Serendipity and the Space Farmer

A Story of NASA, Fast Plants, and the Ukraine

Written by Douglas Niles and Hedi Baxter Lauffer

Based on firsthand knowledge and experiences recalled by Paul and Coe Williams and Dan Lauffer.

Dedicated to Dr. Mary Musgrave

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BY NOVEMBER OF 1997, the launch of a space shuttle from the Kennedy Space Center on Cape Canaveral, Florida, had become almost routine, barely worthy of the national news. The four reusable spaceships made regular trips into low Earth orbit, many times each year. By then, the disastrous explosion following *Challenger*'s launch—which had destroyed the shuttle and claimed the lives of all seven astronauts aboard—lay almost 12 years in the past. The shuttle *Columbia*, poised to blast off on November 16, 1997, would be making its 24th trip into space, and the third of this year alone.

Still, there was nothing "routine" about the experience of the several hundred people gathered on the stands of the VIP observation post that sunny afternoon: instead, they were here for a once-in-a-lifetime experience, all eyes on launch pad 39, just a few miles away. The sun-dappled waters of Cape Canaveral's shallow wetlands brightened a wide stretch of the view, just a stone's throw in front of the bleachers. Some in the audience, including a good representation of middle and high school students, glanced at that sparkling surface, knowing that alligators and manatees dwelled there. But always their attention, like that of the rest of the crowd, returned to the looming form of *Columbia*, poised vertically on the pad, still shackled to the tower before the launch.

A large digital clock, brightly illuminated, showed the minutes and seconds until liftoff. For a time it had paused at T minus 9 minutes, as controllers on the ground conducted their final pre-launch checks. The space shuttle was a marvelously complex piece of engineering, and multiple computers checked and double-checked each system, setting, and procedure before the scientists and engineers could move forward. Finally the countdown started again, measuring the seconds, each tick of the clock increasing the anticipation and excitement among those gathered to watch.

Aboard Columbia, six astronauts waited for the explosive thrust that would catapult them into space. That crew included four Americans—Mission Commander Kevin Kregel, Pilot Steven Lindsey, and Mission Specialists Kalpana Chawla and Winston Scott—as well as a Japanese Mission Specialist, Takao Doi, and Payload Specialist

The clock at Kennedy Space Center.

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Mission Commander Kevin Kregel, Pilot Steven Lindsey, and Mission Specialists Kalpana Chawla and Winston Scott—as well as a Japanese Mission Specialist, Takao Doi, and Payload Specialist Colonel Leonid Kadenyuk of the National Space Agency of Ukraine (NSAU).

Colonel Leonid Kadenyuk of the National Space Agency of Ukraine (NSAU.) Kadenyuk, an engineer, botanist, and expert on plant-based experiments, had followed a long road fraught with chaotic global politics to win his seat. He was about to become the first Ukrainian to fly in space—and he would fly there on an American space ship.

Today the crowd gathered to watch the launch included a notable VIP: Leonid Kuchma, the President of the relatively young Republic of Ukraine. Nine of the high schoolers present were Ukrainians, science students who had won national awards. Ukraine is a country that values agriculture, and many of these students studied biology and botany, and had performed experiments and created projects for their nation's many science fairs. A select group of those young scientists had been rewarded with this trip to Florida, a chance to meet their president, and front row seats for the most important space flight in Ukrainian history. Other teachers had brought their science students from around the USA, including a group of New Jersey, and another from the Indiana School for the Blind, and many from Florida. All of those young people had an actual practical interest in one of the projects aboard *Columbia*.

Ukrainian President Leonid Kuchma.

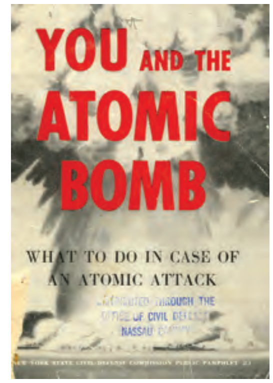
And seated with those young scientists were the "Father of Fast Plants," Dr. Paul Williams, and his colleague, Dan Lauffer. Why were they here? And what did Wisconsin Fast Plants have to do with the Republic of Ukraine and NASA?

The answer makes an interesting tale of science, engineering, and serendipity.

Engineering the Shuttle: Humanity's First True Spaceship

The question "What's up there?" has been tugging at human imaginations since our earliest ancestors applied mythological explanations for the constellations of stars in the night sky, wondered at the phases of the moon, observed the steady rhythm of sunrise and sunset. Thousands of years ago brilliant thinkers had already determined that stars, more or less fixed in the heavens, were different from the planets that, though they looked like stars, seemed to wander through space. Over centuries and millennia, people began to understand and predict those planetary paths. Along the way, in various parts of the world, some bold scientific-thinkers—often persecuted as heretics—postulated that the Earth might actually orbit the sun, instead of the other way around.

Yet until the late 1950s, scientists were limited to observations made from Earth and could only speculate about the space beyond our atmosphere. Designing the technology solutions for the challenges of space travel would be *very* costly. However, science and engineering occur in the context of society, and political and social priorities play an important role in determining what research receives funding. In the 1950s, the political world was essentially divided into two great factions locked in a dangerous Cold War. Led respectively by the United States and the Union of Soviet Socialist Republics (USSR) both of these advanced technological societies began to launch rockets capable of reaching beyond the thin shell of atmosphere enwrapping our planet. The first of these probes carried some simple instruments, with the Soviets in 1957 even sending a dog, Laika, on a one-way mission during which they monitored the unfortunate animal's vital signs. They determined that mammals could survive the stress of a launch, and exist for a time in a zero gravity environment.



1950s pamphlet.

Alarmed by Soviet progress, United States President Dwight Eisenhower created the National Aeronautics and Space Agency (NASA) in 1958, and charged it with leading the country's space program. By the early 1960s, both the US and the Soviets were sending men into space. Some of the best engineers in the world worked on the tremendously complicated rocket systems that not only had to fly on controlled courses, but needed to include enough safety and life support capability to keep their human passengers alive and carry them safely back to Earth. In America these "astronauts" rode in tiny capsules mounted atop rockets; three successive programs sent one (Mercury) two (Gemini) and eventually three men (Apollo) at a time into space.

The Apollo program relied on the huge, and very expensive, Saturn rocket to lift heavy payloads into orbit; it would achieve ultimate triumph with the landing of the first men on the moon in 1969. After several moon landings, and the dramatic aborted moon voyage and miraculous rescue of Apollo 13's three-man crew, the program was phased out during the mid 1970s. Significantly, the final Apollo mission, in

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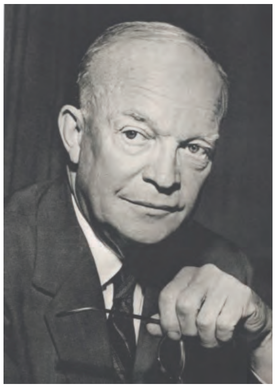
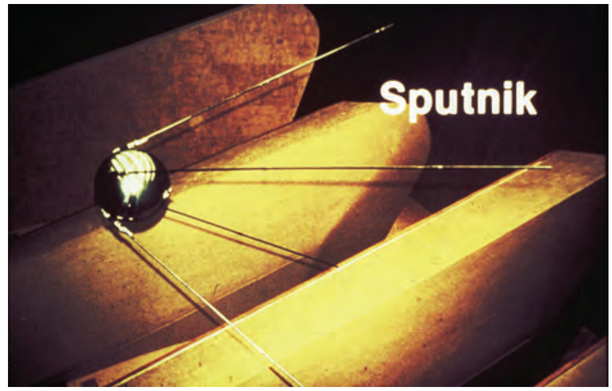
1958: The Sputnik Era



United States President Dwight Eisenhower.



