Innovation Quarterly

2020 Q1
Volume 4, Issue 14

Dream Space

Propulsion engineer sets sights on the stars

Share the Air

Ensuring the safety of future mobility

Sustainable Industry

Four cutting-edge materials science methods

PLUS:
A forward-looking workforce in Korea

Boeing space propulsion engineer Julie Mason in front of a Saturn V rocket at the U.S. Space & Rocket Center in Huntsville, Alabama.

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Page by Page

When we partner, we **succeed**

At Boeing, we connect, protect, explore and inspire the world through our innovations and technical achievements. But we don't do it alone. Working closely with partners and stakeholders across industry, academia and government is crucial not only for our success but also for shaping the future for the benefit of everyone.

The power of collaborative partnerships appears on almost every page of this edition of Innovation Quarterly.

Julie Mason's inspiring quest to become an astronaut would not be possible without NASA's Human Exploration Research Analog research program.

Our joint ventures with such companies as SparkCognition open opportunities to create a safe future airspace management system through SkyGrid, which Amir Husain astutely points out.

Research partnerships, such as our Galician Skyway Project consortium of industrial and government entities in Spain, are developing and testing several key technologies that will create a safe, optimized airspace that one day will be shared by piloted and autonomous vehicles.

Jonathan Lee shares how the new Boeing Korea Engineering & Technology Center exemplifies how each of our global technology centers serves as a nexus of government, academic and industry partners to not only advance the state-of-the-art but also embody our core values of safety, quality, integrity, and diversity and inclusion.

We have the deepest impact when we contribute to and engage with the broader technical community. The men and women featured in this edition of IQ are active in professional organizations, technical societies and standards-setting bodies to share with — and learn from — peers in their disciplines and beyond.

These are just a few examples of how we succeed when we perform as a connected, global team. IQ

GREG HYSLOP
Chief Engineer

Propelled to explore

Space propulsion engineer Julie Mason keeps her eyes on the sky — and beyond.

BY JARED KAUFER, BOEING WRITER

Hovering just inches below the ceiling, Julie Mason's hair rises up. She stretches out her arms to keep from bouncing off the padded walls. This is exactly where she wants to be, learning what weightless feels like, aboard a reduced-gravity aircraft used for astronaut training.

"The first time I experienced microgravity, I floated to the top with a huge smile on my face," said Mason. "I actually looked and felt like an astronaut."

Fitting, as Mason, a space propulsion engineer out of Huntsville, Alabama, wants to *be* an astronaut. And she sees close correlation between her everyday work and her astronaut aspirations.

"Being at Boeing allows me to participate in cutting-edge propulsion research, where I get to lead and work in teams to solve challenging problems," she said. "I'm currently working on a propulsion test program that could benefit NASA's Human Lander System for a 2024 lunar mission."

ROCKET WOMAN
Boeing space propulsion engineer Julie Mason in front of the Saturn V rocket in the Davidson Center for Space Exploration, located at the U.S. Space & Rocket Center in Huntsville, Alabama.

PHOTO: J.P. BOND

PHOTO: NASA

CENTER OF GRAVITY
Julie Mason's first of what she hopes are many journeys in microgravity.

> "I told my parents I wanted to be one of those astronauts."
>
> **JULIE MASON**

"When you're working on a propulsion test program, safety is critical. You're working in a higher-risk environment than just an ordinary office, which is exactly what astronauts are asked to do on a daily basis," Mason added. "Unforeseen issues can arise in outer space that the astronauts must work to solve. You're constantly using analytical skills to evaluate the situation and find a resolution. It's definitely not one for one, but I feel like it's bringing me one step closer."

She took one small step in her path to aerospace as a 12-year-old.

"My parents took me to a launch at Cape Canaveral and a tour of the NASA facility," she recalled. "It was an awe-inspiring moment. And it was at this time I told my parents I wanted to be one of those astronauts."

Fast-forward two decades. In summer 2019, she found herself in a capsule in Houston, by choice, for 45 days. She was one of four participants in NASA's prestigious research program Human Exploration Research Analog (HERA), in which confinement and isolation are intentional.

The program allows scientists to safely determine on Earth how to deal with the effects on the human body and mind of living in space.

Mason's mission made a "trip" to Phobos, the larger of the two moons of Mars. Though they never left NASA's Johnson Space Center, participants acted as if they did, performing a virtual spacewalk. They also worked with a simulated robotic arm and communicated with students "back on Earth." Mason grew lettuce in the team's hydroponic garden.

"Most of our meals were typical to what you might take camping," she explained. "It needed to be rehydrated with hot water. No fresh food or resupply was allowed."

Years earlier, Mason also played a leading role in a different NASA project. She was part of the team that designed the Badger eXploration Loft (BXL), an inflatable space habitat

PHOTO: BADGER X-LOFT TEAM, UNIVERSITY OF WISCONSIN-MADISON COLLEGE OF ENGINEERING

LOFTY IDEA
Mason and project teammates put the finishing touches on the Badger eXploration Loft, perched atop NASA's Habitat Demonstration Unit in Houston.

that deploys upon landing, which sits on top of NASA's Habitat Demonstration Unit (HDU).

A NASA competition had provided three universities with $50,000 each to conceive and build a habitat for an environment beyond Earth. The university with the highest-graded design would be used by NASA to conduct simulated Mars missions. The University of Wisconsin, and Mason, won.

Their entry, the BXL, is an external fabric shell with integral, pressurized airbeams for structure and air conditioning and heating. The interior skeleton is a mixed carbon fiber and aluminum deployable and retractable structure that elevates the sleeping quarters above the living quarters of the habitat using electric actuators.

NASA stationed the HDU in the Arizona high desert near Flagstaff in 2011. It was a shining moment in Mason's senior year at Wisconsin.

"I had the opportunity to be part of a team that stayed a night in the habitat," she said. "It was exciting to be part of the mission and see NASA astronauts sleep in something I created."

Mason's father, Scott, believes her interest in aviation and space started even before she could walk, in the open fields of Wisconsin.

HIGH ASPIRATIONS
Mason exults 22,837 feet above Argentina, on Aconcagua, the highest peak outside of Asia.

PHOTO: JULIE MASON

"I used to own an old Apache twin-engine. When Julie was an infant, we'd strap her in the back in her car seat and go flying around. That was her introduction to aviation, whether she has any recollection of it or not," he said.

In middle school, Mason and her family spent time in Europe, which sparked an interest in foreign languages. This became an unexpected asset in her quest to become an astronaut.

"I feel that it helps me to connect with people from different backgrounds and to learn about other cultures," said Mason, who is now fluent and French and studying Russian. "Learning languages has also been shown to help keep you mentally fit as you age and utilizes a similar skillset as that required for writing computer code."

The summer before she started high school was also a life-changer for Mason. She attended Space Camp in Huntsville on the grounds of the U.S. Space & Rocket Center, which is, coincidentally, a five-minute drive from where she now works.

"We completed mock missions and I was chosen to be a mission specialist," she recalled. "I felt like that's what I would apply for in the astronaut corps, so I wanted to get all the practice I could."

Mason graduated from Space Camp and has been invited back several times to speak with the young campers about her experience and to discuss her current role as a space propulsion engineer. She's never been shy about sharing her space dreams.

