7 Structural Systems Wendel R. Wendel

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I'm going to talk about what we've been doing at Space Structures in the hardware area as well as the software area.

By hardware I mean the physical nuts and bolts, and by software I mean the computer-aided techniques that we build at Space Structures.

Secondarily, I want to talk about the development of a new organizational position of Space Structures in the industry as a systems specialist. I want to cover eight concepts.

One is the standardization of design/fabrication process. We want to get away from the idea that you're going to standardize a component and you're going to mass produce those widgets and send them out the door, and that's going to save building technology. That's a mistaken idea. It will always be wrong, It will never apply. The idea is that you standardize the *process* of how something's built.

Secondly, I want to talk about new forms and shapes. We basically have a box mentality. All of the buildings we are sitting in right now are box shape. There are a lot of other forms and shapes which may be much more appropriate in many different applications. We really are just beginning to touch upon those possibilities.

Third, 1 want to talk about the use of lightweight building materials. Our specialty is working with aluminum, working with membrane materials, working in plastics and glass, Light weight materials open up the marketplace. Space Structures is based in New York but we have offices throughout the world. We're not just a New York firm or a regional firm, but a world firm.

1 want to talk about the three Rs of buildings. I've almost never or rarely talked about this, but we have a bunch of people out there designing buildings which are basically monuments. We really should start looking about the three basic Rs, which means relocatability, readaptability, recyclability of the building.

The fifth one we want to talk about is the restructuring of the labor which goes into building with new building technology. In our own experience, we find 90 percent of the work done is in the shop, only ten percent in the field. We never build anything in the field. We only assemble it in the field. We fabricate in our plants.

I also want to talk about the new market out there which extends the building technology. I know we are having our guest here from NASA talking about NASA technology coming back to the building industry. I actually think we can get more than the technology from NASA, and I want to talk about what our programs have been in those areas. The marketplace is not just terrestrial. You've got to think on a global, galactic scale. Eventually, we want to change the name of the corporation from Space Structures International Corporation. Our plans are once we get something in space, we want to change it to Space Structures intergalactic Corporation.

We also want to talk about quality, quality in the sense that buildings should be structural art. We somehow get the idea that we're finding cheaper and cheaper ways to put up buildings, and that's really what the needs are. But that is not the real cost of buildings. We could really build most buildings as pup tents, and basically protect ourselves from the environment, from the rain, the weather conditions and things like that. A lot of the cost of buildings is it's social status indicator, the costs which go into a building, and if we're doing that, we should at least spend the money in the planning to create better looking buildings.

Most buildings I find are really trashy, industrial designs. I think there's a lot more which can be done, especially if we use technology in those areas, and I think we can be much more creative.

And the last item is the development of the new teams. As a systems specialist in the industry, I see the industry greatly changing. I've found in my thirteen years in building my company we've seen a change in that amount of time. We'll talk at the end about where those changes come about and how the new teams are being put together.

As I said, Space Structures' philosophy is 'where visions take shape,' and we're going to talk about space networks, new forms, new shapes and new systems, and we'll talk about the second generation of space frames. In the products that we do, we do space frames which we call Octa Hubs and Orba Hubs, two different systems, and the new designs tool is called SSCAD, Space Structures Computer Aided Design.

Back in 1980, I invented two new space frame systems. The red one in my hand (see Figure 1) is called Octa Hub. The one in my left hand, the golden, brass colored one is called the Orba Hub system. They were invented about six weeks apart from each other. Both are patented systems, and basically it's the result of about ten years of work in doing different types of structures, mainly specializing in domes.

We decided to get into the space frame area after I had sold two contracts, one for a big atrium and skylight on the Hyatt Hotel in Crystal City, Va. and one for three sports enclosures for Aramco.

Figures 2 and 3 show the Octa Hub system, which 1 invented in 1980. Our basic material is aluminum here. It's an extrusion bolted together with square tubing where the tubing can take various wall thicknesses. We're using pins rather than bolts to put it together to reduce down the amount of on-site installation time. With an Octa Hub system, we typically might be doing a million dollar job and charging only $50,000 for the installation.

Figures 4 and 5 show details of the Orba Hub system. It is a solid aluminum ball. Tapered ends, struts, and multiple types of finishes can be put on the system.

A space frame can be a very simple structure. Figure 6 shows a flat structure that most people expect when they think of space frames. Here in the United States we expect space frames to be little atriums or canopies. But space frames can take many forms. Figure 7 shows the Federal Express Pavilian at the

Figure 1

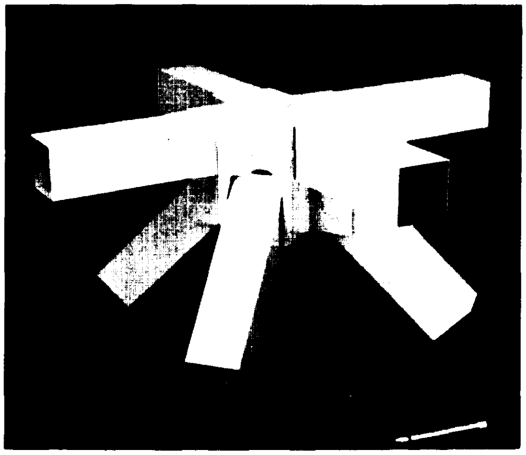


Figure 2

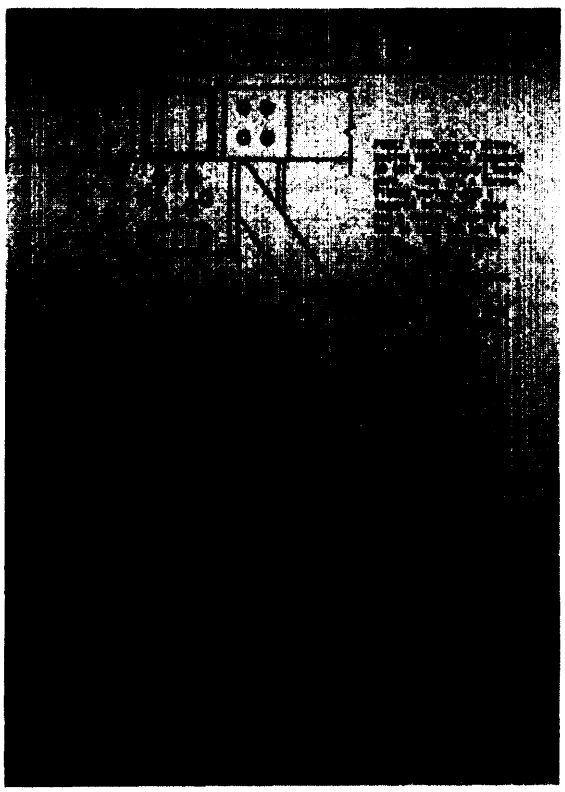


Figure 3

World's Fair down in Knoxville I did for Federal Express back in 1982. It's a multiplate type of design. The whole building is a space frame, as is the laser tower.

I now want to talk about SSCAD, which is one of the main tools and the assets of space structures. We started writing our own program back in 1973. At that time we were buying computer time from Boeing and McDonnell Douglas. About three and a half years ago, we bought our first computer, and we started further development of SSCAD to give us a total knowledge system.

One of the things we've seen in some of the talks yesterday about design, we've almost talked about computer systems basically replacing the pencil. Well, at Space Structures, the computer systems replaced the pencils and eventually we go up and we'll take everybody's pencil away from them. We're going to gold plate it, put it up on the wall and say, "The last day a pencil was ever used at Space Structures." We want to eventually get there.

But what we want to say is also the computer systems can extend the design process. The idea of computers replacing what's being drafted right now is fine, but that's not the real impact. The real impact is when we change the design process, change the possibilities, change the potential.

SSCAD is a computer system designed in about ten main sections. Each amount of the pie on Figure 8 indicates about its magnitude. We use the system from the proposal stages through design, through loading, which means loading up the structure for analysis, and we run our analysis, our finite element anaylsis, on it. We use it for post-analysis processing. We generate all drawings from it. It's used in planning out the fabrication, material management. It's used to plan out the installation of the rigging, which is used to lift the structure, and it's used to store historical data.

We found that while virtually all the computer hardware we wanted was available, software was basically not applicable. We spent almost three times that amount in our own inhouse software development over the years as we have on hardware. You have to plan on those types of expenditures if the system is really going to work. You have to look at having an integrated system which can grow with the corporation.

