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ISSUE 1 / 2025

SIMULATING SPACE

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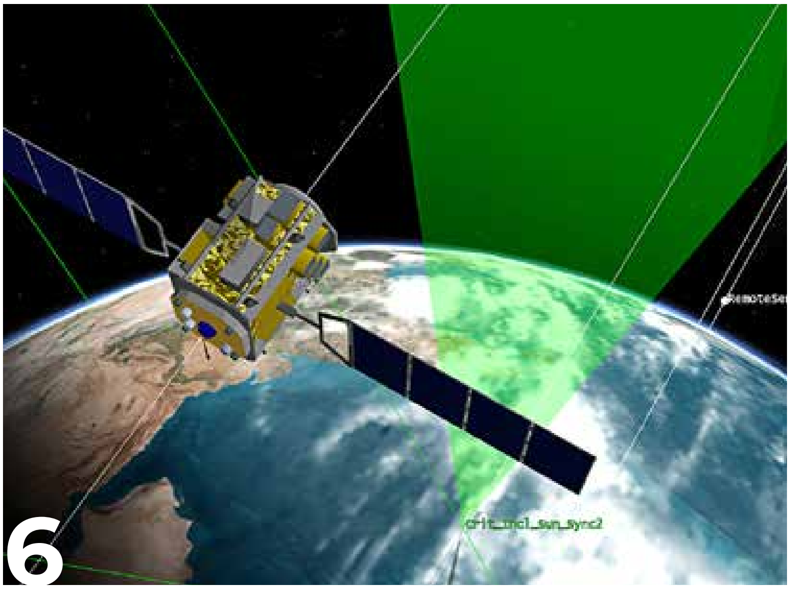

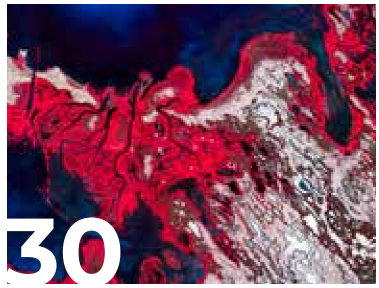

Focus on Space

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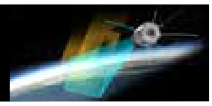
PLAN THE MISSION

ON THE COVER:
A depiction of a notional defense architecture including space-based sensors and interceptors.

DESIGN THE ASSETS



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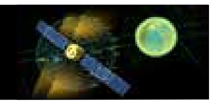
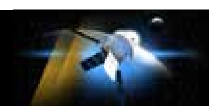


TAKE THE MOONSHOT



ADVANTAGE

Welcome to *Ansys Advantage*! We hope you enjoy this issue containing articles by Ansys customers, staff, and partners.

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Powering Innovation That Drives Human Advancement

When visionary companies need to know how their world-changing ideas will perform, they close the gap between design and reality with Ansys simulation. For more than 50 years, Ansys software has enabled innovators across industries to push boundaries by using the predictive power of simulation. From sustainable transportation to advanced semiconductors, from satellite systems to life-saving medical devices, the next great leaps in human advancement will be powered by Ansys.

Transform Space Exploration and Innovation With Digital Engineering

By **JAMES WOODBURN**, Ansys Fellow, Ansys Government Initiatives

From commercial satellite networks to deep-space exploration, the space industry is undergoing a transformation unlike anything in history. What was once the domain of governments and a handful of defense primes has evolved into a thriving, competitive marketplace where startups and established players alike are pushing the boundaries of what's possible. The rapid acceleration of space innovation is driven by the convergence of digital engineering, simulation, and model-based approaches that enable organizations to develop, test, and deploy advanced space systems with unprecedented speed, efficiency, and confidence.

Ansys is at the forefront of this revolution. Across mission design, space communications, remote sensing, domain awareness, in-orbit servicing, electronics reliability, and launch and reentry systems advancements, our cutting-edge solutions are helping to create a more connected, secure, and sustainable space environment.

DESIGNING THE FUTURE OF SPACE MISSIONS

The complexity of modern space missions demands a new level of precision in early-stage design and performance analysis. Pioneers like Dr. Jim Wertz, a leading figure in space mission analysis and design, emphasize the importance of leveraging advanced modeling tools to streamline decision-making and optimize mission architectures. The ability to simulate and assess the validity of trajectory designs and orbit determination results, as well as to evaluate the long-term sustainability of lunar and cislunar operations, is critical to success.

Ansys solutions, such as Systems Tool Kit (STK) and Orbit Determination Tool Kit (ODTK) software, provide an end-to-end digital engineering framework for mission design, allowing organizations to rapidly model and analyze cislunar trajectories, assess spacecraft performance, and validate navigation strategies before committing to costly physical builds. MDA, a leader in synthetic aperture radar (SAR) and space-based communications, is pioneering new approaches to persistent, all-weather Earth observation via orbital determination and other Ansys solutions. Even at the university level, students are using STK software to gain real-world experience in mission planning, preparing the next generation of space engineers to tackle the challenges ahead.

REVOLUTIONIZING SPACE COMMUNICATIONS, REMOTE SENSING, AND PNT

As space becomes increasingly congested and contested, the demand for robust communications, precise positioning, navigation, and timing (PNT), and high-resolution remote sensing is greater than ever. Companies like Wyvern are leveraging hyperspectral imaging to unlock new capabilities in environmental monitoring, agriculture, and defense. Meanwhile, PierSight is transforming ocean monitoring by providing near-real-time insights for maritime security and environmental protection. New Space Systems is simulating the effects of shock and vibration on electronics that are critical to spacecraft components and subsystem design.

Digital engineering plays a crucial role in ensuring the reliability and resilience of these space-based assets. Ansys' multiphysics simulation solutions help organizations optimize radio-frequency (RF) and free-space optical (FSO) communication systems, mitigate thermal stress on sensitive components, and validate satellite designs for extreme launch and spaceflight conditions. Companies like Astranis are using these capabilities to bridge the digital divide, deploying innovative satellite technologies to bring high-speed internet to underserved populations around the world.

ENHANCING SPACE SITUATIONAL/DOMAIN AWARENESS AND ON-ORBIT MANEUVERABILITY

Proliferated low Earth orbit (pLEO) and increased cislunar traffic presents an unprecedented level of challenge in ensuring the safety and sustainability of space operations. Space situational awareness (SSA), space domain awareness (which extends SSA to include aspects relating to characterization and intent), and on-orbit maneuverability are no longer optional; they are essential for protecting valuable assets and preventing catastrophic

> ***"The ability to model entire system-of-systems architectures, evaluate thousands of design alternatives in real time, and simulate mission scenarios before launch is a game-changer — one that will determine which organizations lead in this new space economy."***

collisions. For example, Orbit Fab has developed space refueling services, which use simulation for fuel calculations and controlled collision planning.

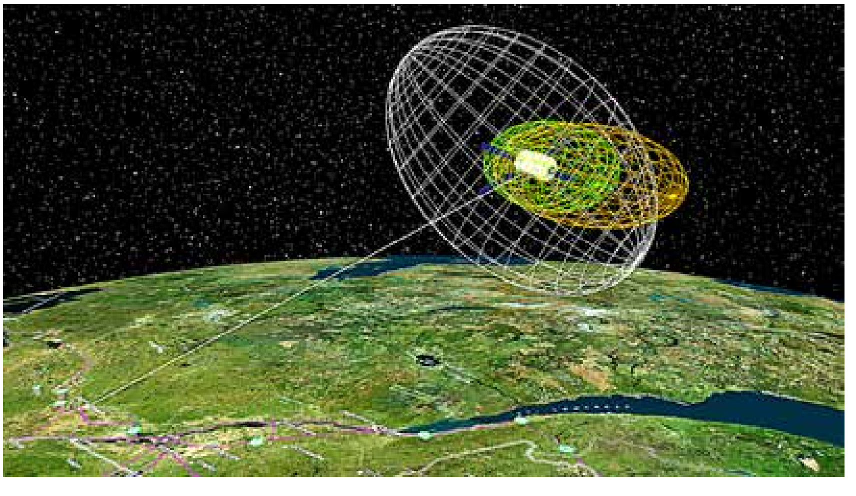
At the same time, space radiation remains a formidable challenge. Ansys is working with organizations such as Space & Bean to develop cutting-edge radiation shielding solutions while our simulation tools provide mission-critical insights into the effects of electronic discharge and bulk material interactions in space environments. These innovations are essential for ensuring the long-term viability of space assets and protecting sensitive electronics from the harsh conditions beyond Earth's atmosphere.

ADVANCING THE LUNAR ECONOMY AND DEEP SPACE EXPLORATION

The return to the Moon is no longer a distant goal — it's an imminent reality. Companies like Intuitive Machines are spearheading lunar exploration, infrastructure development, and robotic exploration that will lay the foundation for a sustained human presence beyond Earth. Meanwhile, emerging players like MaiaSpace and Stoke Space are leveraging digital engineering to develop next-generation propulsion, launch, and reusability technologies that will accelerate our journey to the Moon, Mars, and beyond.

Firefly Aerospace is another key player in this new era, tackling challenges across launch, landing, and orbital systems to support a variety of government and commercial missions. By incorporating digital engineering into every stage of development, these companies are not only reducing costs and risk but significantly increasing the likelihood of mission success.

As Wertz and other industry leaders have noted, the future of space will be defined by how effectively we integrate digital engineering and simulation into the mission life cycle. The ability to model entire system-of-systems architectures, evaluate thousands of design alternatives in real time, and simulate mission scenarios before launch is a game-changer — one that will determine which organizations lead in this new space economy.



Simulation of position, navigation, and timing (PNT)

THE DIGITAL ADVANTAGE: SECURING SPACE FOR GENERATIONS TO COME

Space is no longer a frontier of exploration alone; it is an integral domain for global security, economic growth, and scientific advancement. The ability to rapidly innovate, de-risk missions, and optimize performance across the ecosystem will define the leaders of tomorrow.

Simulation is the catalyst for innovation that propels human advancement in the space industry, whether you're building new business opportunities, safeguarding our assets on Earth, or exploring the cosmos. Every groundbreaking launch and ambitious vision for space relies on meticulously planned interactions between challenging environments and complex products to ensure mission success. From mission planning to the design of spacecraft systems to postlaunch maintenance, simulation is essential.

In this issue, you'll see how simulation is revolutionizing the space sector by empowering innovators to anticipate and mitigate risks, enhance efficiencies, and reduce costs as we embark on a new era of discovery.

Advancing Space Mission Analysis and Design With SIMULATION

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

Before a rocket launches or a satellite reaches its destination in low Earth orbit (LEO). Before a rover lands on the Moon or an unmanned spacecraft begins its journey to the far reaches of our solar system. Before any of these missions begin, the engineers and researchers at the heart of these projects must undertake space mission analysis and design (SMAD).

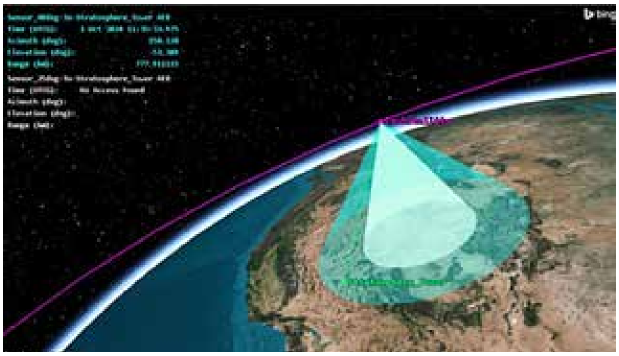
SMAD encompasses all elements of a space mission, from the requirements and mission parameters to the vehicle design, technology used, and testing. At its core, the goal of SMAD is to achieve mission objectives while reducing costs and risk. This is incredibly important because space missions are becoming increasingly complex, lengthy, and expensive.

"Even a small space mission can cost hundreds of millions of dollars and take many years to complete," says Jim Wertz, the president of Microcosm, Inc. and an adjunct professor of astronautics at the University of Southern California.

To illustrate the importance of SMAD in saving costs, Wertz shares an example of replacing a malfunctioning satellite. One way that companies can prepare for a malfunctioning or failed satellite is by having a spare satellite already launched into orbit. However, if the failed satellite is located in an orbit far away from that of the spare satellite, engineers would have to change the spare's orbit to effect replacement.

The issue here is that the delta-V, or a change in velocity, which is directly related to fuel use, required to achieve this is very large once a satellite is in orbit. "Going from an equatorial orbit to a polar orbit, for example, takes more delta-V than it took to get to orbit in the first place," says Wertz. As a result, it becomes very difficult and perhaps even prohibitive to move the spare satellite. Instead, "it makes a great deal of sense to leave the spacecraft on the ground and have a rapid and responsive launch capability," says Wertz.

SMAD serves as a way to analyze situations like these and determine the most efficient path forward — before making a choice that could cost millions of dollars.



Simulation results analyzing sensor fields of view

While innovators continuously push the boundaries of what is possible in space, they must overcome challenges throughout all areas of SMAD. These are some examples of key challenges throughout the analysis and design process.

1. **Launch to orbit:** Determining the best orbit to achieve your mission, figuring out the complexities of satellite constellations, and timing your launch
2. **Vehicle design:** Designing vehicle hardware and software that can withstand the harsh radiation and thermal environment of space
3. **Space operations:** Dynamically gathering real-time data on the environment that you will be operating in to ensure collision avoidance
4. **Systems engineering and design reference mission (DRM):** Accounting for all systems and the operating scenario in a system-of-systems context that accounts for factors such as terrain and weather, as well as how these factors interact and change
5. **Communications systems:** Ensuring that increasingly complex space mission communication systems are reliable and can achieve near-real-time communication between in-orbit spacecraft and between in-orbit spacecraft and Earth bases
6. **Payloads:** Designing payloads that can accommodate a variety of missions and orientations
7. **System test:** Minimizing the need for expensive physical tests that can be prohibitive or impossible to achieve on Earth

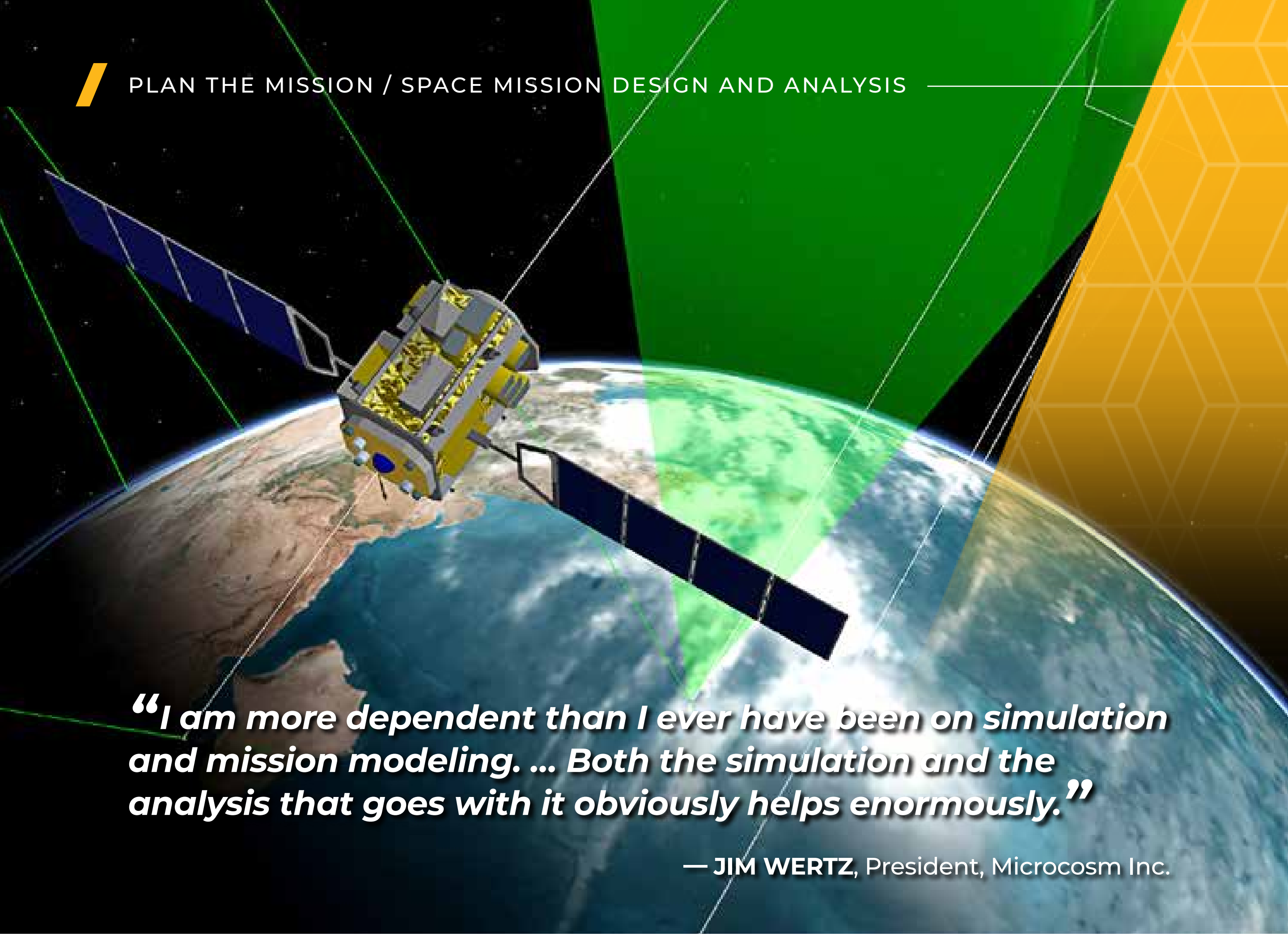
Adding to the complexity of SMAD is that "the government has a tendency to do its own mission analysis and design, which doesn't allow much room for companies to come in and make suggestions," says Wertz. This minimizes the ability of the broader community to share its inputs and innovate together.

UNDERSTANDING SIMULATION SOFTWARE'S ROLE IN SMAD

Engineers in the space industry have many challenges to overcome throughout all areas of the analysis and design process. However, in space, failure is not an option. Due to the time and costs needed to actualize a space mission, there is intense pressure to ensure that the mission design is right the first time. Companies in the space industry must invest heavily in ensuring that all design elements are thoroughly analyzed and optimized.

That's where simulation comes in. "I am more dependent than I ever have been on simulation and mission modeling," says Wertz. With simulation software, engineers can rapidly perform the analyses they need with reduced risk when compared with the extremely large number of resources that go into a physical test in space. "A simulation I can do relatively quickly, maybe in a matter of a few months, and it dramatically lowers the cost," says Wertz. "Both the simulation and the analysis that goes with it obviously helps enormously."

As an example, Jim Woodburn, Ansys Fellow, shares the problem of determining where to place an antenna on a spacecraft to enable communication with ground stations on Earth. While the solution to this problem may be straightforward if you are dealing with a satellite in LEO or geostationary orbit with a side that



"I am more dependent than I ever have been on simulation and mission modeling. … Both the simulation and the analysis that goes with it obviously helps enormously."

— **JIM WERTZ**, President, Microcosm Inc.

always faces the Earth, other mission profiles may prove to be more challenging.

"Consider a more complicated example where the spacecraft is on its way to the Moon and needs to change its orientation along the way to keep critical instruments from pointing at the Sun or to distribute heat," says Woodburn. "Using Ansys simulation software, we can model all of these conditions, along with potential antenna placements, to see when each potential configuration might be precluded from talking with the ground." This isn't all simulation can determine, either.

"We can also investigate predicted temperature profiles across spacecraft components, the amount of sunlight hitting the solar panels, which affects power generation, and possibilities for radio-frequency interference," says Woodburn.

Consider developing a large satellite constellation. Designing large collections of cooperating satellites involves determining:

- What the mission requirements are and the value added by each part of your constellation
- How you can achieve your goals and what technology will be used
- What coverage and timing you will need to achieve your goals
- Where you will want to deploy this constellation, which will affect the functionality and radiation levels
- What your budget is and how many satellites you can afford
- How many launches you are using to deploy your satellites, as well as the planned trajectory of those orbits
- How you will avoid collisions
- What your plan for satellite end-of-life entails
- How you are developing potential redundancies for individual satellite failure

With Ansys simulation software, engineers can perform the calculations needed to answer these questions efficiently and without sacrificing accuracy. For example, simulation software can help determine the fewest satellites that engineers can deploy to achieve their mission goals, saving costs and time. Engineers can also find the best altitude while accounting for the consequences of altitude selection (for example, a higher altitude may have better coverage but greater latency), radiation (which will differ depending on the altitude and where you are in relation to the Van Allen radiation belts), and more.

Engineers can enter inputs describing candidate mission profiles and spacecraft components into validated Ansys models. Ansys simulation tools are then used to generate outputs that describe the performance of the system under a prescribed set of conditions.

These outputs can then be vetted against mission requirements and weighted as part of iterative trade studies to efficiently find optimized configurations.

Of course, this is just a small part of what Wertz describes as "the complex problems that we hope to solve by doing better simulations and more complex and involved modeling of spacecraft."

Exploring vehicle thermal considerations in space

PLANNING FOR THE STARS: WHAT'S NEXT FOR SMAD

The rise of commercialization in the space industry is a core driver of several industry trends that will continue to affect SMAD.

For instance, take lunar and cislunar missions. In addition to governmental missions like the NASA Artemis program, many commercial lunar missions are on the horizon. "With the Artemis program, we are seeing a huge increase in interest in missions to the Moon and to cislunar space," says Woodburn. These missions are sparking commercial interest, with Wertz sharing that they can be near term and generate profit and real-life income.

As for the role of SMAD here, "the trajectories involved in these missions tend to be more exotic than those used by near-Earth missions and require more advanced analysis tools to take advantage of the low-cost orbital connections available when more gravitational bodies are involved," says Woodburn.

Commercialization is also a driving factor in modern satellite design, which includes an increased reliance on small, low-cost, and low-weight satellites. Additionally, autonomous technology may be of increased importance to SMAD in the future.

"I also believe that the age of autonomous spacecraft is right in front of us," says Woodburn. "The increase in onboard computational power, the use of in situ measurements for navigation, and the rapid development of AI/ML-based mission planning and anomaly resolution strategies all point to future spacecraft having much less reliance on the ground to perform their missions." Woodburn also shares that rideshares are another concept that may become more popular in the future to drive down launch costs and increase access to space.

When determining if these technologies are feasible for a specific mission, engineers can rely on SMAD and Ansys simulation software to perform comprehensive analyses that will help power the next generation of space missions.

For those looking to join or grow in this field, Wertz encourages you to consider the big picture and the broad trends occurring throughout the space industry.

You can learn more about Wertz's views on the future of space on page 64.

LEARN MORE

Watch the Ansys Space documentary "Simulating Space."

ansys.com/simulating-space

How SEE Is Using SIMULATION To Help Advance the Space Economy

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

What do engineers from the early 1800s and modern rocket scientists have in common? One thing that connects them is the math that they use to understand the world around us, such as the formulas used to track satellites.

Also similar is the palpable excitement about an industry on the verge of a major shift. In the 1800s, engineers may have been excited to see the rise of different public transit systems — canals, roads for horses, and railroad systems spanning countries and continents — and in our modern age, the next stage for transit may be in outer space. However, innovation in new frontiers is never easy. Succeeding in this celestial venture will require figuring out how to create a viable space economy, says John Carrico, owner, chief technology officer, astrogator, and technical adviser at Space Exploration Engineering (SEE).

The path forward will involve a great deal of innovation to revolutionize the space industry in new ways, from low-thrust engines to efficient propellants. That's where companies like SEE come onto the field. Using its aerospace expertise and knowledge from participating in more than 60 operational space missions, SEE acts as an adviser and a mentor to help make aerospace companies "more successful more quickly than previous missions," says Craig Nickel, principal aerospace engineer, flight dynamics and mission operations specialist at SEE.

By partnering with a wide variety of industry-leading companies, SEE has a front-row seat to the future of space. SEE is helping companies of all types — commercial and governmental, legacy and new space, low Earth orbit (LEO) and deep space — overcome major challenges in designing, planning, analyzing, and operating missions to achieve success and bring the industry closer to a thriving space economy.

ADDRESSING GROWING PAINS IN THE SPACE INDUSTRY

The space industry is relatively young; even NASA was established less than 70 years ago, in 1958. Despite this short period, a lot has changed.

To start, the space industry — like the universe itself — is constantly expanding. This is especially

“Space is getting a little congested and messy. The biggest challenge facing the space industry and satellite operators is collision avoidance and being able to mitigate that risk so everybody can continue to operate safely in space.”

— **CRAIG NICKEL**, Principal Aerospace Engineer, Flight Dynamics and Mission Operations Specialist, SEE

true in recent years, as we’re seeing an uptick in providers, spacecraft developers, and operators. While exciting, this shift is at the core of some of the key challenges facing the industry today.

“Space is getting a little congested and messy,” says Nickel. “The biggest challenge facing the space industry and satellite operators is collision avoidance and being able to mitigate that risk so everybody can continue to operate safely in space.”

One requirement for achieving this goal is to ensure information sharing between operators to improve operational safety. However, communicating and collaborating in this growing industry is yet another challenge we need to overcome. Important information is siloed because of company or national policies, and different countries have different standards that they need to comply with, which can cause confusion, says Carrico. There may even be issues when coordinating within a single country due to old laws and regulations, many different “standards,” and changing government priorities and incentives in the space industry.

In an already challenging environment, commercial space ventures face more hurdles related to profitability. “The interesting thing about commercial space is that investors need a return on investment and desire the timeline to be quicker than space missions typically take,” says Carrico. These goals mean that commercial space companies may be optimizing for different goals than governmental groups.

Meeting company-specific goals can require custom analyses to identify options for satisfying unique goals and objectives. For instance, a commercial company may want more launch opportunities, so it will sacrifice some margin on its final orbit accuracy, Nickel says.

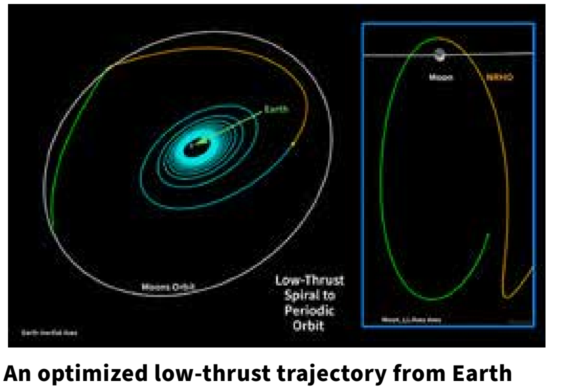
To reach these ambitious goals, commercial companies are also constantly innovating to push the limits of what’s possible. The rapid pace of this innovation results in even fewer accepted “rules” or standard practices to rely on. As a result, engineers don’t just need custom analyses — they need analyses that are quick and flexible enough to keep up with advancements. And simulation can fill this role.

THE ROLE OF SIMULATION IN THE MODERN SPACE AGE

While some of the fundamental math used in the space industry has been used by generations of engineers, the sophistication of the technology that applies this math to a problem has grown exponentially. “It’s not that we’ve got better algorithms, but we can run them faster and more often,” says Carrico. Given the same 10 minutes, an engineer from the 1800s could complete a few calculations by hand while modern engineers with access to tools like simulation and cloud computing can generate thousands of outputs.

This multitude of results provides a statistically significant sample to better assess risk, says Nickel. As such, tools like simulation software empower modern engineers to confidently trim down margins and accept tighter tolerances on requirements. This increases efficiency and lowers costs by, for example, accurately determining the minimal amount of propellent needed to achieve mission objectives. Engineers can use these results to manage uncertainty and find more opportunities for success.

As for SEE’s role in this process, the company benefits from being at the nexus of legacy space missions and startups. SEE can aid smaller companies in identifying and managing risks using its experience with the rigorous techniques



An optimized low-thrust trajectory from Earth to a lunar NRHO orbit, designed by SEE with Ansys Systems Tool Kit (STK) digital mission engineering software

and practices that it continues to develop and apply to expansive government missions.

Leveraging the power of Ansys software, SEE can identify and communicate the trade-offs between reducing costs and increasing mission success probabilities. This is particularly important for commercial companies that are focused on maximizing their return on investment and minimizing spending.

As one example, consider a company deciding between two spacecraft engines for a lunar mission. One engine may have slightly better performance but comes with a higher price tag. SEE can help determine if this engine is worth the cost by using Ansys simulation software to determine how significantly the engine differences will impact the design and overall mission viability.

Throughout its partnerships, SEE has applied simulation to help partners innovate, manage risks, increase efficiency, and minimize costs throughout the entire mission. "We'll go through the whole design process and then stay through operations until the end of the mission," says Carrico.

For some examples of the diverse benefits of simulation software in the space industry, let's explore some of SEE's previous work.

USING SIMULATION FOR MISSION AND TRAJECTORY PLANNING

If you were to fly into the space surrounding Earth, you'd find space debris almost anywhere you turned: in LEO, cislunar space, and even lunar space. That's in addition to the growing number of active spacecraft, such as CubeSats and mega-constellations. This crowded environment means that planning your trajectory and getting into your orbital slot can be like "threading a needle," says Carrico.

To help solve this challenge, SEE uses Ansys Systems Tool Kit (STK) digital mission engineering software and Ansys Orbit Determination Tool Kit (ODTK) orbital measurement processing software to calculate probabilities and determine the optimal trajectories that spacecraft operators need to achieve mission success.

This work is also aided by collaborating with third-party commercial providers that can help streamline the process of determining an orbit that will avoid collisions.

THE NEED FOR SIMULATION IN ENHANCING COMMUNICATIONS

Improving existing communication capabilities is an imperative stepping stone on the way toward a future space economy. For instance, as more commercial companies attempt to traverse deep space, the ability to contact their spacecraft will become increasingly challenging, says Nickel. Although solutions like NASA's Deep Space Network (DSN) exist, the DSN is currently overtaxed and will not be able to support all future deep space missions. As a result, the future space economy will need additional ground network providers.

The fast-moving space industry is already hard at work to mitigate this challenge. "Commercial providers, in response, are building larger, more capable antenna dishes," says Carrico. NASA is also encouraging commercial companies to provide these services by awarding those that can support relay satellites for communication, tracking, positioning, and timing.

SEE applies Ansys simulation software to this communications challenge in a variety of ways, such as performing link budget analyses, as well as modeling trajectories, coverage, and networks. This helps SEE determine the best locations to place satellite dishes and antennas to achieve mission goals.

"The Ansys software allows us to model not only the specifics of our orbit but all sorts of hardware and other constraints on Earth, such as if communications are going to be blocked by a mountain," says Carrico. With this knowledge, the company can determine the best way to avoid communication obstructions.

As an example of this work, take the KPLO/Danuri mission in Korea, which involved bringing a new ground antenna online and designing a ground system using STK and ODTK software. During this mission, SEE provided support for operations, system accuracy analysis, and validation — using simulation to help ensure mission success.

QUICKLY RESPONDING TO EMERGENT CONTINGENCIES WITH SIMULATION

A sense of directed chaos permeates a command room that is packed with engineers who are trying to determine why their spacecraft is undergoing a sudden, unexpected issue. There are people at every console, pens flying over paper, teams poring over spreadsheets, and urgent conversations happening in every corner of the room. In the middle of it all, SEE is using Ansys simulation software to try to determine what happened — as well as the next corrective course of action.

This "targeted commotion," as Nickel calls it, isn't theoretical. After the launch of Astrobotic Technology's Peregrine mission, Astrobotic noticed a propulsion anomaly, which ended up being a constant oxidizer leak that affected its orbit. The SEE and Astrobotic flight dynamics engineers used STK software to model the leak during the mission. They used the model, along with other observations, to determine what was occurring and how it would affect the trajectory.

"We would solve for where we thought was the effective acceleration, where the leak was in the body frame, and then we would go over to other parts of the control center and talk to the guidance, navigation, and control (GNC) folks ... and we would say, 'We think the leak might be here,' and we could compare results," says Carrico.

Through this process, SEE and Astrobotic were able to determine where the leak was coming from and its strength. They then could predict the spacecraft's current path and make a few critical calculations, including solving for the thrust correction and planning for a safe reentry into Earth's atmosphere. These corrections, which were made via their adapted model, were used in real time, "so we were able to keep (the spacecraft) alive for the rest of the mission," says Nickel.

Even with a disabled spacecraft that did not land on the Moon, Astrobotic gained a lot of new knowledge, such as data on different payloads and information on how different elements perform in space, which "is buying down the risk for future missions and for their customers," says Carrico.

