolution of the object within the image is also related to the location of the object relative to the camera and is not only related to the camera sensitivity.

Figure 3
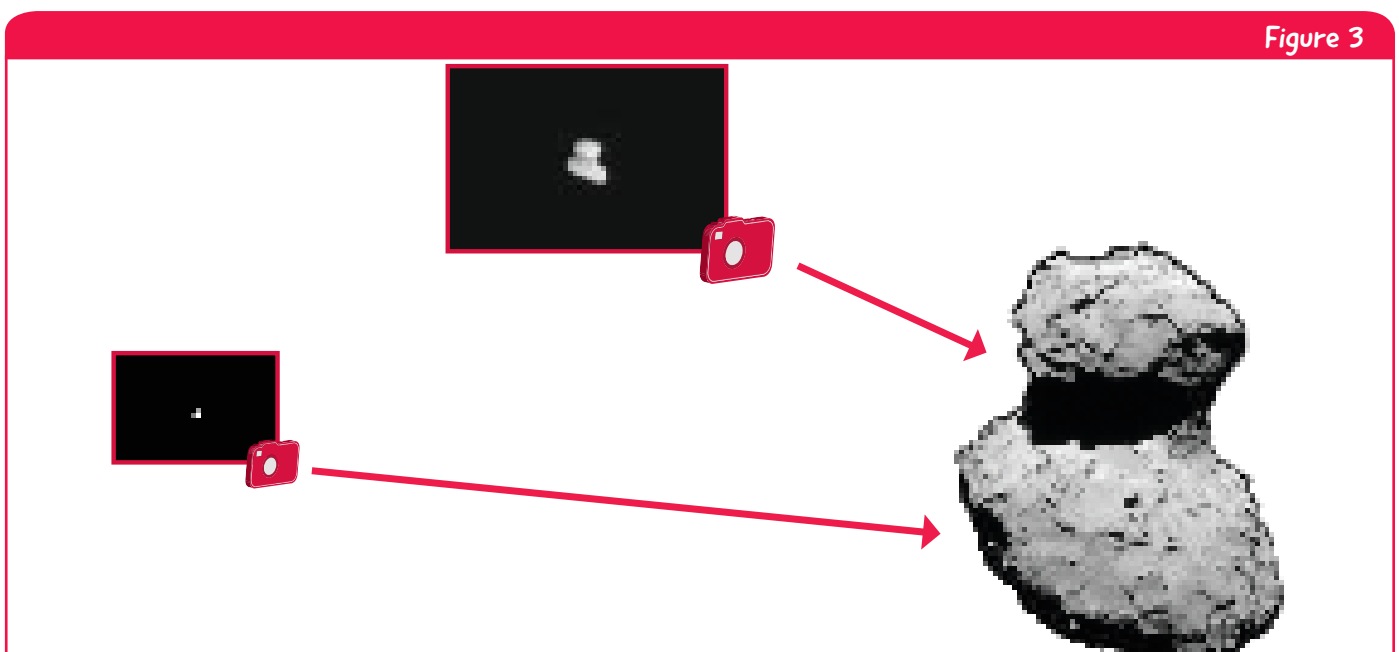
↑ When an object is closer to the camera, the object covers more pixels on the camera sensor than when the object is futher away. The image obtained from closer to the object will have a higher resolution of the object.

*Resolution: the resolution of an image is a measure of its quality or how well it represents the original subject.

ESA's Rosetta spacecraft imaged the comet 67P/Churyumov-Gerasimenko several times during its approach in July–August 2014. Compare the quality of the images during the journey towards the rendez-vous: the details of the comet sharply increased as Rosetta moved closer to the comet but the camera remained unchanged (see Figures 3 and 4).
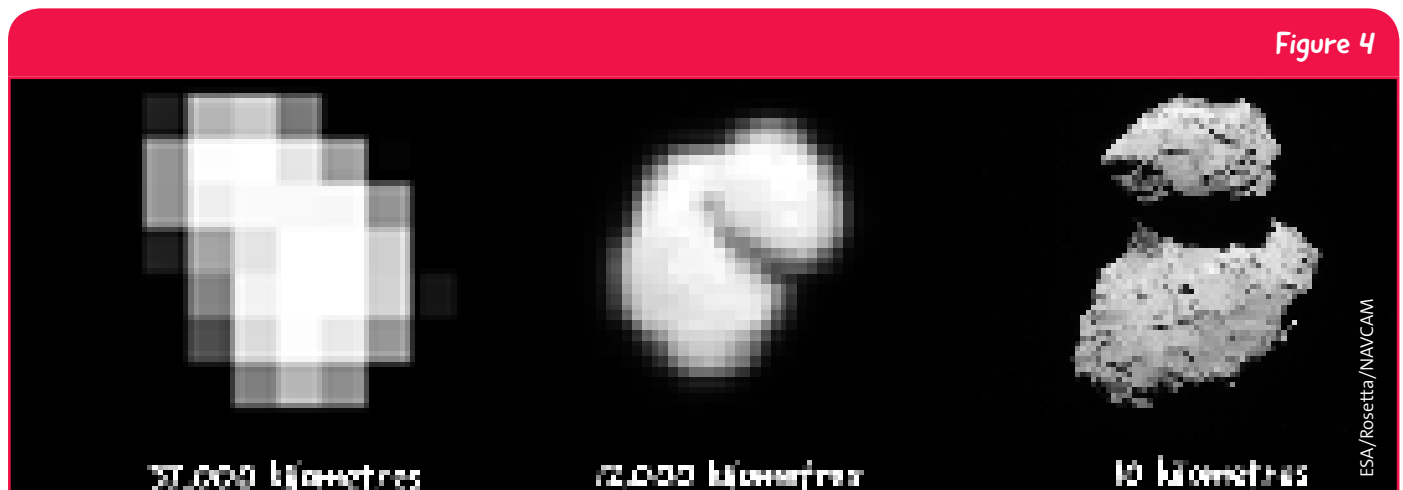
Figure 4

↑ ESA 's Rosetta spacecraft imaged the comet 67P/Churyumov-Gerasimenko several times while approaching it during July – August 2014. The details of the image sharply increase because when Rosetta was closer to the comet, the comet was larger in the camera's filed of view. For a larger version of the figure see Figure X1 in the Appendix.

Pixelation and art

Aboriginal Australians use paint dabbing techniques to represent various symbols in some of their paintings. The combination of sweeping colourful dots aligned in various shapes is a very effective technique that enables beautiful patterns to be made. Figure 5 shows an example of Aboriginal art using dots.


Figure 5

↑ This Aboriginal painting represents a lizard surrounded by sweeping colours. The background is composed of hundreds of individual spots of different colours.

