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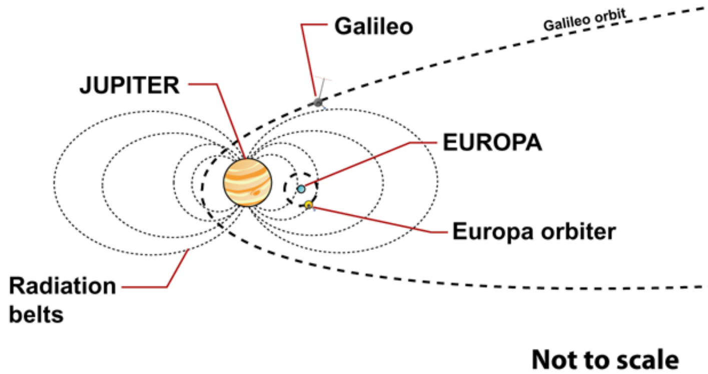
PIXEL THIS!

Is there life—intelligent or otherwise—elsewhere in the universe? Or is Earth unique in having just the right conditions to support life? Even scientists don't agree about the probability of extraterrestrial intelligence. As for simpler forms of life, here on Earth no hot nook nor cold cranny seems too harsh to make a comfy home for some living thing. Giant tube worms flourish on the ocean floor near thermal vents where scalding, sulfurous water boils up from the Earth's crust. At these depths, the pressure is far greater than a human—or even most sea creatures—can survive, and no sunlight penetrates. Tiny Earthlings (worms, fungi, lichen, bacteria, etc.) have also been found thriving in extremely cold, acidic, alkaline, salty, and dry conditions.

WHAT ABOUT OUR OWN BACK YARD?

So, is it possible that some hearty creatures could have set up housekeeping elsewhere in our own solar system? Certainly no other planet or moon would be friendly to us humans, or to dogs, cats, birds, or even worms as we know them. But there is one very curious place that just might have the right conditions for some other, less complex forms of life. That place is Jupiter's moon Europa.

Judging from Jupiter fly-by pictures taken by the two Voyager spacecraft in 1979 and by the Galileo spacecraft as it has zipped past Europa in its elliptical orbit around Jupiter these past 7 years, this moon seems to have a liquid water ocean underneath a crust of ice. If so, it is certainly not the Sun that is keeping the water in a liquid state. The Sun is too far away. The heat would have to be coming from Europa's core. Europa and Jupiter's other large moons are locked in a gravitational tug o' war. As the moons orbit Jupiter, they are squeezed and stretched by gravitational forces from Jupiter and each other, similar to those that cause ocean tides on Earth as the Moon orbits our planet. These *tidal forces* on Jupiter's moons cause tremendous heating in their cores. On Io, huge volcanoes are the result. On Europa, a liquid ocean could be the result. On Europa, this heat could also be a source of energy for living things, just as thermal vents are the source of energy for some life forms on Earth's deep ocean floor.



Although the Galileo spacecraft has gathered quite a lot of information about Europa, it has spent only a very limited time near this moon. NASA would like to send another mission to the Jupiter system just for the purpose of studying Europa. This spacecraft would orbit Europa, rather than Jupiter.

The big challenge is that Europa orbits inside Jupiter's horrendous *radiation belts.* While Galileo just dips in and out of the worst of this field, spending most of its time in orbit at a safer distance, a Europa spacecraft would be continuously bombarded with charged particles trapped in Jupiter's radiation belts. All the spacecraft systems and instruments would have to be extremely hearty and robust.

TOUGH, TOUCHY, TINY PIXELS

Instruments used for imaging would be among those most vulnerable to Jupiter's radiation. Cameras used on spacecraft are similar to digital cameras, except a lot tougher and a lot more sensitive. Instead of film, cameras on spacecraft have special light-sensitive silicon devices similar to computer chips. These are called *charge-coupled devices*, or *CCD*s. Each CCD is made up of hundreds of thousands (or millions) of tiny picture elements, or *pixels*, for short.