WHY COLLABORATION IS THE FUTURE OF SPACE

With the rise of commercial space startups, the space industry is moving quicker than ever, but that doesn't mean that the culture is simply competitive.

"We need lots of people doing different things in space who interact to establish a true space economy," says Carrico. Across the industry, there is mutual excitement about this burgeoning new space industry and the shape of the future cislunar economy.

"Being collaborative is certainly a part of making that ultimately successful," says Nickel. In particular, empowering the broader community to leverage lessons learned from all the missions taking place today via information sharing is key.

These global collaborations can happen in a variety of ways, such as between different startups focused on complementary technologies, with third-party providers that offer time-saving services via cloud computing, or between governmental and commercial organizations. Throughout these partnerships, simulation and digital engineering can also serve as a connecting thread that enables knowledge sharing and the formation of new, innovative technologies that will help us launch a new space economy.

LEARN MORE

Find out about other exciting work that is helping to form the foundation for a new space economy.

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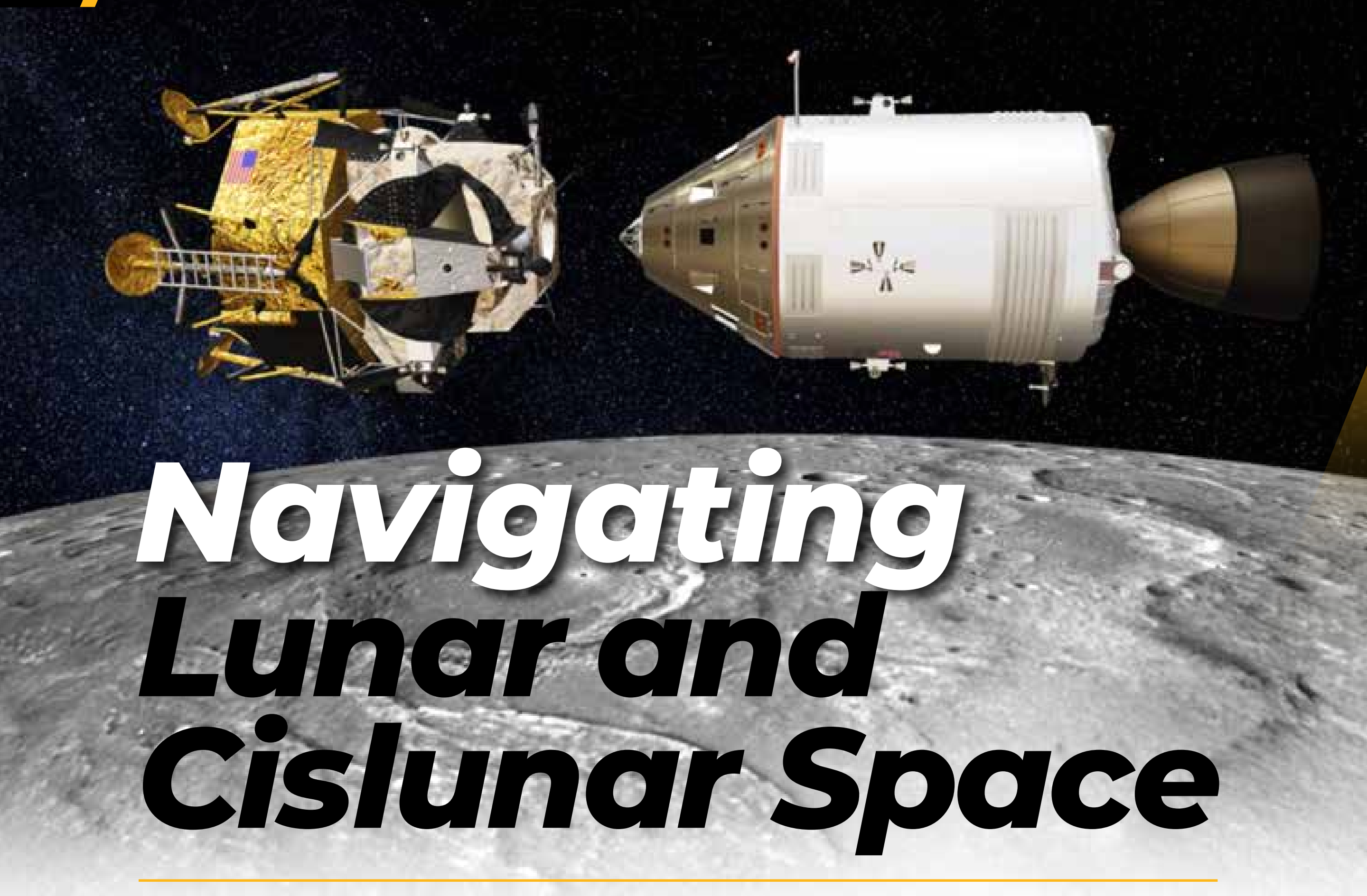


Navigating Lunar and Cislunar Space

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

"I still say, 'Shoot for the Moon; you might get there.'" — **BUZZ ALDRIN**

On Friday, Oct. 4, 1957, Sputnik 1 became the first artificial satellite to be successfully placed into orbit around Earth. Despite its relatively small stature, Sputnik 1 helped launch a new era of missions in lunar and cislunar space — that is, the volume of space between Earth and the Moon — that extends through today.

The famed Apollo program, for instance, included the goals of carrying out a scientific exploration program of the Moon and developing the human capability to work in the lunar environment. To achieve these goals, the Apollo program ran missions between 1967 and 1972 that expanded our knowledge for lunar missions and inspired future generations of space innovators.

In more recent history, the Artemis program has also come onto the scene, quickly establishing its place as one of the most important lunar missions. Artemis is a human spaceflight program aiming for the Moon, but reflecting a much broader mandate and unique emphasis than its predecessors.

Artemis is focused on long-term progress, including sustained infrastructure on the Moon that would involve a base camp and regularly sending crews up. Artemis also differs because it uses previously unexplored orbital options like distant retrograde orbits (DROs). It also relies on international cooperation, including the collaboration between global governmental and commercial space organizations.

With each successful mission, the space industry has continuously proven humanity's ability to transverse lunar and cislunar space. However, this does not mean that the journey is simple. Ensuring that such missions succeed without a hitch involves careful planning and precise, specialized trajectory design, which is only becoming more difficult as the space industry grows.

LUNAR AND CISLUNAR NAVIGATION

At its simplest, lunar and cislunar navigation involves finding the right path to get you to your destination. While the engines firing a rocket may propel you to a destination, the tracking and navigation processes will direct you to your goal.

Historically, all space mission tracking has been achieved from the ground. This direct ground-based tracking involves a network of ground antennas that communicate with a spacecraft while also observing its location.

As any mission operator would tell you, ground-based tracking is not perfect. First, there's the persistent challenge of having limited ground-tracking resources, which will only become more restricted due to the growing number of missions on the horizon.

Second, various physical effects associated with ground-based tracking cause cyclical injections of uncertainty in the orbital solution. Figures 1 and 2 show spikes of uncertainty over a one-month period (that is, one revolution of the Moon around Earth) for ground-based line-of-sight tracking via range and Doppler.

To address the shortcomings of ground-based tracking, researchers are investigating other forms of tracking for the space industry.

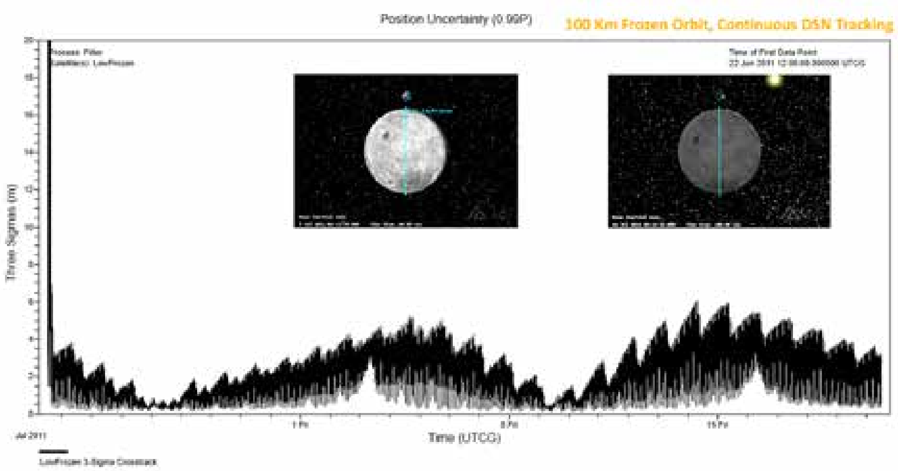
Space-Based Relays

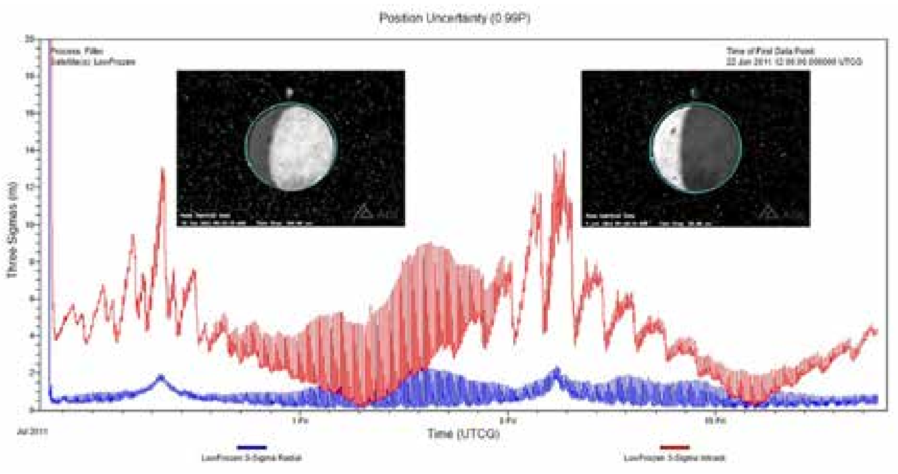
One alternative to ground-based tracking is a space-based relay. In fact, this approach has seen successful demonstrations, as with China's Queqiao relay satellite deployed to track and communicate with the Chang'e 4 lander on the far side of the Moon.

As seen in figure 3, space-based relay tracking (typically achieved via range and Doppler) can potentially provide full coverage of orbits around the Moon. These relays can also aid communications.

Another form of tracking that is currently deployed is space-based optical tracking. This involves one satellite with an optical sensor tracking another satellite by taking pictures that show the subject against a starry background.

One advantage of space-based optical tracking is that the sensor platform has a great deal of movement, which changes the angle at which it observes an object and helps in the





Figures 1 and 2. Simulation images showing line-of-sight tracing from Earth to the Moon (via range and Doppler).

orbit determination process. While space-based optical tracking instruments may not be as accurate as their ground-based counterparts in some cases, they may be a better option because they are not subject to weather-related outages.

Moon-Based Ground Stations

One navigation possibility that is not yet in use is tracking from a lunar ground station, such as those proposed by the Artemis program. These stations would enable ground tracking from the Moon instead of from Earth. Tracking of lunar orbiters from a lunar ground station would benefit from changing geometry in the way Earth-orbiting satellites are tracked from Earth ground stations.

Non-Navigation Signals

Passive radio-frequency (RF) tracking is an example of using a non-navigation signal to enable cislunar and lunar navigation. To understand how passive RF tracking works, figures 4 and 5 show a satellite in orbit about L1 and its downlink to two ground stations on Earth's surface. The dual collection of the downlink facilitates the generaton of time difference of arrival (TDOA) and frequency difference of arrival (FDOA) measurements. Using these measurements, a satellite can be tracked using its own downlink.

Optical Navigation

With optical navigation (which is distinct from optical tracking), a satellite takes pictures that help it navigate, often autonomously. In Figure 6, a satellite takes pictures of both Earth and the Moon from the vicinity of L1, which it will then use to determine the direction toward Earth and the Moon and thus its own position. This relatively cost-effective technique can be used alone or to augment other tracking data, depending on mission requirements.

Global Navigation Satellite Systems

Another navigation possibility is to use existing global navigation satellite system (GNSS) signals, such as the global positioning system (GPS). Although existing GNSSs were designed to work in the near-Earth environment, it has proven to be helpful in space missions, even at great distances from Earth.

One example of this is the Magnetospheric Multiscale Mission (MMS) and its specially designed GPS receiver. MMS explored the use of GNSS well above the typical altitude of the GPS constellation and expanded GPS use about halfway to the Moon.

Lunar Navigation Satellite System (LNSS)

Finally, an LNSS design would employ multiple satellites orbiting the Moon. LNSS has the potential to provide high orbit accuracy around the Moon while requiring fewer satellites than GNSSs orbiting Earth.

FURTHER EXPANDING INTO LUNAR AND CISLUNAR SPACE

The future of space is bright. In the coming years, the next Artemis missions are looking to set the stage for the next age of space — and Artemis is not alone in this resurgence. As Jim Woodburn, Ansys Fellow and AGI chief orbital scientist, says, NASA's Commercial Lunar Payload Services (CLPS) program is carrying a few payloads to the Moon that are of interest to "navigation buffs." This includes the Lunar GNSS Receiver Experiment (LuGRE), which will be launched on the Firefly Blue Ghost Mission 1, "Ghost Riders in the Sky," and the Next Generation Lunar Retroreflector (NGLR).

There's no psychic ball that will tell us the

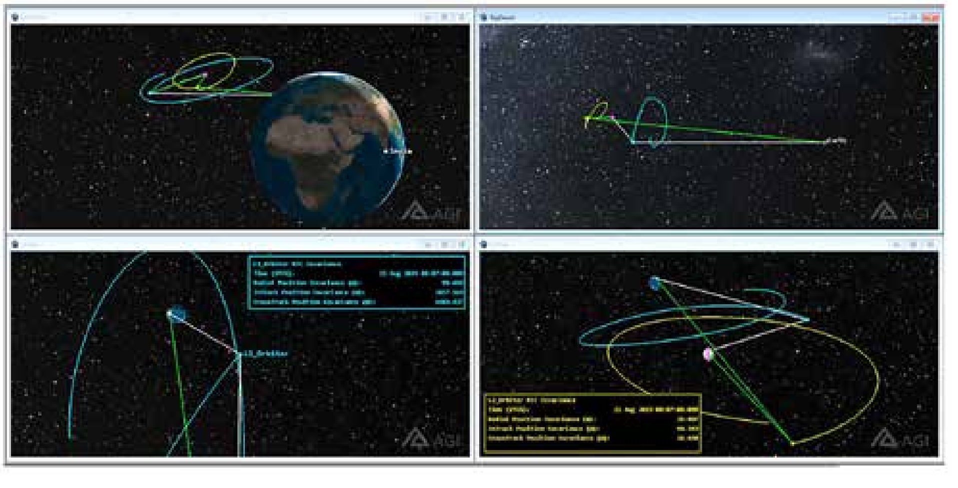
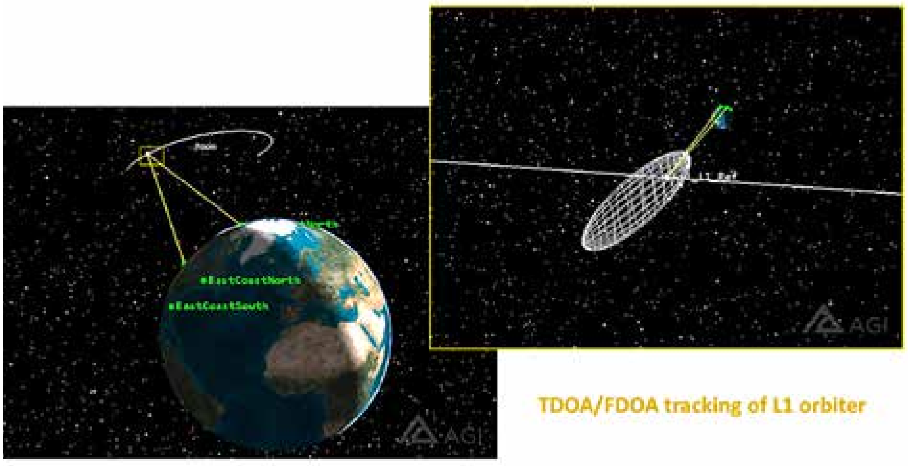


Figure 3. Simulations showing space-based relays in Earth-Moon L2 and Earth-Moon L1.



Figures 4 and 5. Simulation images showing passive radio-frequency (RF) tracking.

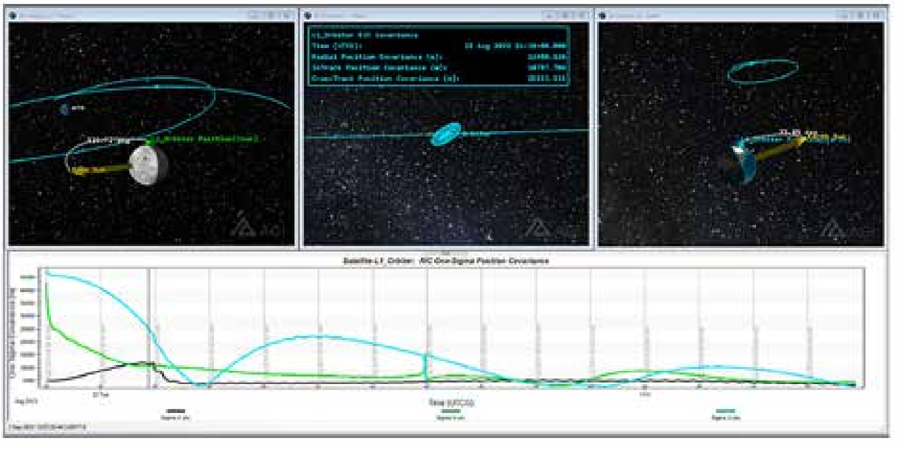


Figure 6. A simulation example of the optical navigation of an L1 orbiter.

future of space. However, if you asked experts in the industry to make educated guesses, they'd tell you a few things.

"I think the future of navigating in space is more interesting and exciting than ever," says Woodburn. "Some of the biggest trends in cislunar space, beyond an explosion of general interest, seem to be the desire for more spacecraft autonomy — taking advantage of increased computational power and the promise of onboard artificial intelligence and machine learning (AI/ML) algorithms to lessen the need for ground contacts and the push for a position, navigation, and timing (PNT) system in the lunar regime." This lunar PNT system would benefit satellite navigation, lunar surface navigation, and lunar communication by bringing GPS-like capabilities to the region near the Moon.

Ansys also has a role to play in this future. First, as with space missions themselves, Ansys simulation software is constantly growing and adapting. For example, Woodburn shares the new Ansys capability to use landmarks on the Moon for optical navigation simulation analyses, such as those involving satellites in orbit around the Moon.

"The enablement of digital engineering workflows holds tremendous promise for accelerating the exploration, development, and commercialization of space," says Woodburn. "Unlike the terrestrial environment, where digital engineering practices are an accelerator for program development, in space, digital engineering practices are essential to the ability to iterate on designs that cannot be tested in the field."

Using simulation, engineers can model the most common challenges that space missions face in a digital environment that accurately reflects actual mission conditions — helping us safely navigate to the Moon and back.

LEARN MORE

Learn how Ansys ODTK can support mission design and planning.

ansys.com/products/missions/ansys-odtk

Navigating Through the Darkness With MDA Space and SAR

By **CATY FAIRCLOUGH**,
Corporate Communications Manager, Ansys

MDA Chorus.
Image courtesy of MDA Space.

How many ships are sailing across Earth's oceans right now? While this may seem like a daunting question — our oceans have a surface area of around 139 million square miles after all — those in the maritime industry can use the automatic identification systems (AISs) onboard seafaring vessels to identify themselves. As its name suggests, an AIS is used to automatically track ships, as well as for monitoring and data exchange purposes. Many countries and global organizations, such as the International Maritime Organization (IMO), have specific rules mandating the use of an AIS, which enables broad knowledge about human activity across our oceans.

But what if a ship does not comply with these regulations and decides not to share its location via AIS? Ships like these will not appear when using conventional tracking methods and are referred to as dark ships, dark vessels, or dark fleets.

Exploiting this lack of surveillance, dark vessels can participate in illegal, unreported, and unregulated (IUU) fishing practices that harm marine environments, local economies, and global food security. IUU is a widespread issue, with one study finding that 72% to 76% of industrial fishing is untracked.

To combat harmful activities like this, we need an alternative method of tracking — such as using Earth observation satellites. "Earth observation has always been a very important aspect of the space economy," says Dr. Minda Suchan, vice president of geointelligence at MDA Space. "There are things you can see from space that you don't have the same perspective of here on Earth." For example, she shares how dark vessels can be seen and tracked with radar imagery generated by Earth observation satellites, which makes this technology important to many across the globe.

> ***"Simulation is always going to be a critical part of building satellites and understanding how satellites operate in space."***
>
> — **DR. MINDA SUCHAN,**
> Vice President of Geointelligence, MDA Space

Dark vessels are also only one of many reasons why Earth observation is an important capability. Other industries that can use this technology include mining, forestry, and environmental, such as organizations monitoring the effects of climate change via ice mapping.

No matter the specific use, MDA Space uses its wealth of experience gained from developing world-leading space technology over 50 years and over 450 missions to address these critical global challenges. MDA Space's expansive work includes partnering for communication satellites, space observation, space exploration, and infrastructure missions. Through this vast, longstanding work, MDA Space can "bridge the gap between the proven and the possible," says Suchan. One of the proven products that MDA Space develops to push what's possible is its RADARSAT-2 satellite, which can be used to solve a variety of customer issues, including dark vessels detection and IUU fishing.

EXPLORING THE BENEFITS OF THE RADARSAT-2 SATELLITE

To understand the RADARSAT-2 mission, consider a customer investigating a potential dark vessel in its country. The customer requests an image of a location where it suspects the dark vessel to be sailing at a specific time. After receiving this request, MDA Space will command the RADARSAT-2 satellite, instruct it to collect data to image the target area, receive the data, download the data, analyze and interpret the data, and then deliver actionable insights to the customer — all while maintaining a highly precise orbit, says Lambert.

To generate the data that customers are looking for, RADARSAT-2 relies on a particularly important sensor technology: a synthetic aperture radar (SAR) antenna located at the bottom of the satellite.

This SAR antenna sends coherent radar signals to the ground and then measures the beam's reflection after it is reflected back up to the satellite, explains Dr. Casey Lambert, head of RADARSAT-2 mission operations for MDA Space, who is deployed directly at the Canadian Space Agency. This measurement is used to form an image of the area that the satellite is observing, such as the example seen on the next page.

SAR is "a very versatile Earth imaging tool" that enables applications you can't achieve with optical images, says Lambert. For example, SAR can "see" in low-visibility conditions like clouds, smoke, and darkness, observing objects like dark vessels that may otherwise remain undetected. SAR also allows you to observe ground motion and "the small but steady changes that happen through climate monitoring," says Suchan.

Another benefit of the SAR used by the RADARSAT-2 mission is that it functions 24/7 and can survey large areas at once. "We travel around the world once every 100 minutes,"

RADARSAT-2 imagery of shipping vessels. *Photo courtesy of MDA Space.*

says Lambert, "so we are able to cover a lot of ground and image large areas of the Earth every single day." Specifically, these satellites can monitor up to 500-kilometer swath widths, says Suchan.

While the RADARSAT-2 mission is already impressive, MDA Space remains focused on reaching for the stars by constantly optimizing and evolving its services. "We've been continually improving on a number of different metrics," says Suchan. These metrics include increasing the swath width, increasing image resolution, and improving data delivery times.

Another point of progress is the ability to reprogram on-orbit, giving MDA Space the flexibility to meet future mission needs with current satellites in space.

"Being reprogrammable on-orbit allows you the flexibility to change, sometimes even making changes here on Earth to satellites that are already in space," says Suchan. As part of this, the company is developing MDA CHORUS, MDA Space's next-generation mission that builds upon and shows the progress and innovation of its proven RADARSAT technologies. MDA Space will use this multisensor satellite constellation to provide improved radar imaging to customers.

Throughout it all, MDA Space turns to simulation software to keep up with its constant improvements and maintain a rapid pace of innovation.

ADVANCING SAR SATELLITES WITH ANSYS SIMULATION

"Simulation is always going to be a critical part of building satellites and understanding how satellites operate in space," says Suchan. "Simulation is an important aspect of not only understanding what you can do (in the present) but also supporting what you will do in the future and the planning process."

Take the RADARSAT-2 satellite as an example. The MDA Space team needs to ensure that the satellite is constantly operating at a very high level of reliability to perform its current routine operations. To do so, the team turns to Ansys Orbit Determination Tool Kit (ODTK) orbital measurement processing software and Ansys Systems Tool Kit (STK) digital mission engineering software to help with "operating on a daily basis and running reliably every day," says Lambert. Simulation software can also help support the constant advancements that are needed throughout the full lifespan of the RADARSAT-2 mission. "In terms of continuous improvement, we're not able to do anything with the hardware in space," says Lambert, "but we can improve what we have on the ground."

To increase its accuracy and efficiency, the MDA Space team once again turned to STK and ODTK software. "Ansys was instrumental in improving the orbit determination products that we were generating for the RADARSAT-2 mission," says Lambert. "By improving the orbit accuracy, we were able to improve the sensitivity to small ground movement, which is a significant improvement to what we were able to do in the early parts of the mission." These improvements enabled MDA Space to enhance the value of its products for customers. For example, by improving the orbit accuracy by almost one order of magnitude, MDA Space was able to detect ground movements at the centimeter level.

These developments aren't static either. MDA Space can make continuous orbit accuracy enhancements from the ground via software updates. The company has also "been able to automate the process of orbit determination using STK and ODTK software," says Lambert. This resulted in a 50% reduction in computing time and a significant improvement in reliability.

Simulation software also aids with MDA CHORUS constellation development of dual-band SAR satellites. "When you start moving into constellations, that's where simulation becomes even more important," says Suchan.

MDA CHORUS relies on two satellites. The first satellite provides C-band broad-area imagery up to a 700-kilometer swath width. This satellite is trailed by a second X-band satellite that offers a smaller swath width with a higher resolution. The combination of these satellites enables the MDA Space team to use the expansive data collected by the C-band satellite to determine what it may want to examine closer using the X-band satellite.

Optimizing the timing between these satellites and figuring out how to maximize the unique functionality of the dual-band design is where simulation comes in. "Simulation absolutely plays a key role not only in how to manage the different satellites but how to optimize operations between the two satellites," says Suchan.

Throughout MDA Space's work, "simulation data allows you to be very efficient, as well as allows you to plan very carefully and maximize the imaging opportunity that you have," Suchan says.

MDA SPACE'S NEXT STEPS

One industry trend that will aid in the continuous improvement of MDA Space's technology is artificial intelligence (AI). AI has "an incredible capability that can affect the full value chain," says Suchan. This can increase efficiency in MDA Space's design, production, manufacturing, and analytics processes. Suchan tells us that the MDA Space team is already using AI to build a natural language search for its archives, which contain over a million radar images. This project will help locate data, interpret imagery, and unlock the value of SAR for those without expertise in the area.

By using growing technologies like AI and software-defined satellites, MDA Space is well positioned to continue to lead in the global space economy. "MDA Space has so much opportunity to further expand our role as a trusted mission partner to our customers," says Suchan.

This growth will be aided by the STEM community, which also shows immense growth. "Talent is always going to be an important part of the space industry and is certainly a core part of MDA Space," says Suchan. At MDA Space, this talent includes engineers with a variety of disciplines and mindsets who form the heart of the company. These engineers create trusted, complex systems that companies have relied on for over half a century and will continue to power the next stages of the space economy.

> ***"Ansys was instrumental in improving the orbit determination products that we were generating for the RADARSAT-2 mission. By improving the orbit accuracy, we were able to improve the sensitivity to small ground movement, which is a significant improvement to what we were able to do in the early parts of the mission."***
>
> — **DR. CASEY LAMBERT**, Head of RADARSAT-2 Mission Operation, MDA Space

LEARN MORE

See how Ansys RF Channel Modeler software extends RF signal analysis.

ansys.com/applications/rf-channel-modeler-simulation-software

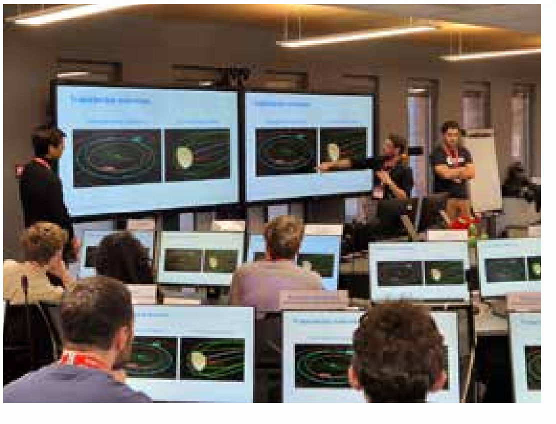
How University Students Train for Space Careers

By **SUSAN COLEMAN,** Director Academic and Startup Programs, Ansys

Concerns over a shortage of skilled workers and engineers in the European aerospace industry date back at least a decade.[1] Members of the European engineering community have proposed that greater strides should be taken at the academic level to better equip graduates and encourage more students to enter the field. Advocates contend that with technology advancing daily, skill sets must evolve and collaboration is needed to set up a bridge between educational institutes and the aerospace industry to increase talent and skills.[2]

To help mend such skills gaps, the European Space Agency (ESA) launched the ESA Academy in 2016 to enhance university students' educational experience with practical and theoretical hands-on learning. Students are encouraged to explore various disciplines, including space sciences, (concurrent) systems engineering, space medicine, spacecraft operations, project and risk management, product and quality assurance, standardization, and commercialization.

Since its inception, the Training Programme (TP) — one of three main ESA Academy programs at the organization — has integrated cutting-edge technology, including Ansys Systems Tool Kit (STK) digital mission engineering software, to complement students' academic experiences and advance skill sets with industry-ready



University students in the ESA Academy's Training Programme, an education initiative managed by the European Space Agency, integrate Ansys Systems Tool Kit (STK) software to explore space applications, including spacecraft trajectory analysis and orbit system design.

> ***"In the frame of our activities, it is essential to use a tool such as Ansys STK software. Without it, we could not offer the same hands-on experience to our students."***
> — **NIGEL SAVAGE**, European Space Agency Academy

tools. The ESA Academy accesses Ansys' tools through the Ansys Academic Program, which provides universities and academic institutions with affordable software for use in the classroom and in research. To date, the ESA Academy has trained more than 4,300 students in space-related domains.

APPLIED LEARNING: PUTTING SPACE DESIGN INTO PRACTICE

The ESA Academy welcomes university students from ESA Member States, as well as Canada, Latvia, Lithuania, Slovakia, and other countries per ESA agreements. Programs are open to undergraduate- and graduate-level students, though the majority of students are at the graduate level pursuing master's degrees.

The three main programs also include ESA Academy Projects — a continuing program that enables students to gain first-hand, end-to-end experience of space-related projects — and ESA Academy's Engagement Program, offering funding opportunities for conferences, scholarships, and short courses.

The TP offers approximately 30 training sessions every year in different fields of ESA expertise to complement what students learn at their universities and better prepare them for a career in the space sector.

Sessions are generally four or five days with longer training options offered during the summer. All sessions take place at the Training and Learning Facility (TLF) located at the ESA Education Training Centre at the

The ESA Academy's Concurrent Engineering Workshops challenge students to develop mission plans and designs using a concurrent engineering approach, which encourages students across teams to work collaboratively while completing different stages of design and development in unison rather than separately.

ESA European Space Security and Education Centre (ESEC-Galaxia) in Belgium. The TLF houses a training room and an educational concurrent design facility.

Every year, students in weeklong Concurrent Engineering Workshops develop mission concepts to demonstrate ESA technologies or new missions to explore the solar system or deep space. Concurrent engineering encourages students across teams to work collaboratively while completing different stages of design and development simultaneously rather than

mission architectures. Students used STK software for spacecraft trajectory analysis, as well as orbit and communication system design.

Nigel Savage, administrator of the TP, says STK software assists concurrent engineering approaches to space design by providing a shared platform.

"In our Concurrent Engineering Workshops, we have all different disciplines in the same room, and students work in a concurrent way using a collaborative system, in which any changes to a parameter in

The ESA Academy prepares university students for careers in space by supplying them with training and practical experience.