Georges Seurat (1859–1891) was a French painter who stunned the world with a painting technique called pointillisme. The pointillisme technique involves making many small dabs with the paint brush rather than longer brush strokes as is done traditionally. This technique is similar to representing pixels on the canvas. Figure 6 shows a painting by Seurat.
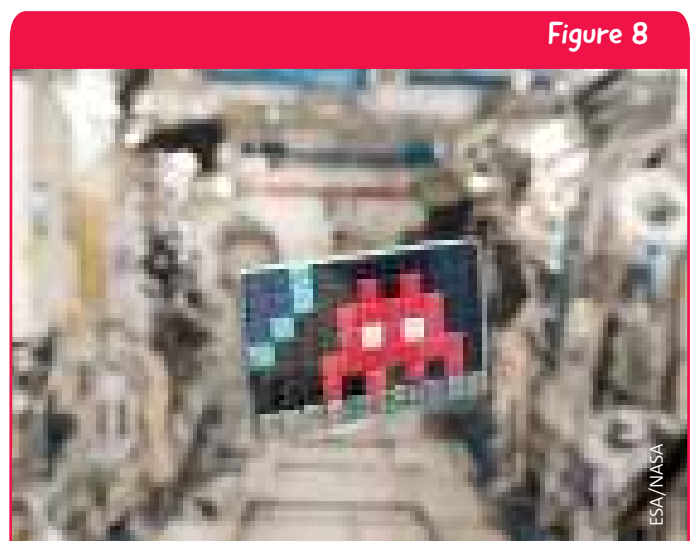

Figure 6
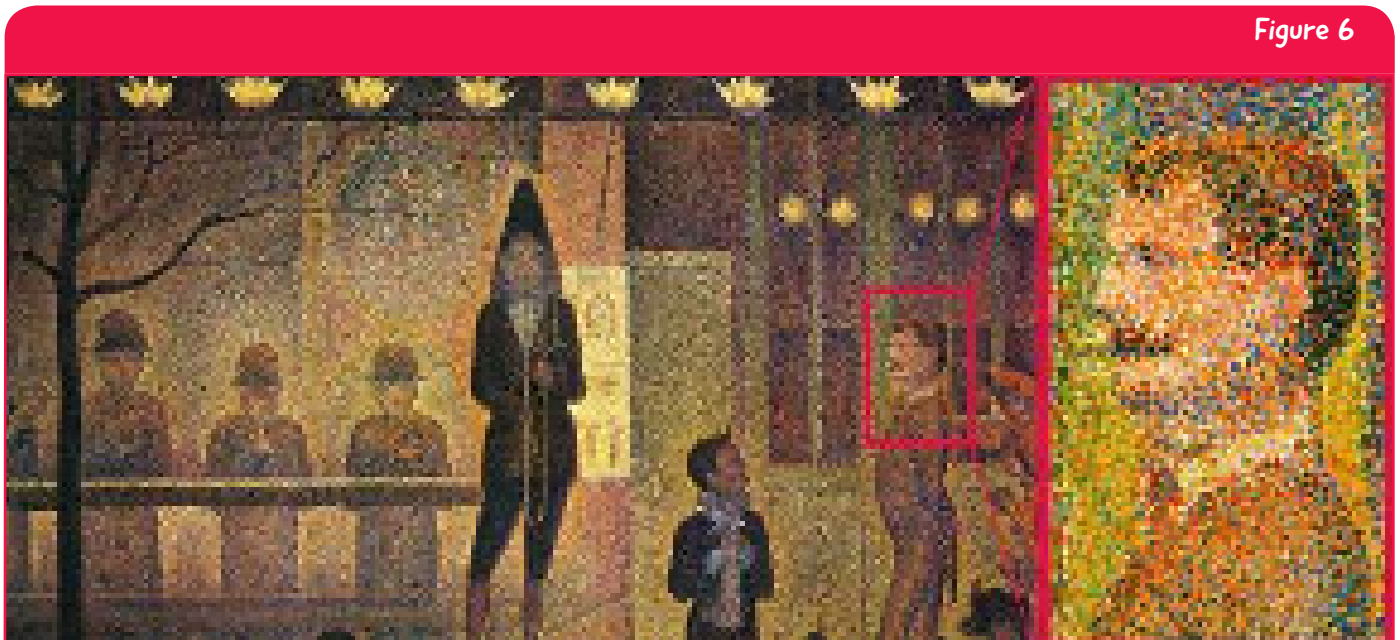
↑ Parade de Cirque (1889) by Georges Seurat. Zooming into the picture in more detail (right) reveals the small dabs of paint used to build up the painting typical of the pointillisme technique.

Invader is a French urban artist born in 1969 who models his street art on the pixelated arcade games graphics of the 1980s. Typically Invader's art is displayed in urban areas — for example, Figure 7 shows the Pac-Man character on the Guggenheim museum in Bilbao, Spain. More recently, Invader has worked with ESA and brought some of his pixelated art work to various ESA establishments and to the International Space Station. Figure 8 shows a piece of art by Invader called 'A Space Invader' floating around the International Space Station.

Figure 7
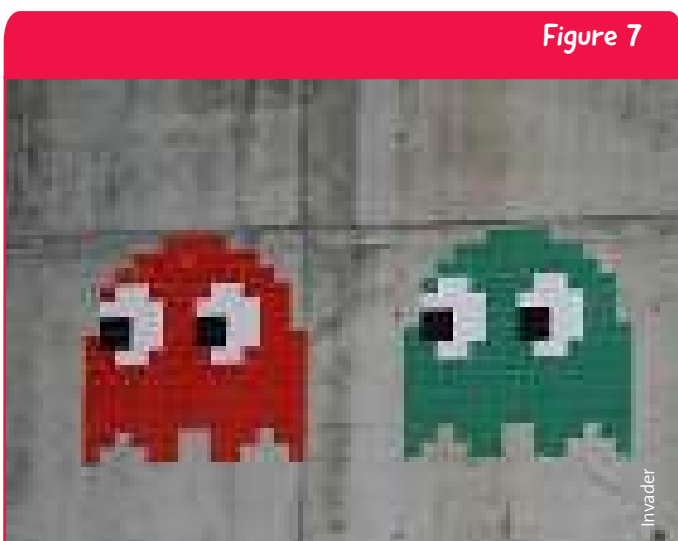
↑ Invader's Pac-Man pixelated art on the wall of the Guggenheim museum in Bilbao, Spain.

Figure 8

↑ Invader's art was brought to the International Space Station by ESA. A Space Invader named 'Space2' is floating around the International Space Station. See also Figure X4 in the Appendix.

Pixel your space

Pupils will learn about pixels, the tiny elements that make up any digital image, and the relationship between the number of pixels and the quality of the image. Pupils will create pixel art – pixelated versions of another image – which can be used for a class display.

Equipment

- Images printed from this document – see Figures X1–X4 in the Appendix
- Student Worksheets (one per pupil) printed from this document – see pages 13–16
- Rulers
- Pencils
- Colouring pencils or crayons
- Squared paper (0.5 cm) – optional.

Introducing pixels (10 minutes)

Create curiosity by showing the class images with different resolutions (different numbers of pixels) from space and videogames and by showing artwork from the artist Invader (Figures X1 to X4 in the Appendix). Discuss what features are identifiable at low and high resolutions (fewer and more pixels respectively). Come to the conclusion that more pixels give a higher quality image.

Creating a pixel artwork (1 hour)

Show the class the original and pixelated images of Paxi, ESA's mascot, to compare the different numbers of pixels and the quality, or resolution, of the images (see Figure X5 in the Appendix).

For younger pupils

Copy the Worksheet (page 13–14) and distribute to each pupil. For Tasks 1 and 2, ask the pupils to complete the grids on the Worksheet – one grid should be drawn over the picture of Paxi and one grid should be drawn in the empty square on the right of the worksheet. The pupils should finish assigning numbers to the rows and letters to the columns to facilitate the work. Lead the class in colouring the first 5 pixels together and then allow the pupils to complete the pixelation alone. Using red, green and black coloured pencils or crayons, fill each square in the empty grid with one colour. For each square, the colour should be the average colour in each square of the original image.

