

Audio®

SPECIAL ISSUE
BINAURAL SOUND

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**NAKAMICHI 1000
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A MAGNIFICENT SYSTEM

**SURVEY OF
BINAURAL SYSTEMS**

FIRST BINAURAL PROJECT?
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LEXICON CP-1
SOUND PROCESSOR
GREAT FOR MUSIC AND MOVIES

SONY CDP-X7ESD
COMPACT DISC PLAYER
FAULTLESS SOUND



- 48kHz
- 44.1kHz
- 32kHz
- Emphasis

Emphasis On

06030
0 270301 3 11

Output Level

Min Max

Left Rec Level Right

Min Max

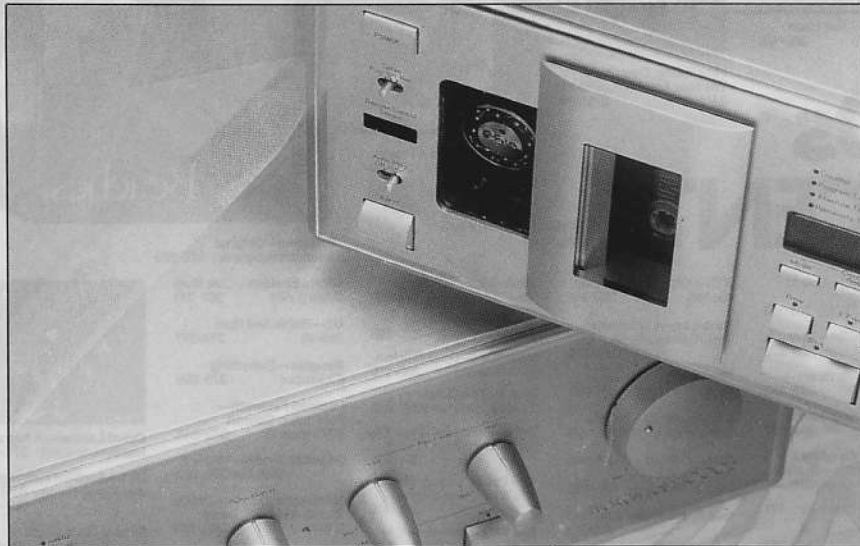
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Audio

NOVEMBER 1989

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The Blue

Some years ago, in the pre-digital era, my partner and I plunged into making a binaural recording. We built, almost from scratch, a complete binaural system, with audio quality representing the peak of the art for that time.

We used the system to make recordings of first-rank musicians playing first-rank music in different acoustic settings. These recordings amply confirmed the long-recognized virtues of binaural technique. As far as we know, they were the first, perhaps the only, binaural recordings of professional musicians playing serious music that were made by independent audio experimenters. We believe that the audio community will be interested in the story of our project, told here in full for the first time.

Our story is in two parts. The first tells how we built the system, with intense efforts to reach a truly state-of-the-art level of audio performance. Our master tape still exists, and it can hold its own for high quality, even in this digital era.

Of course, the audio experimenter who follows our lead will have a decidedly easier time of it today: Digital is here at moderate cost. But the user must learn how to employ digital equipment for truly top performance. He can learn the importance of top audio performance by listening to excerpts from our master tape, which were transferred to cassette in real-time duplication (as described in the accompanying sidebar). The cassette not only demonstrates binaural technique in full application but will surprise many listeners by showing the superb quality that was possible with top-notch analog recording even then.

The second part of our story is about our experiences in making the recordings: What we learned about the system's advantages for the recordist, as well as what it brings to the listener. The benefits for the recordist are so marked that we have to remind ourselves why binaural sound has never entered the mainstream. The require-



Sculpture: Madi Lanier

Max Affair

ment of headphones for the full effect is one reason; the commercial and technical advantages of multi-track recording are others.

But the technical advantages of binaural recording have slowly resulted in a modest body of use in the music industry of late. We'll look at that trend in some detail further along.

Building the System

We built our system because we did not have, before we started, top-grade audio recording equipment. We believed we could build key elements of the system to higher performance standards than those of any equipment we could rent or find available in most pro recording studios.

Our confidence was based largely on the very high skills of my partner (anonymous here at his request), a graduate engineer with long professional involvement in advanced audio design. He was the technical leader and designer. I, as a journalist who had been an amateur builder of ham radio gear and home hi-fi systems in my early years, was a good backup with the soldering iron but was more useful to the project for alertness to sources of music and acquaintance with professional musicians. A third important skill was supplied by my wife, Madi, a sculptor with years of professional experience. Madi was the key to our production of the dummy head, the centerpiece of any binaural recording system.

