Searching for inspiration when it comes to living sustainably? Just look up!

Astronauts on the International Space Station must protect their resources—their lives depend on it. The same is true on Earth. For the planet to survive, we must also conserve water, air, food, and energy, and cut down on waste. ***Space on Earth*** explores how innovative efforts in space are inspiring bright ideas on Earth, and how thinking like an astronaut can help us save the planet.

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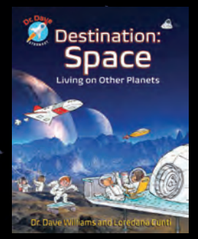
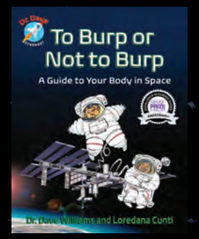
Also by Astronaut Dave and Loredana Cunti





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To Bug and Bean, with love to infinity and beyond — LP
To those committed to preserving our planet for future generations — DW

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INTRODUCTION

SPACESHIP EARTH

Have you ever seen a photo of the International Space Station (ISS)? It's kind of an odd-looking thing. Picture an insect with really big wings that stick out from a tiny body. Those wings are solar panels that collect energy from the sun, and they make the ISS look pretty big. But actually, the area where the astronauts live and work is small—not even the size of an American football field. That's not a lot of space to house everything astronauts need to live safely and well for months at a time.

No wonder, then, that ever since humans launched themselves into orbit, "sustainability" has been the name of the game for space travel and stays. Astronauts have to protect their resources and their environment because their lives depend on it. They can't open a window to get fresh air because there is no air. They can't pop out to the store to pick up new supplies of water or food. They can't take out the trash. And they can't buy new parts if an important piece of equipment breaks down. They have to take very good care of their home because that space station is their whole world. Pollute the air or water, for example, and someone might get sick (or worse). Run out of power, and the systems that make it possible to live in space will fail.

Planting trees helps keep the air we breathe clean.

Down here on Earth, we think a lot about sustainability, too. Taking care of our environment is a top priority. We know that living unsustainably—using too many fossil fuels, for example, or creating too much garbage—has contributed to climate change. And so, we work hard every day to protect the planet for future generations. We recycle, we turn off the tap when we're brushing our teeth, and we walk to school instead of driving, if we can. We know that the future of the planet depends on actions like these—and that even more needs to be done. Earth's average temperature has risen by about 0.8°C (1.5°F) over the last 100 years. That doesn't sound like a huge change, but it's enough to melt glaciers, cause droughts, and kill off certain species. And the temperature is still rising. Scientists expect it to increase at least another 1.5°C (2.7°F) by 2100.

If that happens, we will find ourselves in trouble that may be too hard to fix. Changing weather patterns will force some people out of their homes due to rising sea levels, forest fires,

Dying coral reefs

or floods. Those same conditions may also make it harder for us to grow the food we need to feed ourselves. And while some species may become extinct (like coral), others may enjoy the warmer temperatures. Mosquitoes, for example, could become a lot more common in many more places—bringing malaria and other diseases with them. It's a pretty scary picture—just as scary, in fact, as what would happen to those astronauts on the ISS if they didn't take care of their environment.

When it comes right down to it, then, our planet isn't so different from the ISS. Think about it as Spaceship Earth. It's bigger than the space station, to be sure, and that size can sometimes make it seem like we have a limitless supply of the resources we need. But the plain truth is that we don't. So maybe it's time to get inspired by the astronauts who live and work in space. How do they keep their air and water clean, and make sure there's enough food to eat? How do they cut down on trash and energy use? Are there ideas being explored in space that could spark innovations in our own backyards? The answer to all of these questions is "Yes!"

Throughout this book, we'll take a closer look at some of the key environmental problems we're facing on Spaceship Earth, and then we'll look up—way up!—for inspiration. By the time you finish reading, one thing will be very clear: there's no shortage of amazing and innovative ideas for protecting this planet we call home.

ASTRONAUT INSPIRATION: INTRODUCING DR. DAVE . . .

If you want to start thinking like an astronaut, it's probably a good idea to meet one!

This book can help you out with that. One of the authors—Dr. Dave Williams—has made two space shuttle flights and performed three space-walks on the International Space Station. He's actually lived in space for about a month, in total. When it comes to space-age sustainability, he knows what he's talking about—and he's excited to share his experiences and ideas. Keep your eyes open for the "Dr. Dave's Life on the ISS" or "Dr. Dave's Living in Space" feature in each chapter. They'll take you inside the International Space Station for an up-close look at how astronauts take care of their environment.

Dr. Dave is also a scientist, so he's included a few experiments that will help bring what you learn to life. Watch for the "Experimenting with Dr. Dave" feature in each chapter.