Our basic system uses a Hewlett Packard 9000 series 32 bit processor, and we have a shared resource management system. This is the fastest equipment available right now, and it's probably the right direction rather than our main frame direction. We look at going both directions. The shared resource management appreach gives us capability of having almost unlimited units connecting the others, sharing the resources through a mainline data-storage area, and we can hook up to our system. Right now we're running five separate units on it, plus one up in Cambridge. We can run 140 or 150 units with no problems.

SSCAD is menu-drive type program. Figures 9 and 10 show two sections of menu-driven system. We can teach people how to use the system in one day. We often have architects and engineers coming for one-day sessions at Space Structures to design their projects. Within an hour's time they can be using the system. It is truly user friendly. In most of the computer systems you're keypunching in numerical information. You really want to be putting in graphical information. You want much more sophisticated programs. That is where we have spent our money.

Figure 9 shows how the menu basically has soft keys on it. You hit, let's say, number one, preprocessing menu. You bring it up (Figure 10), and you say you want to generate a space frame geometry. So you hit another one again, and you can get it to generate all different types of forms and shapes. In space frames, you can do horizontal, vertical, sloped, towers, trusses, multi-layers, pyramids, multiple plates, steps, conical domes, cylindrical, anything the mind can imagine. The idea of a space frame as being a little horizontal form is very much limited in network thinking. Network thinking gives you the capability of looking at a lot more different forms, and you get efficiency out of form.

Figure 11 shows a design for a hanger for a 747, a large, curved form. For this aircraft, you need 196 feet clear span going into it, and the SSCAD system shows the types of forms you

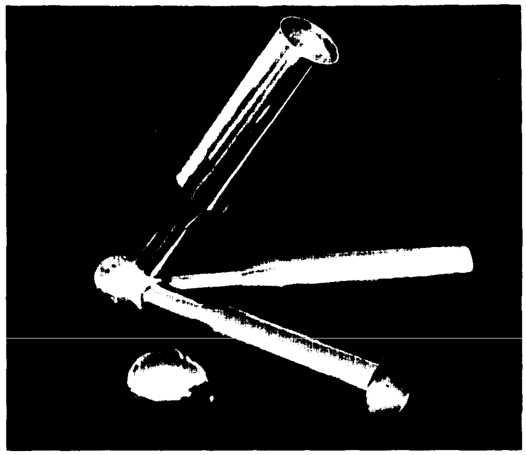


Figure 4

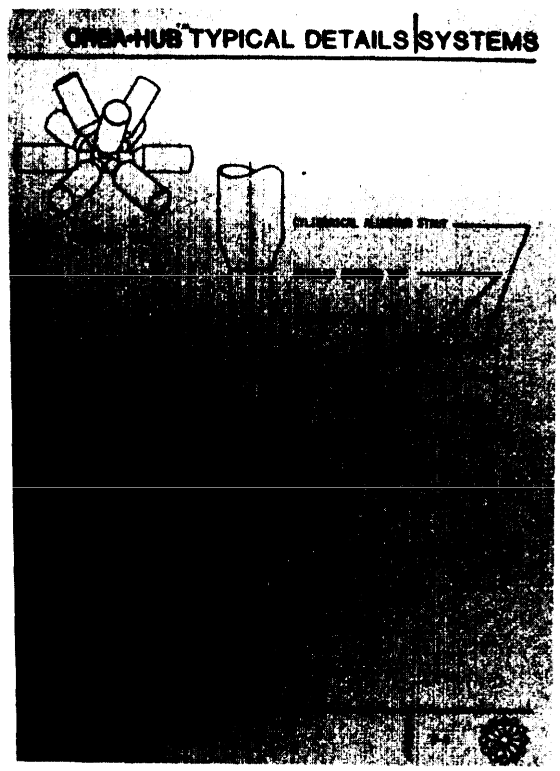


Figure 5

can generate. This form was generated in less than two or three minutes on the computer. You basically define the outlines of the structure. You can generate the form. You can manipulate and transform it.

Using color coding, we can color the outer members, the diagonal members, the inner members. The program enables the user to look at a drawing and modify it, and make design decisions and look at the options.

We find often when architects come to our operations and spend a day with us designing in their particular project; we can review 20 or 30 design concepts. In contrast, in the design profession, you say 50 percent of the time is spent pushing a pencil. The result is that often the first design on the paper typically is the last design on the paper. It doesn't give you much flexibility.

We went into network design because with the complexity and the sophistication of buildings, you want the capability of many different forms and shapes.

Figure 12 shows a ridge type of form, a Stroh's Beer project we're building for a retrofit project in Detroit. The geometry here was generated in less than one minute, the SSCAD system is all graphically oriented.

Figure 13 is a bottom view looking from the fifth floor below. The architect wants to say, "What am I looking at up inside the building?" So we said we'll move you in space down, and look up inside the building itself.

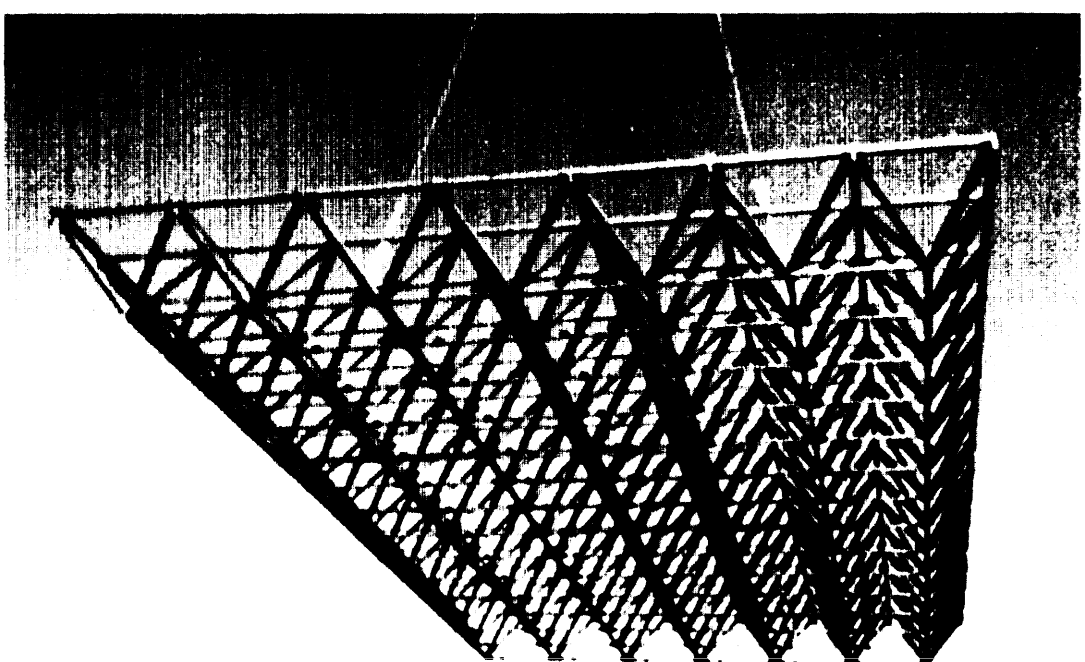
Figure 14 is a multiple folded type plate form, joins two buildings together, built over in Somerset, New Jersey. Again, some new forms which can be appropriate for the particular application.

In network design, you can create almost anything your mind can imagine. Basically you can take your visions and you can put them into reality.

A multi-folded plate for an entranceway for a corporate headquarters, an exciting type of forms. The folded plate is one type of space frame form which has a lot of advantages.

You can also marry structures together. Figure 15 shows a cylindrical form with a dome on top. This is a structure we did for the U.S. Steel Corporation for an aquatic application for

Figure 6



a tanker top which we did about six years ago.

I want to show you what the computers can do besides generating just the graphics and the design space. That's only about ten percent of the potential use of the computer systems in the whole design and fabrication process.

This is a drawing which is color coded basically showing a structure. I'll take a new GSA building built in Boston. It has a big atrium, 90 feet by 120 feet. With computers you can basically see how the structure performs. We can simulate the deflection that might result from a snow load and model it very quickly, Figure 16 shows just the top members. You can see how the geometry shows the plate action. You can see the deflection of the structure towards the center, and this way you can check it graphically. You can exchange so much more information, how a structure behaves, how it works, using the computer system.

