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NASA Technologies and Emergency First Responders

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In addition to pushing back boundaries in science and exploration, NASA has a long history of finding applications of space and aeronautics technologies that provide broad public benefits. The basis for NASA's direction to do this can be directly traced to the opening declaration of policy and purpose of the National Aeronautics and Space Act that created NASA in 1958. Since that initial call to action, many advances in aerospace research have been applied to a wide variety of fields, including emergency response. These secondary uses have resulted in advances that protect first responders, aid emergency personnel, and contribute to accident prevention.

I. Introduction

In fall of 2007, a series of wildfires ravaged Southern California. Exacerbated by record-breaking heat, a summer-long drought, and strong winds, the fires, which claimed 9 lives and destroyed over 1,500 homes, tested the abilities of nearly 10,000 firefighters—some amateur and some professional. The blazes consumed tens of thousands of acres and forced evacuation of over a quarter million people. While workers on the ground fought to contain the more than a dozen fires, in the sky they had a seemingly unlikely ally. NASA had launched Ikhana, an unmanned aerial vehicle, to analyze the wildfires and give ground-based personnel a better understanding of what they were up against.

Operators at NASA's Dryden Research Center in Edwards, California, piloted the Ikhana aircraft over the West coast, from Southern California nearly all the way to the Canadian border, giving a wide view of that season's wildfires. Ikhana was carrying a sensor developed at NASA's Silicon Valley-based Ames Research Center, the Autonomous Modular Sensor—Wildfire, a device capable of looking through the smoke to see hot spots, flames, and temperature differences. The data was then overlaid on maps and down-linked in near-real time to the National Interagency Fire Center in Boise, Idaho, and made available to fire incident commanders to assist them in allocating fire-fighting resources.

While this flight was one in a series of such flights, flights that are continuing today as part of the Western States Fire Mission, which is demonstrating the improved wildfire imaging and mapping capabilities of sophisticated sensor and communications equipment developed by NASA, this story is one in a series of many in which the Space Agency plays the seemingly unlikely role of aiding emergency response personnel.

NASA has a long history of making the jobs of those who protect us easier and safer, with emergency response and first responder groups benefitting from NASA-derived technologies nearly as long as NASA has been in existence. Since its inception 50 years ago, NASA has been contributing technologies that protect first responders, aid emergency personnel as they do their jobs, and contribute to the industry through training and accident prevention. Many of these are the outcome of partnerships between NASA and private industry and are among the

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more than 1,660 commercialized technologies featured since 1976 in the Agency's premier publication, Spinoff.

It makes sense that advancements for space exploration would have applications in emergency response. Parallels between the two are bountiful. NASA equipment is designed to work in the extremes: the extreme heat, the extreme cold, far from civilization, with limited access to power sources. NASA requires that its mission-critical equipment is self-sufficient and fail-proof. These qualities are the same that emergency response personnel require in their line of work, where—like with NASA's human space flight missions—failure is just not an option.

II. Protecting First Responders

In the 1960s, as part of the Apollo program, NASA developed a heat-resistant coating that kept the command module from burning up during atmospheric reentry, but that now prevents or delays building collapse due to fire. The Apollo heat shield was coated with an ablative material whose purpose was to burn, and thus dissipate, energy. The burned material charred to form a protective coating which blocked heat penetration beyond the outer surface. Avco Corporation entered into a contract with Ames to develop spinoff applications of the heat shield in the arena of fire protection, specifically for the development of fire-retardant paints and foams for aircraft. This led to world's first intumescent epoxy material, Chartek. The latest product derived from Chartek technology is coined Interchar and geared toward making America's high-rise buildings and public structures safer.

An Interchar coating is typically applied at a thickness between 1 and 8 millimeters, so it does not impact the overall shape of the steel. Because this is a thin layering process, architects and building planners can still explore intricate and innovate architectural designs, especially when the steel is exposed. It offers fast cure times, superior adhesion to steel surfaces, and a strong, durable barrier to the steel beam underneath. Altogether, these attributes provide up to 4 hours of fire protection and help prevent steel infrastructures from collapsing prematurely, in turn, giving building occupants—and any emergency personnel attending to them—more time to evacuate safely.

