NAAPO (North American AstroPhysical Observatory)

"Signals"
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Donation from John Kraus

Dr. Kraus recently made a donation to the Radio Observatory. Our great appreciation is best expressed in the text of Bob Dixon's thank you letter that follows. -ja-

Dr. John Kraus
1854 Home Rd.
Delaware, OH 43015

Dear John,

Thank you very much for your generous donation of $2,500.00 to the Radio Observatory. As you know this will go a long way in improving and expanding our current operation by allowing us to obtain needed parts and repairs for our equipment.

With our new group of volunteers we are making good progress with the software for the new computer system, and hope to soon implement a program of maintenance and improvement to the physical structure of the telescope.

As you know, we are in a good position to play a major role in NASA's expanded SETI project if their budget makes it through Congress. We are very optimistic for the future and your donation does a great deal for us in the present. Thanks again.

Sincerely,
Robert S. Dixon
Assistant Director

Ohio State University Research News Service

May 1988

A Change in the way we listen for signals from "Out There"

Ohio State University's 15-year-long program of listening for signs of intelligent life in the universe is undergoing an overhaul—new equipment will allow scientists to reorganize the way they run their search.

Thousands of unidentified transmissions have been detected by Ohio State's large radio telescope since astronomers began listening in 1973 for signs of life, says Robert Dixon, assistant director of Ohio State's radio observatory. The nature of these transmissions has never been established, however, because astronomers were never able to study them.

The telescope's fixed design uses the rotation of the Earth to conduct its search. So researchers, unable to stop the planet, couldn't temporarily halt the search pattern they used to stuy these signals, Dixon says. When scientists did go back to look for them after the search pattern was completed, the signals were gone.

"These signals were some type of intermittent transmission," Dixon says. He admits that it is unlikely these transmissions are from an extraterrestrial civilization. "But how can we be sure when we don't know anything about them?" he asks.

"We do know that the source of some of the strongest signals we've seen were at least as far away as the moon," he says. "There was nothing we picked up that was in low Earth orbit."

Under the new system, the search pattern will be interrupted when the telescope detects an unidentified signal so the scientists can study it. Then the search will be resumed.

"We will stop and examine them right then and there," Dixon says.

Modifications to the telescope will be able to neutralize the effects of the Earth's rotation on the instrument for as long as two hours, Dixon says. A new computer will automatically stop the search once an interesting signal is detected and activate sensors to study it.

Private contributions funded most of the improvements, modifications and additions to the telescope, Dixon says. He says he cannot place a monetary value on the work done.

The transient nature of these transmissions made examining them impossible under the current search procedures, Dixon says. A single scan of the sky takes several years to complete.

"We have been searching systematically on a grid," Dixon says. "We slowly and carefully search through the whole sky. When we would find a signal, we noted the source but continued the search."

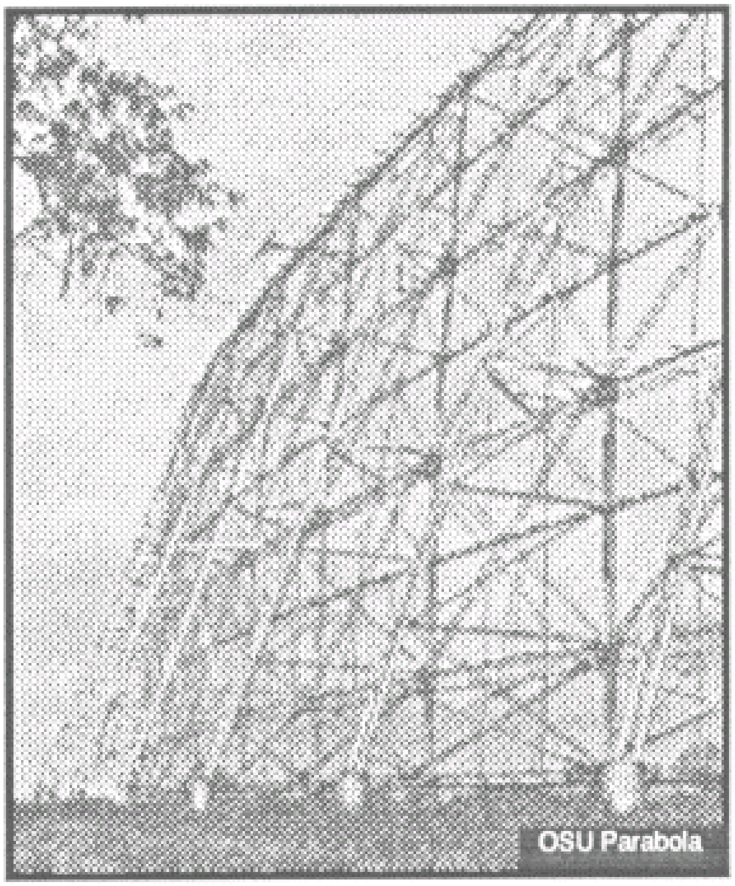
Only after they finished a complete scan did the astronomers go back to study these transmissions. But they were unable to study even one of the signals. They were absent when the scientists pointed the telescope at the right spots.

Ohio State's new search method will not be followed by others conducting full-time searches, such as Harvard University, Dixon says. "There is room for different approaches," he says. "Ours is just one of them."

The National Aeronautics and Space Administration is also planning a full-time search program. But Ohio State's 15-year program has been the only full-time search until now.

Other searches have been sporadic.

Telescopes listened for only hours or days at a time. There was no systematic pattern, Dixon says. Just a select number of stars would be targeted.



Ohio State's radio telescope listens for transmissions in what is popularly termed the "water hole." This narrow range of frequencies is so named because it is located between the hydrogen and hydroxyl (OH) emission lines. Combined, hydrogen (H) and hydroxyl (OH) form water.

The "water hole" is between 1400 and 1700 megahertz. It's attractive because there is low background noise at those frequencies, which makes detecting faint signals easier.

"It is a reasonable assumption to think that they would transmit there because of the low background noise," Dixon says. "In a poetic sense, it is analogous to the African watering hole, the age-old meeting place of different species."

Dixon believes that if our planet did hear from another civilization, they probably would be slightly more advanced than us. "They probably will have solved their energy problems and be able to transmit continuously. Sending signals takes a lot of power. It probably won't even be a societal decision. Someone may be transmitting in their own back yard."

Dixon believes intelligent life exists elsewhere. Ohio State's radio telescope is strong enough to detect a signal from a telescope of comparable sensitivity and power 1,000 light years away. The Milky Way galaxy is about 100,000 light years in diameter and the Earth is about 30,000 light years from the galactic center.

"At any one time there are three of four possible stars, that might have solar systems capable of supporting life, in the beam of our telescope," Dixon says.

Dixon's explanation of the change in Ohio State's methods was presented recently at a Space Life Sciences Symposium in Washington, D.C.

Course Offering

Radio Astronomy

EE 693/793

Fall Quarter 1988
3 hours

Prof. Kraus

General astronomy fundamentals, radio astronomy fundamentals, brightness, flux density, emission and absorption, temperature and noise, polarization, Poincare sphere, Stokes parameters, wave propagation, Faraday rotation, radio telescope antennas, interferometers, aperture synthesis, resolution, radio telescope receivers, radio sky, spectra, solar system, our galaxy, pulsars, extragalactic radio sources, thermal emission, non-thermal emission, synchrotron self-absorption, cosmological considerations.

Text: RADIO ASTRONOMY, 2nd Ed., Kraus, Cygnus-Quasar, 1986

Prequisite: EE 512 or Phys. 657 or equivalent

Sign-up under course code number 17220-5.

Please note: Dr. Kraus is welcoming all of us to participate in this course, even if we cannot register for it. Let him know if you are interested, because he intends to arrange the time based on when most people can make it. -ja-

Is Hartley Really Faster?

The following is a reprint of a letter that appeared in the July 1988 issue of ***Byte*** *magazine, that I thought might be of interest to some of the software member of the group. -ja-*

Mark A. O'Neill did a fine job of explaining Hartley transforms ("Faster Than Fast Fourier," April), and BYTE proved itself once again to be a premier forum for the intelligent discussion of technique.

The article is wrong, however, in asserting that the fast Hartley transform is faster than the fast Fourier transform (FFT). This conclusion follows only when the Hartley transform is compared with an entirely naive implementation of its Fourier counterpart. There are two essential and well-known tricks used in modern FFT algorithms that, when combined, actually make the Fourier procedure the faster of the two.

The first trick was published by J.W. Cooley et al. not long after his famous paper that introduced the basic FFT method. It adapts the computation to the important circumstance of real-valued data by transforming a pseudosequence of half length. The even-numbered points in the original sequence of length N are taken to be the real parts, and the odd-numbered points the imaginary parts of the pseudosequence, so that no rearrangement of the input array is required.

The transformation of this shortened sequence can be carried out by performing N/4 "butterflies" on each of $\log_2(N/2)$ levels. This transform is followed by an additional N/4 butterflies to turn its results into the first half of the Fourier coefficients for the original sequence. The second half is neither calculated nor stored, since the coefficients are known a priori to be the complex conjugates: X (N-k) = X x (k). This last level of butterflies involves the same necessity for retrograde addressing that marks all levels of the Hartley transform and reflects the deep relationship between the two approaches.

This trick alone evens the race between the Hartley and the Fourier transforms. Both require $\log^2 N$ [sic; This probably should be $\log_2 N$; Jerry Ehman, webpage editor] levels of computation. On each level, the Hartley procedure requires N/2 butterflies, each involving two real multiplications, for a total of N x $\log_2 N$. The Fourier procedure has only N/4 butterflies on each level (because the transforms is of half length), but each requires a complex multiplication. If these were done in the usual way, as Mr. O'Neill suggests, using four real multiplications apiece, then the contest would be a draw.

A second trick, however, can be used to make Fourier transforms the more economical computation on most computers of the present era. Because multiplication instructions typically require much longer to execute than those for addition or subtraction, this trick succeeds by reducing the number of real multiplications at the cost of an increased number of the quicker operations. I learned the technique from a friend who called it "Golub's method," but I am unable to cite a reference duly crediting its originator.

The idea is to compute a complex product (A+iB) x (X+iY) with only three real multiplications: (a=B) x (X-Y) + A x Y - B x X + i(B x X + A x Y).[sic; I believe that the term "(a=B)" should be "(A+B)"; Jerry Ehman, webpage editor] When the products required for Cooley's real-valued FFT algorithm are taken this way, the number of time consuming real multiplications is reduced to three-fourths of those needed for the fast Hartley transform. A well crafted Fourier routine is therefore faster.

Commercial Fourier transform packages also employ other tricks to achieve increased speed and accuracy. Many of these are equally applicable to Hartley and other related transformations. Probably the most important additional notion is to abandon the level-by-level sequence of calculations implicit in the foregoing discussion in favor of an ordering that groups operations involving common multipliers. This allows computations corresponding to angles of 0, 90, 45 degrees, and so on, to be handled by specialized loops that are much faster than the general case.

J.W. Hartwell, Hillsborough, NC

Computers Search for Real E.T.s

Amateurs are using micros to help

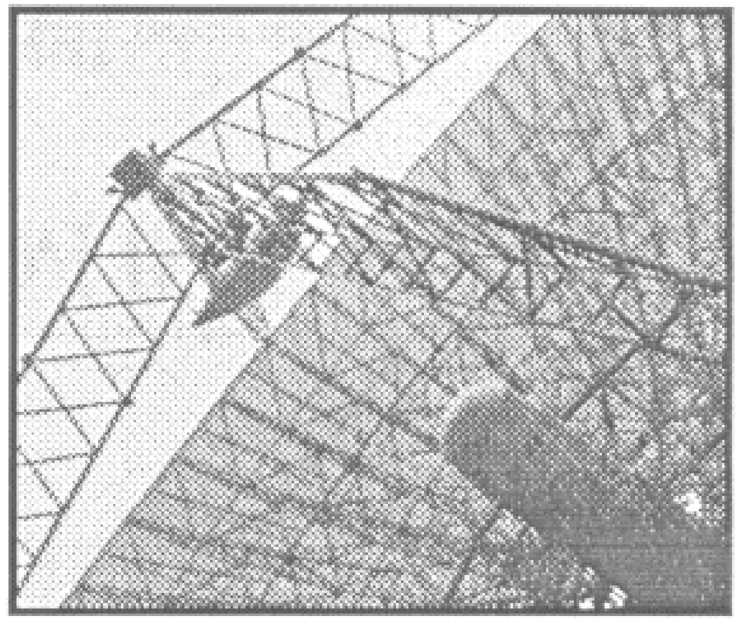
by Randall Rothenberg
from *Popular Computing*, February 1985

One of the most chilling lines in cinematic history came at the conclusion of *The Thing (From Another World)*, the 1950's science-fiction classic that starred James Arness as a mute, blood-thirsty, 7-foot extraterrestrial vegetable bent on wreaking havoc in an isolated Arctic military station. You may recall the basics of the plot: after discovering a flying saucer buried in the frozen tundra and accidentally defrosting its occupant, the men find their attempts at communication met with destructive behavior. So they rig up an electric-arc generator and transform their unwanted guest into ratatouille. Having vanquished the Thing, they crowd around the base radio and inform Washington of their adventure.

"What should we tell them?" asks the radio operator. Replies a colleague, "Tell them-to watch the skies."

Decades later, Americans are heeding that admonition. They are closely watching — or more accurately, listening to — the skies while engaging in a curious sport known as SETI: the search for extraterrestrial intelligence. These are boom times for SETI. Although speculating about the existence of life on other planets is an ancient and noble occupation, today it can claim support from the National Aeronautics and Space Administration, major universities, and a small but growing group of dedicated amateurs.

Why the sudden popularity? Some SETI enthusiasts tip their hats to the movies; *ET* and *Close Encounters of the Third Kind* have certainly helped their cause. But would-be alien-watchers are unanimous in pointing to an innovation that is less cultural than technological: the personal computer.



"Micros have made all the difference in the world," asserts Paul Horowitz, a youthful Harvard physicist whose SETI project, funded by the Planetary Society, has been called "the Cadillac of SETI" by a NASA staffer. "We can do in one minute what would have taken the earliest SETIs 100,000 years," Horowitz explains. Thirty miles from Horowitz's Cambridge laboratory, in a tree-enshrouded glade, an 84-foot radio telescope slowly and methodically scans the skies. Every 30 seconds, inside a control building adjacent to the large parabolic dish, a graph with a long baseline and a single large spike appears on the screen of a WICAT System 150 micro computer, depicting the radio noise being received from the stars and galaxies beyond the earth. Any time the peak grows beyond a certain intensity, the machine beeps and records the information on a Winchester hard disk for later analysis. Was the spike merely radio interference? Probably. A pulsar? Maybe. A transgalactic civilization? Probably not. But with the computer's method of digital analysis, Horowitz needn't guess. "Straight silicon," says Horowitz, referring to the computer's method of digital analysis. "In SETI, that's now the way to go."

SETI, indeed the science of radio astronomy itself, is undergoing a transformation not unlike the one computer science experienced earlier. What was once the province of a rarefied cadre of Ph.D.s working for the wealthiest institutions has reached the level of home-brew. Searches once conducted by professional astronomers who borrowed time on the government's massive radio antennas and room-sized super computers are now carried out by amateurs (albeit knowledgeable ones) with back yard dish antennas and inexpensive micro computers.

Tuning in the Right Channels

No matter how it's conducted, SETI rests on a few laws of physics: heat an object — any object — and it gives off radiation. Objects heated to different temperatures emit waves of different frequencies, including radio frequencies. The universe is a tremendous transmitter of radio waves — galaxies give off waves of certain frequencies, as do dwarf stars, supernovas, and quasars, all of which create audible and visible broadcast interference. For example, if you were to point your TV antenna straight up and attach your television set to a chart recorder, you would see additional interference when the Milky Way passed overhead. The basic technique of radio astronomy is the capture and computer analysis of these waves from on high, which give us a picture of the universe vastly more detailed than anything we receive from visual astronomy.

Astronomers searching the skies for radio waves from intelligent civilizations tune their receivers in to extremely narrow frequency bands (or channels), assuming that a civilization would target its signal finely to differentiate it from natural celestial radio signals, which are very wide. Furthermore, SETI researchers focus their efforts on a region of the radio spectrum where they think other civilizations are most likely to transmit a signal — the region where emission from hydrogen, the most abundant element in the universe, predominates. Moreover, with the least interference from other natural sources, this region offers astronomers a perfect area for undisturbed searching, It stretches from 1420 megahertz (1420 million cycles per second) — the frequency at which hydrogen atoms emit radio waves — to about 1700 MHz, near the broadcast frequency of the hydroxyl ion. Because a water molecule results from joining a hydrogen ion with a hydroxyl ion, astronomers refer to this region of the spectrum as the radio "water hole," the place where our civilization is most likely to meet theirs.

NASA currently has a yearly SETI budget of $1.5 million and the equivalent of 10 full-time staff members at the Jet Propulsion Laboratory in Pasadena California, and the Ames Research Center in Moffett Field, California. Supplementing NASA's effort is the work of the Planetary Society, a non-profit organization founded in 1980 by Cornell astronomer Carl Sagan and Bruce Murray, former head of the Jet Propulsion Laboratory. The society's Project Sentinel scans 131,000 channels simultaneously in its search for an extraterrestrial signal, feeding the information for signal analysis to a WICAT micro computer, a 68000-based computer from the World Institute of Computer-Aided Teaching in Utah.

But searching the frequencies of the water hole in all directions of the sky, narrow channel by narrow channel, is an overwhelming task. The Milky Way galaxy is home to some 300 billion stars, and approximately 10 billion other galaxies exist in the known universe. Some astronomers believe there may be 10 billion life sites in the Milky Way alone from which a signal could originate. Even a search of a mere one million stars would take 20 years glued to a dish.

"There are assumptions everyone has to make about the nature of the signal we expect," says Dr. Kent Cullers, a SETI project scientist at NASA Ames responsible for generating computer algorithms to analyze the signals. These assumptions, according to Cullers, are aimed at narrowing the scope of NASA's project to make it more manageable. "But that means there are still many frequencies we are not looking at and many different signal types we can't spend time on. That's where amateurs come in."

Today, amateurs are conducting searches for extraterrestrial intelligence by adapting existing micro computer equipment and using software that allows 8-bit micro computers to perform signal analysis. An amateur can put together a home-brew system for less than $5000, including the computer.

Computers have several uses in SETI, but the most important is performing a fast Fourier transform (FFT). The FFT is the mathematical tool that forms the basis of many important computing functions, notably the CAT scan so critical in medicine today. FFTs are available on plug-in boards for many popular micros and can also be found on disk. A Fourier transform enables a computer to separate the noise coming into a receiver into its distinct components and then tell the strength of each signal.

"Doing this analysis fast is where the trick is," says Cullers, who helped develop a machine-language FFT for computers with 6502 microprocessors. The SETI ideal is to accomplish the signal analysis in real time; that is, to pinpoint the frequency and strength of signals as they are received, rather than capturing the signal on tape or disk and analyzing it later. "If you're willing to narrow your band width at the outset, you can limit the input to your computer so that it can do real-time analysis," says Cullers. In other words, amateur searchers face a trade-off: they can finely target their searches, looking only at specific frequencies in the water hole and do the FFT in near real time; or they can capture a broad signal and slowly look at the component channels one by one.

