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Understanding Systems Integration: Notes for the Teacher

In this activity, students are introduced to the idea of systems integration: Designing a machine so that all its various functions work together smoothly. The activity can be easily adapted to different grade levels and to whatever investment of time the teacher finds appropriate.

Systems integration is a major concern of the Deep Space Systems Technology Program (also known as X2000), which JPL conducts for the National Aeronautics and Space Administration (NASA). In this program, engineers design and build advanced technology systems to be used in many new spacecraft, in support of NASA's thrust toward faster, better, and cheaper space missions. Find out more about this program at ***http://dsst.jpl.nasa.gov****.*

Other space science and technology activities for children can be found on JPL's ***The Space Place****,* ***http://spaceplace.jpl.nasa.gov,*** *also supported by ITEA.*

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This activity requires some planning. Taking apart a machine or mechanical device to analyze its parts, and then putting it back together again to see how it works can be quite educational and empowering. But the newer appliances often contain circuit boards and other miniaturized devices with roles that are difficult to identify. Whether the teacher tackles this issue alone or decides to involve the class as a whole, there are several approaches that will bring about a positive result.

K-4: A teacher could create an after school science inquiry class for first, second, and third graders. The teacher could guide the process so that the students attain a respect for the integrity of the machine, and so that working parts do not get lost or destroyed. The students may watch demonstrations that model how to proceed, and also use tools to take apart and put back together a variety of simple machines and motors.

5-8: A technology teacher may set up stations centered around a variety of older devices ranging from mechanical pencil sharpeners to toasters, boom boxes and televisions. The task is to work in teams, take apart the device, draw pictures of how the device fits together, identify parts and subsystems, then put it all back together. Students are can be asked to compare, contrast, discuss, and present ideas about integrated designs.

9-12: Many school shop and automotive areas are being closed down. The opportunity to experience machines in a hands-on way is becoming more challenging. Group science and technology projects may benefit from partnering with local businesses that have shop facilities. A field trip with planned activities that include demonstrations and guided hands-on experience may amplify the effect of a classroom discussion or activity.

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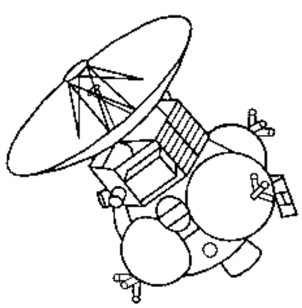
THINK SYSTEMS!
HOW ENGINEERS THINK ABOUT SYSTEMS INTEGRATION

As exciting as astronauts' lives are, their adventures look a little tame compared to those of robotic space explorers. Robots can go where it's doubtful any astronaut could *ever* go, no matter how elaborate the shielding and life support systems on the spaceship. Some places are just too dangerous. Imagine heading into the Sun to get a closer look. Could any human be protected from the 2400 K (3800° F) heat at 2 million kilometers (1.25 million miles) from the Sun?

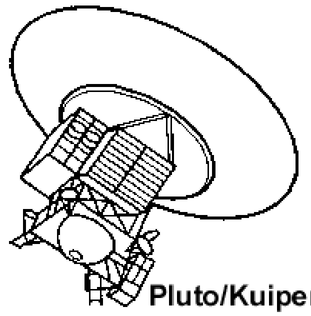
And what would be the point of sending a human, when a robotic explorer, a spacecraft, could scout the region more thoroughly with its instruments than any human could with all five senses.

Over the past forty years, our space program has scoped out the solar system. Now we are about to explore the most daunting destinations, performing the most challenging tasks. To carry out such technically difficult missions affordably, the National Aeronautics and Space Administration (NASA) has created the Deep Space Systems Technology Program (DSST), known also as X2000, a program that will create the advanced technologies needed for NASA's 21st century missions. The X2000 First Delivery Project is already designing robotic explorers for a fleet of four sleek spacecraft:

Europa Orbiter: Searching for the possibility of an ocean beneath the ice-covered surface of Jupiter's 2nd moon, immersed in Jupiter's high radiation magnetosphere.



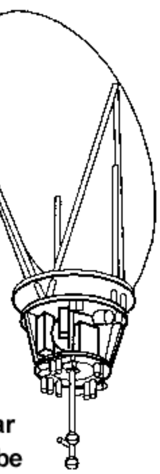
Europa Orbiter



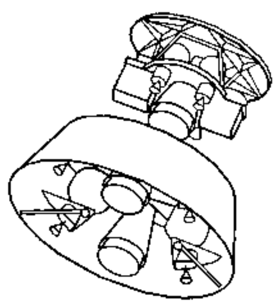
Pluto/Kuiper Express

Pluto/Kuiper Express: Taking the first close-up pictures of the coldest and farthest planet and, beyond in the Kuiper Belt, the icy bodies left over from the formation of the solar system.

Solar Probe: Heading in close to the Sun to explore the mysterious dynamics of the solar wind.



Solar Probe



Mars Sample Return

Mars Sample Return: Bringing bits of the red planet back to Earth to help us better understand its history.

To design the X2000 generation of robotic explorers, engineers will have to *think systems* more than ever before. A robotic explorer is more than the sum of its thousands of parts. All those parts must form interrelated subsystems that work together as a whole.

