

Visit to Nissan Technical Center, July 8, 1991

Background

Our hosts were Mr Jun-ichi Kobayashi (Product Development Section, planning Nissan's future CAD capabilities), Mr Yoshida (in CAE User support), Mr Katoh, (Mr Yoshida's boss) and Mr Ono (Production Engineering CAE). Mr Kobayashi was the most informative and interesting of these. He has been with Nissan since 1974, and spent 10 years in Manufacturing Engineering before coming to the NTC to work on CAD/CAM/CAE.

Background of Nissan and the Nissan Technical Center (NTC)

Nissan is Japan's second largest car company, behind Toyota, and 4th in the world. In the last several years there has been considerable progress upgrading CAE and an effort is underway to link styling, design, engineering, and test data into one system world wide. Mr Kobayashi acknowledges that this will be difficult for two main reasons: Software incompatibility and people incompatibility. So far they have linked design and engineering offices in Japan, USA, UK, and Spain, and can share data and software because (luckily, says Mr Kobayashi) all these offices had IBM or IBM compatible mainframes already when the integration effort began.

The Nissan Technical Center is in a beautiful location and comprises many modern buildings. "Amenities are becoming more and more important." The main design/engineering building, where we visited, is new since April and has an open, airy, atrium design. There are no offices, only wide open spaces with many large tables where meetings can be held. All the engineering disciplines for car design and prototype production are housed in this building except the engine people, who will move in next year. Thus, colocation has been adopted as a design efficiency strategy.

All of Nissan's car design in Japan is centered at the NTC or at the Central Laboratory in Yokosuka, where fundamental studies are carried out in materials, power trains, electronics, and vehicle technology (body, chassis, user interface). In the styling and design area (perhaps half of all vehicle design and engineering?) the engineers are working on several vehicle design projects at any one time. I estimate that 100 - 200 stylists and designers are at work on one car project (plus probably another 200 doing more detailed engineering). Unless I misunderstand badly, this is a remarkably small number of engineers for the number of cars they design. Uncounted in this total are manufacturing engineers at NTC and at the factories.

Product Development Process

I estimate that typical new car development process takes about 4 years. Styling and design occur during the first 1.5 years or so. "The rest is trial, error, and design changes." In the first prototype, new components are often tested by attaching them to existing cars. Later prototypes use completely new equipment. Die design in particular takes about one year, but changes keep coming in during the last year before production starts. During the first 1.5 years or so, or whenever prototypes are being built at NTC, the factory people make frequent visits to NTC. As prototype work shifts to the factories, the NTC people travel there. CAD data do not travel well to the factories (see below).

Design begins while styling is still in progress. This is typical of overlapped jobs in Nissan and other Japanese car companies. At some point during styling, the exterior shape is frozen and this Master Data package is then passed on to downstream activities. Interior styling continues to be worked on after the exterior is frozen.

Apparently all Japanese companies feel pressure to reduce the design cycle but there is no specific program at Nissan to do so. "We already design cars in 4 years, compared to 6 in the US and 8 in Europe. If we shortened any more, we would just get a lot of negative reactions from overseas. So we will use the ability to design faster in other ways." I was not told what ways, but obviously two are to reduce the time pressure on their engineers (who often stay until 9 or 10 pm) and to do more analyses on each design.

The main reason why Japanese car companies can design faster is the "fuzzy design method." This means being willing/able to start a design task before all the "required" information is in fact in hand. There is less structure in this method and, yes, changes must be made later. But no one gets blamed for these changes and in any case they come amid a stream of other changes anyway, so the important thing is to be able to respond quickly to changes. The CAD system contains no explicit change management system, according to Mr Kobayashi.

Note that this explanation agrees to the letter with that of Prof Fujimoto. (See Fujimoto visit report.) Even though Mr. Kobayashi is responsible for planning Nissan's future CAD needs, he refused to ascribe much importance to the use of CAD/CAM/CAE in speeding up the design process. In view of later examples (crash test simulations, search for assembly problems before the first prototype, etc.) this claim is disingenuous. But I did not try too hard to fight it.

[Via a separate communication, I obtained the following opinions from Prof Hiroshi Sakurai of Colorado State University, a graduate of Tokyo University

and former employee of Nissan: The main reasons why Nissan can design a car in 4 years are 1) average 2700 working hours per year for engineers vs 1800 per year in the US (Toyota people work even longer); 2) overlapping of jobs: for example, Nissan's body engineering begins when only rough exterior data are available whereas US designers wait for smoothed data even though the difference is often less than one mm (Prof Fujimoto cited precisely the same example!); 3) outsourcing of many components to small companies who work their engineers even harder and pay them even less. He notes that even in 1980 Nissan could take a car from exterior freeze to volume production in 2 years even though they had only a few CAD terminals. But he admits that CAD/CAM/CAE may have kept the lead time from becoming even longer and the number of engineers from growing. I note that cars are very much more complex now than in 1980.]