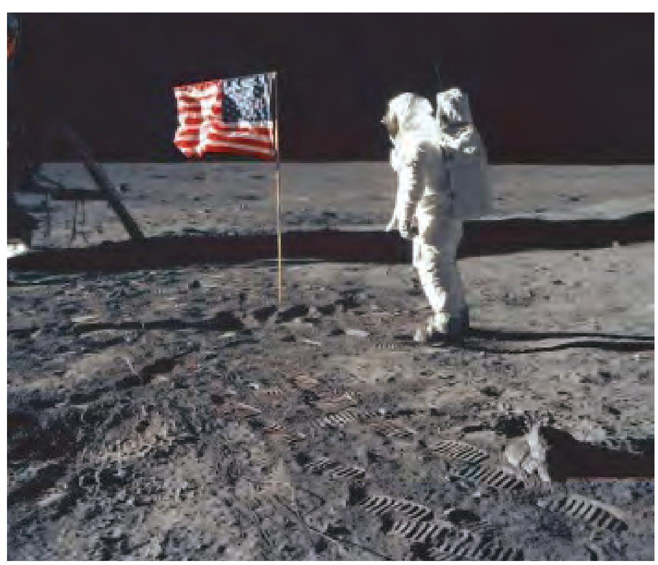
Sputnik: world's first artificial satellite, launched by the Soviet Union in 1957.

1975, involved the American capsule linking up with a Soviet Soyuz capsule in space, allowing American astronauts and Soviet "cosmonauts" to pass back and forth between their ships. It was a very early symbol of the increasing international cooperation that would continue as humans ventured farther, and more frequently, into space.

Flying to the moon and back had been a significant engineering accomplishment, but it was very expensive and mainly symbolic; there was little scientific value to simply repeating the same mission over and over, and everything from the huge rocket to the Apollo capsule to the lunar lander could be used only once and was then discarded. The real future of the space program, NASA scientists realized, would be in conducting operations, especially science experiments, in the near vacuum microgravity of space. These operations required not merely a capsule that could go up and come down, but an actual, steerable vessel that could be maneuvered through space, and would be capable of reentering the

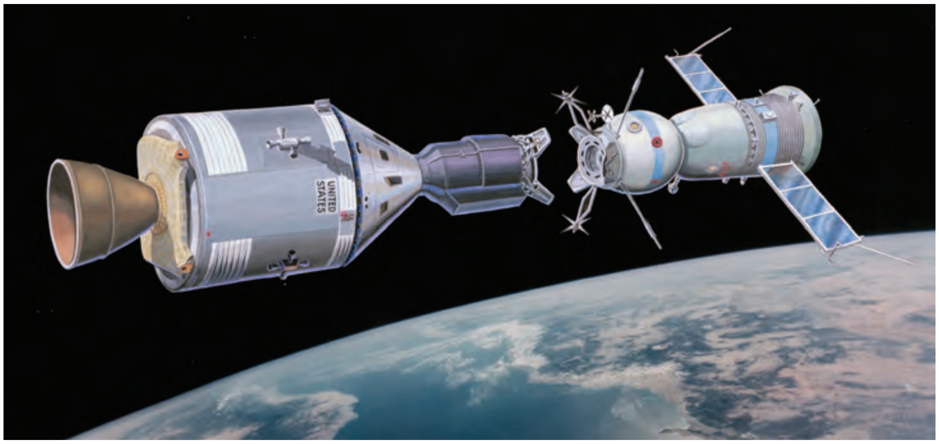
1960s: Both US and Soviets send men into space

1961: Yuri Gagarin is the first human in space.



1969: Neil Armstrong and Buzz Aldrin take first steps on the moon.

1975, Final Mission, American capsule links with Soviet Soyuz capsule.



atmosphere to be controlled like an airplane—a glider, actually—so that it could safely land on a runway and, ideally, be used again. It would have to be engineered with enough life support capacity to allow as many as eight astronauts to survive for more than two weeks, and it would have to be strong and fireproof enough to withstand the tremendous heat and force generated by a reentry into the Earth's atmosphere.

The answer to these requirements was the space shuttle, the world's first reusable spacecraft. The first space shuttle was a prototype, designed so that engineers could test the ship's capabilities in flying through the atmosphere. It was named *Enterprise*, both to honor a series of proud United States Navy vessels, and as a popular culture nod to the iconic starship in the *Star Trek* television series. *Enterprise* flew several times in 1977, riding into the air by piggybacking onto a huge, specially modified Boeing 747 called the Shuttle Carrier Aircraft.

The shuttle was engineered very differently than the straight-up rockets of the early space launches. The shuttle vehicle itself was strapped to a huge external fuel tank, and two additional rocket boosters were strapped to the sides of the tank. The boosters, and the shuttle, were to be reusable; only the big fuel tank would be a one-use component. By 1981, the first operational shuttles were ready to launch, and *Columbia* had the honor of making the program's first flight into space on April 12, 1981—which happened to be the 20th anniversary of the first manned space flight, made by Soviet cosmonaut Yuri Gagarin. Three other shuttles, *Discovery*, *Challenger*, and *Atlantis*, followed in short order.

During the early and middle 1980s, shuttles flew frequent missions, allowing astronauts to perform an unprecedented number of experiments

1981: Four shuttles are operational—*Columbia, Discovery, Challenger* and *Atlantis*.

Space shuttle launch.

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Teacher-in-Space payload specialist Christa McAuliffe.

in the microgravity environment of the large cargo bay. The shuttle was used to launch not just astronauts, but satellites and the components for the first space stations, serving essentially as a truck "delivering" these complicated devices to space. Even early in the program, the space shuttle also had an important education component. In 1985 a courageous teacher, Christa McAuliffe, was selected from among many applicants and trained as an astronaut so that she could conduct lessons to children across America from the lofty heights of space.

Challenger, carrying McAuliffe and six other astronauts, launched on January 28, 1986 as the 51st shuttle mission, known as STS-51. Seventy-three seconds into the flight, a tremendous explosion completely destroyed the shuttle and killed all seven astronauts. The space shuttle program was suspended for 32 months as investigators sought to figure out what had happened. Eventually they determined that a connection in the shell of one of the rocket boosters had cracked, probably because it was unusually cold in Florida that morning, causing a fiery leak that had ignited the volatile fuel in the huge external tank, resulting in the catastrophic explosion.

Scientists and engineers poured over all the evidence they could gather—from weather data to video and launch records—to design a solution for housing the solid rocket boosters that would make the shuttle safe again. In September 1988, their solution was put to the ultimate test when the shuttle program resumed and *Discovery* was launched with newly engineered rocket boosters. All went as designed, and with this engineering success, NASA commissioned the construction of *Endeavor* to replace the lost shuttle. By the 1990s the shuttle program was again humming along, with *Columbia* becoming a reliable workhorse of the small fleet, flying 21 missions by the end of 1996, and two more in early 1997.

The Challenger crew: Back row (L-R): Ellison Onizuka, Christa McAuliffe, Gregory Jarvis, Judith Resnik.
Front row (L-R): Michael J. Smith, Francis "Dick" Scobee, Ronald McNair

Engineering a Solution for Kraut

Williams engineered a tool, a model organism, as part of his solution.

Mention the practices of *engineering,* and rockets, bridges, cars, or other mechanical accomplishments typically come to mind. Chances are that *sauerkraut* would not make it to anyone's list of engineering accomplishments. Yet, while rocket scientists were engineering the technology that transported men to the moon, other scientists—biologists and plant pathologists—at the University of Wisconsin-Madison were equally committed to solving the serious problems faced by Wisconsin cabbage farmers, whose crops were suffering from a devastating blight. Although saving 100,000 tons of sauerkraut might not *seem* as important as putting the first man on the moon, for the scientists engaged in cabbage research and the farmers whose families depended on those cabbage crops, it was.

Dr. Paul Williams was one of those scientists with a passion for understanding the natural world and a gift for engineering solutions to plant diseases. In 1962, he joined the faculty at UW-Madison and began seeking a way to create disease-resistant cabbage varieties. If Williams had simply *discovered* a variety of cabbage that resisted the blight, this part of the story would end without mention of engineering. But no such cabbage variety existed.

