Comments from

It is with pleasure that I introduce this volume of *Los Alamos Science*. The volume culminates a two-year effort by our Laboratory's Human Studies Project Team. The team was formed to address questions concerning the ethics and conduct of human radiation experiments that were carried out by Los Alamos researchers from the Manhattan Project days through the 1960s. The credibility and forthrightness of the team's effort has a very special meaning in the context of today's mission and tomorrow's challenges. This Laboratory continues to be the steward of nuclear weapons technology. As the world tries to roll back the number of nuclear weapons and reduce their impact on the community of nations, it is our job to help make that possible by maintaining a credible nuclear weapons technology base in the absence of testing and by developing the specific technologies needed to safeguard nuclear materials and retire them permanently. Working with plutonium and other radioactive materials while limiting radiation exposures thus remains at the heart of our mission just as it was during the Manhattan Project. Concurrently, maintaining public trust regarding environmental, health, and safety issues has become ever more important to the success of our mission. The Human Studies Project Team's review of past work on radiation protection and the human experiments as well as their examination of the current state of knowledge regarding radiation and risk are presented in this volume and represent a major effort by our Laboratory toward achieving public trust through the sharing of experiences and information.

The need for the team became evident in late 1993, when our credibility and integrity were put in question by the widespread publicity regarding the plutonium injection experiments and other human radiation experiments. Challenged by Department of Energy Secretary Hazel O'Leary's openness initiative and encouraged by Dr. Tara O'Toole, the DOE Assistant Secretary for Environment, Safety, and Health, we decided to try to turn the negativity that gripped the media, the public, and many of the Laboratory's employees into a positive force. In my editorial of January 28, 1994, I encouraged all employees to keep open minds because I was certain that the Laboratory and the nation would gain perspective from a thorough review of both the science and the ethics of the human radiation experiments.

Our initial responsibility was to participate in the Department of Energy's openness initiative by gathering information for the agency and for President Clinton's Advisory Committee on Human Radiation Experiments. To that end the Human Studies Project Team, sponsored by the Laboratory's Environment, Safety, and Health Division, was charged with combing the archives and other sources for anything and everything related to human radiation experiments. The team includ-

the Director

Siegfried S. Hecker

ed scientists, physicians, lawyers, ethicists, archivists, and others, some from the Laboratory, some from local universities, and a few representatives from state government. At the beginning there was tension between the retiree experts on the team, who had participated in the radioactive tracer studies done at Los Alamos during the 1950s and were outraged that their mentors Wright Langham and Louis Hempelmann were being maligned by the public, and the younger generation on the team, who had less reverence for the past. But everyone wanted the truth to surface and the team soon became a smoothly functioning body. The documents that were found were reviewed on a weekly basis, decisions were made about removing material that was confidential under the privacy act, and the material was released to the public. That process continued for over 15 months until the entire team was satisfied that all existing documents had come to light. Over 500,000 pages of historical documents were reviewed, and the relevant ones were released with no editing and no editorial comment. It was for the public and President Clinton's Advisory Committee to decide the value and judge the ethics of what had been done. In total, the team released over 1,600 documents. The members also responded to hundreds of specific requests for information from the President's Advisory Committee and from individuals who were concerned about their own exposures. All in all it was an extraordinary accomplishment.

However, there remains a second ongoing job. It concerns our own evaluation of what happened in the past and our efforts to learn from that past. This volume, written by members of Human Studies Project Team in collaboration with the *Los Alamos Science* staff, is dedicated to educating ourselves and the public about radiation, about the human experiments, and about the real consequences of exposure to plutonium. It's also dedicated to saying things as they are. Some of the facts about the plutonium injection experiments are difficult to accept, especially for those of us who take pride in the accomplishments of our Laboratory. We know in retrospect that hospitalized patients were injected with plutonium, and there is no documented evidence that any of them fully comprehended what was being done to them. Most of the eighteen subjects received five micrograms of plutonium, a tracer amount, but nevertheless five times greater than the limit set for workers in the Manhattan Project immediately following the results from the first three injectees and about ten times the amount that we allow today. In general, the health of the injected patients was not followed after the main study was complete even though it was apparent from the experiments that most of the plutonium would remain in their bodies for the rest of their lives. Also, even after the subject of plutonium became declassified, the injectees were apparently never told what was done to them even though a few were called back so additional plutonium excretion data could be gathered. That is not a pretty picture. The President's Advisory Committee came to the conclusion that the injectees and their families had been ethically wronged. We don't believe there are many among us who would disagree with that conclusion, and certainly today, those experiments could not and would not be done in that manner.

