TAKING ON THE FUTURE

Harold Agnew and Los Alamos scientists discuss the potential of the Laboratory

Harold Agnew and Paul White

The occasion of the fiftieth anniversary of Los Alamos National Laboratory offers an opportunity to celebrate the past and explore questions about the future. What is the Laboratory's mission now that the Cold War is over? What responsibility does the Laboratory have in maintaining the nation's nuclear capability? What kinds of activities are necessary to avoid surprises from foreign military technology? Why has basic research always been an essential part of the Laboratory? What is special about the Los Alamos culture? What new opportunities have been brought about by the end of the Cold War? How can the Laboratory contribute to the economic security of the nation?

Last October Los Alamos Science *invited Laboratory physicists, mathematicians, biologists, chemists, and computer scientists to discuss these questions in an open forum. To add historical perspective and a little more spice, we invited Harold Agnew to join us. Harold began his career at Los Alamos during the Manhattan Project and was director of the Laboratory from 1970 to 1979. He became president of General Atomic Company after leaving Los Alamos and is now retired. He is known for his candor, his enthusiasm for nuclear energy, his pride in Los Alamos, and his strength as a leader. Harold very effectively encouraged the participants to express their diverse interests and opinions.*

Here we present a condensed version of the day-long discussion. We thank everyone who participated and hope our readers will appreciate the individuality, talent, creativity, and passionate commitment to science and the nation that characterize these scientists and, in fact, the entire staff of the Laboratory.

Harold Agnew: I was asked to begin this discussion of the Laboratory and its future by commenting first on the past impact of the nuclear-weapons laboratories. Following World War II, the Lab's first big impact on world politics was in 1948 when NATO was first being formed. In a program called Backbreaker, Los Alamos and Sandia had the job of producing fifty Mark V fission weapons and then shipping them over to England on a newly initiated Air Force B-47 squadron. The Soviet Union had been gobbling up the Eastern European countries, but as soon as NATO was formed, backed up by the deployment of the Mark Vs overseas, Soviet expansion came to an abrupt halt. NATO's success in stopping Soviet expansion certainly enabled, in the long run, what transpired in the last two years; that is, the disintegration of the Soviet Union. Most people don't appreciate what transpired in the late forties and early fifties and the role the weapons labs played. We actually made all the weapons at Los Alamos and worked with Sandia on packaging those weapons in appropriate aerodynamic shapes. People also seem to forget that Sandia was part of Los Alamos in the early days. Now there's some talk of consolidating Sandia and Los Alamos under a single University of California contract as part of the plan to scale down the weapons program. It will be interesting to see what happens. I've given just one brief example of the importance of the United States weapons capabilities, hoping to illustrate how important our weapons labs are to the stability of both this nation and the world. Clearly the United States needs to maintain a credible nuclear weapons deterrent capability, and I think Los Alamos is in the best position to help do that job, not only because of its facilities but also because most of the weapons in the stockpile were designed at Los Alamos. I am somewhat concerned about proposals to make Los Alamos the sole nuclear-weapons laboratory, but if there is to be only one, I believe it should be at Los Alamos. On the other hand, I don't like the idea that Los Alamos may perhaps work on nothing but nuclear weapons. The Laboratory employs a tremendous group of technical people who can contribute to a broad range of national needs. I think your director, Sig Hecker, has done a tremendous job of fostering collaboration with General Motors, and with industry in general. That is the sort of thing the Labs are going to have to do. Now I'd like to hear your major concerns and ideas about the future of the Laboratory.

Greg Canavan: As I see it, the entire future of the nuclear-weapons program in this country is very uncertain. On the one hand, the military forces are essentially walking away from nuclear weapons as fast as they can. On the other hand, a lot of senior people in the defense establishment understand that nuclear weapons are a class unto themselves and that we must maintain nuclear competence regardless of whether these weapons are currently popular relative to smart conventional weapons. Those senior people will be around for the next decade or two and will ensure that the nuclear-weapons laboratories maintain some level of competence. But it is doubtful whether the laboratories will be asked to develop new nuclear technology. If you listen to the debates within the nuclear establishment, you hear some say it would be useful to develop an earth-penetrator weapon in case we have to fight a Gulf-type war again, but that's about the only new need that's mentioned. So it's clear that the size and scope of the nuclear establishment are going to contract pretty sharply over the next one or two decades. The question is: What does that mean for Los Alamos as a whole? Los Alamos has always been a unique institution. Over the last five decades both the importance of nuclear weapons and the difficulty of advancing nuclear technology have required that Los Alamos be a fairly broad-spectrum laboratory at the forefront of a whole range of technologies, including materials, explosives, nuclear physics, atomic physics, radiation transport, and so on. But nuclear weapons are not going to be a catalyst for technology development in the next one to two decades.


Greg Canavan

It's clear that the size and scope of the nuclear establishment are going to contract pretty sharply over the next one or two decades. The question is: What does that mean for Los Alamos as a whole?

David Sharp: As I see it the need for national security is going to transcend the end of the cold war. The world is going to remain an uncertain place, and nuclear-weapons technology is not going to disappear. We will have to live with uncertainty on the political landscape as well as with the virtual certainty of new technological challenges. So we will need to maintain a nuclear-weapons capability. One of the keys to that capability is people. How are we going to retain a group of people who are smart, motivated, and knowledgeable about nuclear weapons? The only way is to give these people things to do that are interesting, challenging, and important. I have a couple of thoughts on what those things might be.

First, in the present political climate we need to develop the capability to design simple, robust nuclear weapons, the reliability of which can be guaranteed in the absence of full-scale testing. We have to learn to design weapons on the basis of better computations, better modeling, and the testing of components. Second, this Lab is rich in dual-use technologies, technologies that apply to both defense and non-defense problems, and we need to turn those strengths in new directions.

Ray Juzaitis: These are good suggestions, but the political process may have overtaken our technological preparedness. The constraints on nuclear testing imposed by the Hatfield provisions will prevent the type of deliberate and careful transition that you are describing. A few years ago Congress legislated a Test-Ban Readiness program, but at the same time, our budgets were cut, so we could not address all the technical issues and requirements that “test-ban readiness” implied. Now we are caught. We would like to put on the shelf more robust and safer weapon design as well as execute some good “bridging experiments” in anticipation of a zero-test environment, but the political climate may now prevent us from doing so.

Gene McCall: Just yesterday, during a private meeting, a fairly high political appointee in the defense department said to me, “If you think we’re going to develop a new nuclear weapon, you’re whistling up a drain pipe.” I think that the Lab is going to have to adjust very quickly to a new and uncertain world. We will probably have to maintain a drastically reduced stockpile with a very small group of people. I suspect the number of people in the Los Alamos weapons program will be reduced to half of what it was a decade ago, which was 30 percent more than it is now, and that half of our weapons work will be nuclear and half conventional. That’s probably a pretty good mix, and you might even find people who can transfer from one area to the other because the design codes and the experiments for both are similar—at least for the parts of nuclear weapons that you can test above ground.

As far as maintaining a nuclear-response capability, remember, Harold, you old-timers developed the first deliverable nuclear weapon in about three years. And you started out not knowing whether it would work and not having all the basic measurements needed for design. But we’ve got all that information now. If we wanted to respond to a national crisis, we’d be able to come up with a smaller, more efficient weapon—and do it faster—even if we started from scratch again. So, what do we want the program to be capable of doing now? We need to maintain the stockpile, but we need to specify what that entails. We must also be able to respond to future belligerent governments.

Unless we have a program that exercises our nuclear capabilities to at least the intermediate level of contained underground testing, there will come a time when no one will be able to certify a weapon and the whole image of deterrence with safe and reliable nuclear weapons will fall apart. Then I think we’ll see a major political readjustment with respect to what it takes to maintain our nuclear capability.

Stirling Colgate: The key issue is the political perception of deterrence. Right now there’s nothing to deter, but as soon as some government poses a threat to us, we’ll have to face what we mean by an effective deterrence. My guess is that we’ll be asked by Congress to certify nuclear weapons at the same high level of confidence as the airlines certify 747s. But unless we have a program that exercises our nuclear capabilities to at least the intermediate level of contained underground testing, there will come a time when no one will be able to certify a weapon and the whole image of deterrence with safe and reliable nuclear weapons will fall apart. Then I think we’ll see a major political readjustment with respect to what it takes to maintain our nuclear capability. We will always be worrying about a dictator like Saddam Hussein building up a nuclear capability or a change in politics among the states in the former Soviet Union. So this Lab should be anticipating what it takes to maintain a responsible nuclear-weapons program that will generate an effective, acceptable deterrence for the future. We should be taking the high ground on this issue because we are the ones who will be counted on to provide the capability when the need arises.

Harold Agnew: And that capability can’t be maintained without testing. Many people argue, incorrectly, that we need testing primarily to maintain reliability. But reliability is just one part of the whole enchilada.

Over the years the stockpile has been extremely reliable and quite safe. We’ve had an extensive surveillance program, and there have been very few glitches. Part of that confidence comes from continually designing, testing, and deploying many different weapons systems. When we start demilitarizing and cutting back, I worry that the diversity of systems is going to decrease and we will be in danger of having all our eggs, so to speak, in one basket. That could be disastrous.

