Tracy Peters checks out the installation of 5 of 8 Johnford custom 2600 F machines built to perform slow, super-high precision machining on large, critical lens components for the James Webb space telescope. The 8 machines were redesigned, rebuilt, tested and delivered in a total of 10 months by Taiwanese manufacturer Roundtop Machine Tool. "We considered that a remarkable performance," says Tracy Peters. Tinsley employs 102 people in a 150,000 sq ft facility.

The Hubble's Optometrist

How an advanced optics company solved world's greatest vision problem.

Story and photos by C. H. Bush, editor

Remember all the stories in the late '80s about how NASA blew $2 billion dollars putting the Hubble Space Telescope into orbit, only to discover that a flaw in one of its mirrors caused the instrument to produce out-of-focus pictures? You may even recall that some of the stories joked about the Hubble's fuzzy vision and how the high-priced instrument needed an optometrist.

As it turned out that's exactly how Nasa solved the problem. For the Hubble's "spectacles" Nasa turned to Richmond, CA's Tinsley Laboratories, Inc., a company specializing in designing and producing precision aspherical optical components for both military and commercial applications.

"We got involved about six months after they discovered the problem with the primary mirror on the Hubble," says Tracy Peters, manufacturing equipment manager for the James Webb space telescope project at Tinsley. The James Webb is the next generation in space telescopes, destined to replace the Hubble in 2011. "The error was in the primary mirror. They knew how much the optics were off, so they basically had the telescope's prescription. What they didn't know was how to repair the problem, which is why they came to us."

Eyeglasses for the Hubble

According to Peters, it wasn't possible to bring the big

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Tracy Peters (left) and Dante James, mechanical designer discuss installation and fixturing of Tinsley's Leitz pmm-c 700 CMM..

mirror back to earth for repairs, so the solution needed a highly creative approach.

"I guess we were the only company in the world that came up with a solution," says Peters, "which is why we got the contract. Tinsley has developed a a proprietary technology called CCOS, which stands for computer controlled optical surfacing. Basically, what that means is that we can make highly precise lenses in very strange shapes. Most lenses that you see are spherical. Most of ours are not. Most of the lenses we work on nowadays are shaped like a race track. They're truncated round or, like the ones we're working on for the James Webb Space Telescope, six sided, but not hexagonal."

Backtracked to Get Prescription

To come up with a prescription for the Hubble's spectacles, Nasa used a form of reverse engineering.

"What they did was take pictures of stars and then backtracked to figure out what the image was supposed to look like," Peters recalls. "They used a computer to enhance the images to actually take out the fuzziness. And then from that they were able to figure out what was wrong and come up with a prescription. We used an an interferometer to measure the correction required. We were able to prove that our parts were what they wanted, and so far it has worked great. The Hubble has taken mankind further into space and back in time than ever thought possible. I strongly recommend that anyone who is interested run a Google search on the Hubble and take a look at the incredible views of our universe produced by that instrument."

The prescription correction for the Hubble called for lots of odd-shaped small lenses placed in precise locations with orientations able to be controlled by computer.

Tinsley's success on the Hubble led to the company receiving the contract to produce the lenses for the James Webb Space Telescope, which, unlike the Hubble, will be placed in synchronous orbit 940,000 miles out in space. It will remain in view of the Earth by matching our planet's orbit around the sun.

"The James Webb will be too far out for astronauts to do any repairs," Peters says, "so this time around everything has to be done right the first time. We take our work very seriously here. We don't have any room for mistakes."

Nonstandard Fabrication Techniques

The corrective lenses for the Hubble were eliptical, and they were ground on an angle, which, according to Peters, meant Tinsley had to use nonstandard optical fabrication techniques.

"Actually, just about everything we do here uses nonstandard manufacturing techniques," he says. "To produce our workholding tools and fixturing, I have two Haas horizontals and six vertical machining centers, all equipped with optical scales. Most of the work we do with them is pretty light machining. But that's just about the end of it when it comes to standard machining."

Tinsley's manufacturing requirements are so nonstandard, in fact, that the company decided it needed to put a scientist in charge of buying or building the equipment needed to produce the lenses for the James Webb telescope.

