MARCH 2006 / VOLUME 58 / NUMBER 3

➤BY BILL KENNEDY, CONTRIBUTING EDITOR

HIGH-STAKES machining

Producing 'high risk' aerospace parts requires unique strategies and tactics.

For aerospace components, perfection is status quo. Completely reliable performance is mandated.

However, making parts that support low-risk flight can be a high-stakes business proposition. Producing small volumes of high-value, high-precision parts requires a combination of manufacturing strategies, tactics and organizational culture designed to avoid the potentially devastating costs of nonconforming parts and disrupted delivery schedules.

High-Reliability Planning

Numerical Precision Inc., Wheeling, Ill., produces a variety of sophisticated aerospace and defense parts, including key components for the new James Webb Space Telescope, communication satellites and the space shuttle. The company provides its customers with what it calls "hi-rel manufacturing." Such unwavering reliability, the company says, is a result of its highly analytical corporate culture, which emphasizes detailed manufacturing solutions for complex parts and assemblies.

"Sometimes, I refer to it as 'high risk,' because of the dollars involved," said Egon Jaeggin, founder and president of Numerical Precision. "The bottom line is

A restraint fitting, made out of titanium (Ti6Al-4V), for a composite satellite structure.

Numerical Precision

Paramount Machine

This complex 10.67"-dia. nozzle plate, machined from solid titanium, is an air-conditioning component for the new Airbus A380 jumbo jet.

if you work on an $85,000 component, there is no room for error. You have to train and motivate and create a culture that is totally different than that of other machine shops."

Karl Dahlstrom, vice president of engineering at Numerical Precision, said effective project management begins with preprocess planning. "When a job is being considered, a team gets together that represents the different expertise in each of the departments," he said. "We come up with the preliminary process and, at that point, we determine what level of job it's going to be."

The jobs are ranked on a scale from one to five. A level-one job may be a simple pin or washer, and require only review and confirmation of planned process steps. A level-five job might be a nose connection fitting for a composite structure on a satellite system, involving complex multiple-axis machining of a titanium component and wire EDMing. "A level-five job carries a financial risk to the company, and, therefore, entails approval of the sequence of operations by a company officer," Dahlstrom said.

Part complexity is not the only characteristic used to evaluate jobs; a project involving a new customer or a significant challenge regarding delivery may also receive a high ranking.

Jaeggin said an "instrumental tool" in the planning process for complex parts is the use of stereolithography apparatus (SLA) models. Created from the part's CAD file, these models "give the toolmakers and machinists full visualization of what this darn thing looks like. You can hold it, touch it, feel it."

Dahlstrom said particularly complex parts benefit from SLA evaluation because "you can physically see how your fixturing is going to be used, how the tool is going to reach into a deep cavity, or how you are going to access internal features that may need EDMing."

Close Collaboration

Reil Industrial Enterprises Ltd., Mississauga, Ontario, specializes in the machining of highly detailed and intricate parts for makers of space vehicles and defense systems. Among the low-volume, high-value parts Reil Industrial manufactures are components of the space shuttle's articulated robotic manipulator system—the Canadarm.

Space-related and defense work is profitable, said Bill Reil, the company's vice president of manufacturing, "but you don't do as well as people think." Although margins may be higher than commodity-level machining, "the risks are much higher," he said.

The key to success is close collaboration with customers. "Manufacturing engineers from our customers will come in and want to know how we are going to go about making their parts," Reil said. "So it's really a collaborative effort between the customer and the guys who are going to do the work." In many cases, the collaboration produces design changes that improve the manufacturability of parts, reduce costs and speed delivery.

Tooling Tactics

Every job has a deadline, but achieving maximum metal-removal rates, Reil said, "is not a big issue, because we are not doing production. We are going for ultra-high quality, as opposed to hog it out, rough it out and get it off the machine."

Many aerospace components are thin-walled and made of materials that may spring back or suffer metallurgical changes while undergoing heavy cuts. As a result, machining parameters are conservative. "We take very light cuts, so it minimizes the distortion," Reil said. "Our depths of cut in roughing are from 0.010" to 0.020", and in finishing from 0.001" to 0.005". Springback is common with titanium, so that's why we do a semifinish and a finish pass. We tickle these things all the way down."

K.L. Steven Co. Inc., Rio Rancho, N.M., concentrates on smaller aerospace parts, those "you can hold in your hand [that are] made of all the nasty materials—the high-strength, high-temperature alloys for the hot parts of the engines," said Steve Weitz, president and owner.

Regarding the shop's metalcutting tactics, "we are looking for consistency," he said. Running an insert hard and changing it frequently will remove metal fast, but the time needed to change out the tool and reset it must be considered as well. "You have to balance what it takes to get [a tool] back into production."

K.L. Steven

Valve pistons and seats for engine hydraulic systems machined from hardened 321 stainless steel.