It is worth noting, when considering (see below) that Nissan has distributed its design software worldwide to its overseas design offices, that exporting the fuzzy design method has been a failure so far. Real problems thus remain.

Product Development Methods and Use of Computers

Nissan's CAD/CAM/CAE consists of many computers, programs and databases. Nissan is in the midst of trying to merge all these into one seamless process but it is a hard job. What they have is like "islands of automation" in the factory world.

Nissan is in the process of converting from styling using clay models to direct styling on the computer. In the old clay model method, stylists carve quarter and full scale models and paint them to look quite real. These models are digitized and computer data created. In the new method, stylists draw shaded sketches which "technicians" (high school graduates) put into the styling computer to create boundary patch models whose shape resembles that indicated by the shading in the sketches. These models can be shaded and rendered very realistically, including showing light reflecting off the surface. The stylists sit with the technicians and adjust the shapes of the surfaces. Apparently the technicians make a very strong contribution to this process and are not mere data input drones. They must have both artistic and computer skills as well as the ability to make the stylists confident and comfortable in the presence of the computer. At some point in this process, the model is used to drive a large gantry NC machine which carves out a clay model which is then painted and judged as in the old method.

When the stylists are satisfied, the data become the Master Data for the car's exterior and are never changed thereafter.

Interior styling is apparently done in a similar way.

The boundary model data are passed, perhaps with some pain, to the design and engineering computer system. This system is separate and builds a new database starting from the master exterior data. Most of the work is done in 3D wireframe form using Nissan's proprietary CADII system (see history below). This system is good for the designers, who can put in as much detail as they want without swamping the data storage and manipulation capabilities of the software. No solid modeler can hold the detail and manipulate the data efficiently, they say. However, the wireframe models are useless when communicating with the factory people or the tooling designers. So there are problems.

The master data or the design version of them are also passed to super computers for various analyses (see lab tour below). Converting data for use by these programs takes a long time, another problem that adds time, effort, or number of people required.

CADII data are also used by industrial engineers for doing manufacturability and assemblability analyses. The assembly path of a part (we saw a windshield washer tank) can be visualized as the engineer moves a view of it around the screen using knobs. He can see interferences, view from several angles, try different paths, and so on. There is no analytical support for this. He can also attach images of tools to the heads of screws or nuts to evaluate access for tools. These issues are of the most importance in designing the engine compartment, which is the most crowded area. The success of this process depends entirely on the experience of the engineer.

While there is no analytical support for assembly analysis, there are criteria. For example, a torque wrench must have 60 deg swing room. Less requires redesign or an OK from the factory. Nissan tried using Hitachi's AEM but concluded that it is intended for small parts assembly of large production rate items for consumers. Neither Nissan nor Hitachi can do real design-performance-manufacturability tradeoffs, they say. Cost should be the criterion but no one has a method.

(Ten years ago, engine compartment design problems were found by making Xerox copies of drawings of parts and sliding them around on a table, or by making transparencies of parts and doing the same.)

In this way, hundreds of assembly problems are found before any metal is cut, comprising the majority of all such problems. There isn't enough detail in the CAD models to permit the rest to be found. Many of these involve flexible items like pipes and wires. It is typical that thousands of design changes to improve assemblability will be made after prototypes are built.

There is some indication that Nissan is beginning to adopt modular assembly, similar to what shipbuilders did 20 years ago. Examples given were entire

dashboards built up in advance and then inserted into the car with a robot. This is in fact not new, since 1) you can't install efficiently things in a dashboard once it is in the car and 2) GM and VW have used robots to put in dashboards for several years. However, the module approach has a bright future, although it may require some redesign of the vehicle's structure. Sticking one part after another into the engine compartment is getting harder and harder to do. However, more success at getting around this problem with modules will mean that maintenance and repair will become harder and harder! The modules are likely to be big and heavy and require special tools and hoists to remove later.

In any event, if Nissan continues along this track, it has the CAD tools in hand to do the necessary studies in advance of building prototypes, an essential ingredient. However, the long term effort may not be directed at effecting robot assembly. Data in a handout shows that Nissan ramped up from 540 robots in 1980 to 2000 in 1985 but has only 2462 in 1990, indicating real saturation at this level. "In 1980 we thought robots would replace people. We know now that it won't be that easy. Yet the goal is still 100% automatic final assembly."

