



LOCKHEED MARTIN

Inventing the Telescope of the Future with MakerBot's Professional Solutions

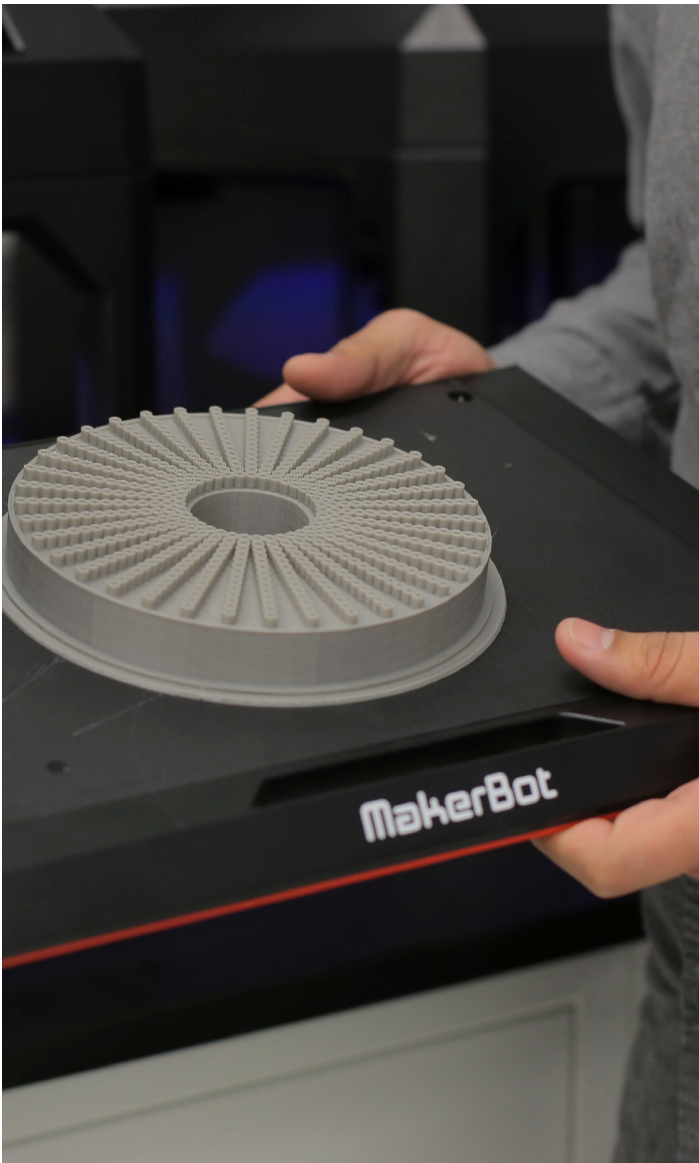
Discover How Lockheed Martin's Engineers Rely on MakerBot's Professional Solutions to Efficiently and Cost-Effectively Develop Radical New Designs for Space Telescopes