Building this head was our first construction assignment. A dummy head's main requirements have long been established: Real-life size, realistic shape, and especially important, "real" external ears. We also felt that the outer material should at least approximate human skin's elasticity.

To get us started, my wife produced a realistic head and shoulders in clay, with carefully delineated external ears. This new individual quickly assumed the name "Max." His eyes were closed, and his head was slightly forward—an intent listener.

Max's metamorphosis from clay to his mature stage followed steps familiar to sculptors. Around his head, he received a coating of plaster that closely followed the contours of the clay. The plaster coating was divided into sections so it could be removed after it hardened; the sections could then be reassembled into a hollow mold with a negative of Max on the inside surface.

For the mature Max, we chose General Electric RTV silicone rubber, a wonderful material that is an inert, somewhat viscous liquid until a curing agent is added. Then, in a short time,



the material becomes a very tough rubber, permanently taking whatever shape the container gives it.

We poured the silicone rubber and the curing agent into the reassembled mold. When the rubber was hard, we took off the plaster cocoon and had our dummy, with lifelike ears and skin. The hardened rubber had a grayish-blue color, so we changed the dummy's name to "Blue Max."

The underside of the dummy, somewhat below shoulder level, got a wooden base, to which we attached an adjustable stand holding Blue Max at any height up to about 5 feet. He is still

The recordings produced with the Blue Max dummy head confirmed the virtues of using binaural technique. The story of this project is told here, in full, for the very first time.

Blue Max

Riverside Church

standing in my partner's laboratory, unfazed by the passage of time.

Ears for Blue Max

To complete the dummy, we had to give him ears—microphone surrogates for the real thing. We used two small condenser mikes—the brand name has been obliterated from my memory—that had been damaged. These microphones got new diaphragms of ultrathin plastic, metallized on one side, and stretched to the proper tension. We also cleaned and tightened the assemblies.

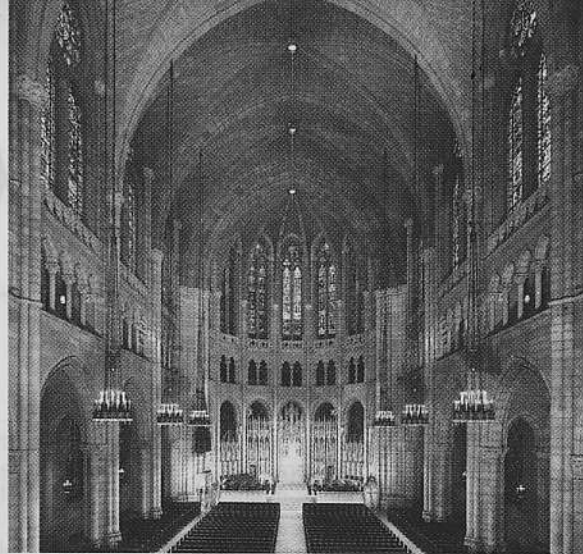
These refurbished microphones, by our careful tests, performed extremely well—above the standards of the period's commercial units. Frequency response was very flat to 20 kHz, with a slight rise around 18 kHz.

Installing the mikes required some surgery on Blue Max. We drilled holes through the representations of the ear canals, into the interior of his head. The holes were sized so that they would hold the microphones tightly. We inserted each mike so it was flush with the exterior rim of the ear canal.

This placement made it certain that sounds reaching the mikes would be subjected to all the influences of the head and external ears: The blockage and diffractions of the head, the frequency discriminations of the ears, and especially the differences between the two ears in all these factors. These differences would be preserved for the listener by feeding each mike separately to the corresponding ear via headphones, the essential delivery scheme of the binaural technique.

With these complex signals corresponding closely to those a real ear canal would get at the reception point, and delivered to the listener's ear at a point corresponding closely to the mike pickup point, the listener would, in effect, be taken back to the original musical event.

This offers distinct advantages. Stereo localization, for one, is truer and very stable. The elements in the reverb, moreover, are well reproduced with respect to frequency character, amplitude, direction, etc., so the hearing system gets truer ambience and can deal with it in a "real" way, exercising its well-known power to focus on the signal through ambience and noise.