> *Nobody is quite sure just what the right number is, but everybody starts getting uncomfortable when we start talking about reducing the stockpile below a certain number.*

There is no question that the world ahead is going to be one of proliferation. More and more little nations will acquire some nuclear-weapons capability—maybe for terrorism, or to make themselves feel good, or to blow up a city or something. We're going to have to cope with that fact. But, the military's attitude is: "Look, we'll never get permission to use nuclear weapons. The rules for their maintenance and surveillance are a pain in the neck. And furthermore, they occupy a lot of ammunition-storage space. I don't want any part of them." Carson, you must remember General Kerwin's experience with the first group of Davy Crocketts that were sent overseas. These were small-yield nuclear weapons that had a range of a couple of thousand meters. It was a nightmare for him to maintain command and control of those things on board ship. He essentially had to put them under his bunk because they were short-range, tactical weapons, and you had to have them forward. If you had them forward then you were worried about command and control. They had to be authorized for use early, yet the probability of ever receiving such authorization wasn't realistic. Eventually the Army gave up on the whole concept.

Greg Canavan: In the strategic situation that persisted up to the collapse of the Soviet Union, we thought that we knew what the roles of nuclear weapons were. There were credible arguments that nuclear weapons could be used in this or that strategic or tactical scenario. The fundamental problem right now is that nobody can think of a use for nuclear weapons other than in the case of the resurgence of the Soviet Union. The services are denuclearizing as fast as they can. The Navy is throwing nuclear weapons off their carriers, the Air Force is downloading them from every airplane they can, and the Army has gotten rid of all of theirs. Our military leaders don't see any credible scenario in which nuclear weapons can do anything—except, perhaps, for using an enhanced radiation weapon on a Sprint missile as a defense against theater ballistic missiles. Short of the resurgence of the Russians, no one in the military services sees a clear need for nuclear weapons.

> *It's worthwhile to consider what would happen if the United States renounced possession of all nuclear weapons*

Harold Agnew: One doesn't know what's going to happen in China. They are selling long-range missiles to other nations, and we don't seem to be improving our relationships with China.

Paul White: Most people who pause and think about what it would mean to have a complete free fall of the nuclear-weapons establishment stop and say that we need to keep at least a few hundred to a couple thousand nuclear weapons. Nobody is quite sure just what the right number is, but everybody starts getting uncomfortable when we start talking about reducing the stockpile below a certain number.

Harold Agnew: You have to keep a large enough number so that the Kadaffis of the world don't get the idea that just by having a few nuclear weapons they can become your equal. You've got to have a factor of a hundred or so above any credible number that they could conceivably whomp up.

Carson Mark: The idea of fighting with nuclear weapons is going to remain in free fall. That's why the Navy can get rid of certain classes of weapons and why the Army doesn't know what to do with the ones they have. But still, we need to maintain a position of deterrence.

Stirling Colgate: It's worthwhile to consider what would happen if the United States renounced possession of all nuclear weapons. What would happen to Western culture? Could we persuade the French, for example, to give up their nuclear weapons?

Harold Agnew: No way! If only France had them, then in two weeks Germany would be saying, "Mein Gott, we're not going to let those frogs do that to us."

Stirling Colgate: Now, if it's absolutely impossible for us to get rid of all our nuclear weapons, we can start talking more sensibly about what we can do. The United States, for the foreseeable future, is going to be the custodian of nuclear power for the world, and that is the challenge the Laboratory and the nation must face.

Gene McCall: Part of our problem is that plans for deterrence are being developed by political scientists who are simply throwing out numbers. But there are quantitative ways of estimating how many nuclear weapons we need to maintain in the stockpile. You pick a possible enemy nation and ask how many weapons we need to destroy 80 or 90 percent of its national wealth if we are attacked. If you do that for the whole world in reasonable scenarios, you can come up with a number. Now, it's probably not the right number because you'll never think of all the situations that could occur, but at least it's a number that has a quantitative basis.

Merri Wood: Any estimates you make today are going to be different tomorrow and different five years from now. Furthermore, there will always be a need to make changes in the stockpile, either for strategic or tactical reasons or because we're worried that elements of the stockpile are turning into silly putty. Then, what Stirling said earlier becomes an issue, namely, that after a while we're not going to find anyone to certify the new nuclear weapons.

But the real problem, as I see it, is that we'll find far too many people who are willing to certify new or modified nuclear weapons based on very little data, or maybe no data. That's the issue. At the nitty-gritty, working level, how do you maintain the weapons designers' judgement and experience in the absence of testing? When I interviewed fifteen years ago for a position as a nuclear-weapons designer, people were saying there might be a comprehensive test ban any day, so all of us have thought about that possibility for a long time. The real need for nuclear tests is to validate designers' and engineers' judgement about phenomena that can't be tested without nuclear explosions. It's the designers' judgement that's really critical. You can't be too conservative, and you can't be too risky—it'll get you either way.

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Gene McCall: I think you're exactly right. The scary part is that there will be no shortage of people who are willing to certify untested weapons, especially if they are certifying their own designs, or if they want to please someone in Washington. If the laboratories cannot conduct tests, the United States should consider the possibility of eliminating its capability to design and certify nuclear weapons.

Stirling Colgate: Try testifying to Congress about how you have certified a nuclear weapon's capability without really knowing what you're talking about. They will hammer you to pieces.

Harold Agnew: Now, if the military has no more future requirements, why do you need somebody to certify something that isn't going to be used?

Merri Wood: But there will always be future requirements as long as we are required to maintain a stockpile.

David Sharp: I always felt that the function of nuclear weapons was to have them, but not to use them. If we are actually forced to use nuclear weapons, deterrence has failed. The point is not to imagine all the possible scenarios in which nuclear weapons might be needed. Rather, we have to maintain the capability to design a weapon that works precisely because we cannot anticipate all those possibilities. And the only way to maintain that capability is to have a group of people who are actually doing something reasonable, credible, and defendable that will maintain their designer's edge and that doesn't depend solely on full-scale testing. I've heard it said how important full-scale testing is and I personally accept those arguments, but I don't think they are going to prevail during the next few years.

Dual-use technology is another route to maintaining the Laboratory's capabilities. We are rich in dual-use technologies that apply not only to conventional warfare but also to other areas. I am concerned about how to maintain a cadre of people who can design nuclear weapons when we need them and who, in the meantime, are doing something useful that will keep them intellectually alive.

Stirling Colgate: I object to this notion that you have to find something interesting for the weapons people to do. All you have to do is to define the problem. The Lab has to address the stewardship of nuclear power. Once you've defined that, you have to have people here who are bright enough to address the matter. You don't have to tell them what to do.

Here's a technical example. With normal drilling rigs like those we use at the Nevada Test Site, it would be rather simple to place a command post or nuclear-tipped missile about 6 kilometers underground. I can imagine Saddam Hussein or some-

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one else in a hostile nation saying, "Well, we've got a lot of oil rigs around here. Let's put more of our command bunkers and a whole batch of our new missiles from China down at six kilometers." Now what does it take to deter him from saying, "We're now sending off one nuke just to show we have the capability, and we have fifty more down there." Each time we tried to destroy one, we would need about a 40-megaton explosion. I claim we would be absolutely stymied and that he could just come up and say, "You can't do it, so just do what I tell you." Now, there's a problem, and we should be trying to solve it rather than talking about what we are going to find for all these weapons designers to do. They're bright enough to think of the problem; they're bright enough to think of the solution.

Gene McCall: I think the military answer to that problem is that we go after the doorways of those underground bunkers with conventional precision munitions.

Stirling Colgate: Until you've conquered a nation, do you actually believe you will know where all those bunkers really are?

Jim Smith: Another part of the stewardship role is stockpile maintenance and weapons dismantlement. If we want to reduce the stockpile by ten thousand warheads, who will take the parts and where will we put those critical masses anyway? Although the public will say, "Make them disappear," Congress will understand that we need to maintain confidence in the materials and that the explosives and plastics change with time in a weak-radiation environment. They also eventually become unavailable from the manufacturers That's why you've got to bring those materials up to date. We can in a short period of time go back and re-invent the nuclear expertise if we have to. But the most important thing is that we have a collection of people here who are doing the best science they can, who can respond in time of crisis, and who know how to handle plutonium, and so forth.

Gene McCall: Jim, your question about what do you do with weapons parts brings up an interesting dual-use technology. The Japanese, for example, are creating a program to burn plutonium. Why don't we design safe plutonium reactors that burn weapon parts? That's something we can do well.

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Harold Agnew: The Committee on International Security and Arms Control of the National Academy of Sciences is looking into what should be done with returned plutonium, but no one on that committee has any expertise in reactors or anything else of that nature. The idea of using plutonium for reactor fuel has come up, but the DOE is a basket case on anything having to do with nuclear reactors. Clearly Los Alamos could get involved in that problem. You have a unique facilities for studying critical assemblies in the Nuclear Technology and Engineering Division, and you have other relevant expertise as well.

Ray Juzaitis: Political support for the Laboratory as an ongoing institution will ensure that the Lab itself continues and diversifies its activities. But an important issue is to ensure that our core weapon-design folks participate in that diversification. These are the folks who are going to define their own futures based on their special disciplines, the types of technical problems they are used to solving, and the technical culture they in which they are used to operating. That "culture" involves an integration of experimental data, theory, and large-scale computing. The synergies, and the diversification that is relevant to the preservation of nuclear weapon design competence, will not and cannot be defined by external forces but must be defined by the designers themselves. These people are used to working in close-knit teams. Since the beginning, teamwork has been a very important element in the nuclear-weapons design. It's important to keep this core team together and evolving by attracting new people.