Making New Technologies Viable through Faster Iterative Design

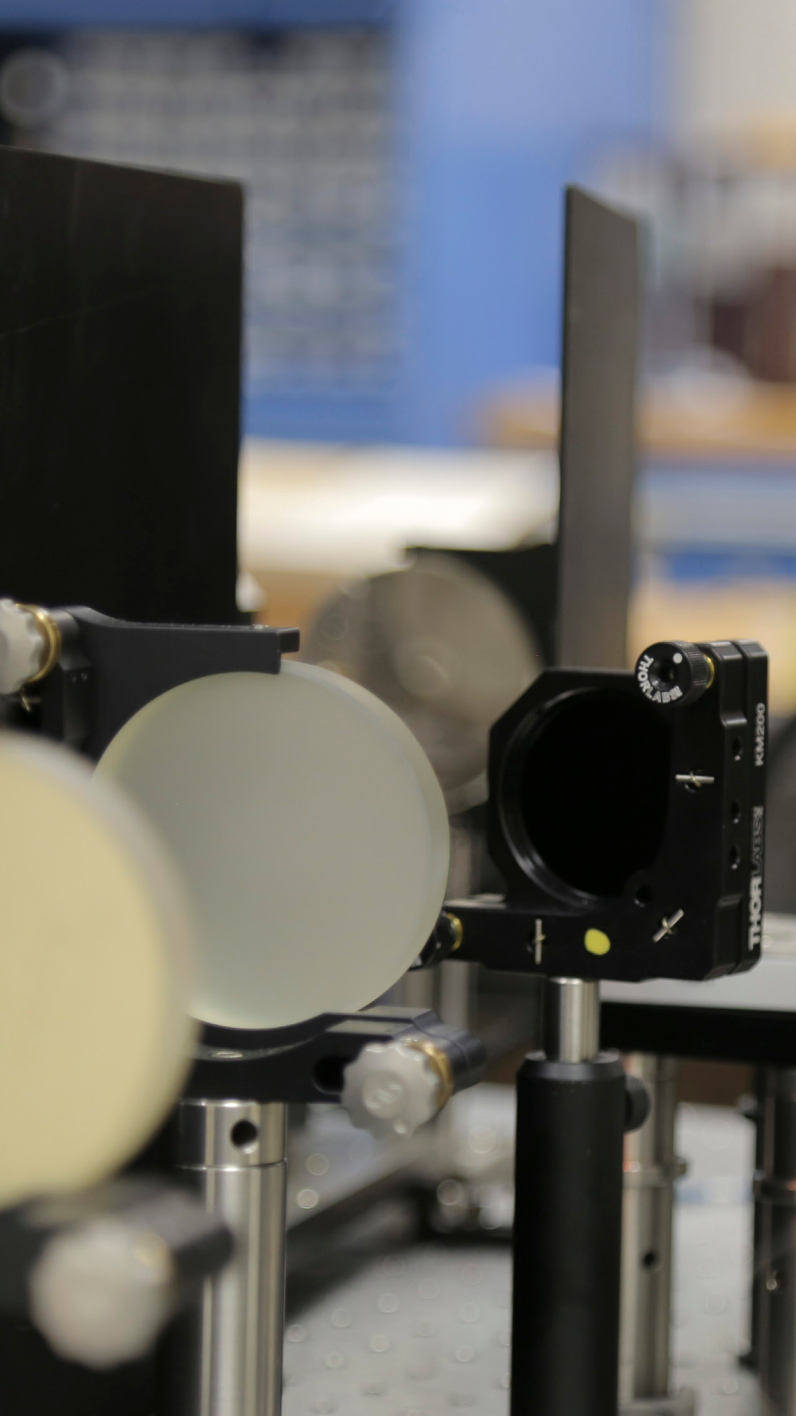
Lockheed Martin is a world-renowned company with a long legacy of achievements in aerospace, defense, and emerging technologies. For this global leader, tackling complex challenges, pushing the limits of scientific exploration, and devising innovative solutions are all part of its DNA. So it's no surprise that the U.S. Defense Advanced Research Projects Agency (DARPA) selected an elite team of scientists and engineers from Lockheed Martin's Advanced Technology Center (ATC) to create a potentially revolutionary design for a new, futuristic space telescope.

Because of traditional optical systems, today's space telescopes are heavy, astronomically expensive, and bulky. In line with the project's requirements, DARPA's version would have to be lighter, and less expensive to send into space. It would also have to be adaptable and even more powerful. As the ATC team soon discovered, the fundamental principles of telescope design would need to be reconceived.

To tackle the challenge, the ATC needed to create a new, vastly condensed optical technology. It also needed a cost-effective, fast means of creating prototypes that would help the team understand how to implement this technology. With the help of researchers at the University of California at Davis, the ATC co-developed SPIDER, or the Segmented Planar Imaging Detector for Electro-optical Reconnaissance. And with the help of MakerBot's professional solutions, the team rapidly and easily iterated on designs for prototypes.