When the CCD camera takes a picture, it converts the pattern of light into a pattern of numbers. The highest numbers represent the brightest parts of the scene. For example, the CCD could assign numbers from 0 to 255 to the different brightness levels. A pixel sensing no light at all (that is, black) would get a 0. Very bright light (totally white) would get a 255. Everything in between would get a number based on how bright or dark the shade of gray. But what about colors?

For each color picture, several pictures are taken, each through a different *colored filter*. Each filter lets through only a certain color of light. For example, a red filter lets through only red light. So the red-filtered pixel data will show the brightness of the red colors in the scene. After computers on Earth combine the pixel data from three pictures, one taken through a red filter, one through a blue filter, and one through a green filter, we can see the original colors in the scene from space—and all from shades of gray!

For a Europa mission, this same technology will be used, but NASA is developing new techniques and materials to make the imager able to withstand the terrible beating it will get in Europa's radiation environment. This development project, called the *Planetary Imager Project*, is also working to improve the sensitivity of the CCDs, since they will be operating at very low light levels in the outer solar system far from the Sun.

The tougher CCDs NASA is developing will also come in very handy for use on robots that can go into situations that are unsafe for humans. For example, when Russia had a core meltdown accident at its Chernobyl nuclear power plant in 1986, people sacrificed their lives to go into the buildings and try to seal off the leaking radioactive material. Robots equipped with radiation hardened instruments could help with such work in the future—although let's hope it never happens again.

Pixel Play

We can see just how CCDs work. Let's build our own "Sim-CCD Array," then have some fun with it. For a class, you can divide into two or more teams, depending on how many game sets you wish to construct. You will need:

Tools

Photocopier, paper cutter (or scissors), ruler, pencil

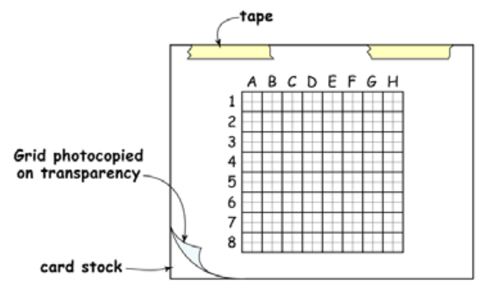
Materials (for each team):

Light weight card stock, letter size—8 sheets
Transparency film for overhead projector, letter size—2 sheets
Letter size envelopes—5
Copy paper, letter size—as needed.
2.5-centimeter (1-inch) wide transparent or masking tape—about 60 centimeter (or 2 feet)

Build the elements

1. Simulated CCD **array**

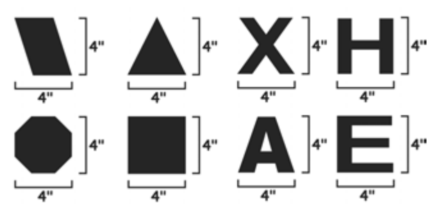
- Figure 1 at the end of this article is an 8 x 8 (64-cell) array, each cell having a unique address (A1, A2, B1, B2, etc.). Each cell is further divided into four quadrants. For each team, make an enlarged (about 140%) photocopy on transparency film of this Figure 1 array. Each cell (including its four quadrants) will be about 1 centimeter (or 1/2-inch) square.



- Using tape, hinge the transparent array copy to a card stock base on one long side.

2. Set of "**images**"

- Cut into four 8-centimeter (or 4-inch) squares as many sheets of card stock as you have teams.
- Cut identical sets of four geometric shapes (triangle, trapezoid, circle, parallelogram, octagon, etc.) using as much of the space on the paper as possible. You want the shapes to pretty much fill the 64-cell array created in Step 1. Each team will have identical sets of four different geometric shapes.



- Do the same thing for four alphabet shapes. Use upper case letters and avoid letters with curves (O, D, S, etc.). Again, cut them as large as possible from the 8-centimeter (or 4-inch) squares.