Different load magnitudes are shown by color coding using the eight different colors on the screen. You can show where the highest compression loads are, what the highest tension loads are. Computers can give you a feeling for the network and new design freedom which you couldn't have by doing it by hand no matter what happens. So the technological development of the computer systems have allowed the development of network systems.

The system also drives plotters which we use to produce assembly drawings of the structure. Everything's numbered, the different hub types, all of the different strut types. The members are numbered so you can ship it out in the field. It takes about six minutes to draw it like this, where by hand it would have taken us eight hours three or four years ago. This gives us gigantic productivity gains and hundred-, sometimes thousand-fold reduction in time and expenditures needed to design the structures.

The programs take the geometry and the loads and convert them into actual fabrication drawings. Then we run computer-controlled equipment like our Wasino equipment, Japanese machines which are computerized controlled. Basically, we convert our design output into paper tape forms or magnetic-tape forms for production instructions.

We've been able to reduce all of the hand op-

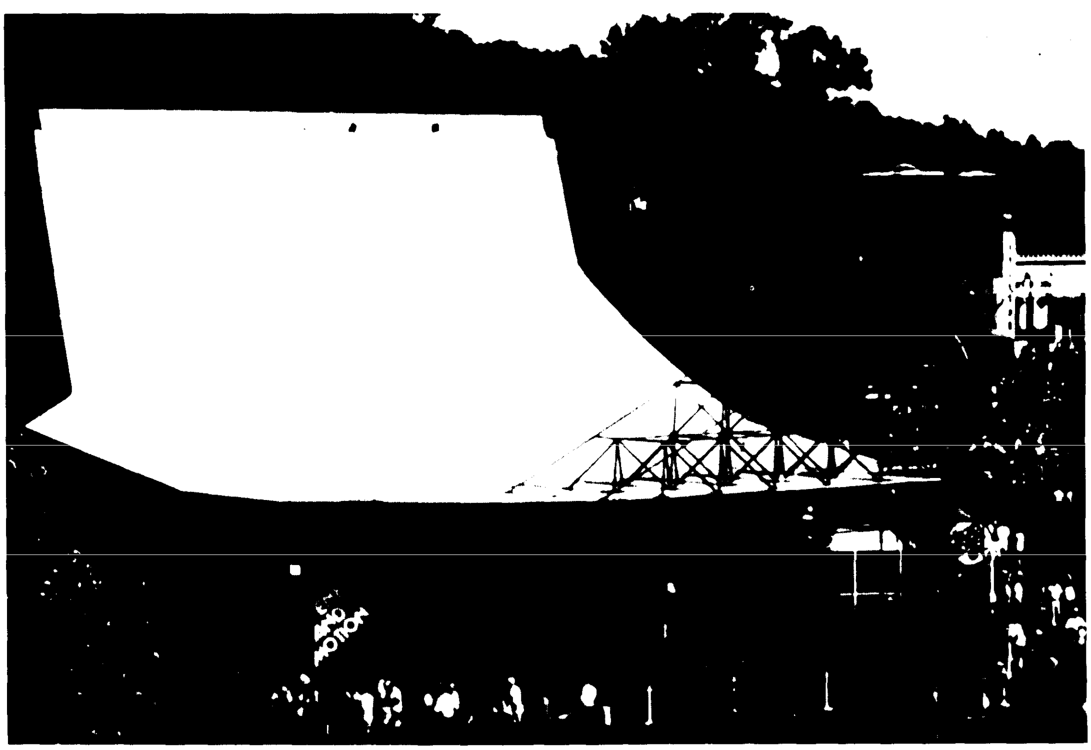
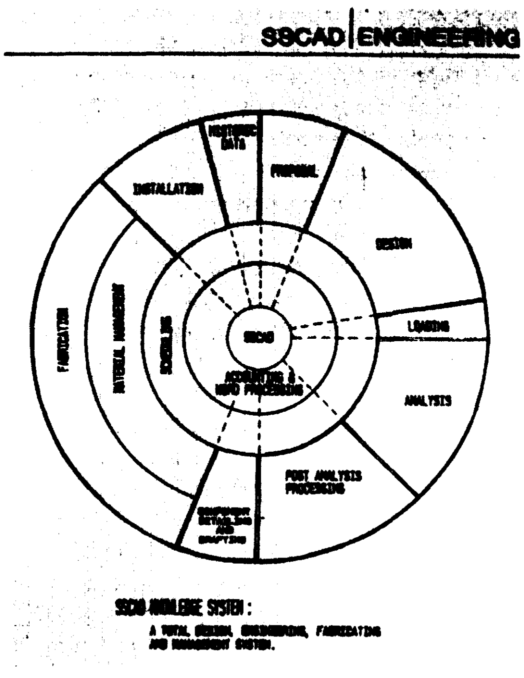


Figure 7

Figure 8



erations used to machine something. You create a new design freedom. You create new types of quality control because it's computer run and computer generated. There are fewer errors occurring, and the system gives you the capability of variation very easily because we've standardized the process. The standard thing in Space Structures is how we design, how we exchange that information, not the final end product. That means the network created can be very variable to meet the particular project's form and requirements.

What we can do with the system is easily generate a drawing like Figure 16, a bank structure with the whole space frame as the whole network.

Figure 17 shows the actual structure under construction. In this case, it's built on the ground, off to one side of where the actual foundation is, and assembled. It's an 80-by-80 foot space frame over in New Jersey. It's a bank building, and you just lift the structure up, being relatively light weight, working in aluminum. You lift the structure up, put it in place, and it basically starts to give you more and more of the structural form assembled as a network.

Figure 18 shows a conical form, using the ORBA Hub system, which certainly would not have been possible without our system. Every hub and each different row is different in the geometry and its orientation. Computer-controlled machines can generate those easily.

Figure 19 shows structure assembly for a project we did for Skidmore, Owings & Merrill in Chicago. We assemble it in three sections, lift it up, put it in place, the main entranceway for this office building, and here's what it looks like from the inside. Again, the cone form gave SOM a new shape, a new form they could easily use. Somebody could easily fabricate it.

Figure 20 is a look up through the structure itself. Figure 21 shows a barrel arch form, which has certainly become very much more popular during the last two or three years. People are learning the value of the old idea of the arch which was a great shape back in Roman and in medieval architectural times. Somehow it became out of phase because the new materials didn't allow it to be built very easily. With more sophisticated building technology, you can easily go back to the value and the benefits of using the arch type of shape.

Figure 22 shows some of the hanger projects we're building throughout the world. We're finishing one at Miami International Airport, a 226-foot clear span. Figure 23 shows how the structure is assembled. We assembled it in three sections on the ground, or multiple sections, depending upon its length and the design requirements. The structure is built out of aluminum.

Figure 24 shows a step form at 1300 New York Avenue in Washington, D. C., we are doing for Skidmore, Owings & Merrill. Figure 25 is a look up through the structure itself.

Different networks can have different forms and shapes. Figure 26 shows one being built in Culver City out in California right now.

Dome structures are also possible. Figure 27 shows a dome stadium, designed for Toronto, capable of opening and closing. We're talking about worldwide the building industry not being locally oriented. If you get into new technology, it opens up the marketplace. Probably about ten percent of our work is done overseas.

Tomorrow we see our movement where we're going to answer the phone at Space Structures within three or four years. Somebody is going to call up and say, "I want to build a space frame." The question will be back, "Is it terrestrial, aquatic or space application?"

We have a new division at Space Structures called Starnet Structures which is going after the Space Program. It is the 'Job Site in the Sky Program.'

Figure 28 is a part of a Space City that we have developed. We have our applications in to two NASA contracts right now. We've been talking to Grumman, Lockheed and Spar on possible joint ventures going up to the Manned Space Station Program.

The drawings are conceptual, what we call cartoon drawings in the aerospace business — what something could potentially be like. But you have to think, if you're in the building industry, on a galactic scale or else you're going to limit yourself, and the Japanese are going to come in tomorrow.