"All my teachers were very supportive of my goals," she said. "I still keep in touch with my physics teacher and have gone back to participate in STEM activities with his classes."

Though her goals are out of this world, she wanted to stay close to home for college. She enrolled at the University of Wisconsin-Madison, double-majoring in engineering and French. While there, however, she was selected to participate in the NASA Flight Opportunities Program at the Johnson Space Center in Houston, working side by side with NASA engineers and scientists in the microgravity program. And that's how she had a chance to float in a converted jet.

"I conducted experiments on an airplane dubbed the 'Weightless Wonder,' which does parabolas in the sky," she recalled. "We had 30 seconds of microgravity in the plane."

Her power-packed college career also included her introduction to Boeing via a Seattle internship.

"I just loved the culture and the people. I felt like I was constantly learning from everyone around me and that Boeing was a place where I could grow and become a better engineer," she said.

In her final semester in 2012, she got a letter she'll never forget.

"I remember carrying around my Boeing offer letter through the halls because I was so excited. It was a dream come true to come to Huntsville, where I spent time at Space Camp as a kid, and work as a propulsion engineer. It truly felt like I was coming full circle."

Mason first worked on propulsion design when she started at Boeing, but she has since begun to focus on the research side of propulsion.

"I see propulsion engineering as something that will help us get to Mars if we can build and improve the systems to get there," she said.

Although immersed in her work, Mason continues to add to her well-rounded resume. She achieved her master's degree in aerospace engineering from the University of Alabama-Huntsville. She has earned scuba certification, wilderness first-responder certification and a pilot's license.

LIKE FATHER, LIKE DAUGHTER
Mason at the controls of a Cessna 172 with her dad, Scott, above Wisconsin.

PHOTO: JULIE MASON

> “I am confident I am on the path to becoming an astronaut.”
>
> **JULIE MASON**

PHOTO: NASA

MOON MESSAGE
Mason still has this poster from her childhood. Astronaut Jim Lovell (left) gave her a boost with his autograph in the lower left.

And she has dreams to climb the tallest peaks on all seven continents — which she already started by bagging Aconcagua, the tallest mountain in South America.

She draws parallels between ascending mountains and traveling to space.

“When you summit a mountain, you’re exploring new environments and working in a team to accomplish a goal,” she said. “Exploring outer space is not something you can do alone.”

And just like on the peak of a mountain, she keeps her eye fixed on her ultimate goal. NASA recently sent out a call. Julie answered. She just applied for the next class of astronauts.

“It’s every four years,” she said. “The more you apply, the better your chances are of getting accepted, as NASA likes to see what you’ve done between applications.”

If she does not get selected this time, she plans to pursue her doctorate, become EMT certified and possibly even head to Antarctica to conduct research.

“I believe if I work really hard and focus all my energy on achieving my goals, I am confident I am on the path to becoming an astronaut,” she said.

In Mason’s dining room, a poster hangs on the wall, not of a musician or movie star or athlete. It’s an original Apollo 13 mission poster signed by NASA astronaut Jim Lovell. It includes a message: “Hi Julie — I can’t wait to see you walk on the moon.”

Someday soon, she just might.

Our crew received specific training from NASA prior to Human Exploration Research Analog (HERA) that helped me be successful during my 45 days in isolation. I used my time in HERA to develop and practice these skills, knowing they would make me a better crewmate and that I could apply them in life after HERA. While I ultimately hope to use my skills as an astronaut one day, the lessons I’ve learned pertaining to communication, team building, personal growth and happiness are also useful in everyday life.

LESSON 1:
Process-based goals you can focus on day to day are important for enjoying the journey.

As a goal-oriented person, I tend to focus on setting goals each day with a strong understanding of how they fit into my long-term plans. I knew that going into HERA, I would need to put parts of my life, including some of these plans, on hold. I learned a new mindset while in isolation. That was to let my HERA experience become the path toward achieving alternate goals that I could focus on within the 45 days. I learned to let go of a lot of things that were out of my control, to accept the rules of the simulation in the name of science and to be a part of a larger mission. I found growth opportunities and self-improvement in isolation through this self-awareness and training provided by NASA for our mission. This shift in mindset has continued outside HERA, where I find myself with a greater appreciation for the process and the journey.

LESSON 2:
Trust, respect and transparency play a key role in the development of a successful team.

Our HERA crew transformed from a group of strangers to a successful team with established norms and a common idea of how we wanted to live and work together. Reflecting on my role in this process has helped me better understand how teams form in a typical development cycle. Heading into HERA, I was warned about the potential for disagreements and was provided training on relationship development and maintenance. I knew that crew members from previous isolation studies did not always remain friends after confinement together, but I went into the habitat with a different mindset of creating lifelong friends. My goal was to understand individual viewpoints and determine any expectations for our living and working arrangement. I attempted to be proactive in eliminating potential conflicts by communicating my intentions, respecting my teammates and trusting each. I learned a lot from every one of my crewmates along the way. And the result was a mutual trust and friendship. As a more reserved person, it was exciting to step out of my comfort zone and get to know my teammates. Being able to learn, practice and become a successful HERA team is something I’ll take with me and apply to the current teams on which I work and in my day-to-day interactions.

LESSON 3:
Isolation was different than I expected but ultimately confirmed my desire to be an astronaut.

One of the reasons I enjoy expeditions is that they are both physically and mentally challenging. These environments foster my ability to prepare and meet those challenges. I went into HERA with an idea that the experience might be similar to camping or mountaineering. However, there was something different about the confinement of HERA. On a mountaineering expedition, you interact with new people daily and experience the elements of weather and nature. But during HERA, we did not go outdoors at all, and our interactions were mainly limited to crew members. I found by focusing on the mission, my crew and daily gratitude that being a part of HERA was as enjoyable and challenging as many of my trips in nature. Participating in HERA strengthened both my confidence and my desire to be an astronaut.

Recognizing Advanced Developments and Research

Tech RADAR

Boeing's Foresight and Technology Intelligence Community of Practice tracks innovation and new ways of thinking around the world.

The next best power source: body heat

West Lafayette, Indiana

As we wear more electronics, researchers at Purdue University have created a thermoelectric, flexible fabric that turns body heat into power.

purdue.edu

New wing design inspired by insects

Providence, Rhode Island

Brown University researchers are discovering what insects and birds have known all along: Rough and sharp wing edges might be more effective and stable.

brown.edu

Microscopic measurement of nanoparticles

Minneaoplis, Minnesota

Mechanical engineers at the University of Minnesota have developed a prototype instrument to more effectively and quickly measure the surface area of aerosol nanoparticles.

experts.umn.edu

A better way to group by text

Viçosa, Brazil

A computational math approach to grouping documents based on both vocabulary and semantics similarity improves the quality of document clustering compared to techniques that cluster based on vocabulary alone.

locus.ufv.br

Computer chess champ makes quantum leap

Aarhus, Denmark

As the world races to build a quantum computer, a research group at Aarhus University in Denmark used AlphaZero, a computer algorithm renowned for its prowess at chess, to control a quantum system.

nat.au.dk/en/

Hands-off robot holds without touching

Zurich, Switzerland

Levitation is happening in Switzerland as a former ETH Zurich University doctoral student is developing a robotic gripper that uses sound waves to hold objects.

ethz.ch/en.html

Printing carbon fiber composite repairs

Seoul, South Korea

Researchers in Korea, in collaboration with Boeing, have developed a portable printer that can repair carbon fiber reinforcement plastics which have typically been patched by hand layup.

snu.ac.kr

Q&A with Amir Husain

How artificial intelligence is crucial to future mobility.