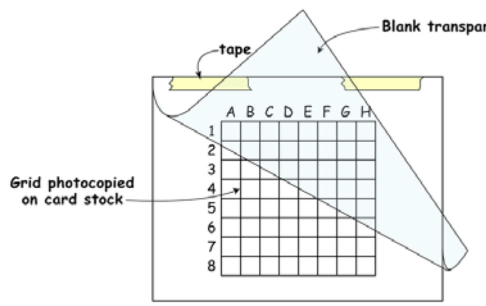
3. Simulated **Memory**

A1 ___	C1 ___	E1 ___	G1 ___
A2 ___	C2 ___	E2 ___	G2 ___
A3 ___	C3 ___	E3 ___	G3 ___
A4 ___	C4 ___	E4 ___	G4 ___
A5 ___	C5 ___	E5 ___	G5 ___
A6 ___	C6 ___	E6 ___	G6 ___
A7 ___	C7 ___	E7 ___	G7 ___
A8 ___	C8 ___	E8 ___	G8 ___
B1 ___	D1 ___	F1 ___	H1 ___
B2 ___	D2 ___	F2 ___	H2 ___
B3 ___	D3 ___	F3 ___	H3 ___
B4 ___	D4 ___	F4 ___	H4 ___
B5 ___	D5 ___	F5 ___	H5 ___
B6 ___	D6 ___	F6 ___	H6 ___
B7 ___	D7 ___	F7 ___	H7 ___
B8 ___	D8 ___	F8 ___	H8 ___

On regular notebook paper, make a list of the 64 cell addresses (A1, A2, B1, B2, etc.), leaving space beside each for data. Make a photocopy of the "memory" page for each team. (Or, each team can make its own original simulated memory).

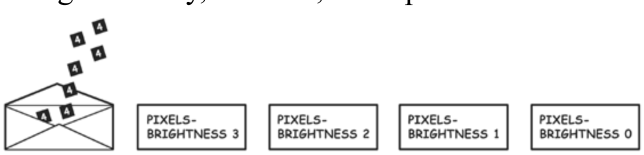
4. Simulated Image Generator (**display**)

For each team, make an enlarged (about 140%) copy on card stock of the 8 x 8 (64-cell) simple matrix array (Figure 2 at the end of this article--the one with cells not divided into quadrants). Use a tape hinge on one long side to attach a blank transparency sheet over the card stock. Note that this is the "device" that will display what the "array" has recorded.



5. Simulated Pixels (**pixels**)

For each team, make a set of enlarged) about 140%) photocopies on regular copier paper of Figures 3, 4, 5, and 6 on the last page of this article, plus one more enlarged copy of Figure 2. The number in each cell is the "brightness level" of that particular shade of gray. The darkest gray is 4, while the lightest is 0. Now, cut each array into "pixels" that exactly fit the cells on the arrays. The Figure 2 array, all white, will represent 0.



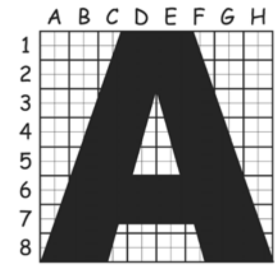
You can store the pixel sets in five small envelopes, labeled 4, 3, 2, 1, and 0. So, there will be a total of five brightness levels, with "0" being the brightest and "4" being the darkest.

Send and Receive a Picture

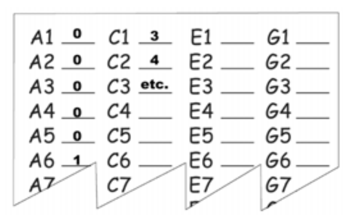
First, let's use the Sim-CCD Array to see how a real spacecraft CCD works and communicates its image to Earth. Two teams or individuals can do this, each having a complete "Sim-CCD Array" setup. One array represents the remote imager on the spacecraft and the other array represents the Earth base.