Well, lets start thinking, you know, twenty

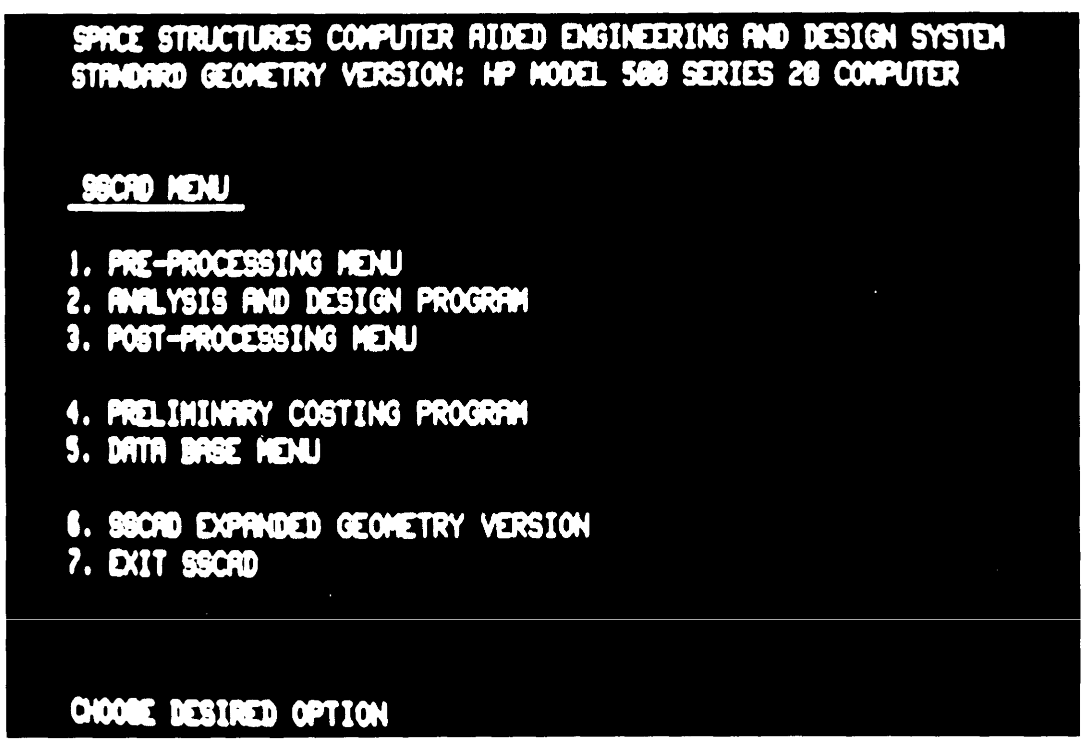


Figure 9

years ahead of them and start moving in those directions.

We should quickly talk about how structures should have some structural art form to them. We're creating structures; we're creating environments. They have to have a value to them other than just enclosing and being a climatic envelope. They should have a good design to them, and the structures are more and more with network design being able to be expressed as structural forms, and I think it has a great value like that.

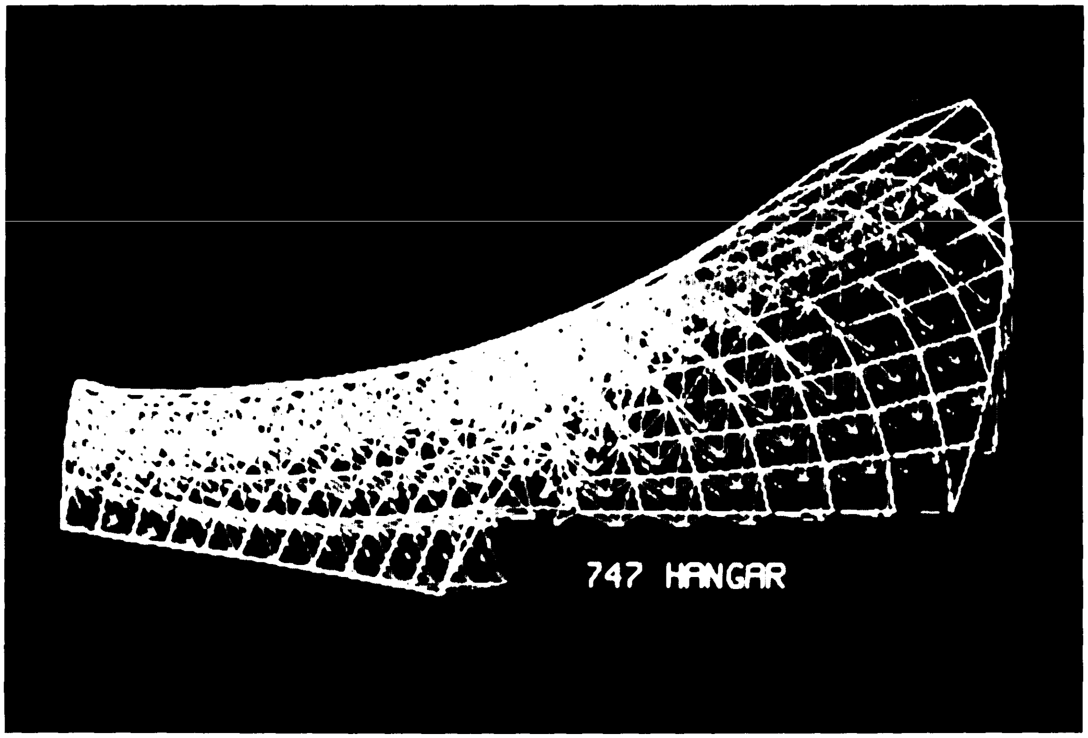
Figure 29 is Caesar's Palace out in Las Vegas, and is an example of all the structures at Space Structures which are designed around three basic goals: structural efficiency, project economy and system elegance.

What's the team work that's being put together? We see ourselves as part of a new team. In the past, teams typically combined architects/engineers, the general contractor and the owner. We see two new members becoming involved in the initial design stages of the project. Ourselves as a systems specialist, and a construction manager.

Almost 80 percent of all of our contracts are negotiated; more than 50 percent of them right at the front end of a project, typically under Phase One of the contract. We work with architectural/engineering firms and help them in design and development during Phase One of a project. With the computer systems, you're able to budget the project on the first day and trade ideas back and forth. With the new team we hold meetings at the beginning of a project, and get everybody who is going to be involved with the project at initial meetings. You can save owners hundreds of thousands and millions of dollars in a project if everybody who is a major participant in the project comes together. We have spent some long, twelve-hour sessions on some projects. When everybody walks out of the door, there has been participation. The areas of responsibility and their direction are pretty well tied down. You can pick up from six months to a year by expediting a project on the way. The marketplace has recognized how important this organizational strategy is and has responded.

Wendel R. Wendel is **the President of Space Structures International Corporation** in Plainview, New York.