3D-printed prototype of disk for SPIDER, showing a radial configuration of lenslets.



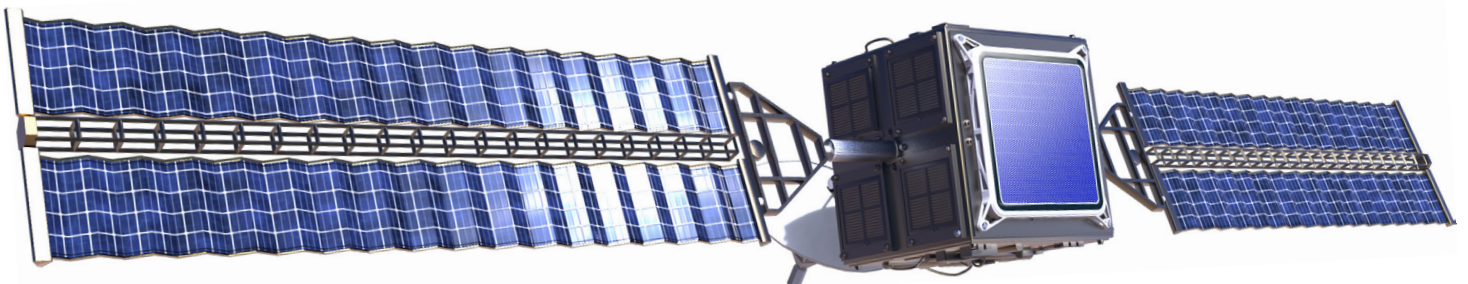
The Groundwork for Designing a New Telescope

To redesign the telescope from the ground up, the ATC chose a relatively new technique for collecting light, known as interferometry. In the world of optics, this technique uses many tiny lenses to collect photons which are then processed via microchips to create a high-resolution image.

Partnering with experts at UC Davis, the ATC co- developed a special silicon chip to channel light fed from tiny lenses. ATC's new system could reduce the size, weight, and power needed for optics by 10 to 100 times while offering similar resolution. As an array, SPIDER is cheaper, faster to produce, and lighter than the optics in traditional telescopes, making the technology easier to send into space.

The SPIDER imaging technology can be fitted to any number of flat shapes, however the best arrangement for a particular purpose will depend on the context of the application, the object or vehicle it's mounted on, and tradeoffs between spaceflight efficiency and light collection. To explore and test these concepts, ATC engineers designed different SPIDER arrays in Solidworks, then prototyped them to further refine and iterate on their models.

Testing equipment at the Advanced Technology Center in Palo Alto, California helps simulate images the instrument would see, process, and regenerate.



Artist's Concept

Accelerating Scientific Discovery

MakerBot's professional solutions have allowed Guy Chriqui, Senior Research Engineer at the ATC, and Sutyen Zalawadia, Mechatronics Engineer, to quickly accelerate the iterative design process and cost-effectively prototype for SPIDER on their own. Outsourcing any of this work just wasn't an option, as Chriqui explains: "We would get quotes in the thousands of dollars with an eight-week lead time for just one version of a model — I can't imagine what 14 versions would cost."

Chriqui and his team also have a cutting-edge machine shop in house, but the MakerBot 3D printers nearby allow the SPIDER team to iterate new versions in only hours. Plus, since the ATC has many sensitive projects, outsourcing work to contractors would not just slow down projects and increase costs, it would also require approvals and paperwork that could be avoided by turning to a MakerBot a few feet away.

By accelerating the design process, MakerBot Desktop 3D printers have bolstered scientific experiments, enabling more tests, more insights, and more potential breakthroughs in a shorter period of time. Moving more quickly from ideation to iteration and refinement gives engineers a big competitive advantage, helping deliver better solutions faster to clients.

