Research at The University of Alabama in Huntsville is more than the pursuit of basic science and knowledge — it’s the application of that knowledge as we strive to enhance competitiveness by developing, applying and transferring research into the marketplace to enhance the economic development of our state and nation.

UAH has extensive partnerships with governmental agencies, including NASA’s Marshall Space Flight Center, as well as the U.S. Army’s Aviation and Missile Command, and the Army’s Strategic Missile and Defense Command. However, UAH’s partnerships extend beyond the bounds of government laboratories. We build competitive alliances of technical focus that benefit all of our partners.

UAH continues to excel in the breadth and depth of its research efforts. This edition of Research Review highlights only a few of the exciting research activities at UAH. I invite you to learn more about our research and development programs at UAH — “Where research has no boundaries.”

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Dr. Lawrence R. Greenwood
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UAH researchers find novel way to speed diagnostic disease detection

Ice crystals within thunderstorms may help predictions of severe storms

UAH scientist investigates ways to reduce noises associated with aircraft

Data mining expertise at UAH is helping Air Force with war-like simulations

Nanotechnology research may provide alerts against attacks of bioterrorism

UAH researchers hope plant extract will combat parasites that kill thousands
Krishnan Chittur was sitting in the emergency room anxiously awaiting news about his infant daughter, Athena, born six weeks before she was expected. As with all premature babies, the doctors ran a multitude of tests as a precaution. A radiologist viewed dark spots in Athena’s lungs while viewing an X-ray and suspected pneumonia, common for premature babies.
Athena was immediately put on antibiotics to combat the possible infection. A blood sample was taken and sent away for tests, and the doctors explained it would take three days to get the results. Meanwhile, the physicians would continue to administer antibiotics to the child.

The test results, in fact, did return in three days and were negative for the bacteria that would have otherwise caused pneumonia. Krishnan Chittur, a chemical engineering professor at UAH, remembers asking the physician why the long wait getting test results.

“They told me they were using the best techniques available to doctors; it just took three days,” Chittur recalls. “Clearly, if Athena had pneumonia, the source of that infection would have been in her blood stream, and it should have been possible to detect it using more direct, sensitive tests.”

Ironically, this personal experience relates very closely to research that Chittur and his associates at UAH are conducting. They believe they have found a novel way to detect nucleic acids in complex mixtures, which can lead to finding infections faster and less expensively.

The system is simply called UD3 — Universal Diagnostic Disease Detection.

“Infectious agents are usually detected using indirect means. Testing laboratories will look for antibodies or watch a sample taken from the patient grow in some growth medium for a few days,” he said.

Chittur and fellow researchers have developed a process that seeks a direct test for the source of the infection. “It sounds easy but a significant problem has to do with sensitivity. Often the levels of the infectious agent are so low that it makes it close to impossible to detect them, so we are in a kind of race. We would like to detect them when they are at such levels when it will be possible for physicians to knock them out with available medication, and before they are able to grow to large numbers and overwhelm the patient.”

He said tests are available that look for bacteria or viruses directly. These tests observe the genetic material carried by the bacteria or viruses. These tests, known as nucleic acid tests, are a rapidly growing market. Chittur said, for example, the Red Cross tests blood donors right away for HIV and other pathogens and have an answer within hours.

Most of these tests, however, require copying molecules. This is an expensive proposition, and it’s difficult to look for more than one target at a time.

The UAH research took a different approach. A key principle in Chittur’s scientific investigation is “complementarity.”
"If you decide you want to look at something, say a bacteria or virus, then you find something that will strongly bind itself to it," Chittur said. "Researchers know the sequence of genetic information carried by various bacteria and viruses."

Those codes are reflected in four letters — A, T, C. and G. He explains that “A” will always bind to “T” and “C” will always bind to “G.” So, with a sequence AATTCGCTAAT, then you can design a probe with the sequence TTAAGCGCATTA and be assured that this molecule will bind to the specific target. The next step would be to add a light tag or a radioactive tag to the beginning or end of the sequence that would help detect the target molecule.

Researchers then take a sample, add the specific probe sequence and look for the tag. If that molecule is present, it confirms the presence of a target virus or bacteria. Chittur said the process is easier to describe than to carry out.

He said several problems exist, some similar to existing nucleic acid tests. The amount of material researchers are dealing with is so small that numerous copies must be made — not an easy task in itself, Chittur said. Additionally, searching for multiple targets in one step is difficult and expensive.

UAH researchers, meanwhile, have taken a novel approach to improve this process. They have designed a probe that contains two parts — one part that is complementary and a second part that is targeted to a specific sequence that can bind after the complementary portion binds to the target.

"Using our method, we can easily look for multiple targets using a simple technique," Chittur said. "We have shown this to work by taking samples from tick-infested dogs and we could easily detect the ticks (bacteria)."

Chittur is the principal investigator on the project, but he credits others with making significant contributions — Jeffrey Dowell, Joseph Ng and Marc L. Pusey.

Jeffrey Dowell is a graduate student in UAH’s Biotechnology Science and Engineering Ph.D. program and Dr. Ng is an associate professor in Biological Sciences and coordinator of the Biotechnology Science and Engineering Program at UAH. Marc Pusey works at Marshall Space Flight Center and helped the group with protein crystallization.

The UAH research team has filed for a patent on this technique and are seeking venture capital funds to commercialize the concept. Meanwhile, they continue to refine their investigation for real-life applications and seek research money from federal agencies to add to their knowledge.

