THE NEW SPACE RACE

Thomas Markusic founded Firefly Space Systems, Inc., in 2014, for one simple reason: to make space more accessible. The former SpaceX engineer is using next-generation rocket technologies and leading-edge engineering practices to move Firefly toward the mass production of affordable launch systems for small satellites. Its goal is to get these launch systems to market quickly, using the simplest and most cost-effective technologies available. While few companies are rewriting the rules of their industry to the same degree as Firefly, this company has valuable lessons for every organization that's seeking to increasingly invigorate development efforts.

DIMENSIONS: You often use the term "new space" when describing Firefly's mission. What does "new space" mean to you?

THOMAS MARKUSIC: The "old space" paradigm was based on government control of space access, a culture characterized by bureaucracy and rules, and relatively slow, methodological progress. By contrast, "new space" is about picking up where the pioneers of the 1950s and the 1960s left off. It's about having a bold vision of providing high-speed space transport for civilians, creating re-usable vehicles that can orbit the Earth, and eventually colonizing other planets. Firefly wants to democratize space by dramatically lowering the cost of access and dramatically increasing spaceflight opportunities for more people. By privatizing the space industry, we want to subvert the dominant big aerospace paradigm of slow progress and high costs. As a new space company, we are shifting to mass production methods, rapid application of real-world lessons, and ubiquitous use of advanced design tools, such as simulation, that can help us move quickly.

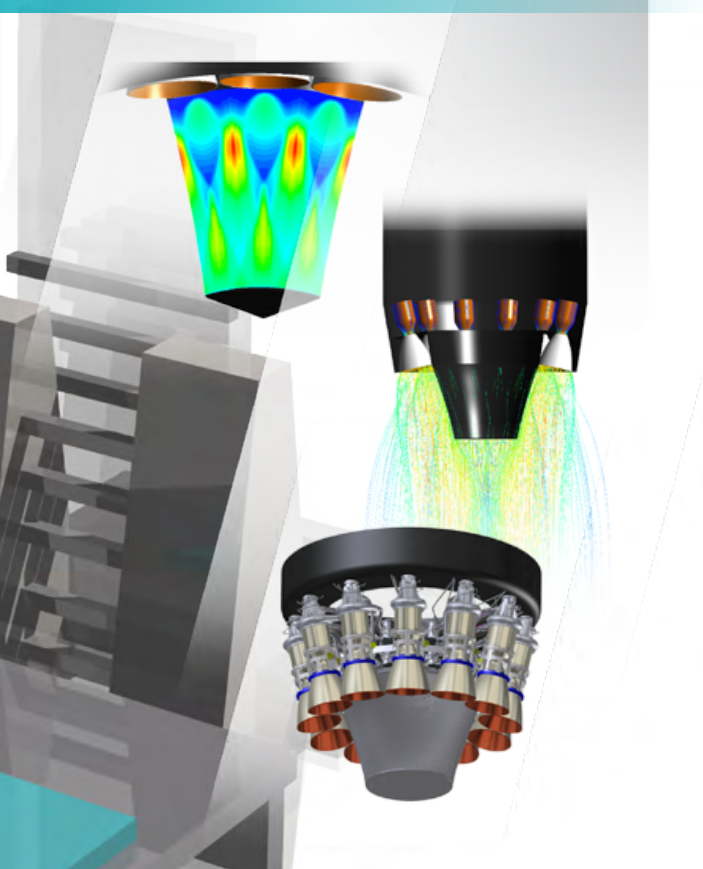
Firefly Beta represents the second vehicle in a scalable family of launchers specifically designed to address the needs of the light satellite.

D: Firefly was founded on the tenets of innovation and disruption. How are those ideas reflected in your business model, your culture and your engineering team?

TM: First of all, we chose to base our operations in Austin, Texas, specifically to remove ourselves from the traditional "old space" business model. We're a new kind of company, with new partnerships, new ideas and new ways of working. If you raise your eyebrows when you hear we're headquartered in Austin, that's the reaction we're looking for.

SIMULATION AT FIREFLY

Firefly's first-stage aerospike engine utilizes a cluster of 12 conventional rockets. ANSYS CFD software is used to understand the complex 3-D flow field that evolves as the plumes from the 12 engines merge and to help reduce temperatures by an order of magnitude.



"Firefly wants to democratize space by dramatically lowering the cost of access and dramatically increasing spaceflight opportunities for more people."