No stranger to MakerBot, the ATC used the Replicator 2 and 2X to prototype parts and tooling for the James Webb Space Telescope back in 2013. They have since updated with the Replicator (5th Gen), Mini, Z18, and now the Replicator+ and Replicator Mini+ — or "the full MakerBot lineup," Chriqui notes jokingly. "They're basically running non-stop, all day long, and have enabled a lot of really quick iterations for parts that may have otherwise slowed completion of the final product."

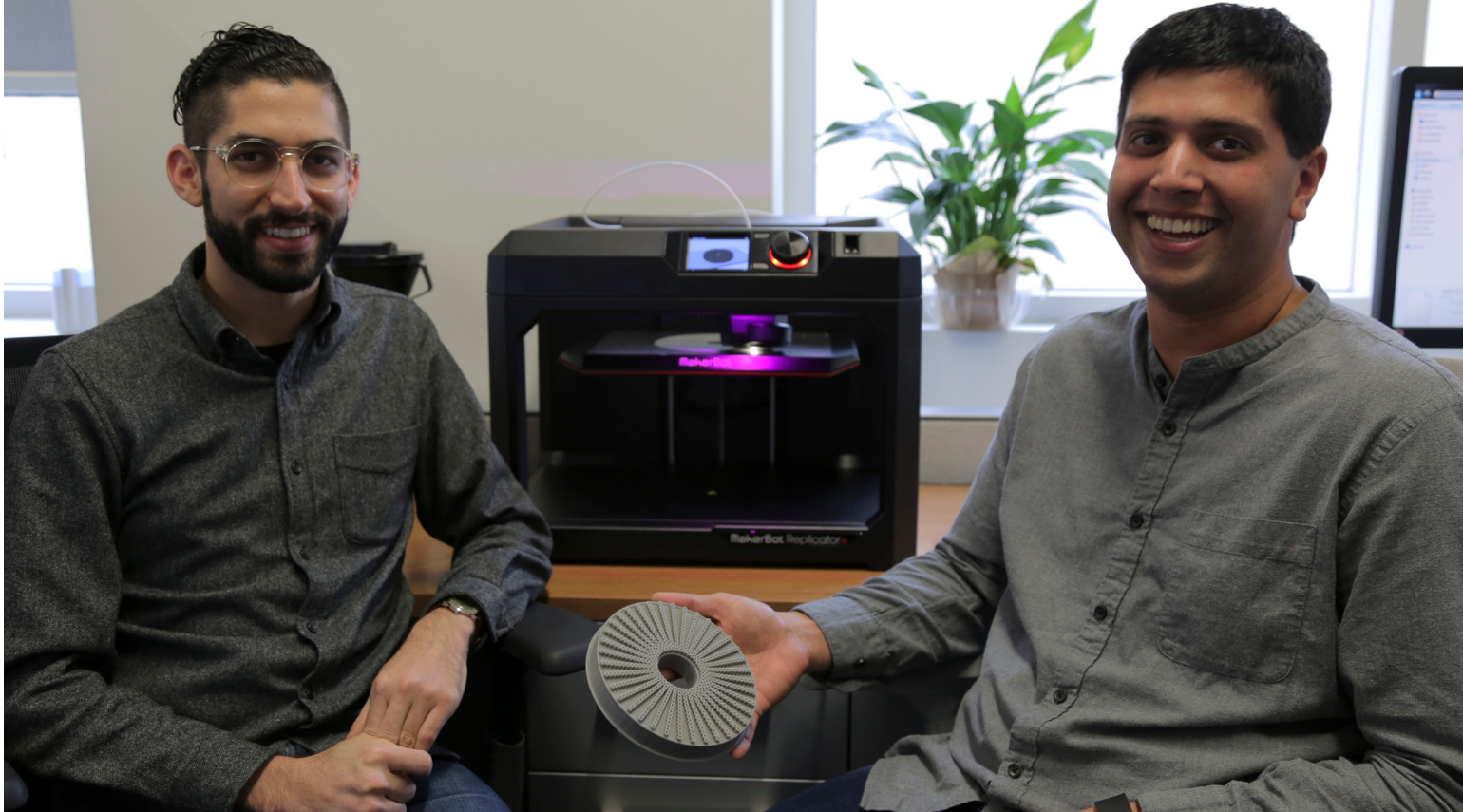


Electro-Optical Engineer, Katherine Badham adjusts instruments on an optical bench used for SPIDER testing.

Beyond prototyping SPIDER arrays, the team's Replicator Mini is also an effective field 3D printer for when the engineers travel to different testing facilities. "When we test smaller rockets, the nose cones blow off and are mostly unrecoverable, so we bring the Mini to the launch site and print different nose cones on the spot," Zalawadia elaborates.

MakerBot's filament has also proved beneficial. With new materials like MakerBot Tough PLA, ATC's engineers can make entirely new products and applications possible, such as high-quality snapping joints Chriqui calls flextures. Whereas these flexible hinges and joints would normally fail when printed as PLA, they function well with Tough PLA, allowing the team to print prototypes that are closer to the final product. In testing the SPIDER technology, the team also found that MakerBot True Black PLA at 100-percent infill is perfect for absorbing light. Good light absorption is important so there is no light leakage that can affect optical tests. They also use neon MakerBot PLA filament to highlight specific parts of a print.

When Chriqui and Zalawadia had the opportunity to test the MakerBot Print platform, they appreciated its added efficiency, especially for assisting coworkers with ad hoc 3D printing requests. The Auto Arrange and multi-printer control features were used for setting up different projects on multiple build plates and sending them to different printers. With MakerBot Print's Native CAD feature, ATC engineers can also work in their preferred program and file format, without the hassle of creating STLs or converting files, and then share files to easily collaborate.