Chittur said this novel approach to detecting bacteria and viruses will have numerous applications for veterinarian and human and medical diagnostics, such as infants born six weeks premature.
A new weather radar technology that will let scientists see when ice crystals inside thunderstorms align may help forecasters predict lightning and do a better job of estimating rainfall.

As part of a class project in a course teaching UAH graduate students how to use the new radar technology, two students and their professor used the new technology to look deep inside the cloud tops of a storm system that moved from Nebraska into western Kansas on June 3, 2000.

“This new dual polarized radar sends out signals with both horizontal and vertical polarized electric fields,” said Dr. Walt Petersen, a senior research scientist in UAH’s Earth System Science Center.

Dual polarized means the radar sends beams with two different pulses: In one pulse the waves oscillate up and down (vertically); in the other pulse they oscillate side to side.

When these beams strike an ice crystal, part of the signal is reflected back to the radar antennae. A portion of the energy in each beam, however, goes through the crystal and out the other side, until it hits another crystal and then another.

Each time a beam goes through a crystal the signal is distorted or delayed. And the relative amounts of delay for the horizontal and vertical signals that eventually bounce back to the radar antennae vary according to how the crystals are oriented. (Crystals standing on end slow the vertical signal more than they slow the horizontal signal.)
"Inside the cloud, as the electrical field intensifies it polarizes the ice crystals."

"Inside the cloud, as the electrical field intensifies it polarizes the ice crystals," explained Major Michael Gauthier, a U.S. Air Force officer and a Ph.D. student in atmospheric science.

If the electrical field is strong enough, it can tilt the tiny ice crystals upright. Flashes of lightning reduce the strength of the electric field and release the ice crystals from their upright positions.

"It's kind of like a feedback mechanism," said Patrick Gatlin, a student in the atmospheric science master's degree program.

To do the study, the team needed data from both the radar and a grid of detectors that pick up the radio signals made by lightning flashes.

Unlike typical lightning locator networks that pick up only lightning that hits the ground, the radio grid picks up and pinpoints lightning that stays inside the clouds — including all of the approximately 2,500 flashes of lightning detected inside the western Kansas storm.

When they looked at the radar and the lightning data together, the trio found an interesting (and expected) pattern: Periods of high ice crystal vertical orientation preceded periods of intense lightning activity.

Predicting lightning outbreaks is important because lightning is closely linked to many other storm processes.

"When you get flash rates approaching 100 lightning strikes per minute," said Petersen, "you almost always get some aspect of the storm that will be considered 'severe.'"

Because the new radar technology can also be used to detect the shapes of raindrops (small, round and buoyant versus big, flattened and falling out of the sky), it might also improve both short-range rain forecasts and estimates of how much rain fell between ground-based rain gauges.

"If you can get estimates of raindrop deformation, you can make estimates of rainfall from weather radar much more accurate," Petersen said.
RESEARCH COULD LEAD TO LESS noise for airplanes in their takeoffs and landings
Airplanes fly over Kader Frendi’s home in Madison frequently, and the roaring of the crafts’ approaches to the airport serve as a reminder of research he is conducting at UAH.

Frendi is searching for ways to reduce noise associated with the takeoff and landing of aircraft. He has been investigating the science of noise generation and noise reduction during most of his academic career.

Frendi joined UAH’s mechanical and aerospace engineering department five years ago, and is spending most of his time today conducting research in computational fluid dynamics and building the university’s capabilities in computing power.

Computational fluid dynamics (CFD) uses computers to solve complex nonlinear partial differential equations that model a problem of external or internal airflow over vehicle shapes. In practice, a physical object and the space surrounding that object are represented by a large number of grid points.

“One of the big concerns in the aeronautical field is the noise level generated by the takeoff and landing approaches of airplanes,” Frendi said. “Most people don’t know it, but during these two flight regimes (i.e. takeoff and landing) the noise from the airframe is almost equal to the noise made by the airplane’s propulsion system.”

Most of the noise during the plane’s approach to the runway is generated by the landing gear, the wing and the moving parts of the wing. Frendi has received a three-year, $200,000 grant from NASA-Langley to understand the source of those noises and to find ways to better control them.

The process of gaining that understanding starts by creating a grid with millions of points to represent a physical object and the space surrounding the object. In this case, Frendi is computing the flow over a section of an airplane wing using approximately 40 million points.

However, a limiting issue in CFD research is computing power. The computations get pretty complex very quickly when at each grid point you need to compute five variables (sometimes more). In addition, the computation needs to be carried out for a certain length of time to get all of the flow statistics. This complication arises because of the turbulent nature of the flow around such objects.

Such research in the past would take months or years. Today, Frendi will get the results within one week. These advances have been helped by more powerful computers, but even today’s fast PCs still lack the power necessary for CFD research.

So, Frendi is using the concept of cluster computing to solve that problem. He has created the CFD Laboratory at UAH by linking 64 computers together. “This 64-node cluster will allow us to find the noise sources and analyze the data much more quickly,” he said.

One of the challenges in cluster computing is dividing the computations among the various machines. Each of the 64 machines will handle anywhere from 500,000 to 1 million points apiece. “We will have to balance the load among the machines,” Frendi said. “If one node doesn’t have an equitable share, then it slows that one computer down. If you slow down one computer, you slow down all 64.”

That leads to another challenge of cluster computing — communication among the machines. But that has been solved with a new Ethernet connection that is capable of transmitting data at 1 gigabyte per second.

“We have moved beyond many obstacles in CFD research today,” Frendi said. “When I was at Langley (NASA research center) 10 years ago, we couldn’t compute 1 million grid points. Today, we are using 40 million grid points. That’s still too small.”