"The Fourier transform looks for sine or cosine waves that repeat over and over again. If you have a nonrandom occurrence of a signal, it'll tell you, says Karl Lind, an engineering associate at SRI International in Palo Alto, California, and an amateur SETI enthusiast. Lind uses a Timex Sinclair computer and three 12 1/2-foot dish antennas to search for signals from Sigma Draconis, a "local" star some 18 light-years from earth. "Finding a pure sine-wave signal is virtually unknown," says Lind. "If you find one, it's a real find." Because of the importance of the FFT some SETI searchers use a dedicated spectrum analyzer instead of a computer with an FFT board or software to separate the incoming signals into distinct narrow broadcast bands.

A Beacon from the Sky

Ah, but what would an amateur be listening for? Kent Cullers likens the problem faced by E. T. watchers to sifting through an entire set of the *Encyclopedia Britannica* each second. "Assume that the set of encyclopedias is filled with random numbers," says Cullers. "You've got to go through it and look for a single coherent sentence. And you've got to analyze it in real time." What's more, Cullers adds, "the only thing we're interested in looking for are things that happen over and over again, not one-time events."

Given the difficulty of the task, all SETI enthusiasts operate under a set of assumptions. For instance, most assume that a civilization would be likeliest to develop adjacent to a sun-like star; there are 773 such orbs within 80 light-years of earth. They assume that a civilization would intentionally broadcast a signal into space in hopes that another intelligent race would pick it up. Some go a step further: they assume that the extraterrestrials would be advanced enough to detect the increased radiation emanating from the vicinity of our sun during the past five or six decades that man has been broadcasting television and radio waves, transmitting microwaves, and exploding nuclear devices. Thus, the reasoning goes, extraterrestrials would aim their signal in the direction of the solar system. Amateur and professional searchers refer to the presumed signal as the "beacon."

SETI folk differ in their opinion of what the beacon would look like or what it would lead to. Nikola Tesla, the eccentric early-20th-century inventor, maintained that it would be a series of pulses reading, "One... two... three..." and so on. Many believe that the signal will be a string of prime numbers. The Planetary Society's Paul Horowitz feels that any extraterrestrial broadcasters would adopt "a two-pronged strategy: a beacon and a message." That view has some support in amateur circles.

"One of the odd things to me is that many astronomers are asking only, 'What's the minimum we might get?'" says Robert Gray, a Chicago-based searcher. "They don't speculate on what we might really get." Gray, the founder of Gray Data, which publishes micro computer reference cards, has invested thousands of dollars in his SETI operation. He watches the skies with a dedicated 256-channel spectrum analyzer built by Hewlett-Packard, a 12-foot steerable parabolic dish antenna, and a Compupro 8/16 micro computer with the CP/M operating system. He has spent the past decade speculating about the nature of the message we someday might receive.

"Since we can't have a real-time conversation," says Gray, "it seems to me that we'd get the whole story. If it were my job to send messages to other stars, I'd send a minimum of the *Encyclopedia Britannica*. If I had the funding, I'd send the entire Library of Congress. If dialog is out of the question, the next best thing is to tell your story.

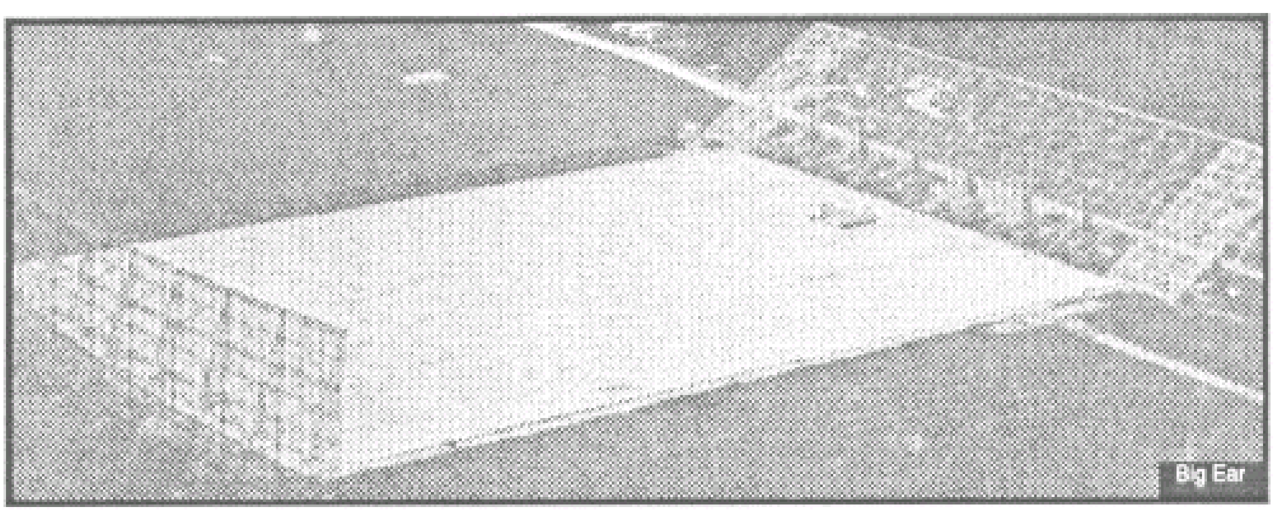
"I don't think I'll ever pick up little green men," adds Gray, with only a slight touch of whimsy. "But when somebody does find something, the exciting thing will be interpreting it."

Translating the Signal

Unsurprisingly, many searchers believe they have already picked up something. "There's no question that SETI is a focus for 'strange events.'" says Kent Cullers of NASA's search project. "If someone has a strange experience, chances are it will cross my desk. Last week, a fellow called me to get computer equipment to contact the UFO that's been chasing him." Nevertheless, Cullers says that serious amateurs have not plagued NASA with reports that turned out to be spurious.

False alarms are, of course, legion in SETI circles. Several years back, for example, astronomers at the National Radio Astronomy Observatory heard a signal at the same time every morning, over a period of several days. Quite convinced that it was real, they did some preliminary investigations. They quickly discovered that each morning at 8 a.m. two local truckers met in a nearby parking lot, started their rigs, and fired up their C.B. radios, creating the "intelligent" signal.

Then again, false alarms sometimes lead to discoveries. The most famous occurred in 1967 at Cambridge University in England. Astronomers received a series of regular blips at intervals of about one second. The source was a well-defined point in the sky. As science writer Edward Edelson noted in his book on SETI, *Who Goes There?*, "In the first euphoric hours after the discovery, the Cambridge astronomers named the source LGM-1. The initials stood for 'little green men.'" Much study was done of the possible beacon, and it was finally determined that it was a previously unknown natural phenomenon, the pulsar.



And there are the unexplained events. In 1977 at Ohio State University — which has the oldest-established professional SETI project in the country and for a time published a journal for E.T. watchers — astronomers saw something they still cannot interpret. "We saw exactly the kind of signal we were looking for," recalls Dr. Robert Dixon, the assistant director of Ohio State's observatory and one of the moving forces behind its SETI program. "It was positively of intelligent origin, positively from outside the earth. But it was a one- time event. It was very strong for a minute and not a fluke. But when we were watching it, it turned off, as if somebody threw a switch." To this day, Dixon and his colleagues do not know what caused the signal; their best guess is that it was a supersecret military satellite. In SETI circles, the Ohio State noise is referred to as "the WOW signal."

Anomalous pulses such as the WOW signal are not rare and provide grist for the amateurs' radio mill. Chicago's Robert Gray, for instance, began his SETI project specifically to search for the source of Ohio State's WOW and now tries to follow up on other reports from serious amateurs across the country. On the North Fork of Long Island, New York, members of the Society of Amateur Radio Astronomers use their big dish and a Commodore VIC-20 micro computer to chart anomalous pulses. They have recorded unexplained signals repeating every four hours during a 12-hour period emanating from the Crab nebula in the area of the constellation Taurus, as well as from a star in the Big Dipper. Even though such anomalous pulses are, by definition, nonrepeating, astronomers have detected certain patterns to them. At Ohio State, for instance, members of the SETI project have begun mapping the "things that go burp in the night" they have received over the years. "Taken individually, you just shrug your shoulders. But they are not random," asserts Dixon of his findings. "They do concentrate in portions of the sky, particularly in the galactic center."

The Debate on Earth

Because their work has yielded fruitful, if inconclusive, results, and because amateurs and professionals are working so closely to advance the science of radio astronomy, SETI is no longer the bastard child it once was. "SETI is taken very seriously right now," confirms OSU's Dixon. Indeed, the International Astronomical Union, one of the most prestigious bodies in the field, has established a commission on extraterrestrial intelligence. And in 1982, the Planetary Society released a petition endorsing "a coordinated search program" utilizing "current radio astronomical technology." The signers included seven Nobel laureates, among them Francis Crick, the co-discoverer of DNA, and two-time Nobelist Linus Pauling. Others are British scientist Stephen Hawking, the pioneer investigator of black holes, and best-selling author and scientist Stephen Jay Gould of Harvard. Among computer scientists, Marvin Minsky, the former director of MIT's Artificial Intelligence Laboratory, affixed his name to the petition.

SETI is not without opposition, of course. Recently, Carl Sagan engaged in a published debate with physicist Frank Tipler of Tulane University, a vocal and harsh critic of extraterrestrial searches, who told Canada's McLean's magazine, "if there were advanced civilizations out there, they would have colonized the entire galaxy by now. They would be here." Added mathematician Alfred Adler of the State University of New York, "Science is being denigrated by such foolishness." To these and other skeptics, the Planetary Society's SETI coordinator, Dr. Thomas McDonough, like to quote Arthur C. Clarke's First Law: "When a distinguished but elderly scientist states that something is possible, he is almost certainly right. When he states that something is impossible, he is very probably wrong."

Regardless of the opposition, dedicated SETI enthusiasts are unlikely to be deterred, even if their efforts at locating intelligent life beyond the earth prove futile. In fact, many predict that E.T. watching will grow in popularity, thanks to the increased availability of appropriate micro computer analytical tools. "It'll be like comet watching," asserts Karl Lind of California. The growth may be all for the best, since some professionals believe there may be only a 20-year window, rapidly closing, until terrestrial radio noises become so loud that they will effectively blot out any incoming intelligent cosmic signal.

But even if E.T. doesn't phone Karl Lind or Robert Gray or Robert Dixon or the Society of Amateur Radio Astronomers or Paul Horowitz or even NASA, all the effort will not have been in vain. As Kent Cullers of the space agency says, "Even if I don't detect a real SETI signal in my lifetime, I will be happy if I have laid the groundwork." Cullers further notes that there is a place for the serious SETI amateur in the radio astronomy field. "Many of the early discoveries in radio astronomy were made by amateurs," he says. Ohio State's Dixon, although not an amateur, agrees. "We've always felt we may not discover intelligent life," he says. "But we will discover a new natural phenomenon."

Alien Watching in Your Own Back Yard

The following appeared as a sidebar to the article reprinted above. -ja-

"E.T. watching," a small niche in the field of radio astronomy, is an excellent place for an amateur to begin an aural exploration of the skies. A simple component system can be set up for well under $1000, exclusive of the computer, but there is a caveat. "If someone tried to put together a system from a block diagram," explains Robert Gray of Gray Data, "it wouldn't work. There are design specifications that are necessary. One has to go to the textbooks or the experts." Fortunately, both exist and are readily accessible. The first thing an interested searcher should do is contact the Society of Amateur Radio Astronomers and its president, Jeffrey M. Lichtman, at 40 Winside Lane, Coram, NY 11721. SARA operates its own amateur SETI program on Long Island, and its newsletter has published for home-brew SETI systems as well as computer programs — written in BASIC — to perform frequency analysis of sky noise. Lichtman has written three books, *Solar Amateur Radio Astronomy* ($7.50), the *Amateur Radio Astronomer's Circuit Cookbook* ($&.50) [sic; "($&.50)" probably should be "($8.50)"], and *Microwave Radio Astronomy, An Amateur Introduction* ($18.50), that are among the best reference works for the true beginner. They are available at the above address.

Robert M. Sickels, SARA's secretary, has published the definitive work on amateur radio astronomy. *The Radio Astronomy Handbook*, available from Sickels at 7605 Deland Ave., Ft. Pierce, FL 33451 ($32, with a 20 percent discount for SARA members) contains detailed instructions on setting up a back yard radio astronomy observatory and modifying off-the-shelf satellite television equipment to serve the purposes of SETI. The book also includes a description of a complete SETI system based on the Timex Sinclair. Sickels has offered the entire system for sale, but the discontinuance of the Timex Sinclair has made some of the components scarce. Write him for information about current availability.

A SETI component system breaks down into two segments, one for receiving signals and the other for analyzing them. While computer owners may be generally familiar with the back end, the front end — which consists of a dish antenna, a low noise amplifier, a mixer, a receiver, and a baseband amplifier — may seem like foreign territory. Yet locating the equipment should involve little effort. "Anyone who can put together a satellite television setup can put together a decent amateur radio astronomy observatory," says Dr. Kent Cullers of NASA's SETI program. With only a few modifications, a satellite TV reception system can be used as the front end of a SETI operation. Again, though, caution must be taken that the equipment purchased is capable of being modified for the specific band width to be searched.

Front-end equipment can be found at electronics surplus and discount stores and through military surplus catalogs, but the best place may be one of the satellite television supply houses now proliferating throughout the country. Two of the best are B.R. Satellite (35 Lumber Rd., Roslyn, NY 11576; 800-421-0148) and Echosphere (1925 West Dartmouth Ave., Englewood, CO 80110; 800-521-9282). Because of an influx of new, high-quality antennas from Japan, a small (5 to 6 feet) dish may cost as little as $100 new. Large dishes (20 feet and over) can cost tens of thousands of dollars in a pristine state, but because they become obsolete for professional purposes relatively quickly, they can often be picked up at surplus prices. *The Radio Amateur's Handbook* (The American Radio Relay League, Newington, CT 06111), the Bible of ham radio enthusiasts, is also an excellent place to turn; it has instructions for building home-brew antennas for under $100.

In general, low-noise amplifiers, mixers (for converting the incoming signal into a frequency the receiver can understand), receivers, and baseband amplifiers are available from anyone who sells complete satellite TV systems. Again, prices vary. Low-noise amps can be purchased for $100 to $300 new. Depending on the frequency range of the signals being explored, the receiver can be either a TVRO (television receive-only) receiver of [sic; or] a standard short-wave receiver. Radio Shack and Heathkit have many varieties of these, starting at under $100.

Any off-the-shelf TVRO or radio astronomy equipment will have to be modified before it is applicable for SETI projects. The easiest way to make sure your equipment is compatible is to find someone who can locate and modify all the equipment for you. Many stores that sell satellite television equipment will modify the antenna and receiver to accommodate certain SETI frequencies. In New York, Ken Schaffer of Orbita Technologies Corp. (21 West 58th St., New York, NY 10019) is the satellite TV whiz-of-whizzes. Serious amateurs would do well to contact him about purchasing and modifying TVRO dish antennas, receivers, and amplifiers.

The back end of the system is even simpler, consisting of nothing more than a computer, an analog-to-digital converter, and the fast Fourier transform that turns you computer into a signal analyzer. A/D converters are available as plug-in boards for virtually any micro computer system. For instance, Hollywood Hardware (6842 Valjean Ave., Van Nuys, CA 91406) advertises a 12-bit, 16-channel board for the Apple II Plus and IIe for $299.95. Tecmar makes an A/D converter board for the IBM PC for $495.

Software FFTs, common mathematical tools, can often be found in the public domain. One software FFT specifically for amateur SETI enthusiasts is available in assembly language from Kent Cullers free of charge if you write him at M.S. 229-8, Ames Research Center, Moffett Field, CA 94035 (enclose a stamped, self-addressed manila envelope). Cullers' version was written for the Apple but can be modified for other systems.

Once you've purchased the components, modified them, and established a system to watch the skies, then comes the fun ... and the tedium. For all that's left is to look and listen — and ponder what to do when E. T. calls.

Observations

Tom Van Horne

In my last column I made the rather obvious point that in order for the OSU SETI project to accomplish its goals, we need to review and thoroughly analyze the data we acquire.

The phase 2 OSU SETI project generated approximately 160 folders of printouts covering about 3 days of data apiece. Shortly after its initiation, the phase 2 study implemented a system of computer analysis of its data that produced a second type of data output. The programs of the computer were instructed to use several types of criteria to examine the data from the receivers in real time. If the data from one of the channels matched one or more of these criteria, then a record giving details of the occurrence was produced. When a large number of these records were accumulated, they were printed out as punch cards which were used for further analysis. The programs that created these records looked for certain unusual patterns of intensity on any one of the 50 channels of data being observed. They were designed to detect bursts of single channel noise or to note the pattern of a single channel signal that increased in intensity in such a way that it matched the intensity curve produced by our telescope when scanning past a fixed sky source. Thousands of cards were produced by this system, recording events that matched all of the various 'search strategies'. When these cards were further examined by computer analysis, there seemed to be a statistical correlation between the occurrence of these signals and the structure of the galaxy. Since we are aware of no natural phenomenon that can generate narrowband intermittent signals that could match our search strategies, we were presumably either observing artifacts of ETI or else some unknown astronomical phenomenon.

Although these cards were produced by the thousands, the programs that created them never really worked in a fully satisfactory manner. Even a limited analysis of our data listings has revealed large numbers of occurrences of cards being generated when the signals in question were by no means single channel. At the time of the computer analysis of the cards, the cards being used were checked against the listings and those which were obviously repeats or part of multichannel signals were excluded. More disturbing and also quickly revealed by limited analysis of the listings, are the number of occurrences of data that SHOULD have produced cards and yet didn't. As valuable a time saver as the automatic data review of the phase 2 system was, the results cannot be considered reliable and therefore the results of statistical analysis of the data cards is also suspect. If the observed correlation of 'search strategy' signals with galactic structure is not valid, then there is no way to say that the observed signals are not a function of local interference. Further, because of the unreliability of the automated search, the possibility of REPEATING signals that match our criteria for

ETI in the data that we have on hand has not been adequately explored. We could be in possession of the answer to our search at this very moment buried in the massive pile of 160 computer printouts that have never undergone thorough examination.

The obstacle to the examination and reliable study of the Phase 2 data has always been lack of manpower. If we had the personnel in the first place, the printouts could have been examined as they were produced. Indeed, for an unknown number of late 70's printouts this was done, but little record of the results remains. My scheme for the analysis of this data is the use of large numbers of people each doing small amounts of work. The problem is that we have a large amount of data of which only a small amount is relevant to our SETI effort. It is possible (I can say from direct experience) for one person to look over several days data thoroughly in a relatively short period of time (< 10 hours). I am planning to hold group 'data bashing' meetings using the help of interested volunteers to scan small sections of the data at a time, doing nothing but looking for occurrences of signals that match the 'search strategies', highlighting the occurrences and marking the location in the listings with post-it notes. With proper documentation of each reviewing session and enough volunteers, it should be possible to separate the 'wheat' from the 'chaff' in less than a year. With the interesting occurrences of data identified, further analysis, both statistical and of individual locations can continue with some degree of reliability.