An example of the shop's quest for consistency is that most of its machines use cutting oil, as opposed to coolant. In high-nickel alloys, the shop found that the tradeoff in the extreme increase in tool life resulting from the use of oil offset the loss of productivity caused by cutting at lower speeds. Weitz said, "Say we are working with a small corner radius. The oil allows us to run it a little bit slower, get more even wear on the tool and consistently maintain radii." He also noted customers' increased emphasis on part appearance. "Aside from dimensional requirements, the actual look is very important. Cutting oil helps with that also."

Reil Industrial

Forward transition component of the space shuttle's robotic manipulator system—the Canadarm.

Occasionally, a high-risk operation can prompt a move from high-tech machinery to highly skilled personnel. Numerical Precision's Dahlstrom noted that aerospace parts typically feature large numbers of small, tapped holes. "When we are dealing with a titanium part that costs $45,000, and we're tapping an 0-80 UNF hole, 0.250" deep, we find there is a lot of risk involved in getting too aggressive with the machine tapping. So we will give that tapping step to a toolmaker to tap the hole manually on a special bench."

Measure Twice, Cut Once

Weitz feels a major distinguishing characteristic of aerospace machining is comprehensive inspection requirements. "I've got a lot more overhead in inspection than a normal machine shop does," he said.

K.L. Steven has to maintain a fully certified department, train machinists and give them the proper tools, and perform inspections on the floor. There is a person who is on the computer almost full time filling out quality-control forms that apply before and after the job. The parts any shop owner makes have to be right, Weitz said, "but he's doing his own inspection. He doesn't necessarily have to be certified externally by the customer."

K.L. Steven inspects 100 percent of the parts it makes. "We really can't do SPC (statistical process control) sampling; it's not going to work on the small quantities we ship," Weitz said.

For certain customers, 100 percent inspection is required. With some customers, K.L. Steven participates in vendor-release programs, wherein "we make parts that do not get any receiving inspection," Weitz said. "The customer approves our inspection department, and our QC manager is approved as their representative in our shop. Essentially, we ship parts and they go into assemblies."

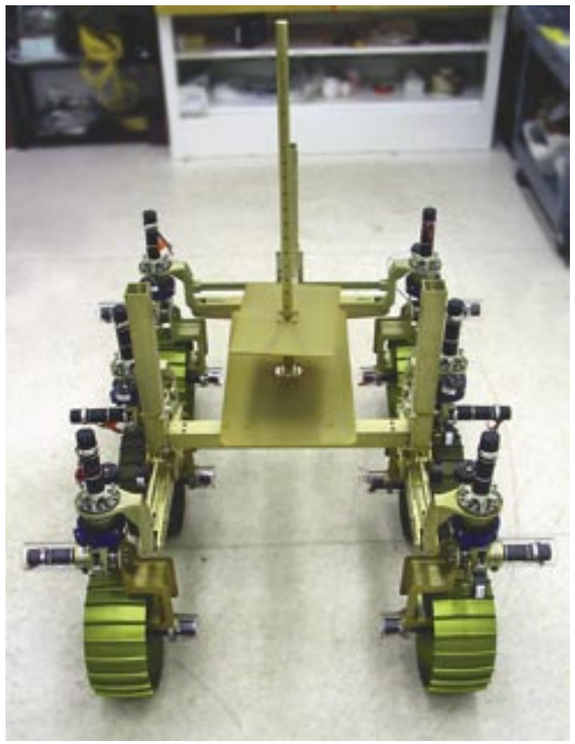
Weitz doesn't consider the inspection requirements onerous, however. "We make a lot of parts for General Electric engines. Personally, I can tell you I'm very comforted to know that the plane I'm riding in has GE engines," he said. "It's a great responsibility and that's the way we treat it."

Repeated verification of dimensions is not limited to the parts themselves. All elements of the machining system are involved. "Some people work under the pretense that if it comes off a CNC machine it's got to be right," said Reil. "That's not always the case. Machines go out of spec through regular use. We are constantly leveling, releveling and verifying that our machines are correct." He said his shop "checks all the variables all the way through. The biggest thing is the old adage: measure twice, cut once."

Changing (Lead) Times

In today's just-in-time manufacturing environment, maintaining inventory is considered risky. But the need to meet customers' emergency demands can make it necessary to take risks.

Paramount Machine Co. Inc., Manchester, Conn., specializes in manufacturing precision-machined parts and assemblies for aerospace and other markets. The company continually seeks ways to improve its ability to respond to short-lead-time situations. In addition to investing in state-of-the-art machinery, developing quick-change tooling and setup reduction tech-



Reil Industrial

Reil Industrial machined and assembled all of the parts for this ground-test Mars rover unit, as well as installing the wiring and performing preliminary tests.