BY JANELLE BERNALES, BOEING WRITER | PHOTOS COURTESY OF SPARKCOGNITION

Amir Husain is the founder and CEO of SparkCognition, a global industrial artificial intelligence company serving the world's largest organizations in energy, national security, aviation, finance and cybersecurity.

In 2018, Husain became the founding CEO of SkyGrid, a Boeing and SparkCognition joint venture that is building an aerial operating system to power the next generation of autonomous aviation.

Q **Fast forward decades, even centuries. When we look up, what do we see?**

A Envision a future with millions of concurrent flights — both piloted and unpiloted. To achieve safe route planning and high-traffic density, we must be able to predict a variety of factors that can change quickly, such as weather conditions, vehicle health and maintenance needs. We can't just default to the old way of doing things by defining large airspace "bubbles" around every aircraft. This manual approach will drastically impact traffic density and system efficiency by reducing the number of aircraft that can share airspace. As more unpiloted aerial vehicles (UAVs) become operational, artificial intelligence (AI) models will be necessary to help define the optimal route based on the drone's health and predicted environmental conditions. AI technology will also be critical to safely sense and avoid new obstacles inflight or completely reroute the drone if the new conditions are extreme.

Q **How are you collaborating with Boeing to make urban air mobility a reality?**

A SkyGrid is a joint venture between Boeing and SparkCognition with a mission to accelerate urban air mobility and enable a wide variety of commercial drone services, including package delivery, industrial inspections and emergency assistance.

As we move from a world with thousands of piloted aircraft flying concurrently to a world where millions of unpiloted aircraft are operating at the same time, many elements of the underlying infrastructure will need to evolve.

We're clearly not there yet. How does that kind of complexity in the skies happen safely and efficiently?

First, today's air traffic control system was designed to cater to the needs of thousands of concurrent flights. As we move to millions of unpiloted flights, the inherent design and heavy human involvement in this system will prevent it from keeping up with flight volume. As such, air traffic control can be augmented by AI to enable large scale UAV traffic.

Second, the system will require the use of artificial intelligence to generate optimal routes that take into account dozens of underlying criteria, from airspace classes to weather and microweather, traffic patterns of terrestrial vehicles on the ground below, environmental considerations, noise and safety considerations as well as the maintenance condition of the UAV in question. These complex decision factors require machine "intuition," implemented perhaps by techniques such as Deep Hashing, because they cannot always be computed from scratch using deterministic algorithms that may turn out to be computationally expensive.

Third, the infrastructure must also leverage AI to predict maintenance needs. To safely monitor drone health and performance as UAV use grows, we will need to complement manual inspection with AI.

Last, the system must enable advanced cyber protection. Seen a certain way, each autonomous aircraft is essentially a flying computer with a network connection that can be hacked if not secured properly. AI-powered cybersecurity will be the key to detecting malicious activity on the edge and preventing it from executing on a drone. This type of security must function even when the drone cannot contact a host network and must be particularly able to deal with sophisticated, "zero day" or never-before-seen attacks.

By combining Boeing's aviation expertise with SparkCognition's advancements in AI, SkyGrid is bringing this system to life to safely integrate drones in the global airspace.

Q **What might an engineer need to concentrate on to dive into the AI world?**

A If I were to emphasize just one thing, it is to focus time and attention on truly understanding the core underlying concepts of computing: programmability, algorithmic efficiency, search, graph algorithms, recursion and other core notions. Thinking from first principles is essential in developing mastery in a subject. I am not a big fan of neglecting first principles and developing familiarity only with the highest, most abstract layers of the technology stack. Your towers of understanding must be built on a firm and deep foundation.

There's almost no area of engineering or science that isn't dependent on or significantly enhanced by the tools of computer science and AI. And to the extent that AI allows you to almost magically build solutions based on observation — on data — it is an incredibly powerful science. When you realize AI will amplify everything and that it does not operate in a silo, then you will continue to find ways it adds value to an enterprise. It's a field with a large number of known rewards but also an uncountable number of unexpected ones! For example, SparkCognition recently hosted a competition in the U.K. where Southampton University students were asked to use our automated model building platform, Darwin, to serve a real-world problem of their choice. To our surprise, students used Darwin to invent water purification technology. This is just one example of an unexpected reward for the field and also illustrates that technology will, in fact, truly change everything.

> "AI will complement human thought and elevate the human condition."
>
> **AMIR HUSAIN**

AI AND THE FUTURE
Amir Husain speaks at SparkCognition's Time Machine 2019 Summit in Austin, Texas.

Q **What drew you to the field of AI?**

A I've been fascinated with computing since a very young age. I developed a lifelong love affair with programming when I first saw a Commodore 64 in action at the age of 4. I started formal research in AI while I was a teenager and published my first Institute of Electrical and Electronics Engineers (IEEE) research papers while I was still 17.

If you think about it, AI is the ultimate use of computers. If you look at early pioneers like Alan Turing, a lot of their attention was focused on how computers could "think." Even Charles Babbage's mechanical computer design from the 1800s was called the Analytical Engine. Once you get deep into computer science, it's hard to not be fascinated by the potential of computers as thinking machines!

Q **But the idea of a "thinking machine" may sound ominous to some.**

A On my journey to understand artificial intelligence, I've reflected deeply on how we humans think. In my book, "The Sentient Machine: The Coming Age of Artificial Intelligence," I discuss many ways human intelligence differs from artificial intelligence. Despite the fears that surround this topic, I ultimately believe AI will complement human thought and elevate the human condition.

Building the shared airspace of tomorrow

Boeing's partnership in Galicia, Spain, is shaping the future of safe autonomous air mobility operations.

BY IGNACIO VIDAL, BOEING SYSTEMS ENGINEER AND GALICIAN SKYWAY PROJECT TECHNICAL LEAD

How do piloted and autonomous passenger and cargo air vehicles safely share the airspace of tomorrow? It's a question that Boeing and our research partners are answering today as part of the Galician SkyWay Project.

The Boeing-led Galician SkyWay Project is a consortium including six Spanish and Galician companies and government entities: the Spanish National Institute of Aerospace Technology, ENAIRE, Gradiant, Televés, Centum and SOTICOL. The program launched in May 2019 to develop flight contingency management solutions to keep people safe in the air and on the ground.

With this consortium, we are developing and testing these innovative solutions at the pioneering Rozas Airport Research Center in Lugo, Spain. Sitting at the edge of a 1,200- by 35-meter runway and equipped with a 40- by 40-meter hangar and a new control tower, the airfield is an ideal location for testing unpiloted aerial vehicles (UAVs), which are currently only permitted to fly in restricted airspace.

PHOTO: ÓSCAR ROCA DACAL

HIGH-FIDELITY SIMULATION
Ignacio Vidal in the Galician SkyWay Project simulator, which integrates all products and serves as a verification engine before critical flight-test campaigns.