Coordinator's Corner

Phil Barnhart

Working Session Notes
6 August 1988

Software Group

1. Software Group needs a Sysgen on both the 11/23 and 11/44. Marc Abel is doing this now.

2. Steve Ellingson has successfully compleated the RFI software. The data being collected is valuable and reveals that the bands we are interested in are clear almost all of the time.

3. Steve Crawford has started the graphics software for the VT240.

4. There is a need for a list of projects that need done, and a plan to get additional members of the software group active.

RFI Group

1. RFI is up and running!

2. Short term tasks:
- data reduction/analysis before D.C. meeting
- data presentation and display
- interpretation of data (listening to identify RFI sources)
- final presentation (slides, overheads, etc)

3. Long term tasks/problems
- connector needed for antenna mounted GaAsFET amp
- need to improve ICOM response time
- ICOM interface serial port needs repair
- improvements needed to discone (frequency response, weatherproofing)
- manuscript for Sept. colloquium
- interfacing RFI system with SETI and general observation programs in real time

Publications Group

1. Recent efforts have focused on support for the RFI project
- block diagram finished
- SWR plot of discone antenna finished
- slides of receiver and antenna finished

2. Fund raising materials need to be raised to the top priority (a publications group meeting will be scheduled to address this issue further)

3. An effort needs to be initiated to gather together all of the facilities documentation and copies of the reports of past projects (like the measurement of the side-lobe pattern) into one manual. The publications group will then do any editing and dressing up of charts and diagrams that would be of value.

Mechanical Group

1. The Mechanical Group needs to get the horn cart moving pronto. This will involve some communication with the people at Manchester, which I should take care of soon.

2. Hain has the WWV antenna up as of this week.

Chief Observer

1. Data analysis on "Interesting Object"

2. Called entire roster - Herb James withdrew

3. Offered a detailed organizational plan proposal. After some discussion it was decided to take up the issue at the next meeting.

Headquarters Group

1. Aquired a new IBM PC compatable

2. Mook has offered to donate a modem for the PC here at Otterbein.

3. 8-inch floppy drives to be picked up

4. No longer any doubt that the files were lost during the painting of Phil's office

New Business

1. We need an electrician to clean up the rats nest wiring ibn the focus room.

Next Meeting 20 August, 10:00 at RO

Again I find the problems of being a volunteer manager of a volunteer organization. I suffer from many of the same pulling of priorities when the chips are down. I just completed a class in the summer term. Last week was final exams and all the stuff that falls at the end of the term. After tomorrow, when grades are in, I will be able to commit more of a full time block to Radio Observatory affairs.

Rarely does an opportunity arise the likes of which I face this fall. Thirty years ago I had the privilage of sitting in the first class in Radio Astronomy at Ohio State University. The course was team taught by John Kraus and Geof Keller. For those interested in how well I did you will have to go to the registrar's office at OSU. I enjoyed it immensely and have emphasized the contributions of the radio astronomers in all my courses dealing with astronomy or cosmology.

This fall, I am going to sit again in a course in Radio Astronomy, taught this time by John Kraus using the Second Edition of his Radio Astronomy text, a book which hadn't been written in 1958. I look forward to this opportunity, because of the tremendous changes that have occurred in all of astronomy since then, due in large measure to the contributions of radio astronomy to the body of knowledge about our universe. In the late '50's the big issue was still the identification of "discrete" radio sources, often by occultation or crude interferometry. Few of us dared hope for the kind of information routinely available today from the radio telescopes hardly dreamed of then.

I strongly urge everyone within driving distance of Columbus to try to get into this class, even if it is just to sit in, as I am going to do. I guarantee a delightful experience. And I speak from experience.

Radobs Notes

1 Jul 88 11:10:51-EDT
From: Bob Dixon
Subject: TV Coverage

A free-lance TV production company is coming to the RO on July 24 at 5pm, to interview me about SETI. They sell these interviews to various stations and networks. Their name is T-Star productions, based in Columbus.

7 Jul 88 23:54:04-EDT
From: Tom Van Horne
Subject: new volunteers

I have been contacted by two more people who are interested in working with us.

Gene Foster (267-6341 home, 292-4110 work) is a chemistry grad student who is good with tools but doesn't have a clear idea of what he'd like to do for us.

Dru Smith (297-7147) is a senior in surveying (engineering) who is very interested in what we are doing and is a definite about volunteering. He is the first person who didn't scream when the possibility of volunteer coordinator was mentioned.

Both of these fine people intend to make it to the Dreese meeting on Tuesday. If Steve would add their names and numbers to the roster, it might be helpful.

11 Jul 88 11:51:14-EDT

From: Bob Dixon
Subject: Recent News

1. Ron Huck made some good arrangements with the chart recorder at Delaware. He lets the paper fall on the floor rather than go on the takeup reel. This lets the ink dry and lets you see the record.

2. Jim: Please fix the vt240 asap. We need it now to make progress.

3. I made a floppy disk for Steve Ellingson to see if his Vax can read it.

4. Ron Koch found the Amplica amplifier documentation. Steve E. has it.

5. Frank Shen tried to install the new Kermit at Delaware Saturday, but could not. It requires the FLX utility program, which we opted not to install during the last Sysgen. Jim or Marc - please install this program now, so we can proceed. I tried, but it is not simple. We also need it to read the software that came with the 11/34.

6. Steve E. has a program to do the RFI study. But we need to understand the Icom software better. Need help from Marc. We need to control the Icom without spawning tasks all the time, as that is too slow for the RFI search.

7. I worked with the Initlz program at the RO Saturday, but it still does not work. This is a great puzzlement. The a/d routines now work with other programs fine (addisp, search). But when used with Initlz, a table of values within ad64 gets clobbered and set to random numbers. I print out the table as the first executable statement, and it is already clobbered. This smells like arrays exceeding their bounds, so I recompiled every subroutine (and the ones THEY call, etc) with subchk and traceback. No error messages. Initlz is the only routine that uses virtual arrays, but I don't know if that is relevant. Any suggestions as to what to do next?