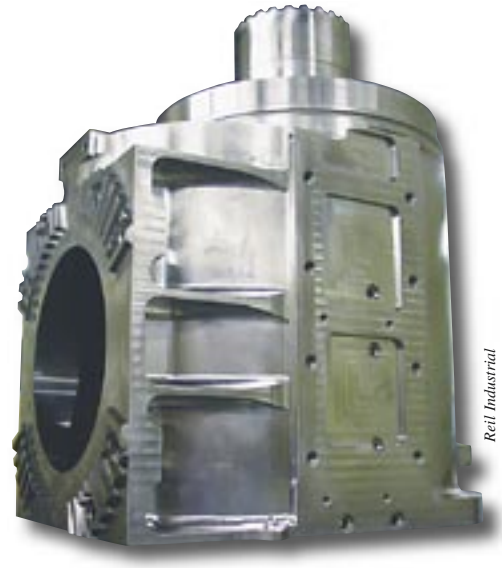
niques, it maintains an inventory of selected components.

Andy Djiounas, Paramount's president, noted that airlines have contingency plans and allocate spare planes so lack of a part won't disturb flight schedules. However, when a missing part grounds a working aircraft, "it costs them thousands of dollars an hour," he said. "They want the part shipped immediately. Then it becomes a fire drill."

To enable Paramount to respond quickly, it keeps quite a bit of inventory on hand, said Djiounas.

In other cases, lead times change and production levels grow as new aerospace technology is gradually introduced. From solid titanium, Paramount machines a complex nozzle plate that is part of the air-conditioning system of the new Airbus A380. "Airbus has only two planes built right now," said Djiounas. "Production won't be starting for 2 or 3 years, but we are still making about 50 to 100 [plates] a year." He estimates production will accelerate to 200 to 300 a year.

Reil said the engineering-intensive nature of the aerospace business breeds short lead times. The engineering takes up such a vast part of the whole project that the manufacturing time is compressed. "The launch date never moves," he noted.



A component machined from solid titanium for the Hubble space program.

The Cultural Difference

As in any organization, the strategies and tactics unique to aerospace machining have to be carried out by the people who work in the shop. According to K.L. Steven's Weitz, the keys to maintaining skills and focus among employees are communication, training and mentoring within the company, with longtime employees working with newer ones to make sure they are following procedures and understand why the procedures are in place. "A lot of it is also just the general atmosphere of working here and the fact that we work hard to retain employees," he added.

At Numerical Precision, "more so than ever before, we train, train, train," said Dahlstrom. "When a top-notch toolmaker applies for a job here, and whatever his rate is, he has to go through a ramp-up training mode."

Dahlstrom added that it takes a different kind of person to do this work. "He or she has to have a high degree of passion and not be afraid of challenges," he said. "It's not just a job." Numerical Precision is seeking to boost that motivation both internally and for the public at large (see sidebar).

Aerospace manufacturing philosophy and practice is an outgrowth of the zero-risk goals for part performance. "It's the dedication to quality that's our first and foremost goal," said Reil. △

The following companies contributed to this report:

K.L. Steven Co. Inc.
(800) 739-9176
www.klsteven.com

Numerical Precision Inc.
(847) 394-3610
www.numericalprecision.com

Paramount Machine Co. Inc.
(860) 643-5549
www.paramountmachineco.com

Reil Industrial Enterprises Ltd.
(905) 670-1070
www.reilindustrial.com

Xtreme motivation

Numerical Precision's founder and president, Egon Jaeggin, participated in the early days of the U.S. space program as part of the team that developed the first hand-held camera used in outer space.

Comparing that exciting time with the present day, he said, "We are struggling with an enormous shortage of highly skilled persons coming into our manufacturing field."

Some of the motivation at Numerical Precision comes from outside the company. "Besides giving us the work, commercial satellite companies allow our staff to come and visit their facilities," Jaeggin said. "It means everything to [the staff] to see where their components end up."

A personal note from an astronaut is also a great motivator. For the space shuttle, Numerical Precision built an articulating portable foot restraint extender (APE) that enables a spacewalking astronaut to move precisely. "The components we made attached to a seat that allowed him to articulate and extend himself to the right point," Jaeggin said. Shuttle mission astronaut John Grunsfeld performed spacewalks on two shuttle missions and sent the shop a picture of himself holding the component, captioned "Thanks for the great APE."

Recently, the company started a program to generate some enthusiasm of its own. It established Xtreme Machining (www.xtrememachining.com), a Web site that, according to marketing consultant Greg Johnson, "doesn't deal with making parts, per se, but rather promotes thinking about the industry in more than one dimension." Johnson said the site is an outgrowth of Jaeggin's ideas and concern for his industry.

Jaeggin has a motivation program of his own, as well. He brought his grandchildren to the manufacturing facility for a visit. Although "they've got all the toys in the world," he said, the children told him, 'Grandpa, you make neat things!' —*B. Kennedy*