Activity 1: Exploring systems integration

Think of a system that has been designed to do some job. An example might be an air conditioning system.

Identify its basic function. In this case, it might be to cool things off on a hot night.

Then think about some different technologies that could be used to accomplish this function. For example, technologies that work to cool things off on a hot night might be

a) Electric oscillating fan.

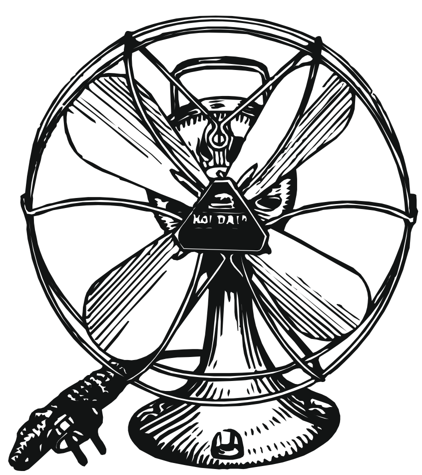
b) Evaporative cooler on the roof of the house, with ducts into the house.

c) Window-mounted air conditioner.

d) Thermostatically controlled centralized air conditioning system.

In all the technology systems, notice how several parts work together. A subsystem is a group of parts that work together to do a particular job. Systems integration refers to *how* the different parts are brought together to work as a unit.

To integrate something means to organize it so that the parts all work together.



For example, you might look at the fan by itself as a system and consider how the design integrates its parts. Perhaps one knob switches the speed of the fan blades from slow to medium to fast. If it's an oscillating fan, another knob may hold it in place or let it sweep from side to side. Another mechanism may allow you to adjust the angle of the blades up and down. The parts involved in each of those three controls—fan speed, side-to-side motion, and angle—are each *subsystems* of the fan. If you were to take a fan apart carefully, you might be able to see how the design integrates these functions into a smoothly working unit.

All technological devices require systems integration in one form or another. Some designs do a better job than others at integrating all their parts. Of course it all depends on what we consider *better.* You might want to use a big fan to create a powerful wind effect in a movie. Or you might want a small fan to fit into a laptop computer to cool it off. You might not care whether the fan makes a lot of noise or you might require a very quiet fan. How the device will be used makes a big difference in how its parts should be integrated.

All NASA's remote sensing spacecraft are robotic explorers. Whether they fly by, go into orbit, or land, our exploration of Earth and the whole solar system is made possible by robotic systems. For such elegant and complex machines to work smoothly, good systems integration must be designed into them.

Consider this analogy between a *robotic explorer* and a *human astronaut* (without a space suit):

Robotic Explorer Subsystems	**Astronaut Subsystems**
Structural (Bus, Booms, Struts)	Skeletal (Bones)
Telecommunications (Radio) Transmitter Receiver	Speech and gestures Hearing
Propulsion	Muscles/Metabolism
Science Instruments	Senses
Temperature Control	Body temperature feedback (homeostasis) system
Command and Data Handling Data Recording Flight Computer	Memory Brain

What might be involved in the *systems integration* task in designing a robotic explorer? In "designing" an astronaut? What makes it possible for the different subsystems in each to work together as a whole?

How would you go about designing a robotic explorer so that all its subsystems worked together? This is the task of systems integration. Think it through by looking at systems you may already be familiar with, such as the human body or simple

appliances. Once you learn to think systems, you will have important insights into how engineers think as they set out to invent and develop new technologies for robotic explorers.

Activity 2: Take something apart and identify its subsystems

Create groups of 3, 4, or 5 students. Designate one person in each group to be a note-taker.

Materials:

Small, used machines or appliances that aren't needed anymore (preferably things that don't work anymore)

Assorted tools that can be used to open up and/or take apart machines and appliances

1) Select a small machine or appliance that you can open up or take apart in order to see the workings inside.
2) Describe the "front panel" controls you see (switches, buttons, knobs, dials), and discuss what they do.
3) Ask yourselves what *subsystems* are these controls part of?
4) Open up the outer packaging of the machine or appliance, carefully removing any screws or other bindings. Take a look at the inside workings of the machine or appliance.
5) Brainstorm about how to identify the different *systems* and *subsystems* you see—groups of parts that work together to accomplish a common function— name them as you may know them, or create names that fit the function. Why do you think the machine or appliance was designed this way?
6) From this information, identify and describe what makes all the subsystems work together. How do the subsystems affect each other? What monitors the functions? What are all the factors involved in making it work together? In other words, *think systems integration!*

Activity 3: Look at Robotic Explorers

1) Look in the library, explore the Internet, or otherwise collect a variety of images or models of spacecraft.
2) Identify *subsystems* and the *systems integration* components.
3) Now, create your own robotic explorer design—assign each person in the group the special task to design one subsystem. Take turns describing one subsystem at a time.
4) Now, discuss how to integrate the subsystems to work together as a unified robotic explorer. Think through how to communicate steps that might help the systems work together smoothly.
5) Draw the design or construct a model.
6) Share results with whole group by presenting ideas and demonstrations.

After all is said and done, we might want to remember that even robotic explorers have a human component—the scientists and engineers who design, build, operate, and retrieve the data from the spacecraft. In a very real sense, every robotic explorer is a subsystem integrated into the whole human enterprise of space exploration.