NeXT Computer, The Ultimate Computer Factory

Benchmarks	
New product design to rollout:	nine months
Board re-design to production:	one week
Part count:	220
Suppliers:	60
Yields:	
Complete systems, first time power-up	80-95 percent
Surface mount solder joint failures	4-6 parts per million
First-time turn-on board yields in test	90-95 percent
Cycle times:	
Complete system	1 hour
Board assembly	20 minutes
Scrap	$70-80 per month
Lot size	1
Employee turnover	2 percent
Total employees	480
Manufacturing only	55 (11 percent)

P. E. Moody

At the NeXT computer factory you won't see:

- tubs of ic's waiting for insertion by rows of benchworkers;
- racks of completed boards;
- piles of rework boards:
- warehouses;
- paper: shortage lists, reject tags, work orders;
- expeditors;
- fingers.

Even if NeXT's 15,000 orders for its new systems disappear;

Even if IBM takes more of the workstation market;

Even if software availability continues to be a problem in this market,

The NeXT computer production facility in Fremont, CA. is one of the most elegant examples of printed circuit board assembly and test we will see for some time, the ultimate computer factory.

Learning from the First Generation

NeXT computers are workstations featuring advanced graphics capabilities combined with communications suitable for networked publishing applications. Customer reaction to the first generation was that although the systems had many features, they needed to be faster and cheaper, in color.

The new systems address the performance, price, and applications software problems. The California start-up has introduced four new models, two color and two monochrome, all powered by the Motorola 68040 chip. Prices on the second generation have dropped ($9995 to $4995 on the basic NeXTstation), with performance increased four to five times.

Using the Motorola 68040 microprocessor and re-programmed system software, NeXT hopes the second generation products are positioned to compete with mid- and high-end personal computers and work stations.

Customers include the William Morris Talent Agency, who have networked their New York and Los Angeles offices with several hundred NeXT systems. Over 200 universities have purchased NeXT systems. Stratus Computer uses NeXT systems and Framemaker for document processing, order processing and customer service.

"Very high quality and low cost manufacturing will determine who will make it in the 90s in the computer industry, and who won't."

Randy Heffner

The Vision, NeXT's Manufacturing Strategy

In the words of Randy Heffner, the young vice president of manufacturing recruited out of Hewlett-Packard by Apple-founder Steven Jobs, NeXT's manufacturing strategy "is a conscious effort to make manufacturing competitive, by effective management of assets of inventory, capital, and people."

He speaks in fast forward, racking up their list of accomplishments:

- incredibly high quality — reject rates of less than 4-6 parts per million
- short (less than one hour) cycle times
- low labor content.

These three achievements support NeXT's manufacturing strategy — to produce excellent quality systems quickly, with great design flexibility, at a cost that allows them to compete in the marketplace on price as well as features.

And in fact, automated board assembly cut costs so much that Sony buys monitor boards from NeXT cheaper than their Japanese subcontractor.

Although the start-up has experienced problems with its market strategy, the execution of the manufacturing strategy has worked. According to Mr. Heffner, "Most start-up companies don't have manufacturing facilities, let alone world-class manufacturing. Very high quality and low cost manufacturing will determine who will make it in the 90s in the computer industry, and who won't."

The Process, Fingerless Manufacturing

The Fremont, CA facility advances how we design and manufacture complex printed circuit boards, and how we assemble computers.

Surface mount technology

In 1986 NeXT saw the possibility of fitting all the power and technology of the most advanced computer workstation into a one-foot cube. To accomplish this they aggressively pursued surface mount technology, a process that would allow them to build an entire computer system on one circuit board. The manufacturing process, therefore, had to guarantee accuracy of component placement.

This process set into motion the plan to build a sophisticated manufacturing system for surface mount technology. The entire board assembly process, from application of wave solder, to complete insertion of all components, takes 20 minutes, followed by test.