Photograph: Nathaniel Lieberman

From all this, the listener gets a sense of instruments in a real space, a re-creation of reality that is one of the hallmarks of binaural reproduction. There is some variation in response to binaural sound from one individual to another, but the majority of listeners with normal hearing, including reasonable sensitivity to the high frequencies, hear the instruments as though they are "outside" the head, disposed in the space around and in front.

Home-Brew Electronics

My partner designed all the electronics for the system: Mike preamplifiers, line amplifiers, two recording amplifiers, and two playback amplifiers. The mike preamps used a very low-noise circuit developed by my partner some time before. The two preamps went into small tubular enclosures that could be clamped to the Blue Max stand, just below the base, and connected to the mikes through fittings on the base.

The two line amps went into one small enclosure that could be put down anywhere between Blue Max and the offstage position of the tape recorder. These line amps allowed us to use very long cable runs.

The recording amps incorporated several no-compromise ideas. For one, they provided recording bias at the highest frequency that could be forced through the recording heads—about 200 kHz. The distortion in the bias signal was virtually unmeasurable.

Performance of the electronics chain as a whole was up to our hopes: Dynamic range, greater than 80 dB; S/N ratio, about 83 dB; frequency response, very flat from 25 Hz to 20 kHz, with a slow roll-off at each end, and distortion in the electronics, around 0.01%. Digital recording has made such figures banal, but at that time, they were very far from common—they represented the peak.

Why hasn't
binaural sound
gone mainstream?
Because of the
commercial and
the technical
advantages of
multi-track and
because of the
need for using
headphones.

The recording and playback heads were top-of-the-line Bogens, made for three tracks on half-inch tape. We planned to use the two outside tracks for the two stereo channels and leave the center blank. The heads performed superbly.

The tape drive evolved from a custom-built drive which we had inherited from an earlier project. The drive checked out well for the 30 ips we planned to use but had more unevenness of motion than we wanted, including flutter and some stick friction leading to modulation noise.

Reduction of the motion problems required remachining and refining a number of parts. We installed a better balanced flywheel on the capstan, eliminated stationary tape guides in the tape path in favor of low-friction, high-inertia rollers (especially on both sides of the head), and made other changes to obtain smoother tape-drive motion. For this work, my partner and I had available a high-precision machine tool (a combination lathe, miller, and drill press) which we owned jointly.

The flutter finally came down to about 0.05%, which was very low for that time period, when smoothness of motion depended mainly on mechanical refinement—not, as it does now, on the frequency stability of digital circuits. Modulation noise was also very low as a result of our work on friction in the tape path.

With the tape drive in good shape, we had our complete system, genuinely at the peak of the art for that period. The immense effort that went into the system was inspired, in part, by a delight in super-fine audio performance. It was equally a financial necessity: The total cost was a fraction of the cost of a complete top-line pro audio system. In this case, low cost and high quality went hand in hand, making our project a viable one.

Recording the Music

The accompanying sidebar, "The Blue Max Binaural Cassette," gives details on the music from our original recording which is currently included on the cassette. Described are the pieces, composers, performers, recording locations, and other relevant information.

The first job we tackled was recording the organ in Manhattan's Riverside Church, a huge interior space which houses one of the most powerful organs in the world.

While Frederick Swann, the organist, ran through soft and loud passages for us, we moved Blue Max around in the forward part of the church to find how he would react in our first for-real job. One of the great virtues of binaural technique was quickly apparent. We got a good balance of sound at any spot within a wide range of distances from the front of the church, along the main center aisle. Blue Max was at home everywhere in this area. We could hear increasing distance from the high-pitched pipes in back of the chancel, but all the music was there,

pretty evenly reproduced, from the top of the scale to the bottom.

A second important asset was the handling of the tremendous reverb in the tremendous space. We could hear the reverb, but it did not overwhelm the music at any of the center area positions. Anyone who has made stereo recordings in a highly reverberant space will realize what a gift this characteristic is to a recording engineer. Getting set in large churches, for example, has usually meant moving several microphones around a lot, sometimes to odd positions, to get a reason-

The Blue Max Binaural Cassette

As noted in the main text, the equipment used for this binaural recording was then at the peak of the analog art. (*Editor's Note: It still sounds pretty good!—E.P.*) The electronic system had a dynamic response greater than 80 dB, distortion below 0.01%, and frequency response flat beyond the limits of hearing. Recording was on half-inch tape moving at 30 ips. The audio quality of the master tape fully reflects these high levels of performance.