So, Williams began collecting seeds for relatives of cabbage—other *Brassicas* like turnips and bok choy—from around the world in hopes of finding disease resistance that he could breed into an existing cabbage line. However, testing for disease resistance required Williams to grow hundreds or thousands of *Brassicas* through their entire life cycle over and over. This process needed

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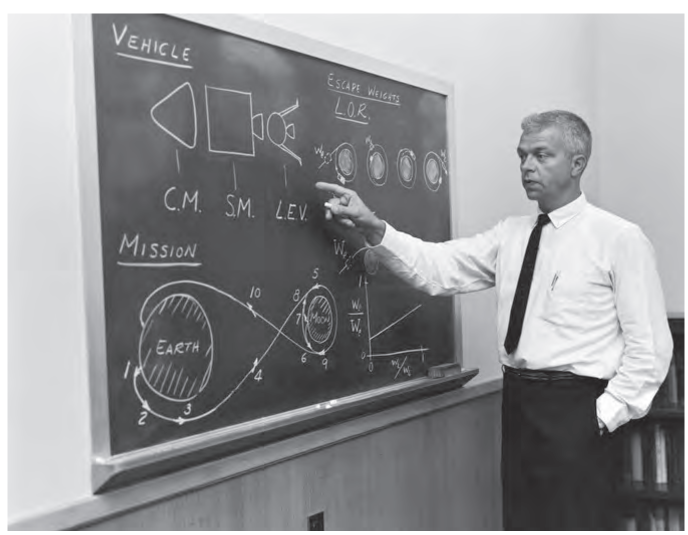
How are rocket scientists like sauerkraut engineers?

Cabbage farmer Chiyeko Suzumoto in Gardena (California).



John Houbolt explains the weight-saving advantage of the Lunar Orbit Rendezvous for the Apollo program.

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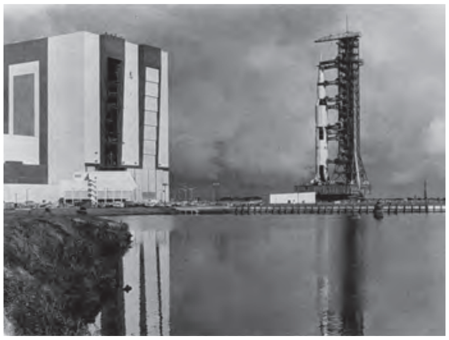
Scientists and engineers working to understand and solve big challenges



NASA

UW-MADISON

lots of space and took a very long time since most *Brassicas*, including cabbage, have at least a six-month-long life cycle. To help the farmers quickly enough to save their livelihoods, Williams needed a solution to a complicated research problem: he needed a new plant that was a close enough relative to cabbage that he could test it for disease resistance and interbreed it with cabbage; *and* he needed it to grow and complete its life cycle quickly without taking up much space.

Growing thousands of *Brassicas* from around the world, Williams noticed that a few went straight to flower without producing whatever food they were bred to produce. He quickly realized that he could use those early-flowering plants to *engineer* a new *Brassica* that met his criteria for a solution to his research needs. Williams inter-mated the few fastest-flowering *Brassicas* that he discovered and collected their seeds; then he chose their fastest flowering offspring and repeated that breeding program over and over. In addition, he began selecting for traits that matched the other criteria for the ideal solution: small size, able to grow with minimal space, quick to produce seed. Eventually, he selected only those plants that could thrive in the temperatures of his laboratory

UW-Madison cabbage researcher, J.C. Walker, working with Wisconsin farmers to find solutions (1957).

under fluorescent lights so he could keep close watch over his plants at all times.

And that is how the rapid-cycling *Brassica* that is now known as Wisconsin Fast Plants® came to be. Using the same scientific and engineering principles used to design and build a space shuttle, Williams created a specialized tool that could help him accomplish his goals. While the shuttle carried scientists into space where they could investigate gravity and the universe, Williams' Fast Plants enabled him to more efficiently investigate cabbage and blight resistance. At that time, no one imagined that these two unique engineering feats might one day cross paths.

A Nation Seeks a Future, and a Botanist Seeks a Spaceship

Five thousand miles away from the kraut fields of Wisconsin and the shuttle's launch pad in Florida, a country on the eastern edge of the European continent was in 1990 just beginning to experience independence. That country, called

World map with the country of Ukraine and states of Wisconsin and Florida, U.S.A. in blue.

Ukraine, is a flat and fertile land adjacent to Russia and occupying an important position on the north and northwestern shores of the Black Sea. It was blessed by a reasonably mild climate, plenty of water, and excellent soil for growing plants. Since the dawn of civilization it had been known as a regional "breadbasket"—that is, a great source of food and agricultural fullness for itself and many of its neighbors. Human habitation there goes back many thousands of years, and in fact many

Ukraine: "Breadbasket of Europe"

Ukrainian wheat field.

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scholars believe that Ukraine is the place where our ancestors first domesticated the horse.

By a thousand years after the start of the Common Era, Ukraine was one of the most powerful nations in Europe, and the wonders of its capital city, Kiev, were the envy of all who saw it. However, the same factors that made Ukraine so desirable to its own people also made it very desirable to other peoples; and its flat and fertile plains did not offer protective barriers, such as mountains and deserts, that could stand in the way of invaders.

Potsdamer Platz crossing opened days after the fall of the Berlin Wall (Nov. 1989). "891121c berlin potsdamer platz" by Frits Wiarda - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons.

Beginning shortly after 1100, C.E., Ukraine was swept by multiple waves of conquerors. First the Mongols came from the Asian steppes, scourging the land and utterly destroying the fabulous city of Kiev. Later, European neighbors as diverse as Poland, Lithuania, Austria and Rumania claimed and conquered sections of the country, plundering its wealth and subjugating the Ukrainian people. All the while, huge, powerful Russia loomed as the greatest threat, as the czars who ruled from Moscow regularly snatched up portions of the fertile Ukrainian landscape.

The Russian revolution in 1917 brought an end to the Russian empire, but within four years that power had been replaced by the communist Soviet Union, which aggressively consolidated its control from Siberia in the Far East to the vast breadbasket along the shore of the Black Sea. Though the Ukrainian Soviet Socialist Republic and the Russian Soviet Socialist Republic sound like equal states, there could be no mistaking the fact that the Russians controlled the entire USSR from their seat of power in Moscow where, like the czars, they ruled from the great palace known as the Kremlin. By the 1930s Ukraine was again reduced to a puppet state, subject to famine and cruelty at the whims of the brutal Soviet dictator, Josef Stalin.

When the Nazis invaded the Soviet Union in 1941, Ukraine—right between Russia and Germany—was one of the first areas subjugated by the attackers. In the initial weeks of the occupation, some Ukrainians actually looked to the Germans with hope, believing that they might serve to liberate the country from the Soviet yoke. Nazi brutality quickly proved even worse than Russian, however, and hundreds of thousands of Ukrainian soldiers fought with great valor as part of the huge Soviet military machine. After the war ended with the utter destruction of Germany in 1945, however, the Soviet Union's epicenter of power became even more focused within Russian Moscow. Stalin would retain his dictatorship well into the 1950s, and a succession of aging bureaucrats would cling to power for most of the rest of the Twentieth Century.

Until, in 1989, the long-divided residents of Germany's Berlin tore down the communist-built Wall that split their city. This act of defiance kindled an explosion of freedom across the USSR, and by 1990 the shell of Soviet power was proven hollow as country after country of the former empire declared independence. Along with Poles, East Germans, Hungarians, Rumanians, and many others, joyous Ukrainians celebrated their freedom, and their new status as an independent

Leonid Kadenyuk

Leonid Kadenyuk.

Leonid Kadenyuk pollinating.

country—though they would remain ever mindful of the powerful Russian bear lurking, as always, just to the north and the east.

Meanwhile, against the backdrop of the Cold War and the fading of the Soviet communist system, a remarkable Ukrainian grew up, was educated, and came of age as a pilot, scientist, and cosmonaut. Leonid Kadenyuk was born in 1951, in a small town in the Bukovnia region of western Ukraine, near the Rumanian border. His father was a teacher, and young Leonid was no slouch in school—by 1967 he had been accepted into Ukraine's premier aviation academy, graduating in 1971 as an accredited pilot and engineer.