Most of the 450 components per board are automatically inserted and wave soldered. Larger components are inserted by two robots. The height and skew of each solder joint, a major determinant of board reliability and infant mortality rates, is checked by a laser.

Automate for Quality, Get Repeatability for Free

The system was fully automated to fulfill NeXT's strategic goals of high quality, high consistency, and low cost. According to Kevin Canty, the material manager, "Anytime you handle a board, you run the risk of introducing a defect. The advantage of automation is that it takes the mundane labor out of building a board. With a program such as robotics or automation, you get repeatability for free.

Change-overs

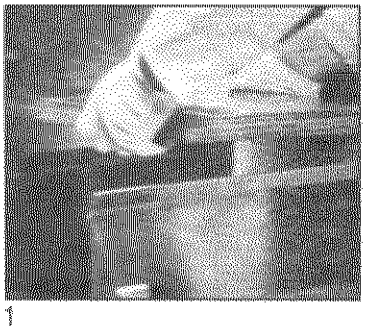
The curse of printed circuit board shops has always been huge numbers of engineering change orders. NeXT's production line makes it easier to control and respond to changes.

Every circuit design comes via Ethernet directly to the production line from the design center in Redwood City.

In less time than it takes to drive to Fremont, the factory can tool up, train robots, optimize the design, compare it to the bill of material, and produce a whole new board.

Surface Mount Technology

1. The board goes to a screen printer where a robot stencils the solder paste that will hold components on the board.
2. The board stops at a paste inspector, a robot laser measuring system that checks height and skew of the 1700+ solder pads, making sure that they are perfect within one ten-thousandths of an inch before the components are put down.
3. The board moves on to the first of two pick and place robots, the first of which places the smallest components from locational dimensions programmed at NeXT at the rate of 150 per minute.
4. The second pick and place robot uses a vision system to accurately place fine-pitch parts.
5. The board is moved along to a computer-controlled oven that dissolves oxide, leaving pure tin and copper for best solder joints. The board is then heated uniformly at 250 degrees centigrade; it emerges from the oven nearly complete.
6. The board passes to the through-hole insertion robot, where two specialized arms — one of which picks, and the other inserts — together can handle 70 parts of all different shapes and sizes, and perform a number of complex operations.
7. Finally, the board arrives at the wave solder station, where the board flows over 700 pounds of hot solder.
8. At the final assembly step before board test begins, the completed unit enters a cleaning system to remove flux and residue.
9. Boards are tested 30 minutes. Completed systems run for 24 hours, after which they are slipped into the chassis.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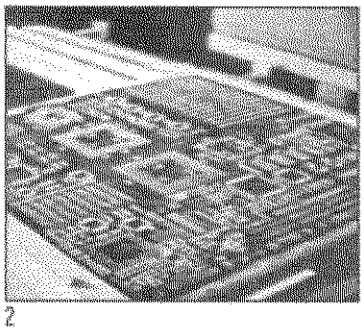
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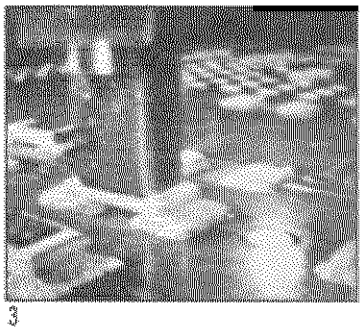
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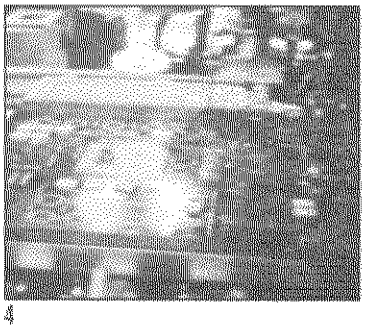
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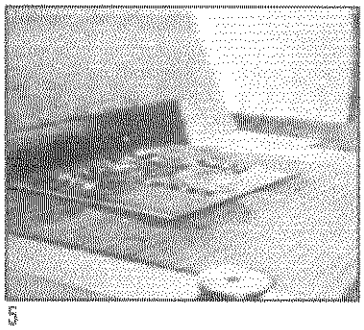
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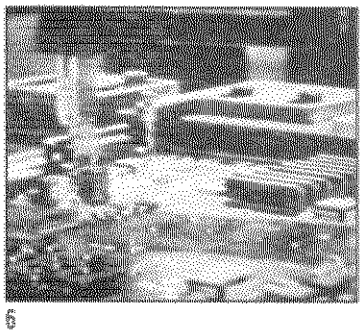
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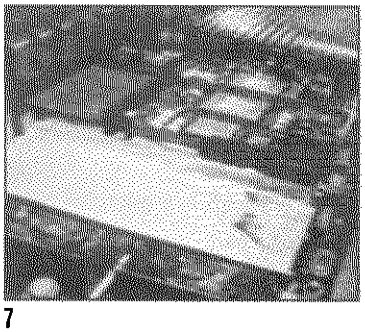
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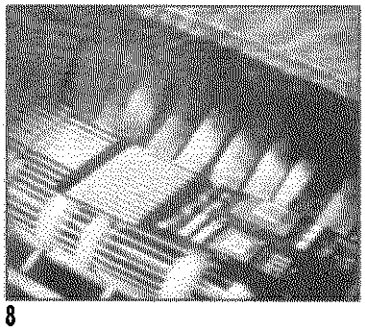
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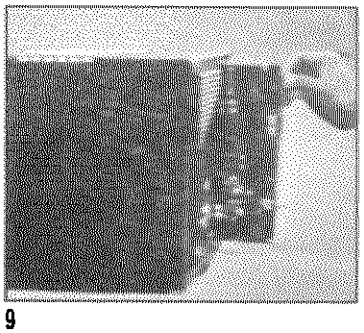
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Photos taken from "The Machine to Build Machines," a video by NeXT Computer, Inc., Redwood City, CA.

