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Down To Earth: NASA Discoveries Advance Human Health

by Brian Bossetta

While the latest missions from NASA may seem like the stuff of science fiction, discoveries from outer space are not only unlocking the mysteries of the cosmos, but improving technologies used every day on Earth, including those in the medtech industry.

Satellites orbiting through space, rovers collecting dust on Mars, and the Webb telescope capturing breathtaking images of the Big Bang may not seem relevant to the health of Earthlings, but the technologies developed by NASA for exploring the deepest reaches of the universe have direct impacts on advances in medical devices and diagnostics.

Spinoff 2024, NASA's annual publication, highlights the space agency's research and development on innovative technologies ranging from the smallest satellites to the most powerful rocket ever launched.

In this year's edition of *Spinoff*, Prasun Desai, deputy associate administrator of NASA's Space Technology Mission Directorate (STMD), notes how this work aligns with the agency's motto: "For the benefit of all."

"At NASA, our discoveries have not only improved our understanding of the cosmos but have led to immeasurable improvements to everyone's life on Earth," Desai writes in *Spinoff*.

For example, he cites advancements in robotic designs and electronics research that led to the discovery of silicon crystals that could improve the mineral health of bones and teeth.

Aliens Inside Us

In its search for life beyond the stars, NASA says it has made significant advancements in detecting diseases. Specifically, through NASA-funded research on what alien life might look like

at the molecular level, scientists have gained a better understanding of the intricacies of the human body and the infinite network of cells contained within.

Or, as biochemist Steven Benner puts it in *Spinoff*, "In diagnostics for infectious disease, you're looking for alien life inside of a patient."

"Of course, we actually know the structures of the genetic molecules in the coronavirus that is causing COVID, for example," Benner writes. "It's actually a bit easier to build a diagnostics assay to detect COVID than it is to build an agnostic life finder to search for Martian DNA, whose structure would be unknown."

Benner is the CEO of Firebird Diagnostics, which sells synthetic DNA and molecule packages to researchers in their efforts to develop diagnostics and treatments for cancer, hepatitis, and HIV.

A better grasp of molecules and DNA structure is important, as Benner explains, because only a portion of what is currently understood in biochemistry is universal, whereas most of what is known in the field is "Earth-specific."

As he further explains, Earth-based, or natural DNA – the molecules that carry genetic instructions – is composed of four nucleotides that are often described as building blocks.

But he asks, what if DNA had multiple — "six or eight" — different building blocks?

To answer this fundamental question, Benner and his research partners constructed DNA-like molecular systems with six and eight nucleotides, based on research funded in part by NASA's astrobiology program.

The systems Benner created add two or four more synthetic nucleotides to the four building blocks in Earth-based DNA, resulting in synthetic or "alien" DNA with structures that are different from natural DNA but are still able to hold and copy genetic information.

Most importantly, this work supports molecular evolution, the fundamental feature of biology and life.

"Ex astris, scientia." – [from the stars, knowledge] – Prasun Desai

What Benner's work shows, according to Mary Voytek, head of NASA's astrobiology program, is that there are alternatives to Earth-based biological molecules, which have the potential to reveal what is possible in life beyond Earth.

Because synthetic — or alien — DNA contains more building blocks than Earth-based DNA, it can bind more tightly and selectively, which means it can provide more accurate test results and targeted therapy.

And, because the molecules bind to targets like the COVID-19 virus or breast or liver cancer cells, they could be a first step in finding cures to those diseases.

Bugging Out

Before an infectious disease like COVID-19 can be treated, the virus must first be detected to stop its spread. During the pandemic, one method for tracking the virus was collecting and testing municipal wastewater for its presence.

As this testing ramped up, many municipalities relied upon a technology developed to identify pathogens inside spacecraft.

As *Spinoff* points out, several small business innovation research (SBIR) contracts helped companies – such as InnovaPrep of Drexel, MO – improve their existing bioconcentration processes and apply it to automated testing for viruses, bacteria, and other pathogens in the air and water and on surfaces in the International Space Station.

Prior to its collaboration with SBIR, InnovaPrep built the disposable filter, called a pipette, by hand, producing about 200 a week.