Remote Imager Team

- *Take the picture*: Select and place an image (geometric or alpha shape) into the **array**.



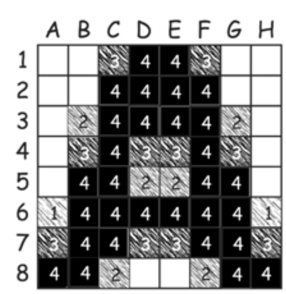
- *Read the cell-by-cell "brightness levels" of the image and record them into* ***memory***. To do this, for each cell, write on the memory sheet a value for the brightness level. For cells that are completely filled with the shape, record the highest brightness level (4). For cells that are partially filled with the shape, note how many quadrants of the cell contain any part of the shape. Use that number to represent the brightness level.



- *"Transmit"* ***memory*** *to Earth Base*. Read aloud the cell addresses and corresponding brightness levels for each cell (allowing time in between each for "Earth base" to receive and record them).

Earth Base Team

- *Get the picture.* Receive and record on a **memory** sheet the **memory** readout as "received" from the remote imager.
- *Make the picture*. From the **memory** sheet, read sequential addresses and "brightness level" values. Place a corresponding pixel at each address on the **display** board. Close the transparent **display** cover when complete to keep the pixels in place.



- *View and identify the **image**.* You can make a photocopy of the completed "display" if you like.

Sim-CCD Games

Using your Sim-CCD Arrays, here are three games you can play as teams or individual players.

We Have a Problem – 1 (Concentration) (For any number of teams or individual players)

The spacecraft has passed through a zone of very intense radiation and the remote imager's sequential data transmission has been disrupted! It is now unable to automatically stream address and energy information. However, the remote imager's memory is still intact. We can request readouts cell by cell, and the imager will respond with correct brightness level. But rival teams want to be first to view and identify the current image. Your team's challenge is to poll (in turn with others) the remote imager's data and guess the image before others do.

How to play: A reader (possibly the teacher, but not a member of any team) selects an image and places it under the transparent CCD array (camera grid).

Then, each team in turn calls out a particular "memory" address, and the reader responds with the brightness level for that cell. All teams fill in the cell on their display grid with a pixel of the appropriate brightness level. The first team to correctly call out the image is the winner.

We Have a Problem – 2 (Bingo) (Any number of teams or individual players)

Jupiter has passed between Europa and Earth, disrupting the sequential data transmission from the Europa orbiter's remote imager. It is now unable to automatically stream address and brightness information. The remote imager's memory is still intact though. When the spacecraft reappears, cell-by-cell data is transmitted for random addresses. (This situation does not really happen!) But rival teams want to be first to learn the current image. Your team's challenge is to receive and record the remote imager's random data and be first to guess the image.

How to play: Two readers (not members of any team) are needed for this game. Reader A selects an image and places it under the transparent array. Using a memory sheet, Reader B selects and calls out a cell address at random (checking off on the memory sheet so as not to repeat any cells). Reader A announces the brightness level of that cell for all teams to hear. All teams fill in the appropriate cell on their displays with a pixel of the appropriate brightness level. The first team to correctly call out the image is the winner.

Data Race (Battleship) (for two teams)

Each team is equipped with all transmitting and receiving materials. Each team positions an image into its array in a skewed position that will be difficult to recognize and records the image data (pixel-by-pixel brightness levels) onto a **memory** page.

All the **memory** pages are given to referee (not a member of either team).

A designated member of a team calls out an address. The referee supplies its brightness level from the other team's memory page and the first team plots it with a pixel. For example, a member of Team A calls an address, and the referee calls out the brightness level for that address from Team B's memory sheet. Team A plots it with a pixel. Then a member of Team B calls out an address, and the referee calls out the brightness level for that address from Team A's memory sheet. Team B plots it with a pixel.