Soviet mobile missile launcher.

In 1976 Kadenyuk was approved for cosmonaut training, and traveled to Moscow where he studied at the Yuri Gagarin Cosmonaut Training Center. In 1977 he qualified as a military pilot, and as a Test Pilot, Second Class, after proving he could fly several dozen types of aircraft. By 1978 he had completed general space training at the Gagarin Center, where he also studied biology and botany, and was trained to perform scientific tests, research, and experiments on plants, whether on the ground or in flight.

For the next ten years he continued his education and training, becoming one of the Ukraine's best pilots and most accomplished scientists. He learned to fly the Soviets' advanced fighter jets, as well as to pilot the space capsules for the Soyuz program and the experimental "Buran" reentry vehicle. He also did work in simulated weightlessness conditions and became an expert skydiver. By 1988 he was a Test Pilot,

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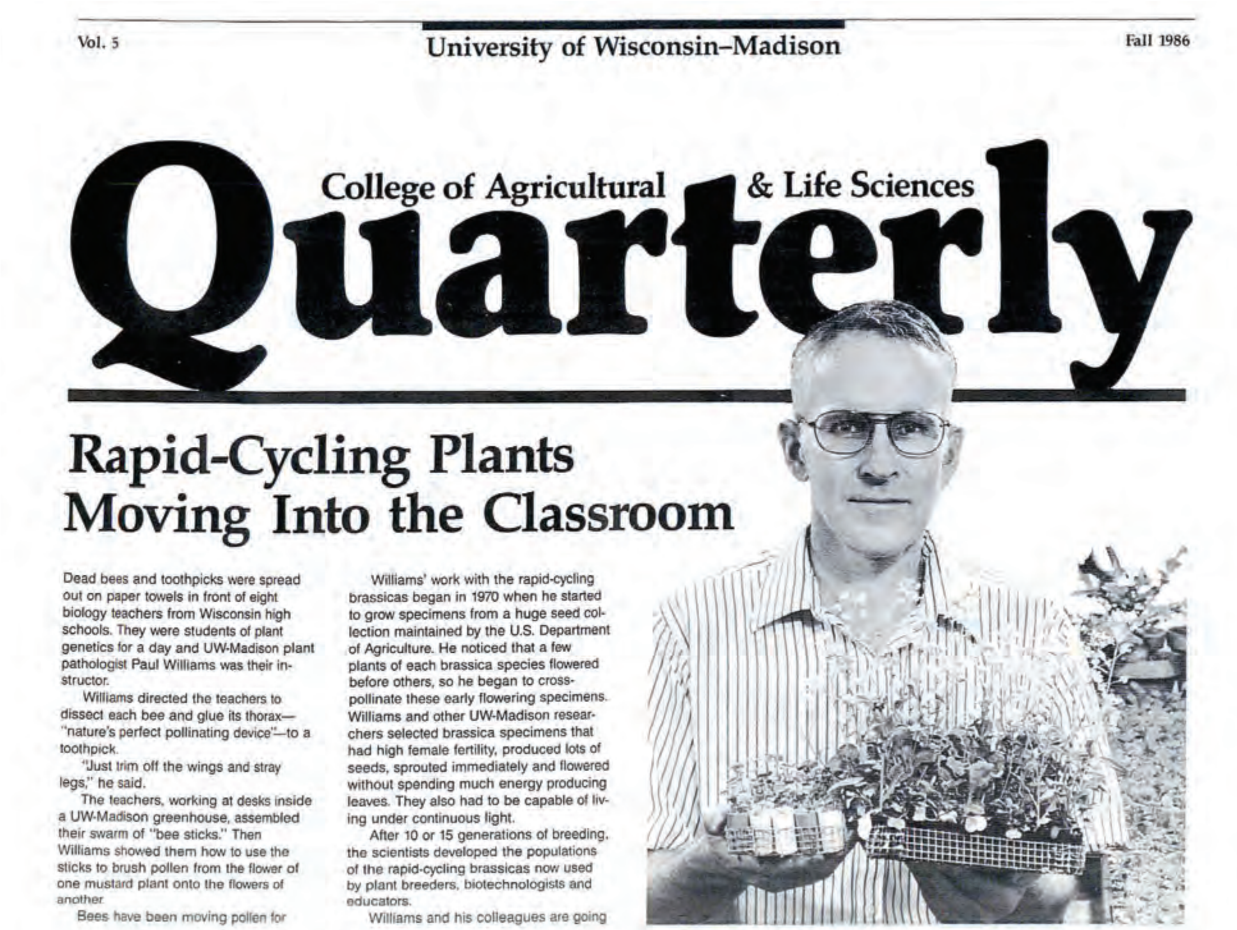
First Class, and had even engineered significant details of the cockpit design for the Soviet's most modern fighter jets.

Following Ukrainian independence in 1990, many Ukrainians working for the Russians decided to return home. Leonid Kuchma, for example, was a high-ranking military officer, overseeing the Soviet Unions mobile rocket launchers—hugely destructive weapons that would only be used in a nuclear war. He left this post to return to Kiev, where he was soon elected as Ukraine's first president.

Leonid Kadenyuk, however, still hoped to fly into space, so he elected to retain his Russian citizenship so that he could continue in the cosmonaut program. He was quickly appointed to command a crew of Ukrainian cosmonauts, but—as Ukrainian/Russian tensions continued to simmer—for the next five years this would-be space explorer would remain an astronaut without a rocket.

Fast Plants Fly!

Like Leo Kadenyuk, Paul Williams never stopped learning and pursuing his interests. In 1985, Williams worked with researchers and industry partners from around the world who studied Crucifers (the larger group of plants that include Brassicas) to create a germ plasm collection called the *Crucifer Genetics Cooperative*. In addition to using Fast Plants as a tool—or model organism—for research, Williams' started the Wisconsin Fast Plants Program and quickly found a home for his rapid-cycling *Brassicas* in school and college classrooms at all grade levels. All of the traits Williams had selected for his research turned out to be ideal for education, since students could observe the entire life cycle of a flowering plant,



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Quarterly

Rapid-Cycling Plants Moving Into the Classroom

Dead bees and toothpicks were spread out on paper towels in front of eight biology teachers from Wisconsin high schools. They were students of plant genetics for a day and UW-Madison plant pathologist Paul Williams was their instructor.

Williams directed the teachers to dissect each bee and glue its thorax—"nature's perfect pollinating device"—to a toothpick.

"Just trim off the wings and stray legs," he said.

The teachers, working at desks inside a UW-Madison greenhouse, assembled their swarm of "bee sticks." Then Williams showed them how to use the sticks to brush pollen from the flower of one mustard plant onto the flowers of another.

Bees have been moving pollen for

Williams' work with the rapid-cycling brassicas began in 1970 when he started to grow specimens from a huge seed collection maintained by the U.S. Department of Agriculture. He noticed that a few plants of each brassica species flowered before others, so he began to cross-pollinate these early flowering specimens. Williams and other UW-Madison researchers selected brassica specimens that had high female fertility, produced lots of seeds, sprouted immediately and flowered without spending much energy producing leaves. They also had to be capable of living under continuous light.

After 10 or 15 generations of breeding, the scientists developed the populations of the rapid-cycling brassicas now used by plant breeders, biotechnologists and educators.

Williams and his colleagues are going

The Fast Plants team in 1990s at the University of Wisconsin-Madison included (left to right) Coe Williams, Paul Williams, and Dan Lauffer.

growing from a seed to a plant that produced seeds, in just over a month. Williams' research and interest in education, and the success of Fast Plants as a classroom tool, began attracting national attention.

