# Visit to Ricoh Tokyo offices, August 29, 1991

**Background**

My hosts were Mr Ageishi, Director of the IMS Department, Dr Toriya, a CAD expert, Mr Yazawa, a lens designer, and Mr Watanabe of the Camera Product Planning Department.

Ricoh, like Nikon, is a diversified optically-oriented company with the great difference that it leans toward computing and communication applications such as copiers and fax machines, with only a small presence in the camera market. It has 34000 employees, of whom only about 13000 are in Japan, and sales of about $5.5B (at ¥132). Office automation, including integrated document preparation, is the main product line. Ricoh has 20% of the domestic fax market and 38% of copiers. However, my visit followed the theme of cameras, making comparisons with Nikon interesting. Copiers (see below) were the subject of a brief discussion.

Ricoh also makes laser printers and the laser engines that go into them. Ricoh also has a laser printer page description language software called Ricoh-Script.

A video showed off the many technologies that Ricoh supports, including R&D on neuro-chips (one chip with 256 small neuro-chips on it), voice recognition as a user interface (any person, limited vocabulary, one word at a time), digital signal processing chips sold to Nintendo for voice synthesis, magneto-optical storage disks, conductive polymers (described by a lady chemist), and so on. The video also hinted at some problems which my hosts confirmed: the company was a pioneer in offshore camera manufacture but has had difficulty finding qualified employees and parts suppliers overseas. Ten years ago Taiwan could not assemble complex cameras for them; now it can but only after lots of on-site training and education. Also, a "restructuring" program has been underway for about a year. They are trying to improve their design methodology by overlapping design tasks, improving communication between designers and production engineers, and increasing the use of assembly automation. But total reorganization is needed first, and the project is still young.

Ricoh has about 4000 engineers among its Japanese employees. The company worries about hiring new ones. Each of the last two years 300 were located, but next year looks difficult.

The visit had five parts: a general discussion of Concurrent Engineering and how copiers are designed and made, an explanation of their own solid modeling product, industrial design of camera exteriors, design of optical trains, and mechanical design of camera insides. The most interesting aspect was their first attempt to write software that will analyze tolerances in multi-element lenses.

## Concurrent Engineering and Copiers

Concurrent Engineering to them means intense communication between product designers and production engineers, including some overlapping of their tasks. Ricoh has done this for years without calling it that. The main method is meetings and design reviews. In view of this, the question arises: what is the restructuring mentioned in the video? Apparently the company is aiming to reduce development time by another 50% and cost by 30%, by 1993. Copiers will be attacked first. A joint team of 400 people is working this problem. The methods are cost analyses, planning of design processes, technology improvements, and more overlapping of product and production engineering. A major problem is that each division of the company has a different culture in its design methods, driven by the different production volumes and rates of product change in each. Only 15% of employees change division each year, so some differences have built up.

They (like many Japanese companies) wonder how to accomplish CE more efficiently. They think the phone and meetings are just fine and wonder how they could afford to give every engineer a PC. Communication is first, then technology. Moreover, they spoke of having to further reduce the conservatism of managers and interdepartmental restrictions. If these institutional barriers can be reduced, then new design technologies like feature-based design, CAD with product and process analyses, and rapid prototyping (like SOUP) will fit right in.

## Copier Design

A new copier takes from 1.5 to as much as 5 years to design, depending on the complexity of the new functions and copying technology being attempted. Apparently 2.5 years is typical. On big projects the spec keeps changing because the market changes rapidly at the high end. New toners and new scanning engines are designed in parallel. There are about 550 design engineers supported by about 55 production engineers. A new copier will occupy 30 designers, while a modification of an existing design may take 10.

These numbers are typical of those obtained from most Japanese companies I visited except car makers: design teams are small and manageable, ranging from 10 to 30 (vs 500 at car companies).

## Design-Base - Ricoh's Solid Modeler Product

Dr Toriya explained this product, which he apparently spearheaded. He works for the Software Division, whose director is another lady, Dr Kunii, whose PhD is in data base management from the University of Texas. She has pushed new data base management products and Dr Toriya hopes to combine them with Design-Base.

Design-Base is a UNIX-compatible system written in C that is similar in many respects to ACIS from the US company Spatial Technologies. Methods and marketing are similar: its architecture is open and its engine is available for licensing to companies that want to use it as part of their own CAD/CAM work. "ACIS is our main competitor in America." D-B is the only UNIX-based solid modeler available in Japan, which says something. It has all the usual features: rendering, boolean operations, free surface modeling using Gregory patches, sections, filleting, and so on.