13 Jul 88 23:16:29-EDT
From: Bob Dixon
Subject: News Items

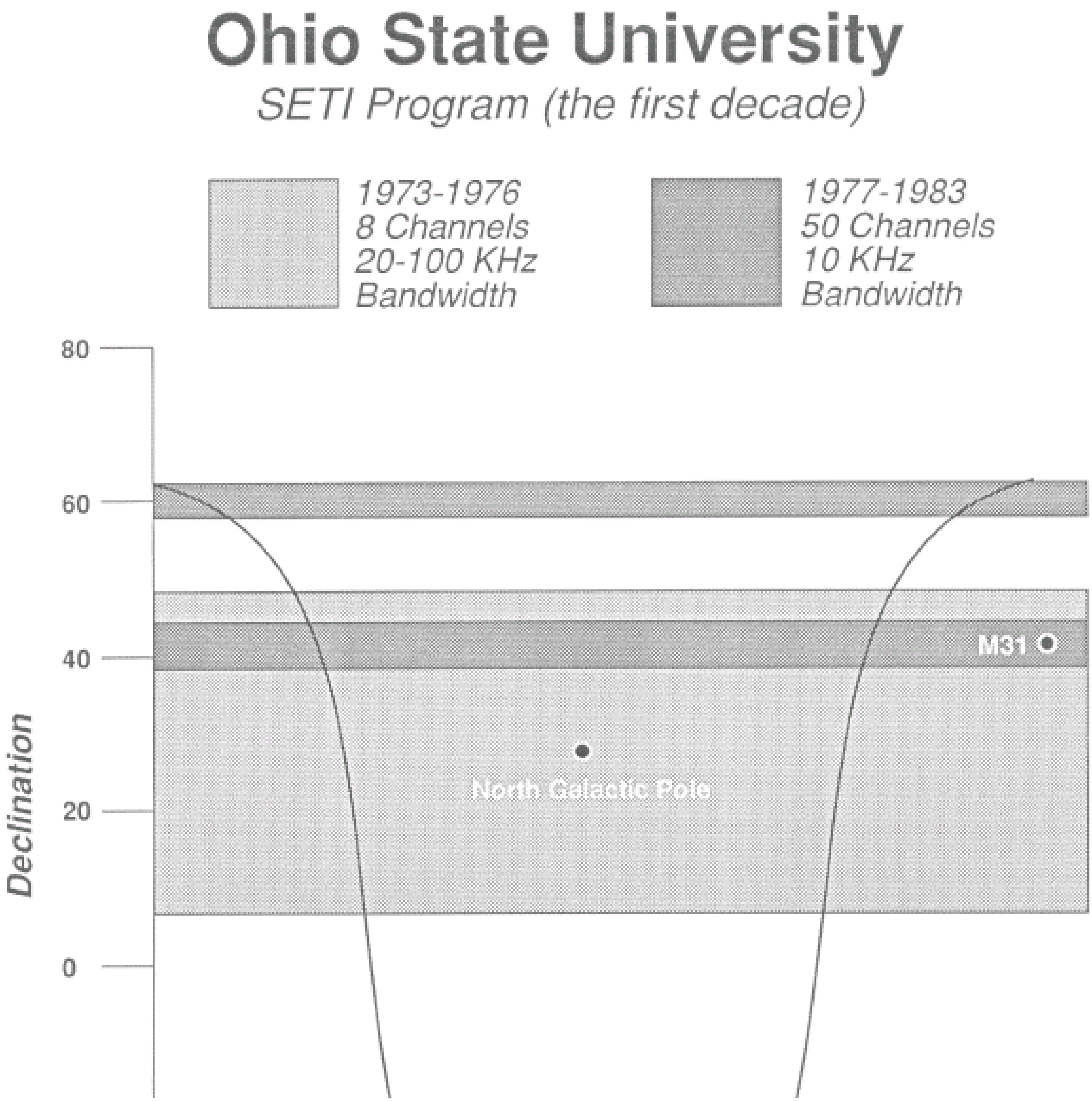
1. The 11/23 dial in works fine. I have been using it all evening.

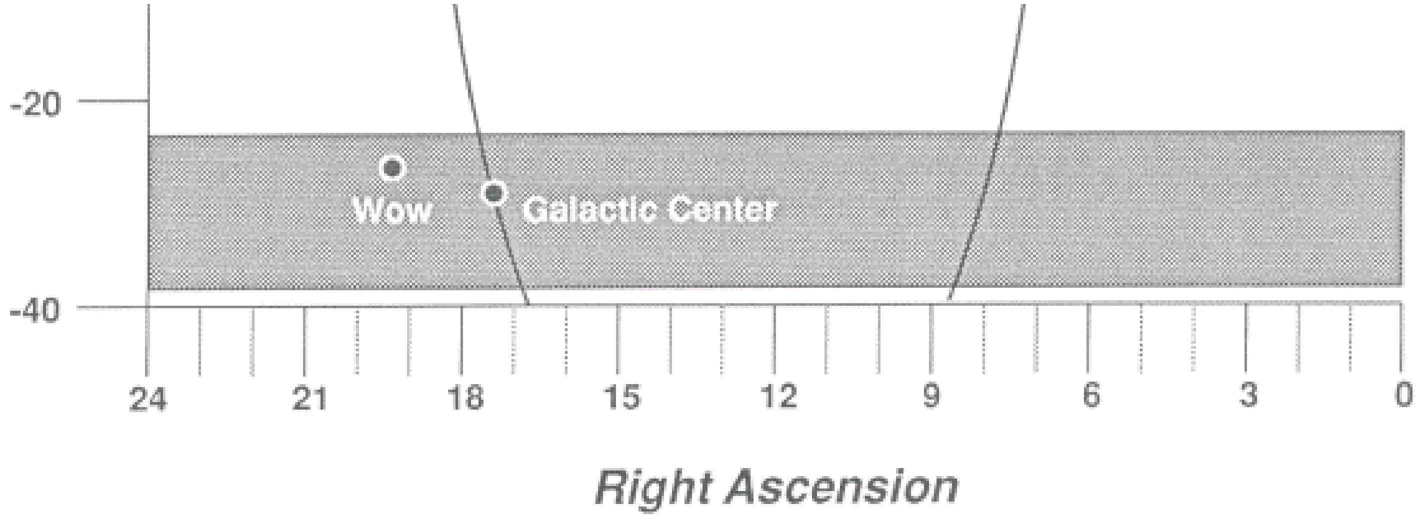
2. I changed contin so that the files it creates are readable by the world.

3. I found the problem at last with ad64 and initlz. After very laborious tests I found that an encode statement was filling an integer rather than a character string, because the declaration statement for the character string had been commented out. The compiler obviously does not catch such errors and it causes real havoc!

4. Now that the SETI program runs, it fails due to hardware problems. Channels 11 and 12 of the a/d converter have out-of-range signals all the time (less than -5V). Please fix this asap as I cannot go further until then.

OSU SETI Program (the first decade)





Last Word From Editor

That's about all we can fit in this issue. I hope you enjoy it. If there are things here that you don't understand, don't agree with, or just want to add too, please drop me a line. There are times when I begin to wonder if "Signals" is being read.

-ja-