By the 1990s, Williams was an acclaimed scientist, flying regularly to Washington DC and serving on a variety of national panels. Still his passion for plants continued, so much so that he brought Fast Plants with him and regularly broke up the usual protocol of meetings. When things slowed down (or "got boring" as he puts it) he would pull the plants out from under his chair, produce a bee-stick for pollinating, and have his colleagues spend a little time helping to pollinate the plants. When the group met again a few months later, he would bring along the next generation of Fast Plants, continuing the process and involving his fellow scientists in his work over the course of several years. Just as the sunny-yellow Fast Plant flowers captivated school children, educational and national leaders of all sorts found themselves enthralled with Williams' plants.

Williams transported his "Washington Shuttle Stock" Fast Plants in cake carriers and make-up cases.

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NASA's plant research

Tibbets, was awarded a grant to research and construct growing systems that NASA might someday use to grow potatoes in space.

But Earth-based experiments could not replicate the microgravity of space.

And the plants they were researching typically required too long to grow for conducting experiments during limited missions. Enter, serendipity: one sunny day Dr. Williams met Dr. Tibbets on a Madison sidewalk and—as passionate scientists with shared interests are likely to do—they stopped to chat. Tibbets explained some of the difficulties he faced in engineering a method for growing potatoes in space. He noted two of the key challenges he was trying to solve: designing a large yet transportable space for potatoes to grow, and dealing with the slow speed at which potatoes develop.

"What if, instead of engineering the equipment, you engineer the plants?" Williams suggested. It happened that he had in his pocket an envelope of seeds from the Washington Shuttle Stock, and he explained how he traveled with the plants on airplanes, and grew them under the bathroom lights of his hotel room when on the road. Intrigued, Dr. Tibbets went off with a small packet of Shuttle Stock seeds.

As Williams describes it: "Two weeks later NASA was on the phone." Scientists with the agency knew that a space shuttle mission, which could last more than two weeks, was long enough to allow experiments in the germination of plants, the growth of the stems and leaves, and the development and pollination of flowers in a microgravity environment *as long as* they had a small, very fast growing strain of plant.

But toting plants on an airplane introduced a new set of challenges, and Williams soon began breeding (i.e. engineering) a line of Fast Plants that satisfied a new set of criteria: petite plants that flowered at a height that he could transport easily in a cake carrier. Williams selected the most dwarf plants in his new breeding program, and his DC colleagues did the cross-pollinating. What Williams fondly dubbed his "Washington Shuttle Stock" became well known in science circles.

At the same time as Williams was traveling between Wisconsin and Washington DC, another US government agency was also investigating plant sciences. Engineers at NASA knew that any long-term exploration of space would require growing plants in space, both for food and as an oxygen source. The agency was already conducting plant growth experiments at the Biomass Production Chamber (BPC) at the Kennedy Space Center. That sealed ecosystem had been simulating the contained climate of a spacecraft since 1988, and had already grown multiple generations of wheat, soybeans, and lettuce. In addition, the space program funded many other such programs around the country. At UW-Madison, a colleague of Paul Williams, Professor Ted

What if, *instead of engineering the equipment*, you *engineer* the plants?

—Paul Williams

Petite Fast Plants, or Astro Plants, growing in bottle caps.

Fast Plants fit the bill perfectly. Tibbets and a Madison area company, Orbitec, then designed small growth chambers that could be used in space, and Fast Plants quickly found their way onto shuttle flights.

By the time of STS-87 in 1997, Washington Shuttle Stock *Brassicas*—sometimes called Astroplants—and other Fast Plant varieties had been used in several experiments on space shuttle missions. Independently, Russian scientists were working with Dr. Mary Musgrave at Louisiana State University in the US, who obtained Fast Plants from Williams' *Crucifer Genetics Cooperative* for research as well. In fact, aboard the Russian space station *Mir* Fast Plants became the first plants to ever go through their entire life cycle, from seed to seed, in space. Later, on the International Space Station, more plant growth and development data were gathered and analyzed, and it was proven that plants could grow in microgravity. However, there were early indications that microgravity affected plant development.

Now, some NASA botanists turned their attention to the question: *What developmental events during plant reproduction fail to function normally in the microgravity environment?* Of course, NASA scientists had many, many questions and, even with the shuttles, there were only brief precious moments in space available for investigations. Only those questions that gained strong support would get attention.

As it turned out, the support for investigating a question about plant growth with Fast Plants in space came about through further serendipity, in the form of a landmark agreement made between the United States and Ukraine.

Global Politics and Local Personalities

While the Cold War ended with the collapse of the USSR, a great many dangerous nuclear weapons remained in the arsenals of each side.

United States President Bill Clinton and Ukrainian President Leonid Kuchma.

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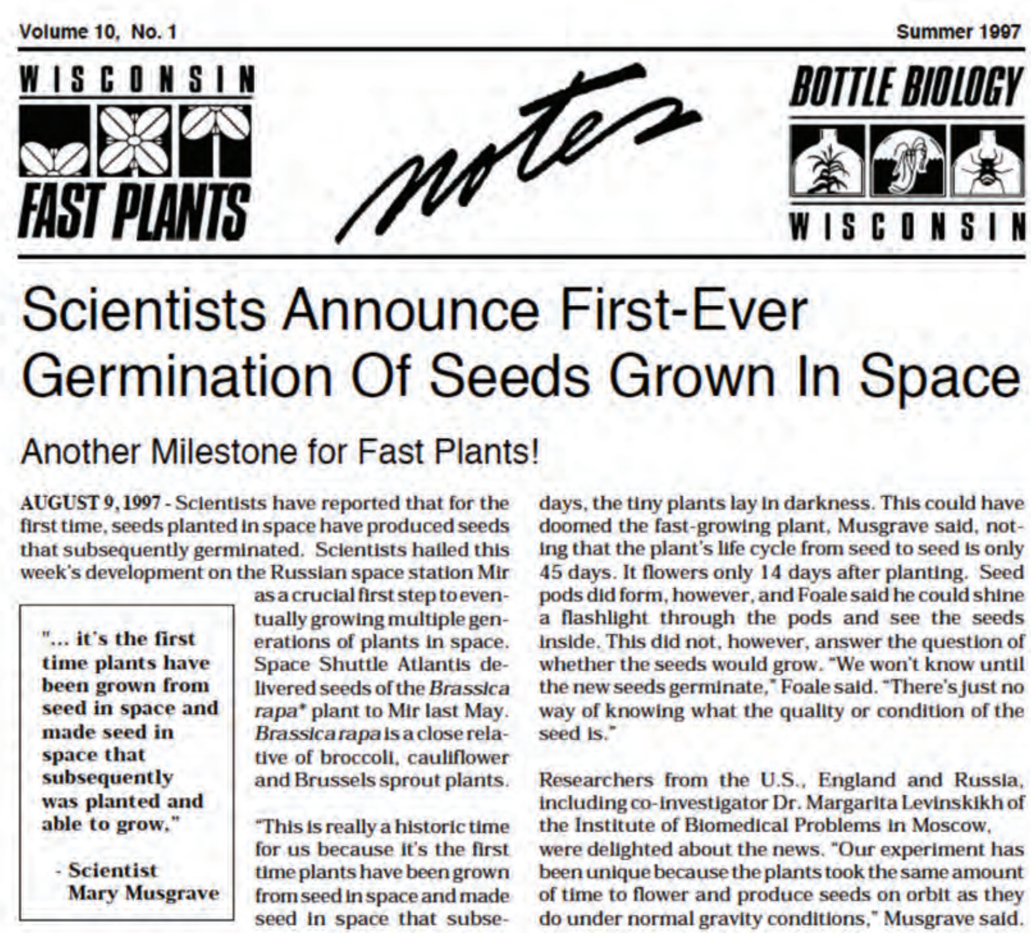
The United States began negotiating Strategic Arms Limitation Treaties (SALT) with many new countries, including Ukraine. As negotiations began, President Kuchma made an interesting request. He noted that Ukrainian astronauts had been trained in the Soviet cosmonaut program, but had never been allowed to fly on Russian space voyages. He wanted one of his countrymen to fly on an American space flight and, furthermore—since botany and agriculture were such a huge part of Ukrainian culture and tradition—he wanted that astronaut to conduct science experiments involving plants such as those being done on Mir, in cooperation with Mary Musgrave.