In the 1970s, together with NASA's Johnson Space Center, Scott Aviation developed lightweight firefighter's air tanks. The new backpack system, which provided 30 minutes of air supply, weighed only 20 pounds, 13 pounds less than conventional firefighting tanks at that time. Pressurized at 4,500 psi, twice that of the conventional tanks, these new tanks were constructed with an aluminum liner wrapped by resin-impregnated glass fibers, eliminating corrosion as well as considerably lightening the load. This significantly reduced the number of instances in which firefighters, when battling a blaze, opted to drop their emergency air supply tanks rather than work encumbered by the oppressive safety gear.

In addition to lightening the air tank, the new system—part of a multi-year NASA-sponsored program to increase firefighter safety—included a harness that transferred the bulk of the load from the shoulders to the hips, reducing user fatigue. Additional modifications included a face mask with a wider range of visibility and a personalized warning device that alerted firefighters when their oxygen supplies are running low without adding to the chaos by confusing others with an auditory alarm. These combined innovations led to the redesign of much of the gear at the time and are still in use today in modern firehouses.

Around this same time, another NASA technology came to the aid of rescue workers. An inductorless electronic circuit developed by scientists at NASA's Goddard Space Flight Center to transmit weather balloon data was applied to a handheld communications device for firefighters. Essential to coordinating hose lines and victim rescue, the rugged, short-range, two-way radio was the first of such devices designed specifically for firefighter use and boasted less expensive, more rugged short range two-way communications.

In the early 1980s, NASA worked with Federal Emergency Management Agency (FEMA) to develop safer fire-resistant suits for firefighters. The joint program, called Project FIRES (Firefighter's Integrated Response Equipment System), focused on application of advanced materials and design concepts, derived from Apollo, to update existing turnout gear that did not adequately protect against many of the hazards encountered in fire suppression activities. NASA supplied lightweight, fire-resistant, heat-protective materials originally developed for use in astronaut space suits and in spacecraft components that require thermal protection to fourteen municipal fire departments for evaluation. The resulting data formed the basis for development of new nationwide protective firefighting ensembles.

One of the fire-resistant technologies studied under Project FIRES and now employed regularly by fire departments is PBI. In 1967, NASA contracted with Celanese Corporationto develop a line of fire-resistant textiles for use in space suits and vehicles. The result, PBI, is now in widespread use in numerous firefighting, military, motor sports, and other applications.

The best way to keep emergency personnel safe, though, is to use a technique NASA has popularized: Send a robot in first. A number of iRobot (makers of the popular Roomba robotic vacuum) employees have drawn from

their NASA experiences to help develop the PackBot Tactile Mobile Robot, used by U.S. troops in Iraq and Afghanistan to help clear caves and bunkers, search buildings, and cross live anti-personnel mine fields. The chief executive officer of iRobot designed behavior-controlled rovers for NASA that led to the Sojourner rover's exploration of Mars in 1997, and the company's president worked at Jet Propulsion Laboratory as a student, building gripper systems for space satellites. Additionally, one of iRobot's senior mechanical engineers honed his technical expertise with NASA, by helping to build a Martian rover whose structural features would ultimately be incorporated into PackBot. Nicknamed Rocky-7, this Martian rover served as a terrestrial test bed for the twin Mars Exploration Rovers, Spirit and Opportunity.

PackBot provides soldiers and first responders with a safe first look so they know what to expect and how to respond. The robot can climb grades up to 60 percent and survive submersion in water up to 6.6 feet deep, and possesses flippers that propel it up stairs, over curbs, and through daunting obstacles such as rocks, rubble, and debris. If PackBot flips over during operations, the robot uses these flippers to perform a self-righting maneuver in seconds. It is also useful in hostage situations and in police reconnaissance maneuvers.

III. Aiding Emergency Personnel

In addition to keeping emergency personnel safe, NASA technologies make them more efficient, aiding in emergency medical treatments and rescue equipment. One of the earliest and most significant ways in which NASA contributed to the science of emergency medicine is through the introduction of telemedicine techniques and technologies.

Telemedicine, the remote delivery of medical care, is important to the Space Agency because, in emergency situations, often those who are in need of care and monitoring, while several miles from a hospital, might as well be as far away as the International Space Station (ISS), orbiting roughly 240 miles above the Earth.