Since its inception in 2016, the ESA Academy's Training Programme has trained more than 4,300 students in space-related domains using industry-ready tools, including STK software.

in sequence. In such sessions, students are guided by ESA systems engineers and use a variety of tools, including STK software, to design their mission. STK software has become a staple enabling tool for all concurrent engineering sessions delivered by ESA Academy.

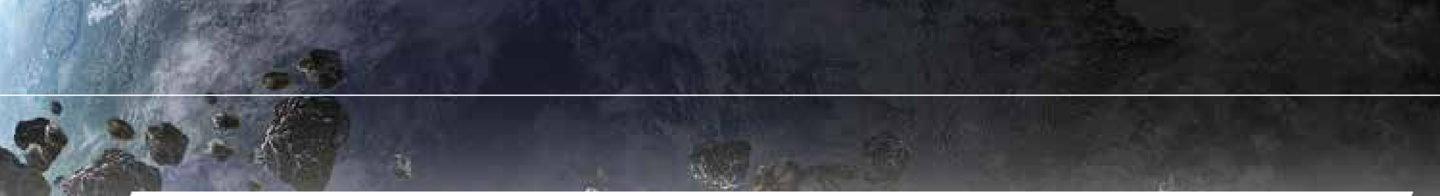
WORKING TOGETHER, CONCURRENT ENGINEERING

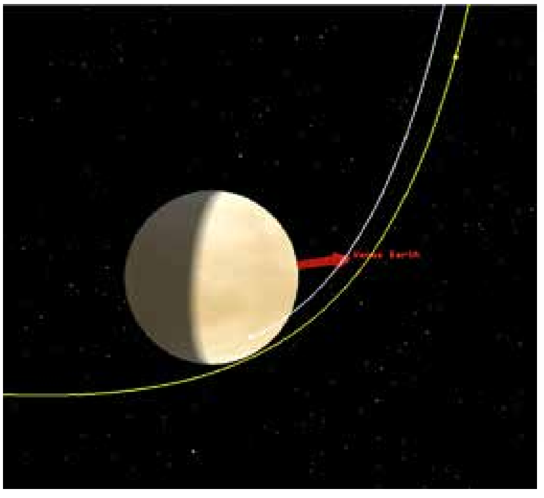
A few years ago, ESA Academy integrated STK software into its Concurrent Engineering Workshops. Students were split into teams of two or three, each responsible for the design of a specific subsystem of a space mission. The aim of parallel efforts is to accelerate and enhance the discovery and development of

one subsystem are directly reflected in the others," he says. "By using STK, the students can make these changes within the tool and see the impacts across the mission trajectory with visualization and collaboration."

Every year, ESA Academy runs several concurrent engineering courses and challenges, and STK software has become an essential tool for the success of these learning activities.

"STK supports Concurrent Engineering Workshops by enhancing the mission analysis iterations, thanks to its reliable features and add-ins, such as orbit simulations — for example, access to ground stations and coverage analysis — and advanced trajectory simulations for both





Students enrolled in ESA Academy programs get to explore space applications using real-life data from actual sites.

interplanetary and low Earth orbit (LEO) missions, spanning single satellite missions to constellations. In the frame of our activities, it is essential to use a tool such as Ansys STK software," says Savage. "Without it, we could not offer the same hands-on experience to our students."

Similarly, affordable access to the software through the Ansys Academic Program is equally needed.

"We are an education office, and with the budget allocated to our training activities, we would not be able to buy software licenses at the professional cost," he says. "The Ansys Academic Program providing us with these tools directly contributes to the level of training that we can provide our students with."

THE ESA ACADEMY'S REACH

The ESA Academy welcomes university students from the following regions:

ESA Member States: Austria, Belgium, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, The Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden, Switzerland, and the United Kingdom.

In addition to the 22 member states, Canada, Latvia, Lithuania, Slovakia, and Slovenia qualify to participate in programs based on their agreements with the ESA.

In addition, Malta qualifies to participate in STEM program initiatives and in the Training and Learning Programme (TLP) based on its agreement with the ESA.

SECURING TOMORROW'S ENGINEERING INDUSTRY

The ESA Academy is committed to preparing university students for careers in the space sector by supplying them with theoretical lectures and hands-on exercises using advanced tools.

"We appreciate the opportunity to use Ansys STK software in our training facility," says Savage. "We really see the benefit of having this tool available for our students, especially in our Concurrent Engineering Workshops where students in groups can use this tool collaboratively and also learn and develop their knowledge of STK for their future careers."

Ansys is dedicated to encouraging science, technology, engineering, and mathematics (STEM) education while ensuring the accessibility and affordability of simulation tools to best prepare students for careers in STEM fields.

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LEARN MORE

Explore the Ansys Academic program and learning resources.

ansys.com/academic

The State of Satellites: Applications, Challenges, and Opportunities

By **MATT LADZINSKI**, Senior Industry Marketing Manager, and **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

When sky-gazing on a clear night, have you ever wondered what exactly you're looking at? The soft glow of planets, stars, and spacecraft may seem similar at first glance, but they do have some distinctive features. To the naked eye, planets emit a steady shine while stars seem to twinkle — and both rise and set as the night progresses. Satellites, meanwhile, typically move in slow, steady, and straight paths and may flare in brightness as the Sun reflects off them.

Every satellite you see in our skies has a purpose, and this purpose must be defined before it is built, launched, and integrated into a constellation. Whether designed for communications; positioning, navigation, and timing (PNT); or remote sensing, a satellite's mission dictates critical decisions regarding size, structure, power supply, sensor payloads, and orbital configurations. As J.P. Ploschnitznig, senior principal application engineer at Ansys, puts it: "We don't say, 'Build the best system, put it up there, and see what it can do.' We say, 'What's the mission, and what do you want from that sensor once it's in orbit?'"

The demand for secure, high-speed global connectivity, precise location services, and high-resolution Earth observation continues to increase, driving significant advancements in satellite technology. With increasing global interest and commercialization of space, there has been a shift in approach involving the deployment of proliferated low Earth orbit (LEO) satellite constellations. Increasingly, the industry is relying on these smaller, networked systems that provide persistent coverage and resilience. This growth is not without challenges, and satellite developers must overcome spectrum management and system integration hurdles — no matter the type of satellite they are developing.

> **“STK software lets you fly many scenarios and ensure you meet the mission requirement. It allows you to simulate any sensor, visualize the coverage, assess the sensor performance, and generate synthetic data to validate your digital engineer options.”**
>
> — **J.P. PLOSCHNITZNIG**, Senior Principal Application Engineer, Ansys

COMMUNICATIONS AND POSITIONING, NAVIGATION, AND TIMING SATELLITES

The satellite communications market is expanding rapidly but faces challenges, such as congestion and competition for radio-frequency (RF) spectrum in LEO and geostationary orbit (GEO), the risk of interference and orbital congestion due to megaconstellations, and the diversity of transmission requirements across various applications. As a specific example of a common challenge, Laila Salman, principal application engineer at Ansys, says the communications of multiple satellites in one area can face interception or interference if operating at the same frequency. Addressing these issues requires continuous innovation in communications technology.

Free-space optical (FSO) communication satellites, for example, are emerging as a promising solution, offering high-bandwidth, low-latency transmissions that are resistant to RF jamming. FSO uses light to wirelessly transmit data over long distances. However, FSO satellites require precise beam alignment and face performance limitations in adverse weather.

Another advancement is seen in software-defined satellites (SDSs), which allow dynamic reconfiguration of frequencies, power allocation, and coverage areas to meet changing mission needs. Hybrid architectures that integrate RF and optical communications while linking constellations in different orbits are also being developed to ensure uninterrupted global coverage and operational redundancy.

PNT satellites, which were once primarily defense-oriented, now underpin critical services across telecommunications, logistics, and autonomous systems. Despite their growing importance, they face vulnerabilities due to jamming and spoofing, which can disrupt or falsify Global Navigation Satellite System (GNSS) signals. Traditional PNT architectures rely heavily on a limited number of satellites, making them susceptible to malicious activities or system failures. In addition, degraded environments, such as urban canyons, subterranean locations, and heavily forested areas pose significant challenges to signal integrity.

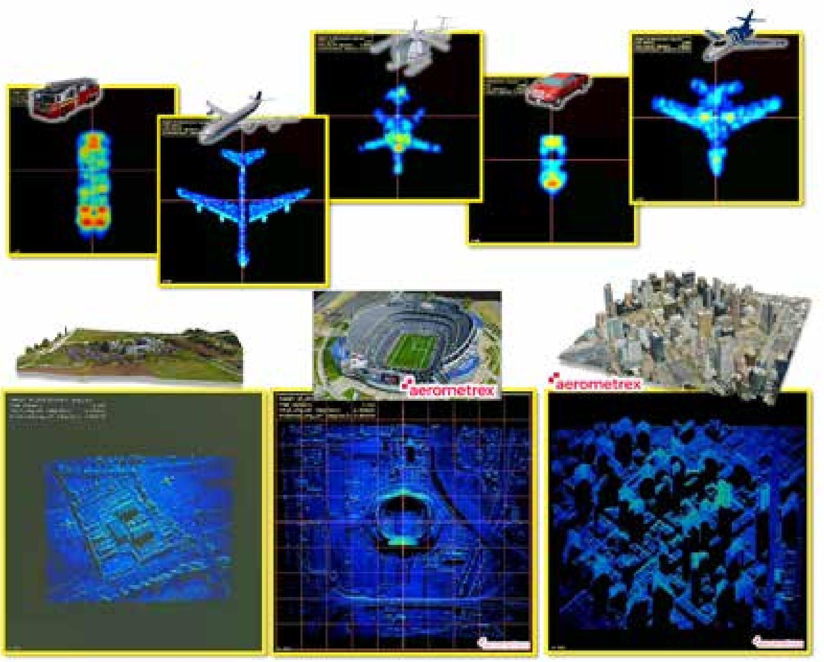
Earth weather conditions from space

REMOTE SENSING SATELLITES

Remote sensing satellites play a crucial role in environmental monitoring, disaster response, defense and intelligence applications, and commercial mapping. The sheer volume of data generated by high-resolution sensors presents another challenge, necessitating advanced onboard processing and high-bandwidth downlinks. The choice of sensors further complicates system design, as different missions require electro-optical, synthetic aperture radar (SAR), or thermal imaging technologies.

Electro-optical and infrared (EO/IR) sensors are widely used for high-resolution imaging in the visible and infrared spectra, supporting applications in agriculture, forest fire detection, intelligence gathering, and early warning systems. Hyperspectral imaging takes this capability further by detecting unique spectral signatures (reflected radiation wavelengths), making it valuable for material analysis, environmental monitoring, and countercamouflage operations. SAR is an advanced remote sensing technology that uses radar signals to create high-resolution, detailed images of Earth's surface. SAR can penetrate cloud cover, smoke, fog, adverse weather conditions, and darkness by using radio waves to create detailed ground images. SAR has become indispensable for surveillance and reconnaissance, offering all-weather day-and-night imaging capabilities.

Artificial intelligence (AI) is also playing a growing role in enhancing remote sensing capabilities. The next generation of satellites



VEHICLE DATA GENERATION (relevant aspect azimuth/elevation)

SCENE DATA GENERATION (with embedded vehicles)

will incorporate AI-driven edge processing so they can process more data on board. This would enable real-time anomaly detection, object classification, and automated tip-and-cue operations. These capabilities will reduce reliance on ground stations, improve response times, and enhance operational efficiency, particularly in tactical environments. To achieve those goals, AI models need clean training data, which can be a challenge. One way that Ansys is helping customers in the area of AI is with Project Loch Ness (ansys.com/campaigns/project-loch-ness), a complimentary, comprehensive training and validation dataset that features a range of SAR imagery and supporting information.

EFFECTIVELY MANAGING THE COMPLEXITIES OF SATELLITE DESIGN

For all its emptiness, space is full of challenges. Decisions made on Earth will determine the success of a mission taking place far from Earth's surface. At their core, these decisions come down to a few primary factors. "Power, space, and weight — these are scarce resources on a satellite," says Pat North, principal R&D engineer at Ansys. "System engineering needs to balance the requirements with the resources."

System engineering employs simulation to construct a virtual model of a satellite and run trade studies to determine the benefits of different components and optimize their design to meet specific mission objectives. With simulation, engineers can determine how a satellite will perform in its operational environment — all from their desks.

Due to these benefits, Ansys software has long played a major role in satellite development. Digital mission engineering tools, such as Ansys Systems Tool Kit (STK) software — formerly the Satellite Tool Kit — enable designers to model and explore sophisticated satellite options in real time. For example, STK software enables engineers and satellite operators to identify targets for observation; study a satellite in a model orbit at a specific altitude; understand when and how often a target will be visible to the satellite; and determine what level of resolution could be obtained with different kinds of sensors and optics.

"STK software lets you fly many scenarios and ensure you meet the mission requirement," Ploschnitznig says. "STK allows you to simulate any sensor, visualize the coverage, assess the sensor performance, and generate synthetic data to validate your digital engineer options."

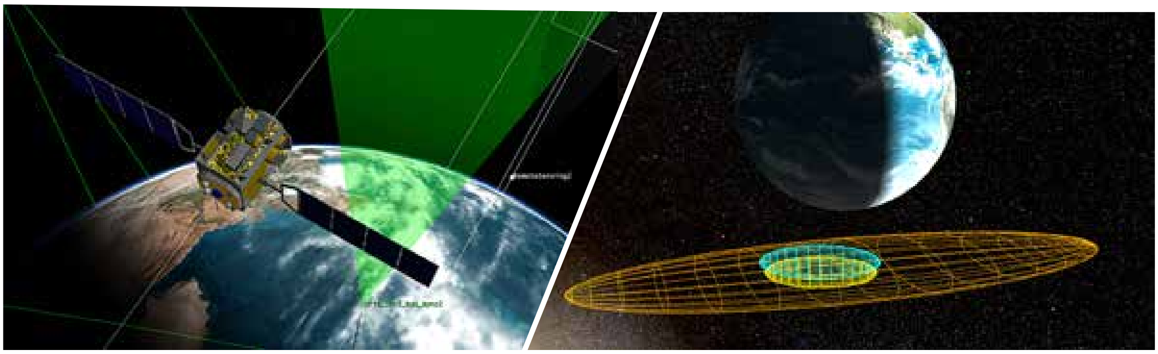
STK software can be propagated with geographic and geospatial reference data for modeling missions so a developer can see where a satellite will be, how fast it will be moving, what it can see or sense, and more. Orbits, altitudes, sensor types — all the parameters modeled by STK software can be manipulated, enabling a designer to model the satellite's ability to deliver on mission goals.

"Ansys STK software offers developers a sandbox for creativity that you simply don't get from a lot of legacy tools," says North.

Not only can STK software enable such a comprehensive analysis, but it provides engineers with essential visualization tools. "STK software produces beautiful videos that are technically critical to enabling people to understand what's going to happen in space — where the sensor is going to look and what it's going to be able to see — without ever launching into space," Ploschnitznig says.

Beyond STK software, Ansys provides a wide range of simulation tools and materials libraries that can help engineers and satellite operators model and refine their designs to achieve mission goals:

- Ansys HFSS high-frequency electromagnetic simulation software facilitates the design and refinement of antennas, such as phased array antennas, and can predict antenna system performance when it is integrated into the satellite payload.
- Ansys RF Channel Modeler high-fidelity wireless channel modeling software enables designers to analyze high-frequency signal propagation effects to model anticipated RF performance.



- Ansys Lumerical software, Ansys Zemax OpticStudio optical system design and analysis software, and Ansys Speos CAD integrated optical and lighting simulation software give access to a full complement of tools for designing and refining optical systems.

With systems like Ansys ModelCenter model-based systems engineering software and Ansys optiSLang process integration and design optimization software, engineers can create integrated engineering workflows that help explore trade-offs and identify options based on specific parameters. Such workflows enable engineers to use these simulation solutions together, passing data from one tool to another. This provides insight into the effects of a change in one area — say, the satellite's altitude — on other aspects of the satellite itself and its ability to meet the mission's goals. With Ansys simulation software, engineers and operators can ask — and answer — important questions about their design before building a single prototype or launching the satellite.

INSIGHT INTO SATELLITE GROWTH: ENABLING GLOBAL CONNECTIVITY AND INTELLIGENCE

Satellite communications, PNT, and remote sensing form the foundation of the modern global connectivity, precision navigation, real-time situational awareness, and resilient space-based infrastructure serving both civilian and defense applications. However, the increasing threats posed by spectrum congestion, cyber vulnerabilities, and adversarial counterspace activities demand continued innovation and investment. The future of these capabilities will be shaped by hybrid architectures, AI-driven automation, and an increased reliance on proliferated satellite constellations.

When looking at the night sky with a new appreciation for all the complexities that these satellite systems have, it's clear that to maintain a strategic advantage, governments and commercial entities must prioritize the development of next-generation satellite communication, resilient PNT solutions, and advanced remote sensing platforms. Investments should focus on security, redundancy, and interoperability, ensuring that critical data remains accessible, protected, and actionable in any operational environment. The ability to deliver timely, accurate, and secure information will be a decisive factor in global competition, shaping the future of operations, commercial enterprises, and everyday life. Simulation software will play an important part in achieving these goals. "In simulation, you're only constrained by the laws of physics, not budget," says North.

LEARN MORE

Watch the Ansys Space documentary "Simulating Space."

ansys.com/simulating-space

An RGB image from the Dragonette constellation taken Sept. 14, 2024, over the Escondida copper mine in the Atacama Desert in Chile.
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How Wyvern Is Creating a Better Earth From Space

By **CATY FAIRCLOUGH,**
Corporate Communications Manager, Ansys

Fans of mythology or Dungeons & Dragons may have heard of wyverns before. Commonly described as creatures akin to dragons but having only two legs, wings, and a pointed tail, wyverns are fearsome creatures that are a source of danger for many a story.

But what does this have to do with space? Instead of a monster taking to the skies, Wyvern — the space data company — is using satellites and hyperspectral imaging to reveal what it calls the invisible truths of planet Earth. The team's "ultimate mission is to provide data about Earth that will enable a more sustainable future for humanity," says Callie Lissinna, verification and validation lead and co-founder of Wyvern.

Today, with its up-and-running Dragonette constellation, the company can collect high spatial resolution, commercial hyperspectral imaging data from low Earth orbit (LEO). Wyvern then provides this reliable, high-quality data to experts in a wide range of industries who are addressing some of today's biggest challenges.

“Simulation is what you need to do to really verify and validate that this thing is going to perform in a space environment.”

— **CALLIE LISSINNA**, Verification and Validation Lead and Co-founder, Wyvern

For instance, consider our climate crisis. Hyperspectral data shows what's really happening on Earth's surface, which is an essential tool for better managing both the causes and symptoms of climate change. One such cause is greenhouse gas emissions, which Lissinna says future generations of Wyvern's satellites will be able to detect and measure in Earth's atmosphere. Hyperspectral data can also enable the early detection of, for example, gas leaks in remote pipelines, enabling engineers to fix these leaks and minimize the emissions entering our atmosphere. That's not all, either. Lissinna also notes that hyperspectral data can detect many types of climate change imagery, such as changes in bodies of water over time, the composition of plant species in specific areas, and more.

Another key use of hyperspectral data will be in the agriculture industry. Wyvern's work can help evaluate environmental conditions that affect crop health and yields. Other relevant uses in this industry include optimizing resource allocation by determining exactly where water or nutrients are needed, observing land cover changes, and monitoring the health of key species. This is all incredibly important work because, as Lissinna says, “we're going to need to feed 10 billion people by about 2050, so we need to know how to best use all of the resources that we have for us on this planet to continue to thrive and live sustainably as time goes on.”

A traditional RGB image compared with a hyperspectral image *(Credit: Wyvern Inc.)*

These are just a few of the many potential uses of Wyvern's space-based hyperspectral imaging data. Using this data, multidisciplinary leaders from all over the world will be able to monitor changes across Earth's surface and make informed decisions on sometimes-hidden problems.

INVESTIGATING THE DRAGON'S HORDE: WYVERN'S CORE TECHNOLOGY

At the core of Wyvern's ability to provide high-quality, reliable, affordable, and sharable data are its satellites. “Satellites have a unique perspective where they can see so much more than we ever could,” says Lissinna. With satellite imaging, Wyvern can obtain global coverage, high spatial resolution, and long-term monitoring capabilities. In addition, cost-effectiveness has been a driving factor in the design of the satellites. Wyvern has launched three satellites in LEO that take daily pictures of Earth. But these aren't ordinary photos since they are taken with hyperspectral cameras.

To understand the importance of hyperspectral cameras, we need to take a step back. Every material on Earth's surface has a spectral signature, which is like a fingerprint of its chemical makeup.

Hyperspectral imaging breaks down these spectral signatures into small spectral bands. "With these small bands, it's possible to see the chemical composition of every pixel in the image," says Lissinna, which provides a level of detail that would be impossible in a normal photograph. This results in a heightened ability to detect and classify materials from these images.

A typical image camera breaks up the spectrum into three spectral bands (red, green, and blue) and then reconstructs them into full color for the final image. As such, a normal photo would show a field of grass as green, for example. With hyperspectral imaging, the spectrum is broken up into many spectral brands, which reveal extra information. For instance, instead of a green field, the hyperspectral data can use its additional spectral bands to differentiate what areas of the field are lacking water or specific nutrients — and that's not all. With hyperspectral imaging, you can see things that would be impossible to determine with the naked eye, such as how chlorophyll is expressed in plants.

Wyvern's current Dragonette constellation produces hyperspectral imaging data with a 5.3-meter ground sampling distance and 23 to 31 unique spectral bands, which enables the identification of unique chemical and physical properties on the surface of Earth. These images are processed to Level 1B (L1B) by the Wyvern team and converted into a STAC-compliant GeoTIFF for better integration into a customer's existing workflow.

To ensure that its current and future satellites — and their orbits — are optimized, the Wyvern team trusts Ansys simulation software.

SIMULATION IS THE GLUE THAT CONNECTS ALL PIECES OF THE WYVERN PUZZLE

Wyvern "uses simulation all throughout our design cycle," says David Miller, mechanical design lead at Wyvern. This begins with the first step of orbital design and mission planning. Here, the Wyvern team uses Ansys Systems Tool Kit (STK) digital mission engineering software to study potential satellite constellation scenarios to determine the most efficient orbits and plan which satellite is best to take each customer order. "STK software is just completely fundamental to that process," says Miller.

A following step for the team is to use simulation to optimize the design of its imaging telescopes. This is an imperative part of the process, as these systems can't be easily fixed if something goes wrong in space. "Simulation is what you need to do to really verify and validate that this thing is going to perform in a space environment," says Lissinna. With simulation, Wyvern can confirm early in the development process that its designs will perform and meet requirements. This is particularly important because it's a long journey from space mission design to deployment, meaning that errors found at later stages can cause extremely long delays.

As for exactly how the Wyvern team turned to simulation software to optimize its design, it uses a number of Ansys products. For instance, Ansys Thermal Desktop thermal-centric modeling software performs the thermal analysis of its telescopes.

Both Lissinna and Miller emphasize the harsh thermal environment in space, which creates plenty of design challenges. For example, the designs must be able to withstand the heat of being in direct sunlight for half their orbit, as well as the extreme cold of the dark side of Earth for the other half of their orbit.

Miller stresses the importance of performing thermal analyses for the hyperspectral telescopes, which are sensitive instruments that need to withstand a challenging environment. "It takes powerful simulation tools to solve the problems associated with that, so Thermal Desktop software is huge for us," says Miller. "We're running simulations all the time because we have so many different cases to study to figure out how our telescope will perform in a bunch of different conditions."

Ansys Mechanical structural finite element analysis software is able to simulate the structural disturbances on Wyvern's telescopes. With Mechanical software, Wyvern can study how deformations, even of just a few nanometers, affect its designs. Additionally, it uses Ansys Granta Selector materials selection software for the complex material selection process. Granta software enables Wyvern to examine a huge number of potential materials to find the ones best suited for its design constraints. Early in the design process, Wyvern uses Granta Selector software to survey the field of available materials for good potential candidate materials: "Granta's custom material property indices and filters help us narrow down material candidates", Miller says. Later in the design process, Wyvern uses the extensive material data from Granta software in its thermal and structural simulations.

Finally, Ansys Zemax OpticStudio optical system design and analysis software is used in designing Wyvern's optical system, creating its control systems that work to precisely adjust optical components, and combining all the analyses to see how that will affect the optical performance of the telescopes.

Combining the results of all these different simulations is another key step in the process. "As we're really progressing into design, it's all of these tools working together," says Miller. By using these powerful integrated tools, Wyvern can have a great deal of confidence in the work it's doing, especially as a small team.

Throughout its design and development process, Wyvern also used simulation to increase efficiency, create an automated workflow, and save costs. "As a startup, we always need to be really capital efficient, and simulations can be a way for us to more affordably verify some key functionality," says Lissinna. Further, as part of the Ansys Startup Program, Wyvern was better able to access the exact tools it needed to develop its products quickly and efficiently.

While the simulation analyses discussed so far occur before Wyvern begins physical prototyping and testing, that doesn't mean simulation ends at that stage. "As we move further along into testing and then flight, we're again using all these simulation tools to validate our tests," says Miller. "In flight, we continue to use STK software to plan our capacity and optimize our operations." To achieve its goal of collecting as many images as possible to help its customers, Wyvern uses STK software to strategically plan and prioritize how to collect all necessary images using the resources it has. This is important because Wyvern's customers depend on it being able to take images at the right location and time, which requires constantly monitoring the orbits of its satellites to ensure performance.

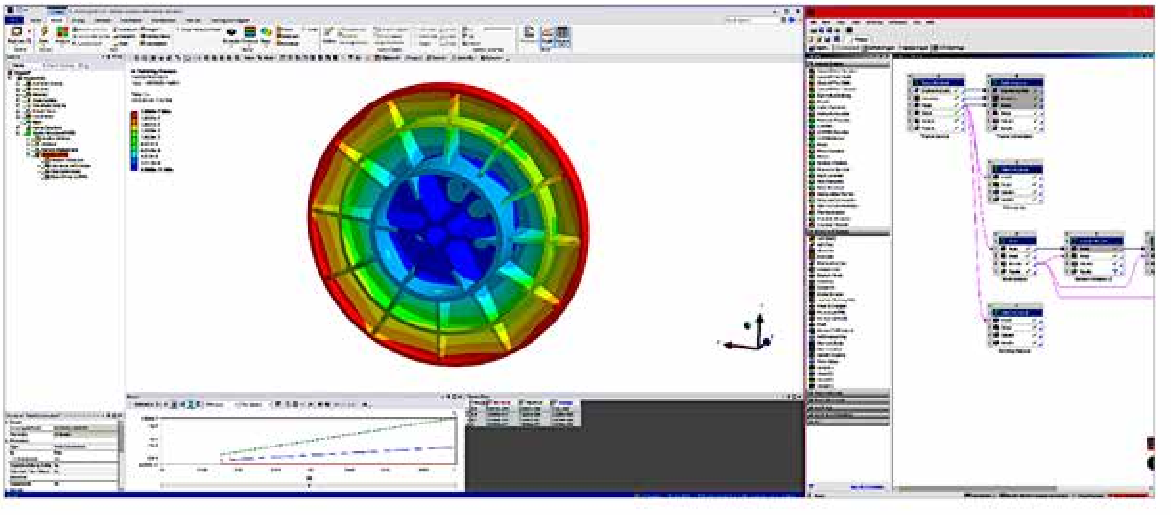
Throughout its current workflow and beyond, simulation software is an integral part of Wyvern's process. As Lissinna says, simulation tools aid in making sure that "all the different pieces of the engineering puzzle fit together" for optimized system performance.

WYVERN'S NEXT ADVENTURES

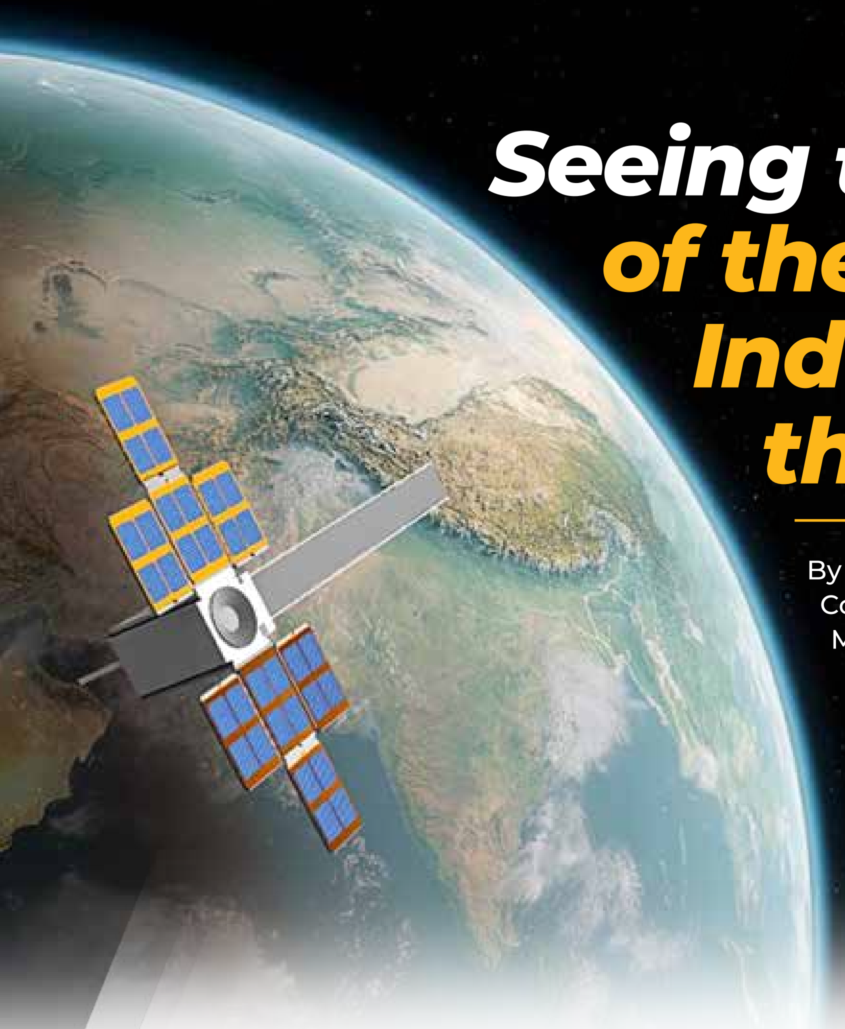
Wyvern is already preparing for its next phases. One upcoming advancement is the development and launch of its next generation of satellites, which will provide better data with a larger spectral range and higher resolution. This will enable it to detect a wider range of materials and chemical signatures. When these satellites join the existing constellation, Wyvern will be able to take more pictures at a higher frequency, as well as offer new products.

By continuing to enhance its technology, the Wyvern team also hopes to continue to play a role in improving the future of humanity. "One goal is to create a better Earth from space, and we don't do that alone," says Miller. Achieving this goal will require Wyvern partnering with new and existing customers that can use hyperspectral data to make positive changes in their respective industries.

Miller shares that future projects for the Wyvern team could include using its hyperspectral data to investigate the Moon or other planets in our solar system. "In the long term, we would love to have satellites in orbit around other planets to help humanity expand into the solar system," says Lissinna. Throughout it all, the team plans to continue to use simulation to help see its visions for the future come to fruition.



A simulation of a mirror in Ansys Mechanical software *(Credit: Wyvern Inc.)*

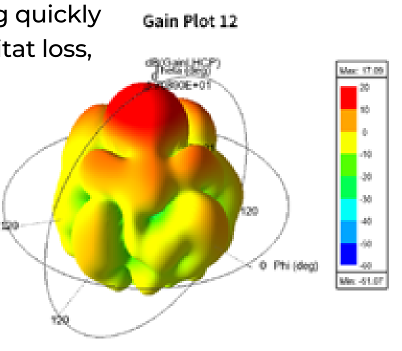


Seeing the Future of the Maritime Industry in the Stars

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

The importance of the oceans is a common denominator in our daily lives, even if it may not be obvious initially. “Nine out of 10 things that you see in your living room have made a voyage in the oceans,” says Gaurav Seth, co-founder and CEO of PierSight. Seth is serious about the importance of Earth’s oceans. His company aims to bring visibility to all human footprints at sea to protect the environment and make maritime commerce more efficient.