CHAPTER 1

WATER INSPIRATION

Make Every Drop Count

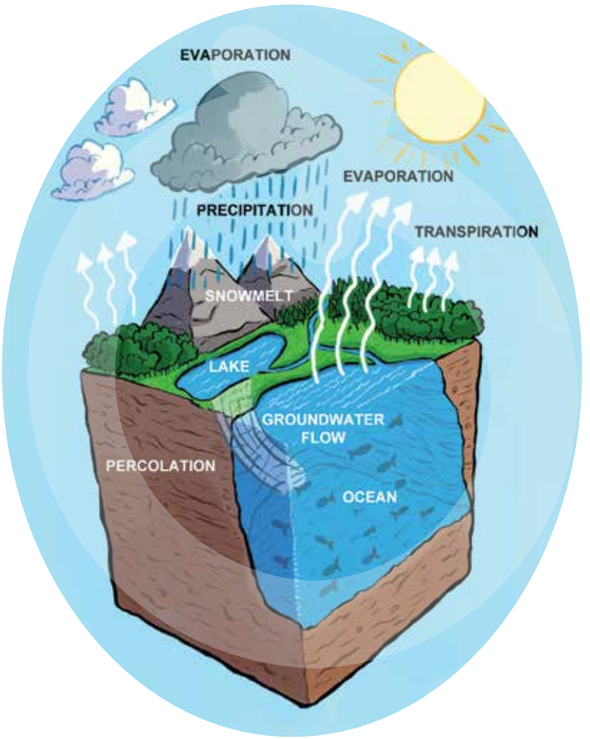
The Trouble Down Here

Close your eyes and imagine our planet. Got it? Chances are your brain is painting a picture of Earth from outer space—looking like one of those big bouncy balls you played with when you were younger. Back in the 1990s, before you were born, a scientist named Carl Sagan saw a photograph of Earth taken from the space probe *Voyager 1* and gave our planet a nickname: the "pale blue dot." What he saw when he looked at that photo was a whole lot of blue—the blue of our oceans and seas and lakes.

A whopping 71 percent of Earth's surface is covered in water. So there should be plenty to go around, right? Look quickly and it would seem so, but looks can be deceiving. We need to remind ourselves that we don't have a never-ending supply of water, and to start treating it as the precious resource it really is.

The Water Cycle

"Wait a minute," you might be saying. "Something's not adding up. What about the water cycle? Isn't Earth's water constantly recycled?" Okay, you have a point. Water is, in some ways, a pretty renewable resource. That's because the same water evaporates into the sky and falls as rain over and over and over again. So we kind of *do* have a never-ending supply of water, don't we? Well, yes and no. While we're not likely to run out in the near future, we might soon have a harder time finding water we can actually use.



There is the same amount of water on Earth right now as there was when Earth was formed.

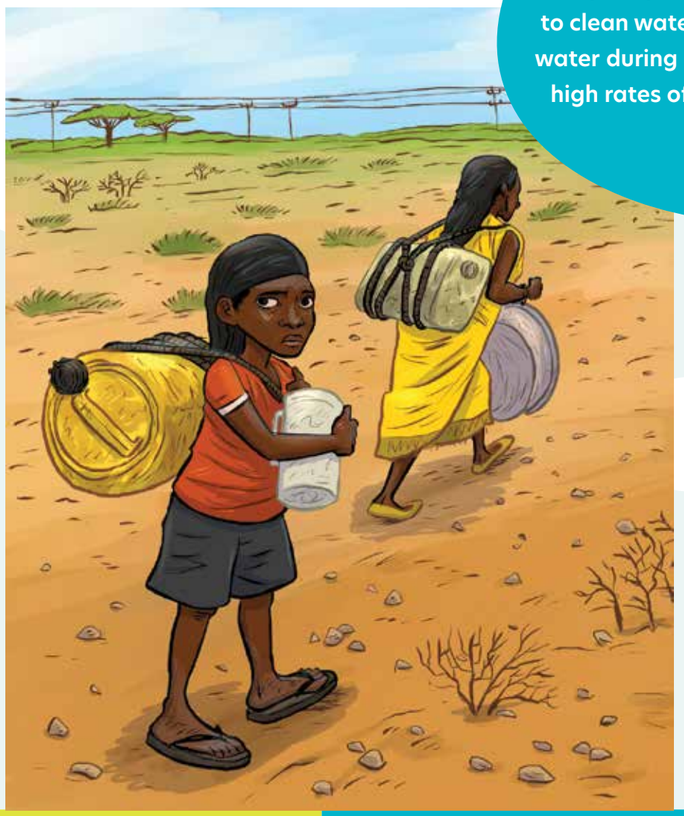
If the world's water supply totaled 1 gallon (3.75 liters), the amount of fresh water would be about one third of a cup (80 millimeters). The amount of usable fresh water (the stuff we can access) would be about two to three tablespoons (30-45 milliliters).

Supply and Demand

Only 3 percent of all that ancient Earth water is fresh water (not saltwater), and 2.5 percent of that is out of our reach. Some of it is trapped in polar ice caps, glaciers, or soil. And thanks to our growing impact on the planet, a bunch of the water we can access is polluted, making it unsafe to use.

Climate change isn't helping. As the planet warms, rivers, lakes, and aquifers are drying up, and more than half of the world's wetlands have disappeared. Weather patterns are changing, too, causing water shortages and droughts in some areas and floods in others.

And then, of course, there's us—a global population that grew by more than 800 million between 2010 and 2020—all creating an ever-greater demand for water to drink, grow food and cook with, play in and on, and power our industries.



