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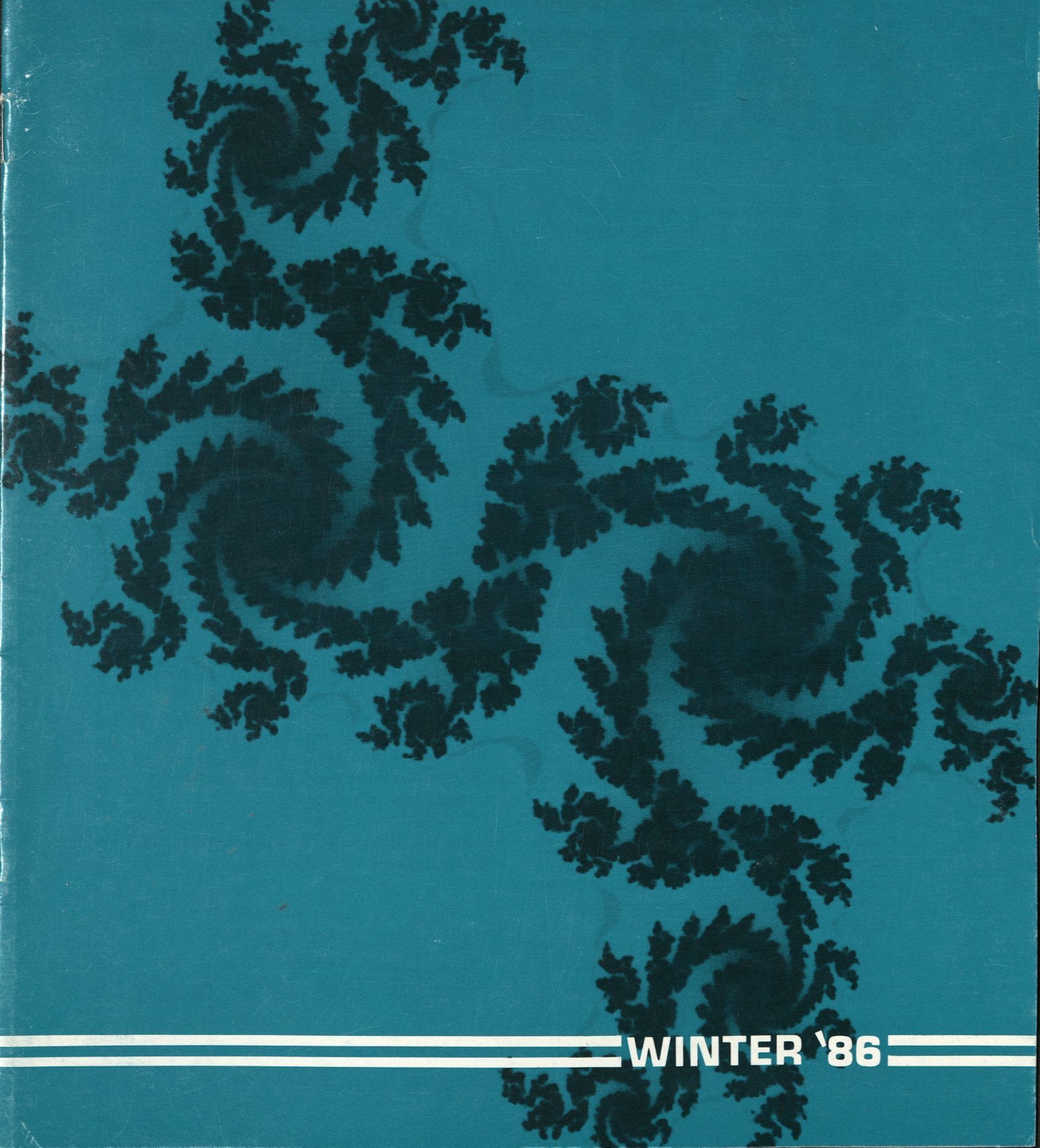

WINTER '86

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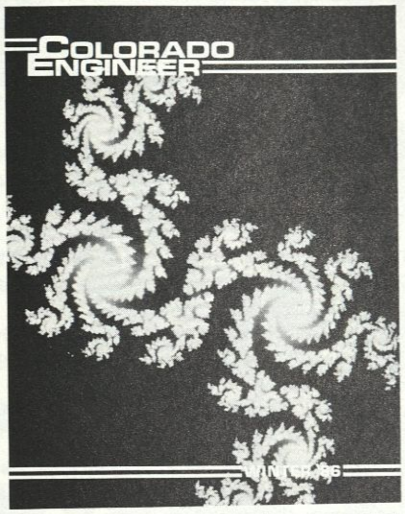
WINTER 1986 VOLUME 83 NUMBER 2



THE COVER: a computer generated "dragon" -- a slice of a four dimensional fractal shape produced by an infinite series in the complex plane. See story page 13.

FEATURES

DEPARTMENTS

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ASIDE

Going to Graduate School

THE DAY I PULLED INTO Lafayette, Ind., will be a day I will not easily forget. It was to be a new beginning and an ending, in a sense, all together.

I had just left dear old CU and was here to finish my education. Yes, I had arrived at graduate school.

My decision to attend graduate school came late in my senior year. Subconsciously not wanting to face the "real" world, I didn't pursue a job very vigorously. I was worrying about even graduating! I applied to a few schools just to see if they felt I had the right stuff.

Lo and behold, I was accepted - and even offered a teaching assistanceship. So, off I was to a new beginning at Purdue University.

Not knowing anyone at all, I chose to live in the Graduate Dorms. I am glad that I did, because it gave me a chance to meet new people rather easily.

It was tough moving back into the dorms after living in an apartment for at least a few years. The hardest part ????? - getting along with my roommate from Mississippi.

I wasn't used to living with someone else in such close confinements. At least in an apartment, there was always somewhere to go to get away - but not here.

There are graduate students here from all kinds of strange and exotic places including Europe, Asia, the Far East and even Texas. Meeting all these different people was fascinating, and continues to be every time I walk through the halls. Even though everyone comes from a different place, we are all here for one thing, and that is to study.

My first day of classes didn't seem so bad. It was mainly review of all the stuff I had learned in my undergraduate classes.

However, this was just the beginning.

From the first homework assignment, I knew I would need to really study. It took about ten hours to complete and was about fifteen pages long! The professors expect you to know the basics, or at least be able to learn it quickly.

The majority of the work is detailed and takes a bit of time to wade through. Therefore, time management becomes a big concern so that I am able to do the things I want to do - like playing volleyball and football and meeting new people. Of course, I usually stay up until 2:00 a.m. to finish my work for the next day.

My first test was a real shocker. They expect you to know the material and not just how to do the homework. In addition, they expect you to know the theory well so that application to problems follows quite easily.

This expectation comes about because of the higher caliber of people that attend grad school. Only a few people continue on to get an advanced degree, and these people really know their stuff.

To help my finances, I was able to get a teaching assistantship. I'm glad I did - not only for the money, but also for the teaching experience.

It's difficult to imagine the other side of school work without experiencing it firsthand. The professors really have a tough job trying to get the students to understand the material.

The class I am assisting is a Fluid Mechanics class, and my background in this area is rather limited (not to discredit the great professors at CU). I have to keep up with the material a little ahead of the class so I know what is going on.

I try to think about questions that the students might ask to better help them understand. Contrary to popular belief, grad students don't know everything!

The first time I met the professor I was to work with, he asked me to teach his class the following week.

He gave me the lecture materials and showed me how to present them, but I was still a little nervous having to talk in front of 50 people I didn't know. I got through it okay, and I've given a few other lectures since then. I am getting better at it, and now I even enjoy it - a little.

Overall, I think my decision to attend graduate school after obtaining my BS degree was a good one. It was hard at first to adjust to the new environment, but I am enjoying the classes and the people.

I have always wanted to continue on toward an advanced degree and during my senior year, I wasn't ready for the "real" world. The opportunity to have a little teaching experience was also a deciding factor.

For most seniors, graduate school should be a consideration- if not now, then in the future. It is definitely well worth the effort.

Rob Williamson

Rob Williamson

Editor's Note:

Be sure to look for the Engineering Societies Page in the Spring Issue (estimated time of arrival: February). Due to the overwhelming response from the societies and a lack of space, we were unable to run the page in this issue.