But now, according to NASA, that output has skyrocketed to 12,000 per week with a system that can easily scale up to meet increased demand.

And that improved production came just in time as the company was able to fill orders from public-health departments, commercial laboratories, and researchers as monitoring efforts were put in place to monitor and track the spread of COVID-19 through wastewater.

Preventing super bugs in space is crucial and requires vigilance, according to NASA. Pathogens, including some bacteria and viruses, can become more harmful in zero gravity.

But sample collection and testing are time-consuming.

To address this problem, NASA's Jet Propulsion Laboratory in Pasadena, CA, led the effort to make it more efficient using automation to modify its sample concentration technology for

space.

One option to enable faster results is a polymerase chain reaction (PCR) test, NASA suggests. PCR technology rapidly amplifies small segments of genetic material — DNA or RNA — by making multiple copies. This creates a larger sample for genetic testing, making it easier to identify the type of bacteria or virus present.

Andy Page, chief technology officer with InnovaPrep, says the company was able to advance its production lines because of the assistance from NASA scientists. "The SBIR program allows you to discover things that you're not going to be able to easily discover without that funding," he said.

The practical applications for these advancements are vast. As *Spinoff* points out, testing for pathogens is not just needed during a pandemic.

For example, recreational facilities use InnovaPrep technology to monitor water quality in swimming pools, hospitals use it to screen indoor spaces to keep them as sterile, and water from cooling towers and municipal water systems is regularly tested for legionella bacteria, which can cause a severe form of pneumonia.

Cordless Cameras

The last thing an orthopedic surgeon needs during arthroscopic knee surgery is to have someone trip over the cords from the camera. But this is exactly what Eugene Malinskiy witnessed during a surgery, when a physician's assistant tripped taking the cables from the patient to the floor with him as he fell. The procedure had to be postponed.

This led Malinskiy to start Lazurite Holdings in Cleveland. In 2022, Lazurite's ArthroFree Wireless Camera System became the first FDA-cleared wireless camera system for minimally invasive surgery.

Malinskiy and his brother developed the camera with support from engineers at NASA's Glenn Research Center in Cleveland; They advised the brothers on technical specifications for the device.

The benefit of cordless cameras for orthopedic surgeons is obvious, and it's not just removing a tripping hazard from the OR. Cords often overheat and burn patients and they can limit the surgeon's ability to maneuver the camera.

But to make their cordless camera work, Malinskiy and his brother needed a power source and wireless communication technology. They drew up design plans to fit those innovations into an economical and ergonomic package – "something that would be comfortable and not too heavy

to hold for long periods."

In 2016, the brothers met with NASA engineers through the Adopt a City program, which enables NASA experts to consult with local businesses.

Through this initiative, NASA engineers connected the Malinskiys with several vendors of high-fidelity aerospace lithium-ion batteries, which were the same-sized lithium-ion battery found in devices on the space station and in spacesuits and satellites.

These batteries were a perfect fit for the cordless camera because they are used to provide reliable power to other small devices used by NASA without being too heavy once inside the device.

The brothers further consulted with NASA engineers on their plan to use the ultra-wideband protocol –radio technology that enables encrypted transfer of a high-definition signal – as well as on the processors and chips for the device's central processing unit.

The concept of surgery and space, however, is already in the works.

Virtual Incision, which specializes in miniature surgical robots, recently launched its MIRA tabletop surgical robot into space. (Also see "*News We're Watching: LivaNova Names CEO; Surgical Robot Goes To Space, And More*" - Medtech Insight, 5 Feb, 2024.)

The device will be carried to the International Space Station by a Northrop Grumman-manufactured/Orbital Sciences Corporation-designed Cygnus cargo spaceship launched by a SpaceX Falcon 9 rocket.

The purpose of the mission is to test the robot's automated surgical capabilities in the hope that such a bold tech demonstration can prove itself as the system-of-choice for clinics that are either geographically remote, or lacking surgeons.

A Very Smart Watch

With help from NASA, specifically its need to measure and provide data on the physiology and health of astronauts during missions, Cambridge, Massachusetts-based wearable technology company Empatica developed a smartwatch, the EmbracePlus, with five sensors, which is now commercially available.