It's a Girl Thing

Women and girls can be especially hard-hit by water scarcity and sanitation issues. In many parts of the world, women are responsible for getting water to the home. In sub-Saharan Africa, for example, women and girls walk an average of 6 kilometers (3.7 miles) hauling 20 kilograms (44 pounds) of water each day. This doesn't leave much energy for other activities, like attending school or working a paid job.

As well, girls who have started menstruating may drop out of school if there is no access to clean water or washrooms. A lack of clean water during childbirth also contributes to high rates of disease.

Down the Drain

A high demand for water coupled with a limited and shrinking supply might be manageable if we were using the water we do have wisely. But many of us are not. The not-so-water-wise leave taps running while they brush their teeth or run the water in the shower for ages before they get in, and they can take their time when it comes to fixing leaky faucets or toilets. And then, there's the water it takes to make all the stuff we use and own. Creating a single pair of jeans, for example, uses about 10,932 liters (2,888 gallons) of water, while producing a 2 liter (0.5 gallon) bottle of soda takes between 680 and 1,242 liters (180 and 328 gallons). That's a whole lot of water going, going, gone.

Add it all up and you've got a global water crisis—what many experts consider to be one of the top 10 threats to our civilization. Some countries don't have enough water to grow the food needed to feed their population. Others struggle to control diseases that show up when unclean water is used for drinking, cooking, and bathing.

And this isn't just a problem in low-income nations. Several U.S. states are facing water shortages, and lack of access to clean drinking water is a big problem in many First Nations communities in Canada. No wonder one of the United Nations' Sustainable Development Goals is to provide universal access to clean water and sanitation by 2030. To make that happen, we need to be much more careful about how we manage our water resources.

BREAKING IT DOWN

1 BILLION **people don't have access to clean drinking water**

2.7 BILLION **find water scarce for at least one month a year**

2.4 BILLION **people deal with inadequate sanitation**

1 MILLION **people, mostly children, die each year from illnesses associated with poor water quality and sanitation**

BY 2025, **two-thirds of the world's population will live in a water-stressed country**

Look Up for Inspiration

Up on the International Space Station, 400 kilometers (250 miles) above the planet's surface, astronauts don't worry about giant manufacturing plants polluting their drinking water, or whether climate change is mucking up the world's water supply. But that doesn't mean they don't have to worry about water. In fact, ever since astronauts began living on the ISS, making every drop of water count has been a big concern.

A Precious Resource

In space, astronauts are always aware of just how precious a resource water is. Because there's such a limited supply on board, they tend to use a lot less of it than we do on Earth. But astronauts and Earthlings all need to drink 10 to 14 cups (3 to 4 liters or quarts) of fluids a day to survive. So it's all of the other things we use water for that make a difference.

At home, there are sinks, showers, laundry machines, and maybe hoses to water a garden or wash a car. All of those things work because many of us have "running water," supplied to our homes by the city or town we live in. We turn on a tap or press a button and—presto!—water comes flowing out. In space, there is no running water. Almost all of the water that's on the ISS has to come from home (more on that "almost all" below!), and space up there is limited. Does a rocket have room to shuttle thousands of liters of water to the ISS for a six-month mission? Nope! Does the ISS have room to store it? Also nope! Instead, enough water to last the crew for a few months is brought by cargo vehicle to the ISS in soft-sided waterproof bags. With such a limited water supply on board, astronauts have to make every drop count by remembering the three Rs—reduce, reuse, and recycle.

Reducing: No Showers, No Flushing, No Laundry

Since astronauts can't reduce the amount of water they drink, they have to cut back in other ways. And they've gotten really good at it! The average astronaut is pretty water wise—because they have to be.

There are no sinks or showers and no drains or taps in space. Instead, small water-filled bags are used for brushing teeth, washing, or showering. Without gravity, water sticks to the skin, like a water droplet on a leaf. Some astronauts spread that water around on their skin to wash and then let it evaporate; others use a wet washcloth to clean their body. Rinse-less shampoo keeps astronaut hair clean, and edible toothpaste takes care of teeth in space. And there's no worry about using water for laundry in space because there's no laundry machine. Astronauts wear cotton clothes that are thrown away when dirty.