Each turn, after plotting the pixel, the team may (but is not required to) try to guess the other team's image. The team that guesses correctly first wins the game. If a team guesses wrong, the other team gets a chance to guess. If other team is wrong, the game continues.

Each team gets three guesses. If a team's third guess is wrong, they lose. Note that it's not a good idea to guess unless your team is fairly sure of the right answer!

Questions to Ponder:

1. If each simulated pixel in these activities is 1 centimeter (about ½-inch) across, how big would the pixel arrays have to be to contain one million pixels instead of 64? Why are many pixels better than few pixels for recording images?
2. If you were planning a mission to Europa, what would you hope to learn from the images? What would you look for first? Where would you look? At what targets would you aim your camera?

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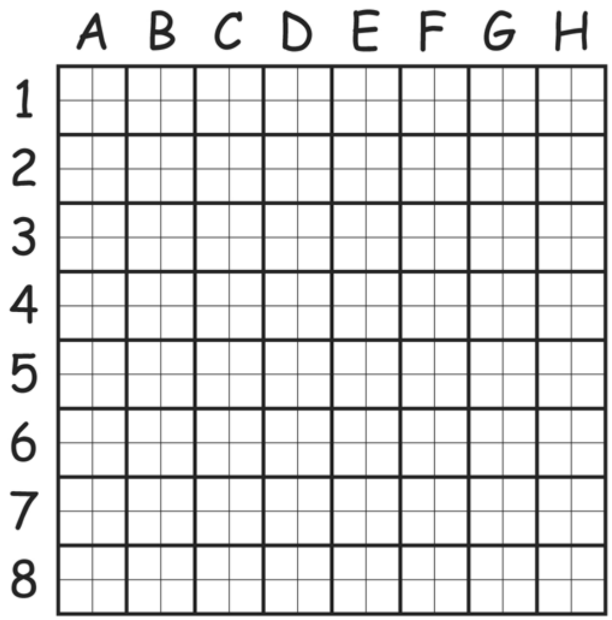