CFD researchers are ambitious, he said, and the science will continue to evolve rapidly. As a matter of fact, Frendi was quick to point out that even though the university just opened the 64-node lab, he is already looking at expanding UAH’s CFD Lab and doubling its capacity to 128 computers. “We’ve designed the lab with growth in mind. CFD research has a lot of applications, and the best way to take advantage of those opportunities is to build the university’s CFD capabilities.”
Researchers at UAH are teaming with a Huntsville-based software developer and the Air Force to enhance commercial software programs with the ultimate goal of improving the training of fighter pilots and soldiers.

In the commercial marketplace of computer games, numerous, inexpensive off-the-shelf programs provide a wide variety of simulated battle scenarios. These games have realistic graphics and often are built to historical accuracy — from famous American Revolution battles to up-to-date military actions.

However, some argue that these inexpensive programs lack much of the artificial intelligence (AI) capabilities that big dollar simulation systems offer.

Such capabilities are necessary to provide the accuracy and depth of information needed during the training of American service men and women for real-life situations.

UAH, the Air Force and well-known software game developer John Tiller are teaming up on a Small Business Innovation Research grant to bring together the inexpensive simulation worlds of commercial games and the demanding needs of the military.
Officials hope enhancements to existing commercial software games will provide better training at a much-reduced cost to the Department of Defense.

UAH researchers John Rushing and Steve Tanner are investigating different ways to customize existing computer games by looking at applications that can be used with multiple, visual artificial intelligence tools.

Tiller, a Huntsville mathematician retired from The Boeing Co., has developed more than 50 computer games, including a series of games called Modern Air Power. The first game in that series involves actual battles from the Vietnam Conflict.

The UAH research scientists are working at improving the game’s Artificial Intelligence (AI) capabilities to provide greater challenges to players. Such challenges may provide the key to better training of Air Force personnel. “We are looking at ways to change the behavior of the simulated enemy pilots in the game so that the strategies they use are better and smarter than our pilots might have expected,” Rushing said. “We are searching for ways to provide players with more challenges and thus improve the training value of the game.”

“Better to learn about and correct these in a game than in battle,” Tanner said.

Another important enhancement that most commercial games do not incorporate would be the ability to track an individual’s reactions during the use of the game and use that information to critique and improve their performance, according to Tanner. “We could identify both a person’s strengths and weaknesses, and change the game play based upon those. For example, if a player is consistently too aggressive or too timid, or if they rely too heavily on ground troops or air support, then the game should recognize those trends.” These tendencies would have to be tracked over a series of training exercises. They can’t be measured through one or two uses.

This Small Business Innovation Research (SBIR) effort is geared toward making improvements in the commercial games required for Air Force training, but at a much reduced cost and within a faster time frame than most Department of Defense simulation and training efforts.

Rushing and Tanner both believe that some of the playability and fun provided by that $50 game available at a local retail outlet may be the key to enhancing multi million dollar joint warfare theater-level models. They believe these enhancements could very well serve the Air Force’s need for improved training and at a much smaller price tag.
Photographs of these polymer etchings represent some of the early studies leading to the development of photonic devices being used in microcantiliver research at UAH’s Nano and Micro Devices Center.
It’s a quiet spring day in Washington, D.C., when an alarm goes off. The wailing sounds of sirens issue an alert for residents in close proximity to the Capitol Building.

Everyone is instructed to remain indoors until law enforcement office officials can determine what type of threat had been detected nearby. Minutes pass before special response units are able to determine that a tanker truck carrying a caustic chemical had been involved in an accident and a small leak in the tanker was spewing noxious fumes on the streets nearby.

Wind currents had forced the cloud of fumes away from the accident scene and past a small box that is attached to a light pole near the intersection of two streets in the nation’s capital. The small device, measuring only a few cubic inches, protrudes from top of the light pole. The gasses pass through a small vent and just a few seconds later, a buzzer and a light attracts the attention of a worker in the Office for Homeland Security. The worker confirms that readings from the device are accurate and he issues an alert.

This could be a likely scenario to demonstrate the importance of atmospheric detection alarms, but this scene could have just as easily involved a bioterrorist attack on Washington, D.C.

Research being conducted at The University of Alabama in Huntsville is providing the necessary technologies necessary to develop small devices that can be used in such scenarios, according to UAH researchers.

UAH researchers Mike George and Greg Nordin are investigating the use of micro-sized devices to assist in these types of developments.

“These types of devices really play to our strengths in micro and nanotechnology photonics,” said Dr. Greg Nordin, a professor of electrical and computer engineering, who also serves as director of the university’s Nano and Micro Devices Center. “We are able to use some of the photonic devices we have developed on our campus in pushing the development of biological and chemical sensor technology.”

The UAH researchers are constructing very small cantilevers to serve as the central sensing devices. These microcantilevers are extremely small, but are relatively large in the nanotechnology environment. Each cantilever is approximately 100 microns long (about the width of a human hair) and about 30 microns wide.

Dr. George, an associate professor of chemistry, said these devices act similar to the inside of a human nose. “For example, the receptors in a nose pick up the smell of a rose and tell the brain that it’s a rose, we are doing the same ting with these microcantilevers.”

He said these small arrays of microcantilevers can be coated five different ways and can detect dozens of gasses.

Drs. George and Nordin said researchers use these micro devices to measure molecular interactions. “Each of these microcantilevers have a material that is sensitive to various chemicals,” Nordin said. “If even a very small amount of a chemical agent is evident, then it chemically binds itself to the cantilever, causes a stress differential and the cantilever bends as a result.”