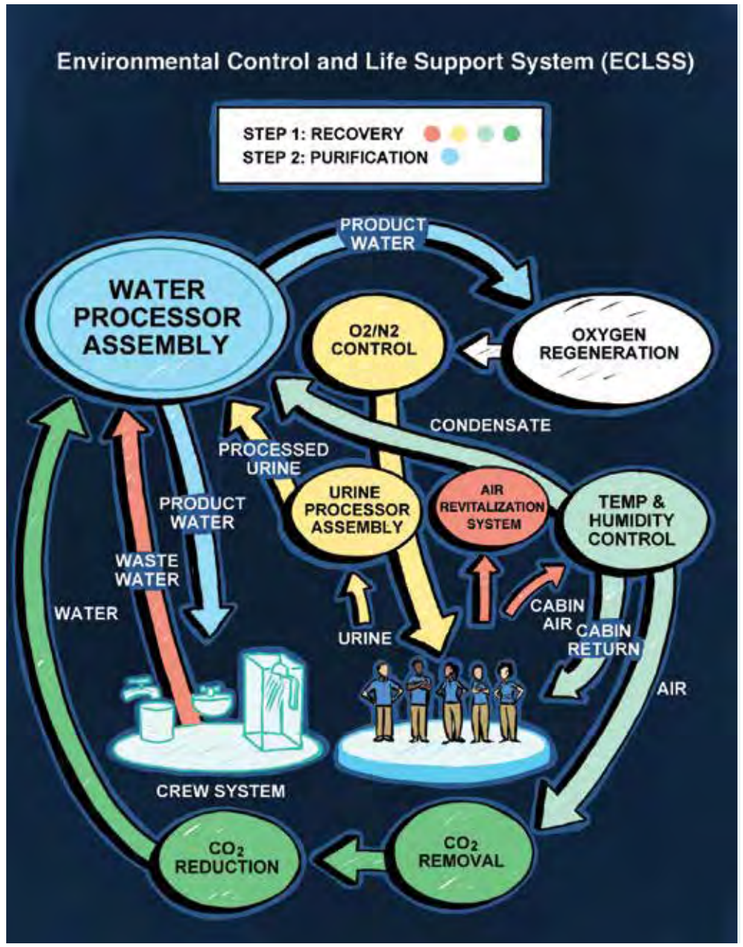
At the end of each day, an astronaut will have used a little more than 4 liters (1 gallon) of water—and about 90 percent of that is for drinking. Astronauts use every drop of the water they get in order to be efficient, but also because there's no drain like the ones we have at home in sinks and showers, and there's no place to store dirty water!

Now, compare that to what goes on down here. In places where water is easy to access, an average person might use between 302 and 378 liters (80 and 100 gallons) per day! That's *a lot* of water! They aren't drinking more. They're just taking longer showers, using water with every flush of the toilet, washing dishes and clothes when the load isn't full, and watering lawns—all without thinking twice about the resource they are using, and wasting, in the process. Unlike astronauts, most people on Earth drink just 1 percent of the water they use every day.

Reuse and Recycle: The Environmental Control and Life Support System

If you can't bring a bunch of clean water to space from home, and you can't store the dirty water that's created after you use what little you have, what's the solution? Space agencies have gotten creative when it comes to finding every drop of water available on the ISS and turning it into drinking water. And it works!

The ISS recycles about 90 percent of its water, more than 3,785 liters (1,000 gallons) a year. The amazing piece of space technology that gets the job done is the Environmental Control and Life Support System—or ECLSS—which recovers water, revitalizes air, and generates oxygen. For now, let's look at how ECLSS recovers water.



The biggest water hog on Earth is agriculture, which accounts for about 70 percent of our freshwater use.

Recovery

STEP 1

The first step in recovering water is collecting it. Inside the ISS, water can be found in many places, if you know where to look. It is in an astronaut's breath when they exhale and in their sweat when they exercise. ECLSS collects those sources of water by working kind of like how a dehumidifier works in your home: water condenses on cool surfaces and is then collected. It can also be found in the hydration systems of the space suits astronauts wear—and, of course, in their pee.

On the ISS, the Universal Waste Management System, or UWMS—a fancy name for a toilet—uses a funnel connected to a suction hose to direct urine to a Urine Processor Assembly (UPA).

Purification

STEP 2

Once the urine is in the UPA, it is pretreated with powerful acids to reduce the buildup of chemical contaminants and control the growth of microorganisms and fungi. The water from the UPA is then combined with the other wastewater that's been recovered and is delivered to the Water Processor Assembly (WPA), which removes gas, hair, and lint before sending the water along to filtration beds for further purification. The final step is a reactor assembly that uses a high temperature and chemicals to remove any remaining contaminants and microorganisms. The mixture of calcium, salt, and other compounds removed from the water during purification is gathered into a bladder and stored, and then either discarded or returned to Earth to be studied. Just to be sure the water is pure, it is checked with special sensors, and any unacceptable water is sent back to be reprocessed.

Is 100 Percent Possible?

It's pretty amazing that 90 percent of the water on the ISS is recycled, but can that figure go higher? Is 100 percent possible? It's hard to imagine. Currently, black water (contaminated with human waste) and gray water (contaminated with bacteria) are discarded. But NASA and other space agencies around the world are working on finding solutions. Perhaps one day a truly "closed system" for water recycling—a system where absolutely nothing is wasted—will be available for use in space and on Earth.

Storage and Reuse

STEP 3

After a quick final check, the clean water is sent to a storage tank for the crew to use. Yesterday's wastewater—and pee—is now totally safe to use for bathing, brushing teeth, rehydrating food, or even drinking. No wonder astronauts sometimes joke that today's coffee will become tomorrow's coffee!

DR. DAVE'S LIVING IN SPACE

Soap, Shampoo, and a Vacuum?

Ask astronauts what they miss most about Earth when they are in space, and you might hear "a long, hot shower!"

About 50 years ago, the first NASA space station, called Skylab, had a shower—a long cylinder of water-resistant material that sealed at both ends when someone was inside. Astronauts could squirt several cups of water over their body using a handheld water dispenser and then lather up with soap. That's when things got complicated. Since there was no gravity to help direct the soapy water down a drain, a handheld vacuum was used to suck up that lather before toweling dry!