To those societies who submitted society descriptions, thank you and we're sorry for the delay. Of course, this also means that anyone wishing to submit a description and logo may still do so. Just drop by ST 3-5.

Dianne

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Messages from the Stars

by Linda R. Brown

FOR THE PAST 25 YEARS, NASA has been developing newer and better tools to study the universe. Astronomers have used NASA-launched satellites, telescopes, and spectrographs to reveal a fascinating collection of celestial objects. They have observed the distant throbbing of quasars,

Some quasars have energy outputs equivalent to that of a billion suns...

the slow birth and violent death of stars, and even a possible black hole in the center of our galaxy.

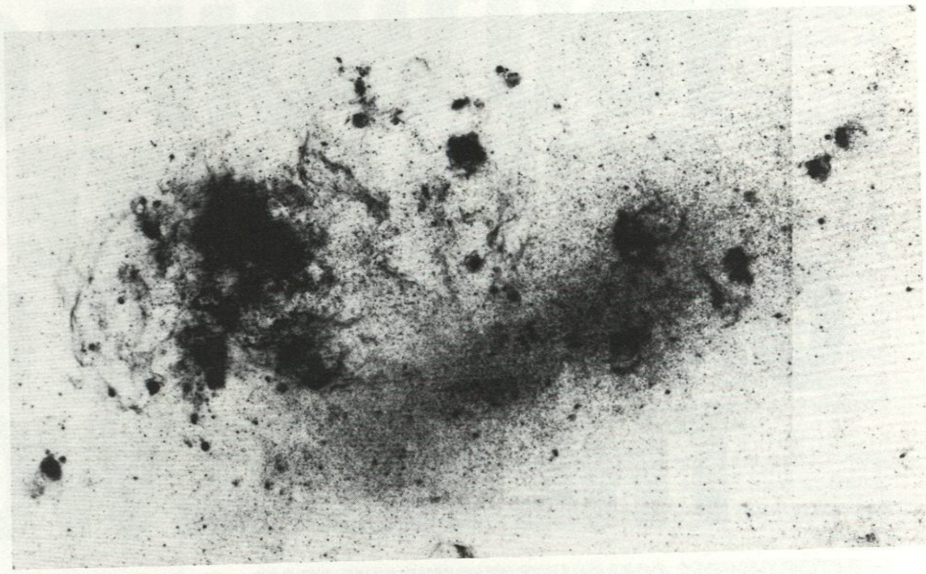
But why do these objects even exist? What makes them tick? To learn the answers, NASA has begun an astrophysical theory program. The program is designed to make the most of expensive hardware like the $1.2 billion Hubble Space Telescope, now scheduled for launch in late 1988. The program may also generate new ideas for better observation equipment in space and on the ground.

Top rating has gone to a team of 21 scientists at the University of Colorado's Joint Institute of Laboratory Astrophysics (JILA). The team, headed by Dr. Richard McCray, has received a $750,000, three year grant. The team's task is to find better ways to "decode" messages in starlight.

Astrophysical theory uses information about celestial bodies carried in their light--not just visible light, but the entire spectrum from radio to gamma ray. When light from a star or galaxy is passed through a spectrograph, the resulting spectrum can be "decoded" by the laws of physics to reveal the object's temperature, composition, relative velocity to Earth, and much more.

NASA is especially interested in wavelenghts best studied outside the atmosphere, including X-ray, ultraviolet and infrared. But the new knowledge can also be applied to radio- and visible-band spectra obtained on the ground.

The ultimate goal of spectral analysis is to



The Large Magellanic Cloud, a companion galaxy to the Milky Way. Superbubbles are visible as rope-like filaments of compressed gas. The bubble on the far left is about 3,000 light years across. (Courtesy of Cerro Tololo Inter-American Observatory)

understand the universe we inhabit. McCray's team is already using its refined methods to develop theories on everything from star formation to galactic black holes.

McCray is interested in "galactic ecology," a term he has coined to describe the intricate cycles of creation within a galaxy. "It's a beautiful concept," McCray says. "A galaxy is like a tidepool, a totally interrelated ecosystem. In a fertile galaxy like our own,

In a fertile galaxy like our own, the death of a star is not a terminal event.

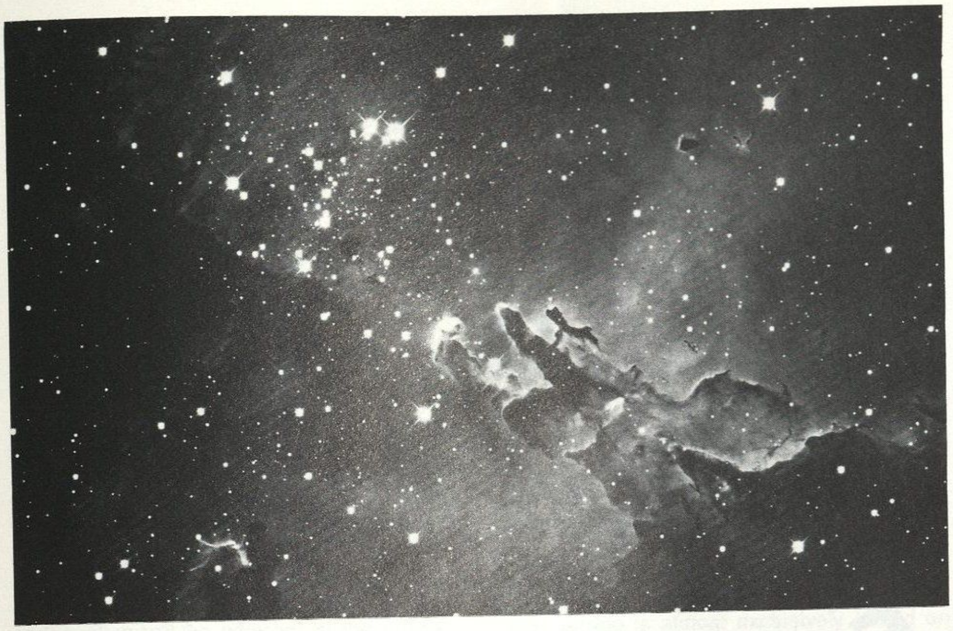
the death of a star is not a terminal event. There's a continual cycle of life, death and rebirth."

In our galaxy, the Milky Way, most stars form when cool interstellar gas is swept up by the passage of a spiral arm. The gas is squeezed into giant clouds, and stars come dripping out in a steady stream. But sudden bursts of star formation also occur, and McCray has developed a "superbubble" theory to explain them.

A superbubble begins with a cluster of massive stars like the Pleiades, a group of hot blue stars easily seen with the naked eye in the constellation Taurus. Massive stars burn their inner reserves of hydrogen fuel within a few milllion years. One after the other, these stars explode, hammering out a huge, relatively empty bubble in the surrounding interstellar gas. The gas is compressed into a shell where a new generation of stars can form.

If the superbubble reaches the top of the Milky Way's relatively thin gas disk, it may burst and spew hot gas into surrounding space. This "galatic fountain" rises and then splashes back into the disk where the gas is available for star formation in a new location. Our own sun may contain gas distributed in this fashion.

Dr. Mitchell Begelman is fascinated by some incredibly violent extragalactic neighbors. Quasars, or "quasi-stellar objects," radiate large quantities of light in the



The nebulous cluster M-16 is an active star forming region. Clouds of molecular hydrogen appear dark since they absorb light from stars beyond. (Courtesy of Lick Observatory)

blue end of the spectrum. Some quasars have energy outputs equivalent to that of a billion suns, all coming from an unseen source just a few times bigger than our solar system. Many astrophysicists believe that quasars are the active centers of very distant, newborn galaxies.

Begelman believes the "central engine" powering a quasar may be a black hole, and that our own galaxy may have passed through a quasar stage early in its history.

"If there's a black hole at the center of our galaxy--and we think we have a pretty good case for one--it's starving now," Begelman says. "But its past activity may have affected the entire evolution of our galaxy."

Black holes may have formed in young galaxies from clouds of gas and dust not yet incorporated into stars. As more and more

This "galactic fountain" rises and then splashes back into the disk...

material swirled into the center of the galactic cloud, density increased until the region collapsed into a black hole.

A black hole possesses gravity so strong that not even light messages can escape. It can be detected only by the high-energy radiation of infalling material.

This radiation may have a profound effect on the surrounding galaxy, Begelman says. Intense X-rays may create a "galactic wind" that streams through surrounding gas and changes the environment in which stars form.

"We hope the Hubble Space telescope will be able to show us the structure of nearby mini-quasars," Begelman says. "The comparison will give us more insight into the ecology of our own galaxy."

Dr. Michael Shull is investigating the very small and the very old. His research has taken him back to an era shortly after the Big Bang when atoms and molecules formed the first stars.

Most astrophysicists believe that the universe began in a great Big Bang explosion some 10 to 15 billion years ago. The early universe was a hot, dense soup filled with radiation and ionized matter in a "coupled" state. Photons were not free to travel and constantly scattered off electrons.

About one million years after the Big Bang, the universe had expanded enough for the photons to propagate freely. Electrons were then able to combine with ionized hydrogen nuclei to form atoms. Shull's research has led him to believe that a small amount of

...stars come dripping out in a steady stream.

molecules also formed at this time--enough to cool the gas so that it could collapse and form the first generation of stars.

Shull hopes that the Space Telescope's High Resolution Spectrograph will help confirm his theory by taking spectra of distant quasars. If molecular hydrogen is present, it will show up as absorption lines in the ultraviolet portion of the spectrum. Absorption occurs as light passes through intervening dust clouds.

The time and space comparisons may shed more light on the formation of our solar system.

McCray is currently drawing up proposals to use the Hubble Space Telescope.

"Some of the proposals are based on the work we've done in the NASA astrophysical grant program," McCray says. "I'm making the argument that we should be allowed to see if our predictions are correct. I think we have a very good chance." ✲

NGC-3034, an active galaxy which may show evidence of "galactic wind." The filaments of gas, top right and bottom left, extend outward some 25,000 light years from the nucleus. (Courtesy of Hale Observatory)

SHAKE RATTLE AND ROLL

by John Lehman

The Three Little Pigs

THIS IS THE STORY OF The Three Little Pigs . . . sort of. Nearly everyone knows the story of The Three Little Pigs. This version is adapted to read as a primer for earthquake engineering. Remember the wolf? "I'll huff and I'll puff"- forget about that wolf. This story uses a different wolf - the earthquake.

In this version of the story, the three pigs, as in the original, are faced with the dilemma of selecting materials and constructing homes. One pig selects straw, another selects wood, and the third selects brick. The house of straw is built simply and with little money. The house of wood is more complicated and expensive. The third house is even more complicated and more expensive than the other two.

The wolf makes the ground tremble; then the earth convulses around the pigs' homes.

To make a short story shorter, the wolf skips all the dramatics- no huffing or puffing. The wolf makes the ground tremble; the earth convulses around the pigs' homes. This incident crumbles the brick house. The pig living in the wood house loses out in this version too, as his house is damaged beyond repair. The pig living in the straw house loses some china that rattles onto the floor, but his hut is still intact. End of story.

Anecdote

This version is oversimplified. The day after the earthquake, the "Barnyard Gazette" would mention that the phones are dead, even at the straw hut. None of the pigs can call their insurance agents. They can't drive on the interstate to visit mom. There is no running water. The wolf (earthquake) has damaged such things as phones, electricity, transportation, and plumbing, leaving even the best prepared barnyard animal affected by the quake.

None of the pigs can call their insurance agents.

The story of the three little pigs does no justice to describing the devastation an earthquake can do to the environment where people live. For example, in September of 1985, Mexico City was devastated by an earthquake which killed nine thousand people. The surviving population of the most populated city in the world was rendered nearly helpless.

The three pigs' story gives some idea of what is involved in earthquake engineering. Certain structures and materials withstand earthquakes better than others. Simple structural designs, which include simple geometry and flexible connections, have withstood earthquake devastation better than the more complicated designs. Brittle materials such as brick and adobe typically crumble and fall more easily than steel and wood structures in an earthquake.

Living and Waiting, Waiting and Living

Places where people live and function socially, such as Mexico City, are a mass of vulnerable systems. Homes, plumbing, transportation networks, communication networks, and fire protection are such vulnerable systems (sometimes referred to as lifelines). The vulnerability of such systems may be engineered to be less susceptible to damage, as one cannot engineer the vulnerability completely out of anything. Earthquakes cannot be engineered out of the earth. These devastating forces have always been around, and always will be. Earthquake engineering is an attempt to make the most of this dilemma: to minimize the risks and damage of earthquakes.

Earthquakes are difficult to predict. No one has been able to consistantly forcast these natural disasters. Although lives might be saved if the world could have thirty minutes to prepare for an earthquake, buildings and lifelines would receive the consequences, regardless of how well an earthquake could be predicted.

Unfortunately, part of understanding what earthquakes do to buildings and lifelines is based on understanding what earthquakes do to the earth. Earthquakes, despite their prominence on the planet, do not occur frequently enough for earth scientists to understand them. Completely understanding earthquakes is essential to recreating earthquake situations and investigating their effects on engineered structures.

Predicting how buildings and lifelines perform in an earthquake is therefore difficult. Knowing what an earthquake is going to do - the whole world is interested. Knowing more about earthquakes is a co-requisite to engineering dependable buildings and lifelines. The goal of earthquake engineering is to make earthquakes survivable.

Given insufficient knowledge about this

...would it be better if the house was torn down and rebuilt using straw?

does not limit the possibilities of how a building will react. Describing "after the fact" *why* a building fell down is easy in comparison to anticipating *if* it will fall down. Knowing "after the fact" information is valuable only if it can be used to avoid recreating poor designs.

One fact is that all earthquakes have been different, and it is safe to say that all earthquakes will be different in the future. One question persists: *How does someone engineer safe living environments?*

A shortcoming of earth science is that rules of thumb dominate the task of predicting what the earth will do at any given time. Accordingly, such rules limit the effectiveness of engineering the risk to humans out of earthquake damage.

The U.S. Federal Government is interested in knowing more about earthquakes

phenomenon, how do we limit injury and death? How do we limit the economic hardship that goes along with living with earthquakes? How big do risks have to be to justify taking action in regard to earthquakes?

State of the Art

Currently, the state of earthquake engineering is almost exclusively based on expert opinion. Nearly everything the world knows about earthquakes is based on the judgment of people who have observed earthquakes and their effects.

Inferences and generalizations based on scientific method are the only source of generating hard data on earthquakes. (In this case, hard data may be loosely considered numbers assigned to qualitative judgments.) Given these qualitative judgments from experts, we can make statistical statements of risk. Collectively, scientists may say how much they trust their "rules of thumb". Engineers, in turn, may say how much they trust their designs.

For example, the world has encountered earthquakes in some areas more than others. In these areas, certain structures are less survivable than others during earthquakes. Someone who is considered to be a reliable expert might predict that a wooden house, built on cripple studs in Palo Alto, California, has a 20% chance of hurting an inhabitant in the event of a groundshaking earthquake. Hypothetically. what an earthquake engineer does with expert opinion data is answer the question: What can be done to make the wooden house safer? Or, in other words, would it be better if the house was torn down and rebuilt using straw?

The Real Story

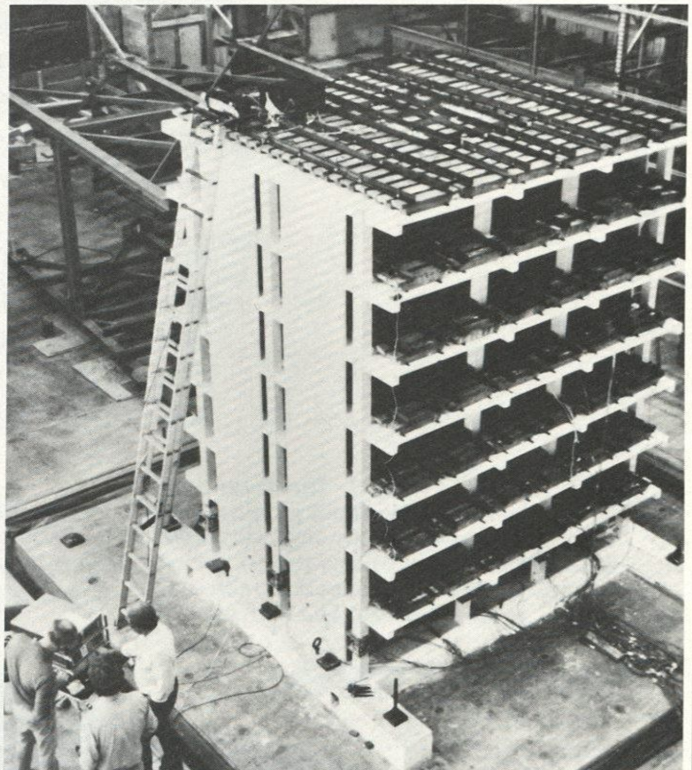
If dealing with an earthquake was as simple as moving in with one's brother (the pig with the straw house), then earthquake engineering would not have much use. Engineering social living is complicated by things such as architecture, plumbing, mass communication, and mass transportation. The world in 1986 is at the mercy of a moving and changing earth. Historically, earthquakes have shown little mercy. The role of earthquake engineering is to deal with the consequences and live with a changing earth.

Engineering Safe Living Environments

PERFORMANCE OF A BUILDING during a simulated earthquake can be analyzed in the lab. The Earthquake Engineering Center at the University of California at Berkley uses a shaking table to simulate earthquake conditions. Various materials and structures for building design are loaded and "shaked" on the table.

The shaking table helps earthquake engineers in several ways. By building small scale models, the table is relatively cheap, and different designs can be repeatedly tested. From the design standpoint, shaker table research generates data on weaknesses and strengths of structures and materials.

The shaking table does not take into account all the consequences of an earthquake. It does, however, simulate dynamic loading conditions that are difficult to foresee and analyze on paper. Knowing what structures and materials to avoid in earthquake-prone areas is a key to engineering safe living environments. ✻



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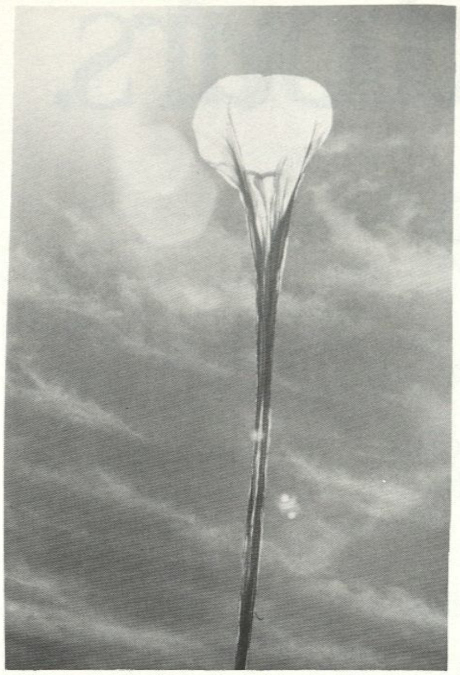


The balloon in flight. Photo by Steve Roughton.

The Fallacy of Fluorocarbons

by Mark Chambers and Dave Massey

THE NATIONAL OCEANIC and Atmospheric Administration (NOAA) is commissioned to provide meteorological information and forecasting.

One division of this organization is the Geophysical Monitoring for Climatic Change (GMCC) program. GMCC operates out of Boulder, Colorado and has global stations throughout the world. This organization investigates concerns that affect the entire globe. Solar radiation, aerosols, and the levels of carbon dioxide are all being observed by scientists at GMCC. Another section of GMCC investigates the ozone layer that protects the earth.

The staff at GMCC consists of a number of professionals and non-professionals that investigate the previously mentioned global concerns. GMCC is tied to the University of Colorado (CU) through the Cooperative Institute for Research in Environmental Sciences (CIRES). CIRES is an organization consisting of professionals supported by CU. Additionally, a portion of the staff consists of students presently attending CU.

GMCC operates out of Boulder, Colorado and has global stations throughout the world.

One of the current problems being investigated by GMCC is that of ozone destruction and, in particular, ozone destruction over Antarctica. Until recently, it has been primarily theorized that this ozone destruction has been due to the presence of chlorofluorocarbons in the atmosphere; the source of these chlorofluorocarbons is from industry such as the propellents found in spray cans.

Some steps were taken to prevent chlorofluorocarbon damage to the ozone, and yet the production of chlorofluorocarbons continues. Whether or not chlorofluorocarbons cause a portion of the damage to atmospheric ozone, or are one of several causes that contribute to ozone change is still under investigation. Even so, chlorofluorocarbons are the leading chemical compound in the atmosphere that could cause ozone destruction.

One possible cause of this perceived ozone destruction has been presented by W.D. Komhyr and R.D. Grass of GMCC and R.K. Leonard of CIRES. This theory is based, in essence, on a transport phenomenon - the natural redistribution of ozone which occurs on an annual basis in the Southern Hemisphere.

This peculiar circulation of ozone happens during the austral spring (spring in the Southern Hemisphere), from September until November. Theoretically, during this period, the middle stratosphere of the Southern Hemisphere undergoes a unique transformation - ozone poor stratosphere from the tropical and subtropical regions of the hemisphere is interchanged with ozone rich stratosphere from the Antarctic region.

In addition to this, a delay in warming of the upper stratosphere of the Antarctic region also causes a disruption of the normal ozone transport mechanism of the hemisphere. Both of these factors contribute to the ozone 'hole' prevalent over the Antarctic during this period and it is this hole which has caused such great concern over the possible destruction of

Scott Kuester and Patrick Reitelbach launch the balloon carrying the ECC Ozonesonde. Leigh Fanning mans the receiving dish while Bernard Mendonca records the event. Photo by Steve Roughton.

ozone. From this transport phenomenon, Komhyr, Grass and Leonard developed a dynamic theory of ozone transport, rather than ozone destruction.

This theory is supported by data obtained from a number of monitoring stations. The instrumentation used by GMCC to investigate the Earth's ozone layer are the Dobson Spectrophotometer and the Electro-chemical

One of the current problems being investigated by GMCC is that of ozone destruction...over Antarctica.

Concentration Cell (ECC) Ozonesonde.

These instruments provide two different methods to obtain ozone data. The Dobson utilizes optical properties to make ozone measurements. The ECC Ozonesonde operates on chemical reduction measurement to get ozone concentration measurements.

The Dobson Spectrophotometer is a ground based instrument that compares two side by side narrow band ultra-violet (UV) irradiances. The relative transmission of the pair of UV bands, as they are absorbed in the atmosphere, are compared and used to compute the amount of ozone in a vertical column of the atmosphere.

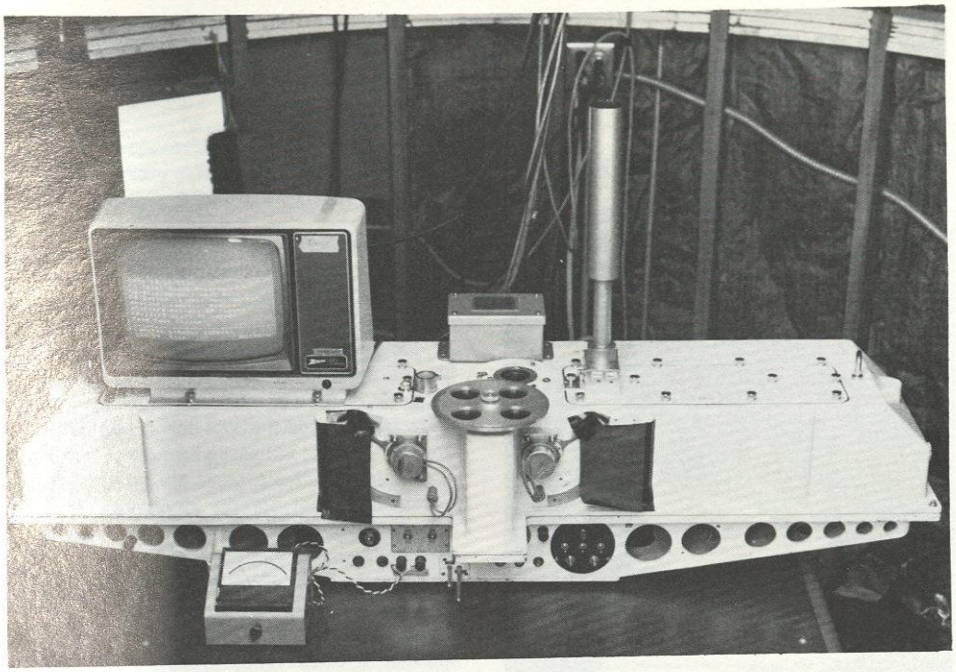
The ECC Ozonesonde is a balloon launched instrument that uses a transmitter to send data to the ground base. On the whole, the balloon launch requires more man-power than the Dobson but it provides an ozone profile measurement at different altitudes. The ECC Ozonesonde was developed at GMCC by Komhyr.

Ozone data has been obtained with the Dobson since 1962. Since 1964, the Dobson data has been accepted as an accurate measure of the amount of ozone in the atmosphere. A 12-month running mean plot of the Dobson data displayed many trends to the GMCC scientists.

The ozone over Antarctica has shown an austral spring decrease since 1964. During the remainder of the year, the ozone decrease recovers to about its original level. This austral spring decrease has accelerated since 1980. Major spring decreases were observed during the years 1965, 1969, and 1973.

Within a period of two years the atmospheric ozone showed a recovery from these major decreases. The recovery was substantial enough to almost overcome the amount of decrease that occurred during these major spring declines. Another significant decline occurred in the year 1980. However, no austral spring recovery has been measured in the years following the 1980 decline.

It is this recent continuous decrease which has given rise to another theory which



The Dobson **Spectrophotometer**

has come to the forefront of atmospheric studies - gas phase ozone destruction. Originally presented by Farman, Gardiner and Shanklin of the British Antarctic Survey, the gas phase theory has been modified by a team including S. Soloman of NOAA and R. R. Garcia of the National Center for Atmospheric Research.

This gas phase ozone destruction is based on a chemical reaction in the stratosphere which produces a change in the composition of the ozone layer. Initially, Farman, et. al., proposed that the prevailing low temperatures of late winter and early spring cause an increase in the growth of inorganic chlorine.

The growth of this chlorine, and the effect of this growth on the NO_2/NO ratio causes a change in the composition of the Antarctic stratosphere. This change, along with the peculiar ultraviolet irradiation found in the polar stratosphere, was believed to be a reasonable explanation for the observed ozone destruction.

Soloman, et. al., however, have proposed that homogeneous gas phase chemistry could not entirely explain the ozone destruction which had occurred. Moreover, it was proposed that a heterogeneous reaction caused the ozone destruction.

This reaction occurred in polar stratospheric clouds, a phenomenon unique to Antarctica. It is this specific heterogeneous reaction which has also come to be accepted as a plausible explanation for

The destruction of the ozone in the austral spring over the South Polar region has been established by a number of sources. Two theories of the cause of this destruction or decrease have become the leading theories: transport phenomenon, and heterogeneous gas phase destruction.

The evidence available to this point might suggest a combined hypothesis, but a definite, general theory has not yet been proposed. Certainly some of the damage to

Certainly some of the damage to the ozone might be attributed to chemical processes

Antarctic ozone destruction.
the ozone might be attributed to chemical processes, as evidenced by the general decrease over a period of time. However, the periods of decrease and recovery must be explainable by some other phenomenon, such as a transport phenomenon.

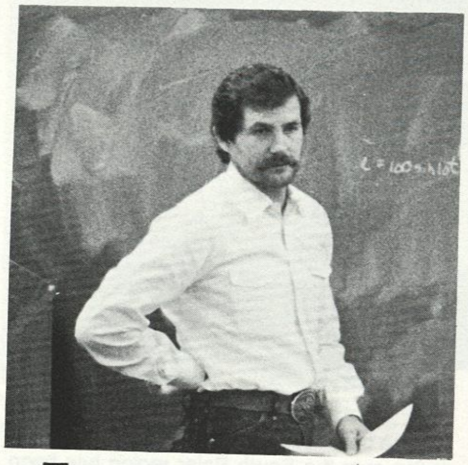
It is this combined hypothesis which perhaps explains both the comparative data and the natural cyclic balance of the overall data. While a number of theories have been provided to explain the existence of ozone depletion at Antarctica, no theory is conclusive enough to sufficiently explain the phenomenon. GMCC has taken a 'wait and see' attitude towards the whole issue but will continue to investigate this peculiar occurrence at an accelerated rate. ✲

The authors of this article wish to express their appreciation to both Bernard G. Mendonca and Walter D. Komhyr of GMCC for their assistance.

PROFILES

"I'm not your typical professor"

by David Witt



THIS YEAR CIRCUITS - 1 unveiled a rather interesting surprise. His name, Bill Edwards; his title, Associate Professor for the College of Engineering. On the first day Professor Edwards walked in wearing a rodeo T-shirt, blue jeans, and Reebok tennis shoes.

While the class was trying to sum up the situation, Professor Edwards started the period in the following manner: "My name is Bill Edwards, and I'd prefer you call me Bill. I'm not your typical professor. I'm not going to stand up here with my back to you and lecture all hour. I don't believe in that. If you ask me a question I'm liable to throw you the chalk, ask you to come to the board, and have YOU tell ME what you think. Now if you don't like it, I'm telling you to get out now."

"I'm not your typical professor" is quite an understatement, as my fellow classmates and I have found out this semester.

Sure he's got all of the typical credentials: B.S. in mathematics, Brigham Young; M.S./MBA, National University; Sc.D. Applied Mathematics, M.I.T.; 13 years professional experience including Bell Labs, Texas A&M, University of Texas; and the list goes on and on - but he's definitely not you typical professor.

How many professor s do you know who wrestle steer? ("Weekend stuff," according to Bill.) Or better yet, how many people do you know in Colorado that not only admit that they are from Texas, but are actually proud of it?

Bill's more like a good old boy from back home, the local garage mechanic, or even someone right out of the hillbilly era. (Bill has actually been inadvertently addressed as a janitor once by a fellow professor.)

The biggest difference I've found in Bill is that he not only cares, but he shows it. That seems to be something you don't find in undergraduate professors. So, being distinctly interested in this new associate professor, I decided to find out what makes him tick.

"I'm not an engineer," Bill says, "I'm a scholar, a scientist." His explanation to this statement is, at heart he really feels he is an engineer (in a sense), but because of his degree and personal research (mathematics and non-linear wave phenomena) many engineering schools would refuse to hire him. Interestingly enough, Bill has taught engineering courses ranging from basic algebra and logic circuits to graduate level communications.

When asked about his education, Bill said, "Is it important what schools I've gone to in the past? If you really want to know, you can look it up in the college catalog. No, what's important is what I'm doing right now."

Being in the classroom with Bill ia a real experience. In every class period at least one person - usually more - goes to the board and actually does a problem, teaching it to (or being corrected and taught by) the class.

"If you're learning you are contributing," Bill says. "All right, now teach someone else something."

When asked about how he conducts his classes Bill commented, "The point is you're understanding what you're doing and you have to be prepared. I have a way of making you [the student] do something. Prepare, get up in front of people, create confidence in yourself, develop a positive ego."

Bill went on to say, "I'm very pro-student. That's the commodity on the market we [professors] put out. Their [the students] performance is a direct reflection upon them and me."

"I've been able to touch the lives of people, that's important to me." says Bill. Touching the lives of people is something he does well. His office contains many pictures of past students, fellow employees, professors, etc., all of whom he is more than happy to tell you a story about.

How many people do you know in Colorado that not only admit that they are from Texas, but are actually proud of it?

A class with Bill becomes a personal thing, both for Bill and his students. Everyone teaches. Everyone learns.

One thing about Bill, though, that you need to be warned about. He is incredibly honest and straight forward.

"Stop by my office sometime and I'll tell you what I think of you," he says. ✲

Fractals: Variations on a Dimension

by *Michael Sandige and Mark Gentry*

JUST WHEN YOU'VE mastered euclidean geometry, someone has to come up with something completely different. Instead of the familiar circles, squares, cubes, or triangles, new geometric shapes emerge--shapes that appear bumpy, wrinkled, warped and crinkled. Shapes that defy description in their apparent randomness begin to appear in the realm of fractal geometry.

Coined by Benoit B. Mandelbrot, a research fellow at the IBM Thomas J. Watson Research Center, the word fractal implies fragmented and irregular. Fractals are shapes with fractional dimension, strange beasts Mandelbrot hunts between dimensions. These shapes have interesting and unique properties, foreign and unexpected to those familiar with euclidean geometery.