We sometimes talk about the two cultures at the Lab—defined by nuclear weapons work and nonweapons work. If we diversify in a way that continually isolates the core group of nuclear-weapons people, we will lose the capability to find the synergies between the two communities. In the past the folks in the nuclear-weapons program diffused into the non-nuclear culture, and vice versa, but they were still familiar with the nuclear-weapons problems. Many of the old-time weapons people are still here, and they form a "reserve" of talent. As time goes on, these people won't exist unless we can recruit smart people from the universities to help work on the weapons problems. Our ability to attract new people into the weapons program must be maintained as we attempt to diversify. Otherwise, the Laboratory will surely lose its competence in nuclear weapons technology.

Harold Agnew: One advantage that the Laboratory has over universities in attracting personnel is that of maintaining continuity. A university's primary function is to teach students, and students stay a while and then go someplace else. So a university is a difficult place to maintain continuity of a team. I agree with Stirling's point that somebody has to be, for the world—or at least for the U.S.—a chief honcho of nuclear capability. The Lab should stake out that role and make it very clear that that's the role it wants to play.

Merri Wood: In the past people have been very eager to work in the weapons program. You didn't have to twist any arms.

You're always going to find people who want to know, to understand, and to contribute even if the program exists in a limited, controlled mode.

Stirling Colgate: A postdoc in the Lab's astrophysics group who has run out of his or her time and looks around at the possibility of either staying at Los Alamos or competing in the university market or somewhere else will find that a position in the weapons program looks mighty attractive.

Greg Canavan: Historically, the technical challenges and the physics of the weapons program have been very exciting. When I was a graduate student, I got interested in some of the physics to the point that one day I woke up and knew I was going to work on weapons physics.

I see a world in which people don't regard nuclear weapons as a part of the solution any more but, rather, as part of the problem. … It may become a real problem to maintain confidence in the nuclear-weapons program.

Stirling Colgate: The curiosity I see among astrophysics students about how a nuclear weapon works, what's going on, and what can be done is just tremendous. You're always going to find people who want to know, to understand, and to contribute even if the program exists in a limited, controlled mode.

Greg Canavan: Right now we have good people in the weapons program, and we're able to recruit more. But I see a world in which people don't regard nuclear weapons as a part of the solution any more but, rather, as part of the problem. Just this past year Livermore's symposium on high explosives was viewed by some as a school for would-be proliferators. I see a growing tendency at the Lab to sharpen the break between the people who work in weapons and those who work in non-weapons areas inside the Lab. That means diffusion of talents into and out of the weapons program will be more difficult in the future. In the next decade it may become a real problem to maintain confidence in the nuclear-weapons program.

Gene McCall: We've been talking mainly about weapons designers, but designers are the tip of the iceberg in the nuclear weapons program. What about the people doing the fabrication and diagnostics?

Merri Wood: Even the politicians recognize the role of diagnosticians in maintaining the stockpile. But when there's no nuclear testing, what role do the diagnosticians have? The physics of nuclear weapons operates in a unique regime of extreme physical conditions, and without tests, there's no place to practice.

Chick Keller: You observe solar eclipses.

Merri Wood: Those happen on a much longer time scale, minutes instead of microseconds, and you are flying around in an airplane or are on top of a mountain so you can adjust and calibrate your equipment right up to and after you take data. In a nuclear test you have to bury all of your equipment in a narrow, deep hole weeks before the test, it must work perfectly the first time, and it must continue to take good data for some period of time in the extremely hostile environment created by the nearby nuclear explosion. Post-shot calibration is, of course, not an option.

Chick Keller: But the physics and the diagnostics are not unrelated. I suggest that we keep the testing team together by doing a variety of related things. In the present situation we are unlikely to have the funding available to keep the team together for the primary mission alone. I used to be in J Division, the old nuclear-testing division, and I'd like to think of myself as part of that broader team. Some of us from that division are looking at the concept of dual-use technology and suggesting that a very large effort be developed that would join the global environmental studies the Lab is now doing with diagnostic capabilities, data integration, and so on. The effort would also include working with industry on sensors and other technologies that have dual uses. There have been many precedents for scientists working simultaneously in both the nuclear and non-nuclear areas, particularly scientists working in the testing program. We don't want to lose our testing capability because the world situation may change. But we can use those scientists in many other ways that relate back to testing.

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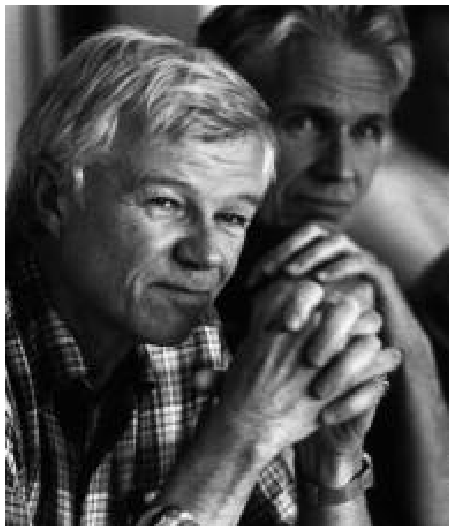
Stirling Colgate: There was a year when seven out of nine Los Alamos nuclear tests of weapons in Nevada were designed by scientists who came to X Division—the Applied Theoretical Physics Division—from astrophysics with the assurance that they could work quarter-time in astrophysics and publish that research. They have published and continue to publish frequent and important scientific results. It can't be all bad to be split a little bit.

Erica Jen: How true is it that weapons work is something of a one-way street in the sense that you are unable to publish your results in the open literature or present them at conferences and that you can't easily move back and forth between the classified and unclassified sectors? I think that the perceived lack of open scientific exchange, together with skepticism as to the scientific vitality of the weapons programs, present difficulties in attracting people from basic research.

Gene McCall: People do weapons work because that's what they want to do—not because they are trapped into it. And although they can't publish characteristics of a weapon, they can publish much of the basic development work. They simply choose not to publish.

Erica Jen: A while back there was an effort to start a peer-reviewed classified journal and to encourage people to publish classified results. Did that ever get off the ground?

Ray Juzaitis: There is a defense journal and there are classified conferences. So, those professional needs are met to some degree. However, the peer community is small, and results are often communicated directly to those who are interested. I would say that most people have not felt the need to publish in the open literature as long as there was assured technical vitality in the nuclear weapons disciplines.



Gene McCall

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Merri Wood: A whole lot of work goes into solving specific nuclear design problems. The work is well documented, and we're very proud of the documentation. So our work is very satisfying. But if this country decides that it doesn't want any more nuclear designers and we have to go outside the Lab to find a job, then we'll have all this wonderful classified work that we can't show to anyone. I think I disagree with Gene. At least in my area of work, I can't publish the results. And the rules for classification are right on the money. I wouldn't want to publish that stuff. I don't want any proliferators getting their information from me. We do this kind of work at national laboratories for a reason. It doesn't fit in at universities or in industries. There's a reason we don't just run out and transfer this technology. We need this technology to build nuclear weapons, but it will not build a better toaster. It's interesting, challenging work. It's hard work, and we think it's important and useful work. But when it comes time to turning it into something else and still preventing proliferation, there are some real barriers.

Harold Agnew: It would be interesting if Edward Teller were at this discussion because he has been on a binge of saying, "Declassify *everything*! Secrecy is bad!"

When I was Lab Director, I know some people were really antagonistic toward the weapons program. I must say I have no sympathy with those people, and if I hadn't been so tolerant, I would have kicked them out. This Lab had a mission, it still has that mission, and it needs to be supported. That doesn't preclude the Lab from doing other things, but I don't think you should be ashamed of or apologize for what has been the primary mission of the Laboratory. And if you follow what Gene and Stirling were suggesting, that mission still requires a rather sizeable program, although the elements in that program may change. For example, I see the Lab making greater and greater contributions to the intelligence field and to efforts to prevent the proliferation of nuclear weapons.

Our government's ability to draw on people from the Lab to evaluate technology development and monitor the activities in other nations has been a real national asset and is appreciated very much by the various intelligence agencies.

The intelligence division at Los Alamos has recently done some spectacular things. Since the early 1960s I can remember observing overhead pictures of one particular facility in the Soviet Union, and just recently some people from the International Technology Division actually visited that facility! We thought that facility had a very different purpose, but now we know that it was part of the Soviet nuclear rocket program. They also learned of another enormous facility located in a huge mountain in Russia, which was designed to test full-scale nuclear reactors and even to blow them up. The Lab could start a joint program with Russia to use some of those facilities for nuclear research.

Greg Canavan: Although the role of nuclear weapons is declining, the weapons business in general is not winding down. The next decade may be relatively benign, but the ones after that look anything but gentle to me. There's enormous potential for military conflict at all levels around the world. And like it or not, the weapons enterprise, particularly in the area of conventional and smart munitions, is likely to expand. This Laboratory has very strong expertise in conventional explosives and a whole range of other related technologies. I believe the Laboratory should play an integrating role in the area of conventional and precision weapons technology. I see us applying our technology to new sensors and new means of manipulating information for the delivery of precision weapons.

The Department of Defense is also interested in simulations of virtual reality in which virtual prototypes of new hardware such as tanks, missiles, or new weapons concepts are created and their performance in battlefield situations is simulated on the computer. The idea is to use high-speed computation to test ideas and concepts even before the hardware is built.