Skylab was the last space station to have a shower. My astronaut training included "toilet training" (yes, that's what they actually call it on the schedule!) and briefings on how to bathe with a wet towel and rinse-less shampoo. By the time I arrived in space, I knew how to stay clean without using much water. But after a few weeks, I was definitely dreaming about a real shower.

Space on Earth

Using as little water as possible. Recycling what is used. Being creative when it comes to finding sources. That's what happens on the ISS because astronauts know their water supply isn't limitless. Down here on Earth, we're also treating our water with care—and we're looking to space for new ideas.

Cleaning Up the Mess

In regions of the world where water is scarce, clean drinking water can be hard to find—and as we saw on page 13, drinking water that isn't clean can cause illness and death. In some places, the same type of purification technology used on the ISS is being used to help make sure everyone has access to clean water.

- In 2006, the nonprofit organization Concern for Kids learned about a well failure in northern Iraq. The village of Kendala had once been home to about 1,000 people, but with no access to drinking water, many moved away. The 150 or so who stayed were using contaminated water from a nearby creek. Working with the Water Security Corporation, Concern for Kids helped to install a water-filtration system based on NASA technology—and for the first time in two years, Kendala had clean, safe drinking water.

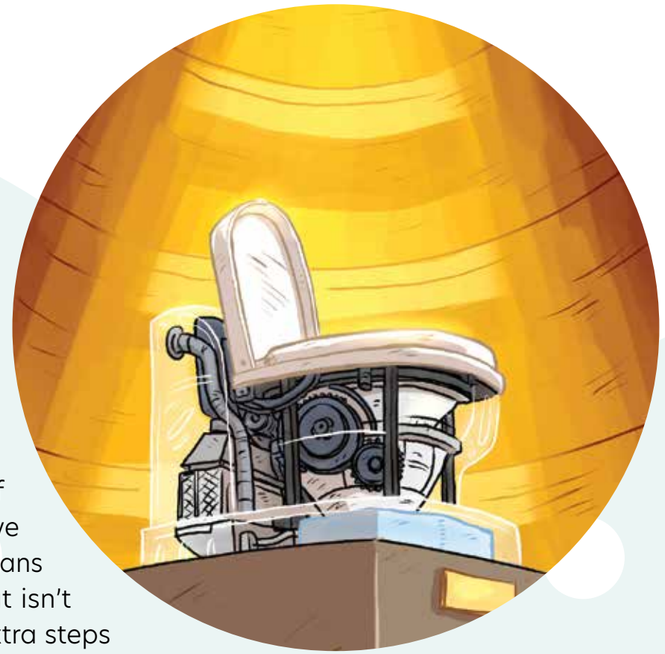
- In the rural community of Chiapas, Mexico, clean drinking water is hard to come by—and waterborne illnesses are common. In 2013, an ECLSS-style water-purification plant—powered by renewable solar energy—was installed. With clean water now available at the local school, fewer children are suffering from parasites and stomach bugs, and the whole community is healthier. There are economic advantages, too, as families don't need to buy as much purified water or medication to treat illnesses.

In Canada's Far North, one bed-and-breakfast owner in Iqaluit, Nunavut, took water recycling and purification to the next level. In 1999, Jens Steenberg installed a biofilter in his sewage tank. Like the system on the ISS, Steenberg's system was all about recycling and reusing, but his system put naturally occurring bacteria to work to get rid of solid waste. Once the solid waste was gone, the system filtered what was left, disinfected it with ozone, and sent the treated gray water back into the B&B's plumbing system, where Steenberg used it to wash clothes and flush toilets. In the Arctic, where both water and sewage treatment are expensive, a system like this could be a game changer; it cut Steenberg's water usage by 60 percent and drastically reduced the need for sewage pickup.

No Water Required

On the ISS, astronauts try to use as little water as possible. Even their toilets get the job done without a tank—which is a pretty big deal considering that the average toilet flushes about 30 percent of our at-home water use straight down the drain. Entrepreneurs are hard at work on developing a waterless toilet for the rest of us, too. Not only will the technology save water, but it may keep us from getting sick.

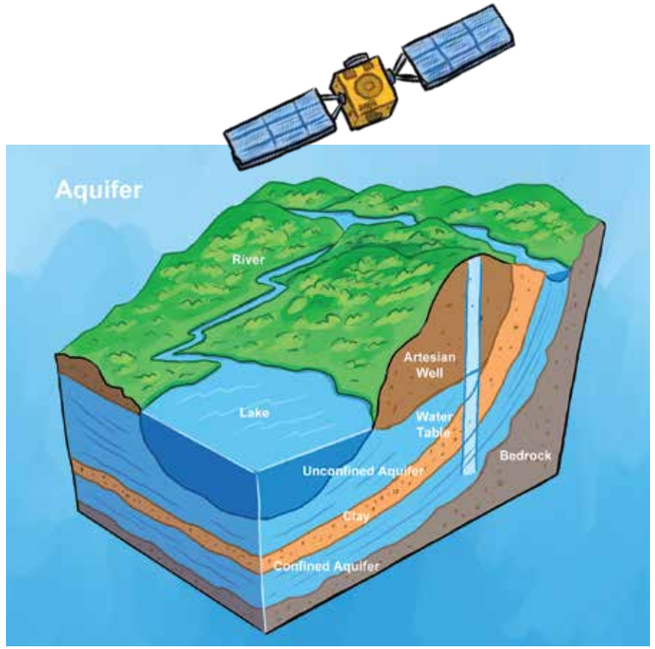
Microsoft founder Bill Gates is all-in on this idea. In 2018, he even hosted a "Reinvented Toilet Expo" to bring together people interested in creating toilets that don't rely on water and do remove the harmful parts of human waste—the bacteria and parasites that can make us so sick if they get into our water supply. There are lots of designs out there, but most involve a system that separates waste, cleans it, and stores it for disposal. That isn't ideal on the ISS, and it creates extra steps and energy use here on Earth, too. Luckily, more ideas are being developed every day.