The recordings have been newly duplicated by In Sync Laboratories in New York City, in real time, using the original master tape and applying the very best of today's duplication techniques. The 22 minutes of music are complete on one side of a C-60 cassette tape.

If you order the cassette by mail, as outlined below, it will bring you three interwoven audio experiences:

The phenomenal acoustic realism of binaural recording, demonstrated in three different acoustic settings—a listening experience virtually unavailable elsewhere;

The ultrafidelity of the original master tape, which can hold its own for superb quality even in the digital era, brought to the cassette listener via the transparency of today's finest duplication methods, and

First-class music extremely well played by first-class musicians specifically for these recordings.

The music is in three groups of two pieces each. The first section features "The Sound of Change" (2:48) and "Space Virgin" (3:42). Ronnie Roullier, jazz pianist, composer, and group leader, wrote these pieces especially for the binaural project. The first is a typical rock number, the second a

splendid example of mainstream jazz. The performers, in addition to Roullier on piano, are: Joe Newman, trumpet; Morty Lewis, tenor saxophone; Wayne Andre, trombone; Joe Beck, guitar; Russell George, electric bass, and Ed Shaughnessy, drums. The setting was the Rutgers Presbyterian Church on Manhattan's Upper West Side.

The second set of selections includes an excerpt from the First Movement of Beethoven's Quartet No. 1, Opus 59 (3:00) and the First Movement of Schumann's Piano Quintet (6:28). The performers are the members of what was then Hofstra University's quartet in residence: Harry Glickman and Raymond Kunicki, violin; Jack Braunstein, viola, and Seymour Benstock, cello. On the Schumann Quintet, they were joined by Jascha Zayde, piano. The recording venue was a recital hall at Hofstra University.

The third and final section of the tape features Bach's Prelude in G Major (3:04) and the Trumpet Voluntary attributed to Purcell (3:25). Frederick Swann, organist of the Riverside Church in New York City, played these two familiar organ masterpieces on the church's powerful organ. As noted in the main text, the binaural technique makes it possible for the listener's hearing system to get a clear account of the music on the recording, through the tremendous reverb in Riverside Church.

Copies of the binaural cassette are available for \$11 each from In Sync Laboratories (2211 Broadway, New York, N.Y. 10024). Simply note that your check or money order, payable to In Sync Laboratories, is for the binaural cassette, and include your name and address.—R.L.

Blue Max

Good microphone placement ensured that every sound reaching the mikes would be subject to all the influences of the head and outer ears.

able balance between music and reverberation.

Blue Max produced a good balance by his very nature, allowing the hearing system to deal with the reverb in a "real" way—a major asset, as already noted. He made microphone placement an affair of great simplicity. We ended by leaving him about 30 feet from the chancel, in the main aisle. We could hear everything there—the voices of all the pipes and the full acoustic power of the church.

There was one unexpected result of our drive for very wide frequency response. The lower pedal notes came through with such power, as a result of their truly enormous acoustic power in the church, that we had to reduce the recording level about 10 dB to avoid overloading the tape. We did not want



to roll off the bass substantially, relative to the higher frequencies, so we accepted a small loss in S/N ratio, which the powerful music rendered inaudible through virtually the entire recording. In the other recordings, no such reduction in signal level was necessary.

When you listen to the organ recordings, you should keep the headphones tightly sealed against your head to avoid loss of the low bass. Also, as with all our recordings, you should set the perceived volume at the highest comfortable level for the "truest" space re-creation. It should be comparable to what the listener would hear at the original performance.

In fact, we believe that listeners will discover that the volume can be very high without any discomfort, if high-quality headphones are used. This results partly from the very low distortion in the recorded signal but also from the hearing system's opportunity to deal with a "real" signal, the gift of the binaural technique.

Jazz in Church

Our second recording, of jazz and rock music, also took place in a church. One rock and one jazz piece were composed for the project by Ronnie Roullier, pianist and jazz orchestra leader. "The Sound of Change" is the rock piece, and "Space Virgin" is the jazz.

We had arranged to make the recordings in the Rutgers Presbyterian Church on New York City's Upper West Side. This space has been used for a long time by independent recording engineers who like its very smooth reverb and the resulting clarity and definition in the music. Roullier assembled the group—six men from the army of talented and skilled pop/jazz recording sidemen available in New York City. We had some of the stars.

None of them had seen Roullier's music before sitting down in the church's chancel. The composer led the musicians in unpressured run-throughs of some passages while we moved Blue Max back and forth along the center aisle of the church.

Again, Blue Max showed his mastery in a wide range of positions. We did rearrange the seating of the group somewhat, to put the powerful trumpet, trombone, and saxophone a little further back so their volume would be more even with that of the piano. The setup, from left to right, was: Piano, guitar, and electric bass; drums in the middle, and then trumpet, saxophone, and trombone.

Finally, we put Blue Max in the main aisle, about 20 feet from the raised chancel on which the musicians sat. Every instrument could be heard perfectly there. When we gave Roullier the signal that the tape was moving, he and the group took off in a display of superb musicianship. They played with a verve and give-all to the music that I still remember with intense pleasure.

In the recording, all the virtues of binaural technique work especially well for the music. If the volume is set high, the result is just very strong, very clear sound, with the musicians seeming "right there." (Of course, if you like a lower volume, follow your inclinations but try the high volume first.) Being "right there" is exciting when listening to this group. The work by trumpeter Joe Newman, for example, is moving and strong. Ronnie Roullier's piano is splendidly in the spirit of mainstream jazz in "Space Virgin"; note especially his solo break about two-thirds of the way through the piece.

UPI/Bettmann News Photos

Max's Third Triumph

We made our final recording, of chamber music, in a recital hall at Hofstra University, using musicians who were then the quartet in residence. The room is quite large but without the very high ceiling that gives churches their strong reverb. Getting a good "live" tone could have been problematic with separated microphones and probably would have required a good bit of moving mikes around.

Yet there was absolutely no problem for Blue Max. He gave us a decent sound from anywhere in a wide area in front of the musicians, who were on a raised platform at one end. We settled on a position about 15 feet from the front of the platform. The string players were in standard quartet positions—first violin to the left, cello to the right, etc. For the Schumann Piano Quintet, we put the piano a little back and to the right, to get it in reasonable balance with the strings.

Again, the performances seemed to us totally first-rate, with complete commitment to the music and high skill. To double-check my decade-old high assessment of the work these musicians did, I recently compared their Schumann with the same music performed by Leonard Bernstein on piano with the Juilliard Quartet (Columbia MS-6929). My judgment is that our players did just as well and maybe a little better. Moreover, with no fuss at all, Blue Max produced a satisfying room tone, with all the performers in proper position. The Columbia recording is no better on these counts—the room tone is maybe a little thinner. We can assume it was made in a megabuck studio with controlled acoustics, artificial reverb if that was wanted, and plenty of mikes carefully disposed to get the performers front and center.

By raising the volume to a high but comfortable level, the listener will move close to the actual scene. He can get the thrill of being right next to highly skilled professionals giving an all-out account of fine chamber music. Of course, it is not as good as really being there, but it will make an excellent substitute for those many nights when a close approach is not possible.

Current Use of Binaural Recording

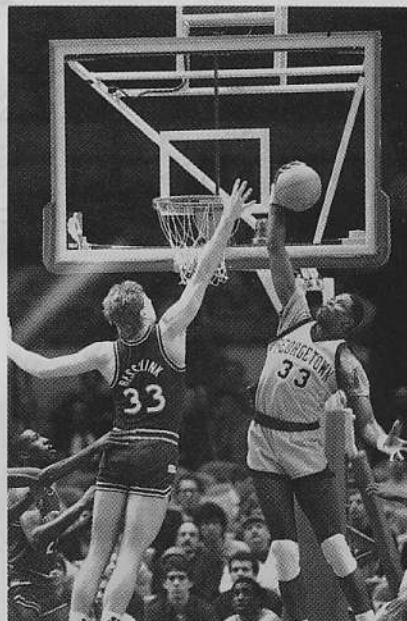
The strengths of binaural technique are evident in these three examples of recordings made more than a decade ago. Recently, there has been a growing interest in binaural technique, especially in Germany, where the Neumann company has developed a series of dummy heads which they use and sell commercially. Called "Fritz," the Neumann head is a near cousin of Blue Max but uses a somewhat different approach to microphone placement. The mikes are deeper in the simulated ear canal and work with an elaborate acoustic filter for needed equalization.

Neumann says their latest filter has made the recordings fully usable on loudspeakers as well as on headphones. This has evidently opened the way to the use of dummy heads in commercial music recordings—especially those made in highly reverberant spaces (for reasons this article has made clear). Our own recordings seemed to us, from the beginning, very effective on loudspeakers, though the full space and reverb effects were obviously lacking. Present in both modes of delivery are great dynamic range, very low distortion, and extra-wide frequency response. The recordings seem excellently balanced on speakers, and the performances are completely enjoyable.

