Getting the Best From Lavalier Microphones, January 1998

May 17, 2004 12:00 PM

EXPERTS SHARE THEIR TIPS

Microphones

Experts Share Their Tips

lav·a·liere, n. an ornamental, usually jeweled, pendant on a small chain, worn by women about the neck. Named after the Duchesse de La Valliere (1644-1710), mistress of Louis XIV of France.

The lavalier (or lavaliere) mic is a special-purpose device, not unlike a shotgun mic or hydrophone. And like those devices, the "lav" has some sonic characteristics that restrict its usefulness. However, though the lavalier mic is rarely a first-choice mic for music recording, there are many situations in which the advantages of small size outweigh sound quality considerations. For example, though a well-positioned overhead microphone is usually the ideal location sound recording tool, when the mic must be invisible to the camera, a lav may be the only choice. Similarly, a well-positioned rostrum mic will usually sound better on an "industrial" presenter or motivational speaker, but the reality is that a lav is almost always the production manager's first choice.

Which is not to say that it's always the sound mixer's first choice. A common refrain, whether on a Broadway show or on location for a big-budget feature film, is that "lavaliers are a necessary evil." Well, they don't have to be. This article explains how to get the best results from lavalier mics in less-than-ideal circumstances.

SELECTING MICS
When selecting a lavalier mic, most of the P.A. rules of thumb apply: Gain before feedback and a flat response are primary considerations (fortunately, these two characteristics are usually complementary). Coverage pattern is also important, though even the most **hypercardioid** lavs tend to be far less directional than larger-format mics.

If you are renting lavs, try to stick to one model; mismatched lavs can result in impossible situations, especially when there are several lavs and a P.A. feed in the same room. An exception to this rule is when a particular mic model accentuates an unwanted timbre or sibilance.

Accessories can make the microphone. Ask your dealer what accessories are available and buy extras—when you are on location and find that you need more mics than you have, the extra clips make it feasible to pre-rig several locations and switch mics around quickly. Plus, you can now afford to lose an accessory, which is all too easy on a busy set.

In general, stick with the manufacturer's supplied mic clip or windscreen; a substitute "universal" clip rarely works as well as the original. Also, compromised mic-mounting solutions tend to fail in the middle of a live feed, leading to stress on the mic-to-cable connection (not to mention stress on the director-to-sound-recordist connection). A warning: Don't temporarily store accessories in your pocket. They all seem to start at a replacement cost of $30, and if you walk off the set with a pocketful of accessories, that can take the profit out of your whole day.

POSITIONING AND SECURING

The all-round best spot to aim for in hiding a miniature mic is just above the sternum or breastbone. The resonance of the chest cavity sounds much better than when the mic is positioned at the throat area. Often, a vampire clip to hold the mic inside the shirt, touching the skin, is all you need. Layers of clothes and physical action can spoil this setup fast, but if you place the mic to favor the head turn (if there is one in the shot), this placement often does the job.

Warning! When using a metal-bodied mic next to the skin, be sure that your power source is grounded properly (especially if it's a generator) and that all cables are wired correctly. A wet field, leather-soled shoes and a truck generator in combination with a hard-wire lav can make your star anchor do the "You're fired!" dance.

To hide a mic in or under clothes, choose a mic with a recessed grille, rounded edges and an LF **roll-off** characteristic. "On collars and ties, I like to hide the lav in the tie knot," says Pete Verrando, C.A.S., a freelance production sound mixer in Dallas for the past 12 years. "The perspective is pretty forced, but the clothing noise is really minimized. Suits make tons of clothing noise. I usually tape the tie to the shirt, as well. I wrap the lav in toupee tape before concealing it in the tie knot."

Once the mic is hung and dressed, the next few inches of mic cable should be loosely looped into an overhand knot, then strain-relieved at the nearest belt or collar. This is the little-known 9**dB** knot, so called because the nature of the loop and knot allegedly reduces noise by 9 dB. Hey, it works.

Successfully positioning a lav mic often necessitates a rather intimate relationship between the sound engineer and the performer. Sometimes actors and models are asked to work in cold environments, yet are costumed as if for a heat wave. A cold-metal sound component against the back can be just the thing to trigger very unphotogenic goose bumps; so, after you battery-up your transmitters and preamps, store them in your pocket for a while.

When your job involves shoving your arm under somebody's clothes, tact and consideration are extremely important. "I don't get much hassle from actors when futzing with their clothes," says Verrando. "I tell them what I'm going to do first, and then get them to help me string the wire through the clothing. It helps to kind of narrate the process as it's happening." This goes double for high-power CEOs. These days, most are pretty media savvy, but if you're on their turf, watch out! Confidence and politeness in these situations are essential, and don't forget those breath mints!

Make friends on the set or backstage. Wardrobe and hair people can help you immensely or, intentionally or not, make your life miserable. They can make useful accessories like mic belts, which can help hide a radio transmitter when a dress has no pockets. Hairdressers can help you with a good head mount that positions the mic in a hat, wig, glasses, mask or hair. A good head mount is hard to beat; the proximity can be excellent, the skull resonates nicely, breath pops are eliminated, and head turns are not a problem. Make sure you have proper strain relief, and keep the wire invisible at the neck. In the case of a dancing performer, take extra care with strain relief.