Protecting the ocean is no easy task, with a variety of threats — from piracy to blockages impeding global trade — spread across the oceans connecting our world. One pressing challenge that we face today is oil spill detection. Oil spills cause environmental emergencies that greatly affect both nature and the people whose livelihoods rely on their environment. Detecting oil spills as rapidly as possible is imperative in responding quickly and minimizing their damaging effects, including biodiversity, habitat loss, and harm to local economies and human health.



Gain plot showing the gain and radiation pattern of an antenna

A rapid detection and response process is also required to meet the challenges of exclusive economic zone (EEZ) monitoring. EEZs contain vast swaths of ocean that require vigorous monitoring to avoid many different threats, including illegal, unreported, and unregulated fishing; human trafficking; and terrorism.

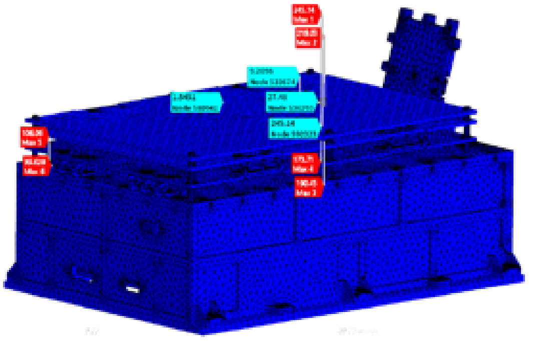
To address these issues, countries need a method of monitoring that is accurate, constant, and able to cover a large area. In other words, we need a method for persistent surveillance in the maritime industry. PierSight’s solution to this challenge? Protecting the oceans via a solution located in the stars: satellites.

WHY SAR AND AIS SATELLITES ARE THE KEY TO PERSISTENT OCEAN MONITORING

The secret to PierSight's vision of persistent surveillance for the maritime industry is the combination of synthetic aperture radar (SAR) and automatic identification system (AIS) satellites.

As a simple explanation of how these technologies work, Seth first describes AIS as similar to an app on your phone that can share live location information. In the maritime industry, AIS satellites pick up location signals tied to a unique ID to identify the location of marine vessels. However, AIS alone is not a complete solution, as malicious agents can turn off their AIS signal or try to fool the system into recognizing that they are in a different location.

To tackle this shortcoming, the maritime industry uses Earth observation (EO) technology to create images of Earth's surface that confirm the locations of ships and other points of interest. But even with this, it is challenging to maintain persistent surveillance at night or under certain weather conditions, such as storms or heavy cloud cover.



Simulation of a deployment structure for the marginal study at flight loads

> ***"Simulation is something very important. In order to do precise engineering, you need to do precise simulations before that."***
>
> — **GAURAV SETH**, Co-founder and CEO, PierSight

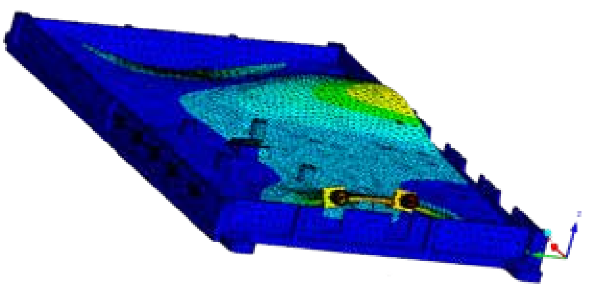
"That's where SAR comes in," says Seth. "Imagine a camera with a flashlight in space … ensuring that you detect ships as soon as they go dark." This metaphorical "flashlight" used by SAR satellites represents radio waves that capture variations in surface properties instead of the optical imagery captured in a photo. Such radio wave imaging is not impeded by darkness or weather conditions.

SAR satellites can constantly image the oceans, process the data in space, and then communicate with relay satellites to downlink locations of interest, such as vessels with turned-off AIS or a potential oil spill. After this, existing EO satellites can take high-resolution images to provide further information if necessary.

Using SAR and AIS satellite technology, PierSight aims to aid the maritime industry by providing all-weather imaging with low-latency data processing, seamless data fusion, and 100% ocean coverage. To do so, the goal is to form a complete 32-satellite constellation that can provide suitable, persistent, and comprehensive surveillance — all while minimizing satellite size and cost.

"We want to build this technology in such a way that it is affordable and mainstream for the vast commercial masses," says Seth. To achieve this affordability, PierSight focused on designing satellites for their specific maritime application area, which reduced their constraints. "Then, we innovated in terms of the system design and technology and have been able to create the world's first SAR in a CubeSat form factor," says Seth. "We can now produce these at a very low cost and proliferate them rapidly."

Also aiding this cost-efficiency is the fact that PierSight's technology is designed with the future in mind. Its satellites employ software-defined radar, enabling it to update its firmware for new generations of its technology without having to launch an entirely new satellite. In parallel with this technology, PierSight is also building a downstream application platform for



Package-level modal analysis to understand the vibration characteristics of the electronic packages

"In order to ensure that you don't fail at this one shot, simulations come to your rescue. So, it's very important to simulate every single thing."

— **GAURAV SETH**, Co-founder and CEO, PierSight

customers that will provide actionable alerts and insights.

Although PierSight's goals are as clear and consistent as its product, achieving them is no simple endeavor. For one, space is a resource-intensive industry, with products traditionally taking a long time and a great deal of funding to actualize. Attaining these resources and proving your vision with such a long lead time can also be difficult. Additionally, space is a ruthless environment. "Even if only a single thing goes wrong, all your good intentions and hard work can be killed by space," says Seth. To address these concerns, PierSight turned to Ansys simulation software.

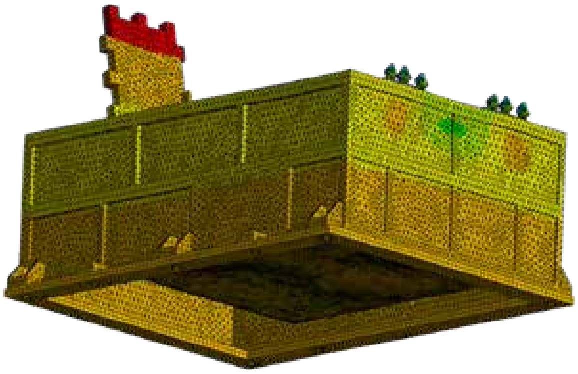
HOW PIERSIGHT USES SIMULATION SOFTWARE TO ADVANCE AN INDUSTRY

"Simulation is something very important," says Seth. "In order to do precise engineering, you need to do precise simulations before that."

For example, PierSight was able to accurately visualize its mission and its satellite's thermal performance in the space environment by using Ansys Systems Tool Kit (STK) digital mission engineering software. This is incredibly important to predict because, as Seth says, spacecraft can experience a temperature gradient of a few hundred degrees over a very small area, depending on the area's position in relation to the Sun. With STK software, PierSight was able to generate the Sun planet vector data and study its effect on designs.

STK software can also predict the potential coverage of a future satellite constellation, which is an important concern for PierSight's customers. Let's say a customer wants to ensure that its full EEZ is covered and that it can receive data at a certain frequency. With STK software, PierSight can simulate the constellation before it even launches to accurately predict coverages and data frequency for a specific time and EEZ in the future, as well as create a visual example for the customer.

The PierSight team also used Ansys HFSS high-frequency electromagnetic simulation



Modal analysis matching in parallel axis (Y direction) to feed with tested frequency

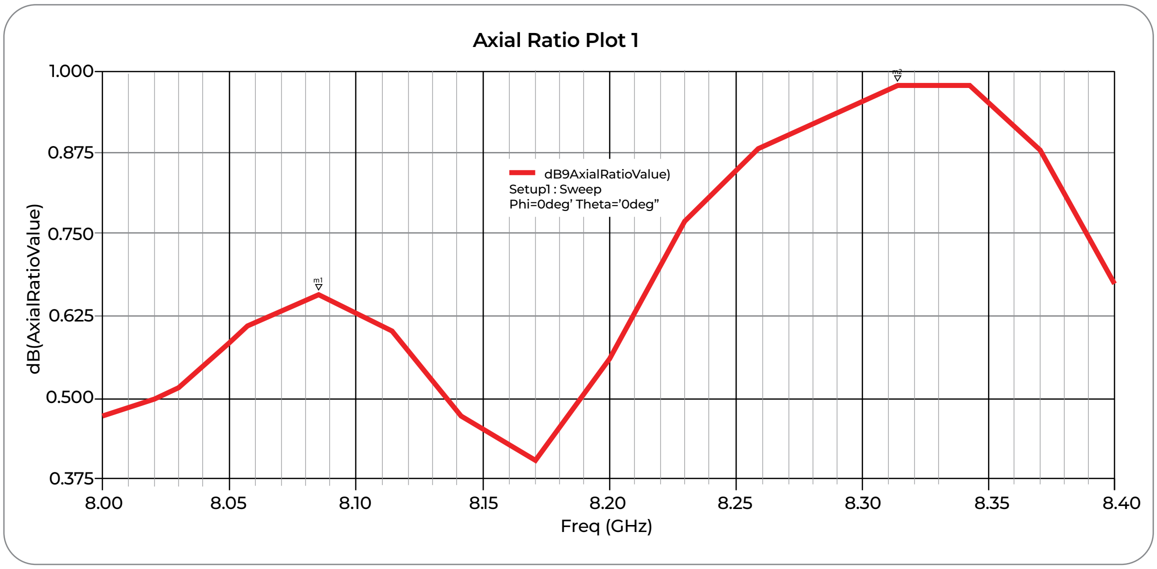
software and the Ansys Workbench simulation integration platform to design the antennas in its spacecraft, including the deployable antenna design that PierSight has already launched.

These antennas need to withstand intense vibrations, so PierSight used simulation to analyze antenna performance before moving on to what Seth calls "really ruthless" physical vibration tests, which included subjecting the three-panel antenna to 1,500 G of shock.

When comparing its simulation and real-world vibration tests, the team confirmed that the results matched, demonstrating the reliability of the Ansys software results. Simulation results help PierSight "gain confidence before a difficult environmental test for space," says Seth, which also helps to increase efficiency from an engineering perspective.

EXPLORING THE FINANCIAL BENEFITS OF SIMULATION SOFTWARE

As for PierSight's financial goals, using the Ansys product suite helps here as well. "For a startup like us who has one shot for success, no matter if the world believes in your theory and loves that you want to protect the oceans, it's still a challenge to get the capital even for a single shot," says Seth. "In order to ensure that you don't fail at this one shot, simulations come to your rescue. So, it's very important to simulate every single thing." Further, PierSight was also able to save costs



Axial ratio plot showing the polarization purity for the circularly polarized antenna

by receiving this software at a discount via the Ansys Startup Program.

In these ways, PierSight used Ansys simulation software to help it achieve both engineering and financial success. But that's not where the achievements end — PierSight's designs have already demonstrated real-world value through the Varuna mission.

SIMULATION HELPED PIERSIGHT GO FROM CONCEPT TO LAUNCH IN NINE MONTHS

PierSight's goal of transforming the maritime industry is already becoming much more than a vision. On Dec. 30, 2024, PierSight's Varuna mission — which is acting as an in-orbit demonstration of SAR in a CubeSat form factor — launched aboard a polar satellite launch vehicle (PSLV) on the Indian Space Research Organisation's (ISRO's) PSLV Orbital Experimental Module (POEM) platform.

Besides using this mission to move toward a higher technology readiness level (TRL), Varuna showcases PierSight's ability to move incredibly rapidly as a company — for example, the satellite used in this mission was built in just nine months. With the normal industry cycle for creating a SAR satellite prototype being around 48 months, this shows an impressive 81.25% decrease in time spent.

Even more remarkable is the fact that the team was also developing itself during these nine months, having started with just two members at the zero-month mark. Here, simulation software was a boon for the growing company as well. "With simulation software, even without having all sorts of deeper expertise, you can still get the problems solved," says Seth.

SEEING A BRIGHT FUTURE FOR THE MARITIME INDUSTRY AND BEYOND

Varuna is just the start of PierSight's bright future. Its next commercial satellite, which is planned to launch near the end of 2025, will usher in the start of its commercial operations. Seeing these commercial satellites launch and form a constellation will signal major success for the company by fully enabling it to generate and share data that can solve customers' problems. A couple of these solutions include:

- Comprehensive and real-time monitoring to identify oil spills via PierSight's satellite constellation, better protecting both marine life and humanity
- Persistent monitoring of EEZs to accurately detect illegal fishing, dark ships, and other unlawful activities at sea, thereby aiding private, government, and nongovernmental organizations

These are not the only goals that PierSight has either. Its team aims to take a complete digital mission engineering approach to its work, which will help it work toward its goal of being one of the largest satellite manufacturers globally.

LEARN MORE

Model your real world space environment with Ansys STK to ensure mission success.

ansys.com/products/missions/ansys-stk

Closing the Digital Divide

Space Innovation Improves Life on Earth

By **RAHA VAFAEI,** Senior Product Marketing Manager, Ansys

In 2023, more than one-third of the world's population lacked access to the internet, meaning that 2.6 billion people were cut off from opportunities for education, employment, healthcare, knowledge-sharing, and even community engagement.

While that figure may seem unfathomable to those of us with 24-hour connectivity, it's actually a 100 million-person improvement over the previous year.

Merely chipping away at the gap between the haves and have-nots is hardly a sustainable solution, however. Given the rapid acceleration of the digital age, those who are already disadvantaged are likely to fall even further behind.

There has to be a way to close the digital divide. Could the answer be a cube-shaped satellite roughly the size of a dishwasher and weighing only about 800 pounds? Astranis thinks so.

The mission of the San Francisco-based startup is to build advanced satellites for high orbits: small, powerful, next-generation spacecraft built for the intense radiation environment of deep space, including geostationary orbit (GEO) and medium-Earth orbit (MEO).

Astranis' business model is next-gen too: The company provides bandwidth as a service by leasing dedicated satellites to small and medium-sized countries, Fortune 1000 companies, and other customers as a turnkey solution. Astranis also proudly serves several government clients defending U.S. national security, including NASA and the U.S. Space Force. In fact, in January, Bloomberg named the company to its list of "10 defense tech startups to watch."

EARLY ACCOMPLISHMENTS, BIG PLANS

Astranis has launched five satellites so far, bringing broadband to millions around the globe, including in rural Mexico, the Philippines, and the United States. The company made history on Dec. 29, 2024, becoming the first single commercial manufacturer to fly four of its own satellites on one mission to GEO.

The Astranis Block 2 quartet, launched successfully by SpaceX from Cape Canaveral Space Force Station, Florida, includes:

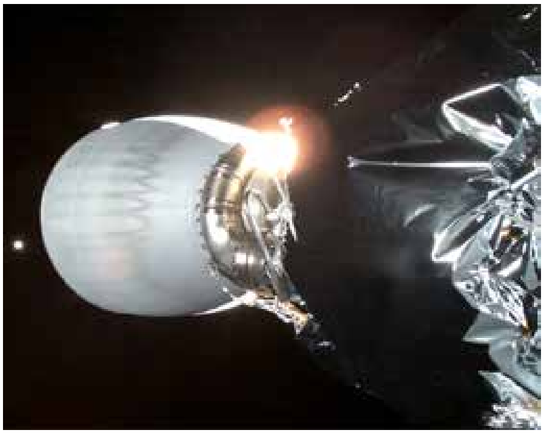
- NuView Alpha and NuView Bravo will provide service to in-flight connectivity provider Anuvu.
- Agila, in partnership with satellite services provider Orbits Corp., will be the first communications satellite dedicated to the Philippines.
- UtilitySat, a multimission spacecraft, will first provide broadband service to Mexico, then serve other commercial and government customers.

The four satellites have completed commissioning and are using their on-board ion thrusters to make their way to GEO. The company plans to launch a total of 100 satellites by 2030.

SIMULATION FOR DEEP-TECH INNOVATION

Simulation plays a crucial role in the success of satellite launches and operations, especially for a company like Astranis, which has already achieved significant milestones and has lofty goals ahead.

As a participant in the Ansys Startup Program, Astranis leveraged multiple Ansys solvers to optimize the MicroGEO iterative development process and qualify the satellite for 10 years of service. That included Ansys HFSS 3D electromagnetic simulation software, which enabled the company to simulate its game-changing design. Astranis also accessed Ansys Mechanical software for analyzing components with different loads and stresses, including the loads during launch and in-orbit operation. It used Ansys Thermal Desktop software for modeling heat transfer and thermal balance.



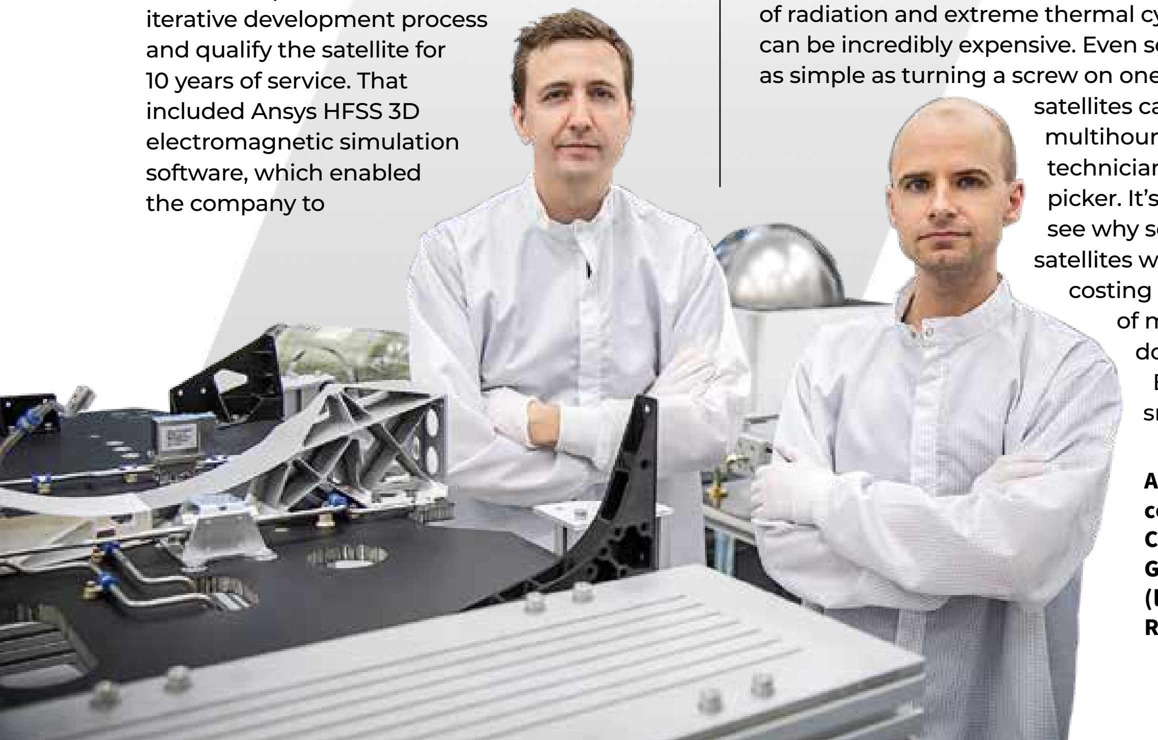
Astranis Alaska satellite deploying solar arrays

Ultimately, simulation helped Astranis produce an innovative deep-tech system fast, efficiently, and at a fraction of the cost of traditional GEO satellites.

SMALL SATELLITES FOR HIGH ORBITS

From our Earth-bound perspective, it's tough to imagine how big and bulky GEO satellites really are, but it's not unusual for a traditional telecom satellite to be the size of a double-decker bus. Building something that large (and making sure that it can withstand high levels of radiation and extreme thermal cycling) can be incredibly expensive. Even something as simple as turning a screw on one of those satellites can be a multihour job for a technician in a cherry picker. It's easy to see why some GEO satellites wind up costing hundreds of millions of dollars.

By making smaller,



Astranis co-founders: CEO John Gedmark (left) and CTO Ryan McLinko

> ***"Simulation plays a crucial role in the success of satellite launches and operations, especially for a company like Astranis, which has already achieved significant milestones and has lofty goals ahead."***

lighter satellites that can be manufactured at a regular facility, Astranis reduced production time and costs, which in turn increased customer value.

As for why Astranis chose to put its satellites in GEO rather than low Earth orbit (LEO), where the vast majority of satellites are, the answer relates largely to two factors essential for communication: positioning and coverage.

Satellites orbiting in GEO basically match Earth's rotation — they travel at the same speed that Earth rotates. With a satellite in GEO remaining essentially "fixed," it can provide uninterrupted connectivity over a specific region, something that would require hundreds of LEO satellites to achieve. In other words, for a country looking to provide internet to its citizens, all it would take would be a single Astranis satellite pointed at one location. The ability to provide dedicated service is a significant advantage for nations prioritizing sovereignty and security in today's interconnected world.

A GAME-CHANGING SDR

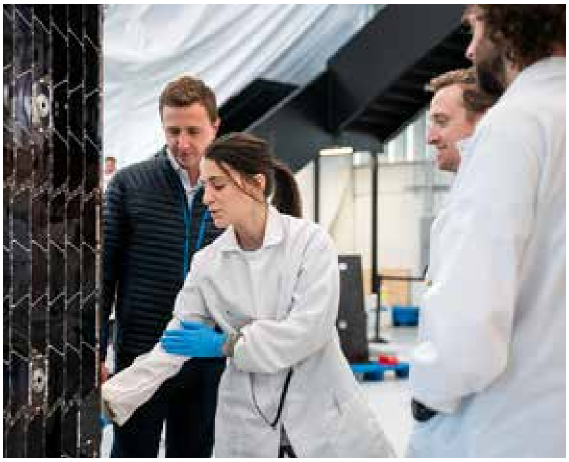
Their size, weight, cost, and other advantages over traditional satellites notwithstanding, what truly sets MicroGEO satellites apart is their proprietary software-defined radio (SDR). Traditional satellite responders, often referred to as "bent pipes," essentially act as passive relay stations. They receive signals from one location, amplify them, and retransmit them to another location without any significant processing or modification. While traditional responders have been effective for many years, their capabilities are limited.

The Astranis SDR is an intelligent computer in orbit that can complete a variety of digital signal process tasks and change its configuration to meet the mission. For instance, it can change frequencies on the fly to avoid jamming or interference.

Ansys software was critical to developing the Astranis SDR, enabling Astranis engineers to address challenges and explore how powerful new SDR designs would perform. Ansys HFSS software provided early-stage simulations that helped Astranis identify and correct design flaws before building physical prototypes. This reduced costly revisions and sped up the overall development process.

Key applications of HFSS software include:

- **Antenna design and optimization.** HFSS software enables the precise modeling of complex antenna geometries, including phased arrays, reflector antennas, and microstrip antennas. With HFSS software, engineers can simulate antenna performance metrics, such as gain, radiation patterns, impedance, and sidelobe levels, and can optimize antennas for specific applications.



Clockwise from top left: Astranis' facility, Alaska satellite engineers, an Astranis engineer working on the Alaska satellite, and Astranis CEO John Gedmark and Astranis engineers

- **Radio frequency hardware design.** HFSS software can model a wide range of RF components, including amplifiers, filters, mixers, and couplers. Engineers can simulate electromagnetic interference (EMI) between different components or systems to ensure compatibility. HFSS software can also be used to analyze power consumption and the efficiency of RF circuits.
- **System integration.** HFSS software can be integrated with other simulation tools to analyze the performance of the entire satellite system, including the spacecraft, the payload, and the infrastructure and equipment on Earth used to communicate with and control a satellite.

WHY SPACE MATTERS

Space-based infrastructure is crucial to expanding internet access, especially when it comes to providing coverage in underserved areas and during emergencies. But global connectivity is just one reason why space exploration and technology are important.

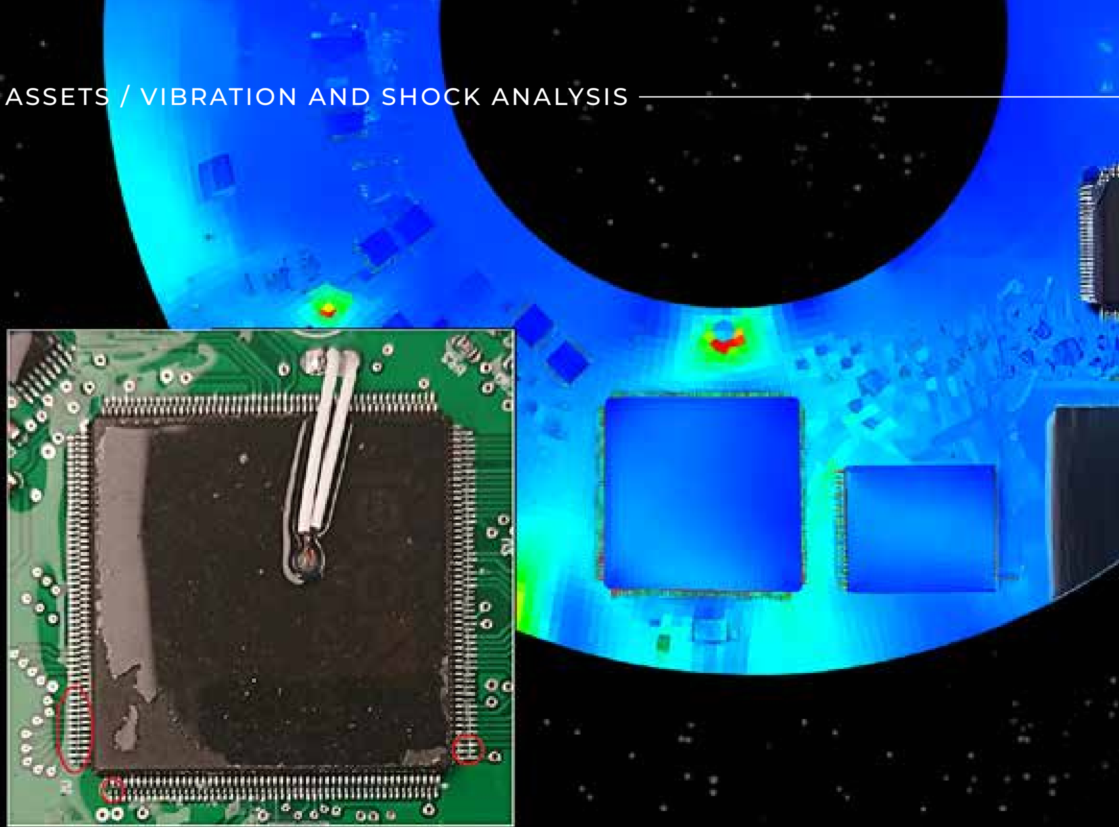
Astranis sees space as a universal rallying point for humanity — from using GPS to get from point A to point B to knowing what the weather forecast will be 10 days from now.

As one of the only companies that knows how to build advanced satellites for high orbits, Astranis is advancing the industry, unlocking the full potential of space technology, and making space-based services more accessible to people on the ground all over the world.

LEARN MORE

Explore Ansys HFSS software.

ansys.com/products/electronics/ansys-hfss



NewSpace Systems Simulates Satellite Shock and Vibration Challenges

Performing vibration and shock analysis of a field programmable gate array with Ansys Sherlock electronics reliability prediction software

By **EVAN SMUTS,** Engineer, Qfinsoft, and
SHANE MARTIN, Mechanical Design Lead, NewSpace Systems

As we learned from the 1995 film "Apollo 13," in space "failure is not an option." This applies to the potential loss of astronauts' lives — which thankfully was averted during the Apollo 13 mission — as well as something as simple as a broken electrical lead on a semiconductor chip due to thermal or mechanical stresses. Such failure of a printed circuit board (PCB) could cause the premature loss of an extremely expensive unmanned satellite, wiping out years of research and development, along with the mission the satellite was designed to perform. So it is imperative to fully test each chip design prior to launch.

> **“*FPGAs are integrated circuits that are the brains of modern control circuitry. For NewSpace’s purposes, they must survive the rocket launch into space, including the intense vibrations and shock loads caused by the rocket blast.*”**

NewSpace Systems, a trusted multinational spacecraft components and subsystems manufacturer headquartered in South Africa, recently ran into such a problem in the design of a field programmable gate array (FPGA). FPGAs are integrated circuits that are the brains of modern control circuitry. For NewSpace’s purposes, they must survive the rocket launch into space, including the intense vibrations and shock loads caused by the rocket blast. They also must perform at 100% reliability for the lifetime of the satellite, typically several decades, during which repeated cyclic loading can lead to fatigue failure.

Initial physical vibration testing of this new FPGA revealed cracking in two electrical leads (shown by the areas outlined in red in Figure 1). This required a redesign of the board. But building and testing physical prototypes is a slow, costly process. So with the help of Qfinsoft, an Ansys Select Channel Partner, NewSpace used Ansys Sherlock electronics reliability prediction software to simulate the

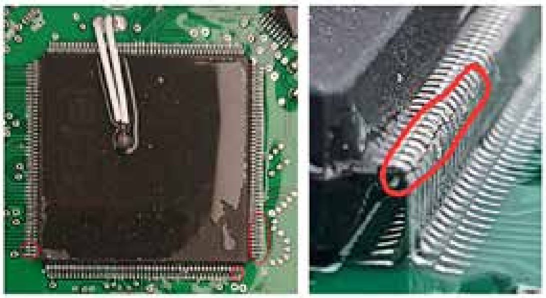


Figure 1. After vibration testing, NewSpace Systems noticed that some of the leads on the field programmable gate arrays (FPGAs) were cracked.

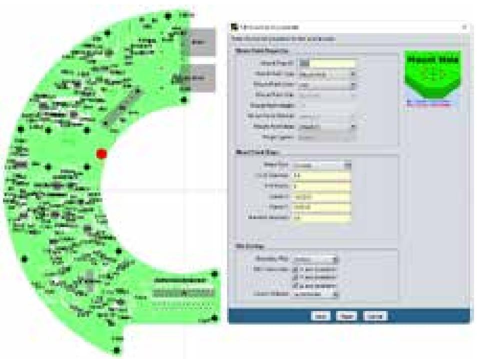


Figure 2a. Mounting points usually have space left for them on the layout design where the holes are drilled through the board (the large black circles).

cause of the failures and test different mitigation strategies. Once the Sherlock model was set up, testing designs took hours instead of weeks.

SIMULATING THE SOLUTION

Sherlock software is a physics-based engineering simulation solution that provides fast life predictions for electronic hardware at the component, board, and system levels in early design stages. While Sherlock software can do some basic analysis itself — for example, solder fatigue — full mechanical loading simulations require an external finite element analysis (FEA) solver. For this purpose, Sherlock software interfaces seamlessly with Ansys Mechanical structural analysis software, running FEA in the background. The results are then interpreted by Sherlock software.

PERFORMING FEA MODELING

Because vibration was the main concern in the lead failures here, NewSpace started by running a modal analysis to identify the natural vibration frequencies of the PCB on which the FPGA was mounted. The natural vibration frequencies are influenced by the board layers, component locations, lead types, board mounting points, and potting and staking adhesive regions.

Let's take mounting points as one example of how components can affect the vibration of a PCB. Mounting points usually have space left for them on the layout design where holes are drilled through the board. (See the large black circles in Figure 2a.) But the exact detail of how the PCB is mounted is lacking. In Sherlock software, NewSpace could define the type of mounting that it planned to use in each location (Figure 2b). The type of mount affects how the load — for instance, shock or vibration

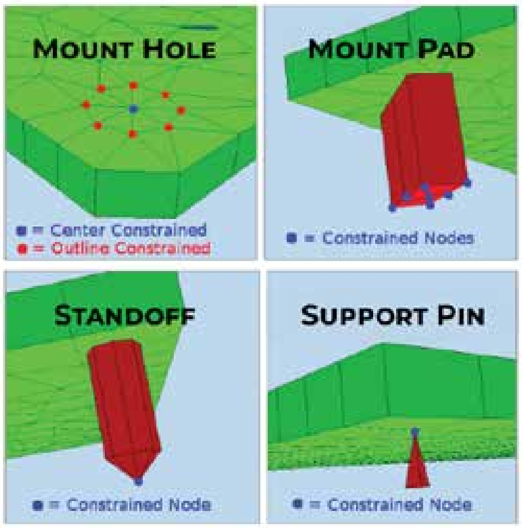


Figure 2b. In Ansys Sherlock electronics reliability prediction software, you can define the type of mounting that you plan to use in that location.