But there are mitigating facts. The pressure to gather data for interpreting the results of accidental intakes of plutonium was enormous and immediate. The choice of the five-microgram injection dose was not an arbitrary one; it was at the limit of detection for the analytical techniques then available. Before the experiments were done, careful work with animals had shown that the injected dose would not be acutely toxic. Also the risk of delayed effects, in particular cancer, were expected to be quite small: The experiences, for example, of the radium-dial painters (many of whom had ingested large quantities of radium, another alpha-emitting radioactive element like plutonium) had shown that only when very large internal doses of radium were present would bone cancers be induced. Thus the researchers at Los Alamos who planned and analyzed the experiments at Oak Ridge and the University of Rochester did not expect the injectees to suffer from their intakes although they admitted to some uncertainty. Fortunately, there is no evidence that plutonium caused harm to any of the patients.

That's an important finding. The press often wrongly states that the tiniest amount of plutonium can kill you. To the contrary, we know from our own plutonium workers that individuals carrying accidental intakes comparable to the amount given to the injectees have lived healthy, vital, and productive lives, some for over 50 years from the time of intake. As part of the effort to educate ourselves, and especially for this volume, the Human Studies Project Team sponsored an informal workshop with ten of those folks and some of our experts in health physics. "On the Front Lines" presents the rather remarkable stories and comments that were shared at the workshop. What may not come across in the telling is the talent and ability of those individuals—many are said to have "golden hands"—and we, and our nation, owe them a debt of gratitude for their skill, their courage, and their dedication in handling very difficult work in the safest and most expeditious fashion. We also hope that their stories will increase our awareness and our respect for each other and for the jobs that we do.

At the end of the workshop, some of the Laboratory experts summarized the safety record in the area of plutonium work as well as the present understanding of the dangers of plutonium exposure. As far as we know, among the thousands of indiviuals who have worked with plutonium, there are only about 50 people in the United States who have plutonium body burdens greater than the maximum permissible level. Of those, there is only one case in which plutonium may have been implicated in the cause of death. That death involved a bone sarcoma in the sacrum, an unusual place to get bone cancer but an area that tends to concentrate plutonium. The exposure records are admittedly incomplete. Nevertheless, it appears that the worker protection standards and the adherence to them have served us well. Remarkably, those standards and the means to implement them were and still are based on the information gathered from the early plutonium injection studies. Those data are used both to calibrate the techniques for monitoring workers and to interpret the amount of accidental intake so that an individual can be taken off the job before the internal body burden becomes dangerous. The article entitled "The Human Plutonium Injection Experiments" presents a definitive review of the motivations, implementation, aftermath, and scientific impact of those experiments. The set of raw data gathered from the injectees, although a rather meager set, constitutes the main source of information on plutonium metabolism in humans. Because it is so important, it has been analyzed and re-analyzed over the years. The article reviews that work and then presents a brand new analysis performed by one of the authors. The new analysis puts to rest many of the ambiguities that have plagued the interpretation of the original data and is yet another accomplishment to emerge from the Human Studies Project.

"Tracer Studies at Los Alamos and the Birth of Nuclear Medicine" adds another dimension to this story—one for which we can be very proud. The doses involved in the tracer studies were extremely small, the volunteers were appropriately informed, and the studies were important both for radiation protection and nuclear medicine. A most exciting spinoff from the radiotracer work was the invention of a new type of radiation detector made from a liquid scintillator. The device was developed in Wright Langham's Radiobiology Group for the detection of low-energy beta particles from tritium so that the metabolism of tritium in the body could be studied. But word got out, and Fred Reines and Clyde Cowan, Jr., then at our Laboratory, came to the Radiobiology Group for help in designing and building a very large liquid-scintillation detector for neutrinos. