DOME STORY

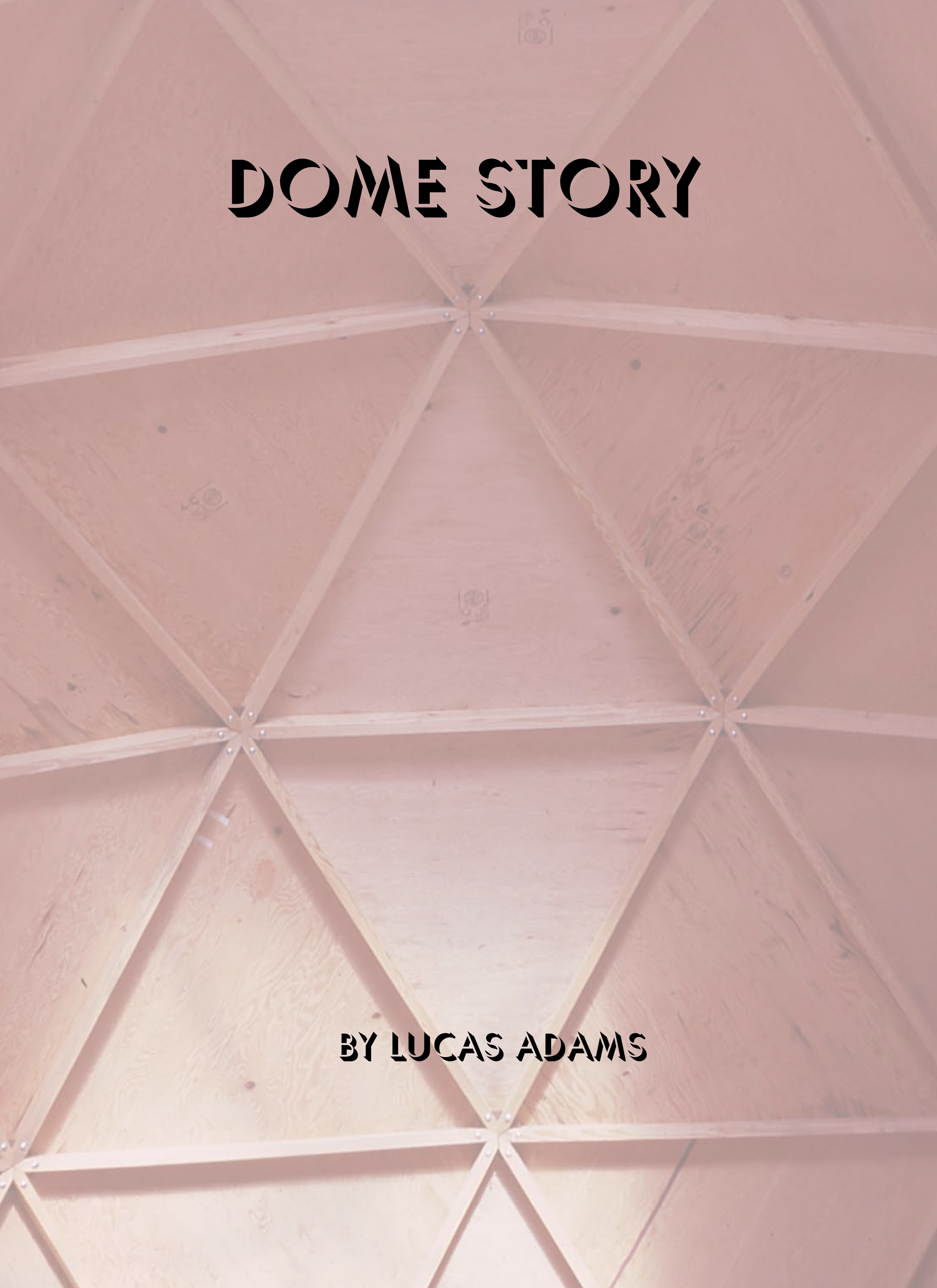
BY LUCAS ADAMS

FOREWARD

This book is based on my experience with building a geodesic dome in Lubbock, Texas in the early 1970s. It is a realistic accounting of the process, with insights into problems and solutions associated with not just this dome but any dome the reader might be thinking about building.

Building this dome was a huge amount of work, but I would do it all over again if given the chance. Why? Because it was a great learning experience in so many ways.

I would, of course, do it differently...



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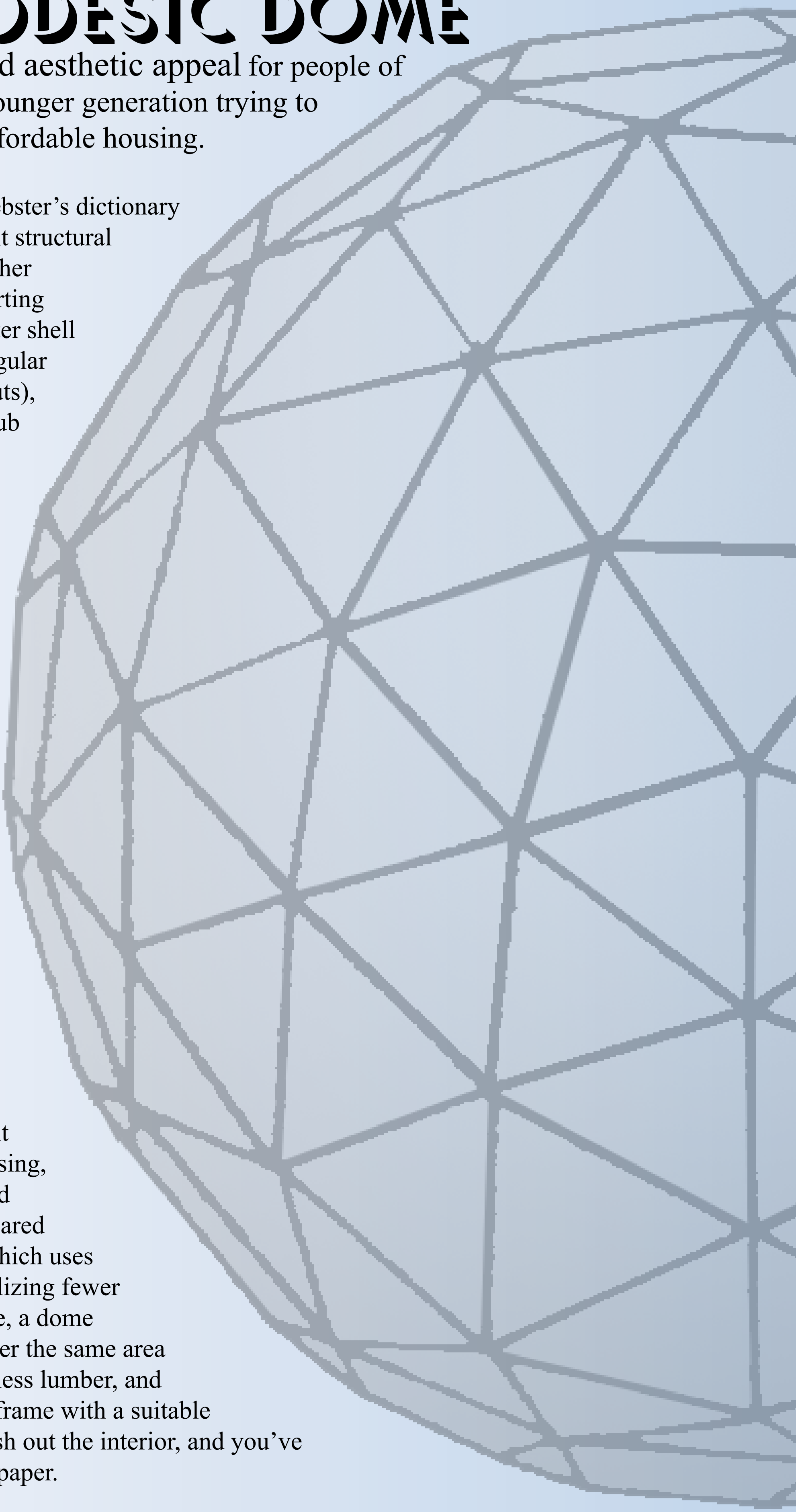
The geodesic dome

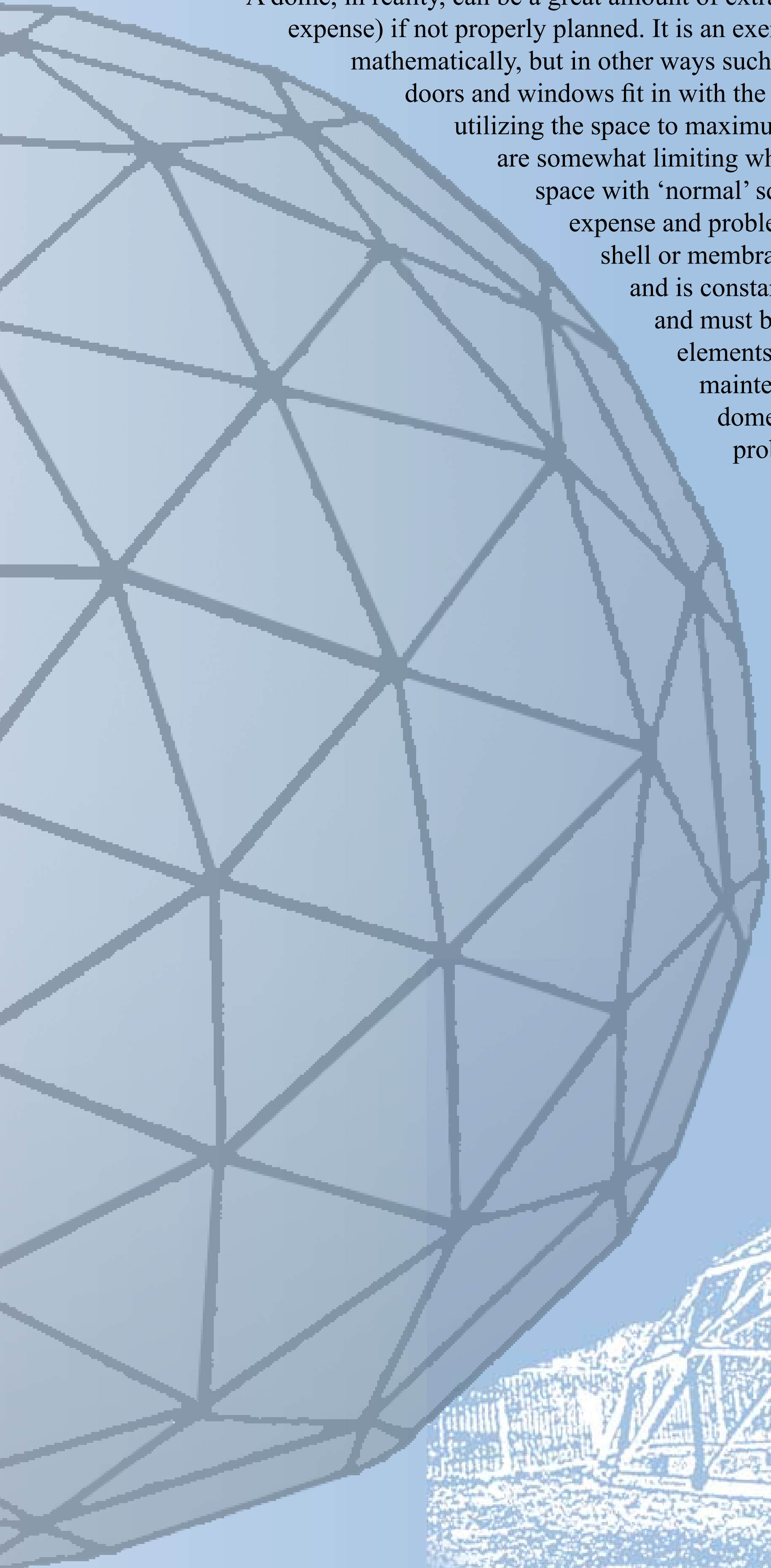
has a lot of conceptual and aesthetic appeal for people of all ages, especially today's younger generation trying to get their money's worth in affordable housing.



What is a geodesic dome? Webster's dictionary defines it as "made of light straight structural elements largely in tension." Another description would be a self-supporting hemispherical structure whose outer shell is comprised of a geometric, triangular web-work or frame of boards (struts), held together with some type of hub system, and covered with a skin. The geometry of the web can vary greatly, from relatively few large triangles to many, many small triangles. In addition, there are several different hub configurations. All of the geodesic possibilities are beyond the scope of this book, however, and if more information is needed by the reader I would recommend Domebook 2, (1971, Shelter Publications) which described not only geodesic math, but several structures which had been built. Other books by or about Buckminster Fuller, considered to be the father of geodesic domes, are also recommended.

When Domebook 2 came out, it offered an alternative form of housing, unique, aesthetically appealing and relatively inexpensive when compared with conventional construction, which uses a great amount of material. By utilizing fewer studs or struts than a regular house, a dome could be framed which would cover the same area as conventional framing with 1/3 less lumber, and infinitely more appeal. Cover the frame with a suitable waterproof material or 'skin', finish out the interior, and you've got yourself a home… at least on paper.

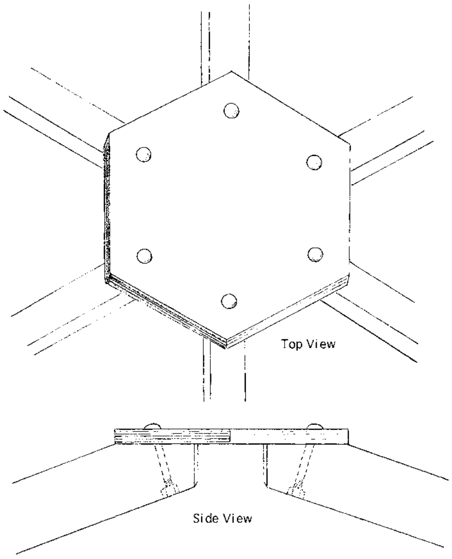
A dome, in reality, can be a great amount of extra labor and materials, (not to mention expense) if not properly planned. It is an exercise in problem solving, not just mathematically, but in other ways such as making conventional things like doors and windows fit in with the structure and function properly, and utilizing the space to maximum benefit. Curved walls and ceilings are somewhat limiting when it comes to breaking up the interior space with 'normal' square or rectangular rooms. The main expense and problem to solve for any dome is the exterior shell or membrane, however. It is both walls and roof and is constantly exposed to weather from all sides and must be designed and fabricated with both the elements and expense in mind, including future maintenance. If improperly constructed, the dome could be an ongoing maintenance problem and a perpetual expense.



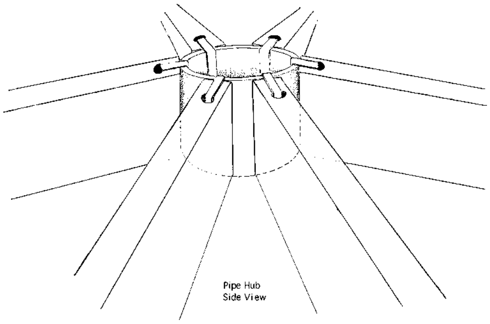
3 frequency icosahedron

External plywood hub and struts

The geodesic home that I built in the early 70's consisted of a 36 ft. diameter, 5/8 hemisphere and a 24 ft. diameter, 5/8 hemisphere, both covered with stucco, and a conventional rectangular garage. (Originally the plan called for them to be covered with neoprene coated 3/4 inch plywood, but that proved to be too costly.) Geodesic math and chord factors were obtained in Domebook 2, which described several different domes.

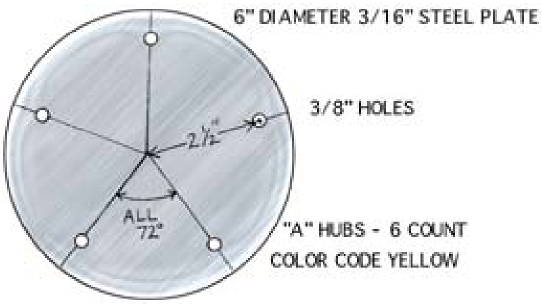


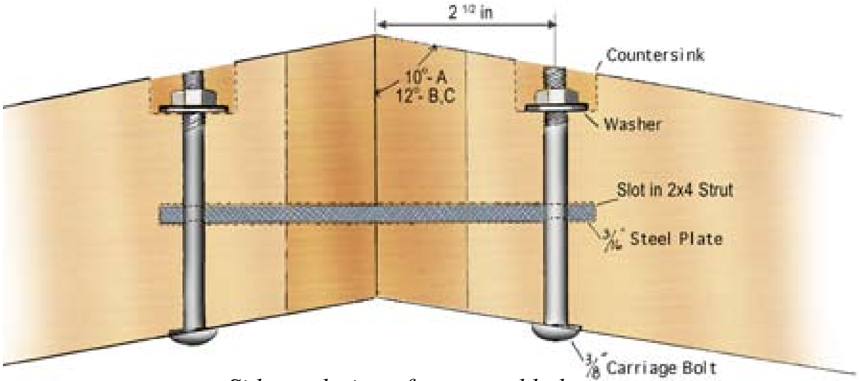
External plywood hub used on greenhouse



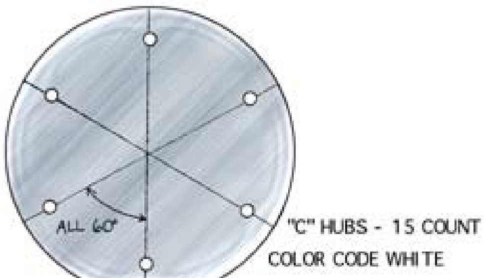
Pipe and strap hub, not used

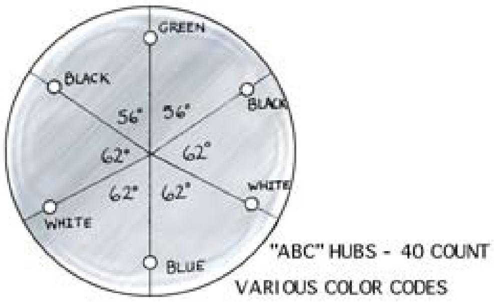
A 24 ft. 1/2 sphere was built first to be used as a greenhouse in order to gain practical experience with such a radical structure, and was an important step. It was framed using 2x4 wooden struts bolted to external 3/4 inch plywood hubs, and sat on a footing of cinder-blocks partially buried in the ground. The skin was made up mostly of translucent fiberglass panels on the south side, and 1/2 in. plywood on the north. There were a few clear as well as blue panels of Plexiglas® on the top. (At that point it became necessary to erect a fence around the property.) The plywood was covered with silicone rubber to waterproof it, which worked well except for one drawback. Even when cured the silicone rubber tended to have an affinity for dirt, and dust-storms in Lubbock are a fact of life. The white rubber took on a dirty brown look, impossible to keep clean. Paint would have been a better coating and a lot less expensive. The external plywood hub, while suitable for the greenhouse, was not acceptable for the other domes because it lacked both strength and aesthetic appeal.





Side rendering of struts and hub

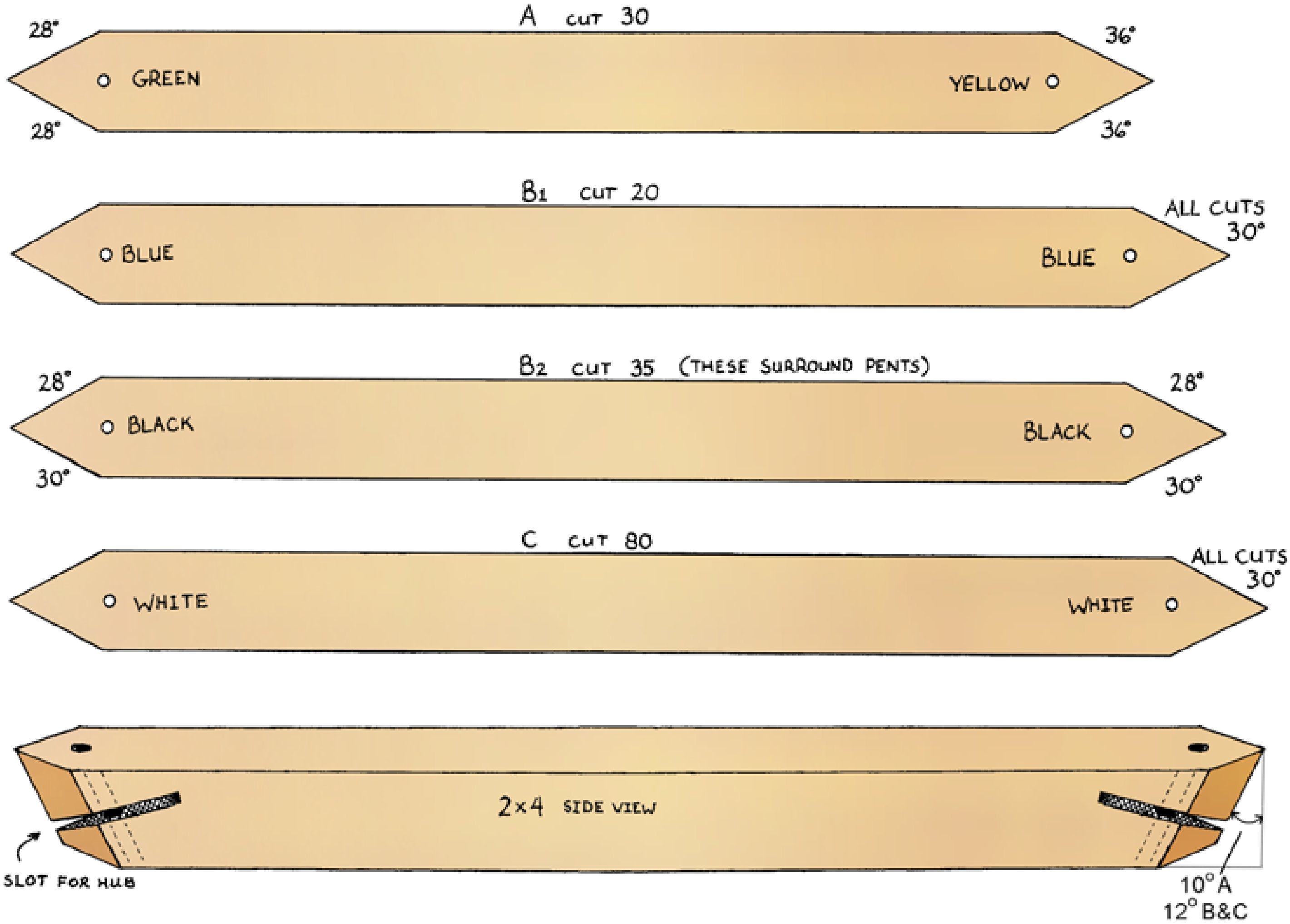




An internal metal hub which would not show while adding a lot of strength was eventually chosen after a comparative test with the wooden hub. I also built and tested a couple of other fastening systems, including an external metal hub and a pipe and strap hub, neither of which were suitable. One of the potential problems with the internal metal hub system was that it required more precision in cutting the angles of the struts where they all came together. Another issue was that the hubs themselves had to have a high level of precision in their manufacturing. At that time the high pressure water-jet cutting system was not common, nor was the plasma cutting system, so every hub had to be individually hand cut and drilled. See illustration 2.

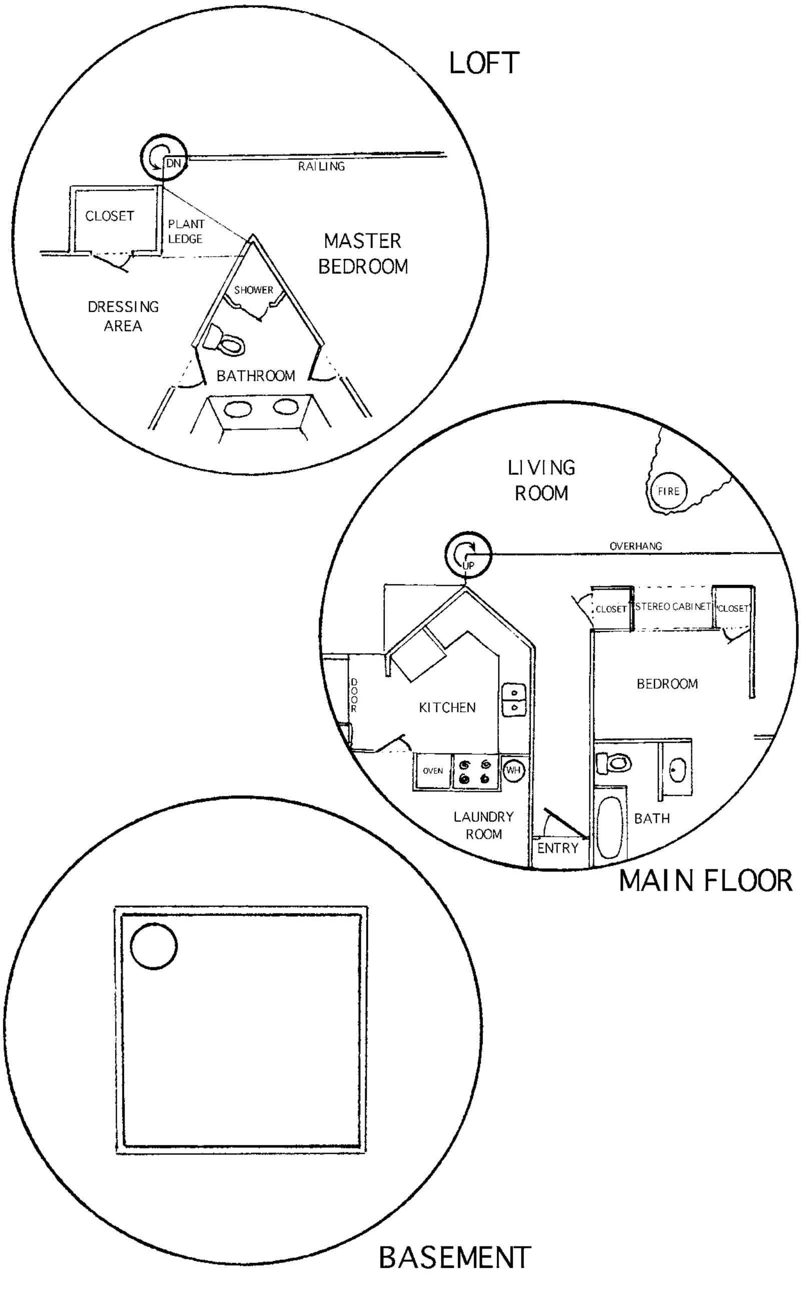
Internal metal hub and struts

I cut 122 six inch diameter circles (hubs) out of a sheet of 3/16 inch thick steel plate, using an oxyacetylene cutting torch hooked to a circle cutting jig. Bolt holes at the appropriate angles were carefully marked on each circular hub using a template, punched to make sure the drill-bit went exactly where it was supposed to, then drilled on a drill press and finally color coded. There were three different hub bolt patterns, a pentagon, a hexagon, and an alternate hexagon. Specifically, there were 6 pentagon hubs, 15 hexagon hubs, and 40 alternate hexagon hubs for each dome. See illustration 3. Note: The ideal way to cut the hubs, including holes, would be the use of a computerized plasma cutter, or water-jet cutter, either of which can be done in an hour with extreme precision. Cutting the hubs, marking and drilling by hand took about 8 to 10 hours.



Next, the lumber for the struts was hand picked in order to obtain the straightest, knot-free, high density wood possible, which is very important. The struts were cut on a radial arm saw to the proper length and angle, using a jig whenever possible, to a tolerance of 1/16 inch. There were 30 A struts, 20 B1 struts, 35 B2 struts, and 80 C struts. The B1 and B2 struts were the same length, but had slightly different angles because the B2's went around the pentagons. The length of the struts was determined by multiplying the radius of the dome by various chord factors; A= .3486, B=.4035, C=.4124. So the length of an A strut for a 24 ft dome would be the radius of 12 feet (144 in.) x .3486 chord factor, or 50.19 inches. The length of B strut was 144 inches x .4035 chord factor, or 58.10 inches. The length of C strut was 144 inches x .4124 chord factor, or 59.38 inches. Longer struts were cut first so that in the event of mistakes the lumber could still be used for shorter struts. 3/16 inch wide slots for the hubs were cut in the ends of each strut, using two saw blades together to equal the thickness of the hub. The next step was to drill the 3/8 inch bolt holes in the ends of the struts and countersink for the nuts, using a jig to insure proper angling. All struts were then color coded. The cutting and color coding of the struts took 1 week.

Because the domes were to be built inside the city limits of Lubbock, I had to obtain a building permit and a contractor's bond. This meant that blueprints had to be drawn up by a registered engineer and architect, and application made to the building inspection department at city hall. Upon receiving the plans and looking them over, the building inspector's office required further documentation of the load strength of the structure, in spite of the fact that a NASA computer had generated the chord factors published in Domebook 2. (Geodesic domes are used by the U.S. Air Force in arctic regions for snow loads and winds in excess of 125mph!) In order to satisfy their requirements I enlisted the aid of a professor in the engineering department at Texas Tech University. After reviewing the plans he determined that the structure was indeed sound and that we could load test the dome, which would satisfy the building inspection department. The building permit was eventually approved, and various jobs were subcontracted out as required by city codes, like the electrical work. The foundation work was also subbed out, starting with the basement.



Modified floorplan

Back-hoe digging the basement

Construction had not even begun, and the first deviation from the blueprints was deemed necessary. The architectural firm that I hired had about as much experience as myself when it came to domes, little or none, and produced the blueprints more as a requirement of the building inspection system than an actual working plan. We all knew that there would be problems and that solutions would be found, and that changes were inevitable when it came to actual construction. However, I hadn't planned on making a change before building began, but that is exactly what happened.

Basement digging completed

Basement digging completed

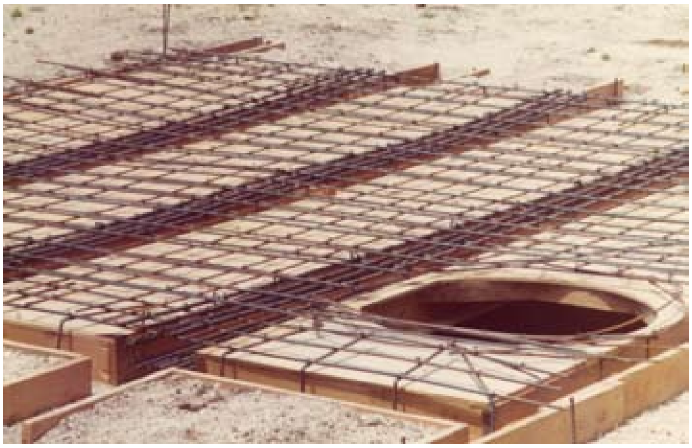
The first subcontractor who was hired to do the basement pointed out two major flaws in the basement design. The plans called for a half-moon shaped basement, with the basement walls being directly underneath the exterior dome walls. This was a poor design, as it would allow water to run off the outside of the dome and directly down to the basement wall, creating a potential water leakage problem. Second, the half-moon shape of the basement would have been difficult and expensive to excavate and build using cinder-block, not to mention having a lot of wasted space. He suggested that we build a square basement tucked underneath the center of the house, with its walls well away from the water-shedding exterior dome walls. Heeding his advice, new basement plans were drawn up and submitted to the building inspection office, and once approved we were ready to go.

Basement walls being built

Basement walls-
note the plastic coating

After determining the footprint of the domes on the site, a square hole approximately 24 feet across was excavated using a back-hoe, and rebar and wire mesh were laid out in the bottom, followed by pouring concrete for the basement floor. There was no plumbing in the basement slab, so the foundation work went quickly. After curing for several days the cinder-block walls were built up on the floor,

Rebar embedded in basement walls



Form boards and rebar over the basement

using cinder-block that had a waterproof coating on the outside. The cinder-blocks were supplied by the basement sub-contractor and were from another project he had completed, with the excess blocks being recycled instead of dumped.

Temporary bracing in the basement

Conduit for electrical wiring was run into the hollow cinderblocks. The hollow cinder-block walls were then filled with concrete and reinforcing steel rods known as re-bar, leaving some of the rebar sticking out the top of the blocks so as to be eventually encased in the slab. The sub-contractor and I had some differences of opinion at this point, specifically, during the pouring of the concrete into the cinder-blocks. As I watched the pouring I realized that the concrete was not being tamped with the rebar rods, so I began to do it myself. In spite of his reassurance that it would not be necessary to do this, I knew in fact that it was. Each opening took almost twice as much concrete as it settled, creating a very solid pour and a very solid wall after it cured. He also suggested not back-filling against the wall, but this would have created another set of problems in pouring the slab, so I did it anyway. The lesson here is, when hiring sub-contractors, try to be on-site when they are doing their work, and get the job description clear with them *before* they do the work. I had several other occasions where this was a problem, partly due to the unusual nature of the project. It wasn't always possible to schedule a sub-contractor at a certain time, so you just had to hope they would come when you were there. It is just as true today as then, but at least cell phones have made this process more efficient.

Rebar tied together

Plumbing stub-outs and curved masonite forms

Next, forms were built over the basement which would hold the concrete slab when poured, leaving a 4 foot diameter hole for the spiral staircase. Six 2x12 beams and several sheets of 3/4 inch plywood used as forms would become a

Overall view of the form boards

permanent part of the basement ceiling, and were temporarily braced to the basement floor using 2x4s and 2x6s. This was a must, in order to support the weight of tons of wet concrete when the slab was poured. The 2x12's were used to make three channels running the length of the basement, and when poured full of concrete would create three strong beams A grid of 1/2 to 1 inch thick re-bar rods was wire-tied inside these channels and on top of the plywood forms, creating a sort of web of steel which, once encased in concrete, would give tremendous strength to the slab over the basement.


Cement truck preparing to pour

Before the concrete could be poured for the slab, the plumbing had to be roughed in. In order to accurately place the stub-outs and outer form-boards, a center point of the dome was permanently established over the exact center of the basement and a large nail was driven into the forms. All future measurements would be taken from this reference point, which was very important! (Regular houses do not need this reference point as measurements are taken from various areas of the slab.) But no matter what type of structure you are building, double check every sub-contractor's measurements, including your own. I was especially concerned that the next step was done right, measuring for the outer forms for the slab.


Concrete being spread


Concrete being spread

The curved outer forms were flexible masonite, reinforced every couple of feet by 2x4 stakes. At that point the bottom 15 struts were laid out around the curved forms in order to mark the exact location of the anchor bolts that would be placed in the concrete. This was done for both the 24 and 36 foot domes and was a critical step, because the bolts needed to match the location of the hubs


Concrete slab immediately after the pour - note the plywood covering over the basement opening


Concrete slab ready for frame

Framing being started

within a half-inch. Once the plumbing rough-in and forms were completed, and the rest of the footings, re-bar and wire mesh were done, the building inspector was called in for the first of several inspections. After checking to see that the footings were deep enough, the steel was in place, and the plumbing rough-in was done to code, a green-tag was taped to the plumbing stub-out, which meant that it all passed inspection and we could go ahead with the concrete pour. (The front entry-way and back patio slabs were done later.) The concrete crew consisted of several people, each working as hard as they could until the pour was finished. The slab was then sprayed with a chemical to keep moisture in the concrete and then the slab was allowed to cure for several days before framing was started.

Note: One thing I would do different today is the inclusion of a product called Fibermesh® in the concrete mix. A small bag of this polymer is added to the mix in the truck and allowed to churn for 5 minutes. The result is a concrete mix with thousands of strands of plastic fibers mixed in, which add strength to the slab.

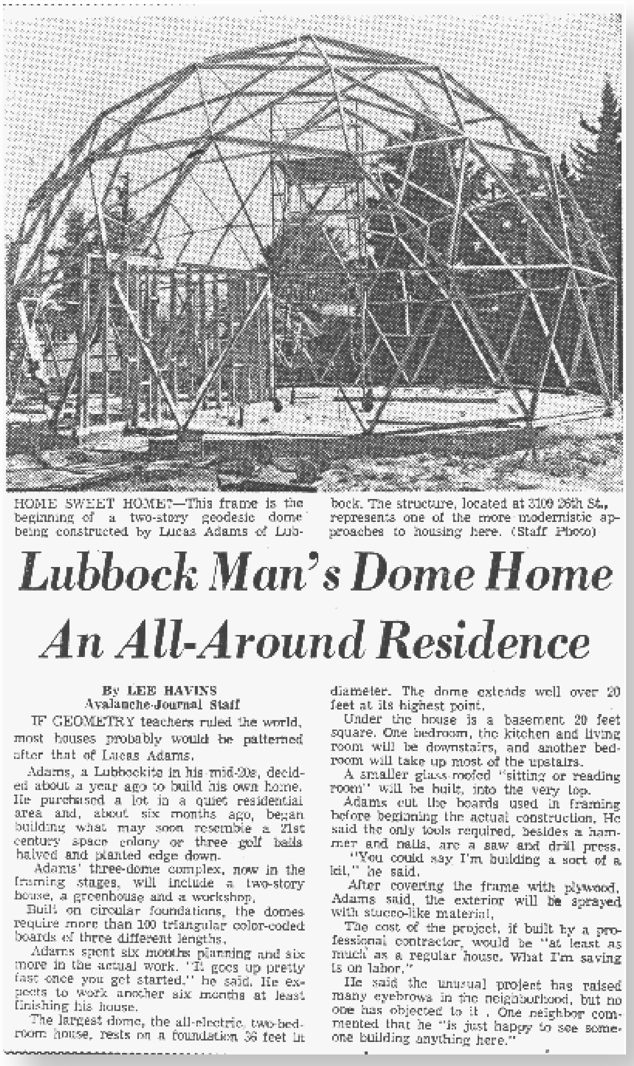
Framing of the 36 foot dome

Framing the domes was very exciting, and went quickly, with no problems at all. Color coded hubs were matched to color coded struts and bolted together using 3/8 inch carriage bolts and a socket wrench. The hubs that sat on the slab were welded to the bolts previously set in the concrete during the pour. After the bottom level of triangles was completed the structure was strong enough to climb on, and with each level it became more rigid. Scaffolding with wheels expedited the framing tremendously, because on the 36 foot dome it was not possible to climb to the next level on the dome itself.

Assembling the dome

Both the 24 and 36 foot domes were assembled in 3 days, and all of a sudden they attracted a lot of attention. People from the newspaper came by for an interview and took pictures of the dome. Supposedly a small story would be in the Sunday paper in the home section, but I didn't give it much thought. I awoke Sunday morning to the sound of the telephone and a friend asking me if I had seen the newspaper. The picture of the dome and story were on the front page! All of a sudden I had the feeling that I had better get over there. Sure enough, cars were lined up for blocks, and people were climbing all over the dome like a jungle-gym! From that time on there was a constant stream of curious onlookers with questions and observations about domes, housing and Buckminster Fuller. It made it hard to get any work done at times, but it seemed necessary to communicate with them. On any given day there would be four or five people stopping by.

Note the sub-framing of 2 inner Ts



HOME SWEET HOME?—This frame is the beginning of a two-story geodesic dome being constructed by Lucas Adams of Lubbock. The structure, located at 3109 26th St., represents one of the more modernistic approaches to housing here. (Staff Photo)

Lubbock Man's Dome Home An All-Around Residence

By LEE HAVINS
Avalanche-Journal Staff

IF GEOMETRY teachers ruled the world, most houses probably would be patterned after that of Lucas Adams.

Adams, a Lubbockite in his mid-20s, decided about a year ago to build his own home. He purchased a lot in a quiet residential area and, about six months ago, began building what may soon resemble a 21st century space colony or three golf balls halved and planted edge down.

Adams' three-dome complex, now in the framing stages, will include a two-story house, a greenhouse and a workshop.

Built on circular foundations, the domes require more than 100 triangular color-coded boards of three different lengths.

Adams spent six months planning and six more in the actual work. "It goes up pretty fast once you get started," he said. He expects to work another six months at least finishing his house.

The largest dome, the all-electric, two-bedroom house, rests on a foundation 36 feet in diameter. The dome extends well over 20 feet at its highest point.

Under the house is a basement 20 feet square. One bedroom, the kitchen and living room will be downstairs, and another bedroom will take up most of the upstairs.

A smaller glass-roofed "sitting or reading room" will be built, into the very top.

Adams cut the boards used in framing before beginning the actual construction. He said the only tools required, besides a hammer and nails, are a saw and drill press.

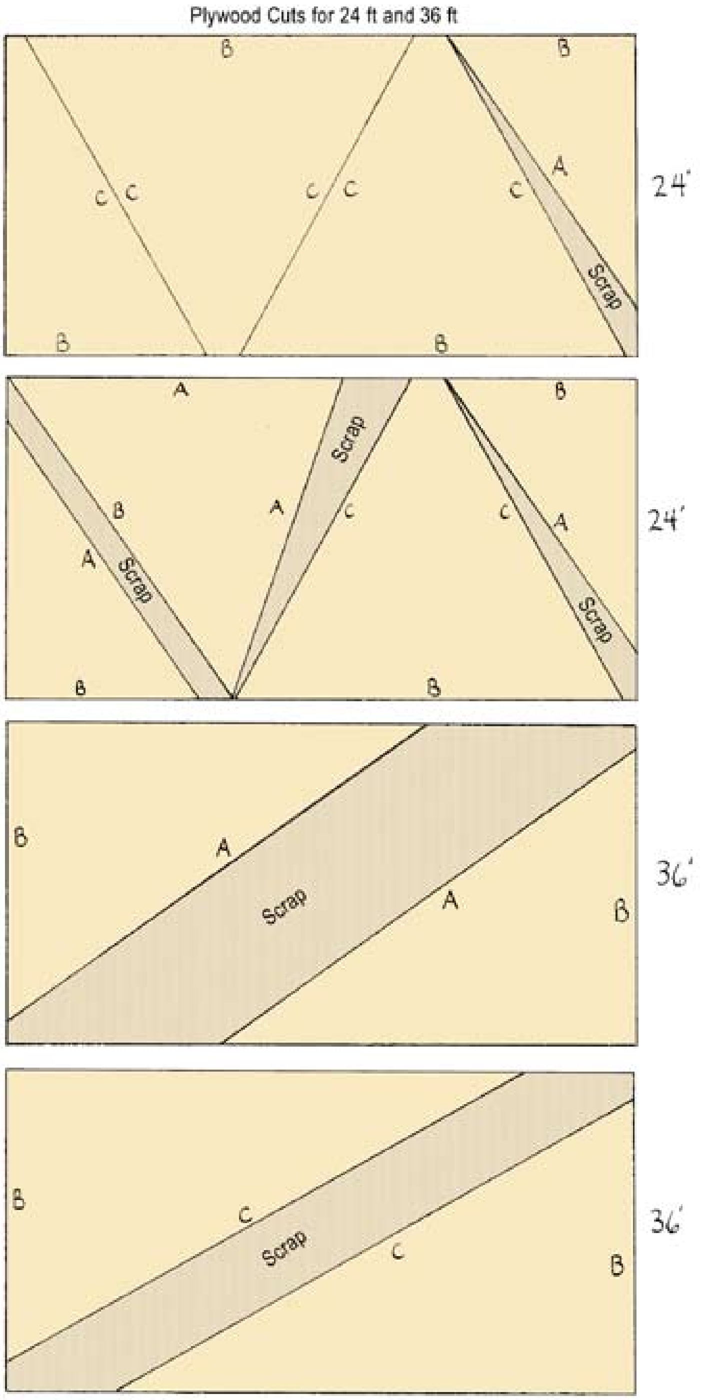
"You could say I'm building a sort of a kit," he said.

After covering the frame with plywood, Adams said, the exterior will be sprayed with stucco-like material.

The cost of the project, if built by a professional contractor, would be "at least as much as a regular house. What I'm saving is on labor."

He said the unusual project has raised many eyebrows in the neighborhood, but no one has objected to it . One neighbor commented that he "is just happy to see someone building anything here."

Article in the Lubbock Avalanche Journal



Next came the job of sub-framing the big dome's triangles. Sub-framing was the addition of more 2x4s inside each triangle which gave more surface to nail to. This was necessary because the 1/4 inch plywood sheathing used on the exterior was in two sections, (a diagonally cut 4x8 sheet of plywood) and the seam between the sections needed support in order to support the weight of the final masonry coating. The 24 foot dome did not need any sub-framing because the plywood panels were in one piece.

The plywood triangles were cut several at a time by carefully stacking the sheets and temporarily nailing them together, marking the top one as a pattern and cutting through six layers at once using a worm-drive saw. Each dome had 105 triangles total, using two different shapes. There were 30 AAB triangles for the pentagons and 75 CCB triangles for the hexagons, so for two domes there were 210


Plywood sheathing

triangles in all. Of those, 25 had windows or doors, so there were 185 plywood triangles cut for the sheathing, and hand-nailed to the frames. This was a massive job, which took several days, and created a new sense of urgency. The plywood needed to be covered immediately with plastic and tarpaper in order to protect it from rain, and possible de-lamination. Note: Some of the scraps of plywood were large enough to use in other places, while some were not.


Tarpaper over sheet plastic


Chickenwire over tarpaper

Stapling the plastic film on the domes was almost nightmarish, because the film was in large sheets, and the wind was gusty for days. Compounding the problem, we were using ropes hung from the top pentagon to scale the outside of the dome, because scaffolding and ladders were useless after the first level up due to the curvature of the shell. Using a hand stapler while hanging on to a rope and trying to keep the plastic down in the wind was an impossible and frustrating task. Somewhere early in this process I decided to invest in a compressor and a couple of air-driven staple-guns, which helped immensely, because the air hoses could be used to hold down the plastic, and the stapling did not require any squeezing action on the trigger. Simply holding down the trigger and bumping the head fired the staples repeatedly, so we were able to go much faster. Tarpaper was then stapled over the plastic vapor barrier, starting at the bottom and working our way up, overlapping as we went. Finally, several layers of 1 inch mesh chicken-wire were stapled on top of the tarpaper. The wire would give the gunite (masonry cement applied by spraying) something to stick to when it was wet, and after curing the wire became a reinforcing matrix. We had stapled over a half a million staples by this point!


Framing The garage and entryway

Another cost-saving opportunity presented itself when the concrete sub-contractor could not work it into the schedule to pour the front entry-way porch. We decided to do it ourselves, and after having observed the previous concrete pours including the back patio I felt confident that we could do the job. The forms were staked in place and reinforcing wire was unrolled inside them. I wanted an exposed aggregate look to the concrete, and this was done by ordering a specific mix from the plant that had small round pebbles in it. Once delivered and poured, we spread and leveled it to the top of the forms, but did not tamp it down. This left the pebbles in the top layer of concrete, which were then exposed by gently spraying with a water hose before it cured. The result was a nice pebbled look to the front porch.

Interior framing was time-consuming

Having protected the plywood shell and having poured the other foundations and driveway, we turned our attention to framing the interior walls, which was very time consuming due to the different angles. We installed 2x6s into the window openings as part of the window trim treatment which would also give the framework additional support during the gunite process. Wet masonry cement would add tons of dead load to the framework until it cured, and I did not want to take any chance of a collapse. The engineering professor had intended to load test the frame at that point of construction by hanging 55 gallon drums filled with water from the struts and measuring the amount of deflection from the slab to the top of the dome. By the time we finished framing the interior walls this was not possible, in fact not even necessary because the dome had become totally supported by the sub-frame, plywood sheathing, 2x6 window frames, and interior framing which extended to the very top of the dome, locking it all in place. (Even the three main struts cut away by an indifferent plumber installing three vent pipes did not weaken the structure, an incident that happened while I was not on site.) It was time to put the real test on the structure, the masonry cement.

Scratch coat of stucco

A friend who was a swimming pool contractor was hired to stucco the shells and basement walls, using a machine that pumped the cement through a hose to the spray gun, hence the name gunite. Since it was impractical for him to scale the dome with a rope and spray cement, he set up scaffolding around the perimeter of the structure and bridged across them with long 2x12's, creating catwalks. This allowed him and his crew to spray the cement and smooth it as they went around the dome, starting at the top and working their way down. The gunite machine was perfect for applying the thick mortar mix because it filled the spaces between the chicken-wire very effectively, better than trying to hand trowel. As the spray gun operator would deposit the material, his helpers would smooth it over and score the surface as they went. Two layers were applied about an inch thick, called a scratch coat, followed by a

Final coat of stucco with coloring agent

final surface coat that had a sandy beige coloring agent in it. The final coat also had a texture to it, which helped to hide any imperfections. All this took about a week, during which time I kept the stucco moist by spraying it daily from a water hose to insure a proper cure. After several weeks 55 gallons of silicone based waterproofing agent were applied using a mop, and the shell was done! (I had started to use a water sealant sold in 1 gallon containers at the local hardware store, but as soon as I applied a little it began to noticeably stain and darken the stucco. It was on the front of the building on one triangle and was apparent for some time, but eventually faded, to my relief. When in doubt, try products in an inconspicuous place.) Exterior doors and windows were the next step.

Front entryway

Window openings

There were only two exterior doors on the big dome, one at the entry-way and the other going out of the kitchen onto the side patio. The small dome had one double-door. The entry-way door was a basic foam-filled metal door, and the kitchen had a glass slider. All of the doors were set in from the shell, each in an alcove design, and one of the problems was a lack of headroom going through one of the triangles into this area. (I didn't want to cut into the bottom support triangles.) There seemed to be sufficient

Mirrored glass on bottom level - Note the silicone

Scaffold work

room at first, but stucco and the concrete slab which was poured later seemed to significantly infringe on the size of the opening. Once 'written' in concrete it was too late to change. In hindsight, making the openings larger and reinforcing the surrounding struts with metal plates would have been the solution.

There were 15 windows on the big dome and 5 on the small one. The very top of both domes had pentagons which were skylights, and the problems to overcome included hail, rain, and the summer sun. The solution was 5/8 inch thick 'Solar Bronze' Plexiglas®, which was also used on the rest of the windows that were above ground level. Solar Bronze Plexiglas® would absorb some percentage of the heat from the sun instead of passing it into the house, but it was expensive. It also had a high expansion/contraction coefficient. The rest of the lower windows were regular 1/4 inch mirrored plate glass. All of the glass was custom cut, an additional expense. Since the windows had no frames to hold them into the triangular openings, we had to figure a way to make them work. The solution was fairly simple.

A 2x6 triangular frame had been built for each window, which fit inside the 2x4 openings, and strengthened each section. (This step had been done before the stucco was applied, in order to run the masonry cement flush with the outside of the 2x6.) Inside this frame a 1x2 inch wide triangular frame was recessed to the thickness of the glass and finish-nailed into place. This was the backing that the glass would rest on, making the glass flush with the outside of the dome. Massive amounts of silicone rubber caulk were used to seal the windows. The caulk was extended over the edge of the 2x6 frame and onto the stucco about a half inch, creating a band about 3 inches wide all around each window. Silicone caulk was a relatively new product at that time, so product information was sketchy, but it seemed to do a good job as a sealant. (It does not have a 30-year life as claimed, however!)Again, the drawback was the dust sticking to it. In fact the dust-storms in Lubbock carried a good deal of static electricity, and would transfer some of this charge to the Plexiglas®. As a result the windows attracted dirt like magnets, making them hard to keep clean. Plex scratches easily, so additional care had to be taken when cleaning them. Skylights were a nice design touch, but maintenance proved to be quite a hassle. Another unforeseen problem was that the expansion and contraction of the Plexiglas® (a half inch on a hot day) made a popping noise occasionally as they touched the wooden framework, and since sound carries well in a dome it was very noticeable. They should have been seated on a thin flexible material, but once installed there was no way to fix it short of taking the windows out. In fact, any sound at all seemed louder, and a heavy rain made a thunderous noise. You could hear a whisper if you were standing in the exact center of the dome. This problem improved tremendously after the insulation and sheetrock were done, which was the next step after the wiring was completed.

5/8 inch thick skylights

Wiring was done by a licensed electrician, and did not take long. One problem that we had (other than extra expense) was an inability to run wiring to a floor plug due to a blockage in the conduit, which happened during the pouring of the slab. Floor plugs are nice, but they involve more work and additional cost, and in this case it was for nothing. In fact, I began to realize that at every single phase of construction (except the stucco, which was a great deal) the dome was costing more from the subcontractors than a regular house would! There should have been no difference.