For older pupils

Copy the Worksheet (page 15–16) and distribute to each pupil. For Tasks 1 and 2, ask the pupils to build evenly spaced grids of 8 x 8 and then 16 x 16 pixels, one in the empty square on the Worksheet and the other over the picture of Paxi. If preferred, squared paper could also be used. Fill the first few squares in as a class and then the pupils can complete the activity individually. Using red, green and black coloured pencils or crayons, fill each square in the empty grid with one colour. For each square, the colour should be the average colour in each square of the original image.

Explaining the concept of pixels (15 minutes)

Pixels (from *pix* for 'pictures' and *el* for 'element') are the smallest unit of data (information) in a digital image. A greater number of pixels means that more information is contained within an image: the more pixels, the more realistically the digital image will represent the original subject. Individual pixels are usually presented as small squares in a two-dimensional grid (Figure 1).

If you magnify any digital image, you will be able to see thousands of small squares, each filled in with a single color. The combination of these squares – or pixels – forms the image. Figure A1 shows how an image is made up of many pixels.


Figure A1

ESA/VITO - Proba V

↑ Magnifying images of the Earth taken from satellites reveals that they are also composed of millions of pixels each containing a specific colour.

The first digital cameras did not have many pixels resulting in 'blocky' images. With the improvement of technology, sensors could register more data – more pixels – and the quality of images dramatically improved. In Figure A2, you can clearly see the difference in resolution in space images throughout the years.

Figure A2
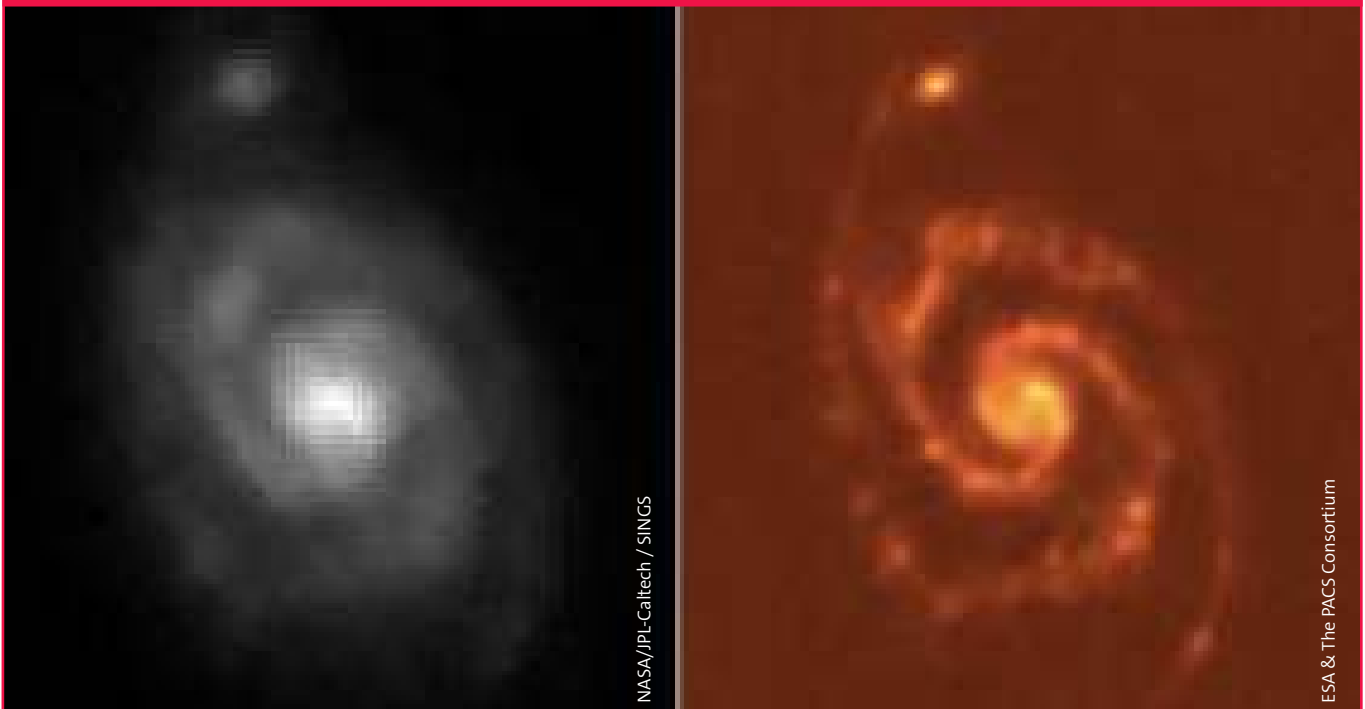
↑ Comparison of M51, the Whirpool galaxy, imaged with the NASA Spitzer Space Telescope (left panel) and an image of the same galaxy taken with the ESA Herschel Space Observatory (right panel).

Classroom discussion (10 minutes)

Discuss the finished artworks with the whole class. Some questions to get started with are:
- Does the 8 x 8 pixel artwork look better or worse than the 16 x 16 pixel one? How do they compare to the 32 x 32 pixel image of Paxi in Figure X5.
- What is the relationship between the number of pixels and the quality of the image (details that you can appreciate)?
- What is the relationship between the number of pixels and the amount of information?
- How far can you go in decreasing the number of pixels and still understand the subject of the image?

Suggested extension activities

Distance versus resolution experiment (20 minutes)

As discussed on page 5, and shown in Figures 3 and 4, if the camera is closer to the object, the object will take up more pixels in the image and the resolution of the object will be better. However, the number of pixels on the camera does not change. This effect can be seen by doing a simple experiment.

Using a digital camera, take an image of an object from 50 cm. Take a second image at a distance of 10 metres. Analyse the photographs and specifically look at the amount of detail of the object in question (see the Links section for suggested imaging software).

Manipulating images on a computer (20 minutes)

Choose a digital image and open the file with an image editing programme (see the Links section for suggested imaging software). Resize the image to 8, 16 and 32 pixels wide and zoom in until you can see the individual pixels. Compare this with pixelated artworks of the same picture that the pupils have composed manually.

Pixel art & craft (1 hour)

Choose an image from this guide, or choose your own image, and ask pupils to create a grid as described in Task 1 on the Worksheet. Stimulate the pupils creativity by creating artwork with material other than crayons such as:
- Paint and stamps (wine bottle corks)
- Coloured paper cut into small squares
- Peg boards
- Coloured stickers / sticky notes
- Heat fusible beads from arts and crafts shops

Pixel collage (2 hours)

Create pixel art on a large scale. Divide an image into sections. Working in groups of 2–3, ask the pupils to pixelate their sections of the mosaic as described in Task 1 on the Worksheet – the mosaic could have 32 x 32 pixels, or many more. When all sections are finished, assemble the wallpaper.