That bend is as small as 10 nanometers, a very small movement but one that can be detected by a light beam that reflects off of the altered cantilever. Nordin said when a certain amount of cantilevers have light deflected from their surface, a warning signal is then generated and is transmitted by some type of communication device.

Nordin said UAH researchers are seeking ways to retain the photonic ability to monitor a deflection as small as 10 nanometers and provide a “read out” mechanism.

UAH has finished the optical design for a first-generation read out mechanism, and has completed the first generation of microcantilever design. Nordin said computer modeling shows the UAH design will work, but more time, and money, will be necessary to develop a demonstration model.

Once this device is developed, Nordin said hundreds of these units could be used in a wide range of locations, especially in high-risk areas, or they can be placed on unmanned aerial vehicles or on other types of remotely controlled vehicles to provide detection without putting anyone’s life at risk.
Scientists at UAH are looking for a natural plant extract to combat a family of parasites that kills thousands of people in Africa and Latin America every year.

The three-year grant from the National Institutes of Health will fund screening of more than 1,000 plant extracts and compounds gathered in Costa Rica and the Bahamas by faculty and students in the university’s Natural Products Group. They hope to find one that kills or inhibits Trypanosoma, a family of protozoan parasites that cause Chagas disease in Latin American and sleeping sickness in sub-Saharan Africa.

“Because of the intense competition from bacteria, fungi, insects, nematodes and other organisms, tropical plants have developed ‘chemical warfare’ arsenals for their own defense,” explained Dr. Will Setzer, a chemistry professor at UAH and the principal inves-
tigator on the NIH grant. "Based on preliminary enzyme inhibition studies, we hypothe-
size that tropical rainforest plants represent a rich storehouse of new chemical agents
which may show inhibiting activity against these parasites."

In its early bioassays, the UAH team will test compounds against a Trypanosoma
pathogen that lives only in mice.

"That's a good thing," said Setzer, "because there's no cure for Chagas disease if you
get it."

With so many compounds already in hand for testing, Setzer says the first order of
business is inventing a "streamlined" anti-Trypanosoma assay. This assay will look for
compounds that bind to and inhibit two enzymes that are unique to this family of parasites.

Unlike most of the bioassays done in UAH natural products labs, this process proba-
bly isn't looking for a cytotoxic compound, said Setzer. Previous natural products research
at UAH has focused on finding toxic compounds that attack cancer cells, which grow and
reproduce more rapidly than most normal cells (and therefore ingest anti-cancer "poisons"
more rapaciously than normal cells).

By contrast, a compound toxic enough to kill the slower-growing Trypanosoma proto-
zoan would probably be so toxic that it would harm the host as well, Setzer said.

"Crude extracts have been assayed for their ability to inhibit key enzymes important
to parasitic protozoa," he said. "We have identified 20 tropical cloud forest extracts that
inhibit cruzain, a cysteine protease from Trypanosoma cruzi that is key to the parasite's
reproduction, and 19 crude extracts that inhibit trypanothione reductase, a key enzyme
involved in the oxidative stress management of Trypanosoma parasites."

It is estimated that more than 18 million people in Latin America carry the
Trypanosoma cruzi parasite that causes Chagas disease. The disease is spread through
the feces of blood-sucking Triatomid or "kissing" bugs. The parasite enters the human body
through the eyes, mucous membranes or open wounds. Fever and swollen lymph nodes
may develop within days. This early acute phase can cause illness and death, especially
in young children.

More commonly, a person might live for several years with no symptoms as the par-
asites invade most organs of the body. About one third of the people who are infected by
the parasite die from damage to the brain, heart or digestive system. Chagas disease,
which is found as far north as Mexico, kills about 13,000 people every year, according
to the World Health Organization (WHO).

The WHO estimates that as many as 500,000 people in Africa are infected with one
of the two Trypanosoma parasites that cause the two types of African sleeping sickness.
Without treatment the disease is usually fatal. The nervous system damage caused by the
parasite can cause retardation even among patients who are successfully treated.
A trip to the Moon. A manned excursion to Mars. It’s the conversation around NASA. These are the words that are creating a buzz around Huntsville — in 1961. And those same conversations are taking place again more than 40 years later.

It was a dream of Dr. Wernher von Braun to go to the moon, and on to Mars. He spoke of the trips as director of Marshall Space Flight Center. When he spoke to the Alabama Legislature on behalf of The University of Alabama in Huntsville, he described to that legislative body of the Saturn vehicles, which would help land on the moon. He also spoke of Nova as “the next big step beyond Saturn.”

As we know, the Saturn/Apollo program culminated in six manned expeditions to the lunar surface. But his vision of a flight to Mars was stopped short. America lost interest after NASA’s conquest of the Moon.

Dr. von Braun’s Nova program was to establish a lunar base. The idea was to put three men on the moon and leave 40,000 pounds of supplies and equipment on the lunar surface. He said add a nuclear third-stage and mankind could go into orbit around Mars and return to Earth.

The same questions that were being asked by the NASA community in the early 1960s are being asked again today. Once again talk revolves around lunar bases and a trip to Mars. Although quite a bit of technological progress has been made since man last stepped foot on the moon, large hurdles and challenges remain before such a return trip could be made and much more research is necessary to take the lengthier step of going to Mars.

John H. Marburger III, director of the White House Office of Science and Technology Policy, discussed the concept of a return trip to Moon and a journey to Mars when he visited UAH earlier last year.