The United States, and NASA, were happy to agree. In 1995, United States President Bill Clinton and Ukrainian President Leonid Kuchma announced the beginning of the Collaborative Ukrainian Experiment, or CUE, providing an opportunity for one or more Ukrainian astronauts to fly a mission on one of NASA's space shuttles. Kadenyuk, by then a full colonel in the Ukrainian Air Force, was the first man selected for this program. He renounced his Russian citizenship and returned to Ukraine, where he was assigned as a scientific investigator to the Institute of Botany in Kiev.

By 1996 he was in Houston, Texas, at the Johnson Space Center and also working with Mary Musgrave to learn about Fast Plants and the experiment he would conduct on the shuttle. As with most Ukrainians, the growth and reproduction of plants was a matter near and dear to the colonel's heart. For his whole life he had both prepared to fly into space, and studied to perform unique and groundbreaking experiments.

But this would be more than just a space flight, for Paul Williams was more than just a passionate



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WISCONSIN FAST PLANTS notes BOTTLE BIOLOGY WISCONSIN

Scientists Announce First-Ever Germination Of Seeds Grown In Space

Another Milestone for Fast Plants!

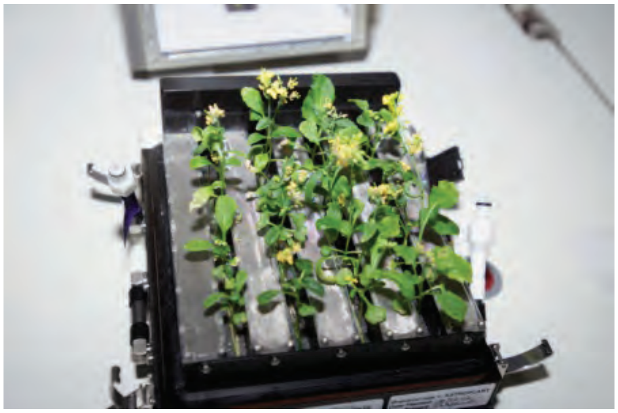
AUGUST 9, 1997 - Scientists have reported that for the first time, seeds planted in space have produced seeds that subsequently germinated. Scientists hailed this week's development on the Russian space station Mir as a crucial first step to eventually growing multiple generations of plants in space. Space Shuttle Atlantis delivered seeds of the *Brassica rapa** plant to Mir last May. *Brassica rapa* is a close relative of broccoli, cauliflower and Brussels sprout plants.

> **"... it's the first time plants have been grown from seed in space and made seed in space that subsequently was planted and able to grow."**
>
> **- Scientist Mary Musgrave**

"This is really a historic time for us because it's the first time plants have been grown from seed in space and made seed in space that subsequently ... days, the tiny plants lay in darkness. This could have doomed the fast-growing plant, Musgrave said, noting that the plant's life cycle from seed to seed is only 45 days. It flowers only 14 days after planting. Seed pods did form, however, and Foale said he could shine a flashlight through the pods and see the seeds inside. This did not, however, answer the question of whether the seeds would grow. "We won't know until the new seeds germinate," Foale said. "There's just no way of knowing what the quality or condition of the seed is."

Researchers from the U.S., England and Russia, including co-investigator Dr. Margarita Levinskikh of the Institute of Biomedical Problems in Moscow, were delighted about the news. "Our experiment has been unique because the plants took the same amount of time to flower and produce seeds on orbit as they do under normal gravity conditions," Musgrave said.

Fast Plants on Mir: Studying effects of gravity on plant growth and development



Fast Plants grown in space.

Dr. Mary Musgrave.

scientist—he was also a passionate educator. When Mary Musgrave phoned Paul to tell about the experiment she was working (CUE) and to see if the Fast Plants Program could get involved and involve students in carrying out the same "ground-based" experiment. Paul enthusiastically proposed training thousands of school children in both Ukraine and the US to coordinate classroom experiments with experiments in the space shuttle, duplicating the soil, growing containers and light sources in both locations, and following the exact same schedule of planting and pollinating. It was this convergence of science research interests and governmental support that led to the most important research of the Collaborative Ukrainian Experiment: Teachers and Students Investigating Plants in Space (TSIPS.)

The whole project would be known as CUE-TSIPS. With support from NASA and the Institute of Botany in Kiev, Williams trained more than two dozen "master teachers" in each country. In the US, these teachers ranged from Lori Gillam, at Stellar Secondary School in Anchorage, Alaska, to Mark Cresse, at Cocoa High School in Florida—just a few miles from the Kennedy Space Center; from Jim Lucey, at Wilton High School in the town of the same name, Connecticut, to Ken Bone at Del Mar High School in San Jose California. Across the Atlantic, in Eastern Europe, a similar number of highly

1997 CUE-TSIPS workshop at UW-Madison with Dr. Paul Williams.

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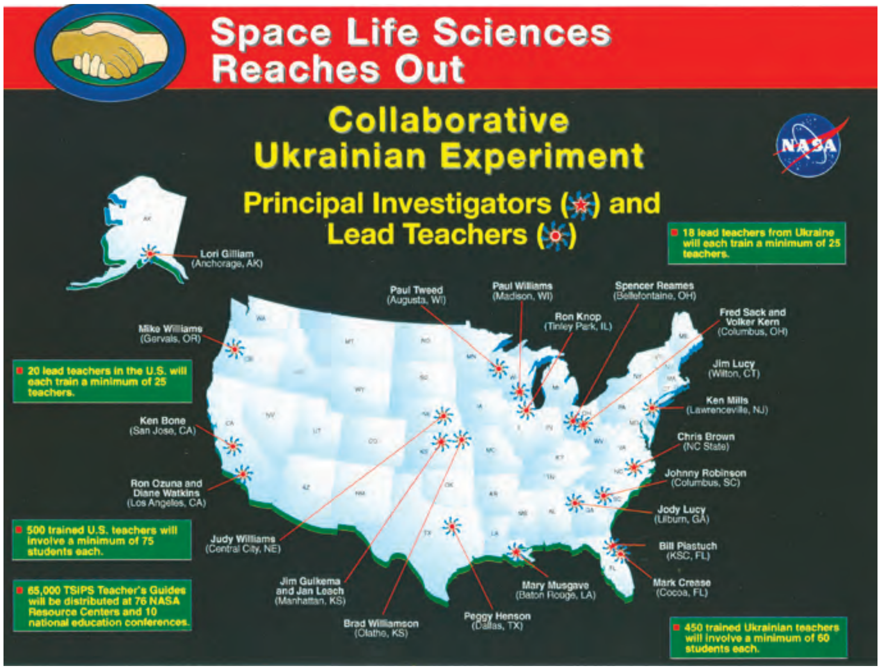
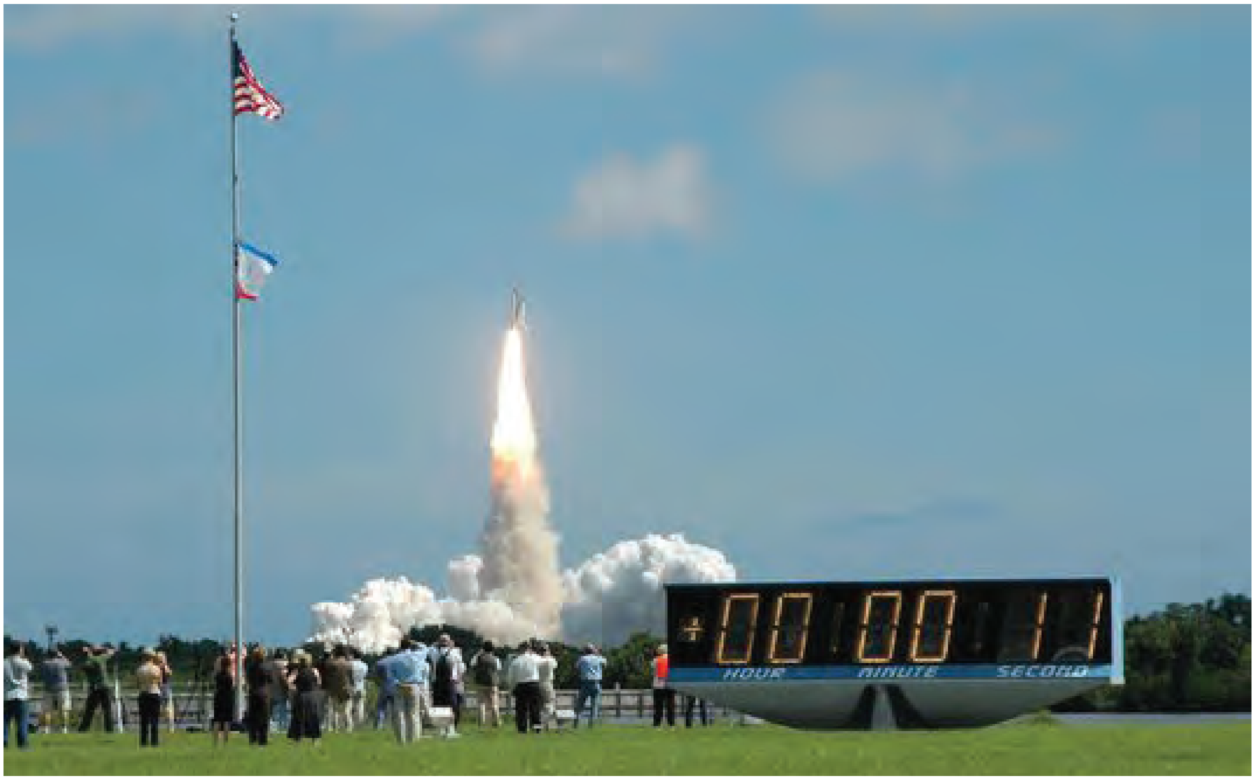
TSIPS: A powerful education component to CUE