It also has several novel and interesting user interfaces that permit very rapid construction of shapes from simple primitives. These were demonstrated on a Sony NEWS workstation, where performance was impressively fast. (As at every company visited, the CAD demonstrator was a very skillful lady.) A PC version exists called D-B Jr. The new UI was written in Motif, so it is easily ported to other machines. It includes ability to call forth standard primitive shapes and to detach surfaces from them and slide them easily along XYZ coordinate directions. Edges can be shifted around, and can be broken up and made into curves. Such operations are entirely artistic in the sense that no "surveying," coordinate values, or dimensions are involved. So, while it is easy, intuitive, and fast, it does not really support engineering. Dr Toriya agrees that feature-based design would not only help but might be easy to add to his existing methods.

Thirty researchers and engineers support development and enhancement of D-B, while 30 more support DBMS work.

Unfortunately, D-B is not widely used inside Ricoh. I was told that it is so recent that there would be difficulty dislodging the considerable investment in commercial CAD, which was purchased for its surface modeling ability before D-B was available. Also, a lot of camera-specific CAE has been added to the existing CAD and they claimed it would be too hard to convert it all. Now, however, Ricoh understands the importance of solid modeling technology, and D-B is expected to be used more and more.

**Industrial Design Center**

D-B was demonstrated here showing aesthetic design of a new copier and a children's educational toy. The final colors of the toy were chosen by a consultant who used color printouts from solid models made on D-B. However, most of the work is done with other commercial software whose name I did not catch.

Most of the discussion here centered on camera external design. This is the first step in making a new camera. Like car design, the first step is a series of hand color sketches, followed by several clay models. Shape is the issue, not size or weight. The final clay is digitized by a laser, a CAD drawing is made, and dimensions are added to create scale and main radii. For this last, a plastics engineer adds his comments, but no molding analysis software is ever used in the entire process. From this drawing a very realistic mockup is hand made and the designers and marketing people critique it.

In a recent case shown to me (RZ 800) the market was ladies, and a major change in the shape was made, eliminating a sharp edge in front and making the whole camera softer looking. The above process (sketch, clay, digitize...) is then repeated. Data from the second version is sent to the mechanical engineers so that they can begin trying to fit their parts inside. They had no access to the first round process.

The first round takes 3 months, the second 4 months.

**Optical System Design**

The optical system division designs both glass and plastic lenses. While plastic poses problems from thermal expansion, it is seeing increasing use in laser printers. These lenses are manufactured in a plant 500 km north of Tokyo. Lenses can have between 3 and 20 elements, the latter applying to complex zoom lenses. Design takes 3 to 6 months and each lens is designed by one person, of whom there are 30 in the department I visited.

Lens design is supported by both commercial ray tracing software (CODE V from Optical Research Assoc in Pasadena), which operates on DEC VAX workstations, and by Ricoh's own, which operates on an IBM 3090 mainframe in Yokohama. Ricoh makes most of the equipment it uses to make lenses. This includes polishers for glass lenses and molding equipment for plastic ones. The spot size of laser beams emerging from lenses is measured for quality control purposes using equipment Ricoh builds.

The process of designing a lens starts with a given specification in terms of cost, focal length, product application, and so on. The first step is to choose a lens type and number of elements. The main construction parameters, such as geometry, lens radii and separation, type of glass or refractive index, and so on, are chosen, often using those of a similar previous design as well as patent data. Ray tracing plus trial and error are used to modify these parameters until the spec is met. The expertise of the designer is the main ingredient.

A major issue is deciding what the tolerances should be. These include all the above parameters plus those of the housing, called the cell. The factory's capabilities are represented by a Monte Carlo analysis, and many studies are run. Particular attention is paid to the "sensitive parameters." These are identified by numerically developing a coefficient table, essentially an empirical array of partial derivatives. The effect of small changes in parameters on lens performance is judged by noting the change in aberrations and the MTF, a measure of image contrast.

Interestingly, the study varies only the parameters that engineers think about, such as radius of a surface, and does not consider that the ideal spherical surface might not be spherical at all. In fact, lens polishing can produce quite spherical surfaces, but this is not yet true of molding. Another surprising problem revealed at a later meeting is that the periphery of a lens cannot be held concentric with the optical axis to much better than 10 microns. In a stack of many lenses, non-aligned optical axes can seriously degrade overall performance. A more accurately made cell does not help this problem.

If performance degrades too much in the face of the stated tolerances, then they are tightened, although some attempt is made to avoid a "sensitive" design, that is, one whose performance is easily degraded if one variable varies even a little. At this point I asked if they use the Taguchi method, a technique often used to attain low-sensitivity designs. I was told that Dr Taguchi visits Ricoh regularly and gives seminars so that the engineers by now are familiar with his philosophy and follow it in principle. However, the main design approach is numerical optimization, using a damped least-squares method.