In this activity pupils are introduced to the concept of pixels and the basics of digital imaging. Astronomy images, videogames and pixel-based art provide an engaging context for pupils to explore different artistic processes and strengthen key skills such as making comparisons and establishing interdisciplinary connections.
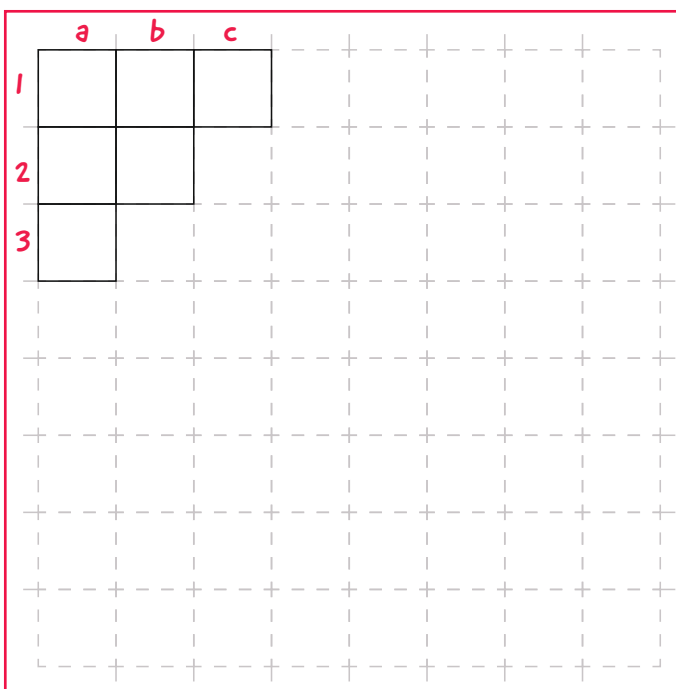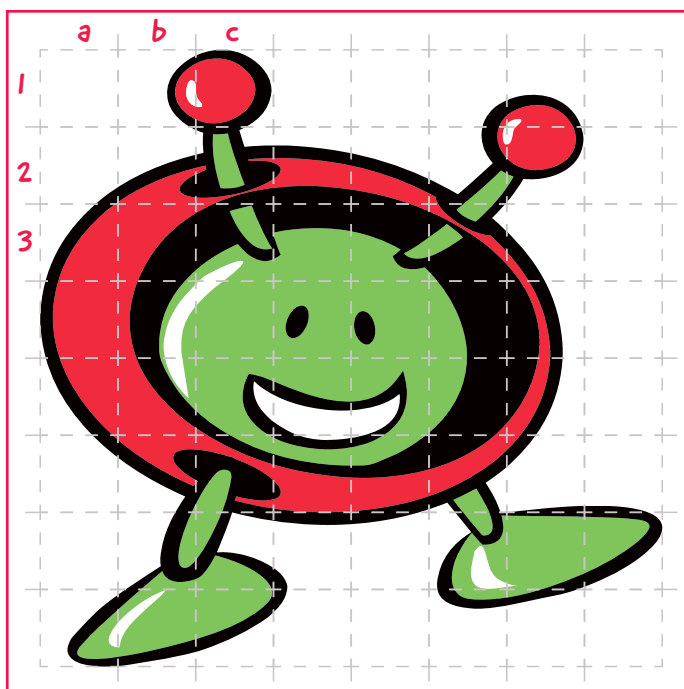
Pixel your space

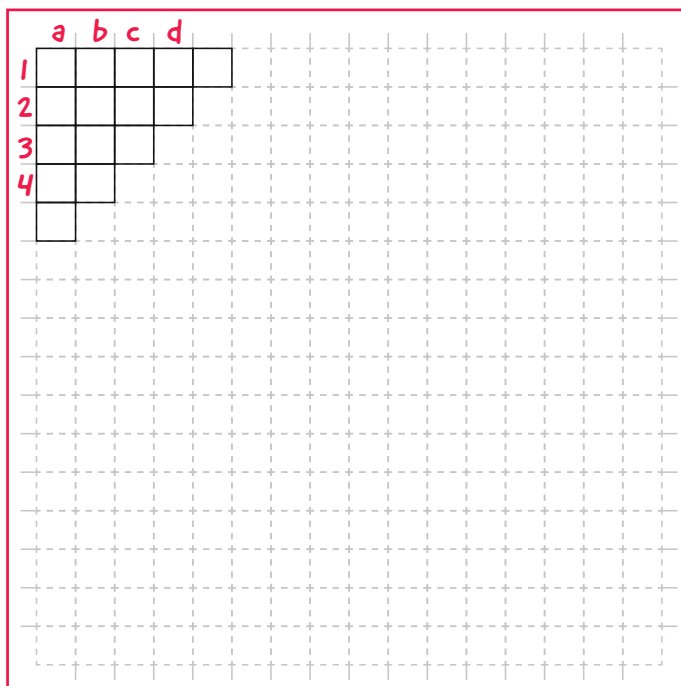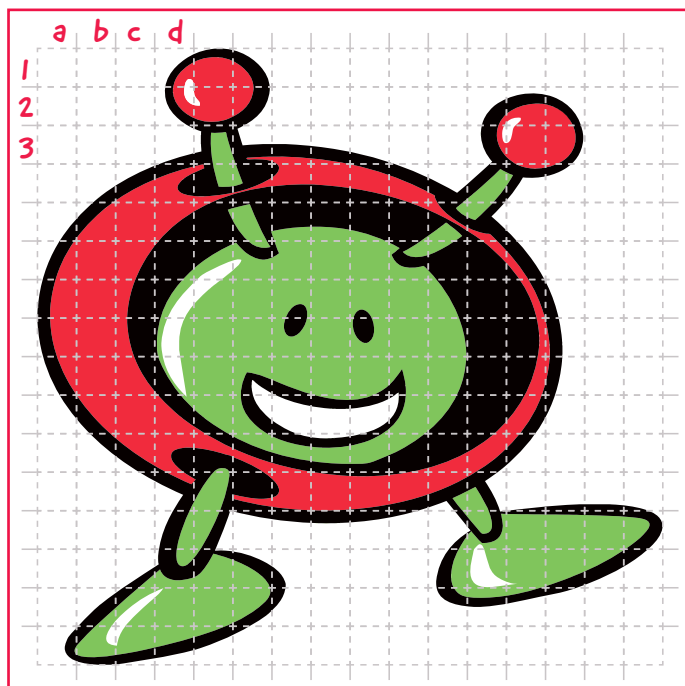## What do you need to do?

Task 1

Using a pencil and a ruler complete the grid that is 8 by 8 squares (64 squares or pixels in total) on the image of Paxi below. Also complete the grid in the empty box. Give numbers to the rows and letters to the columns. A start has been made for you. Each square represents a single pixel.

Using red, green and black coloured pencils or crayons, fill each square in the empty grid with one colour. For each square, the colour should be the main colour in each square of the image of Paxi. For white areas, leave the square blank.

Task 2

As in Task 1, complete the grid that is 16 by 16 squares (256 squares or pixels in total) on the image of Paxi below and another grid in the empty box. Colour each square in the empty grid with one colour (red, green, black) or leave blank.

Task 3

a) Which image looks better? The image from Task 1 with 8 x 8 pixels or the image from Task 2 with 16 x 16 pixels?

_____

_____

b) What is the relationship between the number of pixels and the quality of the image? In which image can you see more details?

_____

_____

c) What is the relationship between the number of pixels and the amount of stored information?

