AVIONICS: INTEGRATING SPACECRAFT TECHNOLOGIES

Using advanced avionics to help students learn how systems work together

Spacecraft may seem almost magical in their ability to coordinate a variety of instruments to explore unknown worlds. Avionics is that engineering art of integrating everything on the spacecraft into a smoothly operating unit. Spacecraft avionics has advanced from merely wiring together varied boxes of functioning subsystems toward putting it all together on a microchip. This engineering leap has also required a leap in thinking about how systems work together. This activity leads to an experiential understanding of avionics, the art of integrating spacecraft systems and the logical framework applied to systems in general.

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The U.S. space agency, the National Aeronautics and Space Administration (NASA), envisions a revolutionary space exploration program for the 21st century. To prepare for the future, NASA has created the Advanced Deep Space Systems Development Program, referred to as *X2000*. X2000 is responsible for inventing and testing new technologies that will be used for multiple space exploration missions.

education outreach

Grade Level:	*4-12*
Group Activity:	*Teams of 4-7 students*
Objectives:	*Learn the basics about avionics, then apply it to learn the basics about how integrated systems work together.*
Materials:	*Paper and pencils, plus (optionally) an assortment of found objects and any other model construction materials.*
Timetable:	*Quite variable, from one to several class periods*
Vocabulary:	***avionics, spacecraft bus, system, subsystem, integration, spacecraft-on-a-chip***

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INTRODUCTION: WHAT'S NEW? IT'S A MATTER OF PERCEPTION!

Scientists who wish to explore space must know not only about their own branch of science but also about advanced technologies related to their fields. Experimental measurement by increasingly high-tech instruments is part of the territory. For this reason, scientists and engineers form project teams to work together and to pool their knowledge and resources.

A spacecraft is designed to function as a fully integrated machine. Yet machines are designed and built part by part. The challenge of advanced technology is to design and assemble machines that are increasingly integrated and miniaturized while providing higher performance.

The role of *avionics* engineers is to invent ways to combine, rearrange, and shrink the flight hardware to achieve smaller size, smaller mass, and enhanced performance. They analyze the parts, while keeping in mind how the whole system works. Spacecraft require propulsion, navigation, power, telecommunications, temperature control, attitude control, data processing, and the various experimental science instruments and sensors. Up until now, spacecraft have been designed with each separate function as a subsystem component. *Subsystem* is engineer-ese meaning simply a set of parts designed and built to serve a particular function—such as communications—that also functions as part of a larger set of parts (that is, a *system*) that has broader functions. These subsystem components are all packed onto a *spacecraft bus*, then cabled together and launched.

The first task of the X2000 project is to design a new spacecraft bus. The *bus* is the main structure to which all the other components are attached. Traditionally, it has housed delicate instruments, giving them mechanical stability and protecting them from temperature extremes, and has provided the chassis to support the circuit boards for radio equipment, data recorders, computers, gyroscopes, and other components. The job of X2000 is to design a new type of spacecraft bus that is

- A technological breakthrough, not just an incremental improvement;
- Relatively inexpensive to build;
- Useable for several space missions, meeting requirements of all.

We are surrounded by products that integrate technologies that were once thought of as separate. The telephone was a breakthrough because it was the first device to integrate telegraph and analog microphone technologies. Now we have devices that fuse telephone, fax, printer, answering machine, and other functions. We have cordless phones, cellular phones, pagers, and pocket-sized remote answering machines. We can communicate face-to-face in real time via the internet using a computer and phone lines. As we become accustomed to these new devices, we grow to think of them as single technologies.

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ACTIVITY INSTRUCTIONS:

This activity is done in four rounds, each gaining in complexity. In the first round, the class as a group discusses current technologies in general terms. In the second round, the class brainstorms ideas for future technologies. In the third round, the class identifies required functions for a spacecraft, proposes a hypothetical space mission, then, in small groups, designs and (optionally) builds models of individual components for the hypothetical spacecraft. In the fourth and final round, newly formed groups integrate the previously designed components into a plausible (or not so plausible!) spacecraft.

You may wish to encourage older or more advanced students to think realistically, suggesting that they become acquainted with the range of existing spacecraft technologies. They can visit the library or space-related web sites such as those linked to JPL's home page (http://www.jpl.nasa.gov) and NASA's home page (http://www.nasa.gov). A particularly good primer is JPL's web-based document, "Basics of Space Flight Learner's Workbook" (http://www.jpl.nasa.gov/basics), especially Chapters 11, "Typical Onboard Subsystems," and 12, "Typical Science Instruments."

Alternatively, you may encourage students to think more imaginatively, suggesting they invent their own technologies to serve the purposes of the space exploration mission.

Depending on how extensively you involve the class in this activity, you can take several approaches to providing for drawing and modeling materials. You may limit the activity to simply drawing the designs on paper. With just a few more materials, 3-D models of components could be cut out of paper and folded, bent, glued, and taped. Models could be built with found objects, readily available in the classroom, or with some planning, brought in for the activity. You could create kits, enabling each group to assemble components from a limited range of materials. Or, students could design their models using graphics software at the computer.

Round 1: General Discussion

Ask the students, as a class, to list products that integrate technologies, identifying the different technologies that are combined. Examples are hearing aids combined with eyeglasses; telephones that are also answering machines, faxes, and printers; and monitors that can be used to watch TV, play video games, and cruise the internet.

Assess students' understanding in light of their responses to questions such as: What are some differences between the separate and combined technologies? What emerges as a working definition for *technology? integration?*

Round 2: Brainstorming

Have students suggest future products that integrate different technologies. Consider different lines of thinking about integrated technologies. Consider such issues as materials (availability, usefulness for multiple purposes), energy (various sources of power), functions (multiple purposes, combined efforts), and applications (specialized uses, general applications).

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Begin to steer the focus toward spacecraft technologies by asking questions such as "What might be some of the issues spacecraft engineers and designers face when it comes to integrating technologies?"

Round 3: Designing a Subsystem

1. Discuss with the whole group the structure of a variety of spacecraft and identify subsystems needed for a spacecraft design. Consider the requirements for spacecraft navigation, telecommunications, power, and propulsion as well as scientific science instruments. (Again, see the "Basics of Space Flight" web site at http://www.jpl.nasa.gov/basics for background material.)

2. Define a spacecraft exploration mission, including some notions about the destination and science objectives. Consider whether the spacecraft is to venture out to deep space, to orbit Earth, or to approach the Sun; and whether it is to be an orbiter, a lander, a sample return vehicle, a probe delivery system, etc.

3. Form a series of project design teams so that each team has the same number of members (if possible).

4. Ask each team to invent a subsystem, focusing on one main technology. Consider the X2000 requirements of low cost, technological breakthrough, and applicability to multiple missions. Consider issues of materials, conditions of operation, and needs for power.

5. Draw and then construct a model of the subsystem design.

6. Share ideas as a group. Have each team explain its subsystem to the whole group. Assess students' understanding of the relationship of structure to function.

Round 4: Avionics Engineering

1. Reconfigure the design teams, so that each new group is composed of one member of each previous group.

2. Working with the subsystem designs and models from the previous round, have the teams design, draw, and build a model of a spacecraft bus that will *integrate* the original spacecraft components into a complete spacecraft. Teams may find that some subsystems need to be redesigned in order to be integrated with the overall design.

3. Have each group display its spacecraft design or model and explain how the technologies have been integrated.

   Assess student understanding of integrated technologies by observing whether they have progressed in their ability to express concepts from the previous rounds.

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