Wardrobe can also provide you with integral mounting as part of a costume and quick solutions to clothes that rustle. Everyone has an opinion on which fabrics make the most noise, but most problems seem to come from layers of different types of clothing rubbing over each other. Starched or stiff clothes tightly worn are also noisy, as is contact with the windscreen, body or cable of the microphone. A few quick passes with needle and thread can often eliminate such problems.

Nevertheless, some wardrobe choices are bad news for the sound person. Jewelry, running suits, corduroy and plastic fabrics can all cause problems and should be tested for sound in an air-conditioned trailer, rather than on the set. Better yet, convince the director that you should attend wardrobe pre-production meetings.

"The main thing about body mics is letting the [assistant director] or who-ever is in charge know that sound needs some time to wire actors," says Verrando. "On crazy shoots, when in doubt, wire 'em and it'll be there if you need it. But it's good form to let all involved know what I'm doing. It also trains the crew chiefs to occasionally expect a little sound setup time."

TOOLBOX TRICKS

Every sound pro carries a comprehensive spares kit and toolbox, but you will need a few more items for lav mics. It's extra stuff to carry, but if you hang up the production while you fabricate and perfect an improvisation, you may not be hired again.

A few thoughts about adhesives. Gaffer's tape, toupee tape and moleskin should be chosen carefully and used

wisely. Residues can fill in microphone windscreens and may gunk up the diaphragm. Never store mics with tape still on them. Camera tape and paper-based tapes are bad choices. Try waterproof adhesives like surgical tape; good, fresh gaffer's tape is always hard to beat. Most of the rest of the kit resembles items from the hairdresser's kit, but have the items on hand anyway.

SMOOTH OPERATION
Lavaliers require maintenance, just like any other piece of pro audio gear. In normal use, there is very little that can go wrong with a lav mic, but heavy use and wet conditions should inspire cautious preventative maintenance. Molded connectors should be visually and operationally inspected, especially after a good yank on the cord. Don't lose your chance to identify the problem before the mic is stored with its twins. Fastener-assembled connectors are notorious for coming unscrewed, so make sure you have the right screwdrivers on set. Make sure all your fasteners are well-seated, but not too tight. Watch for corrosion build-up or dirt in the contacts.

Moisture is the enemy, sweat is the worst. Joe Pino, resident sound designer at the Tony Award-winning *Alley Theatre* in Houston since 1990, recommends the following for sweat-outs: "There's nothing you can do after it happens, as far as I know. Let them dry out and see if they start working again—after a few days, Pow!, there they are like nothing ever happened." In desperate situations, try storing the mic in a zip lock with some form of sealed desiccant. As a preventative step, Pino recommends spraying or dipping new mic windscreens in Scotch Guard and then immediately blowing the mesh out with canned air.

Windscreens are often necessary outside, but they are not "rain screens." "Lately we've been leaving the windscreens off—the windscreen seems to actually wick the moisture into the capsule," says Pino. "We still use moleskin or Elastoplast occasionally as a cover and moisture barrier, especially if the mic needs to be colored to match make-up. It really depends on the performer and the application."

A particularly important point to consider is battery power, including electret batteries, battery-driven phantom supplies and transmitter packs. Pino recommends checking the latest *Consumer Reports* battery tests to see how the various manufacturers' models stack up. Such articles usually include an informative treatise on different battery compositions. The major point to note is that as voltage goes down, the noise floor seems to rise, the output is reduced and gain before **feedback** is reduced. The preferred type of battery starts with a high sustaining voltage that drops off sharply, rather than gradually. Never compromise on batteries, and properly dispose of them immediately to prevent reuse. No matter how much the producer whines about budget, just remind him that cameras need light and sound needs batteries. Never accept rechargeables.

EQUALIZATION
And when you've wired the actors and are set to record, please remember: Critical EQ decisions are often better left to post-production! The watch word is consistency. In live situations, radical EQ settings chosen to favor one voice can leave other actors' voices too thin. Further, radical EQs will not cross-cut well against the "average" EQ setting. Make sure to record some ambient room tone while you still have everyone wired.

In order to reduce noise from handling, clothes, ambience and breath pops, a low-cut (bass roll-off) EQ is allowable. High-frequency EQ should only be added in cases where intelligibility is being lost, such as when the mic is obscured by thick clothes. Unnecessary use of HF EQ can result in too much sibilance, especially in a wireless/Nagra combination. In such situations, another mic placement or another type of mic, such as a shotgun, will often yield better results.

Properly used, lavs can provide an elegant solution to many modern sound design problems, and they can often be used in conjunction with other mics to improve overall sound quality. "I often use a lav to help clarify a line in a boomed scene," says Verrando. "When a scene is great on the boom except for a line or two, I'll sneak the lav in the mix to perk up those lines. A scene doesn't have to be all boom or all lav." Don't be afraid to experiment, and give yourself time to use the best test equipment in your rig: your ears!