Pictured from Left to Right: Research engineers Guy Chriqui and Sutyen Zalawadia use 3D-printed prototypes almost daily in their development work.

Developing Higher-Quality Solutions Faster and at Lower Cost

MakerBot's solutions for professionals assist in everything from rapidly prototyping different concept models to printing in the field to testing to even printing functional, custom tools on demand. ATC engineers save time and money by integrating these solutions into their workflow.

When the team's experiments required a custom tool that couldn't be bought off the shelf, they were able to design it themselves and print 14 different iterations in a single day. "Some little tools that were printed over a year ago are still in use in the lab," Zalawadia remarks. Producing conceptual and functional models at such a high quality that they can remain in use over a year later is just one of the cost savings MakerBot's professional solutions offer.

With MakerBot 3D Printers — the only FDM printers at the ATC— the team has dramatically sped up its product development cycle. Even

though the ATC has access to industry-leading machine shops and advanced manufacturing technology, MakerBot's professional solutions add distinct advantages to the ATC's workflow that the Center's other resources can't. The ATC's success using these solutions highlights MakerBot's disruption of traditional rapid prototyping, a vastly more expensive and laborious process than desktop 3D printing.

Redefining Space Exploration

With the breakthroughs achieved at the ATC, the SPIDER team can continue its mission to engineer telescopes that are lighter, more powerful, and much cheaper; telescopes that could one day travel farther, explore distant planets at high resolution, and look deeper into the endless depths of space.