Researchers on the ISS often have backgrounds in aeronautics, physics, geology, and engineering and are expected to conduct a wide variety of experiments in these fields, as well as perform sophisticated repairs and construction projects. While these astronauts are always well skilled and capable, what they are usually not are medical doctors. Even if a crewmember were a doctor, though, the strict equipment weight restrictions and tight quarters aboard the orbiting laboratory would prevent the station from supporting a clinic full of medical testing equipment. The approach of telemedicine, then, aims to give astronauts in space access to a full range of medical expertise and tests, while leaving bulky equipment and large medical staffs on the ground.

These same principles apply to emergency medical technicians, who are required to keep patients alive and stabilized before and during transport to medical facilities. Data collected by instruments in the field can be automatically transmitted into radio signals and sent to receiving stations as hospitals where signals are decoded and recorded. For example, transmission of an electrocardiogram from an ambulance to a hospital enables a physician to read the report and advise ambulance attendants on emergency procedures.

Toward this end, Glenn Research Center, formerly the Lewis Research Center, helped design the first EMS Communication System, a complex system that included telemetry links between ambulances and hospitals for advanced life support services.

More recently, NASA telemedicine research into employing portable ultrasound devices for use in space has shown applications for emergency medical personnel. The Advanced Diagnostic Ultrasound in Microgravity (ADUM) studies conducted aboard the ISS may have direct application for the evaluation and diagnosis of hundreds of medical conditions of interest for treating exploration crews, and in turn, patients on Earth.

Ultrasound—conducted using a small and relatively lightweight machine—is the only medical imaging option currently available on ISS. Since it is not feasible for a crewmember to return to Earth for a quick medical checkup, the ability of crew members to use an ultrasound machine with remote instruction, sending information to the ground for analysis, can assist in timely treatment as well as avert unnecessary evacuation. Crew members as far away as Mars could be remotely examined by doctors on Earth using a modification of this technology, a capability essential for long-term space exploration. To expand the effectiveness of ultrasound telemedicine for space and Earth, Johnson and partners at Detroit's Henry Ford Hospital worked to develop non-traditional ultrasound techniques. Commonly used for purposes such as imaging fetus development, abdominal conditions, and blood flow, thanks to the ADUM experiment ultrasound has now been demonstrated useful for diagnosing conditions such as collapsed lungs and tooth and sinus infections—in some cases displaying greater effectiveness than X-ray imaging.

On Earth, the use of a relatively small piece of medical equipment like an ultrasound machine to diagnose various health problems without specialized medical expertise nearby could save lives as well as health care costs. The need for technology to transmit high resolution ultrasound imagery over the Internet led to the formation of

Mediphan, a company that drew on NASA expertise to adapt video-streaming innovations into devices that can store and send diagnostic-quality ultrasound images from anywhere with an Internet connection. Doctors can receive transmitted ultrasound information from great distances and assist with remote medical diagnosis and treatment, with a high degree of confidence and efficiency. This technology essentially allows anyone in the world access to unique clinical imaging expertise and is in use in select fire departments and first response units around the country.

Other NASA medical advances are aiding in the treatment of trauma victims. During the 1990s, engineers at Ames developed a prototype pressure suit for hemophiliac children, based on research of astronauts' physiological responses in microgravity. Zoex Corporation picked up the design and patents and developed an anti-shock garment for paramedic use. The suit reverses the effect of shock on the body's blood distribution by applying counter pressure to the legs and abdomen, returning blood to vital organs and stabilizing body pressure until the patient reaches a hospital. The DMAST (Dyna Med Anti-Shock Trousers) employ lower pressure than other shock garments, and are non-inflatable.

More recently, Advanced Circulatory Systems, Inc. and NASA's Kennedy Space Center collaborated on an impedance threshold device. The resulting technology is encapsulated in the ResQPOD Circulatory Enhancer, which improves the standard of care provided to patients with a variety of clinical conditions due to low blood flow. ResQPOD generates negative intrathoracic pressure during respiration to increase blood flow to the body's vital organs. It is unique in that it non-invasively enhances the body's biophysical performance without depending on pharmaceutical or other outside agents. ResQPOD uses the relationship of the heart, brain, lungs and chest cavity in a manner similar to a bellows to increase venous blood return to the heart. Multiple studies have shown a significant improvement in cardiac output and blood flow to the brain with the use of the impedance threshold device, as well as the device's ability to prevent shock secondary to blood loss. ResQPOD has been added to the set of medical equipment that is available for returning astronaut crews, and commercial applications have fallen into two categories: Non-spontaneously breathing patients who can benefit from enhanced circulation, and spontaneously breathing patients who suffer from transient hypotension or low blood pressure. The ResQPOD technology was just inducted into the Space Technology Hall of Fame in April of 2008.

