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Designing for the Barely Imaginable

What is the weirdest, most alien, eye-popping, nose-shocking, skin-crawling place you can think of?

Ponder these destinations:

1. Clouds rain gasoline, forming huge lakes.
2. Volcanoes spew red-hot lava and the sky is full of poisonous sulfur gas.
3. As far as you can see in all directions is bright white ice, broken only by dark, rough rivers of more ice.
4. It is far colder than Earth's South Pole all the time.
5. It's hot enough to melt lead and the atmosphere weighs down on you as if you were diving far beneath the ocean's surface.

These would not be healthy places for humans or just about any other Earthlings.

But, believe it or not, all these environments are real places in our own solar system.

They are, in order . . .

1. Titan (moon of Saturn)
2. Io (moon of Jupiter)
3. Europa (moon of Jupiter)
4. Mars, Pluto, and most places in the solar system
5. Venus

No person has ever visited any of these places. Then how do we know what they are like? Because we have sent our technological "spies" to investigate, and they have faithfully reported back their often surprising findings.

Build 'em Tough

We have sent light sensors, image makers, rock sniffers, matter analyzers, magnetic field sensors, temperature detectors, particle counters, pressure indicators, and sample collectors. These instruments, for the most part, have given us information that even our own five senses would not be able to tell us had we gone to these places personally—that is, if we could survive and operate in these harsh surroundings, which we couldn't.

All the instruments we have sent into space were designed and built especially to operate in these harsh, alien environments. They are tough enough to withstand huge temperature extremes, intense radiation, and the vacuum of space. They are sturdy enough to withstand the bone-rattling vibration of being blasted off the surface of Earth on a rocket.

How do NASA engineers know what kinds of planetary instruments to develop in the first place? Well, they ask. What do scientists want to know about space and about alien worlds? And, once engineers know the questions to be answered, they use their know-how, ingenuity, and imaginations to come up with the kind of "sense enhancer" that will get the right kind of information and be tough enough to survive its task.

Expanding Our Senses

Here on Earth, we ordinarily get our information through our five senses: seeing, hearing, smelling, tasting, and touching. The instruments that give us information about other worlds are, in a way, like our five senses, greatly enhanced and made quite portable and autonomous. One way to classify scientific instruments is by which sense they are most like. Table one describes some examples of instruments that are a bit like our eyes, ears, noses, tasting tongues, and touching fingers.

Design an Alien World

Here is a space mission design activity your whole class can do.

1. Divide the class into groups of three or four students.
2. In each group, one person is the recorder, ready with paper and pencil.
3. Now, in each group, use your imaginations to create an alien world. Brainstorm! Your world can be a planet, a moon, or even an asteroid. Throw out wild ideas. The recorder, in addition to offering his or her own ideas, will write down everybody's ideas as they come up.

   It may be tempting to populate your world with strange, intelligent creatures and maybe even civilizations. However, for simplicity, stick to worlds with either no life forms or only very primitive ones (like bacteria or one-celled plants).

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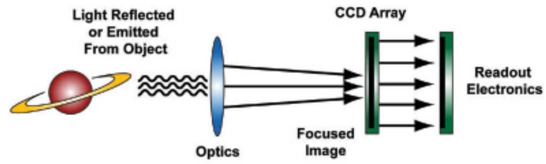
Table 1. Kinds of planetary science "sensing" instruments.

Viewers ("eyes")

For example, *imagers, infrared radiometers*

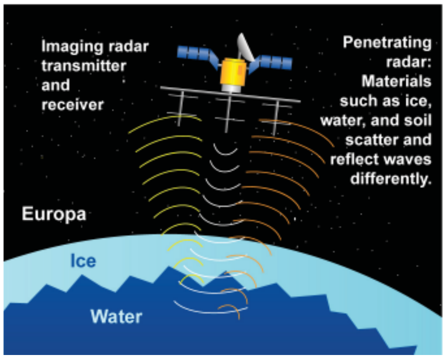


These would include any kind of imagers (sort of like fancy cameras) that detect light, including light our eyes cannot see, such as infrared and ultraviolet light. Imagers tell us about surface brightness, color, shape (topography), and texture.