First generation 68030 products go down the same line as the new boards. It's simply a matter of reprogramming the robotics.

Vision scheduling

Boards flow down the 162-foot line using electronic (no cards) kanban. One board sits in front of each process; a new board is not started until one is taken off at the end of the line.

Seamless manufacturing

NeXT had the advantage of starting from scratch. It was not necessary to maintain and add islands of automation. They were able to develop an in-line system of linked automation. Board flow is directed by one of the three levels of CIM.

The most innovative applications of new manufacturing technology on the line are optical scheduling, electronic kanban, and programmed movement of boards. They are what allow this unique system to manage inventory and quality so well.

In fact, for one quarter, inventory adjustment on $4 million totalled only $2000. Inventory turns have hit ten times per year. Long leadtime items such as monitors, optical drives, and printers have lowered the sustained overall turns rate to between six and seven. As throughput increases in this start-up, inventory moves faster.

MIS

Many high tech manufacturers make computers, but do not use them well. Not so here. NeXT uses a custom system on Tandem hardware for MRP and Master Scheduling. MRP is used primarily for long-range planning, not for shop floor control or tracking, which are handled by automation and simple eye-balling of product flow.

The Master Schedule slots customer orders. Because all systems are built to order, accuracy of ship dates is critical to the success of the distribution strategy.

Gray is gray

The color coordination — gray, white and black — and Bauhaus simplicity of the plant reflects the founder's vision of thorough integration of all elements of the physical design — furnishings, color, lighting. The 40,000 square foot facility is laboratory-clean.

During the start-up, one supplier's machine arrived at the facility in glossy stippled texture, rather than flat gray, as specified. "Take it back and repaint it," was the order. This was the supplier's first encounter with concern for color integrity. His initial response, "You can't tell me that the company president cares what shades of gray his machines are!" soon faded. The machine was returned to the factory, sanded down, and repainted.

Mr. Heffner's role

Mr. Heffner's opportunity at NeXT has been to work from a clean slate, with the vision and support of Steve Jobs, to design and implement a well-integrated, spotless computer factory.