He said President Bush believes that establishing a long-term goal for NASA could
help provide a more stable funding source than has existed for the space agency since those early days when President Kennedy challenged America to go to the moon.

“He (President Bush) is trying to get away from the spikes in NASA’s funding. What the president wants to see is a sustainable budget, a budget that is more consistent. Other areas of science funding are more stable than funding for space. NASA’s budget rides up and down on these big programs. If we can make that happen, then funding for other science areas within NASA would be much more predictable.”

Marburger said the Moon-Mars program is not sorted out yet, but providing a long-term goal for NASA should be better for science than the current situation.

As UAH played an important role in research and educating scientists and engineers during the space race in the 20th century, the university will surely play a similar, critical role for the latest version of manned space flight during the 21st century.

Research already taking place on the university’s campus today could have a very significant impact on how these trips may be conducted.

Clark Hawk, director of the UAH Propulsion Research Center, is investigating various propulsion systems that would be required for such a trip.

Civil engineer Sam Toutanji has been conducting research for years to perfect a building material using materials from the moon without using water.

Researcher Jim Blackmon is conducting research on a new material that helps dissipate heat generated in the vacuum of space.

Professor Ed Meehan leads a team of scientists in finding solutions to the problem of bone loss that astronauts experience as a result of long-term exposure to microgravity.

World-renowned professor S.T. Wu and his colleagues are working on new models that might predict the solar flares and eruptions that cause solar storms as much as several days or weeks before they explode from the surface of the sun. That information will be essential for astronauts flying through interplanetary space, where risks escalate exponentially and the acceptable margin for error shrinks just as fast.

These researchers will be among thousands of scientists and engineers across America and around the world that understand the value of discovery. It was Dr. von Braun who said curiosity sets man apart. And it is that curiosity that makes him learn. “The guy who is curious — the restless searcher for new knowledge — never knows where his curiosity will lead him. All he knows is that some time, in some way, the knowledge he digs up will better the lot of his fellow man.”

Dr. von Braun was convinced that the exploration of outer space would produce undreamed of benefits for all of those who inhabit the Earth. “And the very fact that nobody knows for sure what all of these benefits will be opens new prospects and excites our imagination to further progress.”
As Clark Hawk sees it, discussing a mission to Mars begins and ends with propulsion. There is not much need to discuss traveling to the Red Planet if there is no energy behind a spacecraft pushing it along the 130-million-mile journey.

Hawk is director of the Propulsion Research Center at The University of Alabama in Huntsville (UAH). He envisions several options that would allow a craft to travel that long of a distance — options that mostly involve nuclear power.

“A combination of a propulsion system that involves nuclear power and an electric thruster is one of the near-term possibilities that makes sense and offers a very real chance of success,” Hawk said from his second-floor office at UAH’s Technology Hall. “The engine would require a lot of power. Something on the order of up to 1 megawatt.”

Combining this tremendous power with an electric device that has a specific impulse of 3,000 to 4,000 seconds would create a propulsion system that could
provide enough energy to make a trip to Mars and return back to Earth in a time frame of less than two years. Specific impulse is the amount of thrust achieved for a specific amount of propellant flow per second, such as one pound of propellant per second.

This nuclear power source and electric thruster combination would provide more energy, be more efficient, and would provide faster speeds than existing chemical combustion engines, according to Hawk.

An example of a propulsion concept that could be used for the lengthy trip to Mars is magnetoplasmadynamics (MPD). While the physics may seem a little complicated, the technology is relatively simple. It can provide very high thrust densities (lots of force in a small package) and moderate to high specific impulse.

The MPD thruster mainly uses an electromagnetic (Lorentz) force to accelerate an ionized gas to high exhaust velocities. The force is produced by an interaction of the discharge current and either a self-induced or externally applied magnetic field.

Another option would be a nuclear thermal thruster. The engine would include a nuclear fission reactor, which would work in a similar fashion to nuclear power plants on Earth. For example, a nuclear reactor aboard a craft would heat up from fission reaction inside the chamber.

A coolant, generally hydrogen, would be used to keep the reactor cool. As the temperature of the hydrogen increased, it would be expelled out and propel the spacecraft along its journey. This type of propulsion is not as efficient as other systems (a specific impulse of 850 to 1,000 seconds), but it would generate much more thrust. The advantage of this system is travel time will be measured in months, not a couple of years.

One of the issues that exist with any propulsion systems designed for extreme distances is the durability of the thruster when being operated months at a time. “If these thrusters are operated continuously, they can lose mass from the reactor core or the nozzle, which confines and directs the flow of a very hot gas during the months of operation necessary for the duration of a flight as lengthy as a mission to Mars,” Hawk said. “This introduces safety and reliability concerns for a manned flight.”

UAH research engineers and scientists are searching for ideas on building an electric propulsion device that could withstand the environment of high-temperature gases flowing through the thruster at speeds of up to 30,000 kilometers per second. This compares to a speed of 3,000 meters per second for chemical combustion engines. “The big question is how to we dump that much energy through a thruster without damaging the driving device,” he said.

Hawk said UAH is involved in a collaborative effort with Colorado State University on a unique accelerator that uses an electrically conducting composite structure to accelerate the gas. The device uses carbon fibers surrounded by graphite. “It is creating a thruster with longer life possibilities, but we’re still not sure it will satisfy the requirements of a mission to Mars.”

One possible, troubling aspect in all of these propulsion systems is the use of a nuclear power source. The idea of putting radioactive material on a rocket to be launched into space is a little unsettling for some Earthlings.