Figure 10



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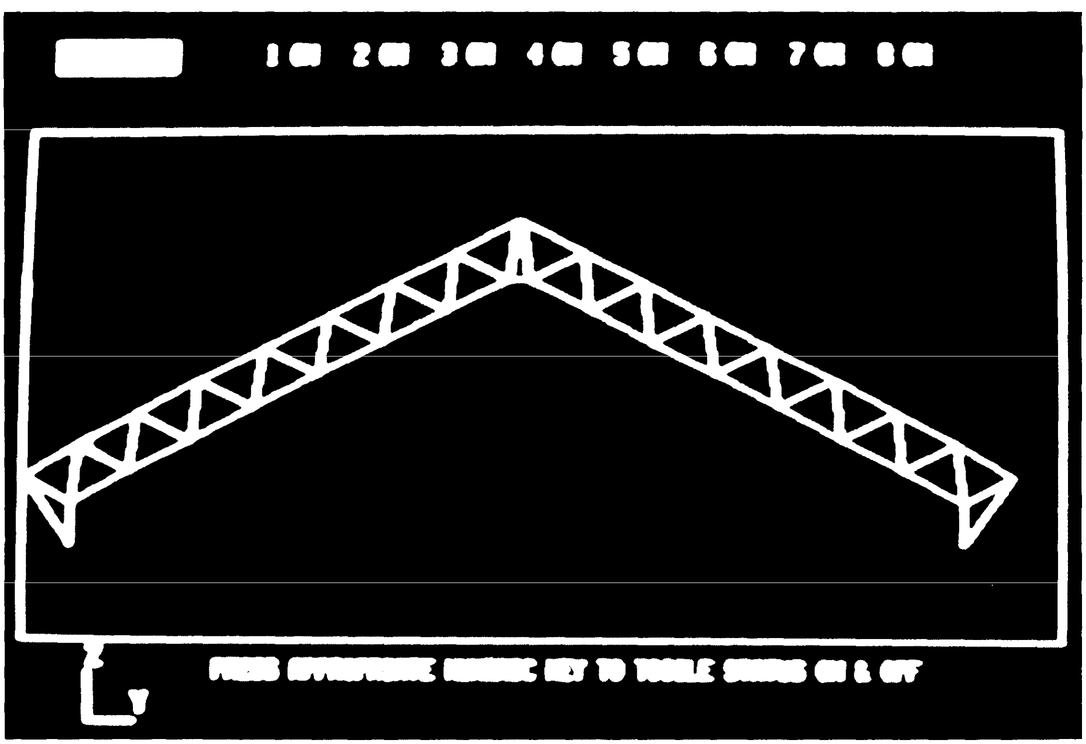
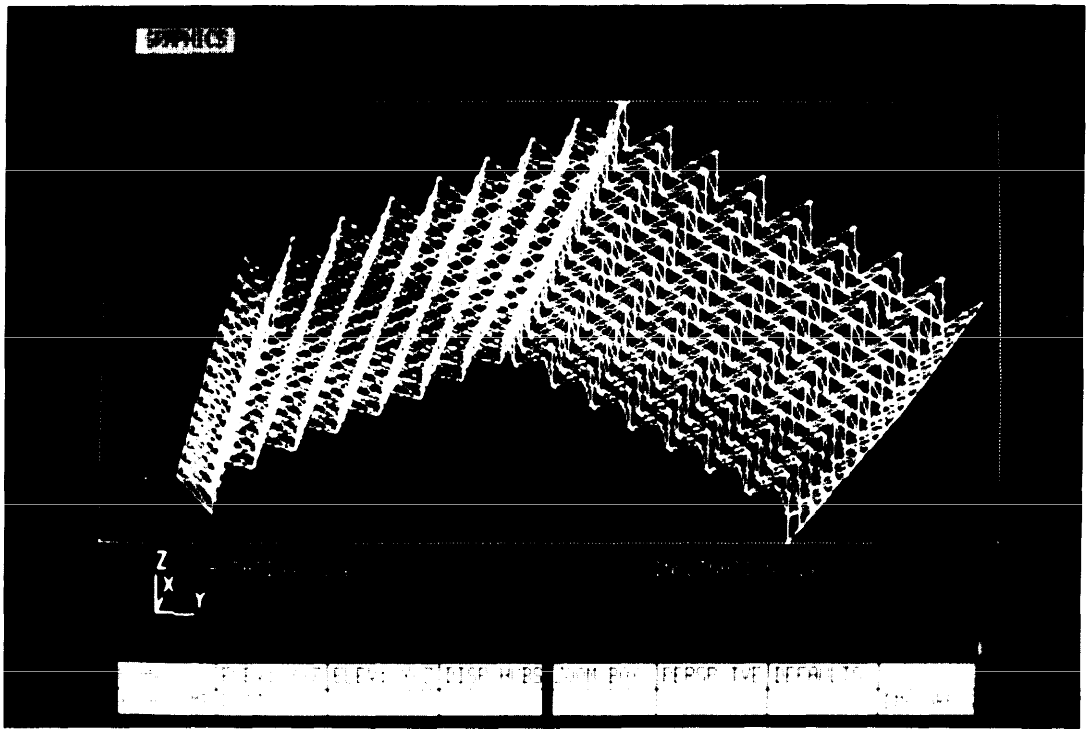


Figure 12

Figure 13



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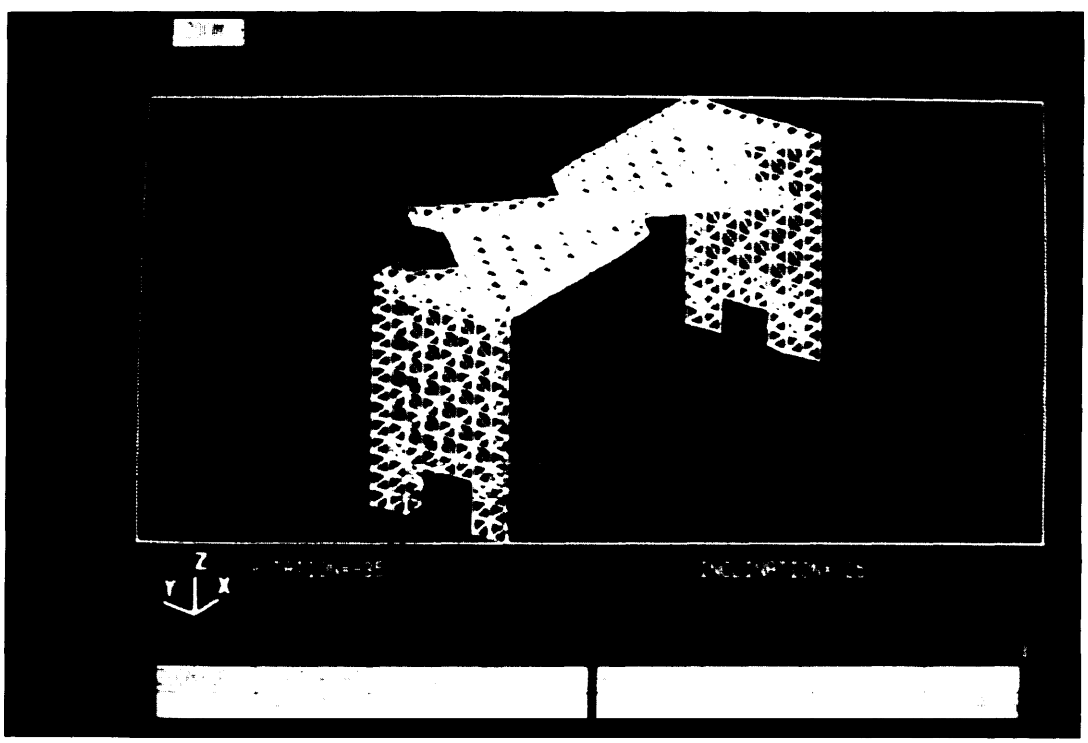