Flight Contingency Management Solutions and Technologies

Our Galician SkyWay Project is researching and developing several advanced technologies in pursuit of a common goal: to strengthen the safety of UAV operations and pave the way for a future ecosystem where traditional aircraft and UAVs coexist within an airspace.

Here's how we're solving for potential UAV flight contingency scenarios in order to ensure redundant layers of safety:

Detect and Avoid

Airspace is shared by a wide range of aircraft: commercial airplanes, gliders, emergency helicopters, hot air balloons and now UAVs. Aircraft rely on awareness of the surrounding environment to be able to maintain a safe distance, so it is key to provide UAVs with tools and sensors that alert them when another aerial vehicle is getting too close. One way that we are addressing this is by equipping unpiloted aircraft with high-resolution cameras using synthetic vision algorithms based on deep-learning technologies and passive radars. These spatial awareness technologies can identify potential risks in the nearby airspace, issue alerts to piloted and autonomous aircraft and, if needed, trigger avoidance algorithms that compute a safe trajectory for the aircraft to avoid a collision.

Power Failure

When an aircraft loses engine power, it can still rely on its gliding capability to perform an emergency landing. With piloted aircraft, the pilot makes the decision on the appropriate gliding path to follow, where to land and how to land. However, with UAVs, we add algorithms and artificial intelligence to the mix. The Boeing team in Madrid has developed automatic solutions that compute the safest gliding path to the nearest landing site while, at the same time, taking into account the current weather and the performance characteristics of the specific aircraft.

PHOTO: BOEING PHOTO

A UNIQUE TEST ENVIRONMENT
The Galician SkyWay Project researches and tests technologies from throughout Boeing and partner organizations at the Rozas Airport Research Center in Lugo, Spain.

The Galician Civil UAVs Initiative

The Spanish region of Galicia, where Rozas Airport is located, has started the strategic Civil UAVs Initiative, which aims to achieve greater efficiency in a range of public sector services and activities through the use of aircraft and autonomous marine vehicles.

The development of an aeronautical industry in Galicia is a government priority, leveraging research and development to guarantee competitiveness of the local economy in an inclusive and sustainable growth model, enabling Galician society to respond to global economic, social and environmental transformations. As part of that effort, Galicia aims to grow its industrial base in the field of autonomous civil aircraft applications by creating a technological park around Rozas Airport in Lugo.

Rozas Airport Research Center itself is a joint initiative between the Spanish National Institute of Aerospace Technology, the national air traffic manager ENAIRE, the Galicia Regional Government's Galician Innovation Agency (GAIN) and the Galician Institute for Economic Promotion, as well as the Ministry of Science, Innovation and Universities.

This project is the result of services and work co-financed by GAIN and is part of a cooperative agreement between GAIN, the Ministry of the Economy and Competitiveness and the Agency for Technological Modernization of Galicia. The project also counts on the support of the European Regional Development Fund.

PHOTO: ÓSCAR ROCA DACAL

WALKING THE TALK
SkyWay Project teammates (left to right) Eduardo Cuervo, a computer technologist; Emiliano Bartolome, an engineer; and Vidal are working to ensure safe shared airspace for future mobility.

Autonomous Emergency Landing

We are combining traditional visual odometry algorithms and a state-of-the-art neural network (trained against a database of thousands of runway images) to make autonomous aircraft operations and contingent event landings even safer. By combining these advanced technologies, an autonomous aircraft can determine its position relative to the runway's known heading and dimensions to safely conduct an autonomous emergency landing.

Communication Security and Assurance

Communication between UAVs, piloted aircraft and ground traffic control needs to be reliable and impervious to interference. To protect the aircraft from cyberattacks, the Galician SkyWay Project is building jamming and spoofing detection systems for both radiolink and Global Navigation Satellite System (GNSS) signals. We are developing health monitoring boards and redundant link systems that use the 4G cellphone network.

Navigation Solutions

Similarly, we are researching complementary solutions for backing up satellite navigation services, which may be highly vulnerable in low size, weight and power systems, also known as low SWaP systems. We are harvesting all possible options: 4G cellphone coverage, terrestrial TV antennas, image-based navigation and others. Aircraft may one day use a combination of solutions, including software-defined radio, image registration techniques, downward-looking cameras and aircraft attitude, to navigate without relying on satellite signals.

Contingency Manager

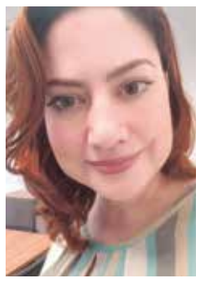
The behavior of all of these technologies will be supervised by a global contingency manager, which monitors the current state of the aircraft and makes decisions on what to do, taking the role of an overseer with an embedded artificial intelligence. Importantly, the behavioral rule set for this embedded AI is fully understandable by a human and fully coherent and interpretable by a machine, making AI and human intelligence complementary layers of safety.

As a pathfinder for these technologies and the future mobility technologies that we are working on throughout Boeing, the Galician SkyWay Project aims to develop operational and safety solutions posed by the emergence of UAV systems increasingly sharing airspace with traditional aircraft. The technological learning and experimentation will benefit not only those collaborating on the project but also the broader aviation industry.

Through technology development and investments, as well as work with other industry leaders, new and existing partners and regulators, the unified approach of the aviation industry to prioritize the safe development of airspace management technologies and governance — including flight contingency management — will help make the future mobility ecosystem a reality. IQ

From the **Boeing Technical Journal**

Contributing Authors



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Harris was featured in the February 2018 issue of IQ.

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The Boeing Technical Journal is a peer-reviewed, proprietary periodical for Boeing subject matter experts to capture and share knowledge.

This abridged BTJ selection has been approved for public release.

Research highlights from the content on the following pages were shared in the December 2016 issue of IQ.

It’s all in the approach

GBAS landing system in Brazil could offer safety and efficiency.

BY GLAUCIA BALVEDI, MONICA ALCABIN AND MATT HARRIS

The Ground-Based Augmentation System (GBAS) is a differential augmentation system designed to correct range errors on GPS signals, enabling the execution of precision approach procedures. In the current GBAS configuration, an airport ground station sends correction messages via very high frequency (VHF) to GBAS Landing System (GLS)-capable aircraft, which in turn employ this information to calculate their positions in compliance with the International Civil Aviation Organization’s (ICAO’s) signal-in-space requirements (accuracy, availability, integrity and continuity), enabling precision approaches under Category I and Category II minima. Designed to substitute instrument landing systems (ILSs), GBAS has tangible benefits for airlines and other aircraft operators, such as airport capacity gain, more efficient communications, improved performance-based navigation operations, fuel savings, noise reduction and automation of routine air traffic control functions.

Despite all these positive advantages, GBAS has not been certified in Brazil yet or in other low-latitude regions as it has in other parts of the world at middle latitudes due to differences in the ionospheric behavior. Brazil is located under the geomagnetic equator, which implies it is under harsh ionospheric disturbances, leading to disruptions in GPS signals such as scintillations. These disturbances affect GBAS performance. As a result, the signal-in-space requirements are not guaranteed to be achieved, impeding satellite-based aeronautical navigation capability. The only currently certified GBAS station uses an ionospheric threat model initially developed for mid-latitude locations, such as continental United States (CONUS) and is inappropriate for low-latitude regions. Recent research pointed out that the ionospheric disturbances over the Brazilian territory tend to be more severe around the spring and summer (September to March in the southern hemisphere) and during the night, from 6 p.m. to 6 a.m. local time, in magnitudes not covered by the CONUS threat model. Therefore, solutions tailored for mid-latitude regions are not certifiable along a wide area of the Brazilian territory and South Atlantic. Boeing has around 15% of its GBAS-equipped customers in low-latitude areas, indicating unused technological capabilities by airlines, aeronautical services providers and airports.