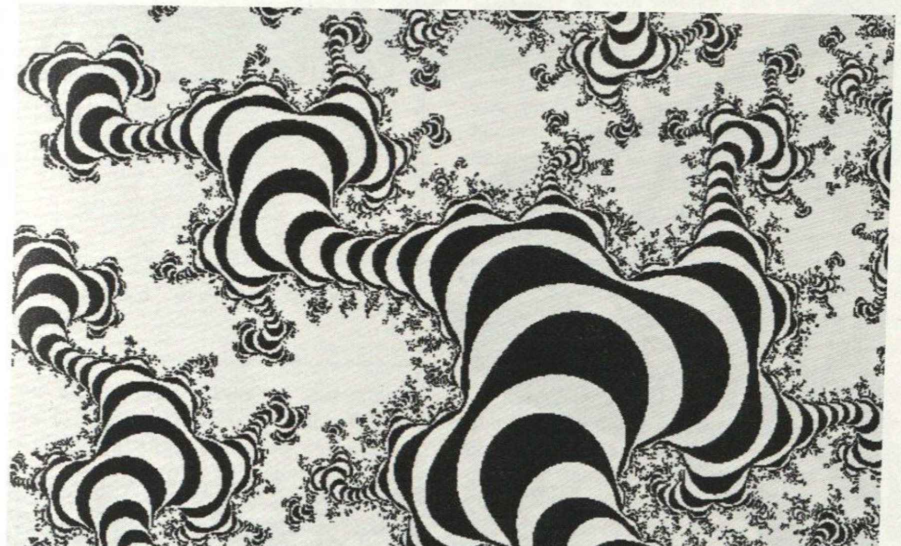
Nothing in nature is a perfect geometric shape like a square or a sphere; fractals were invented to approximate nature. For example, it would be very difficult to accurately model a tree with cylindrical stems and elliptical leaves.

Fractals, in their patterned random wanderings, do a much better job of imitating nature. As you look at a branch of a tree, each smaller connecting stem is similar in shape, differing only in scale. This infinite series of self-repeating shapes is a distinguishing property of fractals. Many fractal sets are infinitely self-repetitive at smaller and larger scales.

Another unique property of fractals that imitates nature is their infinite detail. In nature, the detail of objects is related to the scale at which they are viewed. From a high flying airplane, the fields of a farm appear flat and featureless. As the airplane descends to land, features that were not visible before become apparent. Upon touchdown, the ground nearby had even more texture. Approaching the ground with a magnifying glass shows a new, deeper level of detail.

Fractals, unlike other geometric figures, mimic this property of detail at every level of magnification. On the screen of a powerful computer, for example, a fractal mapped onto the two-dimensional screen may look like a warped circle, but as the computer changes scale for a close look at the edges of the map, an entirely new set of features unfolds.

A spiral from the Mandelbrot set twists into infinite depths near the complex coordinates 0.26 + 0.001i.



Detail from the Mandelbrot set at the complex coordinates -0.26 + 0.001i.

Fractals are being used for a growing number of applications as their popularity increases. Since the mathematics behind fractal images is extremely time consuming for even the fastest computers, the use of fractals has not been widespread. However, new generations of faster computers constantly make new applications practical.

Fractals have a wide range of applications in many areas that lack handy general equations. Although these areas span everything from biology to sociology, fractals have been used primarily in the field of high resolution computer graphics. This primary use involves creating the extremely realistic computer images in motion picture simulation, as well as art in a bizarre and enchanting new form.

Mandlebrot, in his book *The Fractal Geometry of Nature.* explains how a combination of fractals with random numbers can be used to create some of the most realistic landscapes ever simulated. This idea of mating random numbers and fractals has been used in computer animated images to reproduce plants, mountains, clouds, and their irregular surfaces. A more subtle use of this method produces the textures of normally geometric objects and backgrounds.

Art in a bizarre and enchanting new form...

Many of the masters of computer simulation have used fractals in movies for special effects with a high degree of realism.

Lucasfilm's computer graphics team, now known as Pixar, is leading in this field.

An example of the spectacular graphics emerging from their work is the Genesis sequence in the film *Star Trek II*. The Genesis missle impacts with a dead world, sending a wall of fire out to engulf the planet. The planet cools, as mountains and seas begin forming. The film shows a breathtaking journey around the planet and through the growing fractal mountains at blurring speeds.

Practical applications aside, the shapes created by fractal geometry also provide a new art form. Mapping a raw fractal to the computer screen shows an infinitely large collection of shapes and patterns. Each pattern generated will yield thousands of smaller, similar, but distinctly new patterns at a new scale.

Certain color combinations, applied to pleasing patterns, can create images that are strangely captivating. Once one has explored a fractal until one tires of the style of patterns it offers, one can change its formula slightly, opening the door to an entirely new set of patterns waiting to be discovered.

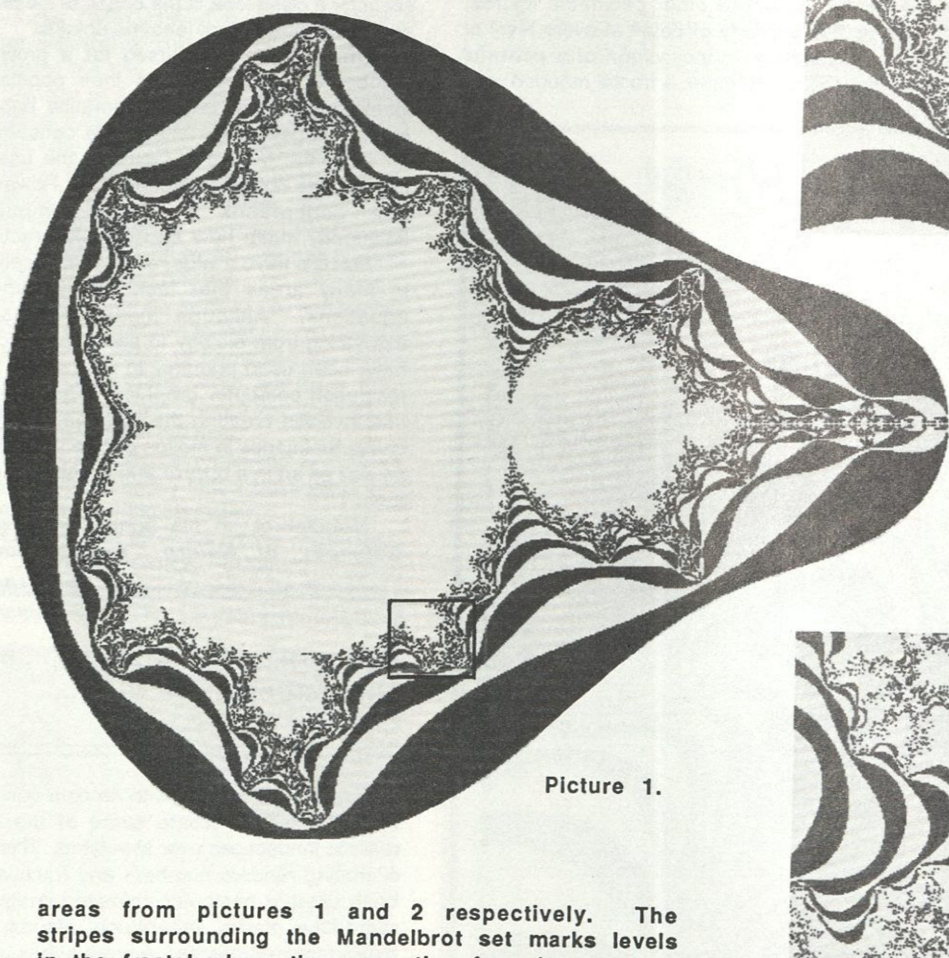
Approaching the ground with a magnifiying glass...

In his book, Mandelbrot outlines the fractal aspects of almost everything mathematically unrelated to eucledean geometry. Since the images he works with are so difficult to describe, he defines his own language to describe the features of his fractal "monsters."