Stamping dies and plastic injection molds for body and interior parts can be designed in about a year. All the important exterior dies are made inhouse. They are just beginning to use new nonlinear deformation software recently developed at the machine tool division. Up to now many problems had to be solved during die tryout. "Dedicated technicians are a big Japanese advantage," said Mr Kobayashi. Stamping plant people visit NTC often during early styling design because (see above) the master data are frozen early. While some of this visiting may be done by passing CAD files around the network, most of it is done face to face.

A big problem, other than die design errors, is die design changes forced by other design changes. These cause a stream of changes throughout the final year before launch. Thus the environment of change Mr Kobayashi referred to above, that makes the use of overlapped jobs less of a strain than might be supposed.

The use of CAD data to find problems and do designs prior to making any prototypes obviously saves time and money. However, it appears that this process is most successful during the three prototypes that NTC builds. When the plants start getting involved in prototypes, the use of CAD data wanes because 1) the prototypes are much more compelling, 2) they are easier for people who did not do the original design to see and understand, and 3) those CAD tools and data are NTC's, not the factory's. This is a typical problem of "ownership!" The only data easily shared by all are the exterior shell descriptions.

Tour of CAE Facility

CAE facilities are used to do exterior styling and many complex analyses, plus actual design engineering. The facilities comprise two Cray supercomputers, two IBM 3090's, two Unisys 2200's plus several more large mainframes for supporting 3D CAD drawings, solid modeling for casting and forging design, and routine data management. The Yokosuka engine design facility has its own Unisys 2200 for designing castings and forgings using solid models. The IBMs and Unisys' support 1400 graphics terminals. Many of these terminals use SDRC's I-DEAS package. The mainframes also support I-DEAS in IBM's form (CAEDS) but all agree that performance is poor and workstation implementations are better. In addition, there are over 3000 PC's of various types, including 1000 Macs. The penetration ratio for PC's is about 0.5 (one PC for two engineers). The computers at NTC are networked worldwide with similar computers in the UK, US, Spain, and Australia. The same software is supported at all sites.

Several demonstrations of CAE were given:

- Very realistic rendering of car exterior shape, including reflection of light off the body. This is a surfaced wireframe model. It becomes the master for all later design.
- Stereo display of the car's interior, showing dashboard, seats, and shift handle. This was not too detailed. Using special glasses, one could get a pretty good stereo impression.
- Complex multicolor 3D wireframe rendition of the engine compartment. This picture occupies about 20 - 30 megabytes. They anticipate needing 40 or more MB. Mr Yoshida claimed that commercial CAD packages cannot manipulate this much data. I argued this point with Mr Kobayashi later, giving examples from shipbuilding that I was familiar with. But he countered that they discuss this problem with SDRC, who is a joint venture partner with them, and SDRC agrees.
- View out the front of the car from the driver's viewpoint. This view was not constructed from the master data file, but from elsewhere, maybe from scratch. In the future all these programs will be linked with common data.
- Crash test simulation. This was a replay of Cray output. The software for this is called PAMCRASH, purchased in France and modified by Nissan.
- Aerodynamics simulation. This is also Cray data being replayed. They can analyze wind drag but not noise. This was a surprise to me. I have seen a paper presented that described Nissan efforts to calculate noise generated

between the engine compartment and the ground. This sim shown to us on this visit explicitly represented airflow under the car, however.

- Plastic flow simulation in an injection mold. This is a typical commercial software capability.

I asked if noise from engines and transmissions can be analyzed by computer and was told Yes.

Other CAE applications include a few attempts to use expert systems to help designers with routine but troublesome problems, or to help junior engineers design things that only senior engineers could before. One case is design of trunk, brake, and axle systems.

Another non-artificial intelligence application is use of 3D modeling to study how to package parts in pallets and shipping containers, and to see how to use last years' jigs and fixtures for this years' parts.

Considerable effort has been made to export this design software system to Nissan's suppliers. Nissan and IBM have a joint venture that supports the software and sells it. A low cost workstation version is also for sale to small suppliers. At many suppliers there are now hundreds of terminals running CADII on both host type computers and engineering workstations. Mr Kobayashi said that Toyota and Unisys have a similar joint venture for selling Toyota's CAD to its suppliers. Problems arise trying to sell to a large supplier like Hitachi, which has its own CAD software and hardware, and to overseas suppliers who have different data standards. US suppliers have a data format standard, for example, that forced Mr Yoshida to write a data translator.

History and Goals of Nissan's CAD Efforts

CAD tool development and user support, including support of business data systems, is provided by 220 people in the R&D Systems Department. In 1985 it had only 70 people.