The Brazilian Department of Airspace Control, DECEA, for Departamento de Controle do Espaço Aéreo, is working toward regulating the GBAS operations in Brazil. The initial proposal from DECEA is to develop a safety case in the Rio de Janeiro region, permitting GBAS CAT I operations at Galeão International Airport. One of the expected outcomes of the safety case is the assessment of the period of the day (not necessarily 24/7) the system would be allowed to safely operate in that harsh, ionospheric scenario. However, operators have also claimed other key airports in the southern region of the Brazilian territory where GBAS could be implemented to complement Required Navigation Performance - Authorization Required (RNP-AR) and Area Navigation (RNAV) approaches. These locations are frequently affected by meteorological conditions during the winter season in the southern hemisphere (June to September) and may provide a solid business case for GBAS implementation in such airports. In this case, minimums could be lowered from Non-Precision Approaches to CAT I, at least.

Boeing Research & Technology-Brazil developed a method to estimate percentages of approach operations classified according to meteorological conditions and assessed the impact of potentially implementing GBAS CAT I, II or III operations. Fifty-two aerodromes, operated by Brazilian Airline GOL in 2017, were selected to test and validate the proposed methodology and to understand opportunities for landing operations under severe weather conditions in Brazil.

A total of 2,332,838 valid Meteorological Aerodrome Report observations encompassing six years of historical weather data were used to perform analyses that considered the overall historical weather dataset, seasons, a time-window interval within the day and the GOL flight network schedule. Results showed that for around 1.34% of weather observations, Brazilian aerodromes operated under ILS CAT I or more strict approaches. For 71% of the cases when weather approach requirements were stricter than the runway capability implemented, it referred to CAT I or CAT II requirements. Seasonal analyses show a greater demand for ILS procedures during autumn and especially during winter. A time window from 6 a.m. to 6 p.m. was used during analyses, aligning with the time interval that DECEA is considering certification of GBAS operations in Brazil. Results show no vast difference within and outside the time window for the landing categories considered except for CAT III, which are more in demand within the interval of 6 a.m. to 6 p.m., even though CAT III demands represented only 0.03% of the historical weather data considered.

Two approaches were used to match the GOL flight network schedule (base year 2017) with the historical weather dataset. The first considered all ILS demands. The second only considered cases in which weather conditions were more severe than the runway capability implemented. For the first approach, ILSs (i.e., CAT I, II and III) were demanded yearly in 1.29% of GOL operations over the last six years, being 0.74% for CAT I, 0.48% for CAT II and 0.06% for CAT III. The second approach showed that 515 GOL flights would be affected yearly, requiring cancellations or delays, holding in the air or landing in another aerodrome. The more affected aerodromes tended to be concentrated in the southern region of Brazil, but Congonhas Airport in São Paulo had the majority of GOL flights impacted by severe weather (104.5 flights per year).

Apart from the analyses of demands for instrument landings for several airlines in different regions of the globe, the method has the potential to drive operations to pinpoint schedules less affected by severe weather conditions.

The Federal Aviation Administration GBAS program is currently conducting research and development in many countries, prototyping efforts to reduce the technical risk and validate new requirements to meet the GBAS Approach Service Type D (GAST-D), which will be capable of supporting approaches up to CAT III minima. The requirement validation effort supports the acceptance of national and international standards for GAST-D. This effort will support approval of the ICAO Standards and Recommended Practices and Radio Technical Commission for Aeronautics Minimum Operational Performance Standards.

Global Scale

Boeing around the world

Autonomous Loyal Wingman fuselage comes together in Australia

The major fuselage structural assembly of the first autonomous Loyal Wingman has been completed in Australia. Applying digital engineering and composite materials to achieve agility goals, the 38-foot (11.7-meter) aircraft is one of three prototypes to be developed as a part of the Loyal Wingman – Advanced Development Program in partnership with the Royal Australian Air Force, which aims to complement and extend airborne missions through smart teaming with existing military aircraft. Lessons learned from the program will be applied to the Boeing Airpower Teaming System, which is being developed for the global defense market.

Boeing HorizonX incubator launches in London

Ten startups have been selected to participate in the London-based Boeing HorizonX Aerospace Technology Institute Accelerator. The three-month program aims to significantly boost the aerospace startup ecosystem in the United Kingdom, with a focus on transformative industry 4.0 or sustainability-enabling technologies. During the incubator, experts and strategists from Boeing, ATI and GKN Aerospace will mentor the startups on how they can go to market quickly and with scale.

Building the future workforce **in Korea**

A diverse team, an inclusive environment and the expertise to change the world.

BY JONATHAN LEE, MANAGING DIRECTOR,
BOEING KOREA ENGINEERING & TECHNOLOGY CENTER

When we launched the Boeing Korea Engineering & Technology Center (BKETC) in the Gangnam District of Seoul in November 2019, the top priority was hiring the best talent in the vibrant technology sectors in Korea. Our objective was to create a team that could adapt technologies from other industries ahead of competitors in the aviation industry and elsewhere. That led us on a search for engineers with nontraditional aerospace backgrounds to help build this future.

We started staffing with engineers who specialize in electronics and connectivity fields from the consumer electronics, automotive and aerospace sectors. We were looking for candidates with expertise in displays, sensors, embedded software, smart factory and artificial intelligence. BKETC started to build its capabilities around these focus technologies.

But technical expertise is only one facet of workforce development. We did not look merely for engineers with specific skills for our initial openings but also for candidates with potential and a willingness to invest in growing with the center. We wanted employees who brought new and different perspectives to the aerospace industry. More than anything, we wanted diversity — in experience, perspective and gender.

Diversity in work experience is one aspect of the center. But more importantly, we have diversity in gender and education. Approximately 40% of our engineers are women. About the same percentage are educated in the United States. Some were educated in the United Kingdom and Canada. Evidence shows that a diverse and balanced workforce accelerates innovation.

PHOTO: BOEING

EXPERTISE IN THE RIGHT ENVIRONMENT
Jonathan Lee is the managing director at the Seoul, South Korea, headquarters of BKETC.

PHOTO: BOEING

COLLABORATION IN KOREA
Teammates at the Boeing Korea Engineering & Technology Center are creating a workplace culture founded on diversity, inclusion and collaboration.

Boeing has 12 research centers located around the globe — five throughout the United States as well as centers in Australia, Brazil, China, Europe, India, Korea and Russia. Employing local talent and expertise, each technology center builds collaborative partnerships with the nexus of academic and research institutions, government entities and private companies in each locale.

That emphasis specifically on gender diversity matters everywhere, but especially here in Korea, where less than 11% of engineers and engineering students are women. Our industry can do better, starting with BKETC. There are deep structural challenges that will take a collective, collaborative, long-term effort.