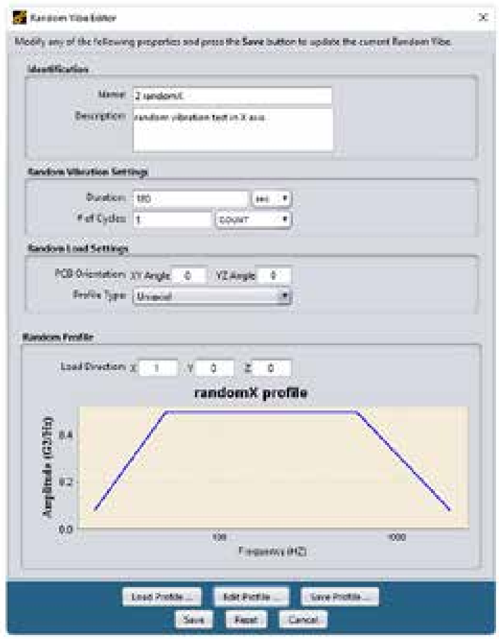


Figure 3a. The random vibration (RV) loading event related to the rocket launch.

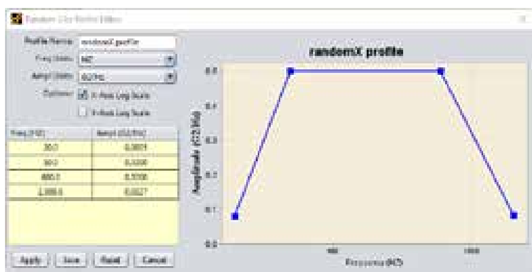


Figure 3b. An associated vibration power spectral density (PSD) statistical profile.

— is transferred into the board material.

For the certification tests, NewSpace was interested in three mechanical events: random vibration (RV), mechanical shock (MS), and harmonic vibration (HV). Each event was defined by a unique loading profile. For example, the RV loading event related to the rocket launch is shown in Figure 3a, with its associated vibration power spectral density (PSD) statistical profile (Figure 3b).

NewSpace had to consider frequencies between only 20 Hz and 2,000 Hz, which were required for the RV analysis. Sherlock software identified five vibration modes ranging between 991 Hz and 1,829 Hz. This meant that the HV analysis could not be performed, which required vibration modes below 200 Hz, thereby eliminating HV as an area of concern.

For RV, NewSpace considered vibration in all three axes (x, y, and z). Displacement contour plots showed how the RV displacement was dominated by the first natural frequency. (Compare the shapes in Figure 4, with red indicating higher displacement.) While the general performance of the board was good, Sherlock software calculated outright failure of a component in the z-axis vibration. That component was, as expected, the FPGA.

Sherlock software predicted that the FPGA had a 100% chance of failure, with multiple leads exceeding the strain limit. NewSpace identified an almost identical correlation between high lead strain and cracked leads identified in both the experimental testing (see inset photos in Figure 5) and simulation results.

“Sherlock software predicted that the FPGA had a 100% chance of failure, with multiple leads exceeding the strain limit. NewSpace identified an almost identical correlation between high lead strain and cracked leads identified in both the experimental testing and simulation results.”

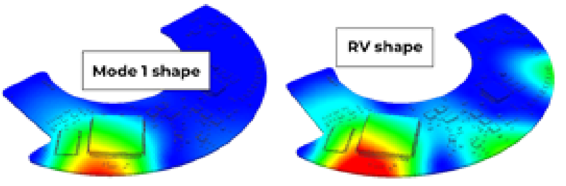


Figure 4. Displacement contour plots show how the RV displacement was dominated by the first natural frequency. (Compare the shapes in the figure, with red indicating higher displacement.)

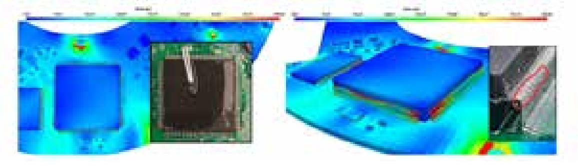
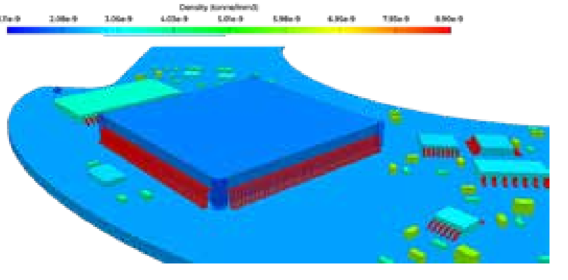


Figure 5. There’s an almost identical correlation between high lead strain and cracked leads identified in the experimental testing.

COMBINING SOLUTIONS TO REDUCE FAILURE

To prevent lead failure of the FPGA, NewSpace tried a combination of two solutions. The first was to add additional mounting points to the components’ PCB to increase the frequency of its resonant mode so that it fell outside the damaging vibration spectrum. Secondly, the chassis was stiffened using a process called “staking” to increase its resonant mode and reduce the deflection of the chassis under vibration. Staking refers to using resin or adhesive to glue components together or to the board. The adhesive anchors the chip to the board surface and takes some of the load off the leads.

The combination of mounting and staking solutions was optimized by performing Ansys Mechanical software’s RV analysis on the chassis and PCB and assessing both the total deflection of the chassis and fatigue lifetime of the leads. As expected, NewSpace saw an improvement in the performance of the leads under vibration. Sherlock software’s lifetime prediction indicated that some leads would, unfortunately, still fail, but these failures would be fewer in number than before and would occur only after 2.3 years — significantly longer than the previous simulation indicated. After running a few more simulations, NewSpace was able to produce an FPGA with 100% reliability over the lifetime of the satellite, which was the original target.



Figures 6a and 6b. To try to prevent lead failure of the FPGA, NewSpace looked at adding “staking” to the corners of the FPGA.

LEARN MORE

Explore Ansys Sherlock software.

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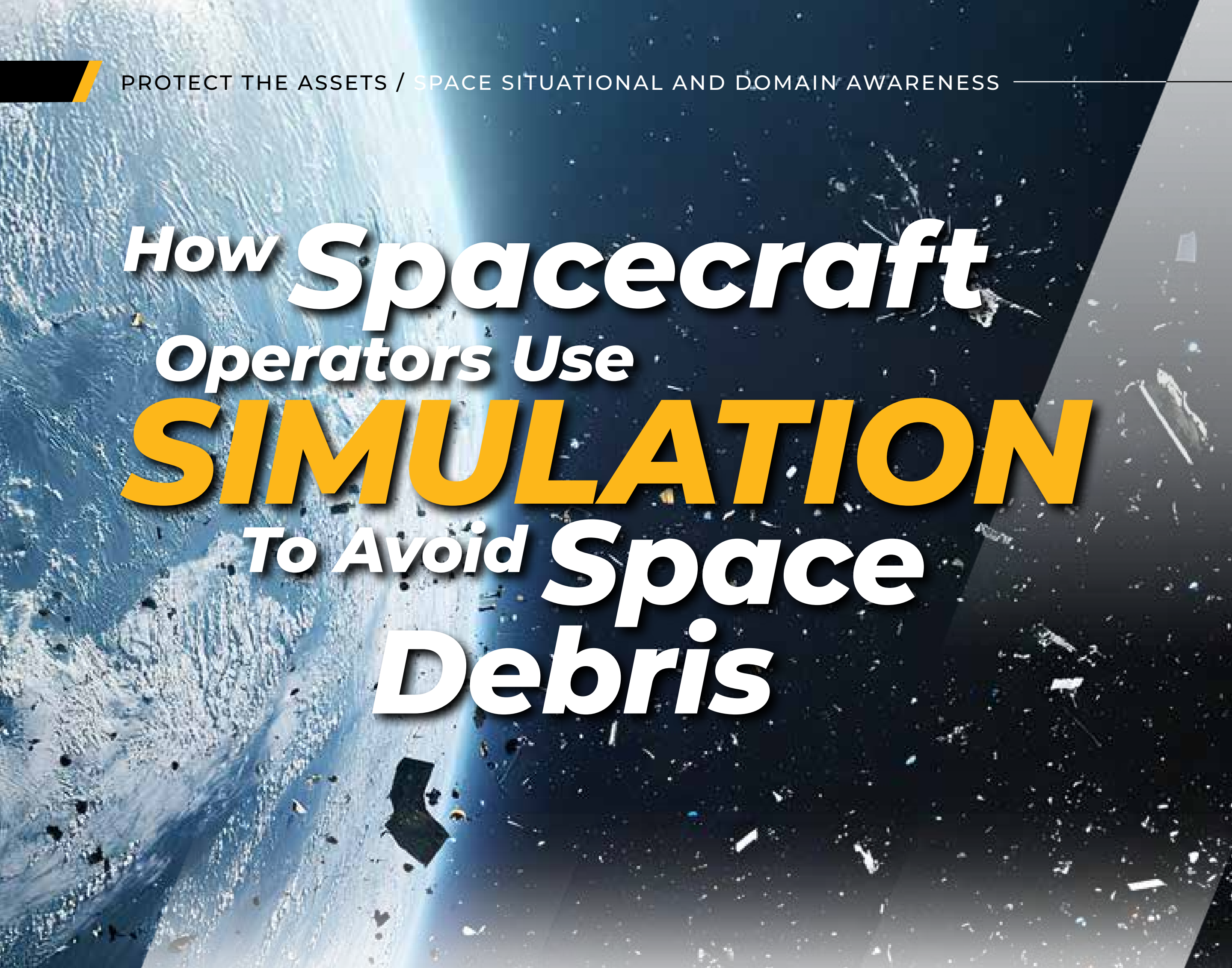


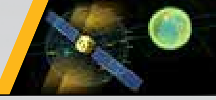
How Spacecraft Operators Use SIMULATION To Avoid Space Debris

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

A vessel created from ores found deep beneath Earth's crust hurtles away from its creators at 17,000 mph through low Earth orbit (LEO). While LEO was once a clear expanse of space surrounding Earth, this environment is becoming increasingly crowded with both active satellite missions and space debris. This debris ranges from discarded upper stages of launch vehicles and retired satellites to wreckage from accidental collisions.

According to Space-Track.org, approximately 11,000 active payloads and 17,700 analyst objects are currently in orbit around us. As for space debris, that number is more challenging to pinpoint. Space-Track.org, for example, approximates 19,000 pieces of debris in our orbit while the NASA Office of Safety and Mission Assurance (OSMA) estimates that there are over 21,000 pieces of orbital debris larger than 10 centimeters in existence. LEO also contains a large amount of debris that is too small to be tracked but can still cause great damage upon collision with a spacecraft.

No matter the specific number, the fact that space debris will continue to pose a significant obstacle for the space industry remains true. "Space debris is challenging because of the sheer scale of the problem," says Alex Lam, application engineer II at Ansys. "LEO, defined by NASA's Commercial Space program as the region of space between 100 km and 2,000 km above Earth's surface, encompasses over 1 trillion cubic kilometers in volume. Detecting and tracking a speck of space debris in such an enormous volume is akin to finding a needle in a haystack the size of the Earth. Plus, the needle just happens to be traveling at 17,000 mph." Finding these metaphorical needles will become increasingly challenging as the number of debris and satellites in LEO rises.



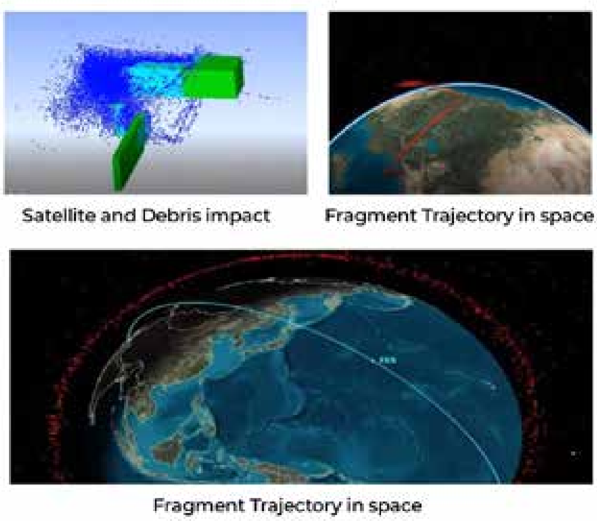
> **"*SSA and SDA are cornerstones of a successful space mission, and Ansys simulation software has been developed to help engineers perform these analyses effectively, enhancing their ability to minimize collision risk.*"**

Looking ahead, the overarching consequences of this crowded environment may even become catastrophic. In the 1970s, NASA scientist Donald Kessler proposed what is now referred to as Kessler Syndrome. This infamous theory predicts that a chain reaction could happen in space where two colliding objects would produce debris that would then collide with other orbiting objects, creating even more space debris. This scenario could cascade throughout LEO, possibly creating a near-impassable "debris belt" around Earth composed of the dangerous debris of former spacecraft, which would impede future space missions.

While we have not reached a world in which Kessler Syndrome has actualized, this grim prediction emphasizes the urgency of avoiding collisions in space. However, this is no easy task.

Matter in orbit around Earth moves very quickly and often in unrestrained trajectories; even a small piece of debris, such as a tiny paint fleck, could set off this syndrome, harming our ability to perform space missions. Maintaining a collision-free trajectory, however, comes with its own set of challenges. Engineers also need to prioritize fuel conservation and avoid communications delays between spacecraft and Earth-bound communication centers, which would reduce our ability to react quickly to obstacles. These obstacles will only be compounded as Earth's finite orbits become increasingly crowded.

So, how is the space industry dealing with these challenges?



Simulation examples showing the modeling of debris impact in space and tracing the trajectory of the fragments after impact to avoid collisions with other satellites

THE TECHNOLOGY USED TO AVOID AND MANAGE COLLISIONS IN SPACE

Let's return to our example of a spacecraft navigating the increasingly cluttered environment of LEO, where most human-made satellites and space debris are located.

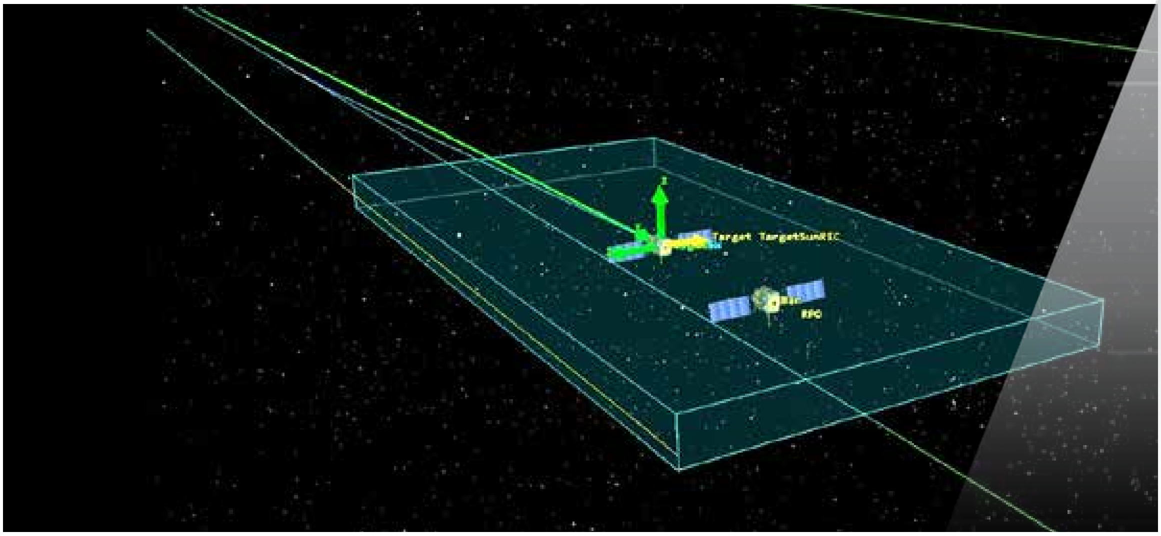
While the spacecraft's path can be planned using existing safe operations protocols and standards (such as the "NASA Spacecraft Conjunction Assessment and Collision Avoidance Best Practices Handbook"), guides cannot answer every question or scenario that a spacecraft operator may have. Static guides will also not remain up to date on the locations of debris and satellites. To help fill in these knowledge gaps, operators need constant updates on best practices and the positions of satellites and space debris. Then, they must determine their best course of action to avoid collisions with these objects.

To achieve these goals, spacecraft operators can turn to space situational awareness (SSA) and space domain awareness (SDA). Put simply, spacecraft operators:

- Use SSA to track objects and their operational environment to achieve advance warning and perform collision avoidance maneuvers (CAMs)
- Use SDA to build upon SSA and characterize the intent of space objects to better avoid them

To function properly, both SSA and SDA require the use of advanced tracking systems, accurate data, predictive algorithms, and data integration tools.

The use of SSA and SDA technologies is on the



Simulation analysis of rendezvous and proximity operation (RPO) support

rise. Lam shared how the responsibility for SSA in the U.S. is shifting from U.S. Space Command to the Department of Commerce, "which I believe recognizes the value of commercial space and more open data sharing beyond conventional defense purposes," he says. There's also growing interest in the commercial value of the SSA industry and even a recognition of the need to expand SSA and SDA beyond conventional Earth orbits.

While SSA and SDA are instrumental technologies in the future of space, they are not the only technologies required. For instance, what happens if a spacecraft needs to be refueled while in orbit? This scenario necessitates an ability for in-orbit maneuverability and servicing.

One way that operators can refuel a spacecraft operating hundreds of miles above Earth's surface is through in-space servicing, maneuverability, and manufacturing (ISAM), which extends the mission lifetime of spacecraft by allowing them to repair, replace, or upgrade parts; remove debris; and refuel. As part of ISAM, a spacecraft may need to perform a rendezvous and proximity operation (RPO) to further enable repositioning, docking, repairing, refueling, or other mission-extending activities. One example of this technology would be "companies like Astroscale advertising active debris removal and performing RPO for mission extension of in-situ inspection," says Lam.

While these relatively newer and emerging technologies are essential components of a spacecraft operator's toolbox, they are imperfect. Common challenges include:

- Finding software with enough sophistication to enable the navigation of a complex orbital domain while delivering operational flexibility
- Developing appropriately robust, low-latency, and accurate tracking systems, predictive algorithms, and data integration tools
- Accurately combining data from disparate sources
- Developing innovative and reliable technologies, such as autonomous technologies for ISAM and RPO
- Improving spacecraft designs to minimize debris creation from launch through the end-of-life deorbiting process
- Developing innovative debris removal technologies
- Building widely accepted and comprehensive international regulations, policies, and accepted standards for space debris

Addressing these challenges will have an immense impact on improving mission success rates. As a result, engineers are turning to Ansys simulation software to achieve this and solve some of the pressing issues in this sector.

ENHANCED OBSTACLE AVOIDANCE VIA ANSYS SIMULATION SOFTWARE

SSA and SDA are cornerstones of a successful space mission, and Ansys simulation software has been developed to help engineers perform these analyses effectively, enhancing their ability to minimize collision risk.

For instance, Ansys technology can be used to evaluate potential SSA system designs before the construction stage even begins. According to Lam, this includes using the Ansys Optical portfolio "to design lenses, mirrors, and detectors that maximize the capability of a given system" and the Ansys Electromagnetics portfolio "to design antennas, develop beamforming strategies, and characterize expected performance against debris with different shapes and sizes." These simulation tools can also be used to generate training data for artificial intelligence/machine learning (AI/ML) algorithms before the system is deployed.

As for deployed SSA and SDA systems, engineers and operators can use Ansys Orbit Determination Tool Kit (ODTK) orbital measurement processing software to process incoming measurements for cooperative and uncooperative objects in order to produce an ephemeris that has a realistic covariance. Meanwhile, Ansys Systems Tool Kit (STK) digital mission engineering software allows users to determine the collision probability between large catalogs of space objects. If the findings from this analysis indicate that a CAM is required, engineers and operators can plan an optimized maneuver that both maximizes fuel efficiency and minimizes collision risk. In the case of a collision, the Ansys LS-DYNA multiphysics solver can be combined with STK and ODTK software to better understand the resulting debris field and its implications by performing a forensic analysis that reconstructs the collision dynamics. Simulation software can also be used to dynamically analyze and compare potential trajectories and determine an orbit.

As for RPO and ISAM, simulation provides the ability to "try before you fly," says Lam. "Simulation allows you to mitigate risk and understand exactly how a close approach is going to go before you actually maneuver two very expensive satellites near each other."

A few of the many ways that engineers can apply simulation to these analyses are by using:

- STK software to plan an RPO maneuver
- Ansys Discovery 3D product simulation software and STK software to create a 3D spacecraft model with functioning solar panels and evaluate how solar panels are shadowed by another spacecraft maneuvering in close proximity
- ODTK software to process tracking measurements during RPO and ISAM when in close proximity
- Ansys Mechanical structural finite element analysis (FEA) software to evaluate contact dynamics for spacecraft that make intentional contact
- Ansys Electronics electromagnetic, signal integrity, thermal, and electromechanical simulation solutions to evaluate how RF communications change in the vicinity of another spacecraft
- Ansys RF Channel Modeler high-fidelity wireless channel modeling software to evaluate inverse synthetic aperture radar (ISAR) imaging of spacecraft in close proximity
- Ansys Speos CAD integrated optical and lighting simulation software to evaluate optical imaging of spacecraft in close proximity
- Ansys Thermal Desktop thermal-centric modeling software to evaluate thermal effects caused by spacecraft shadowing and ensure that all payloads remain within their thermal limits

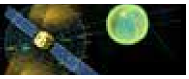
AN OUTLOOK ON COLLISION AVOIDANCE IN SPACE

In regard to SSA and SDA, "we are pushing the capabilities of detecting and tracking objects in space by building more exquisite telescopes and more powerful radars than ever before," says Lam. "These increasingly complex SSA/SDA systems demand maximum uptime with the highest possible performance." As for operations involving RPO and ISAM, the room for error will remain extremely low, resulting in demanding workloads for satellite operators who must ensure that all systems perform nominally.

While these technologies grow, simulation will continue to be a necessary tool to "ensure that these new technologies meet their demanding requirements before they ever get fielded, allowing for reduced risk and cost to programs," says Lam. That's not all either. Simulation software can also generate training data for AI/ML algorithms that are used by satellite operators and empower researchers to assess solutions for more exotic orbit regimes where new research is happening now, such as cislunar space.

Protecting the spacecraft in orbit around Earth is imperative not only for the existing services they provide — such as connectivity and resource monitoring — but for the innovative future uses we'll see in the coming years. To achieve this long-term reliability, SSA, SDA, ISAM, RPO, and other protective technologies must be at the forefront of our journey to the stars.

LEARN MORE



Watch the Ansys Space documentary "Simulating Space."

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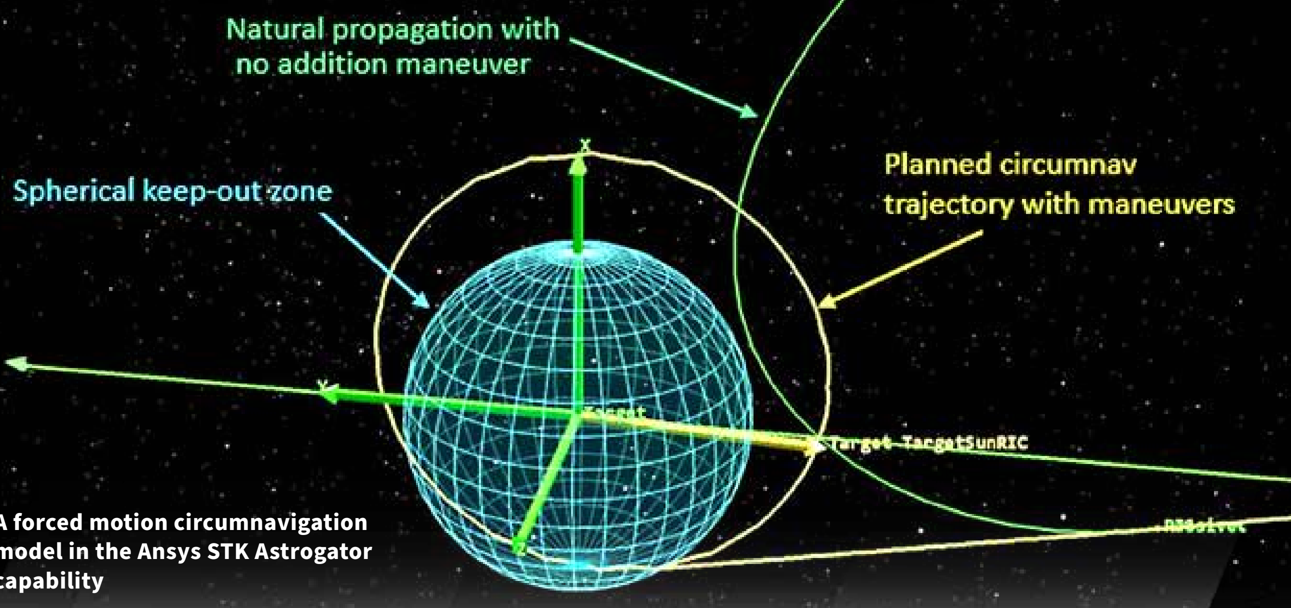
Ensuring Safe Skies:

The Importance of Passive Safety in Spacecraft Flight



A forced motion circumnavigation model in the Ansys STK Astrogator capability

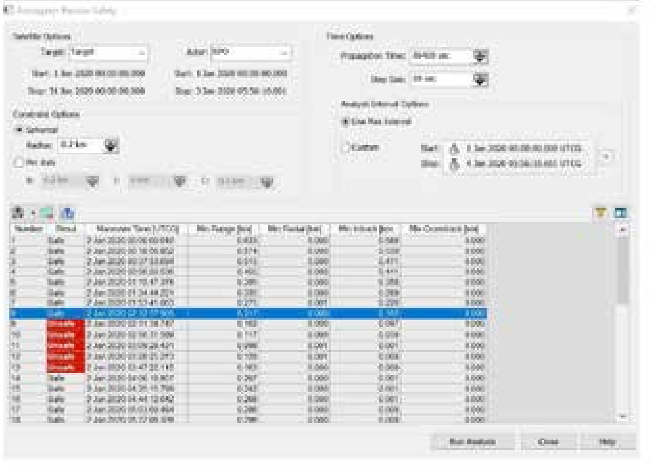
By **SELBY STOUT,** Application Engineer II, Ansys

Space travel has always captured the imagination of humankind, but the risks associated with venturing into the great unknown cannot be ignored. Ensuring the safety of spacecraft and any occupants is paramount in space exploration. While active safety measures play a crucial role, passive safety features and analysis are equally vital for mitigating risk. This becomes even more critical when two spacecraft are performing rendezvous and proximity operations (RPOs). Let's dive into the significance of passive safety for RPO analysis and its contribution to safeguarding astronauts and valuable assets.

DESIGNING A CLOSE PROXIMITY TRAJECTORY WITH SAFETY IN MIND

Depending on your role, passive safety may have several different meanings ranging from collision avoidance to structural shielding. For now, we will focus on the trajectory design and collision avoidance aspects of passive safety. When designing a close proximity trajectory, ensuring that satellites will not collide is the highest priority. This is becoming more critical as close proximity missions are increasingly common with new satellites. While this is challenging to verify in normal circumstances, what happens when an engine goes down, communications are lost, or the satellite enters safe mode? In situations like these, it is important to understand where the satellite will go in the absence of any additional inputs or maneuvers. In the absence of additional maneuvers, the satellites cannot collide, but usually a safe stand-off distance is desired throughout the

"The Passive Safety Utility tool enables you to analyze flight safety in situations in which a critical error may occur. This helps mission designers verify your passive safety requirements and validate that the satellites will not collide."



STK software's Passive Safety Utility interface. The tool enables targets, actors of interest, and keep-out zones to be specified.

event. Ensuring these constraints can be a long, tedious process, but Ansys Systems Tool Kit (STK) software and the Astrogator capability can help.

The Astrogator capability has long been known as the premier orbital design engine, especially for RPO missions, and it has a built-in tool for passive safety analysis. The Passive Safety Utility tool enables you to analyze flight safety in situations in which a critical error may occur. This helps mission designers verify your passive safety requirements and validate that the satellites will not collide.

The tool runs on top of an Astrogator trajectory and validates each maneuver that you have designed as it relates to a specified target. At the end of every maneuver, it will pull a state vector and propagate it forward in time. This propagation does not include any maneuvers or altitude shifts that were planned for the future, thus simulating a natural propagation with no additional inputs. This propagation can be compared against keep-out zones or conjunction requirements to help verify passive safety.

MAKE AN AUTOMATED PASSIVE SAFETY CHECK

In the following example, we will look at applying this tool in a forced motion circumnavigation around a specified target. The image on the facing page shows the planned trajectory in yellow, the desired keep-out zone in blue, and a sample passive safety check as the curved green line.

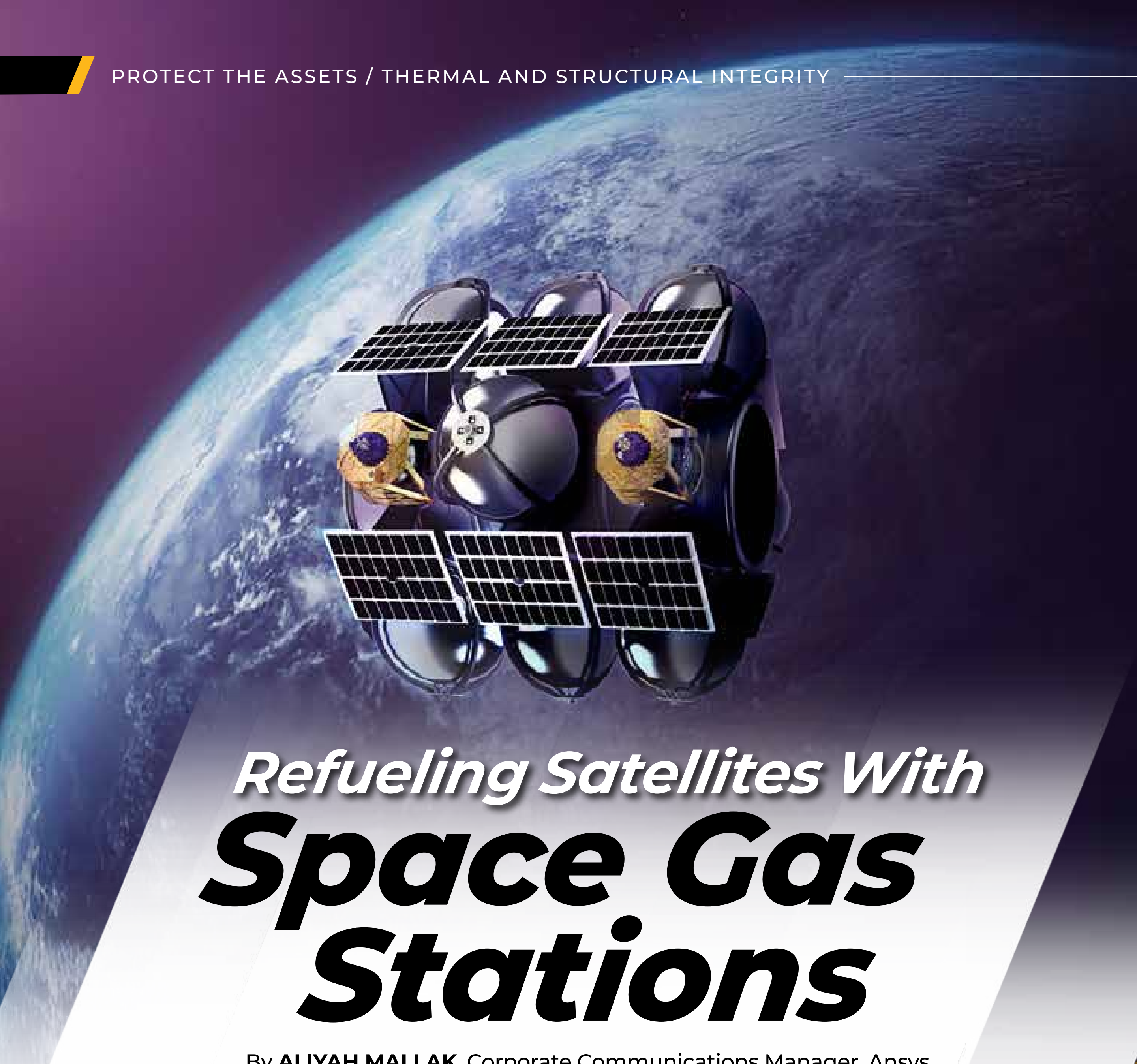
The trajectory shown has more than 40 maneuvers, all of which need to be checked for passive safety. The green trajectory shows a passive safety propagation for one such maneuver. In the case shown, the maneuver in question was executed, but no additional maneuvers could be executed. This resulted in the satellite drifting backward relative to the target. The Passive Safety Utility tool automatically checks all maneuvers in the trajectory and allows the user to graphically switch between each result and analyze the outcome. The image to the left provides a sample of the passive safety interface for this mission. The tool enables the user to not only specify a target and an actor of interest but specify particular keep-out zone sizes and shapes to meet requirements.