CAD at Nissan has three main goals and several historical threads:

1. Data processing, especially test data
2. Design specification control and parts data trees
3. Efficiency of engineering
4. Higher quality
5. Simultaneous engineering
6. Better communication

Historically these have been pursued in the above order, starting in 1960 with data processing and 1965 for specs and parts trees. CADI, Nissan's first 3D CAD system, was installed in 1965 and used for making line drawings of body panels. It was extended into CADII, a surface modeler, by 1974 and used from that time to generate NC data for die making. While CADII was originally just used as a drawing tool, it has now become a CAD/CAM tool with many applications described above.

By 1980 parts data trees, die designs, and test data were starting to be merged into one computer system. By 1985, three programs had emerged, one for test data, one for parts lists, and one for CAD data. There is still no common database for all of this, but that is their goal for the 1990's. In common with this is the push into concurrent engineering, which to them means doing more jobs simultaneously, including manufacturability analyses during early design, before any prototypes are built. Another goal is "production CAE," meaning computer engineering aids for production engineers.

The final goal is to put this common database and set of programs out on the network for all their world-wide offices to use. This was begun in the late 80's and continues today. They say that when production CAE can proceed in parallel with car design, they will have achieved Simultaneous Engineering.

The main improvements they seek are global information sharing (design release and CAD data), global engineering system sharing (software, not just data), and global business information sharing (now done by fax). They apparently have had some trouble justifying some of this effort because they were at pains to contrast their work with typical business computer applications. First, CAD data volumes are 100 times larger. Second, there are many applications and engineers don't read manuals, so good user interfaces are needed. Third, technology and software are always evolving and constant renewal is needed. These descriptions do not apply to business applications.

Future CAD/CAE Needs

When I asked about this, there was laughter. Their answers were a strange mix of the mundane and the far out.

They want everyone to be linked on one network so they can easily send data to each other. This is merely a matter of buying it. However, they want any new program they buy to be instantly compatible in operating system and data format. This is not so easy. In general, Mr Ono of Production Engineering would like tools that provide end-to-end analysis of production problems and design/cost estimates of production and assembly steps. This requires a long term effort at unifying software and databases, plus integrating engineering analysis and test data.

Another desire is to "standardize" design processes. This was a bit hard to interpret. Apparently they mean that they need a way to overcome the working style differences mentioned above. A suggestion is to make design tasks more orderly or procedural so everyone will know what to do and know what the other person is doing. It also means studying each design task, such as locating the washer tank in the engine compartment, and deciding in advance what the main issues and tradeoffs are so that they can be addressed systematically and in the same style each time the problem is faced, regardless of who is doing it and what country it is being done in. (At Hewlett-Packard they call this ensuring that the result is "a Hewlett-Packard product" adhering to the company's standards and capable of being made in any of its plants.)

Mr Katoh emphasized that you can't predict much in the car industry, in spite of the many years and many models under their belts. So much depends on experience and they mine this lode by keeping teams small and lines of communication open. Yet this practice cannot be continued forever, he says. Ways must be found to leverage this experience. Expert systems are not the answer. They are too limited in the kind of input they permit and the forms of knowledge they can store. What is needed is some easy way to put knowledge in and an easy way to get it out.

For example, existing design for assembly methods require too much information and too much detail about the parts before an analysis can begin. How can it be done at the concept phase when only the performance goals are available??

How indeed?

Summary

Nissan is an important example in any study of use of computers in engineering design because, like other large Japanese companies, Nissan does not depend totally on the software vendor community to provide it with software that the community thinks is useful. Instead Nissan has great control over the "technology transfer process" that creates CAD software. Thus its priorities are worth noting in detail.

1. Continue the process of maturing the use of computers. This began as mere data processing in 1960 and has now become CAE. It is in the process of becoming CIE (Computer Integrated Engineering) which means wide area sharing of software and design/test/manufacturing data files. In the next decade it will become CIM (Computer Integrated Manufacturing) meaning direct links between marketing, design, manufacturing, and sales around the world.

2. Increase the ability to capture the experience of people who are currently not well supported by computers so that this expertise can be used by less experienced engineers. Much study of the design process is needed to identify efficient ways of performing many of the tasks, identifying tradeoffs early, getting quantitative models of them, and getting answers when there are still merely preliminary designs available.

3. Increase computer support for manufacturing and industrial engineering activities in order to optimize manufacturing operations and avoid discovering design mistakes after prototypes are built.

4. Find a way, if possible, to use computers to help spread the Japanese method of design to designers in other countries. The "fuzzy" method of job overlapping has resisted exportation so far.