A powerful handheld rescue tool similar to the "jaws of life," the Lifeshears, can quickly cut through cars or other enclosures to free people involved in an accident or other dangerous situation. The tool, which was developed through the joint efforts of the Hi-Shear Technology Corporation, firefighters, and NASA, uses the same power source used to separate the solid rocket boosters from the space shuttle. Lifeshears were used by rescue workers searching for survivors at the Oklahoma City federal building bombing site in 1995 and the World Trade Center in 2001. They are lighter, cheaper, and easier to use than traditional rescue equipment.

IV. Training and Accident Prevention

In the early 1980s, firefighting trainees conducted fire control exercises using a prototype simulator known as the Emergency Management Computer Aided Training System (EMCAT). Developed by Marshall Space Flight Center in response to a request from the Huntsville, Alabama, Fire Department, EMCAT enabled a trainee to assume the role of ground commander and make quick decisions on best use of fire fighting personnel and equipment.

Another fire safety training program was developed at the NASA White Sands Test Facility (WSTF), which stores, tests, and disposes of space shuttle and space station propellants. Since aerospace fluids can have harmful reactions with the construction materials of the systems containing them, WSTF created technical manuals and training courses for the safe use of these fluids. The facility partnered with standards organizations such as the American Society for Testing and Materials (ASTM) to document its results in safety manuals, develop and deliver safety courses, and perform hazards analyses. As a result of these partnerships, private industry can purchase the safety manuals and training courses. One of the main WSTF courses that ASTM markets is "Fire Hazards in Oxygen Systems," which is intended for anyone who operates, maintains, or manufactures any type of oxygen system, including those used in medicine, gas production, chemical processing, and home health care.

Another tactical advantage provided rescue workers by NASA comes from the Mississippi-based Nvision, Inc., which harnessed NASA's geospatial satellite information to provide a disaster management tool for local, state, and Federal governments. NASA, NVision, and a team of local governments created the Real-time Emergency Action Coordination Tool (REACT). REACT is a simple, Web-based tool that city officials can access when they need to make decisions in emergency and disaster situations. It provides a comprehensive network of maps and reports, combined with real-time sensors, shelter and hospital information, and dynamically generated environmental model output during a crisis to help officials make timely, informed decisions under pressure.

A similar approach is being used by NASA in South American and in Rwanda, through the SERVIR

program. SERVIR, Spanish for "to serve," uses satellite imagery to zero in on flood, fire, hurricane, or earthquake locations and has been in operation in Central America, the Caribbean, and southern Mexico since 2005, and in 2009 was brought to Africa. In cooperation with regional governments, the program provides a birds-eye view of natural disasters when they occur. Using NASA's Earth science satellites, the program makes available near-real-time maps of disaster-stricken areas, helping estimate the numbers of dislocated people, disruptions to the infrastructure, and determine the extents of damage. For example, in May 2009, when an earthquake struck, causing mass damage and chaos, officials knew exactly where to send help. The SERVIR program also allows local governments to use NASA's satellite mapping capabilities to better predict potential disasters, like floods and mudslides, as well creating an early-warning system for threats to the ecosystem, including water supplies.

On a more down-to-earth level, NASA technologies have also been applied to systems that alert motorists and pedestrians that emergency vehicles are approaching an intersection. Accomplished through traffic signal preemption, the process utilizes microwave transmissions from an approaching emergency vehicle to immediately change three signal lights to red to halt traffic, and one to green to give emergency vehicles right-of-way passage. Traffic signal preemption is capable of safely clearing intersections for ambulances transporting emergency patients, fire trucks making their way to a burning blaze, and police cruisers involved in a high-speed pursuit of another vehicle. Emergency vehicles also take advantage of the microwave transmission component to establish an intelligent two-way communication network with user agencies such as police and fire departments, transit authorities, and street maintenance units.

V. Conclusion

As NASA continues its missions into space, the Agency will no doubt create new, innovative technologies to carry its astronauts and protect these explorers along the way. It is unknown what new advances will be discovered along the way, as NASA begins longer duration space flights to the Moon and on to Mars, and as astronauts continue to live and work in the orbiting space station. What is clear, though, is that the lessons learned in space will come back down to Earth for the benefits of all mankind.

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