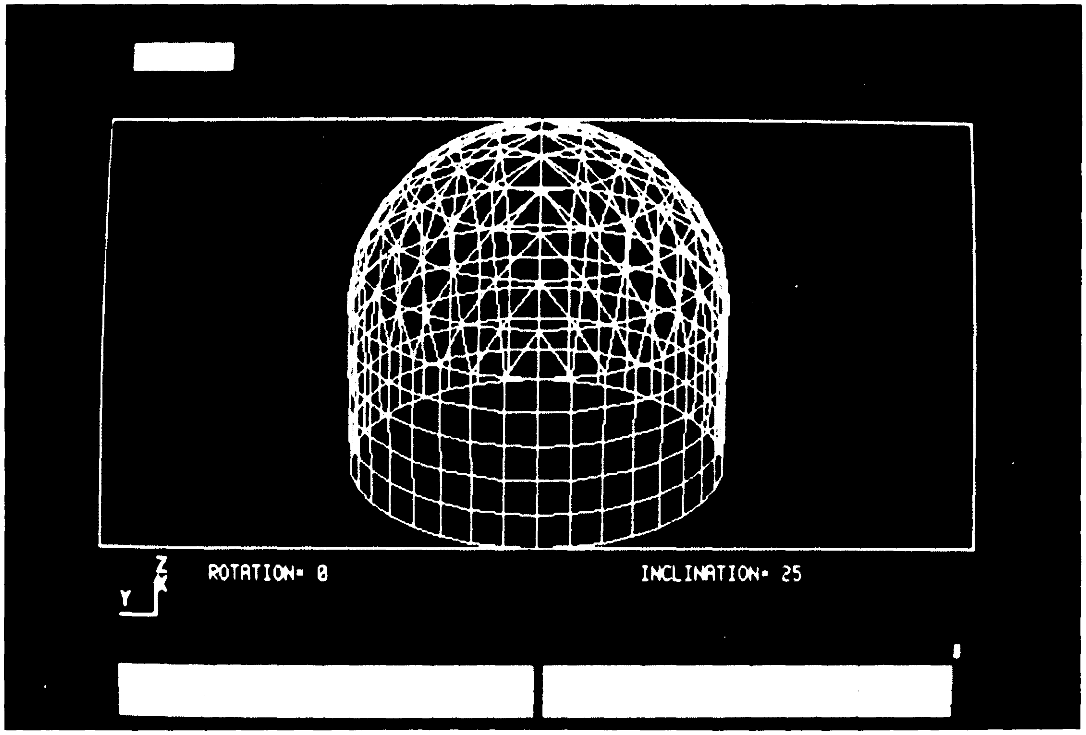
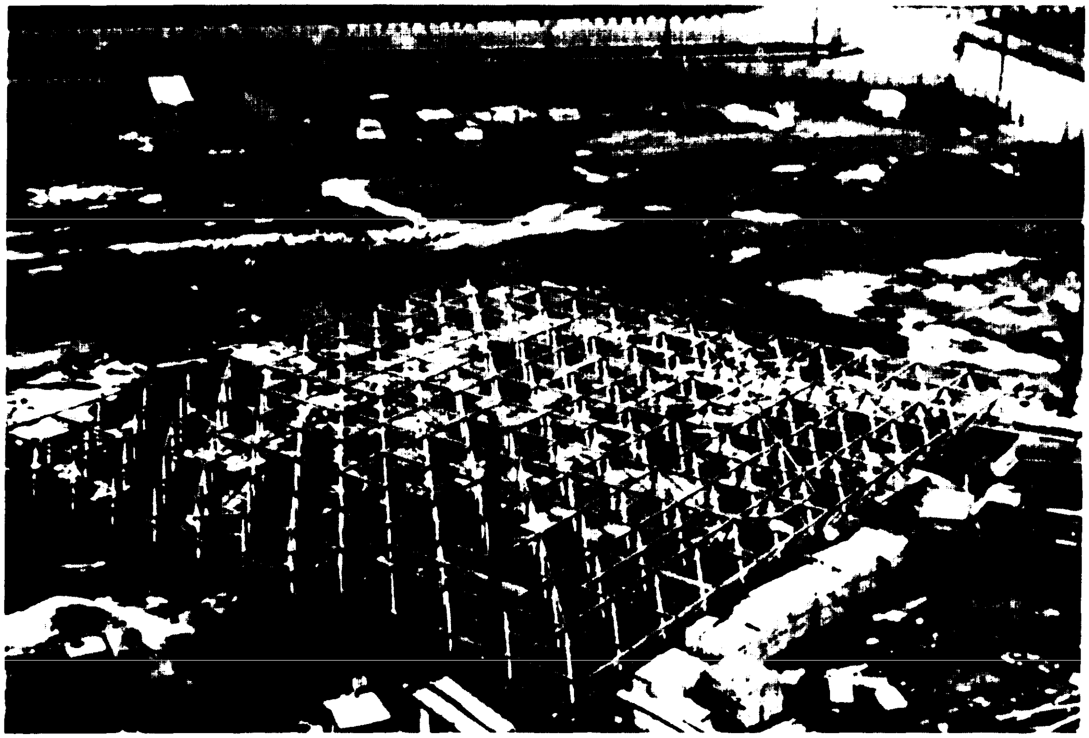


Figure 15

Figure 16

Figure 17



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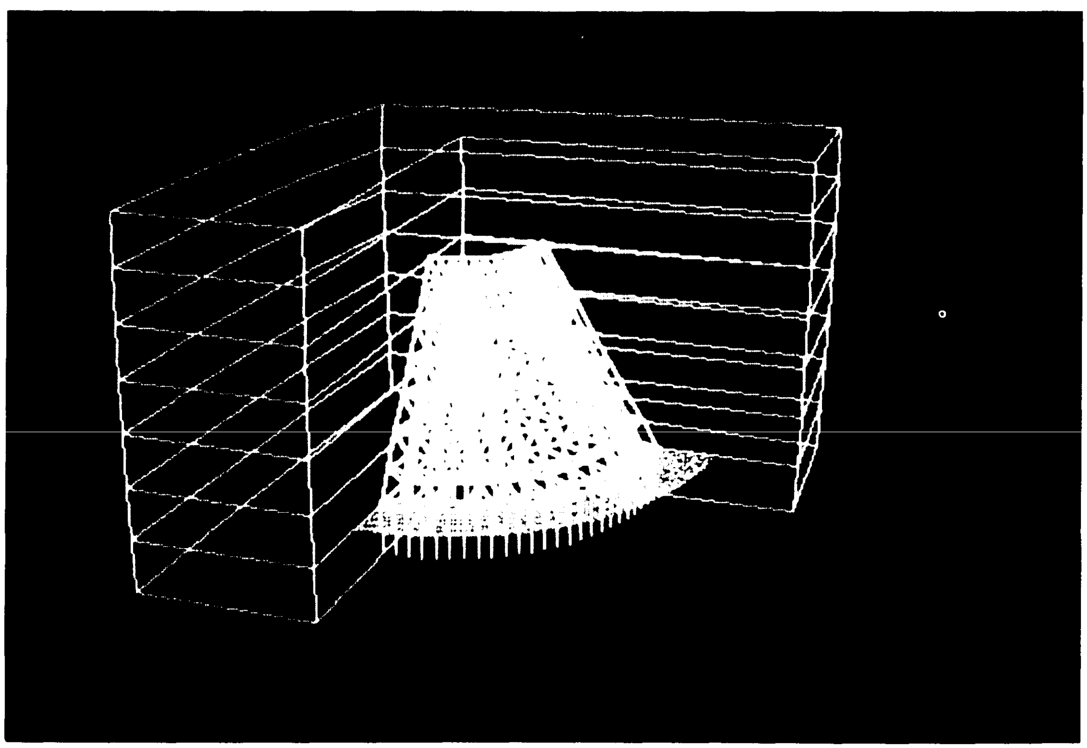


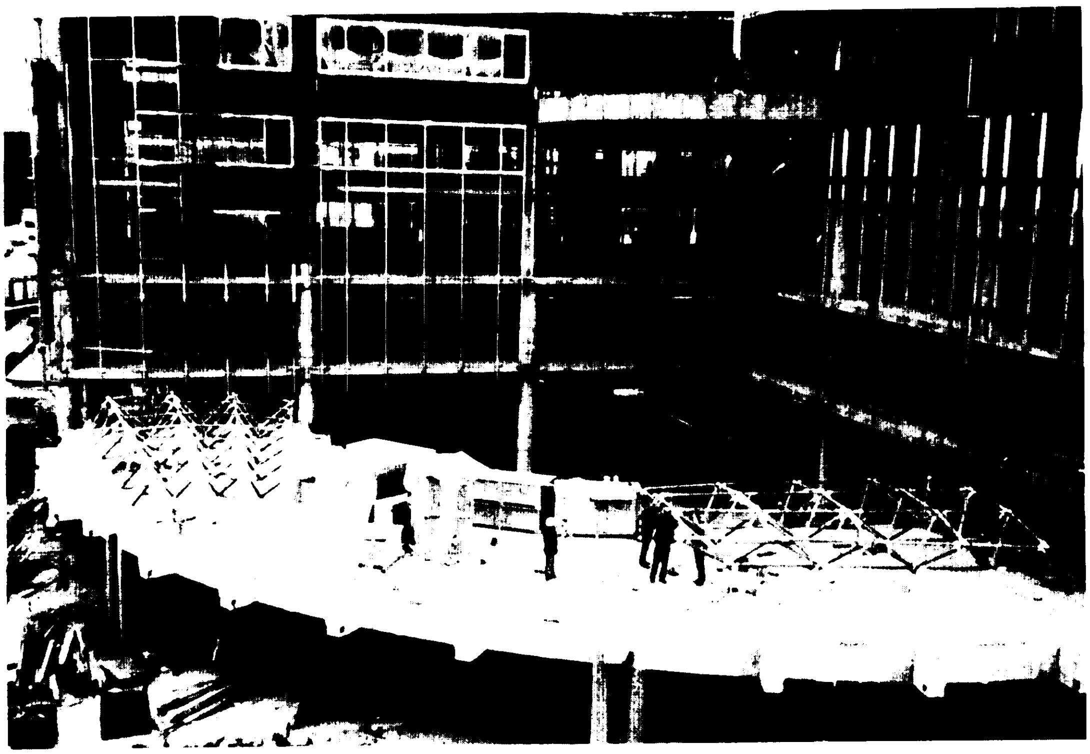
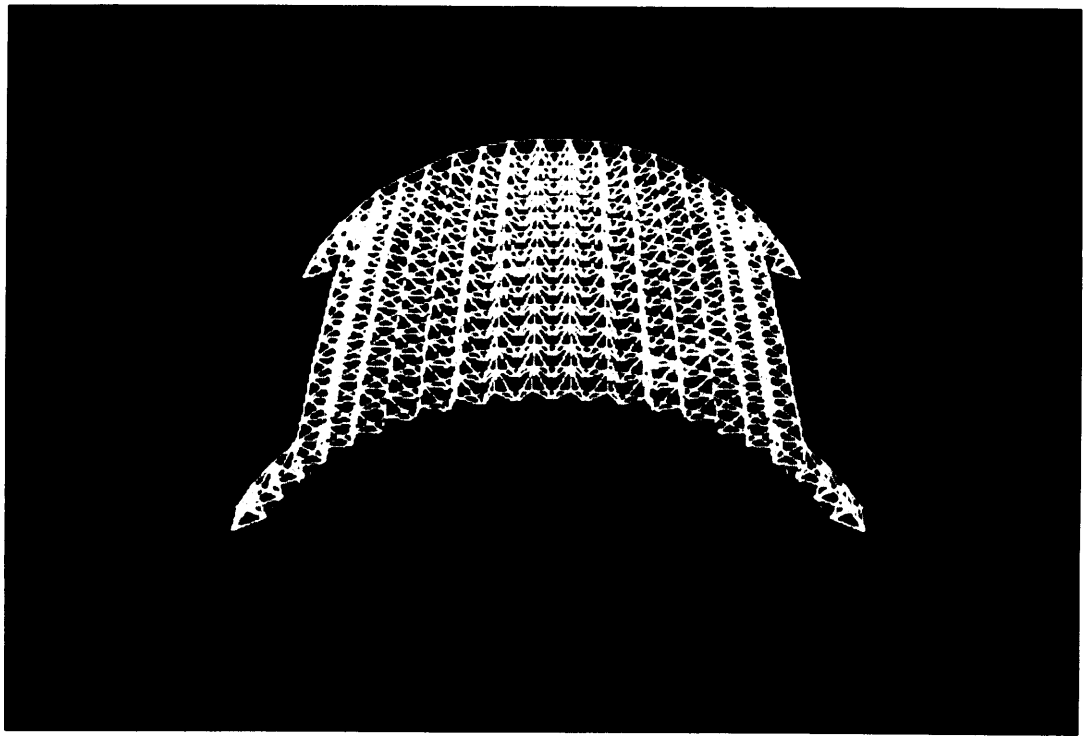