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The Lab has an enormous amount to offer in this area not just in terms of its big supercomputers but also in terms of people in the nuclear weapons program who for most of their careers have been working with codes of superhuman complexity. These people have developed a knack for the essentials of very complex simulations even when they don't understand every detail of the physics that is put into each code. We've already done such detailed simulations for the Strategic Defense Initiative Organization. The components of those simulations could be fit together in new ways that would allow us to test almost any new weapons or sensors or communication concept that the Defense Department would like to try.

Gene McCall: Virtual-reality simulations are now used to simulate what a pilot sees on the radar display of his aircraft. The system detects, or captures, a radar pulse coming out of an airplane, processes it, plays it back, and makes it look to the pilot as though he or she is flying over Albuquerque or Baghdad, for example. The system can be both a training aid and a maintenance aid.

Greg Canavan: It's not only a training and maintenance aid. It can also be used for testing and evaluating actual or virtual hardware in a simulated battle environment.

Gene McCall: Right. You can use this capability to simulate what it takes to destroy a tank, for example. And this type of simulation is relevant to an even larger and more pressing problem, namely, modeling the transportation infrastructure of this country. How does one do transportation modeling? How does one incorporate revolutionary new devices like listening systems into the transportation system? These kinds of problems are already being explored, and they are well-matched to the Lab's capabilities.

Chris Barnes: We already have two efforts in transportation along those lines. One is aimed at simulation-based virtual prototyping of the entire transportation system, and the second has to do with evaluating the design and architecture for intelligent-vehicle highway systems.

Stirling Colgate: In astrophysics we also like to model reality. One of the emerging reality games in astrophysics is the development of smooth-particle hydrodynamics codes or many-particle simulations (greater than 10 million) to model galaxy formation or supernova explosions. We need to try this new reality game on old nuclear-weapons designs and compare the results with old test data and with the results of our standard weapons codes. The resulting competition among various computational techniques will greatly improve our confidence in weapons simulations.

Greg Canavan: I was asked by a general on the Joint Chiefs of Staff to write a paper about what warfare would be like forty years from now. That's so far down the line that we can't predict what technologies will have emerged by then. But we do know that if we continue to improve computers by a factor of 2 every 2 years for the next 40 years—that's a factor of 2^{20}, or about a million—then the best computer will be roughly as smart as a chicken!

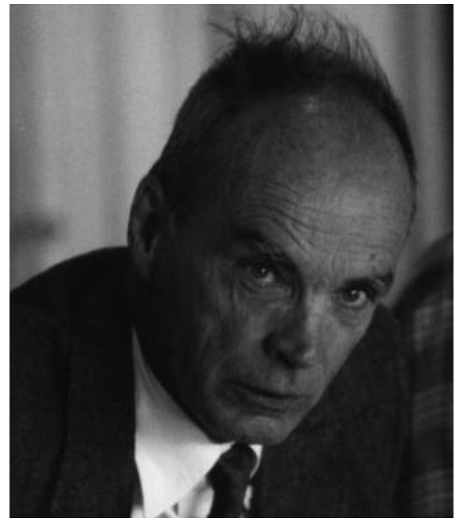
So even over the long term, the smartest military machine and also the smartest commercial planner is still going to be a person. The trick, then, will be to maximize the decision-making performance of individual persons: to get information to them, help them evaluate possibilities so they can make decisions, and get that information back to the battlefield or marketplace as quickly as possible. All the person in the loop is going to do is make decisions.

To maximize human performance in both the military and non-military sectors, we are going to see a convergence of biotechnology, computer hardware, and computer software on a time scale of thirty or forty years from now. Los Alamos has a significant research component in each of those three areas right now. And we need to keep investing in them because they are the wave of the future.

Stirling Colgate: The Lab is in a position to make many kinds of contributions to the military and the civilian sectors primarily because we have a strong basic-research effort. And the strength of that effort was built on the fact that it takes mathematicians and physicists to make a nuclear weapon. That core ability in math and physics interacts with other basic-research efforts at the Lab, whether it's the Human Genome Project or research on high-temperature superconductors or global climate modeling. The edge that the national labs have in math and physics is, I believe, our greatest strength. It means we have the presumption of being able to understand almost anything and the capability to offer that understanding to all areas of applied research. In our interactions with the agencies in Washington, we need to emphasize that we can do computing, mathematics, and physics. You can't find that depth and breadth of expertise in any other laboratory.

Gene McCall: The experimental component at this Lab is also very strong. We do very good experiments, and we do them in a hurry.

Stirling Colgate: I didn't mean to imply that physics is all theory, but the unique thing that has come out



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Harold Agnew

The National Research Council had a panel on nuclear energy, … loaded with people from the establishment, and the report said everything was fine. No one was asking, "Is this really the best reactor technology? What could we do in the future?" There's a tremendous role for that sort of adjudication, and…the labs have the expertise in the hard sciences do it honestly.

of the nuclear weapons program is physics, math, and, if you want, computing.

Gene McCall: And, Stirling, something else that is quite unusual about Los Alamos is the close and very positive association between theorists and experimentalists.

Stirling Colgate: We need to move the Department of Energy away from the idea that the Lab's role is a relatively narrow one, that of maintaining nuclear weapons. In addition we must emphasize the value of maintaining a significant level of scientific expertise that can be tapped for a very broad range of problems.

Harold Agnew: Having people in a multitude of disciplines who can jump on problems such as using image enhancement to investigate the Challenger disaster is a tremendous asset that the nation can use to great advantage. The Lab expertise can be applied to some really pressing problems, one of which might be the problem of waste disposal, not just nuclear waste but chemical and toxic wastes of all kinds.

Andy White: On a visit to DuPont a year or so ago, I heard the suggestion that the national labs should play the role of referee in waste-disposal problems and other controversial issues. The labs could be the final authority making technical decisions on things like deep-well injection of industrial waste.

Stirling Colgate: The strength of our technical culture should be applied to the entire business of risk assessment. The national labs are particularly situated to participate in this area.

Harold Agnew: That type of arbitration is certainly needed for nuclear energy. The National Research Council had a panel on nuclear energy, but the panel was loaded with people from the establishment, and the report said everything was fine. No one was asking, "Is this really the best reactor technology? What could we do in the future?" There's a tremendous role for that sort of adjudication, and as Stirling was saying, the labs have the expertise in the hard sciences do it honestly. But I want to add that I have a bachelor's degree in chemistry, so don't forget the chemists. Originally, all we could do with plutonium was take a glob, cast it, and machine it. We never made any improvements until the chemists and the physicists joined together to really understand how to handle these materials and develop the alloys.

Paul White: At this moment, the Laboratory has a unique opportunity to define its future, one that will be more closely tied to the economic security of the nation. Right now we are in the process of defining unique niches in the marketplace that—because of our history, the capabilities we have assembled here, and the way we do business—are particularly suited to us. Risk assessment, of nuclear reactor technology or of waste disposal options for example, might be one area. What are some others?

Andy White: Computational science is an area in which the Laboratory already excels, and it is an an important component for the Lab's success in the future. Our Advanced Computing Laboratory, or ACL, is designed to provide an integrated computational environment with sufficient computational power for solving the overwhelming scientific problems that are critical to the nation. These "Grand Challenge" problems relate to the environment, national security, economics, and so on, and they require computational resources significantly greater than the resourses generally available today. To attack these problems, we acquired a CM-5 massively parallel computer from Thinking Machines Corporation and integrated this state-of-the-art machine with appropriate networking, storage and retrieval, and visualization resources. Right now we are primarily involved in three "Grand Challenge" applications: global ocean modeling, multiphase flow in porous media, and molecular dynamics simulations of novel materials.

Working with others at Caltech, Jet Propulsion Laboratory, and the San Diego Supercomputer Center, we are part of one of the nation's five gigabit testbeds to investigate geographically distributed computing between large computational resources. Another exciting project that has recently been initiated is the formation of the Computational Testbed for Industry through which we are collaborating with many industrial firms on a variety of problems of mutual interest.

Greg Canavan: Computer simulation and information processing is an area where the Lab has an edge not only because of our tremendous computing power but also because we have the people who know how to harness and use that power. The applications are limitless. They range from the virtual-reality simulations I was talking about earlier to basic problems in fluid dynamics, elementary-particle physics and the evolution of the universe, and to information processing in the marketplace. New opportunities are opening up all the time, and Lab personnel have the know-how to take advantage of them.

Chris Barnes: I come from X-1, a group in the division that designs weapons. About three or four years ago a few of us decided to change directions and learn about neural nets and their application to information processing and massive data manipulation. It was a risky thing to do, but it's really paid off and now we're developing new kinds of neural nets and applying them to a whole range of problems. One relates to preventing proliferation of nuclear weapons through export control.

Preventing the export of equipment related to nuclear-weapons development requires sifting through a vast amount of data. An evaluation of the global data on purchasing, exporting, or licensing of certain types of equipment or combinations of equipment can provide clues about the extent of a nation's nuclear development. Neural nets are a perfect tool for analyzing that data automatically. Another example relates to the interest of the Internal Revenue Service in identifying multinational corporations that are shifting their books around to avoid paying their proper taxes. The types of information processing required for that problem is almost a perfect overlap with nonproliferation problems.

We originally got into this type of information processing because a large banking corporation wanted us to develop a system for doing portfolio management and for determining future profitability of credit-card accounts. Our work on neural nets clearly falls into this category of dual-use technologies. We are playing a useful role in the diversified weapons program as well as in the public and private sectors.

Andy White: Massive data manipulation is an important problem in research as well. We are starting to perform very large global climate simulations in connection with the Department of Energy's High Performance Computing and Communications and Computer Hardware, Applied Mathematics, and Model Physics programs. Soon one simulation will produce as much data as we've stored on the Common File System over the last sixteen years! The first problem is where do you store all the data, and thesecond problem is how do you analyze it and use it to understand what you've done. Developing tools to store, handle, and analyze massive amounts of data is a problem that cuts across disciplines, and the Laboratory is now making tremendous strides in this area.

Information highways are being built across the country, and Los Alamos is on the freeway, the electronic freeway.

Greg Canavan: Many of us worry that the cost of doing business at a laboratory located at the end of a road to nowhere will price us out of the market in some areas of research.

But that's not an impediment in the area of information processing.

David Forslund: Information highways are being built across the country, and Los Alamos is on the freeway, the electronic freeway. Geographic isolation is not a serious problem for the Laboratory in this information age.

Greg Canavan: Not only are we on the electronic freeway but also the value added to many products by our analysis can be so high that we could even live with the high costs.

Gene McCall: Everyone says the Lab should participate in making the U.S. economically competitive and that we should cooperate with industry. But we need a way of developing joint projects that will really make a difference. One approach would be to send 500 people from the Lab for one-year sabbaticals in industry. That way we would wind up with a cadre of people spread throughout the Lab who have some real understanding of current industry concerns.

Harold Agnew: It's also a good way to build up a large constituency around the country.

Chris Barnes: We recently started working on a Cooperative Research and Development Agreement with General Motors, and one of our guys has already talked about doing a sabbatical at GM. Since we already have a group working in this area, he'll have a place to come back to. I believe it's very important to build up a core group of experts at the Laboratory in a particular field before we send people on industrial sabbaticals.

Gary Doolen: One of the most exciting new directions at Los Alamos is nanotechnology, a field that includes research on three very novel areas: self-assembling computers with molecular components, tiny robots that incorporate biochemical sensors, and improved materials with very small grain sizes.

Nanotechnology research spans many different disciplines and will require a substantial investment over a number of years as well as coordination and focus on a scale beyond the range of normal university research. At present the federal government has taken no central-planning responsibility in this area. Some industries have initiated research in nanotechnology, but they are currently downsizing their efforts for economic reasons. In contrast, in 1992 the Japanese invested $200 million in this area because they recognize the potential for large long-term payoffs.

In 1991, several universities and large industries concluded that the Department of Energy sould coordinate a national effort in nanotechnology. Scientists at Los Alamos and Sandia are now working in this area, and each institution has an experimental and theoretical research and development initiative funded at the $1 million level. At Los Alamos, the support comes from the Laboratory Directed Research and Development Fund.

One major success, resulting from a collaboration among Los Alamos, Yale University, IBM, and the University of South Carolina, has been the design and production of conducting molecules that can perform the function of ordinary wires but are thousands of times smaller. On the ends of each molecule one can place chemical groups that bind tightly to selected metal contacts normally found in miniature circuits. The conducting molecules have been made in large quantities and tested for uniformity and integrity using atomic-force microscopes. When these molecules are poured onto a surface containing prearranged metal contacts, the molecules bind very strongly to the contacts; in other words, they self-assemble. Plans are being made to design transistor-like molecules that self-assemble in a similar fashion.

The hope is to combine these self-assembling molecular components with existing technology for electronic switching that is a thousand times faster than the technology used in today's most advanced computers. The combination is expected to yield self-assembling computing devices that are about the same size as today's chips but many times faster. Similar work in the areas of robotics and biochemical sensors also have large anticipated payoffs in both the civilian and military arenas. The Laboratory has unique research and management capabilities for this type of dual-use research, and many people believe Los Alamos should play a major role in nanotechnology.

Erica Jen: Nanotechnology is an example of a program that originated from the efforts of a few individuals who had an idea and the liberty to explore it. It's also a program with the potential to grow quite large, and everybody recognizes that the Lab has the responsibility as well as unique capabilities to develop and to support large programs. But there is also the question of support for small projects and individual researchers who are not tied to any particular program with measurable goals and product specifications and who are not responding to an already existing funding directive. Without such support, you can't expect freedom, diversity, or creativity. At present, individual researchers cannot help but see that decisions and directives at the Laboratory are often governed not by the scientific health of the research efforts but rather by short-term criteria heavily biased toward large-scale programmatic efforts and by fuzzily understood funding policies. The effect on morale and productivity has been disastrous. And I would argue that the nurturing of small projects with as yet no foreseeable connection to big projects is an approach that would enormously increase the institution's ability to make significant scientific and technological advances.

Gene McCall: The type of work you describe has in the past been funded on the budget noise of the large programs. That is why the inertial-fusion program, for example, did not come out of basic research. It came out of the weapons program and, in fact, out of the field-test division of the program. The magnetic-fusion program and the accelerator division came out of the weapons program.

Erica Jen: Still, big programs are much more likely to succeed at the Lab if the people who had the original idea are here and are communicating with other people around them. The work Chris Barnes is doing in applying neural nets to massive data-manipulation problems grew out of the fact that researchers at the Center for Nonlinear Studies were playing with these new ideas, in a rather theoretical and abstract framework, and their research inspired him to get involved. If that basic research program had been at, say, Berkeley rather than at Los Alamos, Chris Barnes would probably never have begun that work, and external researchers would have had little reason to turn to Los Alamos as the natural focal point for related programs. The same is true of Los Alamos research programs in applications of chaos theory and in lattice-gas simulations, which grew out of the research work of individuals here at the Lab, namely, Mitchell Feigenbaum and Brosl Hasslacher, respectively. So how can we continue to support the generation of new ideas?

Erica Jen

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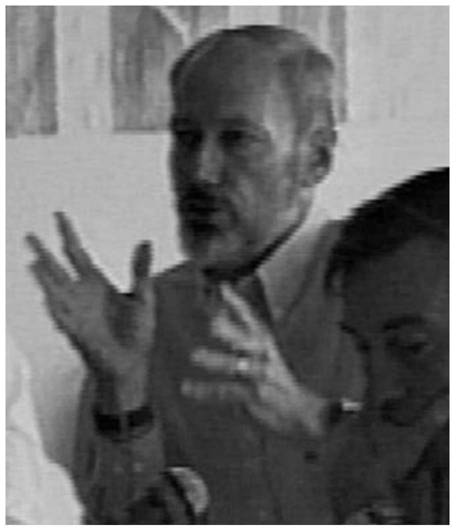
Andy White: It is a difficult problem, and it is a national issue, not just a Lab issue. There's a constant war between big centers and individual research projects. The National Science Foundation is studying the balance at the Foundation between basic and applied research and could make major changes in the current mix.

Gene McCall: That's why I think the Lab must protect the basic research we have by supporting that research within larger programs; otherwise we're going to lose our basic-research capabilities. If we identify basic research as a separate item and hang it out there, it's going to get cut off.

Greg Canavan: The steps the Department of Energy and the Lab have taken to assure Congress that they are in control of the Lab's programs are tending to undercut precisely those things that made Los Alamos a first-rate laboratory in the first place. In other words, accountability is tending to cut out cross-fertilization and make it harder for people to get together and to do innovative projects. In the ten or eleven years I've been here, I've seen a big loss in flexibility.

Harold Agnew: Is the size of the Laboratory part of the problem? It was pretty large when I was director but not as large as it is now. In the good old days we had a theoretical division, a physics division, and divisions for explosives chemistry, weapons tests, health, and maybe a few more. I don't know what the mechanism is now for gathering new ideas, starting new programs, or deciding you are going to send five hundred people out to industry to increase technology transfer. In the old days it was pretty much the division leaders who made the decisions. Carson Mark, the leader of the Theoretical Division, would decide what he was going to do, and Dick Taschek, the leader of the Physics Division, decided what he was going to do. When I became director, we would talk these things over once a month, on a Friday. I provided liquor, which I guess now would be considered scandalous, but it certainly allowed people to forget their inhibitions. We didn't have that many division leaders or associate directors, so everybody could come and speak out.

Chick Keller: I think many of our problems stem from the over-regulation of the Lab, which, in turn, stems from the fact that we are perceived as having no mission. If you have no mission, you've got to get something done, and the health and safety and financial people are told, "Get in line and help make it happen. Right now!" Those people have no vested interest in our productivity.



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David Sharp: Right now a lot of the things that are costing us time and money are being imposed on us by people whose first interest is safety and environment *not* the scientific productivity of the Lab.

Jim Smith: Here's an example. Nineteen years ago I used to carry a gram or so of plutonium in my car from the CMR building down Diamond Drive to DP site. It was legal. I didn't break any rules. Today, we've got to pay for extra security, so plutonium workers cost $600,000 to $700,000 per person each year. And if you want to haul a few grams of plutonium down a road, you have to close the road and bring out the machine guns. All these changes came about because somebody was worried. Nothing ever happened the old way. I never diverted any plutonium. But people in Washington decided it had to be done "right." And right is unbelievably expensive these days.

Harold Agnew: The safety and environmental concerns are here to stay, although we may learn to prioritize them better. I am more interested in the ways in which the Lab is diversifying. The era of greater and greater funding is over. It's probably going to be less. If you want to do some of the new things you've been talking about, I think you have to say, "Look, we think the future will be much better if we do this, so we're going to cut out that." You don't necessarily have to get new money, but you do have to have people who are willing to give up what they are doing and start something new.

Gene McCall: I remember the story of someone once asking Harold how many people work at Los Alamos, and he said, "About half of them." Well, I would say that about half the people at the Lab are willing to change what they are doing as long as they perceive that the people up the line will support them in whatever they are asked to do.

Chris Barnes: The individual has to be willing to take some risk. In my section in the Inertial Fusion and

Jim Smith

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Plasma Theory Group, we had three or four internal proposals for new directions, which were fought for and finally agreed upon by the group. However, we had to take some risks to change fields from plasma physics to neural nets. After four years, it's finally beginning to pay off. Our section is funded, and soon we're likely to be over-funded. But there were a lot of people who thought we were totally nuts to go off and do neural-net work.

Harold Agnew: Flexibility needs to be built into the management as well as the staff, especially during times of change. The last years when I was here, I implemented a tenure limitation for group leaders, something that had never happened at Los Alamos. At first it was traumatic for this small community because people would say, "Gee, your daddy isn't group leader any more. He must have done something wrong." But I used the analogy of academic departments where the position of chairperson is not coveted by most people in the departments, and there's no social stigma for not being the chairperson any more. We also tried a tenure limitation on division leaders, but it was a little harder for them to accept, and we didn't implement it completely. Are there such limitations here now?

Basil Swanson: There's an experiment going on right now in the Isotope and Nuclear Chemistry Division in which group-leader appointments are limited-term appointments. Jill can describe how it works.

Jill Trewhella: I just recently moved to INC Division as leader of the Spectroscopy and Biochemistry Group. I was willing to take that position because it's a three-year limited-term appointment. Historically, INC Division has been strongly associated with the nuclear-weapons program, and until recently, 70 percent of its funds came from that program. Now only 30 percent of the funds are from weapons programs, and the division has successfully redirected its efforts into areas such as environmental restoration and basic science. That's been done by being flexible, looking to the future, and reorganizing the Division. The Division instituted limited-term group-leader appointments specifically to address the issue of flexibility and ensure that the Division responds to changes as needed. The group leaders are funded to spend 50 percent of their time doing research on programmatic efforts so that when they're finished with their three-year appointments, they can make an easy transition back to research without the trauma of having to start from scratch. It's worth noting that the Division has gone from a $35 million budget for the last fiscal year to a projected $45-million budget for the current fiscal year. So, there are new ways of doing things that can be very successful in the present environment.

Gene McCall: The key to maintaining the technical capability of the group leaders and division leaders is to keep them involved in technical work. Years ago even the division leaders did some technical projects. Nowadays, there's hardly even a deputy group leader who does a technical project. In X Division we've had three or four group leaders voluntarily leave their management positions over the last three years because their jobs were so far removed from the actual research.

Jill Trewhella: The reason group leaders in INC Division can keep doing research is that the bulk of the bookkeeping, administrative, and environmental, safety, and health activities are being handled by a separate business and operations unit. The group leader is thereby free to be a technical group leader and stay much closer to science.

I come from the biosciences, which is not a traditional area of strength at the Lab, so my colleagues and I have been forced to be very outward looking, to band together with whomever we can, and to develop joint initiatives such as the new initiative in structural biology.

Harold Agnew: Biosciences and materials science are areas that are really blooming in this country. In the San Diego area every other outfit is a bioscience something-or-other with a "tech" at the end of its name. Does that make your life easier? Is it like nuclear physics in 1943 when the whole world was our oyster?

Jill Trewhella: It helps and hurts at the same time. There is new money in biosciences, but as a result, everybody is jumping on the bandwagon—whether it's appropriate or not. So the quality control gets difficult at times. The Director wants to see biosciences dramatically increase at the Laboratory, but we have to step carefully and think very judiciously about what directions we promote because this is a relatively new area here.

Jill Trewhella

But the greatest strength of the national-lab environment is the opportunity for peer collaboration—the willingness of the people who are at your level to work with you and share ideas. In a university you're so scared, you want to get tenured, and you don't want anybody to write a paper with you unless that person is a student or a postdoc—that way you know your name will come first.

Harold Agnew: In the olden days we got our finger into the biosciences by irradiating rabbits with neutrons and stuff like that to study the effects of radiation. That was the only area of biological research we could justify because we were basically a weapons laboratory.

Jill Trewhella: The biosciences have grown a lot since then. We have initiatives in genome sequencing and informatics, structural biology, medical isotopes, medical applications of lasers, bioenergetics, and so on, and we're supported by funds from both the DOE and the NIH. As a biophysicist, I see the Laboratory as a glorious environment in which to work. Laser technology, high-field magnet technology, neutron scattering, and so on are all available to me here. At other institutions, I would never have had the opportunity to get anywhere near them.

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Harold Agnew: You are so right. I'm an adjunct professor at the University of California, San Diego, and I find that nobody talks to anybody else at that institution—even in the same department sometimes.

Jill Trewhella: In the career that I've had at Los Alamos, it's not at all unusual for me to work and publish with two or three other career-equivalent people. It's wonderful.

Stirling Colgate: This is perhaps the most important aspect of the culture of the national labs. Peer collaboration is a way of life here, but it happens much less at the universities because of the initial pressure to attain tenure and the later pressure to obtain rewards, such as research support, based on individual creativity.

Larry Deaven: And at Los Alamos your peers may be other biologists or physicists, mathematicians, engineers, and chemists. I can point to two areas of biological analysis that emerged within the Life Sciences Division because of that kind of unique interaction. One was the development in the late 1940s of liquid scintillators for detcting ionizing radiation. Those scintillators enabled biologists to study metabolic processes at the molecular level and helped to redefine biology in terms of biochemical and biophysical principles. The second was the development of flow cytometers, which are instruments for sorting and analyzing cells. Those instruments are located in all major hospitals today. where they are used to diagnose cancer and AIDS. It was the interaction between life scientists and physicists here at the Laboratory that gave rise to these unique technologies.

In the early days of the Laboratory, much of the life-science research was involved with irradiating whole animals to refine our knowledge of radiation exposure and to establish radiation-protection standards. When I came to the Laboratory in 1971, we had a small group of cell biologists who were studying the effects of radiation on cells and subcellular particles. Our health-research unit was small compared with those in other national laboratories. However, during the next ten years, we very carefully positioned ourselves in the direction of modern biology, and for that reason, we have a large, multidisciplinary human-genome center at the Laboratory today.


Larry Deaven

It's clear that health-science research and especially preventive medicine are going to be major agendas for this country as the need for defense expenditures winds down.

It's clear that health-science research and especially preventive medicine are going to be major agendas for this country as the need for defense expenditures winds down. The kinds of discoveries being made in the human-genome project—new information on the genetic component of disease and new diagnostic tools—will have a big impact on medical science and the practice of medicine only if delivery systems can be devised to make them available in a cost-effective manner. I believe that the Laboratory has the expertise to help develop affordable delivery methods, and I think we should try to initiate new projects to address the problems.

Gene McCall: We should be a little cautious. We should remember a few phrases, such as synthetic fuels, renewable energy resources, solar energy for the masses, and others that ten years ago were the wave of the future but are hardly ever mentioned now by the mainstream funding agencies. We should build our own base in the biosciences, and we should avoid responding only to what looks fashionable right now.

David Forslund: The unique strength that this Lab brings to all these problems is the combination of ideas and talents from physics, chemistry, biology, materials science, and so forth. This broad combination of people and technology enables us to envision new areas of research and applications that are important to industrial problems. That's a strength we have over some of the industrial-research facilities, which tend to have a more narrow focus.

Larry Deaven: The Lab's diversity is surely paying off in the genome project. We have a robotics effort, we have a strong informatics effort, and we have some innovative work under way from the Chemical and Laser Sciences Division and the Physics Division in the direction of new methods for DNA sequencing. You find elements of those activities at any of the other genome centers, but ours is unique in terms of having all of those elements under one roof. And our center for human genome studies could be used as a model in developing other new initiatives in bioscience and biotechnology.

Alan Bishop

Our biggest challenge—perhaps even nationally—is just how to interface basic disciplines with application teams without using up the resource that generates advances in basic science and technology. Many scientists want to belong to a discipline, …and feel a part of its continuous growth and evolution.

Alan Bishop: Materials science is another area that is intensely interdisciplinary. In the manufacturing process, for example, if you don't have a controlled starting point and the right material that can get you to the desired end point, then there isn't a process. So creating complex materials is an area in which Los Alamos can compete and is competing very well due to our ability to bring together different disciplines. For example, I'm a physicist, and I'm working very closely and effectively with Basil Swanson, a chemist, and his colleagues on new materials with intriguing electronic and light-emitting properties.

However, if you simply take people out of their disciplines and put them into a team to solve some specific problem, you create a very short-term fix, but you can easily jeopardize the technology base of that discipline, which is in fact the source of our ability to tackle complex problems—the base in physics, math, chemistry, and so on, that Colgate and others have emphasized.