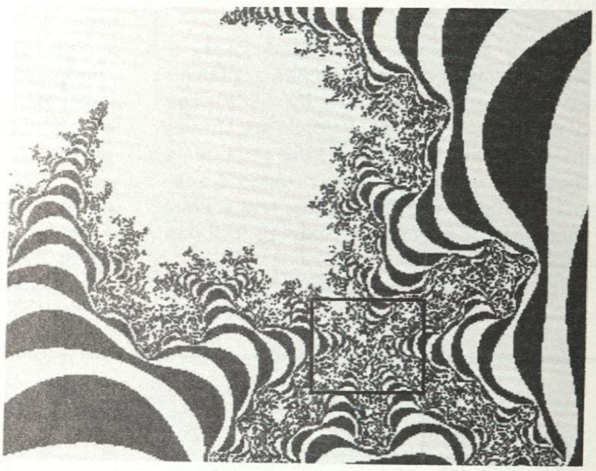
Terms such as pertiling, dust, trema, and molting are used mathematically to demonstrate the unusual properties of fractals and describe their graphs. These fractal sets can be broken down into several major kinds of fractals including random fields, Koch Curves (snowflakes), dragons, and, of course, the popular Mandelbrot set.

Random fields are the basis for generating simulated three-dimensional natural landscapes and textures. To picture this

This is a series from the fractal shape called the Mandelbrot set. Named after Benoit B. Mandelbrot, the first mathematician to investigate it and the new field of fractal geometry it comes from. Picture 1 is the entire fractal set, viewed from a distance. Pictures 2 and 3 are magnifications of the marked areas from pictures 1 and 2 respectively. The stripes surrounding the Mandelbrot set marks levels in the fractal where the generating formula passed a certain point on its way to infinity. Each stripe inward can be thought of as a region where the speed that the function approaches infinity decreases.



Picture 1.



Picture 2.

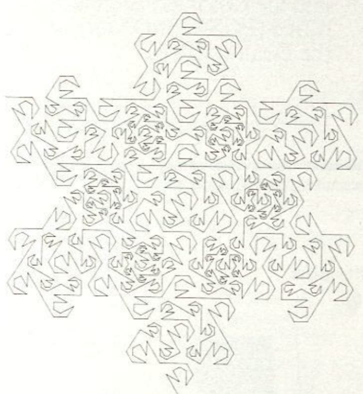
Picture 3.

algorithm, take a triangular plane in two dimensions and inscribe a smaller triangle inside it. This divides it equally into four smaller triangles, connected to the midpoint of the sides, with a common point in the center.

Push each point that connects the four triangles a random distance up into the third dimension. Now, divide each of the small triangles into four even smaller triangles. Push each of their connecting points up or down, perpendicular from the original plane a random distance.

Limit the random amount that these points are moved by the heights of the nearest points. Continue this recursively until the size of the triangles becomes too small to matter.

By using larger random vertical displacement, rough and treacherous mountains with deep canyons emerge. Smaller changes in the random numbers produce weathered hills, and wide valleys. The random factor can be adjusted to build a vast, strikingly natural landscape. The December 1986 issue of *Scientific American* contains an article on this type of fractal with excellent illustrations.



A snowflake fractal based on vectors.

One of the most pleasing and simple fractals is the snowflake, or Koch Curve, fractal. These fractals are vividly self-similar, a property difficult to describe, but immediately obvious from a picture.

To construct the patterned geometric progression for a snowflake, start with a simple set of vectors, connected to form a bent, or crooked, line. The first vector should lie in the same line as the last vector, so that the set resembles a line segment with a middle portion erased and replaced with a few connected lines. Take each vector and replace it with a smaller version of the whole set of vectors.

Like the random plane, repeat this pattern of replacements until a pleasing level of detail is obtained. Using a very similar process, some random vectors, and the third dimension, plants and trees can be accurrately simulated.

Mandelbrot's dragon curves are less useful to directly mimic nature, but they are certainly more pleasing artistically. Dragons are a considerably more complicated fractal structure, that Mandelbrot introduces in his book. Strangely twisted and forbidding, these shapes resemble silent beasts, hiding within the confines of complex numbers and willing to emerge only at a computer's bidding.

They involve an infinite series of mathematical calculations, with each calculation using the previous result to determine the next. Seen projected on the computer screen in two dimensions, these dragons actually rest sprawled across four-dimensional space.

These dragons actually rest sprawled across four-dimensional space.

To subdue a dragon, the squaring $x=ux(1-x)$ is used, where x and u are complex. The first time the formula is used, the complex variables x and u are the coordinates of a single point. As the calculation series progresses, the value of x will often bound off toward infinity, or it may stay small, near one or zero.

Locate a bit of a dragon with the computer as your weapon, set the value of u constant, and vary the initial real and imaginary parts of x respectively with the x and y points on the screen. Every point that you find that, rather unusually, doesn't become infinite after a certain number of iterations is part of the dragon. The final image is certainly self-similar, usually compelling, and slightly psychotic.

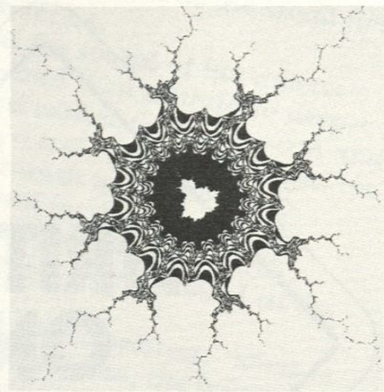
Popular to enthusiasts of computer graphics, the Mandelbrot set has come to be a symbol of high-speed computing power. It is frequently used in advertisements for new graphic based systems, and is usually rendered in an array of inspiring colors.

An image of the Mandelbrot set consists of a large circular cusp surrounded by similar connecting cusps. Each of these smaller cusps is itself surrounded by even smaller cusps, and this pattern faithfully continues past the limits of imagination.

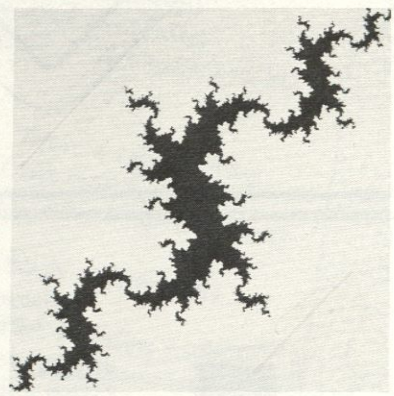
Like the dragon set, this set is based on an iterative infinite series. The formula x=x^2+u is used, with x and u being complex and starting out as the coordinates of a given point. The actual Mandelbrot set is the set of all points where x fails to converge to infinity after an infinite number of iterations.

All the points near the origin fail to converge, and points further from the origin than two always converge. It is the areas between these that are more interesting, areas of instability where convergence mixes with non-convergence in a maelstrom of infinite spiraling patterns.

So far, the beauty of fractal geometry has been used for the simulation of nature and for an odd, new art form. It is the hope of Mandelbrot, and others researching in this field, that fractals may someday be used to mathematically describe the beauty of nature itself. ✻



A minature Mandelbrot set magnified from an arm off the main set. This image is magnified 10^7 times from the picture of the main set.



A "starving dragon" fractal similar in structure to the cover picture.

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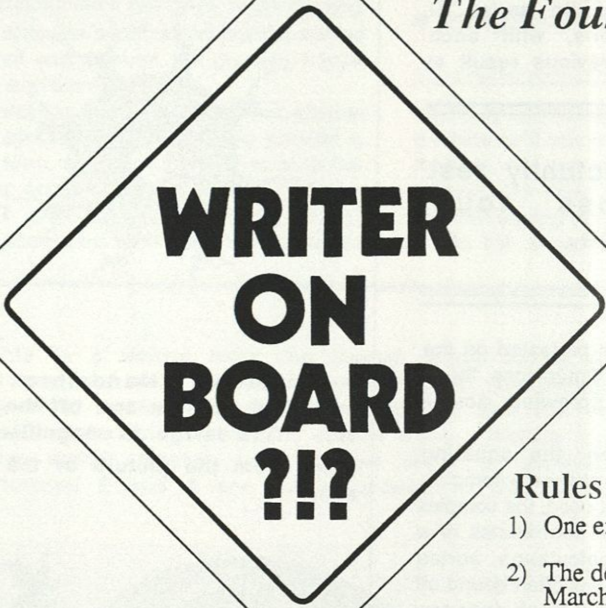
Cover: The image was taken from a photograph off the screen of a Sun 3/160 workstation. We would like to thank the John von Neuman Consortium for Scientific Computing, of which the University of Colorado Boulder is a member, for providing acess to their Sun 3/160 workstation. The John von Neumann Consortium for Scientific Computing is funded by the National Science Foundation.