Furthermore, Firefly has rejected many traditional job titles and personnel hierarchies. We've created a flattened organization in which ranks and organizational boundaries are inconspicuous, where people truly feel that they are part of one organization with a singular mission for success. We've deliberately fostered a communication infrastructure in which every person in the organization is able to clearly see, and is able to articulate, how his or her work contributes to the profitability and success of the company as a whole.

Finally, we've worked hard to create a very diverse team at Firefly. We have senior engineers from the traditional space industry working beside recent college graduates. Why is this important? Because diversity produces a wide range of human capital, ideas, strengths and leadership styles that result in innovation. As of mid-2015, 12 percent of our engineers are women, which I would guess is a fairly high percentage for an aerospace company — and a statistic that Maureen Gannon, our vice president of Business Development, takes great pride in. She is a huge champion of diversity within our business. (See sidebar, "STEM: Not a Man's World.")

D: Can you tell us more about how you have flattened the engineering function in particular?

TM: In the engineering organization, we are deliberately working to eliminate job titles such as analyst, drafter, etc. We firmly believe that, given today's integrated design tools environments, the same engineer who is designing the part can easily generate a physical definition of the part, in addition to performing part-level and system-level finite element analysis (FEA) and computational fluid dynamics (CFD) simulation. This is not always easy because many people tend to get very comfortable with one task. However, we challenge our engineers to be accountable for their products as part of a system — and ensure that they deeply understand their product's cradle-to-grave requirements, functionality, manufacturability and operability.

D: How has your disruptive philosophy influenced your engineering team's use of technology?

TM: When making product design decisions, we perform a series of multidisciplined, collaborative trade studies and analyses before we choose a design path. Our selection of IT and software tools is no different. We did not start Firefly with one single software in mind. We have initiated a number of parallel studies utilizing various computer-aided design, computer-aided manufacturing, FEA, CFD, integrated design environment and software development kit solutions to select the ones that best suit our company and vision. We have been proactive in implementing configuration resources, product life-cycle and enterprise resource-management tools in addition to our technical software tool sets — even at the company's early stage when we have a relatively small team and only one product. We are designing our IT from the ground up and with purpose, before it gets too complicated and forces us to choose a suboptimum system for our company.

STEM: NOT A MAN'S WORLD

Maureen Gannon loves her position as vice president of Business Development for Firefly Space Systems, Inc. She embraces working with the company's engineers and crafting business solutions to match their plans of filling the sky with satellites launched by the company. On occasion, however, she reflects on her own educational and career path — and has often wondered why she didn't become an engineer herself.

"I was always passionate about science and engineering but, as a young girl, I was not encouraged in school to pursue those areas either as a field of study or a future profession," recalled Gannon. "At the time, I felt it was not an option available to me."

After earning a B.A. in international relations and an M.A. in international management, Gannon began her career in technology companies both in the U.S. and abroad — and quickly realized that most engineers she interfaced with were men. She eventually decided to pursue her engineering goals and enrolled at the University of California at Berkeley to gain some technical background. Again, she looked around and found herself surrounded by men. "It started to dawn on me that perhaps I was not the only young girl who had been interested in science and engineering, but had not been encouraged or felt comfortable to explore it as a career," said Gannon.

Today, helping girls and young women pursue careers in science, technology, engineering and math (STEM) is a personal passion for Gannon. As a client of Virgin Galactic in 2009, she pitched and cofounded its now nonprofit foundation called Galactic Unite. She personally raised more than a million dollars to fund the group's first of many STEM scholarships for women. Through funding, education and outreach, Galactic Unite continues to offer the encouragement and support that young people need to pursue careers in STEM disciplines.

In addition to her role as VP of Business Development at Firefly, Gannon strives to continue making a difference in STEM education. She has begun by forming new partnerships with local universities, high schools and even elementary schools to spread the word about engineering and other STEM-related careers and continues to build Firefly's internship program. "We work to attract not just young women, but students of all genders, ethnicities and backgrounds, to careers in science," noted Gannon. "Firefly was founded to break new ground in the aerospace industry — and that means bringing in new thinkers with many different perspectives. The more diversity in our company and our industry, the more diverse our ideas will be. That increases our chances of driving true innovation."

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D: Since the space industry is heavily regulated, how are you cutting time and costs out of the standard approval process — which must be lengthy and complicated?