_____

_____

d) How far can you go in decreasing the number of pixels and still recognize the subject of the image?

_____

_____

Pixel your space

## What do you need to do?

Task 1

Using a pencil and a ruler draw a grid on the image of Paxi below. Draw another grid in the empty box to the right of Paxi. If you prefer, you can draw the second grid on squared paper. Start with a grid that is 8 by 8 equal squares (for a total of 64 squares or pixels); each square represents a single pixel.
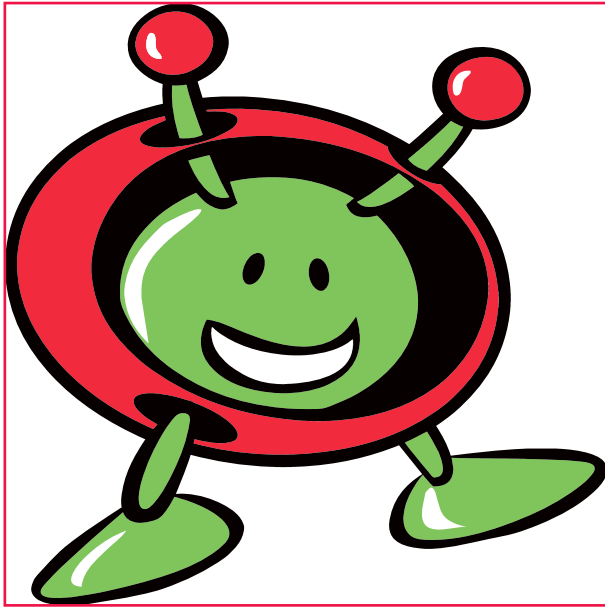
To draw the grid:

- measure the length of the vertical side and divide by 8; draw the horizontal lines equally spaced.
- measure the length of the horizontal side and divide by 8; draw the vertical lines; equally spaced.

Using red, green and black coloured pencils or crayons, fill each square in the empty grid with one colour. For each square, the colour should be the average colour in each square of the original image. For white areas, leave the square blank.
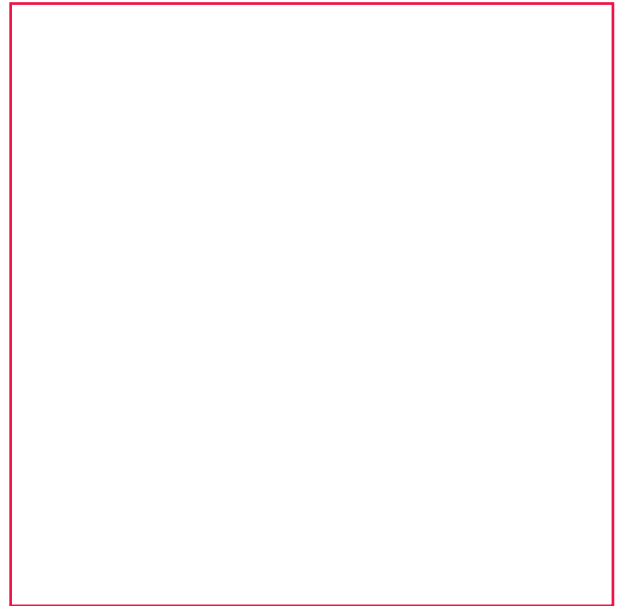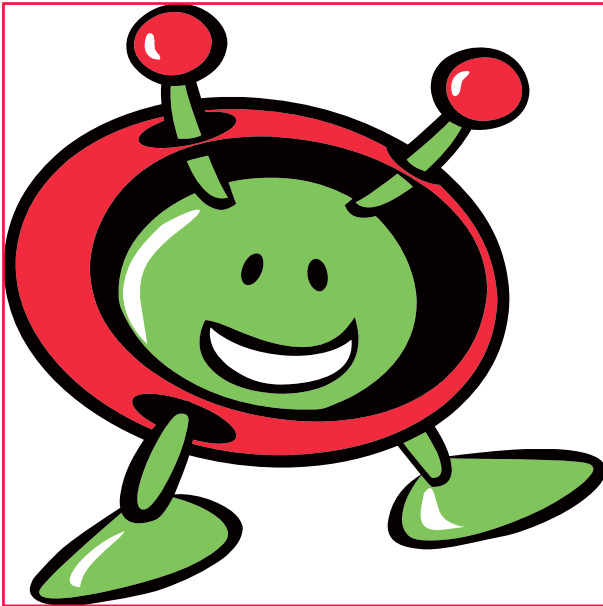
Task 2

As in Task 1, complete the grid that is 16 by 16 squares (256 squares or pixels in total) on the image of Paxi below and another grid in the empty box. Colour each square in the empty grid with one colour (red, green, black) or leave blank.

Task 3

a) Which image looks better? The image from Task 1 with 8 x 8 pixels or the image from Task 2 with 16 x 16 pixels?

_____

_____

b) What is the relationship between the number of the pixels and quality of the image? In which image can you see more details?
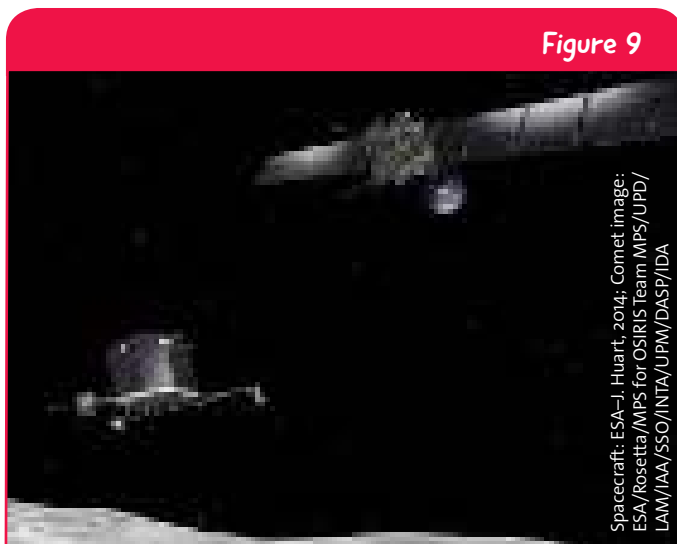
_____

_____

c) What is the relationship between the number of pixels and the amount of stored information?

_____

_____

d) How far can you go in decreasing the number of pixels and still recognize the subject of the image?