Our biggest challenge—perhaps even nationally—is just how to interface basic disciplines with application teams without using up the resource that generates advances in basic science and technology. Many scientists want to belong to a discipline, and they want to be able to regularly come home to that discipline and feel a part of its continuous growth and evolution. They can be effective members of interdisciplinary teams, but they should be able to take the questions from those teams back to their own disciplines where their greatest strengths lie and where the questions can best be interpreted and solved. Trying to convert people from one discipline to another is very difficult, and the success rate is pretty low.

The area of materials science, in terms of both structural and electronic materials, is one where the Lab can have a major impact. And the impact will be felt on both the defense and the nondefense sides of the laboratory. Dual-use actually means something very directly in the area of materials science.

Paul White: Do we have some examples where work in that area has been reinforced by collaboration with industry?

Alan Bishop: I've been working with various companies for the last eighteen months or so, and it has been educational on both sides. At the beginning, high-level discussions are usually widget-driven. The company wants some particular device, and it wants our help in making it. But after a while, the stronger industrial firms—my own limited experience includes companies like Hewlett Packard and IBM—begin to recognize that what they really want is our depth of technology, our expertise in modeling and developing and testing new materials, and our ability to put appropriate science into large computer codes and then simulate effectively. That's the most positive kind of new direction. It's taken over a year to reach that point, and I hope it takes less time in the future, but we got there, and that is encouraging.

Paul White: Some people in the Clinton campaign proposed that the weapons labs devote 20 percent of their efforts to collaborations with industry. Where are we relative to that number?

Kay Adams: I'm the director of the Industrial Partnership Center at the Laboratory, and one of the biggest disappointments I've had is that the DOE expects us to have an economic impact on a company in one to two years, but a more appropriate and realistic time scale would be three to five years. There are companies that view Los Alamos like grandmother's attic where they can find all kinds of neat things to bid on. Well, we don't have much off-the-shelf technology, and I wouldn't want to see us emphasizing the development of off-the-shelf technology because then we'd be destroying our seed corn.

We need to keep replenishing our good ideas, to build synergism between new ideas and new applications, and to leverage the kinds of long-range projects we've been talking about today. We need to build up areas that are four to ten years away from having products. And no one in Washington at this point is ready to accept that as being a fundamental need.

Also, because of the fifty-fifty cost sharing of some programs, we can work only with big companies. But larger firms tend to be less innovative and less interested in taking risks to implement new technology than are some of the smaller companies. So the big firms come to the labs to look for a Band-Aid. Even though the help we offer might get us some brownie points, we lose intellectual property. We also get tied up in knots when we try to work with two or three different companies on the same problem. It would be better to have our technology open to the public so that more people could just run with it. That would probably do the economy more good.

We have not yet determined how the national labs can truly impact the area of economic competitiveness. And yet the DOE expects us to prove we can be outstandingly helpful to the economy in two to three years. We need more time to build on our strengths and show what we can really do.

Jim Smith: I'd like to expand on some of Kay's comments. The Laboratory is working with American Superconductor Corporation and Intermagnetics General, two small businesses, to manufacture wires from high-temperature superconducting materials under a Cooperative Research and Development Agreement, but we also do our own independent research. Right now it looks like we've gotten ahead of the companies, and that poses some interesting questions about intellectual-property rights, and the issues are very cloudy.

We've gotten two kinds of guidance from the DOE. Some people want us to work with industry, and they say that the collaboration is the final product. The people who have been around longer want to see us actually make the product because then they can judge whether we've performed well or poorly. Just what is our mission?

Judging our success in tech transfer is rather difficult because for now Washington can either ask a company if we've helped them, or they can ask us about the properties of the wire we've made. When the companies begin selling products, Washington may be in a better position to see whether we have helped industry.

Harold Agnew: Your funding agency can argue that the reason you got ahead is because you've used the goods from each of the three companies. That presents a real problem.

Kay Adams

We have not yet determined how the national labs can truly impact the area of economic competitiveness. And yet the DOE expects us to prove we can be outstandingly helpful to the economy in two to three years. We need more time to build on our strengths and show what we can really do.

Gene McCall: It is not to the Lab's advantage to deal with a hundred different companies even though it may be to the advantage of the individual Lab researcher. The Lab needs to work on the basis of some overall concept, and if working with a particular company fits into that, fine, do it.

Kay Adams: The basic premise of the Technology Transfer Initiative was that we would be working on dual-use technologies, which would build on our strengths in the defense arena and also have commercial impact. That's a very solid, fundamentally defendable premise. The implementation, however, has presented some significant problems. But we do have some positive models. The Defense Advanced Research Projects Agency and many other organizations in the government have put together groups that have worked with the national labs and industries for years, and they've been highly successful.

Stirling Colgate: DARPA funds research, but, in contrast, we *do* it. That's why, by comparison, working with the Lab presents a conflict of interest to industry.

Basil Swanson: Not just the Lab but the nation as a whole must identify long-term industrial needs because industry has gutted its labs and no longer has the capability to address long-term problems. Industry needs access to new technology, and I think this Lab can bring it to them.

Kay Adams: The reason for doing shorter-term projects is to build credibility. Right now some industries do not look on the national labs as being their friends or even as being a resource for them. They see the labs either as competitors or as being totally nonessential to anything that they are doing. So we have to show that we are willing to listen and that we can actually deliver more than was originally expected.

The work on high-temperature superconductors with Hewlett Packard and DuPont, the work on high-performance supercomputing with Cray Corporation, and the work on advanced numerical methods for oil recovery with Mobil Corporation have all been successful. We're building these alliances, and when people start to work with us on very short-term kinds of things, they start to see the potential that's here and become willing to take a little more risk and work on longer-term projects. Industry will come along. It's just a matter of getting them in the door and working with them. I'm more concerned with the Department of Energy and the national funding capability. We need a realistic way of defining success in the area of industrial collaboration.

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Harold Agnew: It seems to me that the smaller companies really need you more than the larger firms. The labs are not competitors with the little guy because he hasn't gotten to the stage where he's really competing with anyone yet; he just has a dream.

Kay Adams: That's absolutely correct. Right now there are set-asides for small business, but they tend to be extraordinarily small. The entire program for the Technology Transfer Initiative is going to be $141 million and only $6 million has been put aside for small businesses. None of this money has yet been released.

Paul White: Perhaps what small business need now is the technological equivalent of the Agriculture Extension Service. That service was established in 1914 to work at the local or regional level to funnel the results of research done at land-grant colleges into the hands of farmers. In the technology arena, a similar program might channel the results of research at universities and government laboratories into the hands of small business.

Gene McCall: When I look at a possible future for the Laboratory, I see half of the Lab being in defense work with half of that being in nuclear weapons. The nuclear-weapons part interfaces in my mind with the economic competitiveness through the design of a safe reactor for the burning of plutonium from weapons. The non-nuclear part of weapons work interfaces with the modeling and improvement of the transportation system. We ought to work on the design and building of autonomous vehicles and the modeling of the battlefield and of defense systems.

On the more commercial side, we should work on solid-state lasers, which have applications in defense, biology, surgery, compact-disc players, and so on. The biotechnologies are a little bit separate but still seem to form a major thrust in the laboratory. To my mind, those areas, along with materials work, flesh out an appropriate future for the Lab. So far, we have not developed a collective vision for the Laboratory, like the one I just outlined, but once we establish firm priorities and say, “Here’s what we are going to do,” we can start interacting with those companies that match the Lab’s vision of itself. If we work on piecemeal applications with industry, I don’t think we will get consistently good performance from the Laboratory staff.

David Sharp: We do need a collective vision, but we don’t need to emphasize large projects to the exclusion of small ones. In this context large means $100 or $200 million, and small means $10 million or less. The idea that the Laboratory’s strength is geared toward large projects reminds me a little bit of a dinosaur’s strength being geared toward eating large quantities of food. Focusing on finding the one large project is a silver-bullet approach to planning the Laboratory’s future.

We have a great big problem, which is money, but that doesn’t mean there’s one great big solution. The solution is going to come in small pieces from many vigorous efforts in economic competitiveness, in biotechnology, and in the environment. Efforts that start small can grow and become extremely important to the Lab. GenBank, the national database for DNA-sequence data, grew to be a fairly substantial project, but it didn’t start that way—it started with just a couple of people with vision. Small thrusts, which are only a few million dollars, can coalesce and reinforce each other to become a major thrust. But the attempt to start $100-million programs from scratch will be extremely difficult. Anything that big is going to be a line item in Congress, and every one of the fifty states is going to claim that it should have its piece.

Gene McCall: I don’t agree. The burning of weapon plutonium is something we can do. We can come up with a standard, very safe reactor design, and that would be an appropriate large project for the Lab. Roughly 25 percent of the carbon dioxide in the world is the result of power production. As we go to more electric cars and electric vehicles to get away from the pollution and environmental problems caused by burning fossil fuels, the electricity has got to come from somewhere. Now if it comes from a nonpolluting source like nuclear reactors, we’re all better off. But we need to show people that this is a nonpolluting, safe source of energy, and that it will not have a negative affect on the environment of the future. Such a project would be a $100-million project.

Jill Trewhella: The key to a healthy organization is a balanced approach. We need to pursue areas of strength and look for opportunities for large projects. Having a thousand little one-person efforts is ridiculous. At the same time, in the context of building on our strengths and looking for large programs, we need to encourage and provide an environment where small projects can flourish. We can do both. Moreover, we can’t just respond to the national needs for the next decade and ignore what the national needs are going to be in twenty or forty year’s time; we have to do both.