When you run a passive safety analysis, it provides a list of outputs, such as the resulting minimum range, to help you better understand the level of safety for each maneuver. It clearly marks when something is unsafe so you know exactly what to change in your mission design. You can also download all resulting data for use in additional analysis or tools, which can greatly reduce analysis time and help mitigate the risk of collision in operation.

LEARN MORE

Explore Ansys Systems Tool Kit (STK) software and the Astrogator orbital design engine.

ansys.com/products/missions/ansys-stk



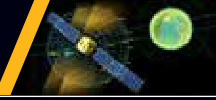
Refueling Satellites With Space Gas Stations

By **ALIYAH MALLAK**, Corporate Communications Manager, Ansys

When cars run out of gas or charge, we simply drive to a gas station and fill them back up or plug them into a charger. Single-use vehicles would be wildly inefficient, costly, and unsustainable. Humanity probably wouldn't be where it is today if all our cars and commercial vehicles were discarded after using up one tank of gas.

Yet satellite systems, which cost $100 million to $300 million on average and take years to develop, are all single use. Satellite lifetimes are set by the amount of fuel onboard when they leave the ground, even if the satellite itself is still in working condition. Once the satellite runs out of fuel, it either burns up in Earth's atmosphere or is pushed into a graveyard orbit, which lies outside other satellites' operational orbits, depending on its location. With about 2,600 objects launched into orbit in 2023 — and that number gradually rising every year — a lot of objects are competing for space.

To help the aerospace community make satellites more efficient and sustainable, Orbit Fab is creating the first commercial spacecraft refueling service. It aims to end single-use spacecraft and enable the next generation of missions based on extended satellite lifetimes and unlimited flexibility for maneuvering. Founded in 2018, Orbit Fab became the first private company to resupply water to the International Space Station (ISS), launched and tested the first fuel propellant depot, and has secured partnerships with other government and commercial customers to refuel their respective satellites in the coming years.



“We heavily rely on Thermal Desktop software for all our product designs.”

— **DIARMUID GREGORY,** Thermal Engineer, Orbit Fab

FILL ‘ER UP : GETTING FUEL TO SPACECRAFT

To make this vision a reality in an efficient, cost-effective way, Orbit Fab has developed what are essentially Gas Stations in Space™. Its refueling service uses reusable fuel shuttles to ferry fuel from storage depots directly to spacecraft. Customer spacecraft will be equipped with the Rapidly Attachable Fluid Transfer Interface (RAFTI™), which can be plumbed into the existing propulsion system.

The depots have simple propulsion and avionics systems that are largely designed for station-keeping and thermal conditioning of the fuel. The fuel shuttles are fully capable spacecraft with:

- A Grappling and Resupply Interface for Products (GRIP™) active refueling component
- RAFTI, a docking and refueling interface that enables on-orbit and ground fueling operations and is compatible with many storable propellants
- An attitude determination and control system (ADCS) and propulsion system that enables six degrees of freedom
- A rendezvous proximity operation and docking (RPOD) system

The shuttles and depots are strategically positioned to take advantage of their respective orbits to create reductions in expended delta-V to reach the customer, reducing the cost of fueling.

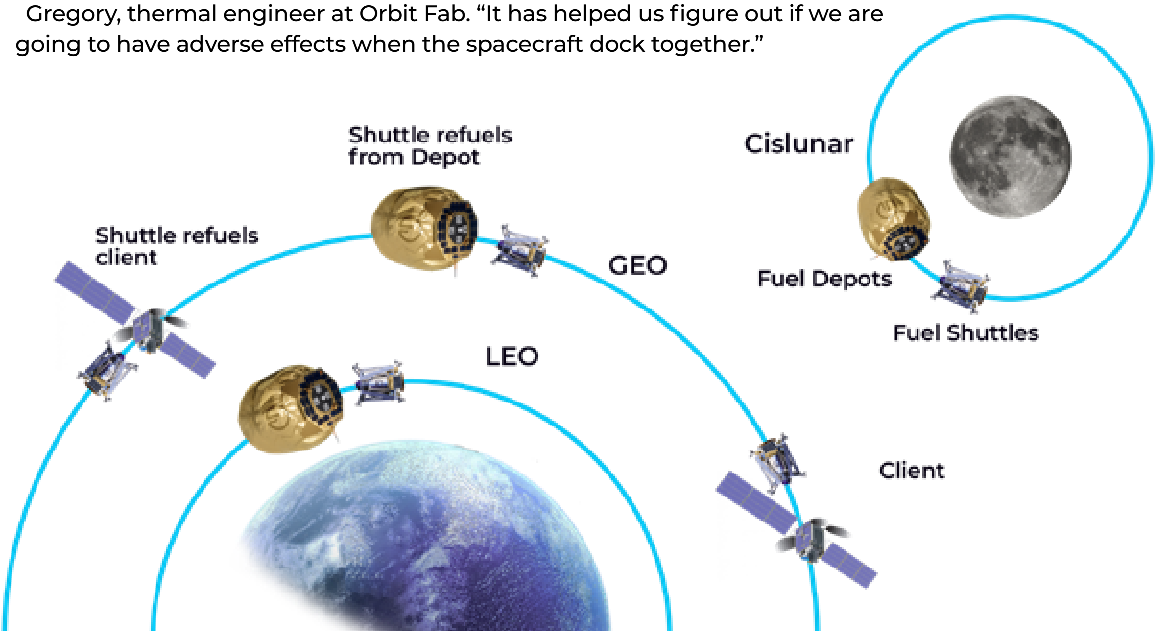
Using its universal mission planning software (UMPIRE), Orbit Fab can optimize refueling services based on individual customer missions. With it, Orbit Fab can determine when, where, and how much fuel a customer needs to refuel. The shuttles fuel up at the depots, maneuver to the customer spacecraft, dock with it using GRIP and RAFTI, deliver the fuel, and then maneuver back to the depot.

ENSURING THERMAL AND STRUCTURAL INTEGRITY IN SPACE

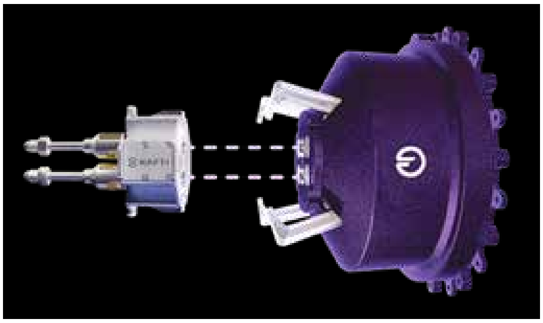
With so many variables in space and among the different systems, Orbit Fab uses simulation to test its interfaces. “Ansys really helps us do that analysis upfront to understand if our mechanism will work,” says Kevin Smith, chief engineer at Orbit Fab.

The Orbit Fab team uses Ansys Thermal Desktop thermal-centric modeling software and Ansys Mechanical structural finite element analysis (FEA) software for thermal and structural analysis of its interfaces.

“We heavily rely on Thermal Desktop software for all our product designs,” says Diarmuid Gregory, thermal engineer at Orbit Fab. “It has helped us figure out if we are going to have adverse effects when the spacecraft dock together.”



Orbit Fab refueling architecture



Rapidly Attachable Fluid Transfer Interface (RAFTI™, left) and Grappling and Resupply Interface for Products (GRIP™) capture mechanism (right)

Because there is no atmosphere in space, there is no way for heat to effectively dissipate through convection. That's why spacecraft have radiation shields that enable the heat created in flight to dissipate through radiative heat transfer. The heat created from the several motors inside GRIP has the potential to overheat, causing issues for GRIP or the customer's RAFTI that it attaches to. To test and study this, the team created an initial model of GRIP and tested it in a thermal vacuum chamber. The team then fed that data back into Thermal Desktop software to calibrate the model with more precision.

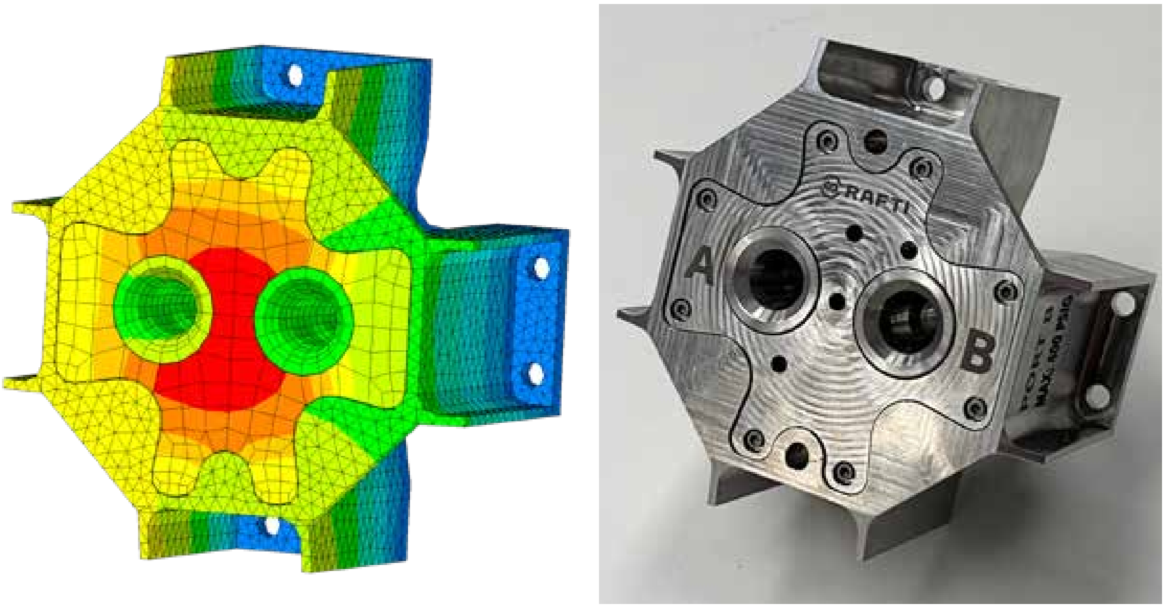
"Being able to parameterize stuff has been really helpful for trade studies and trying out different design options," says Gregory. "We use Thermal Desktop software to iterate quickly and ensure our analysis is demonstrating what is really going to happen in orbit."

Thermal design and analysis is only one piece of the complex puzzle. Sending anything into space produces a lot of vibrations, creating the potential for things to shake apart if not connected appropriately. The GRIP capture mechanism is bolted to the top of the fuel shuttles, so Orbit Fab uses Mechanical software to simulate optimal bolt patterns and test resonance frequencies.

"We use Ansys Mechanical software to evaluate if the bolts will lift off, if we're using the right materials, or if we need to adjust the bolt patterns," says Smith. "We also do vibration studies on the internals of GRIP. If this part of GRIP starts vibrating at a certain frequency and induces vibration in another part, you can get some pretty destructive forces."

GETTING MORE WITH YOUR DELTA-V

Missions that require frequent orbit changes need analytical models for mission planning that can be executed quickly, enabling fast iteration on plans that demand many maneuvers. To address this need, Orbit Fab developed an in-house mission architecture analysis and planning platform, UMPIRE, that integrates Ansys Systems Tool Kit (STK) digital mission engineering software to determine optimal refueling logistics to



Simulation of Rapidly Attachable Fluid Transfer Interface (RAFTI™) in Ansys Thermal Desktop thermal-centric modeling software (left) and RAFTI (right)

“We use Ansys Mechanical software to evaluate if the bolts will lift off, if we’re using the right materials, or if we need to adjust the bolt patterns.”

— **KEVIN SMITH**, Chief Engineer, Orbit Fab

Simulation of orbital maneuvers for a fuel shuttle approaching a client spacecraft

customer spacecraft at the lowest cost and impact.

“The idea is that you can input everything you want your satellite to do,” says Nate Wilson, mission analysis engineer at Orbit Fab. “Start in this orbit, transfer to this orbit, stay in this orbit for (the desired) amount of time with station-keeping, then, using UMPIRE, determine how, when, and where to refuel.”

Planning for refueling during the design phase encourages spacecraft designs that are optimized for other things instead of focusing on fuel consumption and storage. Refueling enables smaller fuel tanks, which in turn make the spacecraft lighter. Customers can use that space for different payloads or even reduce the size of the vehicle in its entirety.

“STK software helps us get very accurate fuel calculations to see exactly how much fuel we are using at each point and how much delta-V we’re spending for each maneuver,” says Wilson. “From an orbital analysis standpoint, the STK Astrogator capability is super useful for making sure we’re getting accurate ideas of fuel use during maneuver calculations.”

In addition to fuel consumption, STK software enables the Orbit Fab team to ensure that its fuel shuttles don’t uncontrollably collide with customer satellites. Using the robotics operation control (ROC) lab at Kirtland Air Force Base in New Mexico, Orbit Fab tested its RPOD platform. Using the three-degrees-of-freedom system, the team could simulate a controlled collision between the fuel shuttles and a customer spacecraft. The force of the collision wasn’t even enough to click a ballpoint pen.

“The whole point of the way people operate satellites is so that they don’t run into each other,” says Smith. “So, one of the biggest challenges we have is, how do we have a controlled collision? How do we convince people that we aren’t running spacecraft into each other? Simulation helps us do that.”

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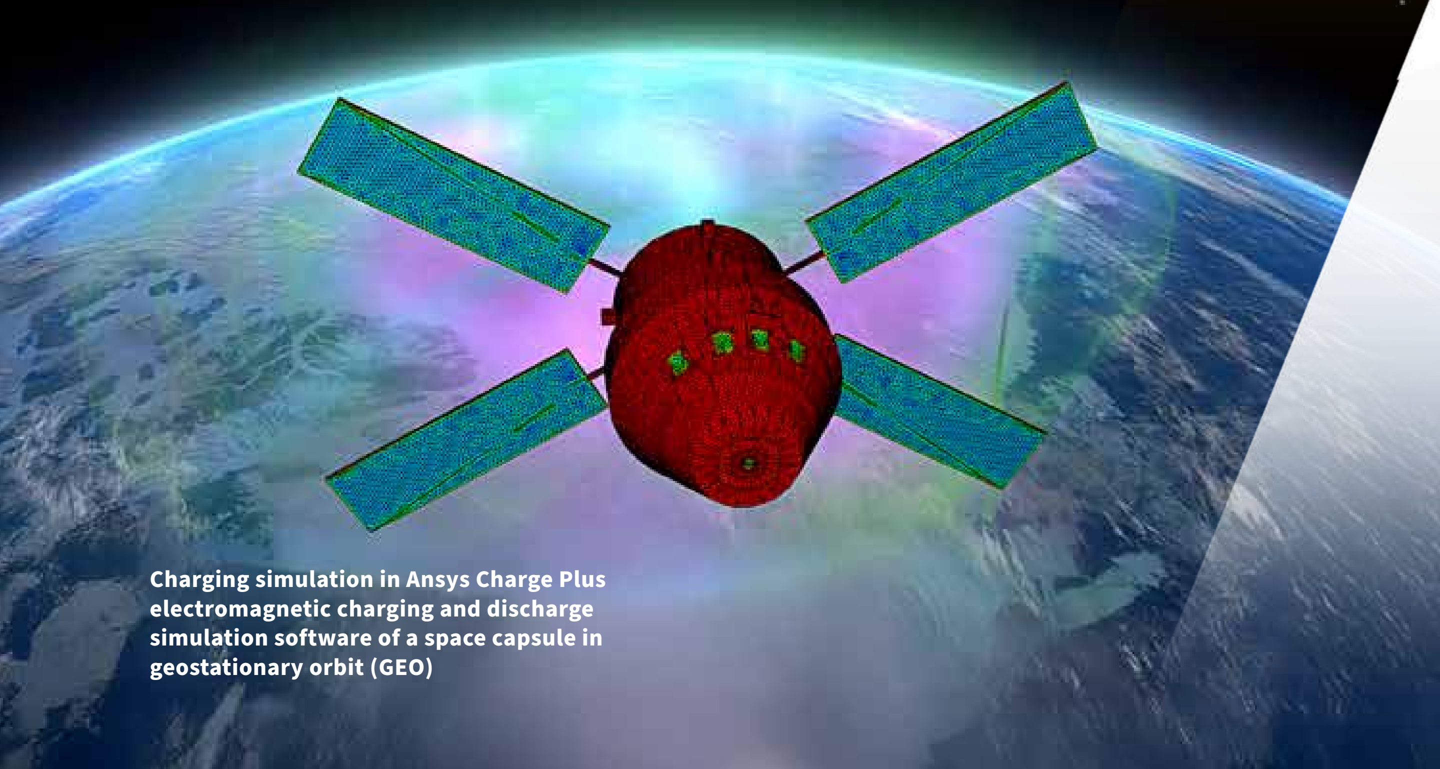
Electronics Reliability in Space: Simulating Rad Hard Designs

By **ALIYAH MALLAK**, Corporate Communications Manager, Ansys

SPACE IS A HARSH ENVIRONMENT. There's no breathable air, radiation levels are 15 times higher than on Earth, and the approximate temperature is 2.7 Kelvin (minus 270.45 degrees Celsius or minus 454.81 degrees Fahrenheit). Thankfully, Earth's atmosphere does a great job protecting us from space's intense climate. But because there is no atmosphere in space, there's nothing to protect satellites and other spacecraft from the extreme radiation and temperature fluctuations. The harshness of space can affect spacecraft components, including power electronics, guidance and navigation, and communications, all of which are critical functions. Because many spacecraft being launched are uncrewed, there's almost no way to repair components should something go awry. To prevent mission failures, the reliability of the electrical components in the systems is paramount. Simulation solutions enable design teams to develop robust space platforms and maximize the probability of long-term success for these expensive programs by offering a means to accurately simulate a broad variety of instruments, materials, and orbital targets.



Charging simulation in Ansys Charge Plus electromagnetic charging and discharge simulation software of a space capsule in geostationary orbit (GEO)

“Too much charge accumulated in a cable connected to sensitive electronics may induce currents that damage the instruments.”

GALACTIC X-RAYS

Much like people, systems on spacecraft are affected by short- and long-term radiation exposure.

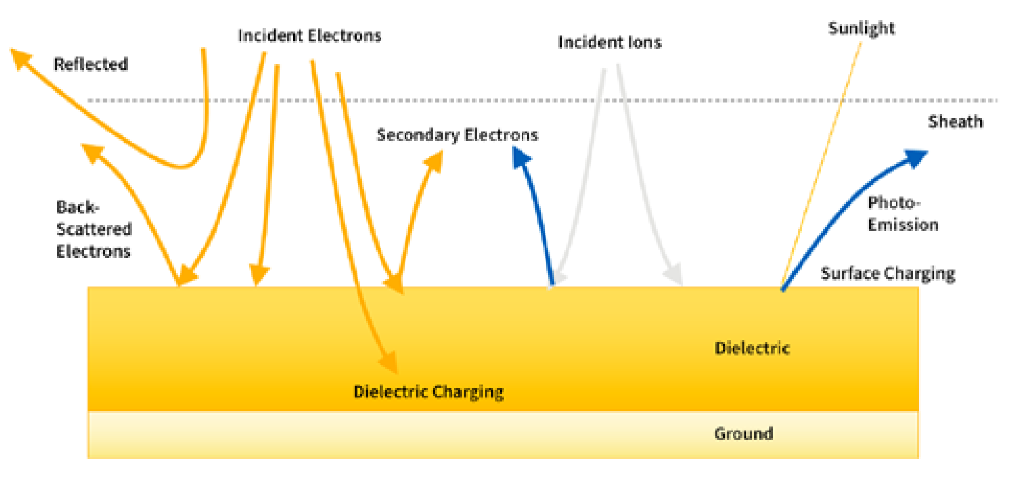
- Short: Single-event effects (SEEs) are electronic disturbances caused by one highly energetic particle.
- Long: Total ionizing dose (TID) is the overall accumulated dose of radiation from different sources, including electrons, protons, heavy ions, x-rays, and gamma rays.

The sources of radiation most commonly are from particles trapped in Earth’s magnetic field, solar particle events (SPEs) during solar flares, and galactic cosmic rays (GCRs). The ionization of these particles can cause detrimental effects on spacecraft electrical systems. The particles cause a charge buildup that can’t dissipate because spacecraft are not grounded to anything. When charge accumulates, it induces electric fields. The magnitude of the electric fields may exceed the breakdown of air, plasmas, or dielectrics and lead to electrostatic discharges (ESDs). Studies show that about half of spacecraft anomalies are caused by spacecraft charging effects.

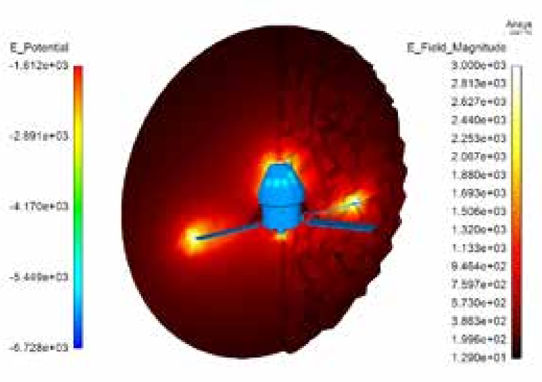
SURFACE CHARGING RISK ASSESSMENT

Surface charging comes from a material response to external radiation, such as ambient charged particles, photo-illumination, and triboelectrification. The material response to the charging effects depends on the material’s properties. The resulting photoelectrons, secondary electrons, back-scattered electrons, and proton-induced electrons interact with the electric fields to form a plasma sheath.

On the way to the Moon, for example, spacecraft encounter surface charging effects of varying scales depending on the transfer orbits. Geostationary orbit (GEO), low-Earth orbit (LEO), and polar, auroral, and lunar orbits all have different plasma environments defined in the design specification standards. Geometry, shadows, and the material properties, in addition to the plasma properties or the triboelectrification amplitude,



Conceptual diagram of physical processes involved in spacecraft charging



The results of the surface charging simulation of a human space capsule. The electric field is monitored in the time domain, in 3D, around the spacecraft.

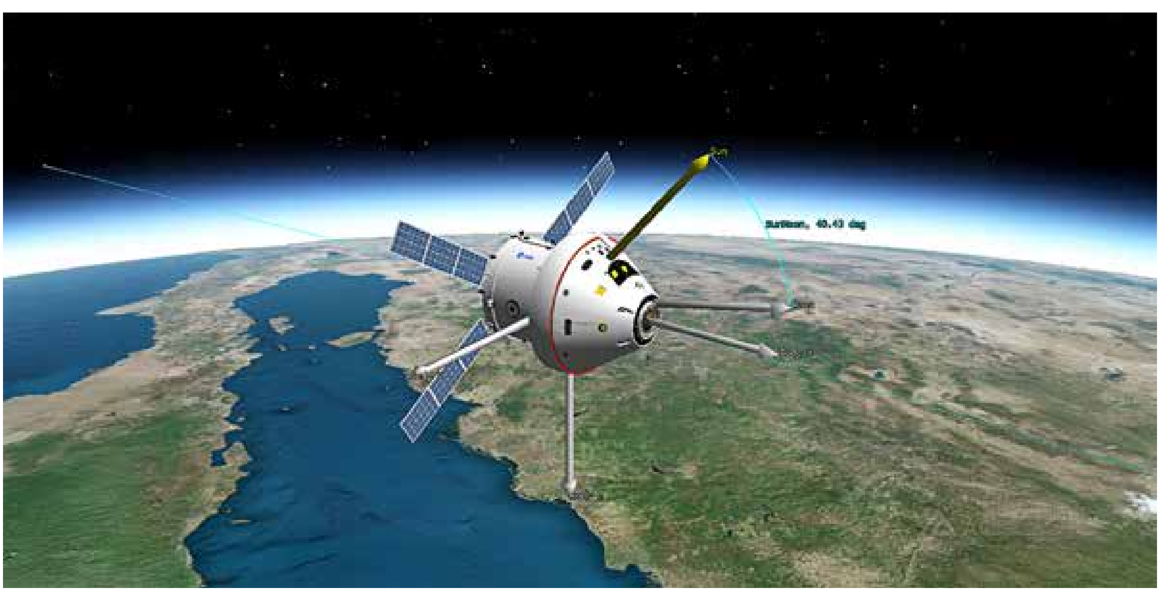
play a role in the charge accumulated at the surface of the spacecraft.

Ansys Charge Plus electromagnetic charging and discharge simulation software uses numerous material properties to track the balance of charge between the surface and environment of the spacecraft. The particle-in-cell (PIC) solver, coupled with the boundary element method (BEM), makes it possible to analyze the spacecraft's charge, examine the distribution of the surrounding plasma state, and plot the electron distribution. Surface charging using full-wave finite element method (FEM) electromagnetic field analysis enables engineers to calculate the fields in 3D around the spacecraft and get more information about whether there is a risk of arcing in the plasma.

INTERNAL CHARGING OF BULK MATERIAL

Internal dielectric charging occurs from the interaction of charged particles from the Sun (and high-energy photons) and the bulk material of the spacecraft. These particles may be accelerated by solar flares or by Earth's magnetic field, such as in the Van Allen belts or near the poles. The charge deposited by these particles induces fields that can lead to dielectric breakdown. By modeling the charge deposition rate and magnitude, engineers can refine their radiation hardening designs, estimate the risk of ESD, and simulate currents induced on electronics.

In plasma environments, where the energy of charged particles is high enough to result in deep dielectric charging, engineers are often concerned with the risk of charge accumulation inside sensitive components, such as solar cells, sensors, and exposed cables or connectors. To assess the risk of ESD in a dielectric, engineers can use high-energy spectrum information exported from the Ansys Systems Tool Kit Space Environment and Effects Tool (STK-SEET) capability and then use Charge Plus software to couple a 3D particle transport tool with a full-wave FEM solution of electromagnetism solved in the time domain. With this method, engineers can monitor potential, fields, charge, and currents induced by the interaction of particles with bulk materials. The particles can be incident upon a variety of geometric configurations, their energy spectrum can be time dependent, and multiple types of particles can be simulated at once.



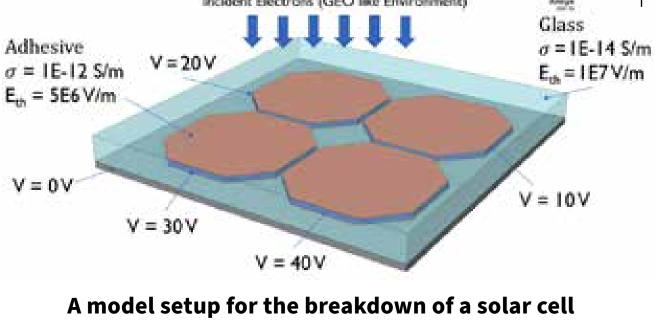
“By modeling the charge deposition rate and magnitude, engineers can refine their radiation hardening designs, estimate the risk of ESD, and simulate currents induced on electronics.”

SOLID DIELECTRIC BREAKDOWN OF SOLAR CELLS

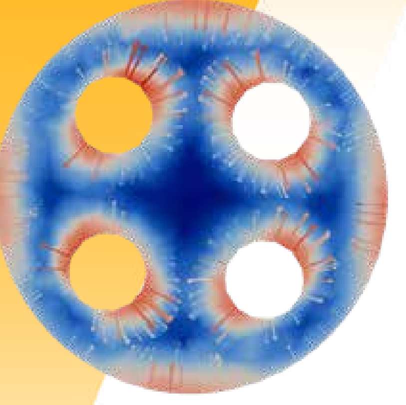
If there is too much charge in the system, then the resulting electric fields will exceed the breakdown threshold of the medium. Discharges occur from the spacecraft to the plasma, from one conductor to another across plasma or air, or directly inside a dielectric/insulator. At worst, these discharges can lead to secondary arcing if the spacecraft isn’t well grounded. Additionally, ESDs radiate electromagnetic radiation, which can damage communication systems.

For example, too much charge accumulated in a cable connected to sensitive electronics may induce currents that damage the instruments. In some cases, due to design constraints, engineers have to accept a minimal amount of primary arcing in the spacecraft. In other instances, a design tailored for a specific radiation environment, such as LEO, may need to be reused in a harsher radiation environment, such as GEO.

To simulate dielectric breakdown, Charge Plus software leverages a full-wave electromagnetic solver and a stochastic tree model that calculates the probability of breakdown as a function of electric field, dielectric strength of the material, and coupling strength to adjacent nodes. That probability distribution is evaluated at each time step and at each node of the FEM mesh used for the problem.



A model setup for the breakdown of a solar cell coupon with the bias voltage applied to each cell and with the properties of the materials. Electrons from a geosynchronous environment were shined from the top with a planar geometry.



The electric field in the dielectric surrounding the pins reached levels that are near the dielectric strength of a typical insulator.

THAT’S RAD HARD

While simulation enables engineers to see how their spacecraft’s electronic components will behave in space, it doesn’t make the systems immune to radiation effects. But it can enable engineers to design and test radiation-hardened — commonly called rad hard — electrical components. Charge Plus software uses Monte Carlo 3D particle transport and FEM to track particle fluences during simulations and use fields as feedback to the transport problem. Engineers can then evaluate the amount of radiation penetration into the interior of different metal thicknesses. This enables engineers to design the metal thickness to balance the weight of the craft with the impact of radiation hardening.

LEARN MORE

Explore Ansys Charge Plus software.

ansys.com/products/electronics/ansys-charge-plus

How Space & Bean's Shielding Technology Protects Small Satellites

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

Put simply, radiation is the flow of energy in the form of electromagnetic waves or high-speed particles. While radiation — such as visible light — is part of our daily lives, space radiation poses unique challenges to those in the aerospace field.

According to NASA, "space radiation is comprised of atoms in which electrons have been stripped away as the atom accelerated in interstellar space to speeds approaching the speed of light — eventually, only the nucleus of the atom remains." This radiation can breach the exterior of a satellite and reach its electronic components, causing immediate and cumulative effects, including the potential for complete satellite failure.

This longstanding challenge may also become more prevalent in the future. “The rapid growth of the small satellite (SmallSat) market in recent years has led to the increasing use of commercial off-the-shelf (COTS) electronic components to reduce costs,” says Kyung Ryeung Min, founder and CEO of Space & Bean. “However, COTS components are at risk of malfunctioning or being damaged in the radiation environment of space.”

Min founded Space & Bean to address this issue and help create a safer tomorrow. To achieve this objective, Space & Bean develops advanced composite materials and shielding technologies to protect COTS components in SmallSats and enable reliable use in the harsh space environment.

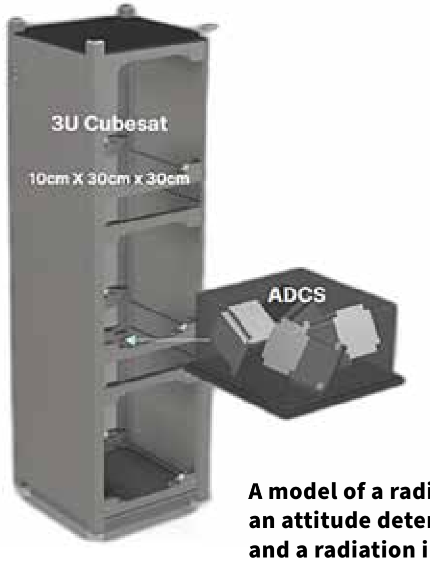
This ambitious goal requires a specific type of company model that is collaborative and not competitive. “Space & Bean aims to provide differentiated value by developing technologies that can create synergies with other companies,” says Min. “We aim to have unique technology and quickly capture the market rather than compete.”

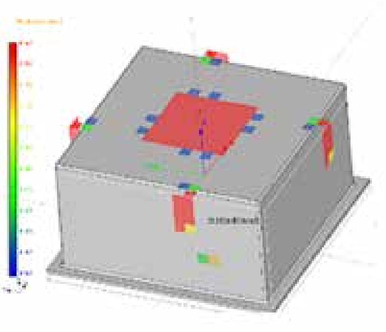
As part of this mentality, Space & Bean views customer trust as an opportunity to expand its technology, says Min. The company relies on this trust and collaboration to constantly evolve and tailor its technology to fit customer needs. One such customized product created to aid customers is SCUTUM R.