_____

_____

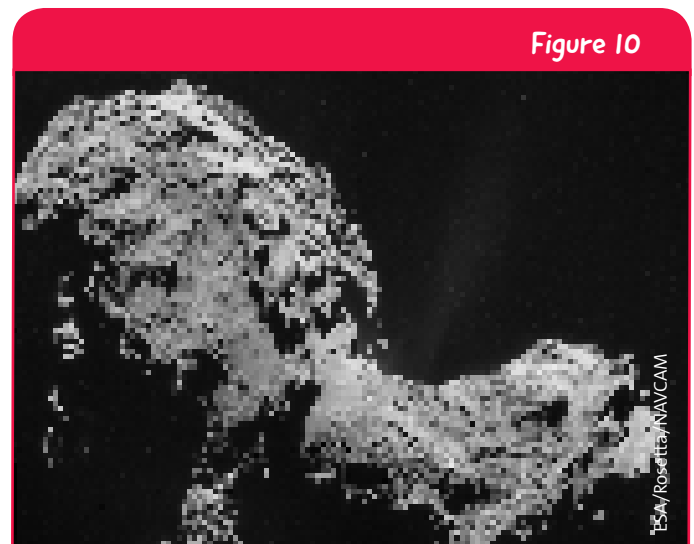## Rosetta

The ESA Rosetta mission was launched in 2004 and arrived at comet 67P/Churyumov-Gerasimenko on 6th August 2014. Rosetta is the first mission in history to successfully rendezvous with a comet, escort it on its journey around the Sun and deploy a lander, Philae, to its surface. Figure 9 shows an artist impression of Rosetta deploying Philae to the comet. The images Rosetta obtained of comet 67P/Churyumov-Gerasimenko during its approach clearly show how the distance between a camera and the object being imaged play an important role in the quality, or resolution, of the image obtained (Figures 3, 4, 10 and X1). When Rosetta got closer to the comet, the comet took up a larger area in the field of view of the camera. The image of the comet therefore covered more pixels on the camera sensor and so more information could be stored and a sharper image was obtained.

Figure 9

Spacecraft: ESA–J. Huart, 2014; Comet image: ESA/Rosetta/MPS for OSIRIS Team MPS/UPD/ LAM/IAA/SSO/INTA/UPM/DASP/IDA

↑ Artist's impression of the Rosetta spacecraft with the Philae lander on its way to the surface of comet 67P/Churyumov-Gerasimenko.

Figure 10

ESA/Rosetta/NAVCAM

↑ Image of comet 67P/Churyumov-Gerasimenko using Rosetta's NAVCAM taken on 19 September 2014 when Rosetta was less than 30 kilometres from the comet.

Hubble Space Telescope

The Hubble Space Telescope is a joint ESA/NASA project and was launched into a low-Earth orbit 600 kilometres above the ground in 1990. The Hubble Space Telescope is one of the largest and most versatile space observatories and is the only space-based telescope designed to be serviced in space by astronauts – since its launch, it has been serviced five times in orbit. From its vantage point outside the Earth's constantly moving atmosphere which distorts the light reaching the ground from space, Hubble has provided stunning, high resolution images of a variety of astrophysical objects and dramatically changed our view of the Universe. Figure 11 shows the Hubble Space Telescope in orbit and Figure 12 shows one of Hubble's most iconic images.

Figure 11

↑ The NASA/ESA Hubble Space Telescope in low Earth orbit, 600 kilometres above the surface of the Earth.

Figure 12

NASA, ESA/Hubble and the Hubble Heritage Team

↑ The NASA/ESA Hubble Space Telescope image of the Eagle Nebula's Pillars of Creation. The Eagle Nebula is a vast stellar nursery spanning around 9.5 light-years across, or 90 trillion kilometres, and is located around 7 000 light-years from the Solar System.

Gaia

On 19th December 2013, ESA launched the largest digital camera ever to be flown in space. The Gaia telescope has an enormous camera which is made up of 106 CCDs working together. All CCDs combined contain 1.5 billion pixels. The Gaia telescope will use its high resolution camera to accurately survey the positions and motions of more than a billion stars in the sky, mapping our Milky Way Galaxy in unprecedented detail.

Figure 13

EESA–D. Ducros, 2013

↑ Artist's impression of the Gaia telescope.

Figure 14

NASA, ESA/Hubble and the Hubble Heritage Team

↑ Gaia's Sky Mapper was briefly used in a special mode during the test phase to image a crowded part of the sky. Whilst there are many stars in the image, Gaia's high resolution camera manages to clearly separate the individual objects.

Herschel

Launched in 2009, the ESA Herschel infrared space observatory is the largest telescope ever flown in space (Figure 15). Its massive mirror, measuring 3.5 metres across, is more than four times larger than any previous infrared space telescope and almost one and a half times larger than the main mirror of the Hubble Space Telescope (Figures 15 and 16). Herschel's large mirror and accompanying sensitive camera greatly improved the quality of images obtained in the infrared – compare the difference between the Herschel image of M51 (Figure 16) and that of the smaller NASA Spitzer telescope (Figure A2, page 10).


Figure 15

ESA/PACS & SPIRE Consortia, T. Hill, F. Motte, Laboratoire AIM Paris-Saclay, CEA/IRFU – CNRS/ INSU – Uni. Paris Diderot, HOBYS Key Programme Consortium

↑ Artist's impression of the Herschel infrared space observatory.

Figure 16

ESA & The PACS Consortium

↑ Image of M51, the Whirpool galaxy, taken with the PACS instruments of the Herschel Space Observatory.

Figure X1

37,000 kilometres   12,000 kilometres   10 kilometres

ESA/Rosetta/NAVCAM
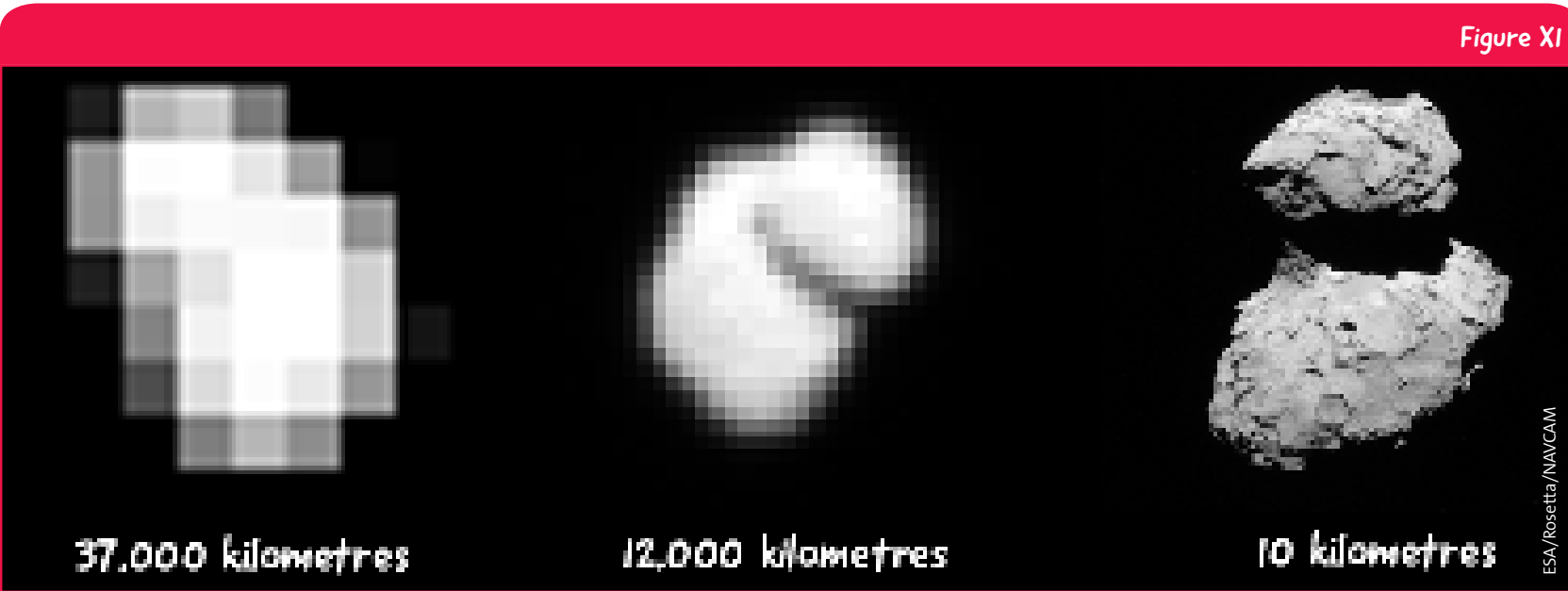
↑ The European Space Agency's Rosetta spacecraft imaged the comet 67P/Churyumov-Gerasimenko several times while approaching it during July -August 2014. The details of the image sharply increase as Rosetta got closer the comet - the comet became larger in the camera's filed of view.