Robert Ecke: One big problem is the lack of a national science policy, so, as Gene was saying earlier, we're always in the position of reacting. Solar energy used to be big, and then a different administration came in and energy was not a big thing, so now we go off and do something else that's defined as a national need. It really is important for the nation to decide what it wants, and then we can respond in a reasonable way.

Paul White: But the nation is made up of people with many different interests, all of whom want different things, and all of whom read the newspaper and listen to the TV and the radio.

Jill Trewhella: And that's why we can't afford to be purely reactive. We have to, at some level, decide what we're good at and set our own directions. We have to be responsive but not reactive.

Robert Ecke: But if we decide we want nuclear reactors and the public doesn't want nuclear reactors…

Stirling Colgate: …then we have to keep leading and that's where advertising comes in. What percentage of industry's budget is spent on advertising? 10 percent? We need to explain the technical issues. We have to be a leader in the technical education of the general public and our political leaders. Leadership in technology starts with managing our nuclear arsenal, and it goes on to any other area that we might be working in. We should be setting the new directions for ourselves, we shouldn't be sitting around asking for them.

Harold Agnew: In the old days we talked to the Joint Committee on Atomic Energy. They had grown up in the nuclear-weapons business, so they understood it very well. The same was true of the Atomic Energy commissioners, who were really a cut above most people in the bureaucracy today. Some of them even had a strong technical background. It was easy to talk with them. They set the policies, but they relied upon the Lab directors for advice. If we had a good idea, it was easy to implement in policy. Nowadays everybody in the Congress wants to have a finger in everything, and if anybody tries to get something accomplished, they get investigated, or as we say, Dingelled, so people hide.

The American people are sending a message to the scientific community that they want help with major problems: health, the economy, the environment. I don't think this means, as some argue, that the scientists are out of the decision-making loop; rather, they have a mandate to consider the broader impact of their work.

David Sharp: We have to realize we are working in a different political environment. The American people are sending a message to the scientific community that they want help with major problems: health, the economy, the environment. This message has been picked up and has bedrock support across the political spectrum.

Thus, at the national level the relevance of proposed projects to specific national needs receives greater emphasis in the overall evaluation process. I don't think this means, as some argue, that the scientists are out of the decision-making loop; rather, they have a mandate to consider the broader impact of their work.

I review programs on applied math. Three, four, five years ago, a proposal by an applied mathematician would state the problem and the beautiful theorems he was going to prove and that would be sufficient for getting funding. Today those proposals contain a description of a whole project all the way from the mathematics problems down to the applied problems where that mathematics is going to be plugged in. The whole proposal is connected to a consortium with industry or some National Science Foundation interdisciplinary center. A lot of people are learning how to play this game of building integrated programs. I don't think they can do it quite as well as we do at Los Alamos, but they're learning because that is the way the funding of programs is being conducted.

Paul White: The mechanism for identifying national needs is different from what it was fifteen or twenty years ago, but that doesn't mean we can't influence what happens. It doesn't mean we can't lead. We have be active, and we have to lead in different ways. ■

The Participants

Kay V. Adams is director of the Industrial Partnership Center at the Laboratory. As manager of all of the Laboratory's industrial activities, she assists in the identification of key R&D technology areas that are of interest to industry and represents those activities to industries and organizations outside the Laboratory.

Harold M. Agnew was a member of the small group that worked with Enrico Fermi to inititiate the first nuclear-fission chain reaction at the University of Chicago in 1942. Shortly thereafter he joined Project Y at Los Alamos and worked on the development of the atomic bomb. He became leader of the Weapons Physics Division in 1964 and director of the Laboratory in 1970. Agnew is a recepient of the Fermi Award, the highest scientific award of the Department of Energy, in recognition of his "many contributions to nuclear physics and nuclear weaponry, and his forthright counsel to the government in the field of national security."

Chris Barnes joined the Laboratory in 1979 to work on inertial confinement fusion theory in the Applied Theoretical Physics Division. Barnes has worked in neural network and machine-learning applications for the past five years.

Alan R. Bishop has been involved in resesearch on condensed matter and nonlinear science since joining the Laboratory in 1979. He is currently leader of the Condensed Matter and Statistical Physics Group in the Theoretical Division.

Gregory H. Canavan came to Los Alamos in 1981 to build advanced lasers and to perform plasma-physics experiments in inertial fusion. For the last decade he has been active in developing and testing advanced concepts for strategic defense and future strategic forces.

Stirling A. Colgate was a staff physicist at Lawrence Livermore Laboratory for twelve years and president of New Mexico Institute of Mining and Technology before joining Los Alamos in 1976. In 1980 he became leader of the Theoretical Astrophysics Group. He is a Senior Fellow at the Laboratory and a member of the National Academy of Sciences.

Larry L. Deaven has been involved in biology and DNA research since he joined the Laboratory in 1971. He is currently the principle investigator of the National Laboratory Gene Library Project at Los Alamos and Deputy Director of the Los Alamos Center for Human Genome Studies.

Gary D. Doolen has been Acting Director of the Center of Nonlinear Studies since 1990. His research interests span nuclear physics, atomic physics, plasma physics, controlled thermonuclear reactors, lattice gas methods and nonlinear mathematics. Doolen is a past senior scientific editor for *Defense Research Review.*

Robert E. Ecke came to the Laboratory in 1983 and has worked in low-temperature physics and nonlinear science. He is currently in the Condensed Matter and Thermal Physics Group and for the past two years has been Acting Deputy Director of the Center for Nonlinear Studies.

David W. Forslund is a Laboratory Fellow, Deputy Director of the Advanced Computing Laboratory, and a Fellow of the American Physical Society. His areas of expertise span physics and computer science and include space plasma physics, magnetic fusion, laser fusion, massively parallel computing, and distributed computing.

Erica Jen is a mathematician in the Theoretical Division and Acting Deputy Director of the Center for Nonlinear Studies. Her research focuses on the mathematical analysis of discrete dynamical systems. Other current projects include electronic-preprint bulletin boards and educational programs in nonlinear science and complex systems.

Raymond J. Juzaitis has been with Los Alamos National Laboratory since 1979 and now serves as the Division Leader of the Applied Theoretical Physics Division. A member of the DOE Verification Panel and the American Nuclear Society, Juzaitis has received two Department of Energy Awards of Excellence for Nuclear Weapons Design.

Chick F. Keller has been involved in computer modeling of fluid dynamic processes at the Laboratory since 1967. He is currently Director of the Laboratory's Institute for Geophysics and Planetary Physics and a Principal Investigator on a joint project between the University of California and Lawrence Livermore and Los Alamos national laboratories on global climate modeling.

Carson Mark came to Los Alamos from Canada in 1945 as part of the British Mission collaborating on the Manhattan Project. He joined the Laboratory in 1946 and served as leader of the Theoretical Division from 1947 until his retirement in 1973. He currently serves as a Laboratory consultant.

Gene H. McCall has been involved in plasma, laser, and hydrodynamics research at Los Alamos since 1969. He was a founder of the Inertial Fusion Program at Los Alamos and leader of the Laser Division; he is now a Laboratory Fellow in the Applied Theoretical Physics Division. He has been an advisor to the Department of Energy and to the Department of Defense.

David H. Sharp joined the Laboratory in 1974 and now holds the position of Laboratory Fellow. His current research interests include the modeling of complex fluid flows and the formulation and analysis of gene regulation. Sharp is a Fellow of the American Association for the Advancement of Science and the American Physical Society.

James L. Smith joined the Laboratory in 1973 to study superconductivity and magnetism in the actinide elements. After the advent of high-temperature superconductivity in 1988, he joined the Superconductivity Technology Center as Chief Scientist. He is a Laboratory Fellow and received an E. O. Lawrence Award from the DOE in 1986.

Basil I. Swanson has been involved in condensed-matter spectroscopy and advanced electronic and electro-optic materials since joining the Laboratory in 1980. He is currently a Laboratory Fellow and the Principal Investigator for Laboratory programs in low-dimensional mixed-valence solids and in spontaneous self-assembly approaches to advanced electro-optic and nanostructural materials.

Jill Trewhella joined the Laboratory in 1984 to further develop her interests in using physical techniques to study how biomolecular structure regulates or controls biological activity. She is currently Principal Investigator for NIH and DOE projects in structural biology and is leader of the Spectroscopy and Biochemistry Group in the Isotope and Nuclear Chemistry Division.

Andrew B. White, Jr., is Director of the Advanced Computing Laboratory and Program Director for High Performance Computing. He has been at the Laboratory since 1979. His leadership of the Laboratory's role in the Federal High Performance and Computing and Communications Program culminated in Los Alamos being designated as one of the two High Performance Computing Research Centers.

Paul C. White is Program Manager for Special Projects in the Nuclear Weapons Technology Office. He acts as a liaison between the Nuclear Weapons Program and the Nonproliferation and Arms Control Program, and serves as the Laboratory's technical representative to the DOE Steering Group, which coordinates U.S. assistance to Russia in the dismantlement of nuclear weapons. White was formerly leader of the Applied Theoretical Physics Division and Deputy Director of the Center for National Security Studies.

Merri M. Wood has worked in the Thermonuclear Applications Group since joining the Laboratory in 1979. Her work has included stockpile support, weapons physics, and advanced development. She has also been active in the Equal Employment Opportunity and Affirmative Action arenas.