About Lockheed Martin and the Advanced Technology Center

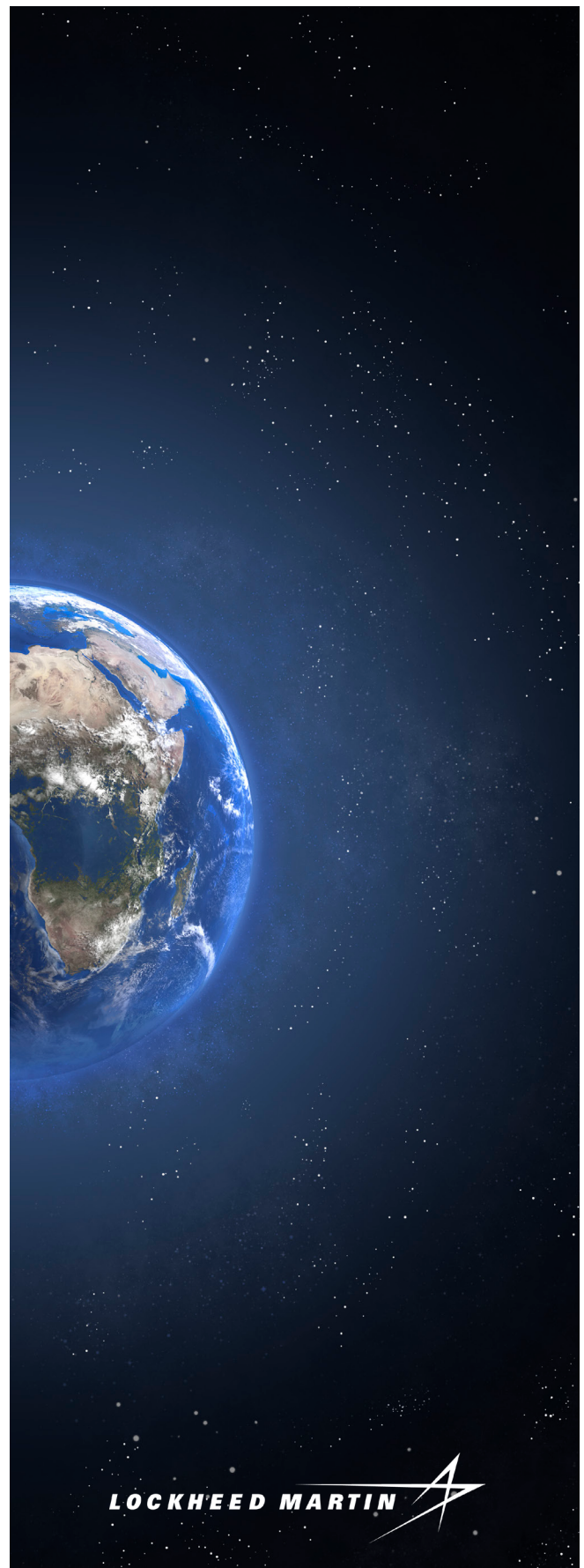
Based in Bethesda, Maryland, Lockheed Martin is one of the largest aerospace, security, and advanced technology companies in the world. As one of its largest divisions, Lockheed Martin Space Systems has a large presence in Silicon Valley, including Palo Alto, California, which is home to the highly specialized, Advanced Technology Center (ATC). The ATC serves commercial, government, and defense aerospace customers by developing complex technological solutions that are both guided by practical business concerns and backed by deep expertise in space science and engineering.

While Lockheed Martin operates in more than 70 countries and territories, it largely conducts business with U.S. and allied government agencies. Landmark projects like NASA's Viking probes, Titan rockets, and the Spitzer Space Telescope are just a few examples of how Lockheed Martin's contributions have helped cement the United States' position as a global leader in science and space exploration.

About MakerBot

MakerBot is a global leader in the 3D printing industry. Our mission is to advance tomorrow's innovators and institutions by empowering the professionals, educators, and students of today. We offer connected solutions that address the wider needs of professionals and educators. We provide a faster more effective way for engineers and designers to test ideas and for educators to prepare students for the jobs of tomorrow.

Founded in 2009 in Brooklyn, NY, MakerBot strives to redefine the standards for reliability and ease-of-use. Through this dedication, we have one of the largest installed bases in the industry and run Thingiverse, the largest 3D printing community in the world.



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