Figure X2

original   32 x 32 pixels   16 x 16 pixels   8 x 8 pixels

ESA/MPS for OSIRIS Team, MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA
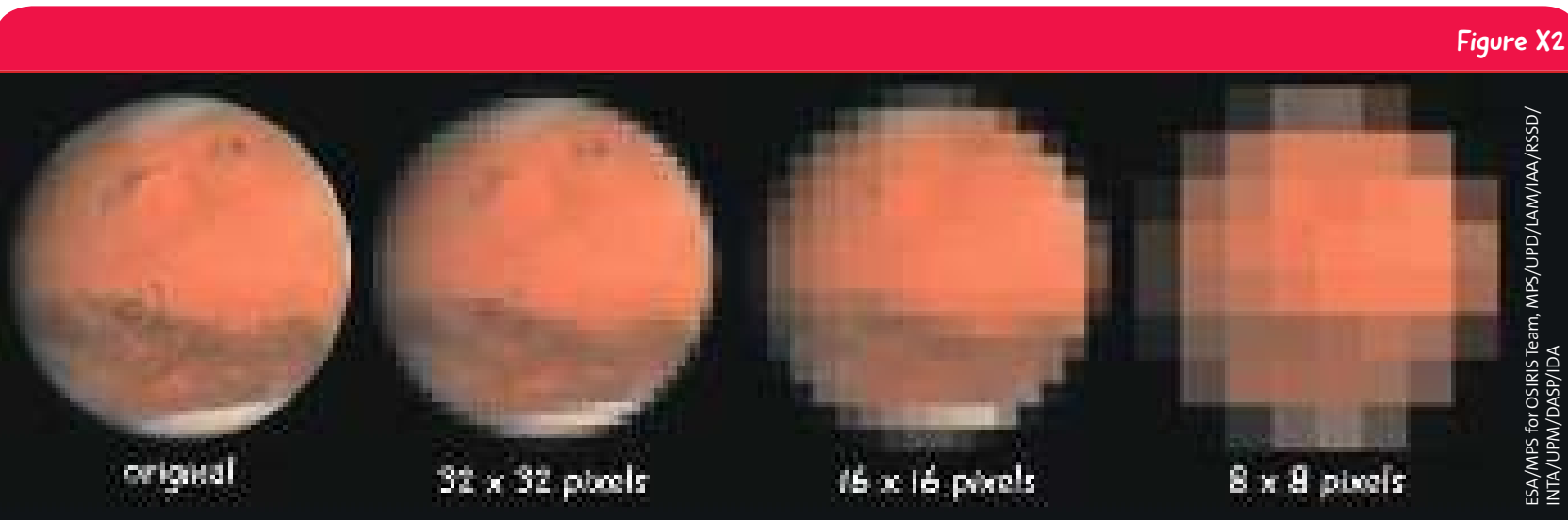
↑ Digitaly manipulated images of Mars at different levels of pixelation. The left hand image is an original image of Mars taken with the ESA/NASA Hubble telescope. Moving towards the right the number of pixels decreases as does the level of detail.
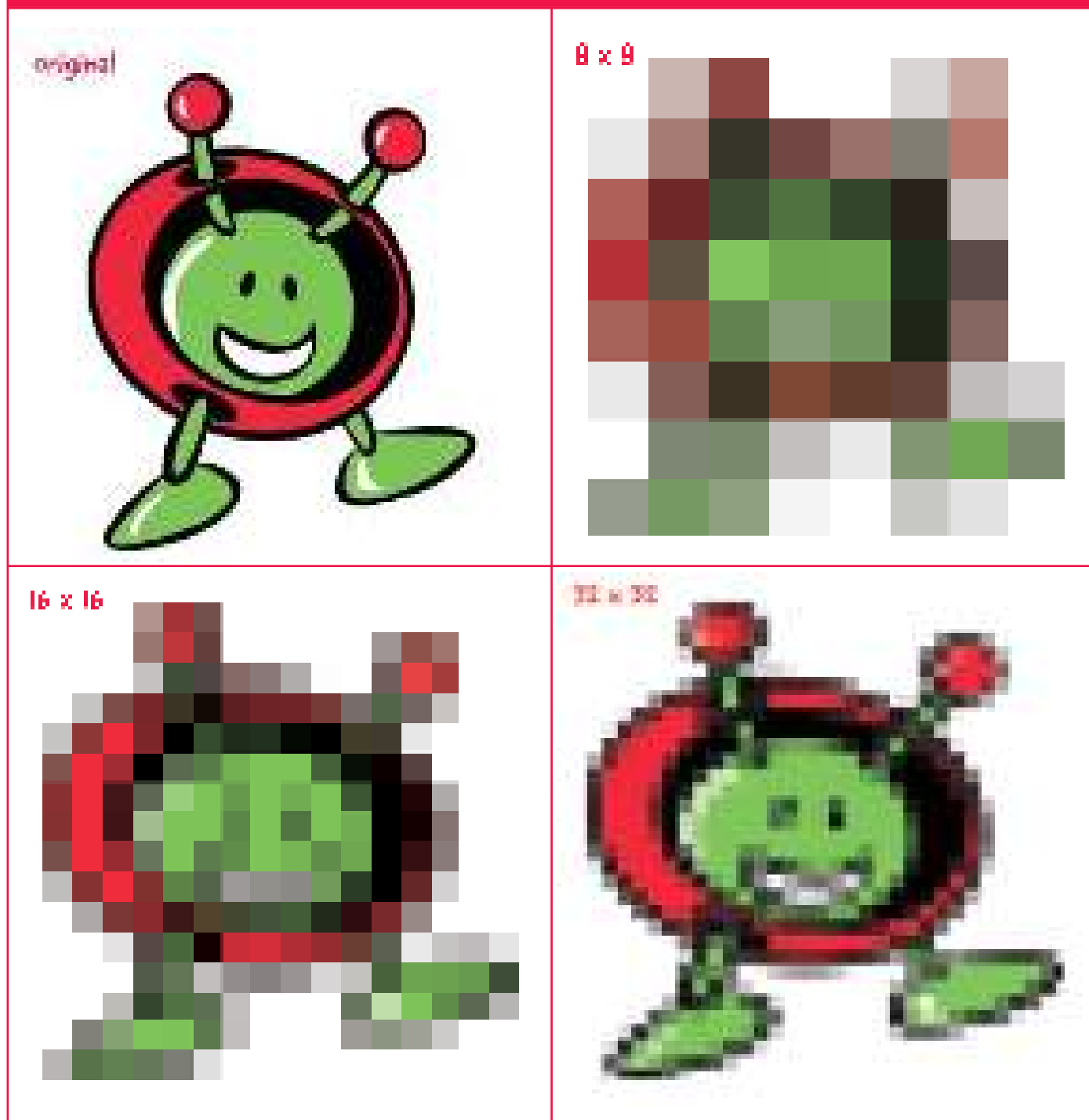
Figure X3
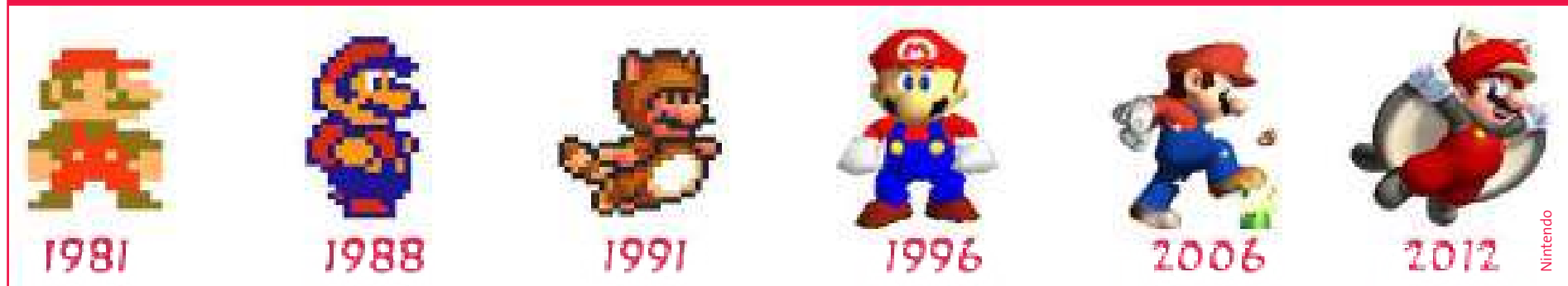
↑ Evolution of the Mario character in the videogame Super Mario Bros through the years showing the increase in the number of pixels and how this relates to an increase in detail.