One type of imager, an infrared radiometer, can measure the temperature of a surface based on how much infrared light (which we cannot see, but rather feel as heat) is being emitted.

Listeners ("ears")

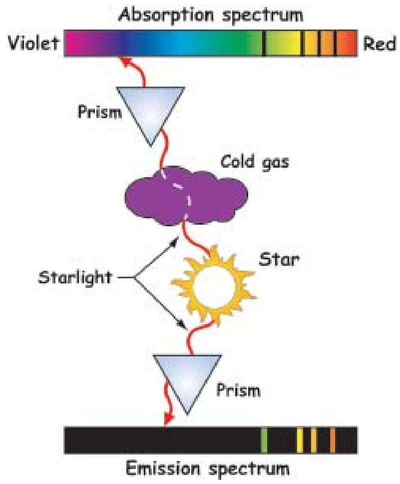
For example, *sounding radar (or sounders), imaging radar, profiling radar*



There's no sound in space, unless there's an atmosphere to conduct the sound waves. But instruments called sounders or radars do listen, in a way. Sounders and imaging or profiling radars riding on a spacecraft transmit radio waves downward and then "listen" for echoes as the waves bounce off the clouds or surface, or even penetrate beneath the surface. These "listeners" can measure distances to different parts of the surface or heights of clouds based on the strength of the echo or how long it takes to "hear" the echo. Thus sounder and radar data can be used to make 3-D maps of the surface as the spacecraft passes over it. Profiling radar can also measure depths of clouds and sounders can measure depths of ice layers or layers of different materials below the surface.

Sniffers ("noses")

For example, *spectrometers*



Your nose detects even tiny amounts of substances in the air. A spectrometer, although it works more like an imager than a "sniffer," can analyze the composition of a gas, a liquid, or a solid.

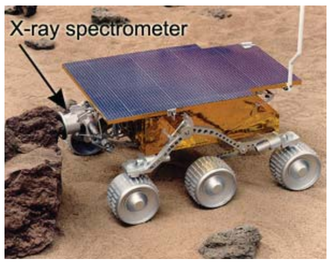
Here's how: Light travels in waves. Light is a combination of many different wavelengths, or colors. Combined, they make white light. If you shine light through a gas (such as water vapor), the gas will absorb some wavelengths (colors) of the light and let others pass through, depending on the gas. Each substance has a unique "fingerprint."

An *absorption spectrometer* separates the wavelengths of light (as a prism) that has passed through a gas, making a kind of rainbow. The spectrometer then detects which wavelengths are missing. They are missing because they were *absorbed* by the gas they passed through. The spectrometer matches this pattern of missing wavelengths, or "fingerprint," with those of known substances, thus identifying the unknown gas.

An *emission spectrometer* analyzes the light coming from (being *emitted* by) a source, such as a star, and identifies the source material (that is, what is burning or glowing) by the wavelengths (colors) of light it emits.

Tasters ("tongues")

For example, *x-ray spectrometers*



Your tongue works with your nose to identify what you are eating or drinking. So, spectrometers might also be considered tasters, since they can analyze what's in a substance that has emitted light or a substance that light has passed through. Other special x-ray spectrometers can directly bombard with x-rays solid things such as rocks and then detect the rock's composition based on the energy "fingerprint" that echoes back into the instrument. In this pictured model of the Pathfiner "Sojourner" rover that explored Mars in 1997, the x-ray spectrometer is helping Sojourner "taste" a rock.

Table 1 (cont'd)

Feelers ("fingers")

Examples are *drillers, scrapers, corers, sample collectors, rock crushers, ice scrapers, particle detectors*

If you wanted to know about a substance, you would probably touch it directly. You would feel its texture, hardness, temperature, wetness, etc. "Feeler" instruments might be mechanical devices such as drillers or scrapers or corers. Or, maybe even rock crushers to find out how hard the material is and get it ready for the spectrometer (sniffer/taster) to analyze it. This sequence of pictures shows a rock (of Earthly origins) being crushed for analysis by a spectrometer.

Other types of "feelers" are sample collectors (as if they are grabbing or trapping something with their hands) or particle or dust detectors (which sense when, say, an electrically charged particle strikes a surface, or the instrument's "skin"). This picture shows how a human-made substance called "aerogel" can trap particles for later analysis.