Basement staircase before

There were other minor problems, like the location of the downstairs toilet drain being too close to the wall. (Remember the importance of checking the sub-contractor's measurements?) The solution was that a special toilet had to be ordered, an additional expense. Problems with the plumbers seemed to be a constant, like when they told me that the sewer line in the alley was higher than they had figured, so I would need an expensive lifting pump, around $4000. I opted to not go that route, looking for an alternative solution. Soon after that they went out of business, which was lucky for me, because the new plumbers that I hired worked relatively problem free. The solution to the lifting pump was simply to raise the drain line to coincide with the sewer line in the alley. Not rocket science but it worked, and with virtually no expense.

Basement staircase after

Railing on top landing

One of the more aesthetically pleasing design features of the house was a 4 ft. diameter spiral staircase that went from the basement to the upstairs loft. It was made from cast aluminum, and came In 4 boxes as a kit that required some assembly. It was well designed, sturdy, and bolted together with no problems. (In hindsight, a 6 ft. diameter would have been better, as it would have made it easier to move furniture around, but it was significantly more expensive. Also the entry hole into the basement was only 4 ft in diameter.) Later, the staircase would be painted with a special paint and the rubber railing cover would be installed. A custom metal railing was fabricated at a welding shop for the top landing.

Fireplace on white marble hearth

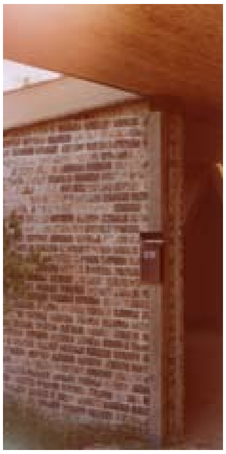

View of fireplace and loft overhang on the right

Another nice design touch was a free-standing metal fireplace (also a kit) sitting on a hearth of white marble, and was capable of heating the entire dome. It proved invaluable working inside during the winter, before the heating/ cooling unit was installed. The wall behind the fireplace was stuccoed all the way up to the top of the chimney, reflecting the heat back inside. Its design created a draft of air which made a tornado of flame, visible through tempered glass. The fireplace was not originally in the plans, so a hole had to be cut in the dome to accommodate the chimney pipe. Using a plumb bob we established the exact location, marked a circle on the plywood sheathing inside the dome, and drilled a series of holes around that circle using a masonry bit. The stucco was about an inch and a half thick in that spot, so it took a little while. After this was done a small sledge hammer was used to break the circular chunk out, and wire cutters took care of the chicken-wire. Sections of single wall chimney pipe were bolted together, and extended through the roof to a height of about 10 feet, for good draw. Silicone rubber caulk was used to fill the gap between the dome and pipe, because it could withstand the heat. It all worked very well except for one problem. Single wall chimney pipe condensed moisture, both inside the dome and outside, eventually rusting the pipe and staining the stucco as it dripped. It did not seem like a major problem at the time, but over several years this process rusted out the fireplace. Another small problem with the fireplace – the dome was so tightly sealed that when the fireplace was being used, caution had to be taken when closing the front door suddenly. If the front door closed quickly, one of the fireplace glass panels would break, imploding into the fireplace. It was a special tempered glass, and a nuisance to replace.


Stained concrete on back of dome


Angled roof flows into privacy wall

At that point of construction the exterior had been finished. A brick privacy wall had been built across the front of the house, that tapered down from the garage to the smaller dome, creating an entry courtyard. This was done for two reasons. The first was to help the radical structures blend in with the existing houses a little better, and the second was


Entry

to try to control the constant flow of tourists wandering through the property. On the day that the brick wall was finished I thought we had the problem under control, but when I returned later that evening I noticed that several bricks were down off the uncured wall! Upon going into the house, I saw a couple of people in the back yard wandering around. They had climbed the wall, damaging it as they went over. It was at that point I realized there would be an ongoing problem with tourists even after the house was finished. (Subsequent owners have reported instances where people would just walk in the house unannounced!)

Not too long after that an enthusiastic realtor came by and wanted to sell the dome. She told me that she had a buyer, even though the project wasn't finished, so I decided to list the property with her (she was the wife of the head of the building inspection department). That was a big mistake. In effect, this froze construction, because the buyer would dictate how the work would be completed, and at the price listed I couldn't put more money into it. When no buyer materialized the realtor suggested that we should have an open house some weekend, which I went along with hesitantly. I had reservations about how people would see and appreciate the dome in this unfinished state. The interior at that point had no insulation, sheetrock, interior doors or cabinets. An ad proclaiming 'Moon House for Sale' was run in the paper, much to my dislike, and the open house was held on a Sunday. As people walked through the door the looks on their faces confirmed my suspicions. Without insulation or sheet-rock, and bare wood, plumbing and wiring showing, it was hard for most people to visualize the finished product. Needless to say, we did not sell the dome that day, or any other day. After the listing with the realtor expired, work resumed on the project, and the next step was the insulation.

Paneling

Six inch thick fiberglass insulation was used instead of four inch to help with the noise problem, and was stapled to the plywood sheathing. The exterior walls only had 3½ inches of cavity space, but the fiberglass would compress that much. Supposedly it was not a good thing to do that, but I found this added to the efficiency in heating and cooling the structure, which was verified by the first utility bill after AC installation. One small problem associated with thicker insulation was that it was harder to sheet-rock over it, since it stuck out more. This problem was compounded by the weight of the sheet-rock (it is heavy) and the fact that most of it had to be put up using scaffolding. Each triangle had to be cut individually since you can't mass-cut it, which was very time-consuming and then hand-carried up the scaffolding. It used the same basic pattern as the exterior sheathing and so we had a fair amount of wasted sheetrock.

Another small problem emerged, which was very aggravating. Some of the sheet-rock nails that I bought were not galvanized, and I did not realize it at the time. When the taping and floating of the joints was done, small rust spots bled through everywhere that there was an un-galvanized nail, necessitating sealing each and every one with varnish to prevent them from bleeding rust spots through when the painting was done. After all this, acoustic ceiling texture was sprayed on, starting above the first level of triangles at ground level. This acoustic material helped abate the noise problem a lot. The rest of the house had a simple spatter texture on all walls accessible

Kitchen cabinets and appliances

to traffic, except for the entry hallway, where brick facia was used for extra durability. The brick facia was 3/8 inch thick and was painstakingly glued to the walls. A few other interior walls had pecan paneling over the sheetrock, and the upstairs bathroom had shiplap boards on the exterior of the bathroom.

Shiplap siding creates visual interest

Custom cabinet in master bath

Kitchen and bathroom cabinets were the next phase of construction, and were built by a friend in his garage. Ash was chosen for the shelves, drawers, and door fronts because of it's strength and nice grain. Shelves made of 3/4 inch ash plywood would resist sagging better than most other materials, and was the cabinet maker's preferred wood, so… I left the design of the cabinets up to him. The oven, cook-top and vent hood were chosen at that time since he needed the dimensions, and were state of the art, with electronic touch pads and a solid ceramic top. Since the kitchen was small it needed to be efficient, and his design took advantage of every square inch. Once assembled, I stained and varnished them a couple of times, sanding between coats with fine steel wool. Next, the white Formica counter-top was carefully glued on with contact cement and trimmed with a router and finally, the door and drawer handles were installed. The same process was repeated for the bathroom cabinets, with the same care and attention to detail.

Tile surface on dome

Installation of the sinks, toilets, upstairs shower stall and downstairs tub was the next series of jobs, and I was able to do them without the aid or expense of a plumber. (I did invest in a series of 'How To'…books, Which were invaluable.) Sinks were installed by cutting holes in the countertops, setting the sinks in place on caulk, bolting on the faucets, and hooking them up to the existing supply lines with compression fittings, and attaching the plastic drain and trap. Toilets were assembled, tanks to bowls, and set in place over the drain with a wax ring in-between, bolted to the drain flange, and hooked to existing supply lines with compression fittings. Hooking up the tub and shower was a little trickier, because pipes had to be soldered together using a torch, which took a little practice. I simply went by the book, and it wasn't rocket science. (Frankly, though, it was occasionally very frustrating.) Each phase of construction was like completing a new course of study in school by this point, and graduation would be the completion of the entire building project. Once the plumbing fixtures class was done it was time to enroll in another class, like the 'tiling the tub and shower stall class.

Skylight over shower stall

Actually, I hired a tile installer to do the shower and tub because it was relatively inexpensive, and after watching him I was glad I did, because there were additional angles, not just flat walls and 90˚ angles. After the upstairs shower was tiled, I installed the glass door unit, caulked, and it was finished. A nice design touch was that one of the skylight

Shower stall

triangles in the pentagon at the top of the dome was over the shower stall.

View of skylight from living room

By the time we had gotten to this phase of construction more than a couple of years had passed, due to the 6 months time off when the house was listed with the realtor, and a general loss of enthusiasm for the project. Even though the house was nearing completion it seemed as though it would never be finished. Still, one by one the final details were done, like the suspended acoustic ceiling in the basement.