trained and motivated educators had carried the CUE-TSIPS lessons throughout the Ukraine.

But the master teachers were only the tip of the iceberg on this project. Each of them went on to train dozens of other teachers to lead their students through the CUE experiments. In all, over 20,000 students in more than 840 classrooms across the United States and thousands of students in the Ukraine would follow this space flight with careful attention. The project would be led by Dr. Williams in the USA, who coordinated with the Ukrainian project instructor, Volodymyr Nazarenko, biochemistry professor and vice president of the Junior Academy of Kiev. Further

President Kuchma had plans for Kadenyuk.



academic support came from Mary Musgrave of Louisiana State University—who personally trained Kadenyuk in the Fast Plants procedures—and Dr. Antonina Popova, a prominent botanist at the institute in Kiev. Overall coordination between the two countries was handled by Thomas Dreschel, a NASA scientist who had already been involved in the BPC experiments at the Kennedy Space Center.

As Colonel Kadenyuk completed his training at the Johnson Space Center, educators around the United States and the Ukraine were working hard to prepare their colleagues, and their classrooms, for an unprecedented opportunity to perform investigative science. The master teachers had each trained their colleagues in the Fast Plants experiments, and so many thousands of U.S. and Ukrainian students were ready to conduct the experiments. Plant growth chambers matching the specifications of the PGCs aboard the shuttle had been distributed and some of the seeds—which had to be flowering plants for some of the experiments aboard the shuttle—were already planted and growing. All that was need was a ride into space.

Columbia Flies: Mission STS-87

Just before 3 PM on November 16, 1997, as light clouds scudded through a mostly blue sky and the audience on the outdoor bleachers held its collective breath; the countdown reached T -10 seconds, and then continued downward. Six seconds before launch the three powerful engines of the shuttle itself roared into life, fueled by the liquid hydrogen/oxygen mix from the huge fuel tank. Smoke billowed across the ground, rising higher than the ship, obscuring much of the gantry tower and the nearby buildings while the last few seconds ticked away. At “zero” the twin booster rockets blasted into life and explosive clamps securing the spacecraft to the tower snapped open, freeing the shuttle from restraint—though at first the ship seemed to barely move.

Soon, however, the five massive engines—three on *Columbia* itself, the other two on the tall,

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Tending and pollinating

Kadenyuk practices pollination.

Fast Plants in microgravity in a plant growth chamber.

sticklike solid fuel boosters strapped to either side of the massive liquid fuel tank—propelled the shuttle off the ground. Roaring noise thundered across Cape Canaveral, swelling in volume with every passing second. Ukrainian President Kuchma—veteran of very many ballistic missile launches—was awestruck as he felt the ground shake beneath him. Faster and faster *Columbia* climbed, trailing fire and smoke, nearing and quickly penetrating the thin veil of clouds. Slowly, gracefully, it rolled into the proper climbing attitude—which appeared to be upside down to the thrilled onlookers below. All five engines still blazing fire, it quickly shrank into a small, bright spark of light in the sky—though the thunder lingered for a very long time.

About two minutes after launch, and already out of sight of the observers on the ground, the tall, thin tubes of the rocket boosters detached from the external tank; they tumbled toward the Atlantic Ocean, their descent slowed by parachutes, as ships closed in to recover them for future launches. Meanwhile, the fuel in the main tank continued to flow to the three powerful engines in the shuttle, carrying *Columbia* ever higher in a gradually flattening arc.

The shuttle package grew lighter as the fuel burned and it accelerated toward orbit. Finally, about eight minutes into the flight, and with the craft already nearly a third of the way around the world, explosive bolts fired above the Indian Ocean to separate the big fuel tank from the shuttle itself. Pilot Lindsey used small maneuvering rockets on the shuttle's body to tilt the nose up, and the main engines shut down. The little space ship had reached orbit, and would stay there for the next sixteen days. It would orbit Planet Earth hundreds of times, and in total travel about six and a half *million* miles!

For those two weeks and two days, Kadenyuk remained busy conducting his experiments on the shuttle, growing some plants from seeds, and tending and pollinating others that had been planted before the flight. He used a specially engineered pair of magnifying goggles to see the tiny blossoms, while he wielded a bee-stick—a dried bee glued to a toothpick—to spread the pollen from one flower to another. At the same time, in classrooms across two countries, students mirrored the astronaut's activities, carefully measuring the plants for height, counting the number of leaves and flowers, and keeping track of the days.

The high points during the mission, both for the students and astronauts, occurred when the Kadenyuk and his colleagues answered student questions through a video downlink. As the students were assembled in Kiev and at the Johnson and Kennedy Space Centers in the U.S.,

Ukrainian science students.

Kadenyuk spoke to the Ukrainian students in their own language. Commander Kregel joined Kadenyuk to speak to the American students, assisting with translation where necessary. Many other students listened in from their classrooms, as the questions looked into the effects of microgravity on plant growth (which turned out to be minimal) and how effectively the astronaut was working with the bee sticks.

One student wondered if the flowers on the space plants grew in the typical pattern—spiraling up the stem—that she had observed on Earth, and Kadenyuk replied that the pattern was repeated in orbit just like the students were seeing in the classroom. Another asked: "We always have bees that fall off our sticks. Has this problem been considered, and how will you deal with it?" With a chuckle, Kadenyuk admitted that the bee sticks and plants selected for the shuttle flight were among the best available, and he also noted that NASA used super glue to affix the insects to the toothpicks. Another student wondered if live bees could be used to pollinate plants in space. "Bees have been taken into space, but never with flowers, so their behavior in microgravity for pollination has not been studied," answered the Ukrainian.

At the same time as Kadenyuk worked with his plants, other shuttle experiments were going on around him. Two "space walks", both conducted by Mission Specialists Scott and Doi, were conducted outside of the shuttle, marking the first time Extra-Vehicular Activities (EVA) had been performed from *Columbia*. One of the space walks lasted nearly eight hours, and the other was of five hours duration. The crew launched a satellite that was intended to study the sun, and experiments measuring aspects of helium, various materials, and effects of acceleration in space—among many other things—occupied the mission specialists' time, which passed all too quickly.