Space law governs the use of nuclear materials being launched into space. The Russians have been using nuclear power in their space program for years and NASA has used nuclear materials in a number of flights. The launch of the Cassini space probe created a furor when it was launched four years ago with 72 pounds of plutonium; however, the value of nuclear propulsion was demonstrated with the success of that mission as the spacecraft reached Saturn a few months ago.

The space agency did extensive studies and concluded that the odds of accidental re-entry were one in 1 million. NASA scientists also point out that if an accident did take place, the added dose of radiation during the next 50 years would be 1/15,000th of the normal atmospheric background.

At some point, Hawk said researchers have to confront a number of very diverse issues when choosing a propulsion system — reliability, safety, efficiency and the length of the trip. “The time humans spend in space will be a significant factor when you look at these various options,” he said.
Commander’s log, June 3, 2017, 428 days from Earth, 312 to Mars: The solar magnetic storm that brushed by Earth yesterday hit us full blast this morning. Good thing the UAH warning gave us enough time to get everyone inside, reef the sail and shield the electronics. Otherwise a quiet day hunkered down listening to grandpa’s Jimmy Buffet chips.

A series of massive solar ejections in late October and early November 2003 forced astronauts aboard the International Space Station to retreat to the more heavily shielded Russian module, and made airline traffic divert from normal flight paths over the North Pole.

Through it all Dr. S.T. Wu, director of UAH’s Center for Space Plasma and Aeronomic Research (CSPAR), was beaming like a proud grandfather.

Wu was beaming because the computer models that forecast (with reasonable accuracy) when those solar storms would hit Earth are based on one of his
“babies” — a theoretical model that Wu and one of his former students, Dr. Sang M. Han, ’85 Ph.D., mechanical engineering, published in 1985.

Now Wu and his CSPAR team are working on new models that might predict the solar flares and eruptions that cause solar storms as much as several days or weeks before they explode from the surface of the sun.

As useful as that information might be for astronauts in low Earth orbit, airline pilots on polar routes and the people who run electrical power systems in high latitudes, it will be essential for astronauts flying through interplanetary space, where risks escalate exponentially and the acceptable margin for error shrinks just as fast.

It is, after all, a long, long way from Mars to the next gas station.

Based on work by Dr. David Falconer, a senior research associate at CSPAR, Wu and his colleagues have modeled four criteria or levels of specific solar activities that apparently precede solar eruptions. These criteria include the length of certain twisted or sheared magnetic field lines rising from the solar surface, the level of electric current within a region of solar activity, a measure of how much the magnetic fields are being twisted, and a measure of total magnetic flux within that active region.

“If we see that they meet those criteria, we can predict that something will happen,” Wu said.

While Wu is confident that he is on the right path, he plans to move cautiously. He will use archival data to test the model against several types of solar events, to see if it can “predict” what has already happened.

“That’s the working scheme, to put it to the test,” he said. “Then we will use forward modeling and get ready to do predictions in the future. If I’m successful we will put some of this science to use.”

Given the complexity of the system, Wu says it might take another five or six years to have a “mature” and reliable system in place to predict solar eruptions.

Based on UAH research, however, space weather forecasters are already beginning to predict when incoming solar storms might hit Earth’s atmosphere, how strong they will be and how long they might last — “the practical information people need to protect their systems,” said Wu.

“That research has paid off in operational products,” said Dr. Craig Fry, vice president of Exploration Physics International, and a retired U.S. Air Force space weather forecaster who moved to Huntsville so he could collaborate with Wu and CSPAR. “We’re trying to be able to track solar disturbances all the way from the sun to the Earth, to be able to predict the arrival times of these storms and how big they will be.”

“We do have the capability to predict the solar eruption shock wave and to calculate the high-energy particle output which might threaten astronauts,” Wu said recently.

The newest UAH-based solar storms model predicted both the strength and duration of the most powerful of the October-November solar storms, but were a few hours off on the time of arrival.

That might be because the storm was on a fast track: A typical solar magnetic storm takes three or four days to travel from the sun to the Earth. The October 29 solar storm hit Earth’s magnetosphere only 18 hours after a massive explosion above the sun.

Using a variety of instruments, including an Air Force satellite launched in 2003 and the STEREO satellites scheduled for launched in 2006, “we want to be able to track disturbances all the way from the sun to the Earth, and to be able to predict arrival times and how big the storms will be,” said Fry.

“If the model really works, we will transfer it to operational use; give it to people for forecasting,” said Wu. “Our end goal is a system that would automatically input data from the satellites into the model. We would like to see how these things initiate. Then we could predict them, maybe next month or next week.”
One of the risks facing astronauts on a lengthy excursion into space would be a tremendous amount of heat generated by the spacecraft from a variety of sources, including a major source of heat such as that produced by a nuclear generator, power plant or rocket engine.

Life would be more than just uncomfortable for space travelers if that heat were not transferred away from the spacecraft and into space.
Dr. Jim Blackmon, a professor in UAH’s Propulsion Research Center, is conducting research on dissipating heat through radiators. While he has been conducting research on thermal management systems for years, he has concentrated his efforts during the past year on a new material that promises to improve current heat transfer tremendously.

That material is being developed in a cooperative effort with a privately owned company, HiTek Services. The company approached UAH because of the university’s testing and diagnostics expertise, and UAH and HiTek have been conducting research since that time. UAH’s research has been conducted under a grant by NASA, according to Blackmon. Because the makeup of the material is proprietary, few details are available.

However, Blackmon said the material’s conductivity is so high that researchers have been having trouble achieving accurate measurements. The material is coated inside thin tube walls, and has shown amazing heat transfer qualities.