But there are also actions we can take right now to make the tech industry more inclusive. For example, one of the women we hired, Taekyung Kang, shared that her prior office did not have a women's restroom in her building. She had to walk for 15 minutes to the next building. That's not right — and it's not conducive to success for individuals or industry. The companies that develop diverse workforces and create truly inclusive environments have an advantage.

We also hired software engineer Haesun Kim. She was surprised she was *not* asked about her marital status during her interview at BKETC. Kim saw that question on other job applications at Korean companies. She wondered why it was necessary and if she might be penalized.

BKETC is part of Boeing Korea, which was established in the 1980s and has grown to include employees in eight Korean cities, including Seoul. At BKETC, as in Boeing Korea more broadly, we studied then applied best practices for creating a well-balanced and inclusive workforce, with an emphasis on supporting women in STEM fields in Korea. We underscored family-friendly practices. Our female employees in Korea can take up to two years for maternity and child care leave. And we encourage our employees to take advantage of Boeing's flexible working hours policies. We host business network groups, such as our Boeing Women Inspiring Leadership chapter, that actively support the personal and professional development of our women and all employees at BKETC.

We are also creating a work culture that helps accelerate innovation. Speed of business is based on how quickly an organization can gather data and share the facts as a team in the decision-making process. In order to do so, it is important that all voices are heard. We provide training on active listening. We encourage open discussion and even constructive conflict so that our teams freely express their ideas. We purposefully removed a barrier in a society where seniority and age can hinder open communication.

In short, we've been intentional about shaping the future of our workforce as much as the future of our technology in aerospace. And because of that intentionality, we are succeeding at both. BKETC employs a diverse workforce in an environment that values diverse experiences and lifestyles. In fact, Boeing Korea recently was designated as a Best Family-Friendly Management Company by Korea's Ministry of Gender and Equality.

Boeing Korea's president Eric John has said that BKETC does "over the horizon" work and keeps Boeing engineering in the lead for aerospace. For him, that is as true of our team as it is of our products and services. Setting a new benchmark for work-life balance enhances opportunities for women in the workforce in Korea — and STEM fields specifically —and makes Boeing attractive in the extremely competitive environment for recruiting engineers.

Sustainable solutions, **competitive advantages**

Four cutting-edge ways materials science creates environmental and economic benefits in aviation.

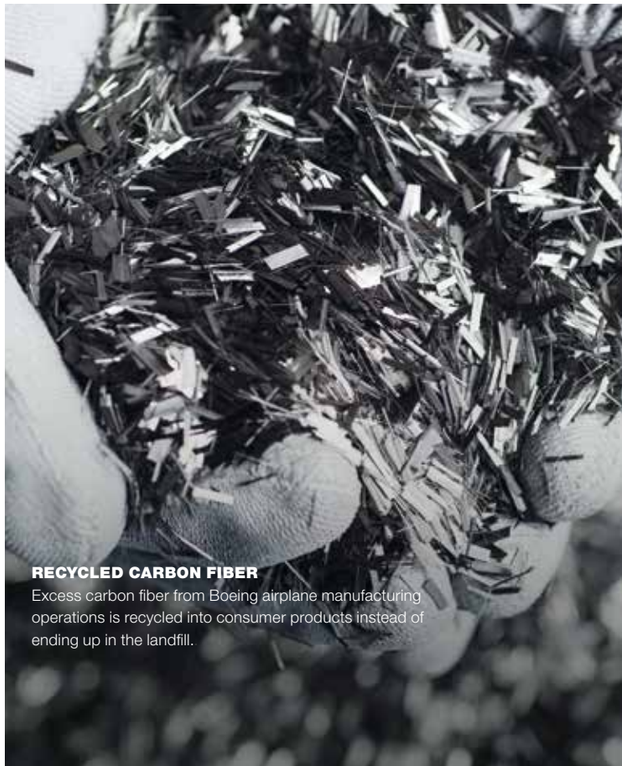
BY SHANYING ZENG, BOEING TECHNICAL FELLOW FOR ENTERPRISE CHEMICAL AND ENVIRONMENTAL TECHNICAL INTEGRATION

The aviation industry has been making deliberate efforts to address the environmental impact of air travel. Notable examples include reduction of aircraft fuel consumption through aircraft design (such as wingtips), operational efficiency (such as optimized routes) and wise energy and water use in manufacturing.

Materials and process science has been at the forefront of this effort as well. For example, carbon-fiber-reinforced polymer composites have made lighter airframe components possible, contributing to at least a 14% to 15% reduction in fuel consumption and thus carbon dioxide reduction. This is best demonstrated on the Boeing 787 airplane family. With the usage of composites exceeding 50% by weight, the Dreamliner is 20% to 25% more efficient than similar-sized airplanes, and has saved 48 billion pounds of fuel since it entered service in 2011 compared to the airplane it replaces.

Likewise, scientific studies have shown that sustainable aviation fuels — such as those derived from jatropha plants, forestry and agricultural waste — reduce carbon dioxide emissions by up to 80% over their life cycle compared to conventional jet fuel.

PHOTO: BOEING



RECYCLED CARBON FIBER
Excess carbon fiber from Boeing airplane manufacturing operations is recycled into consumer products instead of ending up in the landfill.

But we materials and manufacturing engineers can do more. By taking a broader view focusing on reductions not only in the air (weight and fuel) but also on the ground, we can find improvements along the whole life cycle, from sourcing and selection of materials for design, through manufacturing processes, to the end-of-life process and upcycling, when discarded objects or materials are used to create a product of a higher quality or value than the original.

The following four emerging materials and manufacturing sciences innovations are examples of that holistic approach.

Design for Environment

Design for Environment is a method to minimize or eliminate environmental impact of a product over the life cycle. Effective Design for Environment consistently maintains or improves product quality and cost while reducing environmental impact. Concepts such as Cradle to Cradle emphasize renewable resources and sustainable life cycles. Design chemistry approaches select environmentally benign or least-impactful materials and processes as part of product design.

Thermoset Composites

Thermoset composites are heroes in terms of weight reduction — widely used across many platforms — and therefore fuel savings and carbon dioxide reduction throughout airplane service life. The technology does present some challenges, as such resins are normally made with petroleum products, the manufacturing process can be time consuming and energy intensive from production to curing, and landfilling has historically been the main disposal method for polymer composites.

However, significant progress has been made on the science and technology of recycling composites (both cured and uncured materials). For instance, a method for vaporizing and dissolving resin developed by an industry partner company, UK-based ELG Carbon Fibre Ltd., has made possible a groundbreaking, 2018 Boeing partnership to recycle excess aerospace-grade composite materials. This is reducing solid waste sent to the landfill by more than 1 million pounds a year from 11 Boeing manufacturing sites.

Likewise, reduction and reuse opportunities, such as layup pattern design and respooled material remnants, improve our buy-to-fly ratios and reduce material consumption.

Energy Savings from New Materials and Processes

The inherent reusability (via reprocessing or recycling) of thermoplastics reduces energy consumption needed for storing temperature-sensitive materials during production. In addition, various out-of-autoclave cure processes or alternative-energy-source processes are also being developed with promising early results. For example, MIT researchers recently developed a method that uses nanomaterial-enabled capillary pressure to produce aerospace-grade composites demonstrated at lab scale without autoclave, using only 1% of the energy currently required.