This optimization, however, is not used to seek a low-sensitivity design. Instead, it is used to find a set of parameters that best balances a variety of conflicting aberrations, some of which get worse when others get better.

**Camera Mechanical Design and Use of CAD**

Use of CAD is widespread at Ricoh. In 1990, 60% of 50000 mechanical parts were designed by CAD by 1000 engineers using 300 networked workstations or terminals. Electronics is even more advanced: the database has 35000 parts, and 400 engineers have access to 200 networked terminals.

Like Nikon's, Ricoh's cameras are made almost entirely from precision molded fiber-filled plastic. Typical part count is 300 to 400. I was shown the new Mirai Zoom 3, an autofocus, auto zoom, auto exposure, auto flash camera. It sells for $250 in the US. Every part was laid out on a series of foam-core boards around the room where we met. The largest of them is the condenser for the flash. There are four motors which are either somewhat or dramatically smaller than this condenser.

The Mirai took 2.5 years to design, 6 months more than planned. There were 30 full or part time designers on the project: 10 interior mechanical, 5 optical and factory lens people, 10 other factory designers and 5 assembly engineers. Considering that Nikon did not count factory people for me, the size of teams from the two companies is similar, as is the time required. But Nikon mostly designs much more complex SLR cameras. For example, Nikon uses focal plane shutters while Ricoh uses simple two-blade wing shutters in its compact cameras.

The design process has four parts, of which exterior design comes first. The others follow and are undertaken somewhat in parallel with the expected precedences: electronics, optics, and mechanical. The last is done with Intergraph systems. Electronics is supported by other CAD that does flex circuit layout but cannot support circuit simulation or analysis. Similarly, the mechanical CAD cannot support mechanism or structural analyses. Another computer is used occasionally for some FEM work.

The intergraph system supports 3D wireframe modeling as well as external free surface shapes. If parts interfere with the case, they stick out in the picture. Design often consists of the mechanical people fighting the exterior shell people for space. However, they admit that CAD cannot adequately predict these interferences. "We can't really tell until we have the parts in our hands."

As at Nikon, camera design is done in blocks. Each block is done in parallel by a separate team that tries later to fit its block to the next team's block. The defects in this method are apparently known to them and their "restructuring" process is aimed at reducing such problems.

External parts are defined by breaking up the surface given them by the industrial design group. This is just like car design, but the camera people are not used to it. There is no strong tradition for deciding where the boundaries between sections should be, and no FEM is used to see if a choice might be bad for strength or dimensional stability.

Ricoh Optical Company makes the molds and parts from NC data provided by the above process. Typical tolerances in critical areas are about +/- 0.05 mm or 50 microns (0.002"). The parts are made from 20% glass-filled polycarbonate.

Flex circuits are also designed on the Intergraph system. Ricoh is trying to locate integrated circuit design software. I mentioned Mentor Graphics and Harris Corp.

In all, Ricoh agrees that its current CAD is an electric pencil. The main advantage over real pencils is that changes can be made quickly.

No systematic DFA methods are in use. However, the factory critiques the designs and weights ease of assembly 60% of the total. I could not find out how this is done. Sony has a DFA method that they plan to try soon.

At present, all mechanical assembly is manual, mostly done overseas. Next spring they will install a line of 30 Sony robots to assemble a shutter mechanism. I think the possibilities here are large.

**Future Needs**

They want better ability to predict fabrication and assembly costs, plus ways to predict the effect of tolerances on lens performance. Thus they were very interested in our assembly analysis software. They also want better solid modelers that can check interferences for them fast. Such is essentially available now. They also want ways to set tolerances automatically. No such thing exists.

Mr Nishi showed me their early work on tolerance analysis. It has two components: identification of contact chains between parts, and identification of possible detailed contact conditions between various surfaces and edges on parts. The contact chain represents the nominal situation. The possible contacts can pose a combinatoric explosion. It is not clear if his method actually investigates them all or if he is just illustrating some of the possibilities. Lenses rest against each other and determine each others' positions, but his method does not analyze the friction in these contacts or the symmetries imposed by resting spherical surfaces on each other. Thus he may permit odd contacts in his analysis that are unlikely to occur in practice. It is OK to be conservative but there are cost penalties for doing so since one may prescribe tolerances that are unnecessarily tight.

Later Mr Ageishi told me that they recently built a machine to install lenses and check the optical alignment. The machine installs the first lens, then installs and adjusts the position of the second lens using an optical measuring system. When adjustment is finished, a UV-curing adhesive is injected, which cures in 15 seconds. This is, of course, the classic tradeoff against tightening tolerances. The cost may lie in the fact that 15 sec is barely short enough to support production.