Figure X4
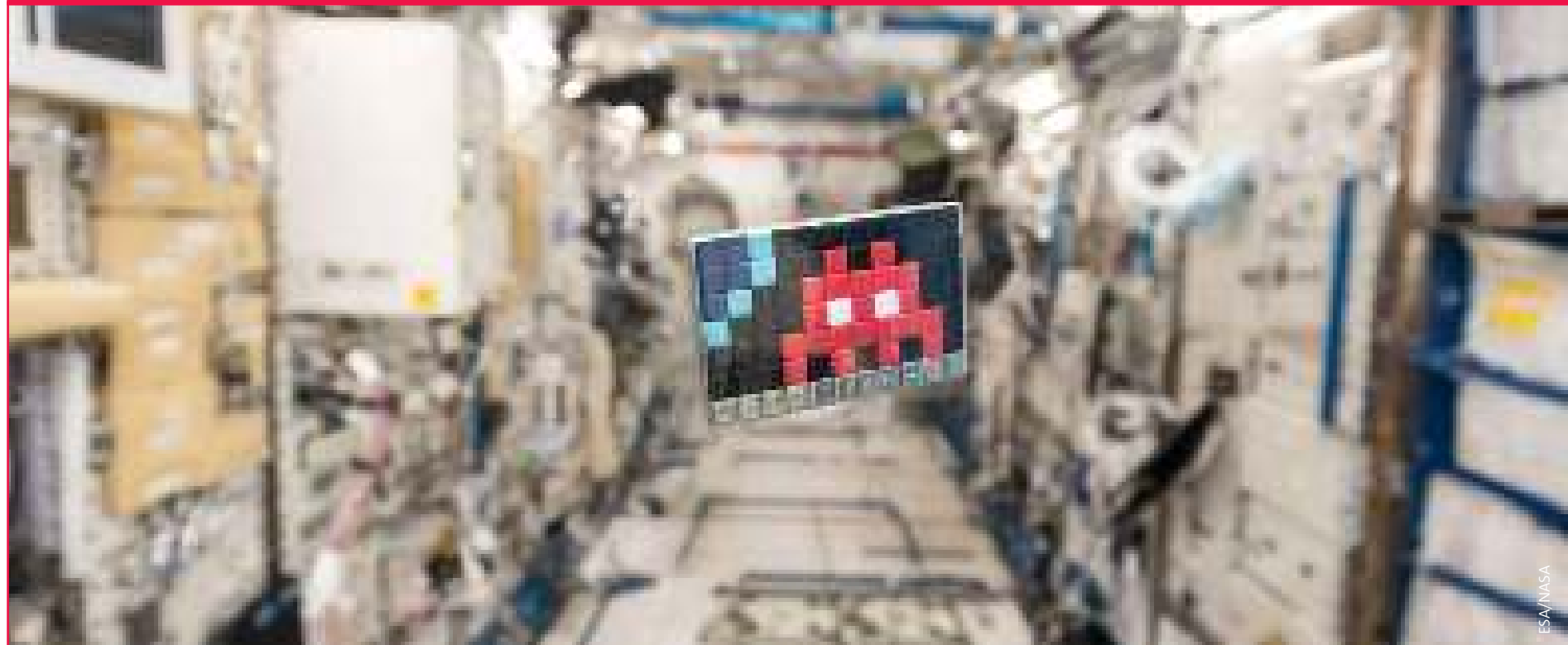
↑ Invader's art was brought to the International Space Station by ESA. 'A Space Invader' named 'Space2' is floating around the International Space Station.

↑ The image of Paxi, the ESA mascot (top left), has been digitaly modified to show the effect of different number of pixels on the quality of the image.

Links

Teach with space

ESA teach with Rosetta website: ww.esa.int/Teach_with_Rosetta/
ESA teach with space – our solar system | PR01: esamultimedia.esa.int/docs/edu/PR01_Our_Solar_
System_teacher_guide_and_pupil_activities.pdf
ESA teach with space – history of the universe | PR02: esamultimedia.esa.int/docs/edu/PR02_

History_of_the_Universe_teacher_guide_and_pupil_activities.pdf

ESA Kids (child-friendly fun & information in several European languages)

ESA Kids homepage: www.esa.int/esaKIDSen/
Rosetta: www.esa.int/esaKIDSen/SEM269WJD1E_OurUniverse_0.html
Super-sensitive space camera takes shape: www.esa.int/esaKIDSen/SEMP0N9TVPG_OurUniverse_0.
html
The Hubble Space Telescope: www.esa.int/esaKIDSen/SEM5C6BE8JG_Technology_0.html
Herschel: ESA's supercool heat seeker: www.esa.int/esaKIDSen/SEM0BAZ2OMH_Technology_0.html
Paxi fun book: esamultimedia.esa.int/multimedia/publications/PaxiFunBook/

ESA Missions

ESA Rosetta mission: www.esa.int/rosetta
ESA Rosetta blog: blogs.esa.int/rosetta/
ESA/NASA Hubble Space Telescope: sci.esa.int/hubble
ESA Gaia mission: sci.esa.in/gaia
ESA Gaia blog: blogs.esa.int/gaia/
ESA Herschel mission: sci.esa.int/herschel

Software links

Imaging software: www.pixlr.com

The artist Invader

Official website: www.space-invaders.com