TM: The space industry is heavily regulated for practical reasons. Even if you're launching a rocket from a remote location such as the middle of the ocean, that launch requires careful planning, since various propulsive stages of the rocket inevitably cross habitable areas during ascent. As a U.S. company, Firefly is governed by Federal Aviation Administration laws and regulations, regardless of our launch locations around the globe. The process of acquiring a launch license requires involving many governmental and commercial entities. There are human and property safety considerations. There are also environmental impact considerations that require careful engineering analyses.

To navigate these approvals as quickly as possible, Firefly needs to have the ability to completely simulate and execute a launch from ground to orbit — considering a number of predictable and unpredictable boundary conditions such as weather, pressure, electromagnetic and electrostatic conditions, and even solar storms. Other design, analysis and simulation activities at Firefly focus on calculating instantaneous impact points in case of an errant flight. The possibility of terminating a flight requires many worst-case analyses and computationally intensive simulations.

While the traditional methods for mitigating launch failures involve a large footprint of resources and manpower, Firefly is leveraging engineering simulation to design and verify a new generation of built-in safety assurance mechanisms for our first rocket — and it will meet the strictest government standards. By demonstrating that our technology works, simulation is helping us to obtain regulatory approvals and get to space faster.

D: Firefly is not only seeking to democratize space by cutting costs, but to create greener, more-sustainable technologies. How do your engineers balance these priorities, which are typically at odds with each other?

TM: Lower-cost, green, well-designed and well-functioning are not mutually exclusive requirements. When science, engineering and the laws of nature are harmonized, surprisingly, things work better. You can see this all around you, in better modern buildings, bridges, roads, clean energy and even high-performance cars. For example, it is inevitable that cars of the future, regardless of the source of energy, will utilize electric motors as the propulsive force. It's just meant to be that way. Electric motors are rotating machines. They utilize some of the most elegant laws of nature, such as electromagnetism, in the right form and in a functional way. They produce force and motion at greater than 90 percent efficiency. For over 100 years, we have invested our engineering R&D talents into perfecting the reciprocating internal combustion heat engine. Imagine what could be possible if that same amount of engineering resources could be expended toward more-refined products that are better harmonized with nature, rather than working against it.

At Firefly, we're adopting a similar philosophy. We're looking at every possible option to take advantage of physical and natural laws to make our rockets better, simpler, more efficient, more affordable and, yes, greener. Our rockets utilize technologies that maximize energy transfer and provide a "simpler, sooner" product for accessing space.

D: Few companies are able to revolutionize an industry like Firefly. What's unique about the DNA of these companies?

TM: I believe that all disruptive companies are problem-solvers. They create products, services and tools that address societal and global challenges, sometimes in an unexpected way. And everyone from the CEO down must be passionate and focused on solving that problem.

At Firefly, engineers are the people actually applying the physical sciences to solve the technological problems related to reaching space. But every technology company should have executives at the helm who have a deep appreciation for engineering and an understanding of what the engineers are trying to accomplish, in addition to thinking about their company's fiscal and fiduciary responsibility to shareholders. Because Firefly is aiming for a highly technical goal, its executives must think well beyond "discounted cash flow" and "net present value." Understanding the very nature of producing hardware that imparts greater than 100,000 foot pounds (ft-lb) to escape Earth's gravity requires different management challenges than, say, writing an app.

Revolutionary companies are also ambitious, hard-working and dedicated to achieving results quickly. As an engineer myself, I'm incredibly impressed with the pace of progress accomplished by the Firefly development team. It is the most productive team that I have worked with, and they have a lot of fun getting stuff done.

We've got a good thing going. Within just 20 months of operation, we will have built world-class facilities and run rocket engine tests using designs completely developed in-house. Nothing drives a technical team to success like a clear vision of an important goal.

Firefly Space Systems

- **Founded: January 2014**
- **Number of employees: 55+**

Prior to founding Firefly Space Systems, Inc., Thomas Markusic served in a variety of technical and leadership roles in new-space companies: vice president of Propulsion at Virgin Galactic, senior systems engineer at Blue Origin, director of the Texas Test Site, and principle propulsion engineer at SpaceX. Prior to his new-space work, Markusic worked at NASA and the USAF as a research scientist and propulsion engineer. He holds a Ph.D. in mechanical and aerospace engineering from Princeton University.