Masquerading as Blue Max

In addition to music, our original recording included a full side of demonstration material—city sounds, moving voices, etc. For these recordings, we used an entirely different system in which studio-grade electronics and fast tape recording were abandoned in favor of portability.

We did search for the best small portable recorder we could find at the time, which turned out to be a

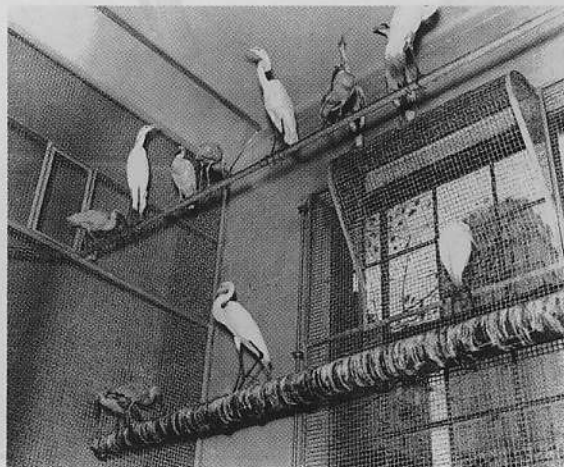


Uher. This unit recorded two tracks on the full tape width of $\frac{1}{4}$ inch, at $7\frac{1}{2}$ ips. For that tape speed (and that time), the quality was excellent, though obviously not up to the studio quality of our larger recording system.

To get binaural input, we used my own head as the dummy head (no coarse humor, please). I spent about two months going around Manhattan with small condenser mikes in my ears and the recorder under my coat. Though the resulting recordings lack the appeal of the ultrafidelity on the music recordings, they do further illustrate binaural technique in action.

The demos on the original recording included: A college basketball game in an enclosed arena whose tiled walls turned the crowd's roars into oceans of reverb (through this din, the binaural system pulled nearby voices, referees' shouts and whistles, and other individual sounds); the bird house at the Central Park Zoo, gently echoing with a mixture of children's voices and eerie bird calls; an exuberant crowd watching New York City's Puerto Rican Day Parade, with many far and near voices around my position and the marching band's music passing in front; a beautiful antiphonal service in a Greek Orthodox Church, with the sonorous priest high on the left, the excellent choir high on the right, and the congregation's responses all around; and rush hour in the Times Square subway station, with loudspeaker announcements competing with massive train noises, voices in the crowd, and shuffling feet.

These and other demo recordings capped our experiment with binaural technique, a most satisfying voyage in so many ways. **A**



Courtesy of Central Park Zoo

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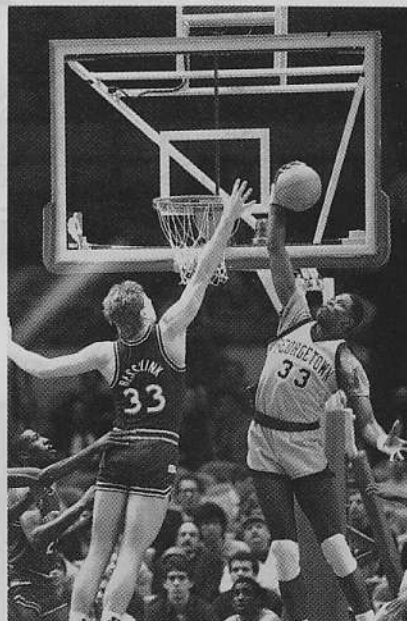
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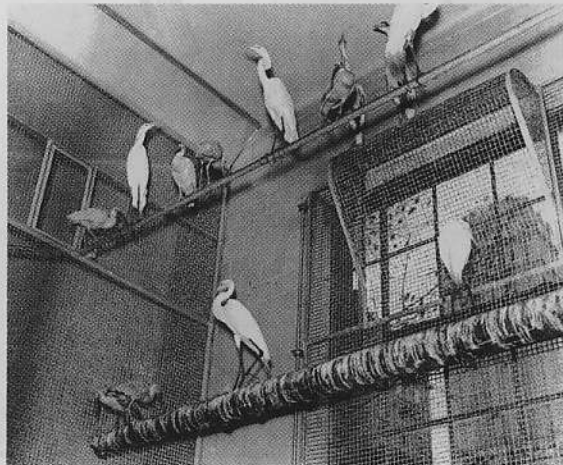


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