The Colorado Engineer Presents...



The Fourth Annual Science Fiction Contest!

The Colorado Engineer will once again try to answer the age-long question: "Can engineers write?" So get those creative juices going and those pencils pushing and enter our science fiction contest... Pronto! Show us that engineers can actually write!

Rules:

1) One entry per contestant
2) The deadline is Tuesday, March 17, 1987
3) Your story must be:
   - Typewritten and double spaced
   - At least 2000 words
4) Four separate photocopies of your story need to be turned into the Colorado Engineer office (ECST, 3rd floor) or the Dean's office.
5) Please put your name, address, and phone number on each copy

The Spice of Life

"Thyme!" called the chubby girl. She glanced nervously back at the small herd of sheep in the meadow, and then forward into the dark forest.

The black and white border collie, perking his ears at the sound of his master's voice, started to turn back toward the meadow, hesitated, and then withdrew deeper into the shadows. He had discovered a bobcat near the herd earlier that afternoon and had chased it into the forest, where it was now trapped in a tree. Thyme had held the hungry bobcat captive for most of the afternoon and didn't wish to let it go now.

The cat, who was now agitated, hungry, and frightened by the sound of the girl's voice, decided to try to escape. Without warning, he leaped from his perch, hurtling himself at the small dog below. With a scream of pain, Thyme rolled in the sage, trying vainly to dislodge the furious form on his back.

Hearing her dog's fearful cries, the girl rushed into the forest, yelling, "What is it Thyme--what is wrong?!" Realizing that the girl was coming close, the bobcat took one last swipe at Thyme's belly and then slunk off into the woods.

"Oh, Thyme," wailed Rosemary. "Speak to me! Paaaappy!" she cried and laid her hands on the blood-spattered fur. Thyme looked up at her, panting.

Moments later, Rosemary's father came running down the path from the meadow. "What happened?" he asked.

"Oh, Pappy, Thyme was trying to chase a bobcat away from the sheep!"

"Let's take a look." Mr. Parsley crouched next to the dog and carefully examined his wounds. "Hmmm," he muttered quietly to himself. "It's going to be hard to get the sheep to the fair now."

"But Pappy, I'm sure you can make him better!"

"Well, now, let's see. It's not as bad as it looked at first. There's really only this bad cut in his side here. See, it just looks bad because of all the blood. Look."

Rosemary squinted at the dog's side, then stroked his head. "Oh, Thyme, you'll be okay. Pappy'll fix you up."

Mr. Parsley stood up. "Camp isn't too far away. You run back and get the first-aid kit."

Rosemary raced off, returning minutes later with the kit. Mr. Parsley found the surgical tape and needle and sewed the gash in Thyme's side, while Rosemary held the dog's head. When he finished, Thyme rose unsteadily to his feet, and Rosemary clapped her hands and cried, "Oh, Pappy, we'll be able to get to Scarborough Fair tomorrow after all!"

Thyme perked his ears and took several tentative steps down the path. "Woof!"

"Look, Pappy! He's ready to go right now!"

"No, Rosemary," her father countered. "He'll need to rest for at least a night. Let's see how he's doing tomorrow morning."

Mr. Parsley led the way back up the trail through the sage to the meadow where their camp lay; Thyme trotted stiffly a few feet behind Rosemary. As they came over the top of a rise, Mr. Parsley stopped suddenly, staring down into the meadow below.

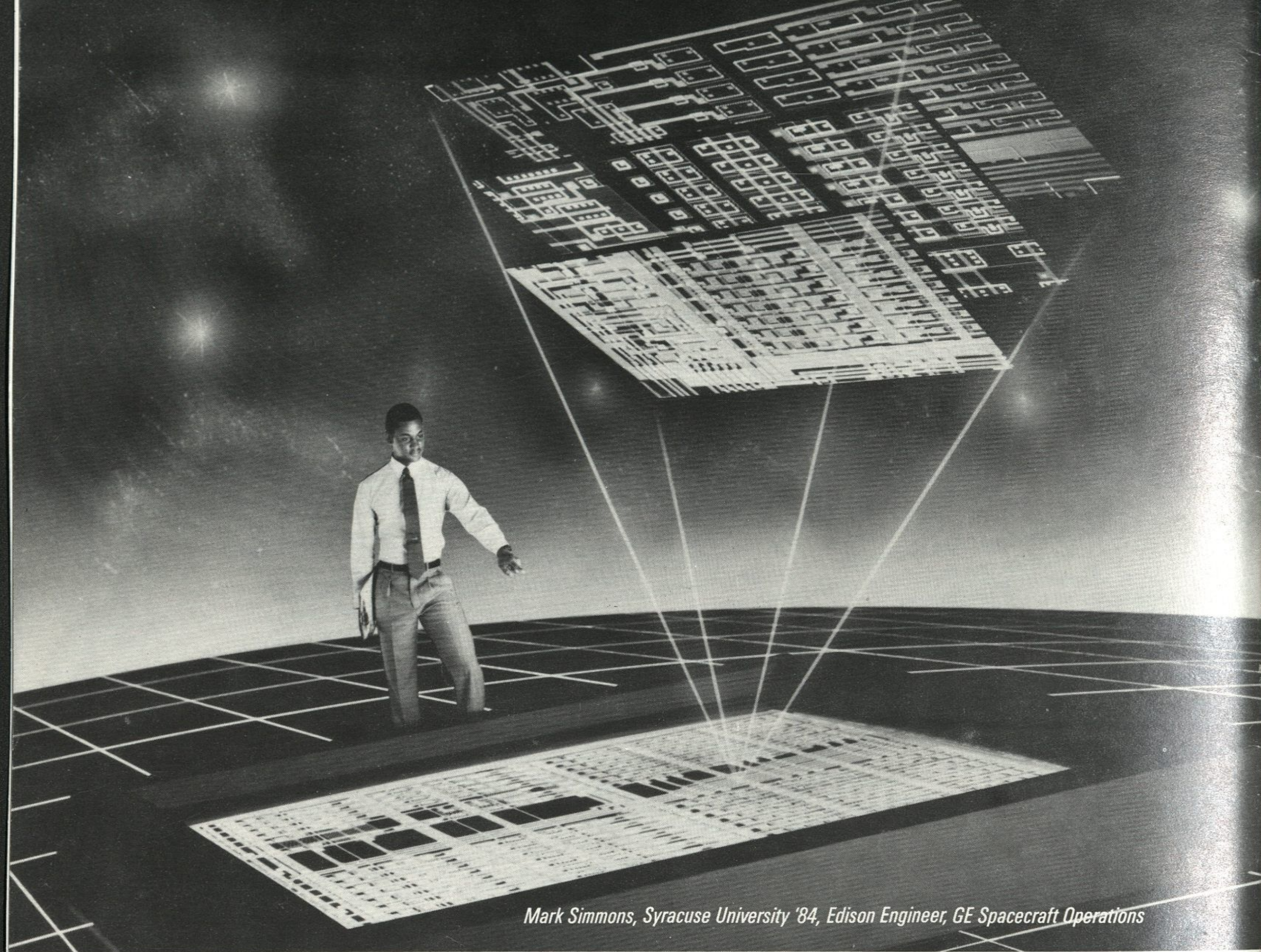
"Hey!" he shouted, "What're you doin'?"

As Rosemary came up next to her dad, she saw the reason for his outburst: down below, a scrawny, tattered teenager had gathered the nine sheep in the flock and was herding them away across the stream.

The dog, all stiffness forgotten, raced down the hill, barking and growling. The boy looked up, anger and fear showing plainly on his face. With a gigantic bound and a whimper of pain, Thyme hurled himself straight into the boy's chest, tumbling him into the stream bed. Struggling to rise, the young thief let out a terrified scream where he discovered that his chest was splattered with blood. Thyme furiously shook the boy's shirt front. Ripping the shirt from his body, the would-be rustler jumped to his feet and ran as fast as his scrawny little legs would carry him away from the meadow.

Thyme collected the nine sheep as Rosemary and her father ran down into the meadow, praising him loudly. Rosemary gave her dog a big hug and smiled at her dad, saying, "Well, Pappy, I guess the stitch in Thyme saved nine."

Ian McEwen and Amber Benson



Mark Simmons, Syracuse University '84, Edison Engineer, GE Spacecraft Operations

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