Disruptive Materials and Process Technologies

Finally, materials scientists are just now proving out the viability of experimental new concepts that could completely transform traditional practices, for instance, pulling carbon dioxide out of the atmosphere and converting it into high-value chemicals and materials that can be used for other purposes. Researchers have developed a nano-carbon dioxide harvester that uses water and sunlight to convert atmospheric carbon dioxide into methanol, which can be employed as an engine fuel, a solvent, an antifreeze agent and a diluent of ethanol. That could both reduce atmospheric carbon dioxide and gain some return on investment through product sales.

We have been developing innovative ways to remove paint from airplanes using lasers. Laser ablation occurs when material absorbs laser light and molecules are excited into the plasma state, thereby vaporizing the material. Laser depainting has several advantages over traditional chemical and media-blasting paint removal methods, while reducing over 90% of hazardous waste generated; eliminating ergonomic risk; and improving speed, quality and consistency.

Boeing and the aviation industry have made substantial progress, but we recognize there's a lot more work to do.

Materials and manufacturing engineers are creating competitive advantages with mutually reinforcing environmental and economic benefits. The future looks even more promising. The early-career engineers and scientists who are increasingly taking a leading role in reshaping the climate sustainability movement will only grow the opportunities and scope to make the world better. IQ

PHOTOS: BOEING

UPCYCLED ART
When Shanying Zeng isn't innovating materials and process engineering, she creates art from flowers that she finds and saves. See her art come together at **boeing.com/iq.**

Young scientists say the most important technological trend isn't technology at all.

BY ASHLEY TRACEY, BOEING ENGINEER AND 2018 SAMPE YOUNG PROFESSIONALS EMERGING LEADERSHIP AWARD WINNER

Technology advancements should benefit the environment, says the young generation of scientists.

During the recent Society for the Advancement of Material and Process Engineering (SAMPE) Materials Forecast Mini-Forum, a poll of 35-and-under technologists pinpointed environmental sustainability, recycling and renewable energy as the most critical emerging trends.

They agree that advanced computing, artificial intelligence, smart materials and autonomous systems will significantly impact the future of the materials and process industries, including aerospace. But they say our planet will be a key player at the technology table, too.

I participated in the forum. Here are my takeaways:

Good for Business

We don't see how we can make technology development decisions without considering the environment, both in terms of global stewardship and value proposition. In addition to the traditional considerations of safety, performance, cost and schedule, we can and should quantify environmental impacts to make better business decisions. It's not just the right thing to do. As my colleague Shanying Zeng points out, we're learning that sound environmental solutions often represent competitive advantages as well.

New Normal

It won't take long for the emerging trend to become the norm. As sustainability, recycling and renewable energy become more prevalent decision-drivers, advancements in the materials and process field will follow. The same is likely true for the influence of lawmakers and decision makers. Specifically, we think we'll continue to see even more development of industry codes, regulations and standardization that are beneficial to the environment.

One for All

This won't be the domain of only a few technologists. Successful technical societies emerge when they build trust with the communities they support through credible forecasts, forward-thinking contributions and a roadmap to navigate the future. Regardless of specific technologies that emerge, the rising generation of technologists and engineers is bringing a focus on global outcomes so that our communities will grow and thrive all while benefiting our planet.

Patent **power**

Boeing's latest ideas and technical breakthroughs recently granted or published by the U.S. Patent and Trademark Office.

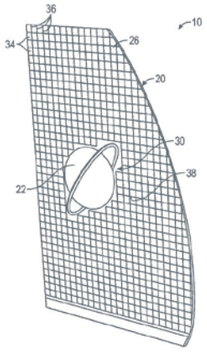
Celebrating Sustainability in 2020

The Earth rolls into the spotlight for the 2020 World Intellectual Property Day, the annual celebration of the role IP rights play in encouraging creativity and innovation.

This year's theme chosen by the World Intellectual Property Organization (WIPO) is "Innovate for a Green Future." The campaign honors inventors and creators shaping a more sustainable world.

Some of the patents featured here are a nod to World IP Day, celebrated April 26, 2020.

More: wipo.int/ip-outreach/en/ipday

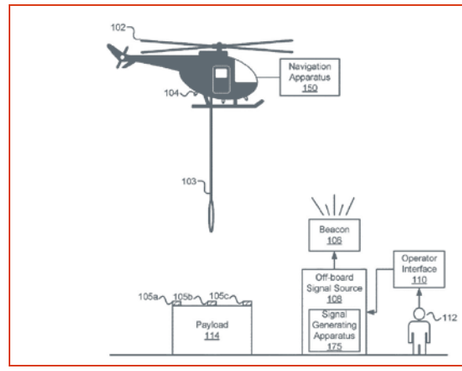


Reusable covering for protecting a finished surface

U.S. PATENT: 10,532,536
INVENTORS: SEAN RICHARD CYSEWSKI, NICHOLAS VAN DEN HANDEL

Storage or compartment structures are often installed on commercial passenger aircraft. Typically, during shipping and installation, the exterior surfaces of these structures are covered with tarp-covered foam pads to protect the finished surface from damage. These foam pads are heavy, bulky, rigid and difficult to accommodate in a manufacturing environment. The pads are attached to the surface of the part with fabric hooks and loop fasteners and must be wholly removed to apply features to the part. This is not only cumbersome to the operator, but it also exposes the entire finished surface of the panel, which increases the likelihood of unintended scratches and dents.

This new Boeing patent describes a system and method of panel assembly in which a reusable and adaptable protective covering is adhered to the finished surface of the panel by means of a low-tack adhesive that is both removable and reusable. This protective covering is not applied as one large, monolithic piece; instead, the covering includes a plurality of patch sections that are defined by perforated lines of demarcation (think paper towels). As such, the operator no longer needs to remove the entire covering to work on one or two small sections of the structure but instead only needs to remove the patches from the covering necessary to access the work area. Once the operator finishes the work on the exposed section, the operator then simply reapplies the patches of covering back into place.



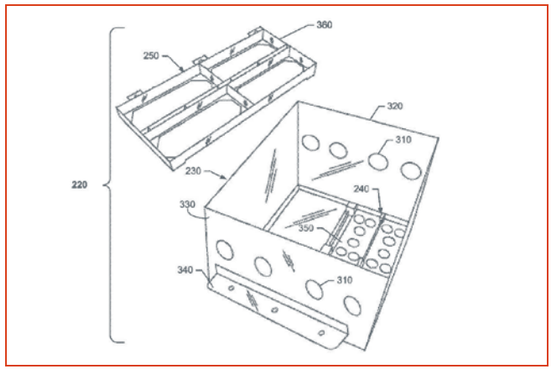
Sensor-based guidance for rotorcraft

U.S. PATENT: 10,532,825
INVENTORS: BRENDAN BLANTON, DEANNA DIBERNARDI, ROBERT ALLEN, KATHERINE GRESKO, TIMOTHY PAUL, JOSEPH KENNEY

When guiding a rotorcraft to its desired location, the air crew and ground crew often communicate by means of radios or hand signals (aircraft marshalling). However, certain conditions, such as a noisy environment, may lessen the effectiveness of radio communications. Additionally, hand signals may be confused or misinterpreted, especially if the rotorcraft operator does not have constant and clear visibility of a payload or with the ground crew member providing the signals.