PREPPING MICS THE ALLEY WAY(courtesy of Joe Pino)
1. Power up the pack.
2. Quick vocal check ("One, two, testing").
3. PFL in cans, work the entire length of the cable, looking for continuity faults, especially at the connector.
4. Second vocal check.
5. Repeat for next mic. *Note: Once mics are turned on at the console by the engineer, they should never be turned off. If you try to save batteries by leaving them off for a late power-up, you're courting disaster.*
6. After check, which should be as late as possible (keep the batteries fresh), the mics should go straight to the

performers.
7. In long shows, it's not a bad idea to change batteries at intermission.

Pino claims that, thanks to these procedures, he has mics over seven years old that are still in fine condition!

LAVALIER TOOL KIT ESSENTIALS
• Small rolls of gaffer's tape, toupee tape, medical/surgical tape
• Vampire clips, tie-tack clips, button-hole clips
• Extra batteries
• Foam windscreens, cheesecloth windscreens
• Velcro body-pack holders
• Zip-lock bags and a sealed desiccant package
• Battery-powered shaver (used to prevent "five o'clock shadow" noise on the collar)
• Breath mints (self-explanatory)

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SONY

SoundByte

SPRING 2001
ISSUE #11

THE SONY PRO AUDIO NEWSMAGAZINE

www.sony.com/proaudio

Producer Walter Afanasieff (left) and chief engineer David Gleeson at the Sony Oxford console at Wally World.

It's a Digital World

Legendary Audio Producer Walter Afanasieff Invests in Oxford and DMX-R100 Consoles

Also Inside:

Digital Audio for Broadcast

NBC Installs Oxford Console

PBS Station Goes with DMX-R100

Public Displays of Affection

KUHT audio specialist Douglas Robertson at the Sony DMX-R100 console.

KUHT/Houston Public Television loves the DMX-R100 so much that they bought three of them.

KUHT/Houston Public Television, the first non-commercial television station in the U.S., has purchased three Sony DMX-R100 digital consoles for its new facility on the University of Houston campus. The first R100 is currently online in the complex's Studio 1 production room. A second unit is slated to go online this summer in another production suite, and the third R100 will be used in an audio sweetening postproduction studio scheduled for construction in the fall.

"We desperately needed to upgrade our audio mixing equipment," reveals Andy Anderson, director of engineering and operations at KUHT, which broadcasts a daily news/public affairs show as well as documentaries, live programming, membership drives, and other productions. "We chose the R100 because it was cost-effective, compact, and offered a great deal of capability. The fact that the console has 48 inputs assured us that it would meet all our requirements. We also needed a unit that had limiting/compression on all the channels."

"The R100 is a dream," states Douglas Robertson, audio specialist at KUHT. "The first of our three boards replaced a digitally controlled analog board from another manufacturer. Right off the bat, the R100's footprint was smaller than the control surface of the original console, not to mention its eight-foot rack of mixer electronics and switch points."

According to Robertson, PBS affiliates are often caught in the conundrum of adhering to the highest broadcast standards and the lowest broadcast budgets. "The R100 solved this problem," he explains. "We bought three for less than the base, no frills price of any of the all-analog industry standard broadcast mixers available today. We could have bought six for the cost of competitive digital mixers. The R100's extensive feature-set, which includes dedicated, simultaneous 5.1 and stereo monitoring and mixing, 9-pin machine control, input and output routing matrixes, and snapshot and dynamic automation, would have cost extra. Plus some of the options, like delay per channel, might not have been available at all."

Robertson describes himself as an audio department of one: "Frankly, most of the actual audio assignments are accomplished by employees whose reason for living is not audio," he explains. "Usually, I design the setup, do the install, train the assigned operator, and move on to the next project. The snapshot automation in the R100, combined with the input and output router, eliminates the need for operators to do complex patching, troubleshooting, and setups on their own. They just call up the snapshot and go right to mic and playback source checks.

"In addition," Robertson elaborates, "there is plenty of memory for operators to customize their own snapshots. With the built-in floppy, they will be able to export those setups to other R100's as they come online. So, instead of having to train operators and producers on the distinctions between different boards and dealing with the preference of one control room over another, I only have to train an operator on one mixer and they're good to go on any air board in the plant."

Referring to the flexibility of the aux bus control as "nothing short of revolutionary," Robertson is "thrilled" that mix minuses are no longer complex thought experiments. "Inherited from the big brother Oxford, you can call up the bus on the faders, turn up the ones you want the talent to hear, pull out the talent's channel and anything else you don't want to send, and you're done," he states. "The comprehensive talkback features make cueing talent through the mix minus bus super simple.

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L.A. Recording Workshop Looks to Sony for Digital Future

The Los Angeles Recording Workshop, a North Hollywood-based state-of-the-art educational facility specializing in studio engineering, digital video editing, and film production, has made a major investment in Sony digital technology. In addition to installing an Oxford OXF-R3 and five DMX-R100 digital consoles, the school has purchased a DRE-S777 digital sampling reverb and a PCM 3348 digital recorder.