Figure 1. CCD array

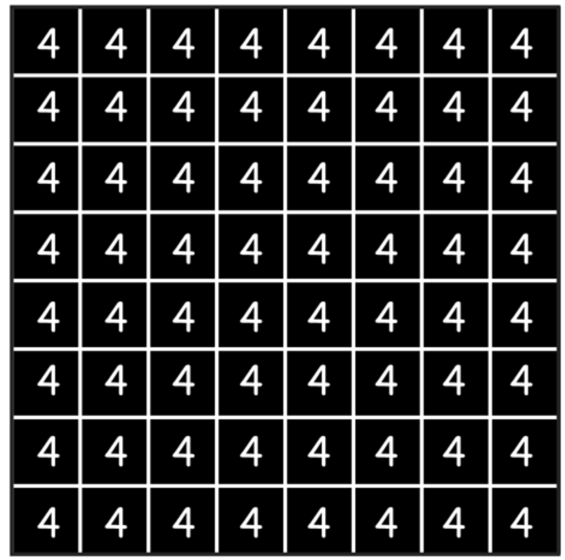

Figure 3.
Brightness level 4 pixels

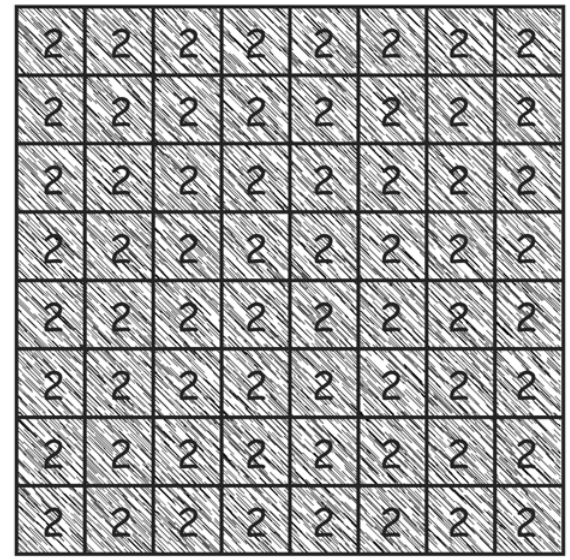

Figure 5.
Brightness level 2 pixels

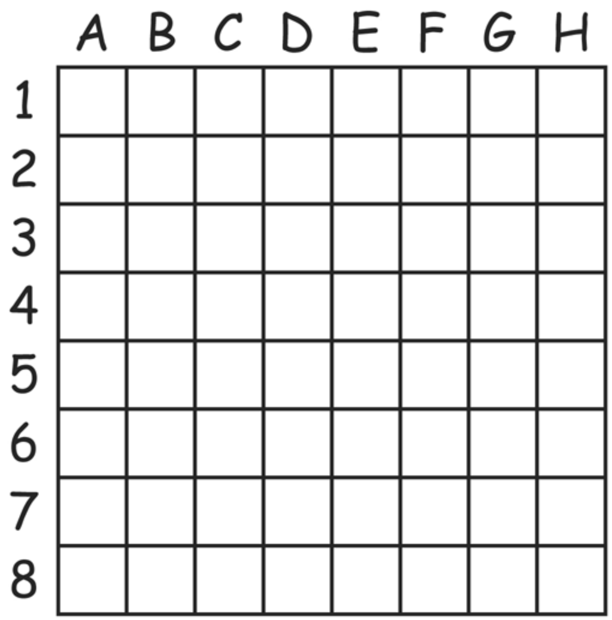

Figure 2. Display array

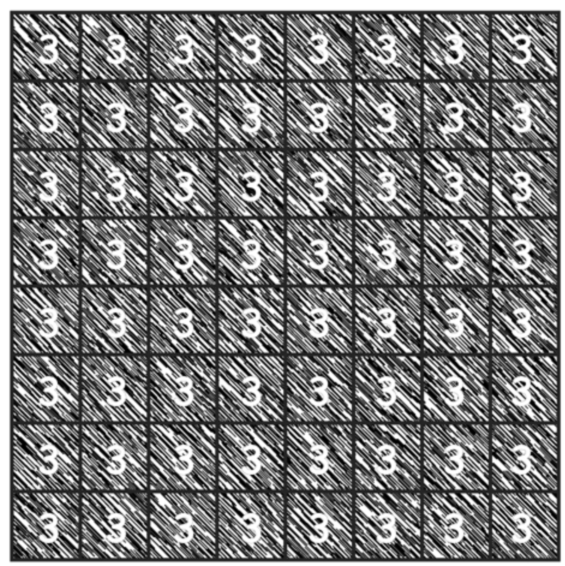

Figure 4.
Brightness level 3 pixels

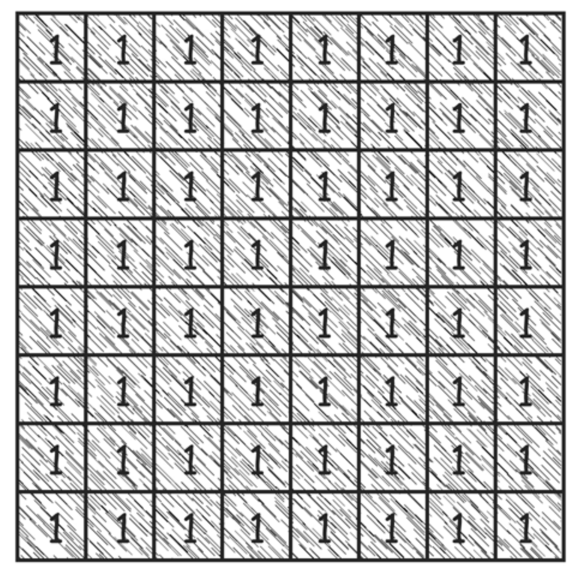

Figure 6.
Brightness level 1 pixels