Figure 19

Figure 20

Figure 21



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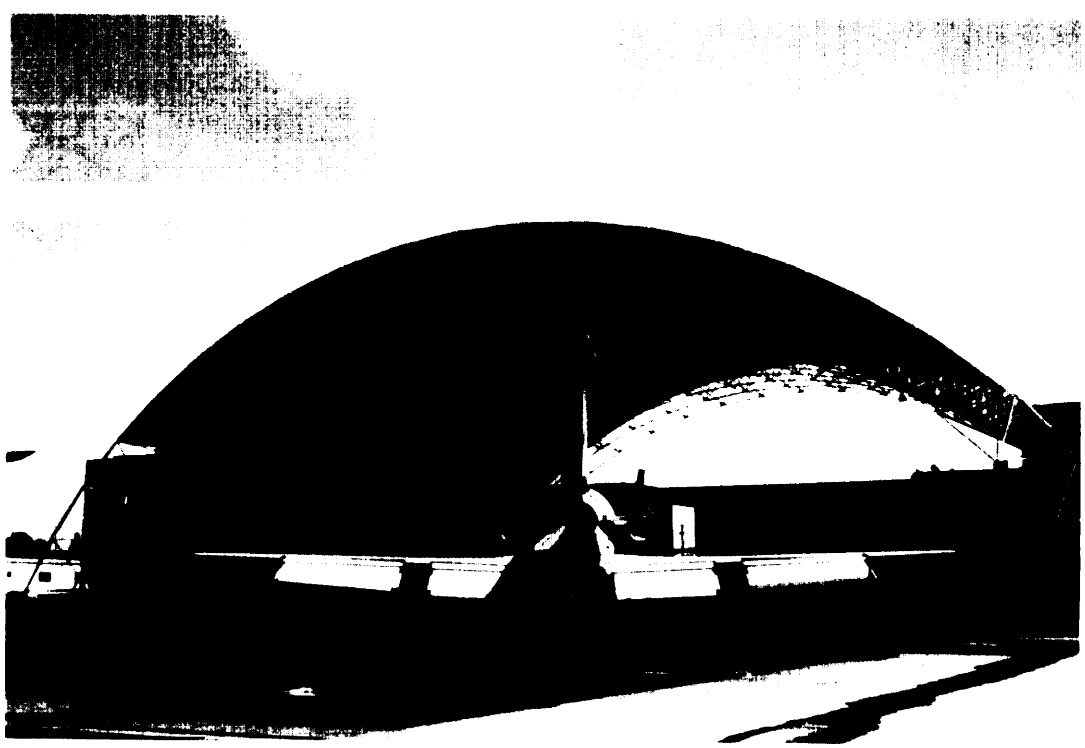