“This material has shown effective thermal conductivity properties far in excess of any known material,” Blackmon said. “We’ve been exploring ways of obtaining valid results, and we are also researching how robust these tubes would be under severe conditions. So far, the results have been very encouraging.”

At this point, Blackmon said his goal is to move the material beyond the laboratory research phase and into advanced applications, but he doesn’t have a timeline.

The tubes that HiTek and UAH scientists are testing are just part of the importance of overall thermal management for long-term spacecraft travel. Heat is generated by the travelers themselves as well as the electronic components and sensors that will be on board. But the overriding issue is the heat created by a spacecraft’s engines and power plants. Long-term missions will not be possible without dissipating the heat from these sources.

Blackmon said heat from the propulsion and power systems would keep building to the point that the craft would not be inhabitable and eventually the equipment would destroy itself. That’s why thermal management research is important, according to Blackmon.

“Controlling waste heat in space is far more difficult than on Earth,” he said. “The only way heat can be dissipated in deep space is through radiators that emit energy in the far infrared, at moderate temperatures, which is not an efficient process.”

Advances in materials science, such as the current research he is conducting, will play a critical role in spacecraft design for future exploration missions, such as a trip to Mars, but also for a number of applications on Earth. “For heat transfer to take place in space, it would take large, heavy radiators. And the area of the radiator can be a significant part of the total area and mass of the spacecraft.”

Blackmon, though, believes these advances will help provide solutions and create improvements in spacecraft design.
No bones about it …

The math is pretty stark: An astronaut loses more than 1 percent of his or her bone mass for every month spent in space.

About 1 percent of the spine. More than 2 percent of hip bones. Every month.

Any proposed trip to Mars would be expected to last at least five or six years. That’s 60 to 72 months.

By the time astronauts from a Mars mission returned to Earth, their bones might be too frail to support their weight under normal Earth gravity — assuming their bones weren’t crushed to shards and powder by the multiple G forces of re-entry.

For people trying to plan interplanetary space exploration, that kind of thing might pose a problem or two.

“Losing one percent of your spine every month would be a bad thing. NASA’s going to have to fix this problem,” says Dr. Ed Meehan, a professor of chemistry and director of UAH’s Laboratory for Structural Biology (LSB), where scientists are part of an effort to find ways to stop the bone loss and, at the same time, find new treatments for a family of bone diseases that afflict millions of people down here on the ground.
“Under normal circumstances our bodies maintain a fine balance between making bone and degrading bone,” Meehan explained. “In old age, the process of making bone slows and the balance shifts to degrading. That’s what causes osteoporosis. The same thing happens when we go into space. The process of making bone slows and the balance gets messed up.”

The problem is stress … or the lack thereof.

“We’ve got internal mechanisms to sense physical stress,” Meehan said. “That physical stress stimulates bone growth. That’s one reason weightlifters develop dense bones. Without the stress of moving around in gravity that mechanism isn’t triggered. Patients in bed rest also lose bone mass.

“NASA thought exercise would solve this, so they put in an exercise program for astronauts in the space station. But they have found that even with exercise, the bone loss is the same as it was a decade ago. They expected to see that the exercise program had reduced bone loss, but they didn’t see that at all.”

Bone therapies are based on trying to restore the proper balance, either by boosting bone production or by slowing bone destruction. Using a variety of tools, the LSB team has determined (mapped) the 3D molecular structures of three proteins involved in the normal process of destroying bone cells and is preparing to map a fourth.

All four of these proteins are involved in the bone destruction, or resorption, side of the equation. If drugs can be developed to inhibit one or more of these proteins, that might restore the balance and slow (or eliminate) long-term bone loss.

One modern process of drug development involves building molecular “keys” to lock or unlock proteins that perform certain specialized functions — such as triggering the process of bone resorption. Before a key can be designed, however, you need a detailed diagram of the lock.

Providing those detailed diagrams is one of the special roles of UAH’s LSB team.

UAH is unique in that it has two facilities using different techniques to determine the structures of proteins, enzymes and other biological building blocks.

In the LSB, scientists grow crystals of purified proteins, then blast those crystals with powerful X-rays. Because the protein molecules are locked into the crystalline matrix, the X-rays are deflected in set patterns that the scientists can use to calculate the structures that cause them. If it needs to look at something in greater detail, the team has access to the more-powerful X-ray facility at Argonne National Laboratory.

Downstairs from Meehan’s lab is UAH’s Nuclear Magnetic Resonance (NMR) Lab. NMR spectroscopy is the same process used in medical MRI machines, although on a scale that lets scientists look at molecular structure at the atomic level.

UAH’s work in this field has already yielded one product, a “gene filter” that helps researchers studying possible causes of bone diseases. Developed in partnership with Research Genetics, the filter helps researchers see which of 5,000 genes involved in bone growth are active and which are inactive under specific circumstances.
High rise structures on the lunar surface? Well, maybe not skyscrapers, but the possibility exists that concrete structures could be built by astronauts using material indigenous to the moon.

Houssam Toutanji, professor of civil engineering at UAH, says raw materials needed to manufacture concrete on the moon exist in abundance. As a matter of fact, he says concrete produced on the moon has a good chance of being stronger than concrete made on Earth.

Toutanji has spent his research career studying the characteristics of concrete, including the last four years investigating the possibility of making concrete on the moon. During those four years, he has had a share of scientists telling him that he was wasting his time—America would never go back to the moon. A wide grin spreads across his face. “Those are the same scientists who are calling me, emailing me and asking me about my research today,” he said.