In water-stressed Madagascar, for example, a very water-friendly toilet is already in use. Developed in England, the Loowatt toilet doesn't need water or a sewer system to work. A biodegradable bag simply stores waste under the toilet until it can be picked up and sent to a "biodigester," which turns it into liquid fertilizer, compost, or even electricity. Virginia Gardiner, whose company developed the Loowatt, believes the toilet can help other places like Madagascar where water and sanitation issues are common. But there's an opportunity for change elsewhere, too. In the United Kingdom, the Loowatt is available for rent to use during public events. Given how much water each flush takes, just imagine how much can be saved by not flushing at all.

Eyes in the Sky

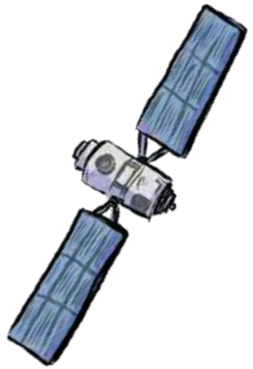
So far, we've learned a lot about how water conservation efforts on the ISS can inspire us to be even more water wise on Earth. But when it comes to taking care of this precious resource, Earth is getting a bit of extra help from space, too. Since 1957, when the Soviet Union launched Sputnik 1, thousands of satellites have been sent into space to gather information about Earth, its atmosphere, and outer space. In 2020, thousands of satellites were in orbit, helping us make phone calls, tune in to our favorite television shows, gather information about clouds or oceans or the polar ice caps, or measure gases in the atmosphere. Some are also helping with our water woes.



"Unconfined" aquifers sit beneath a layer of soil and can be reached by wells and pumps. "Confined" aquifers are trapped between solid layers of rock.

Scientists believe that aquifers—layers of rock or sediment that hold groundwater beneath Earth's surface—contain between 30 and 40 percent of all the liquid fresh water on Earth. And we don't hesitate to help ourselves to that hidden supply. Groundwater is often used to help water crops and supply nearby cities, especially in places that don't get enough rain. In California, for example, 38 percent of the state's water supply comes from aquifers. And in India, about 80 percent of the country's 1.35 billion people rely on groundwater for drinking and farming.

In 2002, NASA and the German Aerospace Center launched two satellites as part of the Gravity Recovery and Climate Experiment—or GRACE. Every 30 days, the satellites mapped Earth's gravity field, looking for changes that could provide information about polar ice sheets, ocean currents, Earth's interior, and the water cycle. As well as measuring changes in the water supply aboveground, GRACE sensed the levels of the water stored in aquifers. In 2015, a study at the University of California, Irvine, used GRACE data to warn that 21 of the world's 37 largest aquifers were being depleted or were in distress. That information can help governments make better decisions when it comes to managing water supply.



Satellites have been keeping their eyes on our water in other ways, too.

- Satellite data has been used to help find places where groundwater is close to the surface. Being able to dig a well with hand tools instead of a high-tech mechanical drill can make a huge difference in some places.

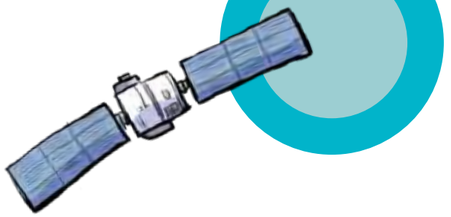
- Satellite data can help determine water quality by measuring the amount of algae present (algae feeds on sewage).

- Satellite data can be used to identify leaks in water supply systems, helping to make sure that not a drop is wasted.

With all those satellites orbiting Earth, who knows what else they'll be able to help us with in the future?

Spot the Satellite

While some satellites are too far above Earth's surface to be seen, others can be spotted in the night sky. On a clear night, find a place away from very bright lights—a backyard or a nearby park will do. Then, look up. The first thing you'll notice are the stars and then maybe an airplane or two. Planes have flashing or blinking lights and move along pretty quickly. Keep your eyes open for a small, steady light traveling slowly and steadily across the sky. Sometimes, they even travel in "trains," like the Starlink satellite network pictured below. It was launched by SpaceX in 2019 as part of a plan to beam the Internet to Earth from space.



Think Like an Astronaut

It could be a while before a waterless toilet makes its way to your house, but don't let that stop you: there are lots of ways you can "think like an astronaut" and make every drop count.