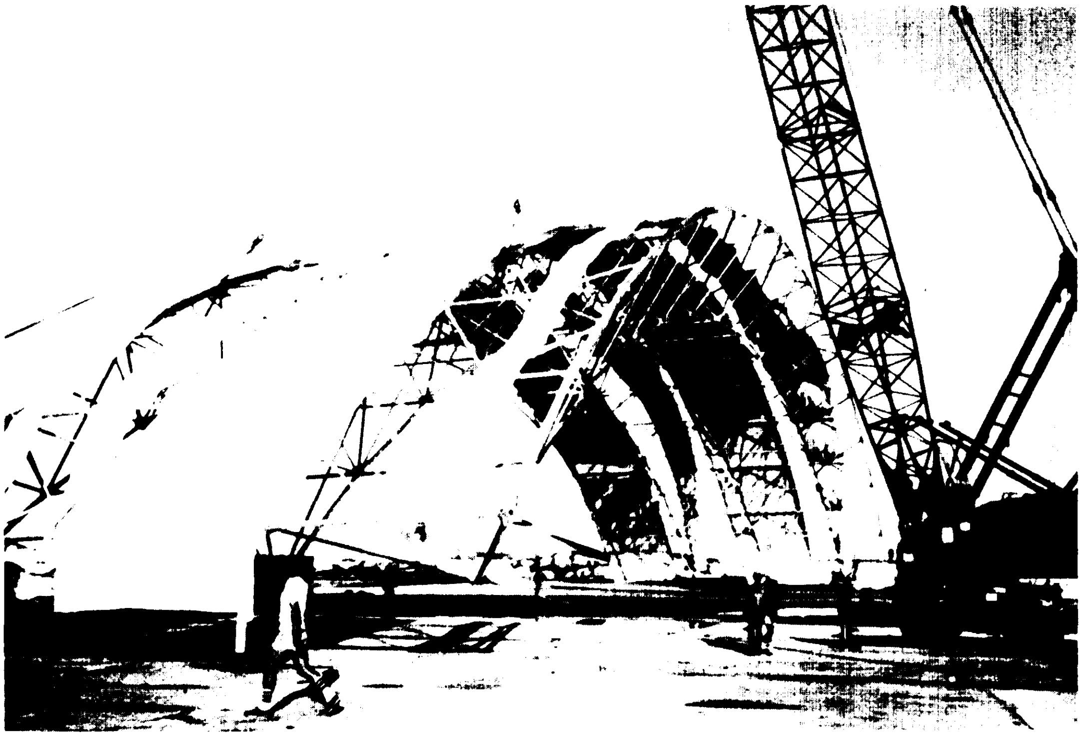

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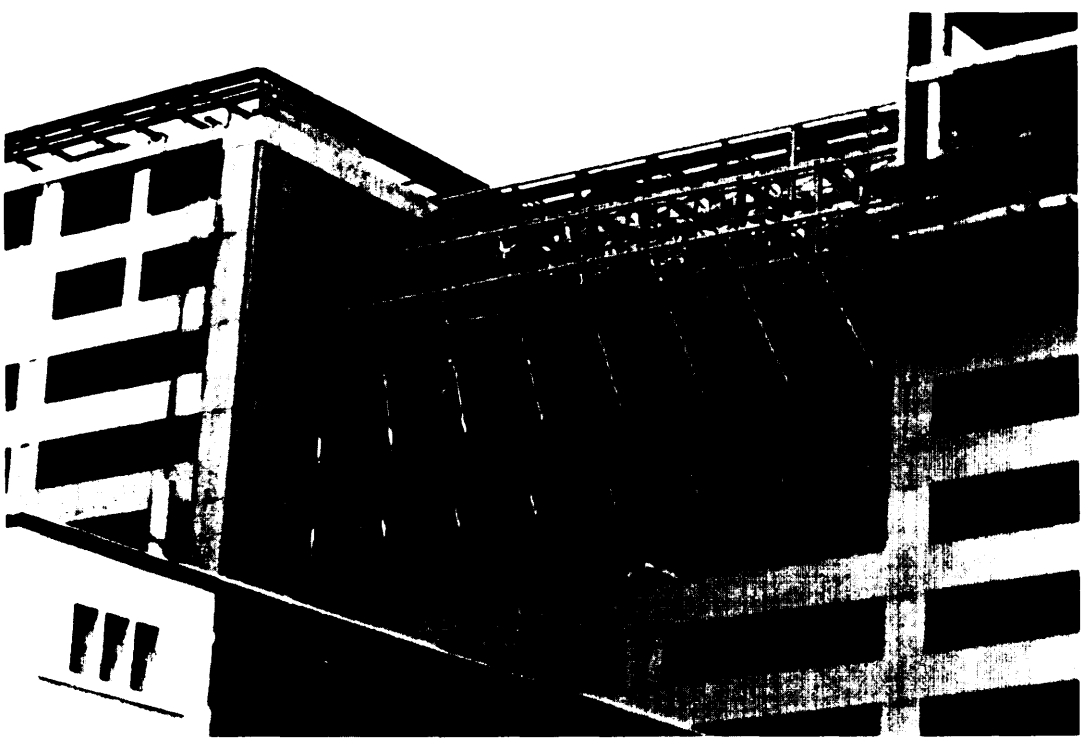
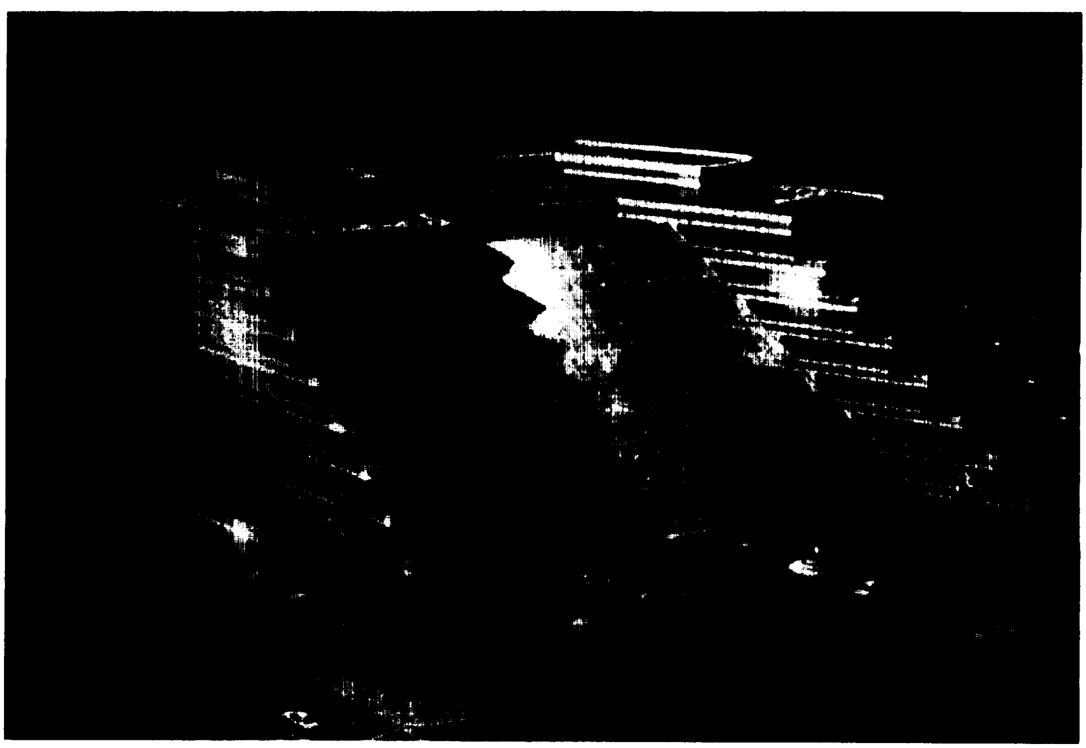


Figure 24

Figure 25



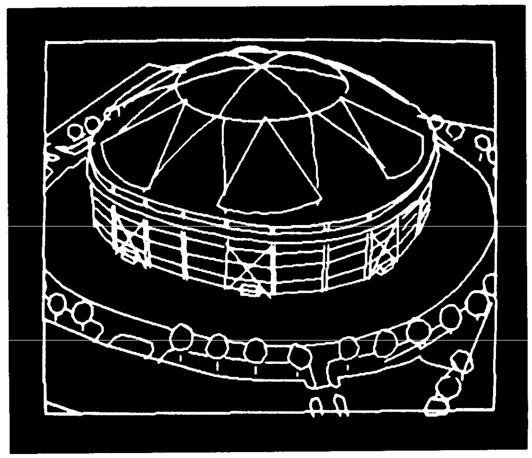


Figure 27

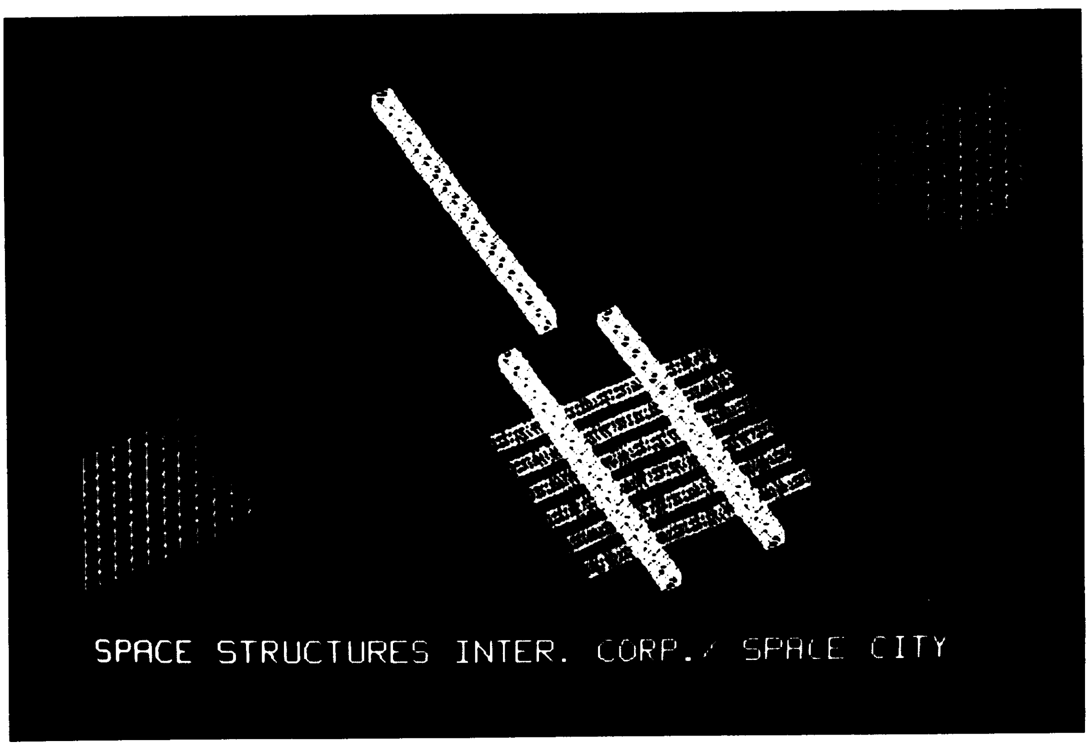


Figure 29