"I graduated with a degree in physics from the University of California in Berkeley," says Peters, "and three years later, after a stop off at Boeing, I came to work for Tinsley. That was seventeen years ago. Back then my job was to design equipment for measuring telescope mirrors. After that I got into designing controls for the machines. One thing led to another until I'm now managing the equipment needed to produce the components for the James Webb space telescope. So far, this place has offered one exciting challenge after another."

The James Webb Challenge

The mirrors on the James Webb telescope are made, not of glass, but of beryllium, a very shiny, light weight and stable metal, Peters says.

Raul Morales electro-mechanical technician checks out the installation at a Delta Tau CNC Control used on the custom Johnford bridge mills.

Louis Rivera (left) and Tracy Peters discuss future use for a 66' x 10' x 2' thick granite slab weighing in at 136000 lbs. The slab will be used as a precision test bench for measuring the James Webb telescope mirrors. Since its arrival, the slab has sunk .042".

"Our equipment requirements here are almost the direct opposite of those of a normal job shop or manufacturer," he says. "Most shops need as much speed as possible combined with precision of plus or minus a tenth or so. In our case, we need precision measured in microns nanometers. We're making the James Webb mirrors to less than 10 nanometers over a 1.6 meter wide part. To do that doesn't take high rapids. In fact, the rapids we need would make a snail look like a speed demon. We just can't get that kind of equipment off the shelf, so we frequently end up building our own polishing machines from the ground up or we use the base from an off the shelf machine and rebuild everything."

For the James Webb telescope project Peters developed a tough set of equipment specifications.

"We needed a large bridge mill with a two by three meter X-Y work envelope. Z travel is never a problem for us, but the ability to handle very precise, tiny incremental movements is. To make matters worse, we needed a machine that stiff enough to eliminate the need for a special foundation," Peters says. "Plus, I needed a manufacturer who was willing to remove their spindles and their tool changer. We don't need a fifty horsepower spindle with glass and we don't have a tool changing problem. We use very, very small spindles and take a very long time to do the work. We needed slow speed and super high precision. A one-year cycle time is not uncommon in our shop."

Other modifications Peters needed were: scales on all axes; an iron bolt plate with holes in it for mounting different types of spindles; removal of the metal enclosure to allow retracting the part from beneath the work head and to facilitate visual inspection.

"We wanted the manufacturer to switch to a Delta Tau controller, which has the ability to do super-fine motion control," adds Peters, "and we also wanted a second set of encoders on all axes so we could have a separate computer system monitoring the machine performance, totally independent of the machine controller. The second computer has it's hand on the E-stop, you might say, so if the machine does something outside the boundaries, it stops the machine and puts it into fail safe mode."

To complete the control and quality control system on the machines, Peters uses an on board probing system that is based on a Heidenhein probe.

"That probe actually can measure the part to about a 10-th of a micron over the surface of it," he explains. "We also have a camera assembly that allows us to zoom in and find the edges of the part, which helps in centering and with tooling. That was another thing we needed, a machine configured to accommodate our cameras."

Meeting the Challenge

Peters also needed 8 machines and he needed them fast.

"I went to the Chicago IMTS show looking for a solution," he reports. "I saw a lot of great equipment, and began negotiations with several companies, including Rountop Machine Tool, who produce Johnford machines. And, frankly, until I went to Chicago, I had never heard of Johnford. When I went to their booth, I was pretty impressed with the quality of their equipment and the fact they had a bridge mill with the travel I needed. What was even better, their prices were excellent, even when compared to other Taiwanese manufacturers."

Johnford Got the Job

For several reasons Johnford eventually got the contract to build the eight machines for Tinsley.

"Basically their price was right," Peters says candidly, "but another major factor was their willingness to cooperate with us. They threw their engineers into the project and agreed to make all the changes we requested. I went to a lot of other machine tool manufacturers and even though it was an order of 8 fairly large machines, they were not really interested in working with us to develop some of the custom features we wanted. What amazed me was that Johnford delivered the first machine in four months and all eight in ten months, which is pretty good delivery even for off-the-shelf machines. We had great cooperation from them and from Absolute Machine Tool, their distributor "

Once the James Webb space telescope is launched and pushing the limits of time and space for the human race, Peters says that everyone involved in the program will have the right to be proud of their accomplishments.

"And, as far as I'm concerned, that includes people who generally don't get much credit for their contributions," he says. "People like Roundtop Machine Tool who made our lives easier in the end. ■

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