PROTECTING SMALLSATS WITH ADVANCED SHIELDING TECHNOLOGY

Space & Bean developed the SCUTUM R shielding solution to reliably protect COTS components on SmallSats from space radiation. However, SCUTUM R is not just a static product; it’s a more customized, comprehensive solution than is typically found in the market, according to the company.

“While shielding material companies typically focus on developing and supplying materials with the performance requested by customers, we differentiate ourselves by going beyond material development to design and manufacture optimal protection solutions based on our shielding technology,” says Min.





A model of a radiation shielding box for commercial parts with an attitude determination and control subsystem (ADCS) (left) and a radiation impact analysis that is used to ensure commercial component reliability for an extended satellite lifetime (right).

For SCUTUM R, this means that Space & Bean offers not only composite materials and radiation-shielded boxes for COTS but an independent space environmental analysis service for commercial parts via its fast radiation impact detection and yield (FRIDAY) service.

In particular, Min shares that a few of SCUTUM R's key benefits are:

- Ensuring maximized space radiation and shielding performance. This is achieved by analyzing the space radiation environment and developing customized shielding materials and structures to minimize the effects of radiation.
- Offering a lightweight design that is optimized for even the smallest satellites without sacrificing shielding ability. "This is key to improving the reliability of satellites and extending their lifespan," says Min.
- Providing customized, flexible designs that can adapt to various satellite systems. This involves performing a radiation impact analysis to determine what composite materials should be applied to the shielding box design.
- Forming international partnerships to prove trustworthiness and performance. "We are currently working with Japanese and American companies to secure global-level reliability and customize the size, shape, and performance to be applied to various satellite systems," says Min.

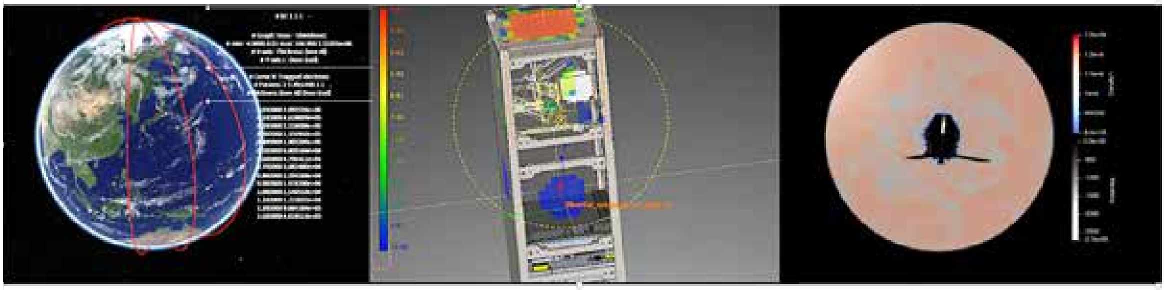
Before these benefits can be actualized and SCUTUM R can be deployed, Space & Bean needs to design, develop, and optimize its unique technology. To achieve this, Space & Bean turns to Ansys simulation software.

FROM SIMULATION TO OPTIMIZED SHIELD

When deciding what software to use throughout the design and development process, Space & Bean — a member of the Ansys Startup Program (Korean language version here) — opted for Ansys software for a few reasons. "Ansys analysis results are recognized as reliable and internationally validated, so it was a natural choice for Space & Bean to adopt Ansys solutions to enhance the reliability of our data," says Min. "We were confident that Ansys would not just be an analysis tool but an important foundation for our technology to be recognized in the global market." Additionally, Min shares that the ability to expand business to analyze both space radiation and electromagnetic wave analysis with the support of the Korean government was also a major benefit of partnering with Ansys.

One way the team used simulation software was for its space radiation impact analysis, which involves studying the effects of space radiation based on a specific satellite's mission, lifetime, and orbit. This information can then be used to determine the optimal protection strategy and structural shielding design, including the ideal locations to place radiation-sensitive electronic components to minimize radiation effects. Here, Space & Bean used Ansys Charge Plus electromagnetic charging and discharge simulation software "to analyze the electrical effects of plasma and electrons during space radiation and to design the geometry of the metal housing and the system for discharge in the subsystem design," says Min.

The team also relied on Ansys EMC Plus electromagnetic interference and compatibility simulation software in its design process. "EMC Plus software has become powerful for analyzing the effects of electromagnetic waves around induction coils in the conceptual design



An Ansys simulation analysis of a satellite's operating environment and conditions, including space radiation levels (left); a 3D model predicting the radiation vulnerability of SmallSat components (middle); and an impact analysis of various space electrons and ions in a plasma environment (right).

> ***"Modeling and simulation software has reduced the time required for design and testing by more than 30%, and (we are) currently targeting a reduction of more than 50%, which is expected to have a positive impact on the development schedule going forward."***
>
> — **KYUNG RYEUNG MIN**, Founder and CEO, Space & Bean

of wireless power transmission systems and for checking the results of designing the thickness and connection of metal thin films in composite housing designs," says Min.

No matter the specific software used, performing a "preliminary analysis with Ansys simulation before a product is built helps us reduce production costs and development time," says Min. "Modeling and simulation software has reduced the time required for design and testing by more than 30%, and (we are) currently targeting a reduction of more than 50%, which is expected to have a positive impact on the development schedule going forward."

Using Ansys simulation results, Space & Bean can better attain its goals by efficiently creating custom composite shielding boxes that increase the durability of COTS components and block space radiation. Looking ahead, "we will continue to actively utilize Ansys simulation to provide precise analyses and reliable data," says Min. As part of this, Space & Bean is considering using additional simulation software to increase efficiency across its portfolio, which consists of four brands. For example, because thermal analysis is a key factor in the space industry and is tied to Space & Bean's ongoing technological development, the company is investigating introducing Ansys solutions in this area.

WHAT'S NEXT FOR SPACE & BEAN

With SmallSats becoming more popular, the company's technology evolving, and an entrance into overseas markets imminent, Space & Bean is on the precipice of enormous growth.

At this crucial moment, Min emphasizes how the company's core goals remain the same: providing optimized, usable, and proven products that address the real-world problems faced by its customers.

For the space industry, this means that Space & Bean is continuing to provide shielding technology to enhance SmallSat reliability and trusted data analyses via simulation that can be used by the global market and organizations like the ESA and NASA. Additionally, Min shares that Space & Bean is developing its own space components that use its radiation protection technology.

Space & Bean is also extending this mentality outside of the space industry to develop reliable protective technologies for other extreme environments, such as those seen in the automotive, defense, semiconductor, and medical fields. This will involve continuing to foster partnerships with customers "to ensure that all of the advanced technologies that humankind utilizes operate more safely and sustainably," says Min. "As technology advances and reliability becomes more important, we will continue to grow and play a significant role in the global marketplace with our differentiated protection solutions."

This growth will also extend beyond Space & Bean too. Min shares how the South Korean government and Ansys are working together to support startups and introduce them to simulation programs.

"In order for Korean companies to continue to develop and grow their technology, I would like to see more support programs that allow them to utilize simulation programs," says Min. "I believe that more opportunities like this will ease the burden on companies and allow them to focus on research and development more efficiently. In the end, I think this will lead to more innovation in the space industry."

LEARN MORE

Discover the benefits of the Ansys Startup Program.

ansys.com/startup-program

Lunar Colonies and the Future of Space

A Q&A With James Wertz

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

Imagine grabbing a warm cup of tea and sitting down for a video call with a loved one. You turn on your computer and launch the app, taking a quick glance out your window as you wait for the other person to log on. Likely, this situation sounds familiar.

But what if, instead of a yard or cityscape, you're viewing the darkness of space and the ancient rock formations of the Moon? In this scenario, "the history of the solar system is sitting outside of your window," says James Wertz, president of Microcosm Inc. and an adjunct professor of astronautics at the University of Southern California. "The Earth is sitting there, and you're watching the people you're talking to, and they're watching you."

Wertz says our ability to achieve such a scenario is not only feasible but possible in the not-so-distant future. Figuring out how to achieve this in the near term, however, is not straightforward. Despite this, it is an important goal from a scientific and commercial perspective — and possibly for humanity as a whole. After all, the Moon is something that all 8.2 billion of us share, says Wertz.

In this interview, Wertz shares more about his personal views on the future of space and the potential for a lunar colony.

“Simulation indeed has a role to play here. As I grow, I’m going to be doing all kinds of new things, and what I want is the potential to test these new approaches without having to go out and physically build and launch. That’s a remarkably long and expensive process.”

Q: What are the space industry’s main areas of growth today?

WERTZ: I would say that the main areas of growth at the present time are primarily twofold. One is the continuing growth of constellations of small satellites in low Earth orbit. There continue to be more and more of them, and that’s going to certainly continue to be the case. We’ll see a very large number of small satellites that are relatively low-cost individually and fairly expensive collectively. The other area of growth is an increased interest in the Moon, Mars, other planets, and moving beyond low Earth orbit and further into the solar system.

Q: From your perspective, what are the challenges of developing a settlement on the Moon? What next steps must we take to achieve this kind of settlement?

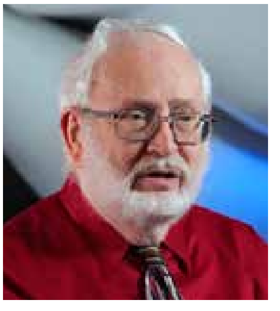
WERTZ: My view of the world is very different than the general view of the world. So, as a consequence, I’ll try to give you a little bit of both. …

One problem is that the programs are very expensive, which tends to drag them out in time. Also, when the administration changes, the priorities that NASA have change, which tends to slide things downstream. …

My view of the world is that three things have to happen:

1. The cost of transportation has to come down. That is likely to occur with either SpaceX or Blue Origin, which could bring the cost of transportation down dramatically.

2. In addition to that, we need to change how things get done. My suggestion is to go from a large, science-driven program to a commercial program. … (In general, people) would like to have something more pragmatic that will benefit them in the near term. … The merit of a commercial program is that it intends to speed things up dramatically.



James Wertz

3. Creating a large lunar enclosure where most of the lunar activity is done within rather than outside. That, in turn, means that we can use the same equipment here as on the surface of the Earth because we’re inside an enclosure on the Moon. It’s basically the same as going out in your garage and building something. You can use the same equipment; the only difference is that everything weighs one-sixth as much. … Your iPhone is still going to work, your computer is still going to work, your dishwasher is still going to work, and the laundry machine is still going to work. All these things would work just fine.

Q: Could you tell us more about what a lunar colony could look like?

WERTZ: Part of what I want to do is to populate the Moon with people. … If you look at an image from NASA, everybody’s outside in a spacesuit, and they’re walking around. In fact, a large fraction of the jobs (in a lunar colony) are inside jobs.

The example that I like to choose is the ambassador from Portugal to the Moon. What does the ambassador from Portugal to the Moon do? Well, first of all, he takes care of the two or three Portuguese citizens who visit the Moon that year. … A large fraction of the remainder of his time will be spent on the internet talking to classes in Portugal about what it’s like on the Moon, expanding into the solar system, and convincing them that they, as Portuguese students, should take part in this expansion into the solar system.

The key issue is that this has to be done in Portuguese. The Portuguese government does not want students in Portugal to learn about life on the Moon in French, Spanish, or English. They want to convince Portuguese students that Portugal needs to be a part of the expansion into the solar system. As do other countries, of course.

And there are going to be other jobs on the Moon. I would argue that quite a few of them would be people who will raise the food, cook the food, clean things, repair things, buy supplies, and fulfill all sorts of tasks that would happen in a small town. But these are not astronauts. ...

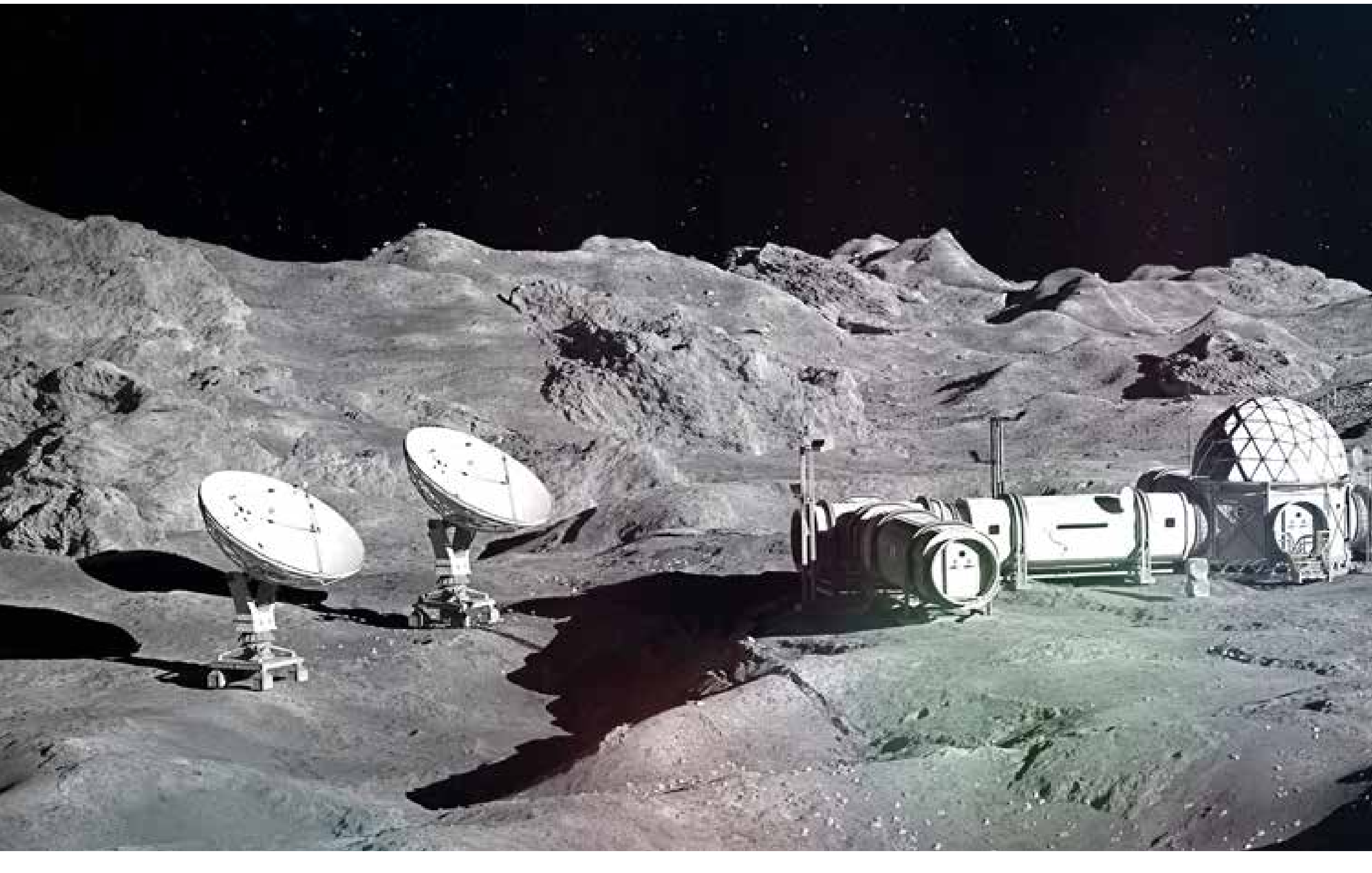
If you ask the average space science expert, they will tell you that they're astronauts and selenauts and cosmonauts, and they get six months or maybe a year or two of training. They go through this in order to work on the surface of the Moon. That's true for a few people but only for very few. There are a lot more people who don't need that training. ... A large fraction of jobs on the Moon don't require that training because there are ordinary jobs there for ordinary people.

Q: How would your vision of a lunar settlement benefit humanity as a whole?

WERTZ: It does benefit humanity as a whole in several ways. The biggest, by far, is in the potential scenario that Earth becomes uninhabitable. That could occur because of the climate activities that we've started to see happen or the real possibility of a nuclear war. If that happens, it is certainly possible that life on Earth becomes nonviable. ... To me, one of the major advantages of the Moon is that Earth's civilization now continues.

A lunar settlement can also make life better for people on Earth, and there are a couple of ways we can go about doing that. One is to provide energy for people on Earth, and there are actually a couple of things there that you can do. Solar-power satellites can beam power back to places that don't have power.

Another possibility that one or two companies are working on is nuclear power via Helium-3. Helium-3 is available in the lunar wind and the solar wind. It, therefore, comes to the Earth and the Moon. On Earth, it's not there in a significant enough quantity that you can recover it in any way. But on the Moon,



it lands in the lunar regolith. That regolith is dramatically old. ... It's in the order of 100 million years old, and some of it's probably older than that.

So, there's been an opportunity for the Helium-3 to land on the lunar regolith and accumulate over the course of time. It's still in small quantities, there's no doubt about it, but it's in large enough quantities that you could mine it and bring it back to Earth.

The advantage of Helium-3 for nuclear power is that it has no radioactive byproducts, which is huge. If I can create nuclear power without generating nuclear waste, I can create more or less unlimited power for people on Earth and people on the Moon.

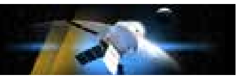
Q: What role could simulation play in developing, maintaining, or growing lunar colonies?

WERTZ: Simulation indeed has a role to play here. As I grow, I'm going to be doing all kinds of new things, and what I want is the potential to test these new approaches without having to go out and physically build and launch. That's a remarkably long and expensive process.

Simulation dramatically drives down both the time and the cost, and that's important to be able to proceed. Being able to run a simulation, understand what's going to happen and what it can do, and combine simulation with analysis and real experiments — I want to do all of this. Doing all of these things helps me move forward much faster than I otherwise could.

What we've seen is a system that is moving dramatically slowly. People are talking about colonizing the Moon 30 years from now. It can occur much faster than that, but simulation plays a major role in that activity in terms of showing people what's workable, what's usable, and what doesn't have to be as precise as it perhaps once was.

LEARN MORE



Watch the Ansys Space documentary "Simulating Space."

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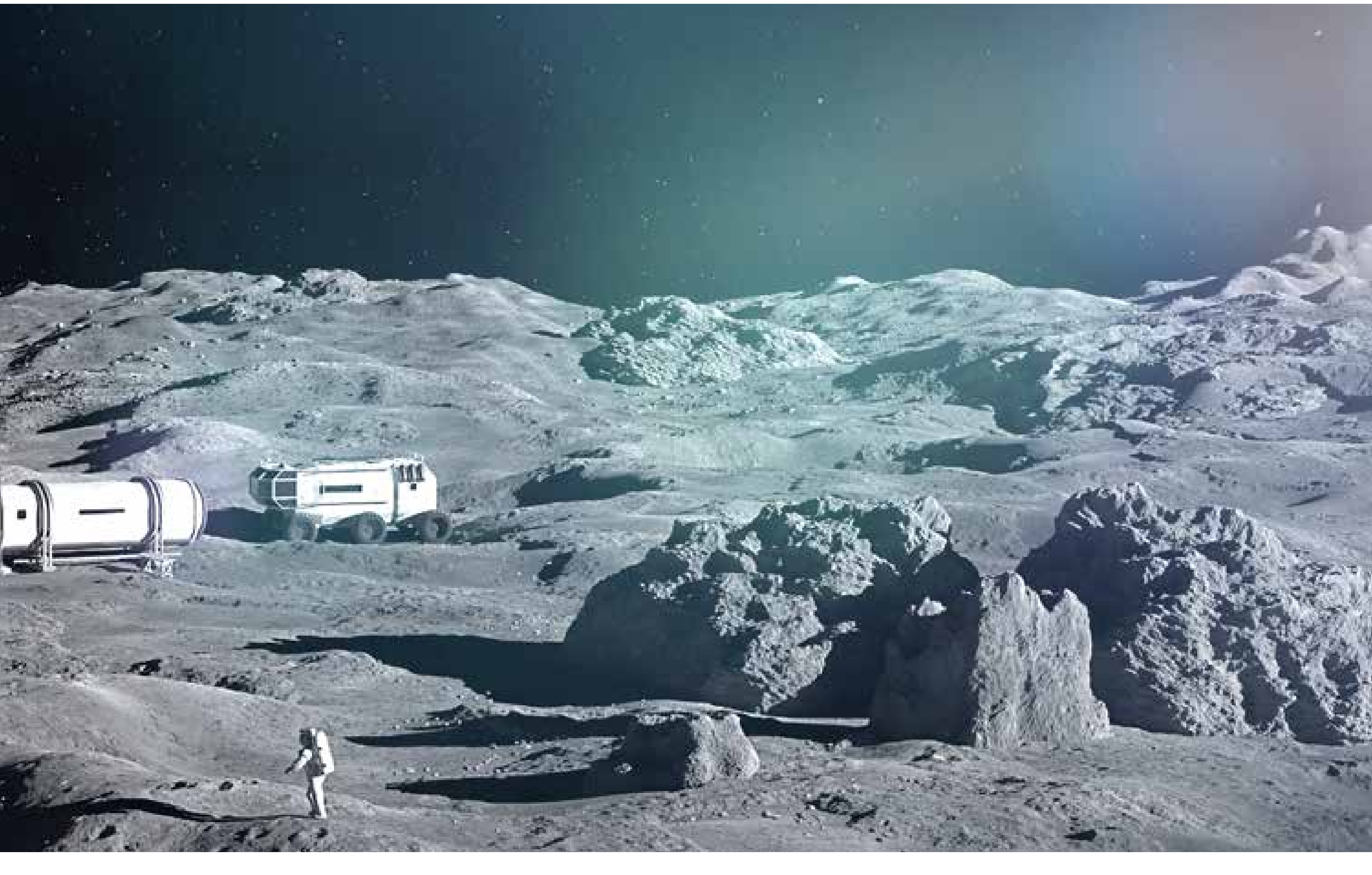
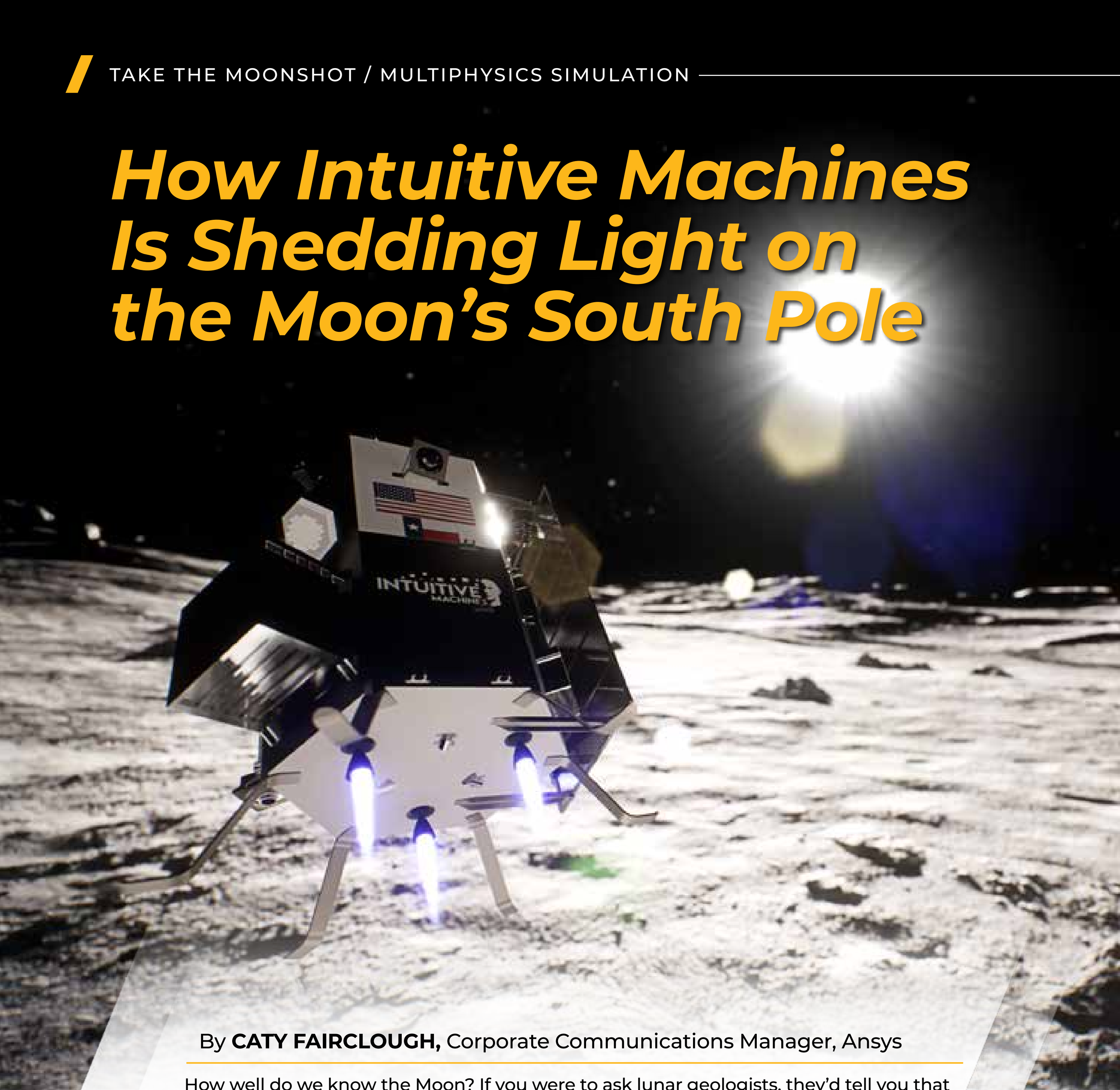


How Intuitive Machines Is Shedding Light on the Moon's South Pole



By **CATY FAIRCLOUGH,** Corporate Communications Manager, Ansys

How well do we know the Moon? If you were to ask lunar geologists, they'd tell you that we have a lot left to explore, especially in the Moon's south pole region. The potential for water in this area has drawn the interest of scientists and commercial businesses alike. Water — or water ice — on the Moon could be melted or even separated into hydrogen and oxygen, thereby providing essential resources for astronauts.

However, confirming if there is water ice in this area and locating it if it does exist will not be an easy task. Beyond the already-daunting job of sending machines to the Moon itself, the terrain at the lunar south pole is particularly treacherous. Deep craters cover a great deal of the south pole. Most of them are in constant darkness and incredibly cold, which makes landing, researching, and navigating an arduous task. Increasing this difficulty are the potential moonquakes and faults found in the area.

To address this challenge, new, innovative technologies are needed, and Intuitive Machines is one of the companies stepping up in this area. As part of its mission to provide services that open access to the Moon, Intuitive Machines developed technology, including its Nova-C class lunar lander, which enabled the company to facilitate the first commercial landing on the Moon and the first U.S. Moon landing in over 50 years.

The Intuitive Machines team has also developed the µNova Hopper (a propulsive drone the size of a minifridge), which can be deployed off of the team's lander. This technology is designed to study the mysterious south pole region of the Moon and search for resources like water ice.

“Simulation for us is a force multiplier. It lets us try different ideas … very quickly.”

— JORDAN REYNOLDS, Avionics Engineer, Intuitive Machines

Jason Soloff, the company’s Lunar Data Network chief engineer, explains that the μNova Hopper was created to withstand the harsh conditions of the lunar south pole. The hopper is designed to traverse the deep craters on the Moon’s south pole, autonomously perform its mission while unable to communicate, and then return to a ridge where it can share its knowledge.

Using the next iteration of this technology, engineers and researchers hope to take photos and drill into the regolith of the south pole to study its composition and learn how to search for signs of water. In this way, Intuitive Machines’ work can contribute to wider goals of looking for water and other resources on the Moon.

“If we can drill into the surface and confirm our theories on how much and if there is any water there, then that would be super exciting because that unlocks habitation in a base and even a refueling station,” says Jordan Reynolds, avionics engineer at Intuitive Machines.

Now, the Intuitive Machines team is preparing for its second mission — and that’s not all the company is working on either.

ADVANCING LUNAR TECHNOLOGY

Landing on the Moon’s south pole is only one of the many goals at Intuitive Machines. As Soloff says, “Intuitive Machines is a diversified space company, and we’re working to advance technologies and change the way that the space economy works — opening it up for all humanity.”

For instance, Intuitive Machines aims to make the space economy more sustainable by using a methalox engine for its Nova-C lander. Methalox is a clean fuel made of liquid methane and oxygen. It is also of interest to the space industry due to the possibility of generating this fuel off Earth by using resources found on the Moon and Mars. Reynolds emphasizes that if humanity is able to find water on the Moon’s south pole and use it to make fuel, “that’s the most pivotal and exciting science.” Intuitive Machines is making significant strides with this propellant system, and Soloff shares that its recent IM-1 mission was the first time that a methalox engine has been repeatedly fired in deep space.

As for communications, the company also provides a validated cislunar communications solution, the Lunar Data Network (LDN). The network supports near-space missions through its lunar operations center, globally commissioned dish network, and upcoming lunar data relay satellites. With the expected influx of satellites in the coming years, there will be an increasing need for communications infrastructure in cislunar space — a need that the LDN will help address.

Beyond cislunar space, Intuitive Machines has long-term plans that extend to Mars too.

For these projects and technologies to succeed, the Intuitive Machines team needs to rigorously test all its designs and adapt them to the harsh environment of space. To do so, the team relies on Ansys simulation software.

Photo of an Intuitive Machines vehicle.
Credit: Intuitive Machines.

SHOOTING FOR THE MOON WITH SIMULATION SOFTWARE

As a small startup with limited resources and staff, Intuitive Machines has found simulation to be instrumental to its success.

"Simulation for us is a force multiplier," says Soloff. "It lets us try different ideas ... very quickly." With simulation, Soloff and the rest of his team can more quickly and easily test ways to solve problems, unlocking their creativity. "What-if" scenarios, such as using different landing gear designs or gimbals, can be virtually tested. Then, using the information generated from the simulation analyses, engineers can easily learn how changing these variables affects important facets of their design, like overall stresses, loads, and thermal performance.

As for when the Intuitive Machines team uses simulation, Reynolds says it uses Ansys simulation software to perform necessary analyses and tests throughout the entire mission. For example, take the initial design stage. Here, Soloff emphasizes how reducing mass is important for space technology. Other requirements include ensuring that machines can survive the forces of launch, as well as the extreme heat and cold experienced during the mission, when the craft has the Sun hitting one side and extreme cold on the shadowed side of the lander. With simulation, the team was able to optimize for all these requirements. "Our analysis helps us design, thermally and powerwise, systems that can withstand extreme changes in temperature," says Reynolds.

To perform these calculations, Intuitive Machines relied on Ansys Systems Tool Kit (STK) digital mission engineering software. One way that the company used this software was to model solar rays and determine when they would hit the lander and hopper and when no light would reach the machines. This is important knowledge that would be difficult to recreate by physically testing on Earth. Further, with simulation, the Intuitive Machines team can perform thermal analyses and see how heat moves through complex materials, a task that is very time-consuming to do by hand. In fact, "I'd say it's almost impossible on the type of timelines that we have," says Soloff. "So, we rely very heavily on the analysis of simulation tools, and the Ansys suite has been fantastic for that."

Part of the reason why Ansys simulation software is so useful to the team is because of its multiphysics capabilities. Intuitive Machines is working on "incredibly complex multiphysics problems that aren't just an antenna pattern or a structural analysis of vibration or shock," says Soloff. "It's about integrating all these disciplines together through an integrated set of model and simulation tools that let us do what we need to do."

Intuitive Machines in space.
Credit: Intuitive Machines.

Ensuring that its communications systems are functional and optimized is another key use of simulation for the team. Here, Intuitive Machines relied on Ansys simulation for everything from ensuring that antennas are oriented correctly to comparing the throughput and bandwidth generated by different ground stations and radios.