What did it take to set this up? Vision and money, although the cost of capitalization is described as "less than you think." Mr. Heffner had seen over 450 factories, and that fact combined with his 13 years of Hewlett-Packard experience, supported his passion to "do it right," from scratch. His capital requests were signed off fairly quickly, with little or no paperwork.

He believes that many companies have not been investing in manufacturing. In the mid-80s he spent much time in the Far East sourcing parts for Hewlett-Packard. At that time very few companies said they wanted to build products in the United States for world markets, competitive from cost and quality perspectives.

The decision to come to NeXT took five months to make. Finally, he was convinced that "They got it. They *got* why manufacturing is important."

He continues: "What happens here is that I want to do world-class manufacturing. I want to build high quality computer workstations at a lower cost than the freight plus a four percent import duty paid by the Japanese or Koreans or Taiwanese. If I can do that, if my total expenses — labor, rent, salary, overhead, depreciation,

scrap, are less than that number — we'll beat them in the marketplace."

The Other Guys

Sun, Apple, and Hewlett-Packard offer competitive products. In Mr. Heffner's opinion, "Apple is best in manufacturing. Yields at Sun are low, although they do little basic manufacturing. Most material is subbed out; sheet metal, packaging, and boards come in already assembled." He jokes that the cost of capitalization at NeXT is less than the value of Sun inventory out at sub-contractors.

NeXT has been accused of selling low-cost technologies, "You guys will go broke selling at that price." To that accusation Mr. Heffner responds: "People don't get it. I say, 'That's great, why don't you buy a few thousand and run us into the ground!'"

Quality, Flexibility, and Speed

Have a perfect day...

The Component Technology Group monitors suppliers' shipments with four different audits:

1. supplier qualification
2. sampling of incoming shipments
3. assembly and test
4. run-in, followed by statistical audit.

Quality control is built into the system to keep the process under control, rather than fixing problems after they occur. No units ship with more than three reworks on them; no blue wires (cuts and adds typically performed to revise a board design) ship either. Mr. Heffner feels that these policies, combined with the four audits and automation, allow NeXT to ship inherently more reliable products.

Surface mount solder joint yields on the 68030 boards are 4-6 parts per million. During some days, there have been 100 percent perfect yields on boards, each one containing 450 components; a perfect day, therefore, for some 100 boards, means approximately *45,000* perfect supplier components!

Measure and display

Production personnel track and evaluate their own processes. Results are posted on one wall, at the end of the production line.

"Time -To-Market Is Everything"

Flexibility and speed

To Kevin Canty, the Hewlett-Packard veteran who runs NeXT's materials organization, "Time-to-market is everything. Nothing else matters. You have to have the right product, the right sense of the market, be light on your feet, and be working with customers to anticipate and exceed their expectations, and turn product on a dime."

He illustrates the need for innovators to get there first:

QUESTION: "Who makes the highest quality turntable in the world?"

ANSWER: "Who cares?"

Since nobody uses turntables any more — it's all compact disc players now for high quality sound — who cares if your product offers the best technology ten years or six months too late?

The company needs to be flexible and fast. Production can prepare to run totally new boards in less than 30 minutes. Maximum steady-state capacity is 3-4,000 boards per month.

The Organization

No hands

Because the NeXT facility represents application of new technologies to the production functions — conveyerized movement of boards, automatic insertion, laser checkout of boards, vision systems — production assemblers number only four. The organization structure is extremely flat.

In the board assembly area there is one production supervisor, one in final assembly, and one production planning manager. Purchasing includes five buyers, two of whom are managers.

NeXT employs two material handlers, one master scheduler, and three logistics professionals to handle import/export, customs, and carrier scheduling.

Contrast this lean staffing level with memories of a computer start-up 15 years ago. To support $115

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million shipments, two production control planners, one expeditor, two stock clerks, supported by a network of component warehouses and various manager types, were required. Inventory turns slogged along at two. Each system took a minimum of three-four weeks for assembly and check out. At the end of each month, everyone got to drive a forktruck down to the shipping dock. At the end of each quarter we all retired to the VFW to get ready for the next push.