Basically, an interlocking grid of metal framework was hung from wires which were hooked on nails hammered into the bottom side of the wooden forms in the basement ceiling which were left in place after the concrete slab was poured. It was easy to level up the framework by measuring off the floor and adjusting the wires, and the final step was to just put the lightweight ceiling tiles into the grid, along with recessed lighting fixtures. The entire ceiling only took about 6 hours, was relatively inexpensive, and looked good. It also helped tremendously with the sound echoing off the hard cinder-block walls and floor.

The interior doors, paneling and other trim work came next, taking several weeks due to the variety of angles we encountered. Paneling was used in the downstairs bedroom and any other walls that hadn't been textured, like the walls under the loft, and was glued with Liquid Nails® to the sheet-rock. It was also nailed with an air-driven finish nail-gun, as was the trim. Wooden doors that had been hung were sprayed with varnish, and the knobs were installed. Finally, it was time for the final step, painting. I bought a 2 gallon paint pot that was air driven, long hoses and a spray-gun, several 5 gallon buckets of acrylic latex, and proceeded to spray the interior. Note: Clean the paint spraying equipment thoroughly after each use, and it will last for years.

Staircase and small dining area next to windows

Painting around the Plexiglass windows presented a problem. Because it scratches easily, the use of a razor blade to remove any over-spray was out of the question, so they had to be fully masked off so as to not get a single drop of paint on them. Compounding the problem was the fact that after only a couple of days the masking tape did not come off cleanly, because the heat from the sun cooked the tape onto the glass. Methyl alcohol and a lot of 'elbow grease' had to be used to remove the tape residue, since other solvents would have damaged the glass.

The spiral staircase required a special epoxy paint, because it was made from aluminum and regular paints don't adhere well to aluminum. Also, durability was important. Here's a warning! It takes a respirator with a special filter cartridge to handle epoxy mists! Xylene was the solvent used to clean out the spray gun, also hazardous!

Entry hallway with faux brick

Railing on second floor

After the painting was finished the dome was ready to have the flooring installed. Carpet was chosen for the basement, main living area and upstairs loft, with linoleum going in the kitchen and downstairs bathroom. Tack-strip was nailed around the walls to hold the carpet in place, and foam padding was glued to the floor. Finally, the carpet was installed, starting with the basement. Indoor-outdoor carpet with a foam backing was used in the basement and glued directly to the floor, so no tack strip was necessary. The noise level was noticeably reduced, but there was still some echo effect from the hard block walls. Once all the carpet was laid, the noise level in the whole house went down by at least 10 decibels. The only problem with carpeting was again the waste factor and expense because of the curved walls, but still, it really was the finishing touch. All that remained was some repainting on the baseboards, which had taken some scratches and dings during this final step, and for the most part the dome was finished.

The final inspection was the last step in the building process, and I suspected that there would be a problem. Sure enough, the building inspection department told me they could not give the final approval because some of the scheduled inspections like electrical and plumbing had not been done, since they showed no entry into their logbook! Fortunately though, I had saved all of the green tags from those inspections, and when I produced them they had to comply. Note to anyone wishing to build a dome or any structure inside the city limits of any town…. SAVE YOUR GREEN TAGS, because apparently the inspections don't always get logged! Building inspectors get busy sometimes, and forget to record it back at the office. At least that's what I'd like to believe, and not that it was some deliberate attempt to stop new, progressive forms of construction.

Kitchen cooking area and doorway to utility room

Fireplace

The reality is that I came away from this project with exactly that point of view, especially when it came time to sell the dome. Once finished, there were plenty of eager buyers for the house, because it was aesthetically pleasing, unique, and well built. Actually, it was overbuilt. The problem was that all the buyers needed to finance the house through banks or other lending institutions, and every single one of them refused to loan money on it! Their rational was that it was an unproven structure, and might not last 30 years. So, if you've ever wondered why there aren't more progressive types of structures being built, and why the forests are disappearing, there is a reason. Fortunately, I had one serious buyer who managed to secure private financing for the dome, and the sale went through. After that, plans to build more domes were put on the shelf, and the experience became one of artistic statement rather than ongoing commercial enterprise.

View from street

The aesthetics of the structure had determined every aspect of construction, as though it had a mind of its own, and the end product bore little resemblance to the original plan. It was, in fact, a large

Native plants were used to help the domes blend in

Downstairs bathroom

piece of sculpture that had been modified and refined in much the same manner as any artwork, to it's ultimate final form.

The floor plan of the house was done in such a way so as to leave as much open space as possible. As you entered the front door there was a short hallway leading directly into the main living room, which was open to the top of the dome and the skylights. To the left, around the spiral staircase, was the kitchen. To the right was the fireplace and a short hallway leading into the downstairs bedroom and bath. The loft was separated from the living room by a half wall, and the only enclosed room upstairs was the bathroom and closet. The loft bathroom was pie shaped, the apex being at the center of the dome, which gave it the shape of the bow of a ship. Inside that bow was the shower stall, with skylight. Horizontal tongue and groove paneling enhanced the 'ship' effect.

Plexiglas® skylight faced southeast

In retrospect, too much attention was given to aesthetics and not enough to functionality, so as a result there was a lot of wasted space in some areas, and not enough space in others. The openness of the interior was nice, but gave no privacy to the upstairs area. A more functional use of the space would have been to completely separate the downstairs from the upstairs, which would have given more square footage of floor space, increased privacy upstairs, and would have eliminated a lot of noise and echo effect.

Other improvements in the design and construction of the dome have been realized since it's completion, some from personal observations and the rest from feedback passed on by current residents. One element that was a nice design feature but not very practical in the long run was the skylights, for several reasons. First, as previously mentioned, they popped with changes in temperature. Second, they attracted dirt. Third, they were hard to clean. Fourth, they condensed moisture inside the house on cold days. Fifth, they allowed too much heat in during the summer. Sixth, and this was a biggie,

Patio doorway

they eventually leaked! The problem was that the silicone rubber dried out and lost elasticity, and the constant expansion and contraction of the plexiglass finally pulled it away from the caulk. I've seen this happen within four years, even using premium 50 yr. silicone caulk. The problem with the caulk at that point was that it had not even been around for 50 years and so product life was mere speculation. (I used premium 30 year silicone caulk several years later on a project, only to have it fail in 3 years. The manufacturer required proof of usage in the form of returned empty cartridges! Who saves the empty cartridges?) The reason for having skylights is outweighed by the negative factors in the long run. The only way to maintain the waterproof integrity of the dome is to eliminate unprotected skylights, or to be prepared to caulk every year. Another alternative, if skylights are a must, is to have them prefabricated with flanges and flashing that is embedded in the stucco.

In fact, the standard concrete shell itself needs attention every couple of years or so, i.e. a waterproofing agent, because of constant exposure to the elements and the tendency for stucco to develop hairline cracks. There is, however, a better method of construction now available that would probably eliminate these problems, which involves the use of polymers and fibers added to the masonry cement during the original guniting process. In fact, even the multiple layers of chicken-wire could probably be reduced to a single layer, since the fibers in the mix would take their place. Polymerized concrete has been proven to be stronger, more waterproof and to last longer than regular concrete and is now being used in structural applications. If I were to build a dome today, this would definitely be the way to go.

Silicone sealant on windows

Some other feedback that I've received concerned the lack of headroom around the doors. At that time I was reluctant to take out too many of the bottom struts in order to have a larger entrance way, because I felt that it might compromise the strength of the frame during the guniting phase. However, since both doors were set back inside alcoves and the interior framing and upstairs floor joists were attached to the dome frame around the door areas, there was plenty of reinforcement in place which would have allowed the removal of several struts. Hindsight is 20/20….

So now you have finished this book and are thinking about building a geodesic dome…

Here are some suggestions.

1. Read several books on domes and also books on conventional construction.
2. Draw up your plans, and then try to visualize walking through the structure.
3. Build small models to further familiarize yourself with the structure. If you can't build a small model, how do you expect to build a larger version?
4. Work out a realistic budget, and assume that everything will cost more. Note: Smaller domes cost less to work on, and are much faster with less wasted materials.
5. Limit extravagances, and once you have started building avoid too many changes, especially with sub-contractors.
6. Talk to your banker or finance company first. They may or may not be willing to work with you on financing. If they won't, you'll need private funding.
7. Have blueprints drawn up by a reputable architect (especially if you are building inside the city limits).
8. Talk to the building inspection department first, if you plan on building inside the city limits.
9. Build outside the city limits if at all possible.
10. Do as much of the work yourself as you can.
11. Obtain several bids from different sub-contractors, and spell out exactly what is expected.
12. Try to remain flexible and to look at the project as an exercise in problem solving.

I would urge the reader who is contemplating the building of a geodesic dome to search out other information, especially people who have actually had a first-hand experience with the structure, and to use this knowledge as a base to build upon. With a little planning and persistence, and a vision of what you would like for it to be, it can be done.