Turn Off the Tap

Do you leave the tap running when you brush your teeth? Turn it off instead. Letting the water run while you brush and rinse can waste 15 liters (4 gallons) of water. Multiply that by two (the average number of times a person brushes each day) and then by four (for an average-sized family), and you've got 120 liters (32 gallons) of water wasted in one house every single day. Keep an eye open for a leaky faucet, too: a faucet that drips just three times a minute wastes 1.6 liters (0.4 gallons) of water a day, or around 600 liters (160 gallons) a year. That's about three full rain barrels, just from one house!

Jump in the Shower

If you're a fan of long, hot baths, consider giving showers a chance. An efficient showerhead uses about 7.5 liters (2 gallons) of water each minute. This means that a 10-minute shower uses 75 liters (20 gallons) of water. By comparison, filling a bathtub uses about 185 liters (50 gallons). As long as you're not taking 25-minute showers, you'll be saving some water. You can also challenge yourself to shower like a sailor—on a sailboat, usable water is about as limited as it is in space. Use only enough water to wet yourself, turn off the water, soap up, and then turn the water back on to rinse off. Then feel good about caring for yourself and the planet.

Wait for a Full Load

If laundry is one of your household chores, here's a useful tip (and if it isn't, why not volunteer to help?): don't run the machine until you have a full load. Some washing machines use up to 70 liters (18.5 gallons) of water for each load of laundry. An average of five loads a week for a full year means 18,200 liters (4,800 gallons) of water, just to clean your clothes. Waiting until there are enough clothes to fill the machine can cut down on the number of loads—and the amount of water used. Energy-efficient washing machines can reduce that by 33 percent, saving about 6,000 liters (1,585 gallons) of water a year.

Drink Water Instead of Juice

This might seem like a strange tip for saving water, but check this out: it takes about 1,000 liters (265 gallons) of water to grow and produce 1 liter (1 quart) of orange juice, while it takes about 1,140 liters (250 gallons) to produce the same amount of apple juice. So, next time you're thirsty, why not reach for a tall, cool glass of plain water. It's good for you and good for the environment.

Put Rain to Good Use

Instead of using tap water for the lawn and garden, go with nature's choice—rainwater. A rain barrel, or even an old bucket or two, in your yard or on your balcony will catch water when it rains. Then, when the weather is dry, you can use that water to keep plants healthy. Depending on where you live, you could save about 5,000 liters (1,100 gallons) of tap water.

EXPERIMENTING WITH DR. DAVE

Build Your Own Water Purifier

You've learned about water purification on the ISS and seen how the technology is making a difference in water-stressed areas around the world. Building a simple solar distiller can show you one type of water purification in action.

You'll need:

- two identical plastic bottles with plastic caps (500 mL/16 oz. or 1 L/1 qt. work best)
- a hand drill with a 1/4" (about 5 mm) or similar-size drill bit, and an adult who can operate it
- hot glue or duct tape
- salt
- food coloring (or if you have some used-up markers, use the felt inside the markers to color the water)
- a brick, piece of wood, or emply box
- a black garbage bag (optional)

1. Stand the two bottles upright and make sure the caps are screwed on tight.

2. Poke a hole through each cap (ask an adult for help with the drill) so there will be an opening between the two bottles when they are connected.

3. Glue or tape the tops of the caps together so the two bottles can be attached end to end.

4. Remove the caps from the bottles. Fill one bottle about half full with water. Add 4 drops of foodcoloring and a tablespoon of salt to represent contaminants in the water.

5. Attach the caps to that bottle, and then screw the empty bottle on top of the other cap.

6. Go outside on a sunny day. Place a brick, a piece of wood, or an empty box on a table or the ground and use it to raise the empty end of the bottles at an angle with the partially full bottle resting on the ground.

7. Over time*, the water in the lower bottle will evaporate and condense in the upper bottle as clear, fresh water. If you were to have this water tested, chances are it would be clean enough to drink.

* It may take a while to collect the water. Try covering the bottle with the colored water with a black garbage bag to see if it speeds up the process.

building up in Earth's atmosphere—and getting up to no good. By trapping heat relatively close to Earth's surface, they act as the main contributors to climate change. Think extreme temperatures, rising sea levels or drought, damage to ecosystems and food supplies, and a whole bunch of other problems that have dire consequences for the well-being of the planet and all that call it home.

It can be hard to think about air as something we need to protect. Like with the water we talked about in chapter 1, it can sometimes seem as if we have an endless supply. But there's no doubt that Earth's air pollution problem is real—and really dangerous. Air may be all around us, but we have to do our part to keep it clean. Miles above Earth, astronauts on the ISS have been coming up with inspiring ways to do that for decades.

BREAKING IT DOWN

91 PERCENT **of the world's population live in places where air quality guidelines are not met.**

93 PERCENT **of the world's children under the age of 15—about 1.8 billion kids—are at risk for poor health and development because of poor air quality.**

INDOOR AIR POLLUTION**—from cooking fires, for example—can be more harmful than pollution outside.**

THE CITY WITH THE WORST AIR POLLUTION **in the United States is Los Angeles, California; in Canada, it's Windsor, Ontario.**

AS OF JULY 2021, **the amount of CO_2 in the air was the highest it's ever been, and the seven warmest years on record since 1880 have all occurred since 2014.**

Look Up for Inspiration

For astronauts living or traveling in space, a constant supply of air is just as important as it is to us on Earth. And while making sure the air is fresh and clean is a big challenge, an even bigger one is making sure there's air at all.