Four R100's have been installed in the Los Angeles Recording Workshop's Sony Lab (pictured left). The fifth board is set up in a 5.1 surround sound-capable studio with a recording room and isolation booth. "Students can start an assignment in the lab, burn their recording on a DVD-RAM, and then take their tracks to the Sony R100 studio to continue the project," explains Knight. "The board is powerful and cost-effective, and its sonic clarity and flexibility are incredible. It was the only choice for us."

Pictured at the Oxford is Los Angeles Recording Workshop director Christopher Knight (right). According to Knight, the advanced section of the Los Angeles Recording Workshop program focuses on digital mixing in the school's recently constructed Sony Oxford suite. The new Sony gear is an integral element of the school's recording engineer pro-

Late Night with Sony

continued from page 6

of EQ required on individual sources and the overall mix.

Any final comments?

The overall experience has been a positive one. The sound of the digital console is excellent, rivaling any high-end console we considered whether it was analog or digital.

We've been particularly pleased with the transition from the analog platform we were used to. The Oxford accommodates this move by offering digital enhancements while still retaining some of the important familiarities akin to an analog control surface.

Public Displays of Affection

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"Here at Houston PBS, we don't do cookie-cutter news shows," concludes Robertson. "We live for change. The R100's astonishing simplicity and flexibility make studio turnovers, pledge drives, station events, and music tapings a pleasure for the ears — not a headache for the sound guy. In the same week I installed our first R100, we went right into our Million Dollar March, the linchpin of our pledge drive and fund-raising efforts. I mixed the first evening with minimal error and handed off to the next two operators to do the following days. The R100 worked beautifully. Everything sounded clean and loud."

"We were impressed by [Sony regional audio manager] Art Gonzales's R100 demonstration at a SMPTE meeting awhile back," Anderson adds. "A true all-purpose board, the R100 meets our needs throughout the station."

"We're extremely pleased that KUHT/Houston Public Television has chosen the R100," comments Courtney Spencer, vice president of professional audio products at Sony Electronics' Broadcast and Professional Company. "The variety of applications they plan to engage it for underscores its versatile functionality. In terms of both cost and flexibility, the R100 is a great fit for KUHT's multifaceted operation."

SoundByte: The Sony Pro Audio Newsmagazine is published quarterly by Sony Electronics Inc. in association with MP&A Custom Publishing, a division of United Entertainment Media. **Editorial Director:** Anthony P. Montesano; **Managing Editor:** Anthony Savona; **Art Director:** Marshall Moseley; **Associate Art Director:** Greg Gennaro; **Cover Photo:** Steve Jennings; **Photo Credits:** Pg. 3, (bottom right) Howard Sherman; Pg. 4, Courtesy of LAUNCH Media. Used with permission; Pg. 5, Courtesy of KUHT. Used with permission; Pg. 6, Howard Sherman; Pg. 8-9, Steve Jennings. **Editorial Office:** 6 Manhasset Ave, Port Washington, NY 11050. Ph: 516-944-5940; Fax: 516-767-1745; **MP&A Custom Publishing, a division of United Entertainment Media — President:** Paul Gallo; **Senior Vice President:** Martin Porter; **General Manager:** Kathleen Mackay; **Director:** Anthony P. Montesano.

NEW MASTERS SERIES OPEN MONTAGE
INTRO MONTAGE TO INCLUDE HEADLINES, STOCK VIDEO ABOUT BUCKYBALLS NOVA, DISCOVERY CHANNEL, SCIENTIFIC AMERICAN JOURNAL.
As part of New Masters' first series on superconductivity, we are going to explore another discovery, Buckyballs, whose repercussions cross many boundaries, including the field of superconductivity. No study about superconductivity can ignore the discovery of organic compounds that superconduct. Organic compounds contain carbon. Organic chemistry is a huge realm of study within chemistry and includes all of the molecules and chemical processes that keep us alive.
SMALLEY STANDUP WALKING INTO LAB AT RICE SHOT ENDS ON C.U. OF SMALLEY GROUP SIGN.
You'll meet Dr. Richard Smalley, Hackerman Professor of Chemistry and Professor of Physics at the Rice University Quantum Institute.
STILL OF GROUP. VIDEO OF FIRST PAPER BALL. STOCK FOOTAGE OF SOCCER ACTION.
Dr. Smalley and his research group were the first to theorize the shape of C60, properly named buckminsterfullerene. The shape of the Buckyball is already familiar to anyone who has played soccer.

2-D GRAPHICS OF BALL AND METRIC MEASURING STICK. BALL SHRINKS ZOOM IN PAST SCALE MARKS ON STICK, SOCCER BALL MORPHS TO ROTATING 3-D MODEL OF C60 BACKGROUND GOES BLACK, FLASHING FINAL SCALE READS ".000000001 METER.=. 1 Nanometer"
If we imagine a soccer ball only one billionth of a meter across and place a carbon atom at each of the corners of the black and white patches, we have conceptualized a good model for the C60 molecule.
PAN RESEARCH GROUP SHOT. OR MONTAGE.
In 1985 Smalley, with his research group, Dr. Robert Curl, graduate students J.R. Heath and S.C. O'Brien, and visiting colleague from the University of Sussex, England , Dr. Harry W. Kroto designed a series of experiment to simulate the properties of carbon chains in a vacuum.
SEQUENCE: SHOT OF APP2, VAPORIZING CARBON,
2D DIAGRAM OF SUPERSONIC BEAM ASSEMBLY (SLIDES), PHILIPPE POINTING OUT PARTS, OVER SMALLEY'S COMMENTS
They used a unique device designed by Smalley, in the labs of the Rice Quantum Institute.
"5:04:xx In this apparatus we call ap 2Éwhen the laser comes down and hits the disc, there's a rush of helium gas over the surface of the disc where the laser hits, and that helium gas is confined to go down a little tube, where the vapor that came off of the carbon disc that was laser vaporized has a chance to mix around with itself and to form clusters of larger carbon molecules, which are swirling around in this helium gas rushing down this tube, until finally the tube stops and (5:01:05) there's an opening into a vacuum chamber and the gas just expands. At that point, all of the reactions between the carbon vapor atoms to make these clusters stops (sic) because they don't collide with each other anymore, and they're just simply thrown through the rest of the apparatus, actually pushed by the helium, gas until they're all going the same velocity, and what happens in the machine is that as this plume of gas expands with the clusters in it, we pick off a little central section of that with what's called a skimmer, (5:05:36) and the stuff that goes through that skimmer then goes into another chamber as a beam ; we call that a supersonic beam which now has these carbon clusters inside of it.
The clusters were accelerated and released into a time of flight mass spectrometer.
Cohen 6:00:49 When you give energy to particles depending on how heavy they are they travel at different velocities so that if you have many different particles with different masses, if you give them a certain amount of energy with an

electric field then the heavier ones will travel slower and that's because their KE = to 1/2 * their mass times the square of their velocity 6:01:17.
COVER WITH SHOTS OF APP-2
Smalley 5:07:25 At the top of the long tube we have a detector that can detect a single cluster hitting it, and that's connected to a computer that looks at the times that the clusters hit the detector, and it senses the first clusters hit, which are the lightest ones, and it counts up how many there are, and then here comes another packet of heavier clusters, they finally hit the detector, the computer counts those up; and here comes another packet of yet heavier clusters, and it counts those up; and so when all of these have finally gone to the detector, the computer has a list of when all the clusters came in time; and the first ones that come were the lightest ones, and the last ones are the heaviest ones, and so you have these ups and downs in the data of clusters hitting the detector, and that's what we call a mass spectrum
SHOOT VARIOUS EXAMPLES OF THE MASS SPECTRA, PANNING ACROSS. SHOOT OVER SLIDE W/SMALLEY IF AVAILABLE?
Smalley(01:03:25) So we vaporized carbon in this apparatus and we did find the linear chains that we were looking to study, but we found something else as well. Not for clusters of 10 or 20 atoms, but rather for clusters of 40, 50, 60, 70 atoms in size, much larger clusters. It became clear that there was something very different going on, and the major signature of this was that for some reason, strangely, all the odd-numbered clusters were missing. There was only 40, 42, 44, 46, 48, 50, all up as far as we could see, hundreds of atoms. Some sort of magic seemed to be going on in the apparatus, that whenever an odd cluster was made it somehow picked up another atom or lost an odd number of atoms and became even numbered. So that was a clear indication there was something special going on.
ZOOM TO 60TH SPIKE, DISSOLVE TO 3D BBALL
But the most bizarre thing was that one of the clusters, in particular, the 60th cluster, was especially abundant in the beam; somehow there seemed to be something going on as the carbon clustered together that made the 60th (01:04:46) cluster very special.
3D RECONSTRUCT OF DESCRIBED SECTION OF APP 2. VIEW ARCS IN, THROUGH WALLS TO INTERIOR OF APP 2. SEVERAL RANDOM SPECIES OF CARBON ARE TRAVELING DOWN THE TUBE. VIEW MATCHES A SECTION WHERE SEVERAL RADICALS COLLIDE, BUT DO NOT BOND W/ C60. SOME RADICALS BOND TO FORM FULLERENE SPECIES
Smalley 05:14:59 The first aspect of Buckyballs that clued us in that something was special was their stability. Here these were species that were able to survive back in the nossle where all these very reactive carbon radicals and atoms were around. They weren't reacting with them. Somehow sixty carbon atoms had formed a object which even though other carbon atoms which were ragingly reactive had come up against its surface, they would not react with them. Which is stunning when you think about it.
SMALLEY, HOLDING SHEET, DEMONSTRATES:
Smalley 1:05:56 So when we were looking at these large clusters of carbon that were being made in this new apparatus, the most reasonable thing to assume for the really large ones is not that they were linear chains, which after all, would have gotten ridiculously long by this time, but rather the ordinary flat form of carbon graphite. The trouble is there was one cluster in particular that seemed to have eliminated all these little things here which are called dangling bonds. You see here's a carbon that only has two carbons next to it and it has one bond hanging out here that there's nothing to bond with. But this 60th cluster of carbon couldn't have one of these, it wouldn't react; it wouldn't behave the way it did. It would seem to be completely inert. And for that matter why would there just be an even number of carbons. When you've got an open sheet like this you could have any number of carbons. The flat sheets just didn't explain what we were seeing. So we started to think, well, maybe there's some

other thing that's going on here, maybe somehow these sheets that are in this apparatus, flying through a vacuum, with nothing else around; unlike these sheets would be in a liquid or in a solid where there'd always be some atoms to come up and tie up these edges, here in the vacuum there's nothing, and so these dangling bonds are so expensive for this cluster to have, that it will do darn near anything to get rid of them, and we began to imagine that maybe somehow, it's curved up, so that these dangling bonds over here can bond with these over here and eliminate it. Of course that only takes care of them on this side and that side, how about the front and the back, well maybe it actually curves (01:07:55) up all around to make some sort of basket thing that (1:07:56) closes at the top, and be something like what we remembered (1:08:01) a geodesic dome looked like.

USE GEO DOMES AND HEADSHOT OF B. FULLER

Early discussions in the group centered on the best-known invention of the recently deceased Richard Buckminster Fuller. Fuller was an American architect and inventor who sought to solve practical problems with simple designs that require a minimum of materials and energy. The use of polygons in Fuller's geodesic domes inspired the discovery of C60's final form.

SHOOT RECREATION OF SMALLEY AT DESK AT HOME. ESPECIALLY CLOSEUPS OF MODEL ASSEMBLING

Smalley 1:09:17 That night I went home, deciding that I would spend the evening working on my computer trying to make a hexagonal lattice curve around and close in itself. Well after a couple hours of playing with the computer graphics I decided quickly it was just too hard a problem to do that night on the computer, so I gave up with the computer program and simply got a sheet of paper and cut out some hexagons. I cut out one hexagon and then I cut out a whole bunch of hexagons exactly the same size, with equal sides on all 6 of the edges, and put them down on my desk, and with Scotch tape, started pasting around a central, initial hexagon, pasting other hexagons around it. Of course it takes 6 hexagons to go around it.

HEXAGON BATHROOM FLOOR (DOUG'S MOM'S HOUSE, MIGHT FIND BETTER)

Well, anyone who's looked at a bathroom floor that has hexagonal tiles on it knows that what you get when you do that (01:10:21) is a flat surface.

IMPORTANT CLOSEUP, TRYING PENTAGON

01:11:20 So then after I thought about it a bit I decided to try a pentagon, because we know that pentagons are sometimes used to do structures, so who knows, maybe carbon is somehow able to put a pentagon in as it's hooking together to make one of these sheets, and maybe that will help it curve. So I cut out a pentagon out of paper, being very careful to make sure the side of the pentagon was the same length(1:11:50) as the side of the hexagon.

STOP ACTION ANIMATION (WIREFAME) OF RADICALS ASSEMBLING SALAD BOWL

1:11:57 Even when you put the 2nd hexagon in it's very clear you don't have to cheat now in order to make it curve. The sheet naturally curves with a pentagon present. And as you attach more hexagons around that pentagon you get a very (1:12:14) clear sort of salad bowl structure.

1:14:22 Since it was clear that the pentagon is the answer to how you curve the sheet, and we knew somehow you gotta get it to curve all the way around, I quickly cut up a bunch more (1:14:32) pentagons.

ZOOM OUT FROM CLOCK, SMALLEY FINISHING C60, EXAMINES. 1:16:20...and put it all together, and by about 2 o'clock in the morning I managed to put the top pentagon right here on a pentagonal (1:16:34) hole and made the first model of the C60 molecule.

USE BUCKYBALL SGI ANIMATION OR FANCIER

The shape of the buckyball was unique to chemists. Here was a symmetrical cage of carbon, a three dimensional example of the aromatic, or ring-like structure of hexagons and pentagons known to be the basis of the graphite crystal.

SGI MODELS, CHICKEN WIRE AS NEEDED, SMALLEY HOLDS GRAPHITE SHEET

Smalley 20507 And the remarkable thing bout this is that if you held a graphite sheet in your hands, and you pull it like this, the force that you'd have to put there to rip it apart, is higher then any other two dimensional network that we know of. This is the all time strongest two dimensional connected network of any atoms in the periodic table Carbon does this job better then any of the others. Also, even though you can see there are holes in the sheet, it turns out that even the smallest atom can't get through the hole. The energy it takes to take an atom and push it through the hexagon is much higher then any of the energy that is around even at thousands of degrees Centigrade.

COVER WITH CONFERENCE AND RESEARCH STOCK

The initial properties of the buckyball and fullerene molecules inspired the scientific and industrial community to reexamine carbon with new interest. Chemists and physicists, experimentalists and theoreticians, universities and corporations all over the world wanted to study the properties of C60.

USE SGI ROTOS

New shapes were discovered: bucky ovals and tubes, layered bucky onions made fullerene cages with many shells or skins.

SGI INDOHEDRAL ATOM OR SERIES FROM SCIENTIFIC AMERICAN

At Rice, Smalley's group even created a process whereby atoms were shrink-wrapped in carbon.

STOCK MICROSCOPE SHOT, PHILLIPE RUNNING SPECTRUM ANALYZER, APP 2

Researchers wanted to see what fullerenes would look like in samples big enough to test and handle with traditional, and less esoteric and expensive equipment then those designed by Smalley. SHOW CHARTS OF PRICE/TIME AND VOLUME/TIME. NEED PICTURES OF KrŠtschmer AND Hoffman. MAY NEED TO REPLACE WITH SMALLEY INTERVIEW

Almost instantly, a demand arose for buckyballs, especially in bulk. No one new that two groups of physicists had already made the first big sample of C60. Wolfgang KrŠtschmer at the Max Plank Institute for Nuclear Physics and Donald Hoffman working at the University of Arizona had been trying to simulate the dust in interstellar space. In 1983 they used a carbon arc similar to a welding rig in a vacuum chamber to produce an unusual double humped spectrograph they called the camel sample. The camel sample was unique, but it wasn't what they were looking for. When they read the published findings of the Smalley group, they began to wonder if the camel sample was actually C60.

Finally, in 1989, the KrŠtschmer group recreated their experiment, announced it at a conference in September of 1990, and the bucky genie was let out of the bottle.

8:06: We got into fullerenes around 1991. That was after they had improved their technique. Actually Huffman and Kratschmer had created the resistive heating of graphite technique and rice had refined it to the arc technique, and that's the technique we use today. 06:56 Basically we run a very large amperage source, a reasonable D.C. source, 35 volts, and we create an arc. This arc is used to evaporate the graphite and the evaporated graphite is carried down the tube here into a collector bag in the back. That material is soot and it contains about 10% fullerenes. 08:19 Well we take that soot material, we call it soot, and we soak it in toluene. What that does is the fullerenes are soluble in toluene and the others are not. And its like separating sand from sugar, if you put water in a sand and sugar mixture , the sugar will dissolve in the water and come out and the sand will be left behind as a solid. So we take that mixture, we filter it and in solution we have pure fullerenes. 08:09:20 What we do with that solution is we roto-vap it which is basically like in the sugar water mixture, you would boil off the water and the sugar would be left behind, so we boil off the toluene and the fullerenes are left behind, those fullerenes are comprised of approximately 75% C60, 25% C70 and although those numbers add up to 100 percent , about 1 to 2 percent are higher fullerenes.

SVEC THIN FILM LAB

Research proceeded at an explosive pace. Techniques were developed to grow thin films of buckyballs. It was hoped that such a thin film would have diamond-like properties in a shape that could be used for industrial applications.
Moss TCSUH 15:05:31 This is a fascinating material because when you combine it with another one in a crystal structure and pack them, you can pack them in the same way that cannonballs are stacked; it's a very familiar structure. Argon forms such a structure when it freezes, copper and aluminum and gold and silver and platinum and palladium all form a structure in which balls puck like cannonballs, like stacked bowling balls or stacked billiard balls, it's called a close-packed structure. If you take these molecules of C60 and pack them together, you will have a single crystal of C60, but these molecules are sort of spinning around; not freely spinning, because it's (15:06:13) not a sphere, but spinning nonetheless.
The crystals of pure C60 turned out to be an insulator. But alternating alkaloid layers with bucky layers yielded something quite different.
DEVELOP ANALOGY VISUALS BOTH ORANGES/CHERRIES AND ANIMATION
Smalley 2:16:19 that was done about two and a half years ago by a group at Bell Labs, where they packed just empty-old buckyballs together, like oranges in a crate, and then they added metal atoms outside, because you know when you pack oranges together, you can get them pretty close together, you make a nice pretty thing, you put oranges on top, and make another layer, and another layer. But if you look at it there's always little gaps in between the oranges. And since these oranges are pretty big, as molecules, the little gaps they leave (2:16:55) are pretty big. And it turns out that the gaps that you get when you pack buckyballs together are big enough to put basically any metal atom in. In many cases, more than one. And at Bell Laboratories they put potassium atoms in there. And the potassium atoms have an extra electron that they very easily give up. The buckyballs turn out to like electrons, so when you put the potassium atoms in, an electron hops off and goes on to the buckyball, the potassium atom becomes positively charged and the buckyball becomes negatively charged. Of course they attract one another. This potassium atom doesn't have just one buckyball here; it's got 4 or 6 other balls around it, and so it's sort of trapped in the middle there. Well if you put a potassium atom in every one of the little holes in between the oranges, and just finish doing that, it turns out that for every buckyball there's 3 potassium atoms. And we call that the potassium buckide salt, it's like table salt, except that unlike table salt, which is an insulator, a colorless, clear crystal that doesn't conduct electricity, this material, with potassium and the buckyballs in it, is a bluish-black metallic solid that really is a metal at room temperature; so electrons move all the way from one side to the other, hardly without stopping in between; and that material, the potassium buckide salt, if you cool it down to about (2:18:34) 20 degrees above absolute zero, becomes a superconductor.
FOLLOW ELECTRON DESCRIPTION WITH ANIMATION SEQUENCE FROM ABOVE, THIS TIME, ZOOM IN TO SHOW ALKALIS DONATING ELECTRONS, COOPER PAIRING, ETC
Cohen TCSUH9:18:11
Now the superconductivity, the mechanism, at this point, is controversial, but the current view is the following: that the oscillations of the buckyball itself provide a way for the electrons that are flowing between the buckyballs that have been donated by the alkali atoms for them to pair up. So if you picture an array of buckyballs, and you picture electrons moving between them, the electrons will then come toward a buckyball and excite the motion of the buckyball; these are called lattice vibrations, and people think of the quanta associated with them and these quanta are called phonons just like the quanta associated with light are called photons. So a phonon is excited by this electron, and then when a second electron comes by, it feels that excitation, and then 2 electrons pair, and once they pair they can travel through the system without any loss of energy. Now that's one current view. A different theorist

will tell you, perhaps, different stories, but this is a popular view, and this is a brand new field, so if by the time someone hears these remarks, the whole field is changed then I (9:19:38) apologize, but this is a rapidly moving area.
INSERT CHU INTERVIEW. DISCUSSES DEVELOPMENT OF BUCKY BASED SUPERCONDUCTIVITY. MAY REHASH ABOVE, DISCUSS WHY MAINSTREAM SUPERCON RESEARCH HAS MOVED AWAY FROM BUCKYS. PRESENT DIFFERENCES IN Tc, CURRENT DENSITY, ETC.
Smalley
RECOLOR, LABEL ANIMATION
2:19:27 Currently the record of bucky salts that are super conducting is made with two robidums and 1 cesium atom in those little holes in between the oranges, and the record temperature is 33 degrees above absolute zero.
2:20:54 Much of the thinking about the theory, the mechanism for superconductivity in these materials is focused on this idea that you have nanometer size balls which can have critically interesting pairing phenomenon that causes this kind of superconductivity (?) on the ball itself. Now these materials themselves may not be the superconductors of the future, but in studying what makes the superconductivity work so well on these things, we may be able to figure out what the secret is; this might be, in a sense, the (2:21:36) rosetta stone of superconductivity.
COMMENTARY ON THE FUTURE OF SUPERCONDUCTIVITY. COVER WITH SGI ANIMATION AND SLIDES AS NEEDED. MODEL OF NANO CENTER? SMALLEY UPDATES, EXPANDS ON FIBERS
Superconductivity may not be the most impressive application of buckiminsterfullerenes, academic value aside. By adding hexagon carbon rings, other useful shapes are created. There is little doubt that the applications that bucky materials will be far reaching.
SMALLEY 042114 In fact this soccer ball structure, this geodesic dome, you realize I'm sure, doesn't have to be just a soccer ball, there are all sorts sizes of geodesic domes. You've got big ones, littler ones, you've got ones in side of ones inside of other ones nested together, overall they look pretty much like an onion. And in fact these objects have now been formed, been detected. They are actually incredibly stable, even more stable then buckyballs. They're called , literally, bucky onionsÉ There's all sorts of applications that are possible for these objects, not only bucky onions that are empty where the inner most ball just has a vacuum in it, but bucky onions where the inner space is actually filled with other materials, little crystals, which have been protected from the outside by this onion skin. Well not only is it possible to have balls, but you can have elongated structures, you can take for example, C70 for example, which is C60 pulled apart with a new line of carbons put in so it is more rugby ball shaped. Well instead of putting one line of carbons in, why not put another and another so now it becomes a more elongated capsule. For that matter how bout putting an infinite number of these in so you have an infinitely long capsule which you could have in your hands. An amazing object it could be a centimeters in length, maybe even kilometers in length, a fiber, which is only a nanometer in diameter cause it's just the size of C60. That object, if you could make it and hold it, it would have the highest tensile strength, the greatest strength of any material you could ever make, it'll be the strongest fiber. It would be a hundred times stronger then steel. And if you put metal atoms down the inside it would effectively a metal wire, but it would be a nanowire. And its expected to have electrical conductivity much higher then copper. In fact if you can make them cheaply, and we're working on this right now, as are other groups, if you make them cheaply, these nanowires have a chance to replacing all of the power grids all over the world just because of their high strength, their light weight , and their high current carrying capability. Well these are some examples of what might be coming in the future when we learn how to build materials on the nanometer scale, as though they were buildings, where the atoms themselves are the bricks and the means that are used to define the architecture of these buildings. This will be the ultimate control on matter we will ever

have on matter, and it is expected by many of us the be the dominate technology in this next century.
Fullerenes have existed in soots since the first moments of the universe. Now we see how the discovery buckyballs can affect our future. Applications even include the potential to use fullerenes in the fight against AIDS. Rice University has become so convinced of the usefulness of this technology that it is creating a nanotechnology center where researches will be endowed with the opportunity to master this huge, or rather nano, potential. New Masters pledges to follow this technology and report on it in a continuing series on buckyballs, fullerenes and Nano-technology.