"Sixth" sensors

An example is a *magnetometer.*

Some scientific instruments directly detect things that none of our five senses can detect. Magnetic fields fall into this category. (Although some birds and other animals may sense Earth's magnetic field and use it to navigate.) If not for a compass, we humans might not know about Earth's magnetic lines of force. An instrument that detects and measures magnetic fields is called a magnetometer. As on the Voyager spacecraft in this picture, a magnetometer is often placed at the end of a long boom so magnetic fields from the spacecraft itself do not interfere.

And don't forget to give your world a name!

You could ask yourselves some of the questions below to get your imagination going.

a. Does the world have a solid surface, or is it a gas ball like Jupiter and Saturn?

b. How bright and what color is your world?

c. What is the material covering the surface?

d. Is there water on your world?

e. If so, is it frozen, liquid, or vapor? And where is the water?

f. What is the surface texture like? (smooth, cracked, cratered, mountainous, hilly, unusual formations, etc.)

g. How hot or cold is the surface?

h. How much does the temperature differ on the day and night sides?

i. Does it have seasons?

j. Is there an atmosphere?

k. What kind of gases are in the atmosphere?

l. Are there clouds?

m. Is the surface hard packed or loose and dusty?

n. Is the same material under the surface as on top?

o. Does it have a magnetic field?

p. What is in the sky? One sun? Two? Any moons?

q. If your world is a moon of a bigger planet, what does the planet look like in the sky?

4. The recorder will now make a legible listing or narrative description of the agreed-on characteristics of your imaginary world, including its name! Someone may even make a cool sci-fi drawing of it.

Describe Your Alien World

5. Now, pick one person to represent the group. This person will describe the world you have designed to the rest of the class.

6. Once all the groups have shared their "designs," swap worlds! Pass your group's description to another group.

Design and Conduct a Space Mission

7. Put yourselves in the place of a team of scientists (including different kinds of scientists, such as astronomers, planetary geologists, or atmospheric chemists) from Earth who would like to learn more about this newly discovered world.

   Use Table 2 at the end of this article as a guide for how to design and describe your mission of discovery.

   a. First, ask yourselves "What do we already know?" Select one or two questions from the list above to which you already know the answers.

   b. Now, what do you want to know? Pick three to five questions from the list above. Then think about which type of instrument(s) (second column in Table 1) would help you find out the answers to these questions.

   c. What would be the best type of mission that could use these instruments to answer these questions?

      - An *orbiter* that goes around and around a planet or moon, studying it for several months or years?
      - A *lander*, such as the Mars Rovers, that will explore the surface?
      - A *flyby* spacecraft that will study the planet or moon for just a few days as it passes, perhaps on to several more "flyby" destinations?
      - A *ground penetrator* that burrows or drills under the surface?
      - Something else?

   d. Now, assume the mission is accomplished. What did you learn?

   e. What didn't you learn? Did the answers to the original questions bring up more questions? (This often happens in science!)

   f. What would be a good follow-up mission for the future?

8. Get together as a whole class again, and have someone from each group present your team's space science mission, its findings, and what kind of mission should be done next.

New Instruments for New Worlds

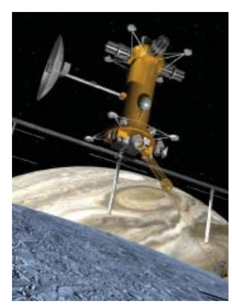
The worlds that nature has made may be even stranger than anything your imagination can dream up. It is important for NASA to keep developing new instrument technologies so that missions of exploration can gather information never before captured and in places never before visited.

NASA's Planetary Instrument Definition and Development (PIDD) Program has the job of picking and developing likely technologies that will help scientists to learn new things from future missions to explore the solar system. Some of the instruments are meant to be part of a spacecraft that will orbit or fly by a planet or moon or asteroid. Some are meant to be part of a spacecraft that will land on the surface of a mysterious world or penetrate beneath the surface.