No Air Up There

Earth has air because it has an atmosphere—a layer of gases that protects life and helps it to survive. But the farther you get from the planet, the thinner that atmosphere gets. That's because the gravity that keeps us all from floating off into space loses its power to hold together the gas molecules that make up our air. Travel 10,000 kilometers (6,214 miles) away from Earth's surface, and those molecules are so far apart that "air" as we know it no longer exists. You're officially in the "exosphere," or what's often called the "vacuum" of space. For humans to live inside a spacecraft or the space station, the air inside must be created, monitored, and replenished. Any glitch in the system and lives are at risk.

How to Breath with No Air: Air Supply on the ISS

The International Space Station gets some of the oxygen on board from Earth. Astronauts bring it with them when they travel to the ISS for a mission, and it also arrives on cargo ships. But it's not enough. If the crews aboard the ISS relied only on oxygen sent from Earth, they'd run out—and that would be bad news. To prevent a shortage of safe, breathable air, the ISS needs to recycle.

Back in chapter 1, we saw how the Environmental Control and Life Support System (ECLSS) helped to supply clean drinking water on the ISS by recycling water from other sources. Another big

part of the system's job is to recycle and supply air. An important part of ECLSS is the Oxygen Generation System, which produces oxygen for the crew to breathe by using a process called electrolysis. It works like this:

1

ECLSS's Water Recovery System grabs water from the air, from condensation, and from astronauts' urine.

2

An electrical current is run through the water molecules—which contain two hydrogen atoms and one oxygen atom. The current forces the atoms to split, separating the oxygen from the hydrogen.

H_2 [molecular structure of hydrogen] + CO_2 [molecular structure of carbon dioxide] = H_20 [molecular structure of water]

3 **The leftover hydrogen is combined with the CO_2 that the astronauts produce when they breathe. The process creates much-needed water and removes excess CO_2 from the air (too much can make us sick). However, it also produces methane, which is not needed on the ISS and can also make us sick. The methane is sent out into space through vents.**

Clean Sweep

In 1970, the Apollo 13 crew found themselves in a life-threatening situation. An oxygen tank exploded in the spacecraft's command module, forcing the three astronauts to move into the much smaller lunar module for the trip home. Once there, a new problem quickly popped up: dangerous levels of CO_2 in the air. Relying on their training and the materials at hand, the astronauts created a filtration system using duct tape, plastic bags, and a tube sock. The Apollo 13 story has a happy ending—everyone made it home safe and sound—but it shows just how important clean air is to life.

In addition to creating some of the air that astronauts aboard the ISS breathe, the Environmental Control and Life Support System also contains the filtration and treatment technology needed to keep that air clean and safe. It includes a system that filters excess carbon dioxide, another system that removes contaminants, and yet *another* system that monitors the levels of the different gases in the air. That's a lot of technology hard at work!

An International Effort

Creating breathable air in space takes cooperation, just like it does on Earth. In the United States, NASA developed the Oxygen Generation System that's currently at work on the ISS. Meanwhile, the European Space Agency has developed a system that converts carbon dioxide into oxygen and water. It can generate about 50 percent of the water needed for oxygen production on the space station and was sent to space on Japan's HTV-7 spacecraft in 2018. The Russian-built Elektron-VM also uses electrolysis to produce oxygen. These systems, and others that are being developed around the world, will be a huge part of life in space as humans go farther and farther from Earth.

Is it possible that there's a less high-tech solution to the problem? On Earth, nature has created its own ECLSS. Forests and plants remove carbon dioxide from the air, create oxygen, and also help to remove contaminants. NASA has been studying the air-purification benefits of plants for decades now, so it's possible that one day plant power will be used on the ISS to help keep the air clean.

Crew members from the USS Iwo Jima recovery ship hoist aboard the Command Module from Apollo 13.

Look Out for Leaks!

A big part of any recycling or sustainability plan is avoiding waste. The ISS crew tries to make sure that as much carefully created and cleaned air stays on board as possible, but it's not always easy. The stuff keeps escaping! Every time the astronauts perform a spacewalk, 9 cubic meters (300 cubic feet) of air is released into space through the airlock. To picture what that looks like, imagine a cylindrical room that's about 1.5 meters (5 feet) in diameter, with a ceiling that is 3 meters (10 feet) high. It's probably bigger than your closet, but not quite as big as your bedroom. Now, imagine all of the air being sucked out of that room and replaced, every time you come in and out. That's a pretty big "leak," but smaller ones happen, too.

Back in 2019, the crew aboard the ISS realized they had a small leak. At the time, it was responsible for the loss of about 0.27 kilograms (0.6 pounds) of air per day—which didn't have anyone too worried. By mid-2020, though, the leak had gotten bigger. Now, 1.4 kilograms (3.1 pounds) of air were escaping, and it was definitely time to fix the problem. But how do you find a small leak on a big space station? You put microgravity to work! The crew released tea leaves into the module where they suspected the leak to be and waited to see where they went. When the leaves began to cluster around a scratch in the wall near some communications equipment, the mystery was solved!