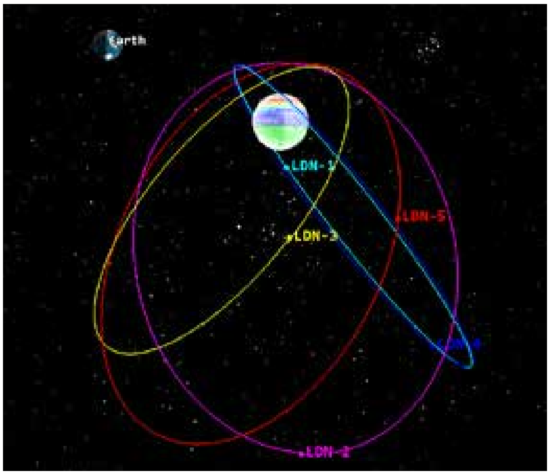
To perform these communications analyses, the team once again turned to STK software to, among other things, analyze how strong its communications are, how much data it can move, the predicted signal noise, the signal strength, and more. Soloff shares how simulation software and modeling truly aid in performing complex electromagnetic analyses. For example, the company uses Ansys HFSS high-frequency electromagnetic simulation software and radio-frequency (RF) simulation to analyze and optimize antennas, radiation patterns, and electromagnetic radiation for communications.

These are not the only ways that Intuitive Machines uses simulation to improve its technologies either. Pictures are essential data points for the company, especially photos of the Moon's south pole. As such, Reynolds says the team focused on using simulation software to ensure that it could successfully collect and transfer that photographic data during the mission. Using its simulations, the team was able to coordinate with communications providers to identify which services would be most ideal for the mission.

"It's a huge team effort to get something on the Moon," Reynolds says. "So, being able to use simulation to prepare for a worldwide mission really helps."

"Not only is STK software capable of simultaneously performing a wide range of analyses — it can do so while keeping up with highly dynamic mission conditions," says Reynolds. "On outer space missions like those Intuitive Machines is performing, conditions such as light, temperatures, speed, radiation patterns, terrain, trajectories, and signal strength can change rapidly. STK software enables engineers to model these changes and account for the whole mission. For example, we used STK's terrain modeling and communications modeling shortly after landing to understand how the vehicle was orientated in relation to the Earth, Sun, and Moon system after our dynamic landing."

Throughout all the different areas where it



Simulation analyses showing Earth inertial axes (top) and Moon inertial axes (bottom).
Credit: Intuitive Machines.

uses simulation software, the Intuitive Machines team finds that an increase in efficiency is a common denominator. Soloff says analyses that could take weeks to perform without simulation take only a matter of days when using Ansys software. This is incredibly important since the team often doesn't have months to solve problems; instead, it frequently needs to find solutions in just hours or minutes. In cases like these, Intuitive Machines can use validated Ansys models to find answers and make informed decisions quickly. This is even true for notoriously challenging calculations, such as accurately solving the three-body problem of how the Earth, Sun, and Moon all affect the mission.

This speed even translates to making informed real-time decisions during missions. For example, Reynolds is developing a real-time simulation "where we can pipe in the telemetry coming from our lander during the mission, simulate that with the STK software, and start visualizing and gaining situational awareness during the mission," he says. This is beneficial because it enables the researchers to rapidly understand the mission situation through their models instead of having to contextualize data on a screen. That way, if something unexpected occurs, they can react more quickly.

Of course, speed is useless without accuracy, which is why the Intuitive Machines team has been sure to rely on proven technology. "What we gain with these tools is not just time but confidence in our analysis," says Soloff. With Ansys simulation software, Intuitive Machines can save time without sacrificing accuracy. This increases efficiency and enables the company to reallocate its efforts and limited resources to other parts of the mission. "We simply could not do what we do without modeling and simulation," says Soloff.

With simulation, "we can go in, model everything, and have the confidence that we don't need to spend another year refining our technologies," says Reynolds. This saves precious time for startups like Intuitive Machines, making it more competitive and mission-ready in a shorter span of time.

THE FUTURE OF SPACE

Curiosity about the universe around us is a connecting thread for many people — from a family spending an evening staring up at the stars on a summer's night to those who make a career in performing leading research in this area.

"Space is the great unknown," says Reynolds. "Seeing what kind of knowledge we can gather in space about the universe and what humans know and don't know is really inspiring." The work that Intuitive Machines does is helping to solve some of these mysteries.

Furthermore, while there are limited resources on Earth, "the solar system is filled with resources," Soloff says. One of these resources is the very ice that the Intuitive Machines team is looking for signs of on the Moon's south pole. By locating resources like this, the Intuitive Machines team hopes that its work will aid in finding the resources needed to better explore the mysteries of space.

LEARN MORE

Watch the Ansys documentary "Simulating Space," which features Intuitive Machines.

ansys.com/campaign/simulating-space

Catching the Innovation Wave in Space With the Help of Digital Engineering

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

When you think of sustainability, what comes to mind? Maybe it's recycling and reducing waste or public transportation and green fuels. For many, the topic of sustainability is centered around Earth-based activities — but this is only one part of this goal. For those working in the space industry, efforts to protect our environment extend to the stars.

For instance, the World Economic Forum (WEF) shares that space debris is expected to become a global critical challenge. While the space sector is experiencing massive growth and technical innovation, this progress comes along with an increase in debris (also known as "space junk") and thus collision risks. Of course, this is not an insurmountable obstacle. Solutions like the WEF's Space Sustainability Rating (SSR) aim to help with this challenge by increasing transparency via a standardized score.

This is, however, just one space-related sustainability challenge. Beyond space debris, light pollution, emissions, and fuel inefficiency also cause environmental issues. Overcoming these hurdles is a task for everyone in the space industry, with many organizations making this a priority.

One such organization is MaiaSpace, a company designing, manufacturing, operating, and commercializing competitive and more sustainable solutions for space launch and mobility. Through its work, the MaiaSpace team plans to deploy a cost-effective mini launch vehicle with a reusable first stage by 2026 — a timeline that anyone in the industry would tell you is ambitious.

Despite this, the MaiaSpace team is undeterred. It plans to rely on the adaptability and culture of risk that come with being a smaller organization, as well as the ability to combine new and legacy space know-how, to reach its goals. Jerome Vila, chief product officer, says MaiaSpace relies on an agile methodology, a test-and-learn iterative approach, and a communal road map to keep moving forward together.

With this flexibility at hand and a team composed of experts from both legacy

"Having the capability to have not only one tool but a set of tools that can work together is really important, and we found that at Ansys."

— **JEROME VILA**, Chief Product Officer, MaiaSpace

and new ventures in space, MaiaSpace looks to rapidly finalize its reusable design and ensure that it is compliant, safe, cost-effective, and efficient.

BUILDING A SUSTAINABLE MINI LAUNCH VEHICLE

At MaiaSpace, sustainability is not a secondary goal. Instead, the company is taking an "end-to-end approach" to sustainability, says Isabella Quinquis, MaiaSpace's chief technical officer. This means that MaiaSpace is considering sustainability throughout its design and development process. As Vila says, MaiaSpace performs environmental impact assessments to consider potential trade-offs for every one of its engineering decisions.

For instance, consider the Maia launcher. In addition to its reusable first stage, the launcher uses methane and oxygen propulsion, which is an efficient fuel option. Additionally, the MaiaSpace team aims to increase the use of efficient fuels by adding a "kick stage" that will use new technology for ethanol propulsion. "The objective of this new propulsion is to limit its environmental impact," says Quinquis, as well as paving the way for in-orbit services.

Building a rocket with the right size to serve the specific market segment of small satellites to be launched into low Earth orbit was also a key consideration in its sustainable design. In a time when many companies are building bigger, MaiaSpace is focusing on optimizing the filling ratio of its launch vehicle through highly modular solutions.

MaiaSpace does not intend to enable space tourism or to colonize Mars. The team is focused on closer-to-Earth missions that have meaningful impacts on our planet, explains Vila. These potential applications include science, Earth observation, telecommunications, navigation, and serving industries like agriculture and fisheries. Being decisive on what its technology is used for is central to MaiaSpace's goals. As Vila says, the company carefully picks what missions it wants to launch.

Through its efforts, MaiaSpace is becoming one of the many companies hoping to improve sustainability in the space industry. "There is an innovation wave, and we have to catch this

A prototype in the MaiaSpace factory in Vernon, Normandy, France

to transform ourselves and reinvent how the space industry is working," says Vila.

However, in the fast-moving space industry, catching this innovation wave is easier said than done. That's why the MaiaSpace team turned to simulation software to address the intrinsic challenges in its industry as it moves toward its goals.

ADVANCING SPACE SUSTAINABILITY WITH SIMULATION

When designing for space applications, you need to make sure that every launch counts. Although MaiaSpace disrupts Europe's way of developing rockets through a test-and-learn iterative approach, "you don't have many opportunities to test like you would test a car prototype or even an aircraft prototype," says

> ***“Now that we have really effective simulation tools, we can obtain good accuracy on the results and save a lot of time and money.”***
>
> — **ROMAIN PALKA**, Thermal Analysis Engineer, MaiaSpace

Vila. Early prototyping and physically testing rockets enable teams to learn and go faster. But to go even faster and increase cost-efficiency, companies like MaiaSpace also count on simulation software.

“Now that we have really effective simulation tools, we can obtain good accuracy on the results and save a lot of time and money,” says Romain Palka, a thermal analysis engineer at the company.

As an example of how simulation makes the approach more efficient, take the team’s early development stages. Here, the engineers turned to simulation software to compare different design options, such as materials and tank thickness. This simulation-aided design and optimization process then continued throughout the development timeline. In fact, Vila even says MaiaSpace used simulation to support physical testing both before and after it occurred. In doing so, the team was able to use its simulation results for its physical tests and then input its test results back into its simulations, which increased efficiency for all parts of the process.

Beyond saving resources, simulation software enables MaiaSpace to try novel ideas and perform tests that may have been too challenging or costly to achieve physically, such as detailed analyses of how its designs would perform in space.

AVOIDING ERROR WHILE STUDYING THE HARSH ENVIRONMENT OF SPACE

In the space industry, the room for error is extremely small, Quinquis says. Mistakes in space can mean life or death, with a difference of less than a decimal potentially causing catastrophic failure. Despite the need for utmost accuracy, achieving this is no simple endeavor. Not only is this work quite literally rocket science, but the environment of space cannot be fully recreated on Earth for accurate physical tests.

That’s why engineers and researchers turn to proven, validated tools that can provide understandable, actionable results. With Ansys simulation, the MaiaSpace team was able to study the launcher’s performance in microgravity and design for the company’s complex missions. “We can use Ansys Systems Tool Kit (STK) digital mission engineering

The two-stage MaiaSpace rocket can be equipped with a small extra “kick stage” to increase performance.

MaiaSpace’s kick-stage Colibri prototype in the test zone

software in order to visualize the motion of the upper stage in orbit,” says Quinquis.

This accuracy is further improved thanks to Ansys’ ability to simulate multiple physics simultaneously. “Having the capability to have not only one tool but a set of tools that can work together is really important, and we found that at Ansys,” says Vila. One of these tools, which is imperative in the space industry, is thermal analysis.

EFFICIENTLY PERFORMING THERMAL ANALYSES

When designing a launcher, some of the most important studies that engineers need to perform are thermal analyses. Not only does a launcher need to withstand the thermal exchanges before and during liftoff, but crossing the atmosphere into orbit and enduring radiation from the Sun are imperative to a functional design. To ensure that MaiaSpace’s designs can hold up in these extreme temperature fluctuations, Palka says he builds simulation models in Ansys Thermal Desktop thermal-centric modeling software.

Thermal Desktop software enables the MaiaSpace team to run simulations with different parameters, perform important thermal calculations, and eventually pick the most optimized design. The Ansys software is “really efficient to use because changes can be easily made so we don’t lose time,” says Palka. With changes occurring frequently, solutions that enable thermal engineers to react quickly and adapt their models to iterative changes are imperative. Ansys software provides the level of adaptability that is essential for thermal engineers like Palka, since design changes — such as mechanical and propulsion changes — can significantly alter thermal results.

FROM HAVING SPACE TO GROW TO A MORE SUSTAINABLE TOMORROW

When we look at the space industry today, we can see the many ways that it is already impacting the people of Earth, such as through GPS, connectivity, weather data, seismic activity detection, and more. The data collected from space technology has also had a big impact on climate research. “We wouldn’t be as aware of climate change if there were not spacecraft,” says Vila. That’s because more than half the parameters that scientists use to monitor climate change come from space.

Looking to the future, the MaiaSpace team predicts that there will continue to be large advancements in space that will yield positive results for all of humanity. An essential element for this progress is the growing base of talent entering the space industry, bringing with it new, innovative ideas. For her part, Quinquis encourages other women to join the space industry. “Believe in your dreams,” she says. “Don’t be shy, and don’t be afraid. This is not something so difficult.”

“There is still so much to discover,” says Palka. To make these discoveries and advance the industry, simulation software will continue to be a key solution for space pioneers.

LEARN MORE

Watch the Spacecraft Thermal Evaluation webinar.

ansys.com/webinars/spacecraft-thermal-evaluation

Revolutionizing the Space Economy With a *Fully and Rapidly Reusable Launch System*

By **ANSYS ADVANTAGE STAFF**

The early era of launch vehicles featured capability to orbit that took many years to develop and cost billions to implement, yet those rockets (and their upper stages) were fully expendable. The first stage, or propulsive booster phase, either would burn up in the atmosphere or was intended to splash down in the ocean. Meanwhile, the payload-carrying second stage would be scuttled on orbit as space debris or burned up on reentry. Many early space missions, such as those aimed at reaching the Moon or exploring other planets, were designed for single use. The engines, structures, and avionics were not capable of withstanding the extreme temperatures of reentry, let alone refurbishment and reuse.

With the space economy evolving and expected to reach $1.8 trillion by 2035, repeatedly building new rockets isn't an economically or environmentally viable option. It also can't keep up with the demand for rapid and assured access to space, nor for the cadence that launch must achieve to support both commercial and military needs in space. As a result, we're seeing a new sort of space race — one with innovators vying to be first to market with the next breakthrough in fully reusable rocket technology and on-orbit dynamic space operations.

Among the contenders is Stoke Space. The Kent, Washington-based startup has upped the ante as one of the only companies working on a rapidly reusable complete launch system, including both the first and second stages of the vehicle. Stoke Space's 100% reusable, medium-lift rocket provides access to, through, and from space with a goal to reduce the access costs to orbit by orders of magnitude from the current partially expendable era.

Stoke Space is partnering with commercial and government customers. The company has raised nearly $500 million in venture funding and has sold multiple commercial launches on its fully reusable Nova rocket. Stoke has also received a $4.5 million award from the Defense Innovation Unit (DIU) to advance "commercial solutions that enable responsive and precise point-to-point delivery

> ***"We've used Ansys simulation throughout all phases of development to help gain an understanding of the effect that various loads — thermal, pressure, inertial, and so on — will have on the hardware during flight."***
>
> — **JOHN ZIADAT**, Engineering Lead, Stoke Space

A Stoke Space test tank. *Credit: Stoke Space.*

to orbit, between vehicles in orbit, and precisely to Earth via novel reentry vehicles and methods." DIU is a Department of Defense (DoD) organization focused on accelerating the adoption of commercial and dual-use technology to solve operational challenges at speed and scale. In addition to the DIU award, Stoke has been on-ramped to the OSP-4 IDIQ contract supporting tactically responsive U.S. Space Force task orders and is also executing study work with the Department of Energy (DOE).

SUPER NOVA

Stoke Space's Nova rocket has a reusable upper stage designed for dynamic maneuverability during all stages of flight. In addition, this novel upper-stage technology is being used for in-space mobility solutions to reposition satellites and other space assets; deliver payloads to different destinations, including lunar bases and Mars missions; and grab materials, equipment, and components manufactured in microgravity and bring them back to Earth, demonstrating what are known as downmass capabilities. When those activities are complete, the upper stage will travel safely through the fiery thermal environment of reentry, landing vertically and propulsively back on Earth, to be quickly refurbished and relaunched.

The second stage of Stoke Space's Nova rocket offers customers dedicated, direct, on-demand access to exotic orbits. Because the second stage is typically more complex and expensive than the first stage, making it reusable significantly reduces overall launch costs. In addition, a reusable second stage can increase the frequency and variety of missions. Even ambitious missions, such as deep space exploration, become possible by making it more affordable to launch heavy payloads.

Ultimately, the ability to reuse rockets without extensive downtime increases the number of missions that can be conducted. Spreading fixed costs over more launches drives down costs and enables the payload customers to spend more on their technologies and core missions.

I BELIEVE I CAN FLY: SIMULATING ROCKET TECHNOLOGY BEFORE LAUNCH

Of course, making reusable rockets that can operate with the frequency of commercial aviation is no small task. In fact, it's one of the biggest challenges in aerospace today. These launch vehicles must withstand thermal extremes, immense internal pressures, high-frequency vibration, and sudden shock. They must also be powerful enough to reach space, efficient enough to conserve fuel, and reliable enough for multiple uses with limited refurbishment.

While these things must be tested and validated in the field, Stoke Space's Chief Operating Officer Kelly Hennig says early development simulation helps eliminate basic failure modes so engineers can get to the test stand sooner and let real-world data be the primary guide.

In this phase, "seamless integration between computer-aided design (CAD) and analysis, fast meshing, and fast solving are crucial, and Ansys excels in these areas," she says.

Stoke Space tested the Nova rocket's stage one engine (close-up in inset) on a vertical test stand in December 2024. *Credit: Stoke Space.*

That's why the Stoke Space team relies heavily on Ansys simulation software — primarily Ansys Mechanical structural finite element analysis software across the entire launch system and Ansys Thermal Desktop thermal-centric modeling software for payload environment analysis. The idea, says Engineering Lead John Ziadat, is to let the hardware believe it's flying in space.

"We've used Ansys simulation throughout all phases of development to help gain an understanding of the effect that various loads — thermal, pressure, inertial, and so on — will have on the hardware during flight," he says.

Scott Zweibel, vice president of government affairs, adds that simulation ensures that Stoke Space meets the requirements at each stage of the mission. That includes keeping the rocket's integrated engine and heat shield — a unique system providing propulsion and protection — safe during reentry.

CREATING A HEAT SHIELD THAT COOLS ITSELF

Reentering Earth's atmosphere safely is one of the most demanding phases for a spacecraft. During this critical period, the vehicle must manage extreme heat and pressure, which can be detrimental to its structure and systems. To ensure safe reentry, Stoke Space used Mechanical software for thorough thermal stress analysis, helping the company develop what it calls "the world's most robust — and the only actively cooled — reentry heat shield."

Unlike traditional reentry heat shields for space planes or space capsules, which rely passively on materials that can naturally withstand high temperatures and absorb heat, Stoke Space's heat shield is designed to actively cool itself. Specifically, a regenerative cooling system allows the propellant to flow through cooling channels in the shield, absorbing heat from the combustion chamber and nozzle to drive the turbine and power the fuel and oxidizer pumps. Thrusters embedded around the heat shield provide steerability and control for the upper stage during reentry.

Unlike most spacecraft shields, which are made of high-temperature-resistant but often fragile ceramic tiles, Stoke Space's shield is manufactured metal. That makes it ductile and robust, requiring less refurbishment between missions.

The Nova rocket's heat shield is only one factor that sets the Nova rocket apart. Its first-stage engine employs a full-flow staged combustion (FFSC) cycle — a high-performance, high-efficiency design with complex architecture comprising numerous interconnected components.

CLOSING THE GAP BETWEEN EXPECTATIONS AND REALITY

In December 2024, Stoke Space hotfired the Nova rocket's stage one engine on a new vertical test stand at the company's Moses Lake, Washington, private test facility. Hotfiring involves igniting a test rocket mounted on a test stand to verify the engine's performance, including its thrust, fuel consumption, and overall functionality, under conditions that closely simulate actual flight.

While this was the first vertical hotfire of the "Zenith" FFSC engine, it was only the latest in a series of tests meant to replicate real-world experiences and minimize the difference between predicted and actual hardware performance.

Ansys has played a crucial role in bridging that gap, Hennig says.

"As development progresses, Ansys' ability to handle nonlinear problems and areas like structural dynamics, thermal, fluids, and acoustics becomes invaluable," she says. "Using Ansys for integrated and comprehensive simulations helps ensure that the physical tests align closely with expectations, making the transition from development to real-world application smoother and more reliable."

Ansys software also helps Stoke Space engineers understand not just whether their hardware works but why, enabling them to adapt to changing parameters and mission requirements.

And because the Ansys high-performance computing (HPC) suite integrates with Amazon Web Services (AWS), it gives Stoke Space cost-effective access to massive computing resources, enabling the company to speed up its design process. In fact, Ziadat says solutions that might have taken more than days on a local machine are now done in hours.

"We need to move fast, and the only way to do that is with digital simulation," Hennig says. "Ansys has allowed us to design multiple iterations, update models after testing, understand the assumptions and whether they were correct, then do it all again quickly."

In the race to build a new breed of rocket, having that kind of speed is an undeniable advantage.

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The Stoke team. *Credit: Stoke Space.*

Firefly's Alpha rocket
Credit: Firefly Aerospace.

Designing Integrated Launch, Land, and Orbit Systems via SIMULATION

By **CATY FAIRCLOUGH**, Corporate Communications Manager, Ansys

As the Sun sets on a clear night, a hush comes over a crowd. Spectators and engineers alike stare as a nearly 100-foot-tall rocket begins its ascent into the skies above, bright flames trailing behind it.

In another mission, a launch vehicle with a higher payload carries a lunar lander, which will deliver an important payload to the lunar surface, or maybe it's transporting an orbit vehicle to low Earth orbit (LEO), where it can support responsive hosting, rideshare, and delivery missions.

Historically, all these elements would have been developed by different companies, but this does not have to be the case. Firefly Aerospace acts as an end-to-end space transportation company that can do all that — and more — to achieve its mission of enabling our world to launch, land, and operate in space. Firefly designs and builds most of the components that it uses in-house, including its own avionics. Firefly's products are designed to be interchangeable for use in all its projects.

To achieve this, Firefly draws on a team

“You’ll see threads of the power of simulation across all of Firefly’s business units.”

— **BRIGETTE OAKES**, Vice President of Engineering, Firefly

that has truly multidisciplinary skills. Brigette Oakes, vice president of engineering at Firefly, shares that Firefly’s expertise includes mechanical engineering and composite structures, electrical engineering, avionics, software engineering (including ground software, flight software, and embedded systems), propulsion engineering for engines, and systems engineering.

It is only by using this versatile team that Firefly can create its unique industry-leading products and achieve its goals.

AN INSIDE PEEK AT FIREFLY’S PRODUCTS IN LAUNCH, LAND, AND ORBIT

Firefly’s products, which are designed at its designated facilities, come in three main categories.

First, there are Firefly’s two launch vehicles:

- Alpha, a small-lift rocket with a unique carbon fiber design. Alpha is intended to support commercial, civil, and national security missions in LEO.
- A medium-launch vehicle (MLV) that will be able to support applications such as space station resupply missions and commercial spacecraft. MLV will be a two-stage rocket, with stage one using the Miranda engine and stage two using the Vira engine. It’s also designed with reusability in mind, having both a return-to-launch site (RTLS) and a propulsive landing of the first stage.

When developing both launch vehicles, Firefly focused on ensuring that their designs were reliable, responsive, and affordable.

In parallel to these products, Firefly also developed five engines with a range of about 45,000 pounds to 230,000 pounds of thrust. “If you like propulsion, you are a kid in a candy store here,” says Oakes. As is the Firefly way, these engines are scalable and can be modified to fit specific mission needs.

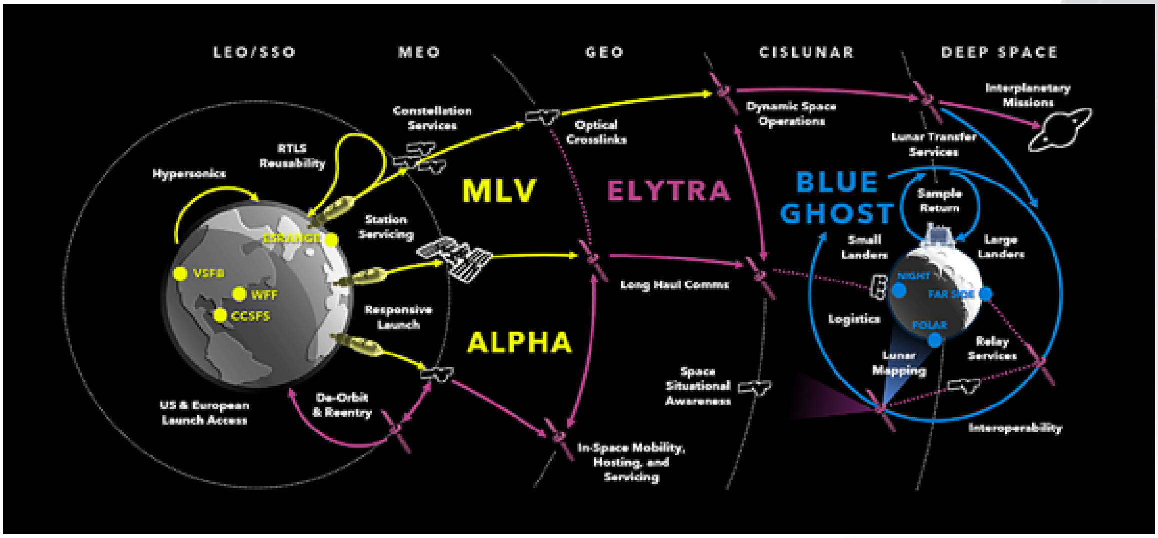
The next category is lunar landers. Firefly’s lunar lander, the Blue Ghost spacecraft, promises to deliver and host payloads anywhere on the Moon’s surface. In terms of compatibility, Blue Ghost can be used alongside MLV and Firefly’s orbital vehicles to fully support end-to-end cislunar services.

Blue Ghost is part of the NASA Commercial Lunar Payload Services (CLPS) program that flew to the Moon in early 2025 on Falcon Nine. Participating in CLPS “opens a door for us to do continuous and sustainable missions to the Moon,” says Oakes.

Finally wrapping up Firefly’s end-to-end space transportation services are its Elytra orbital vehicles. Firefly offers three types of Elytra vehicles:

1. Elytra Dawn, which provides rapidly available platforms for on-orbit hosting, rideshare, and LEO delivery
2. Elytra Dusk, which provides autonomous platforms for responsive on-orbit tasking and mobility from LEO to geostationary Earth orbit (GEO)
3. Elytra Dark, which provides ruggedized platforms for persistent on-orbit services and transfers from LEO to lunar orbit and beyond

Firefly’s Blue Ghost lunar lander (left) and Elytra Dawn orbital vehicle (right). *Credit: Firefly Aerospace.*



Firefly's services and locations. *Credit: Firefly Aerospace.*

Upcoming missions involving Elytra will use edge computing, which will enable the team to execute "some pretty clever optimizations while we're orbiting," says Oakes. In the future, the Firefly team hopes to create a constellation of these vehicles that will provide in-orbit services ranging from cleaning up space junk to servicing other satellites that are in orbit.

When designing products, Firefly needed to conquer a few key challenges, such as ensuring that its designs were as light and cost-effective as possible. In aerospace engineering, every extra pound in your design is one less pound of payload that your spacecraft can hold. As a result, engineers need to create designs that are optimized to be on the razor's edge of their tolerance limit, which is true for every component in the vehicle.

Another hurdle is ensuring that these designs can handle the harsh environments of space. "When you leave Earth and get into deep space, there's no atmosphere," says Jackson Sweeney, a thermal engineer (or, as he says, a "thermal engineering firefighter") at Firefly. "You can see temperatures in space all the way down to minus 200 degrees Fahrenheit, and then on the lunar surface you have some above 250 degrees F." As a result, Sweeney and his team must make sure that Firefly's designs can function throughout this extreme temperature range. Adding to the difficulty of this environment is the structural loading, which includes high and low frequencies, shock, and vibrations.

To overcome these hardships, Firefly uses simulation as an integrated all-in-one product that can aid all parts of its own integrated design process.

SHEDDING LIGHT ON CREATING OPTIMIZED DESIGNS WITH ANSYS SIMULATION SOFTWARE

The Firefly team has been integrating Ansys simulation software throughout its diverse products, programs, and disciplines "from day one," says Oakes. "You'll see threads of the power of simulation across all of Firefly's business units." Today, Firefly uses a variety of Ansys products to address specific needs, one of which is rapidly iterating on designs to reduce time to market.

Ansys software helps Firefly quickly achieve optimized designs. One way that it does so is via Ansys SpaceClaim 3D computer-aided design (CAD) modeling software. For example, this software can help engineers update the design of a bracket in just a few minutes.

As another example of the efficiency benefits, Oakes shares that the Firefly team was able to use Ansys simulation software to take its Specter engine from an idea to hot-firing in only 11 months instead of the typical years that this development process could take. "Simulations help a company like Firefly move faster and be more agile than some of these older companies ... especially when you're talking about spacecraft," says Oakes.

Simulation software also ensures that these quick analyses are optimized to fit mission parameters. For instance, in composite structure design, you want to be as mass efficient as possible, says Oakes. With simulation software, Firefly can find the minimal amount of mass needed for a functional design. As a specific example, the Firefly team used Ansys Mechanical structural finite element analysis software to build a model in a week, compared with the weeks or months that it would need using another platform. This model can then be used throughout the design and analysis cycle, with the team able to test new modifications and iterate to find the minimal mass possible for its design entirely in Ansys software.

The usefulness of simulation software holds true for all of Firefly's products. It also enables better communication among engineers of different disciplines by providing a common tool, which is imperative for Firefly's multidisciplinary team.

ACCOUNTING FOR THE HARSH THERMAL ENVIRONMENT OF SPACE

To ensure that its designs can handle the harsh temperature ranges they will be exposed to during their missions, Firefly turns to Ansys Thermal Desktop thermal-centric modeling software to study conduction, convection, and radiation. Sweeney says this includes conduction throughout every surface on the spacecraft, convection via the fluids (like propellants) inside the spacecraft, and radiation, which is the primary form of heat transfer in space.

Firefly uses this software to analyze every component of its spacecraft, with a variety of goals in mind. To start with, Thermal Desktop software has built-in functionality to study the orbit around any planetary body, which enables engineers to take a wide view of the entire mission. Sweeney says Firefly used this software to analyze Blue Ghost's orbit around Earth and the Moon, as well as its landing on the lunar surface. This full-mission study analyzed all temperature environments, including the "room temperature" of Earth's surface, the heat of launch, the large temperature gradients of space, and the lunar surface. Thermal Desktop software enables Firefly to study how all these "different heating inputs affect the spacecraft," says Sweeney.

This mission-wide view is aided by Thermal Desktop software's ability to integrate with Ansys Systems Tool Kit (STK) digital mission engineering software, which enables better collaboration with Firefly's guidance, navigation, and control (GNC) team. Specifically, after Firefly's GNC team defines the orbit, "we can take those inputs from the STK software, and because it's integrated with Thermal Desktop software, that allows us to model our moments very accurately so we can be confident that we are modeling the spacecraft in the correct environment," says Sweeney. Using this knowledge, Sweeney's team can make recommendations based on the orbit and generated temperature predictions, such as defining the correct spacecraft orientation to ensure a healthy thermal state during the mission. The GNC team will then take that requirement and modify the orbit definition, continuing the two teams' intertwined work.

Firefly also uses simulation to provide a detailed view of specific components. "Thermal Desktop software helps inform us about what component temperatures will result from design (changes)," such as changing surface coating colors, says Sweeney. He shares a few other Thermal Desktop software applications, such as using it to help:

- Develop a heat shield for the Blue Ghost lander. This shield will protect components from becoming too hot from the engines.
- Study the dissipated heat generated by the electronic components on a spacecraft (such as computers or avionics boxes), which impact the spacecraft's overall thermal environment. It's imperative to ensure that these components are emitting heat at a safe level and to modify their designs if not, such as by using different materials to spread the heat or by altering the electronics layout to avoid localized hot spots.
- Design a thermal control subsystem, which helps Firefly's products maintain the temperature range they need to function properly. The multiphysics capabilities of Ansys' software also enabled Firefly to model how much power the spacecraft used because of the thermal control subsystem.

CREATING A BRIGHT FUTURE

When envisioning the future, the Firefly team pictures space becoming attainable for everyone — and its work will play a role in this vision becoming actualized. As part of this journey, Firefly aims to have its spacecraft provide increasingly affordable and reliable access to space while also supporting more advanced missions.

In the short term, this will include performing more launches of Alpha over the next year, the potential for additional Blue Ghost missions and Elytra spacecraft in orbit, and continuing to find "optimal solutions that work for the team as a whole," says Sweeney.

As a company, Firefly is also particularly focused on growing the next generation of space engineers. One way that the company does this is via Firefly's Dedicated Research Education Accelerator Mission (DREAM) program, which encourages students to donate excess payload capacity on the Alpha rocket.

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