Developing a scientific instrument technology is, in a way, a mission on its own. Besides coming up with an idea, or a "new and improved" idea, for gathering needed science information, engineers try to make the technology as small, power-efficient, and low cost as possible. With computers and electronics shrinking in size and growing in capability all the time, spacecraft can be smaller and, therefore, less expensive to build and launch. But that means everything else that goes into the spacecraft, including the science instruments that are the "payload" must shrink too.

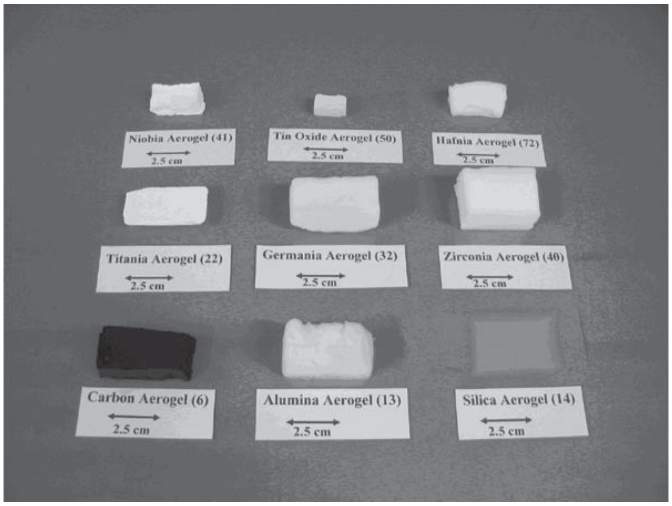
Here are some of the new instruments and technologies the PIDD Program has developed so far:

Ice penetrating radar: Could be used on a mission to Jupiter's moon Europa, as shown in this artist's rendering, to find out the depth of the ice covering the surface and learn whether a liquid ocean lies below it.



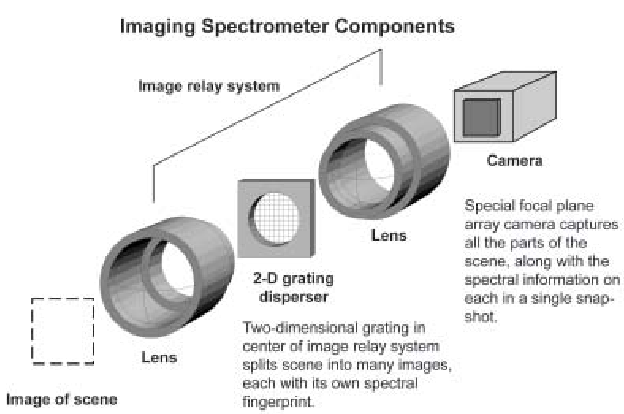
Rock crusher and sorter: Could be used to prepare a rock or a core sample of the ground (drilled out by a different instrument), crushing it into fine particles for an x-ray spectrometer to analyze. Table 1 showed this instrument under "feelers."

New Aerogels: Aerogel is the lightest solid material ever made. It is 99.9% air. So far, the only material used for the other .1% has been silicate,



which is like sand. This aerogel material was used by the Stardust mission to capture comet particles and return them to Earth for analysis. The trouble is, some of the comet particles were very similar to silicate and therefore hard to separate from the aerogel. So the PIDD program is developing some aerogels made of different materials not likely to be found in such samples. The photo above shows samples of some new aerogels under development.

Imaging spectrometer: This is a special instrument that can take a picture of something and analyze what substances are in it at the same time. This instrument has already found a use right here on Earth in diagnosing human eye disease.



Without engineers working hard on these new kinds of instruments for planetary exploration, our knowledge and understanding of the solar system—and all the other solar systems out there—could not advance.

You can read about another new kind of spectrometer that uses a laser and find out how laser light is different from ordinary light. Visit http://spaceplace.nasa.gov/en/kids/laser .

Table 2. Summary of a mission to an alien world

Name of Mission:	
Destination (name of planet, moon, asteroid, etc.):	
Known characteristics of destination:	1. 2.
Questions (3 to 5) to be answered, plus science instrument needed for each investigation:	Question: Instrument: Question: Instrument: Question: Instrument:
Type of Mission:	☐ Orbiter ☐ Lander ☐ Flyby ☐ Other If "other," describe.
What we learned:	
What we didn't learn:	
Proposal for a future mission?	

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