Mr. Heffner's approach to staffing is to cherry-pick the best people. Many are veterans of Hewlett-Packard, Apple, and Motorola. He looks for five qualities in an employee:

1. hard worker
2. street smarts
3. team player
4. technical competence
5. charisma.

All his hires must be familiar with high-volume manufacturing. They must be passionate about joining a pioneering organization, and they must be flexible and interested in what goes on beyond their area. He tries to find people with a core competence, and high growth potential who can learn quickly.

Compared to another organization's employees, NeXT's people might appear to be over-qualified. Mr. Heffner looks for very skilled professionals who are willing to roll up their sleeves, maybe step down a level from what they are currently doing, with the possibility of later reattaining that level. A NeXT purchasing buyer may have been in his previous position the purchasing manager.

Education

Most production technicians hold an associates degree, although it is not a prerequisite. The company offers new employee orientation, lots of on-the-job training, but few formal training programs.

Over 70 percent of the engineering teams and Mr. Heffner's direct report management team have advanced degrees, either masters or Ph.Ds. He jokes that he has told Steve Jobs ("He's a tough grader") that he has a master's degree too, but it's an MBA, so it doesn't count.

Benefits

There is no bonus plan, or profit sharing. Employees are granted stock options (the company is privately held). Performance reviews are conducted every six months.

Distribution Strategy

If we include distribution/transportation strategy in the flow of the entire enterprise, it is important to note that NeXT has chosen not to build a network of finished goods distribution centers. The production system is structured to support this strategy. The idea is to be quick and flexible, to build systems to order. Businessland, Value Added Reseller, and a direct sales force handle the marketing.

Very little inventory and no warehousing costs, therefore, accumulate in the factory. When a visitor walks through the factory, he *is* in the warehouse. On arrival we saw four boxed systems; one hour later they had shipped out, leaving only completed systems undergoing 24-hour test runs.

Design for Manufacturability (DFM), "The untouchable rabbit"

DFM at NeXT starts at the beginning of the initial design process. Production is integrated with the design process.

It's a two-way street. On fine-pitch parts, for example, the process development is completed in conjunction with R&D's product development. Mr. Heffner describes this joint development process and resulting investment in new manufacturing technologies as "the untouchable rabbit. There's no finish line. *It's only a race. It's a rabbit you can't catch."*

DFM means low part count and ease of assembly. Only seven screws are required in final assembly of the system.

The low-cost "pizza box" system uses a magnesium enclosure covered by cosmetic plastic that is easily finished and cost effective.

Design teams

All four new product designs were developed by inter-disciplinary teams from purchasing, materials, component technology and R&D, who met weekly to take steps out of the assem-

bly process, as well as jointly select suppliers. Each time a board is optimized, the process engineer reviews results with other members. Board designers come to the Fremont facility to see how manufacturable their designs are, to see margins for voltage, temperature and yield.

Next for NeXT?

Cut non-production time

Although NeXT's order processing time compares well to the competition, it is clear that since total production time is minimal, non-production functions now represent the areas of opportunity. To speed distribution time, NeXT is setting up relationships with outbound carriers.

• Not surprisingly, processing time at the front end is longer than manufacturing processing time. One of Mr. Canty's goals is to shorten the sales order cycle time from ten to four days, from the time a customer sends in an order, through credit check and technical edits, to the time the shipment is received.

Winning in small ways

Mr. Heffner summarizes NeXT's ongoing strategy: "We have to win in all of the small ways. We're not going to do it with major investments. We're going to do it with understanding what our process capabilities are, and by increasing those process capabilities. It's not rocket science, not something someone else could not do. We have to be innovative, and integrate continous improvement."

"It's not rocket science..."

Randy Heffner

P. E. Moody is Target *Editor*