Development of the device's prototype was funded in part by a grant from the Translational Research Institute for Space Health (TRISH), a research consortium funded by Johnson and the Baylor College of Medicine that looks for ways to reduce risks to astronauts on long missions.

The funding aided the watch's development, which included evaluating different sensors for detecting heart rate and oxygen flow, conducting trials on the watch, integrating all the components and design elements, determining the most comfortable form factor, and choosing a display.

Simone Tognetti, chief technology officer at Empatica, said the TRISH funding allowed the company to implement important engineering features, such as placing the skin sensors on a comfortable, removable strap.

Empatica began mass production of the FDA-cleared EmbracePlus in 2021, which has become a key component of the company's health monitoring platform – a platform, according to Tognetti, in which machine learning algorithms can analyze simultaneous data streams from diverse types of sensors to detect and monitor various aspects of health.

Tognetti hopes that one day the platform, along with the EmbracePlus, will become the "go-to tool" for monitoring patient health outside clinical settings.

Tomorrow's Spinoffs

NASA maintains a robust portfolio of patents, with more than 1,100 technologies and a software catalog with hundreds of codes, making many of the aeronautic and aerospace technologies that the agency is using available for all.

This year's *Spinoff* features 20 examples of technologies being developed across the agency's 10 US field centers, many of which have medtech applications.

For example, at the Marshal Space Center in Huntsville, Alabama, NASA engineers are working on high-flow differential cleaning, a technology that only takes minutes to clean complex 3D-printed parts with small passageways and channels.

This technology provides an option to powder-based additive manufacturing, which typically requires post-fabrication cleaning to remove residual powder from the surface and crevices.

That becomes increasingly challenging with part complexity and current methods have significant drawbacks, according to NASA.

This technology developed at Marshall uses a large volume of pressurized air in a cleaning chamber, with the high flow resulting in decreased pressure as it passes through smaller component orifices removing remnant powder.

> *"NASA is always developing new technologies that could soon find their way into our everyday lives." —Prasun Desai*

At the Stennis Space Center in Hancock County, MS, engineers are working on a remote sensing toolkit with an online portal that offers easy access to NASA Earth-observation data.

This online resource will promote the agency's freely available remote sensing data and its software.

Through its constellation of Earth-observation satellites, NASA collects petabytes of data each year. The toolkit lets users find, analyze, and download the most relevant data for their projects. The toolkit quickly identifies relevant sources based on user input.

Free to use, the toolkit contains data from more than 20 satellites and NASA missions and has potential applications for resource management as well as planning for natural disasters.

At the Jet Propulsion Laboratory in Southern California, NASA researchers are creating biomarker sensor arrays for microfluidics, which has potential benefits in the life sciences, medical diagnostics, pharmaceutical research, and biotechnology.

These biomarkers allow researchers to apply patterns using a wide range of previously incompatible materials in various pH environments enabling extremely fine patterns of detectors suitable for multicolor imaging of single-molecule samples at resolutions far below the diffraction limit and the sensors are small enough to allow for rapid screening for hundreds of functionalities in one microfluidics chip.

Agency engineers at the Goddard Space Flight Center in Greenbelt, MD, are developing a non-scanning 3D imager that provides "high-resolution, real-time, three-dimensional imaging" with a single-lens system that has the potential to enhance remote sensing, machine vision, and robotic vision.

This is possible through the device's simple lens system that instantaneously generates a one-dimensional or two-dimensional array of optical spots to illuminate an object, surface, or image to create a topographic profile.

And the Ames Research Center in Silicon Valley is working on a novel assay methodology to isolate nucleic acids and prepare samples for reverse transcriptase quantitative polymerase chain

reaction analysis that solves the problem of contamination and degradation, thus enabling the processing of a biological sample for gene expression analysis from raw tissue to data.

This technology, according to NASA, has significant ramifications for medical diagnostics, including disease or microbial monitoring in remote areas.

“NASA is always developing new technologies that could soon find their way into our everyday lives,” writes Desai. Improving life on Earth for the benefit of humankind is not just a side effect of the agency’s work, “but a key part of our mission – one that will continue for decades to come.”