Dr. Toutanji said the emphasis placed on his research changed when President Bush announced in early 2004 that America was going to focus its effort in space exploration by returning to the moon and eventually traveling to Mars.
His research and interest in lunar concrete began during a 10-week fellowship at NASA’s Marshall Space Flight Center. He spent that time using real lunar soil brought back from the moon missions of the Apollo program. During his short fellowship stay, he concocted a number of “recipes” and formed small strips of lunar concrete. He then subjected those samples to various types of tests, such as heat, compression and tension.

The fine, powdery nature of lunar soil actually makes it a good ingredient for concrete because it would create a substance that would have less air gaps within the cementitious material, according to Toutanji. “The finer the material, the more homogeneous the material will be, and homogeneity usually provides more strength.”

At the same time, scientists already knew that producing concrete in a microgravity environment does not harm the strength of the concrete. Actually, a 1994 UAH experiment aboard the space shuttle Endeavor showed that microgravity has the opposite effect. The scientists found that a lack of gravity produced fewer voids in the concrete and the material was just as strong. “The combination of low gravity and fine lunar dust could result in a strong concrete.”

Dr. Toutanji’s research so far shows a concrete that is 45 percent stronger. His experiments reveal that concrete produced from lunar soil could withstand pressure of 5,800 pounds per square inch, compared with 4,000 psi for normal concrete on Earth.

While the lunar soil provides most of the raw materials needed to make concrete, a binding agent is required. On Earth, cement and water are used as that binding agent. Obviously, water is not as plentiful on the moon. “The idea that water exists on the moon is open to discussion. Even if we can find water, it will be such a precious commodity, it will be more valuable for use in other applications.”

In recent months, Toutanji’s research has pointed him in a different direction for a binding agent. It took four years, but he has produced a breakthrough that would allow astronauts to produce concrete without water.

“We began looking at the approach of making concrete without water,” he said. “We used the Dry-Mix/Steam-Injected method to produce concrete. We found that this method offers advantages, such as shorter hydration time, higher strength, and less cement and water consumption.” Then, he began experimenting with sulfur to bind the simulant lunar dust together to form the concrete. “We used only sulfur and simulant lunar soil in concrete. We have known that sulfur is useful as a binding material and sulfur cement concrete has been used on Earth in a number of applications.”

The process of making sulfur lunar concrete involves heating sulfur to 250 degrees Fahrenheit to melt it and adding an aggregate (regolith). “After the sulfur and aggregate are mixed thoroughly at a temperature above the melting point of sulfur, the sulfur concrete mixture is poured into a mold of a desired shape. The proportion of sulfur to aggregate is very important in determining the right mix with the best mechanical properties,” Toutanji said.

He said sulfur is found in abundance on the moon’s surface. “The sulfur content of the lunar regolith is mainly controlled by troilite (FeS), and extracting sulfur from the lunar soil is possible using a series of chemical processes.” Thus, making the prospects of constructing permanent structures on the moon proves to be plausible.
Continuous improvement efforts at McDuffie Coal Terminal are expected to have millions of dollars of impact for Alabama.

Officials at the Alabama State Port Authority were searching for ways to improve productivity at McDuffie, one of the largest coal terminals in the country. Port authority officials looked to UAH’s Alabama Technology Network (ATN) to teach and implement lean manufacturing practices. The idea of lean operations is to eliminate wasteful, non-value-added activities in a process resulting in lower costs, improved quality and shortened lead times.

McDuffie handles more than 15 million tons of coal per year. This bulk operation operates 24 hours a day/7 days a week/360 days a year and runs at capacity. Customers of McDuffie expressed that they would like to double the amount of import coal coming through the facility, yet McDuffie management did not believe this would be possible without major capital investment. With the assistance of UAH lean manufacturing specialists, the goal of increased coal flow through McDuffie is now attainable.

Using the basic principles of lean manufacturing, McDuffie expects to drastically increase the amount of coal that passes through the facility, which in turn will improve revenues and better satisfy customer requirements.

“Continuous process improvement is off to a good start at McDuffie Coal Terminal,” said Jeff Siniard, a research scientist at UAH. “There is a very limited amount of lean activity being applied in bulk handling facilities across the country and the work UAH is doing with McDuffie could be used as a model for facilities nationwide.”

The UAH team began their work with McDuffie in 2003 and will likely continue working with the Alabama State Port Authority for years to come. To date, ATN and McDuffie employees have developed an operations model that will use the employees and equipment more efficiently and eliminate non-value added activities. As part of this process, all 160 McDuffie employees have been trained in lean concepts.

Involvement by McDuffie employees is essential in identifying wasteful activities, generating ideas for improvement and implementing those changes. The first major “kaizen,” a Japanese phrase meaning good change, occurred in November 2004 and proved to McDuffie employees that the lean concepts they were learning actually worked.

The kaizen event aimed to decrease the amount of time it took to load a barge. After days of observation, it was determined that the average barge loading time was 119 minutes. The team of McDuffie employees was given the explicit goal of determining how to get the cycle time to 60 minutes or less for loading one barge. The team exceeded the expectation and within a week cut the time by 55 percent, down to 53 minutes.

The Port Authority’s Director and CEO James K. Lyons has been impressed with the increased efficiency. “Lean manufacturing models have proven beneficial to our customers and we anticipate similar results for our program,” he said. “McDuffie’s increasing coal business combined with better operational and throughput performance will secure its place as the most versatile and productive coal handling facility in North America.”
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