By December 5, all the work was done, and at just about sunset on that day Columbia glided back to Earth for a perfect landing at the Kennedy Space Center. Mission STS-87 was over, though the experiences of the students who participated, and of Colonel Kadenyuk himself, would last for the rest of their lives.

Columbia, tragically, would become the second shuttle destroyed in flight when it broke up while trying to reenter the atmosphere on February 1, 2003. All seven astronauts aboard lost their lives. The cause was ruled to be damaged tiles in the elaborate heat shield that protected

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the ship from the extreme temperature. After another pause to analyze the data and engineer a solution, shuttle flights resumed for several more years, with the doughty "space trucks" carrying many of the components of the International Space Station (ISS) to their orbital destination. The shuttle program was finally retired following a mission by *Atlantis* in 2011, concluding a remarkable 30-year period in the history of human space exploration.

Leonid Kadenyuk was rewarded by his country with a significant promotion: as Paul Williams tells it, "He went up a colonel and came down a general." He would go on to become a member of Ukraine's parliament and a science advisor to his nation's president. While he reports missing his time in Houston and Florida, and cherishes the friendships he made in America, his heart remains with his homeland as it continues to seek a secure path toward the future.

CUE-TSIPS Lead Teachers.

Serendipity and the Space Farmer Image Credits

Page 1

CUE NASA/NSAU logo: Scanned image of one of the patches carried into space and back to Earth by astronauts in the CUE mission.

Page 2

Countdown clock at Kennedy Space Center: Image source: http://buzzfactory.net/wp-content/uploads/2013/09/countdown-clock.jpg.

Page 3

Columbia crew: TS-87 Crew photo with Commander Kevin R. Kregel, Pilot Steven W. Lindsey, Mission Specialists Winston E. Scott, Kalpana Chawla, Takao Doi and Leonid K. Kadenyuk. Image Credit: NASA http://www.nasa.gov/mission_pages/shuttle/shuttlemissions/archives/sts-87.html.

Leonid Kuchma: Image Credit A Whisper to a Roar http://awhispertoaroar.com/about-the-film/ukraine/.

Page 4

Galaxy: https://commons.wikimedia.org/wiki/File:SpiralGalaxy_NGC6946.jpg constructed by Renseb, images of the individual colours were taken with the en:Isaac Newton Telescope on en:La Palma and the en:WIYN 0.9m telescope on en:Kitt Peak.

Pamphlet cover-You and the Atomic Bomb (1950): https://www.flickr.com/photos/localcelebrity/3157988713 photographer, John Morrison.

Page 5

President Dwight Eisenhower: https://commons.wikimedia.org/wiki/File:Dwight_D._Eisenhower_-_NARA_-_531434.jpg Image source: National Archives and Records Administration, www.archives.gov.

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Yuri Gagarin 1961: http://ftnews.firetrench.com/2011/07/now-that-the-party-is-over/ .

First steps on the moon: http://www.theguardian.com/theguardian/from-the-archive-blog/2011/jun/01/newspapers-national-newspapers Image credit: Neil Armstrong/AP.

Page 6

Illustration of the linking of American and Soviet capsules in space: http://spaceflight.nasa.gov/gallery/images/apollo-soyuz/apollo-soyuz/html/s73-02395.html en S73-02395 (August 1973) Apollo-Soyuz-Test-Program-artist-rendering.jpg Painting by R. Bruneau.

Space shuttle launch: https://pixabay.com/en/atlantis-space-shuttle-launch-liftoff-604182/.

Page 7

Sharon Christa McAuliffe: https://en.wikipedia.org/wiki/Christa_McAuliffe#/media/File:ChristaMcAuliffe.jpg Uploaded by Wstrwald Created: September 26, 1985 Image source: NASA - NASA Human Space Flight Gallery.

The Challenger crew: https://en.wikipedia.org/wiki/STS-51-L Uploaded by Wstrwald Created: November 15, 1985 Image source: NASA - NASA Human Space Flight Gallery.

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Page 8

Dr. Paul Williams: image source: Wisconsin Fast Plants Program archives.

Cabbage farmer: https://commons.wikimedia.org/wiki/File:CabbageFarmer.jpg Title: Cabbage farmer Chiyeko Suzumoto in Gardena (Calif.) Publication: Los Angeles Times. Publication date: Mar 12, 1951.

John Houbolt: http://www.nasa.gov/centers/langley/news/factsheets/Rendezvous.html Image Credit: NASA.

Page 9

Nasa: http://history.nasa.gov/SP-4406/chap4.html Image Source: NASA History.

UW-Madison: http://www.cals.wisc.edu/wp-content/uploads/2014/08/CALS-Campus-1906.jpg Image Source: University of Wisconsin-Madison College of Agricultural and Life Sciences.

UW-Madison cabbage researcher in the field: Image source: University of Wisconsin-Madison College of Agricultural and Life Sciences.

Page 10

World map: Wisconsin Fast Plants Program.

Ukrainian wheat field: https://pixabay.com/en/ukraine-science-selection-wheat-999369/.

Page 11

Fall of the Berlin Wall: https://en.wikipedia.org/wiki/Potsdamer_Platz#/media/File:891121c_berlin_potsdamer_platz.jpg Image source: File:891121c berlin potsdamer platz.jpg Uploaded by Fwiarda, Created: November 21, 1989.

Page 12

Leonid Kadenyuk pollinating: https://www.flickr.com/photos/nasa2explore/9358792179 Image source: NASA.

Leonid Kadenyuk space suit: http://www.jsc.nasa.gov/Bios/PS/kadenyuk.html Image source: NASA.

Soviet mobile missile launcher: https://commons.wikimedia.org/wiki/File:Army_mlrs_1982_02.jpg Image source: File: Army mlrs 1982 02.jpg Uploaded by Silje: October 5, 2005.

Page 13

UW-Madison newsletter: Wisconsin Fast Plants Program Scan. Image source: College of Agricultural and Life Sciences, University of Wisconsin-Madison.

Page 14

CUE-TSIPS teacher leaders: Image source: Wisconsin Fast Plants Program.

Washington Shuttle Stock images: Image source: Wisconsin Fast Plants Program.

Page 15

NASA plant research: https://en.wikipedia.org/wiki/Hydroponics Image source: NASA.

Page 16

Astro plants in bottle caps: Image source: Wisconsin Fast Plants Program.

Presidents Clinton and Kuchma: http://images.vogue.it/imgs/galleries/encyclo/moda/017851/wl009456-575815_0x420.jpg Image source: Vogue.

Page 17

Fast Plants newsletter: Image source: Wisconsin Fast Plants Program.

Page 18

Fast Plants grown in space: http://onward.nationalgeographic.com/2014/04/17/houston-we-have-some-spinach/ Image Source: NASA.

Dr. Mary Musgrave: http://today.uconn.edu/2009/08/the-effects-of-gravity-on-plant-growth-and-development/ Image Source: University of Connecticut, UConn Today.

CUE NASA/NSAU patch: Scanned image of one of the patches carried into space by astronauts in the CUE mission.

CUE-TSIPS workshop: Image source: Wisconsin Fast Plants Program.

Page 19

CUE-TSIPS leadership map: Image source: Wisconsin Fast Plants Program.

President Kuchma and cosmonauts: http://science.ksc.nasa.gov/shuttle/missions/sts-87/images/captions/KSC-97EC-1684.html Image source: NASA File name: Kuchma NASA cosmonauts.jpg *Photo Release Date: 11/19/97.*

Page 20

Launch Clock: http://www.nasa.gov/images/content/493249main_clock.jpg Image source/credit: NASA/Jim Grossmann.

Page 21

Kadenyuk Pollinating: http://science.ksc.nasa.gov/gallery/photos/1997/captions/KSC-97PC-1517.html Image credit: NASA Image source*: Bionetics and NASA/KSC Public Affairs Office.*

Fast Plants in a plant growth chamber: Image source: Orbital Technologies Corporation (Orbitec).

Page 22

Ukrainian students with Fast Plants: Image source: Wisconsin Fast Plants Program.

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