This newly-issued Boeing patent proposes a response to the problems and potential shortcomings associated with conventional systems for providing ground-to-air guidance information. This patent describes a method where a camera, located on a bottom side of the rotorcraft, acquires one or more images of a plurality of markers of an off-board target, where the plurality of the markers are arranged in a predefined pattern. At least one marker of the plurality of markers comprises a pattern indicator marker, which has different characteristics than the other markers and is used for determining the predefined pattern of the plurality of markers.

An image processor then processes the images to identify the predefined pattern of the plurality of markers and determine guidance information relative to the off-board target based on this predefined pattern. The determination guidance is then provided to a display device within the field of view of the operator of the rotorcraft.



Chassis for rechargeable battery

U.S. PATENT: 10,535,852
INVENTORS: KEVIN S. CALLAHAN, BRUCE L. DROLEN, JAMES C. RUSSELL, JOHN R. LOWELL, THOMAS P. BARRERA, TIMOTHY R. NORTH

Lithium-ion batteries have lower weight and higher energy density than other rechargeable batteries, such as nickel-metal hydride and nickel-cadmium batteries. They also have no memory degradation. As such, lithium-ion batteries are useful for many applications, including aircraft.

However, any number of conditions can cause a battery to generate, collect or emit materials including gas, vapor, fluid and particles. Moreover, certain lithium-ion batteries have particular long-standing issues with thermal runaway, a situation where an increase in temperature causes a further increase in temperature that may lead to decreased efficiency. As such, a way to remove such materials caused by thermal runaway from the battery locale would be beneficial, as unattended material may influence the operation of one or more battery cells.

One of Boeing's first issued patents of 2020 describes a chassis for a rechargeable battery comprised of a lower fixation plate that contains at least one flow channel positioned to collect and passively move away condensate from the battery cells. The lower fixation plate comprises a nonconductive substrate divided into a plurality of segments, each of which fits a single battery cell. Such flow channels can manage the accumulated material in a controlled manner and can help reduce the chance of material from collecting in the bottom of the enclosure, thus protecting the battery cells and helping maintain full functionality.

Out and **about**

Boeing engineers inspire future innovators.

PHOTO: BOEING

PHOTO: BOEING

TOMORROW MEETS TODAY

In celebration of Engineers Week 2020, thousands of Boeing volunteers visited schools and communities to inspire future engineers and innovators.

These hands-on, experiential STEM activities are available at **boeingfutureu.com** to help launch the next generation into aerospace careers.

PHOTO: BOEING

PHOTO: BOEING

PHOTO: BOEING

PHOTO: BOEING

PHOTO: MICHAEL ROSS

2020 BLACK ENGINEER OF THE YEAR AWARDS
Carolyn Nichols (center) of Boeing Global Services was recognized for Career Achievement in Industry at the Black Engineer of the Year Awards in Washington, D.C. She is flanked by her mother, Helen Britt, and Boeing Chief Engineer Greg Hyslop.

WOMEN AT SCITECH
Laurette Lahey (third from left) speaks at the American Institute of Aeronautics and Astronautics SciTech Forum in Orlando, Fla., in January. Lahey, who is Boeing's senior director of flight and vehicle technology, will chair SciTech 2021 in Nashville, Tenn.

PHOTO: MARIAN LOCKHART

PHOTO: ROSS SKEEGAN, COURTESY OF AIAA

PHOTO: BOEING

SIX MILLION AND COUNTING
Norway's Trond Log, along with his family, was the six-millionth factory tour guest at Boeing Future of Flight in Everett, Wash., the only public tour of a commercial jet assembly in North America.

SONOBUOYS ON THE BERING
Boeing's Daniel David and Karina Alvarez (on right) recently donated 71 sonobuoys to National Oceanic and Atmospheric Administration scientists Catherine Berchok and Stephanie Grassia (on left) to aid endangered whale research in the Bering Sea.

What goes up, does come around

Tilt tech: then and now.

In the 1940s, as aviation pioneers were fine-tuning helicopter technology, many of these new rotorcraft began to enter mass production. Just a decade later, however, the difference between a helicopter and a fixed-wing aircraft wouldn't be so distinct.

The maiden flight of the first Bell Boeing CMV-22B Osprey recently took place in the skies over Texas. Known as "Snoopy" for its bold black nose and glossy white coat, the new V-22 variant is the first Osprey built specifically for the U.S. Navy — joining the MV-22 and CV-22 currently in service with the U.S. Marine Corps and U.S. Air Force, respectively.

The first of six V-22 prototypes completed its maiden flight in 1989, but that wasn't Boeing's first venture into tilt technology (utilizing a tilted wing or rotor to increase versatility). That came roughly 30 years earlier with the revolutionary VZ-2. In a sense, the concept comes full-circle with Boeing's latest offering to the U.S. Navy, as the VZ-2 had the word "Navy" right on its tail.

The Model 76 (VZ-2) tilt-wing aircraft was built by Philadelphia-based Vertol, which became Boeing Vertol in 1960. Bell Helicopter Co. developed its first tiltrotor, the XV-3, in the mid to late 1950s. Lessons learned from this program led to the highly successful Bell XV-15 in the late 1970s. Boeing's experience with a vertical takeoff and landing (VTOL) "convertiplane" began with the Vertol VZ-2, which became the world's first tiltwing to fly in 1957.

A press release from the late 1960s highlights its unique capabilities:

"The entire wing and both rotor-propellers could be tilted to a vertical position, thus enabling the 76 to take off and land like a helicopter. The aircraft transitioned from hover to forward flight as the wing and rotor-propellers were tilted forward to the horizontal position. The 76 then flew like a fixed-wing aircraft. Consequently, it had unusual potential for close support under terrain conditions that would nullify the effectiveness of a less versatile aircraft."

The VZ-2 was retired in 1965 and is preserved by the Smithsonian National Air and Space Museum. The data it gathered as a tilt-wing technology demonstrator, however, proved invaluable in the development of more modern tiltrotor aircraft, such as the V-22.

In addition to tilt-propeller VTOLs, there were tiltducts, tail-sitting VTOLs, deflected slipstream, deflected thrust, fan-in-wing configurations, tiltjets, tiltwings and tiltrotors.

Bell Boeing designed the CMV-22B specifically for carrier fleet operations — providing larger fuel tanks for the extended range requirement. The mission flexibility of the new Osprey will increase operational capabilities and readiness, in addition to ferrying major components of the F-35 engine. So as Snoopy takes its place in the U.S. Navy, a salute to the original, the Vertol VZ-2.

PHOTO: BOEING

THEN: In the 1950s, the Model 76 (VZ-2) was Boeing heritage company Vertol's first move into tilt technology.

PHOTO: BELL

NOW: "Snoopy," a Bell Boeing CMV-22B Osprey, takes flight in Amarillo, Texas.


AMONG THE MILLIONS
OF STARS, THERE'S
ONLY ONE EARTH.
Together we share this amazing planet, unique in its beauty
and ability to sustain life. It's our shared responsibility to
preserve and replenish its resources for future generations.
BOEING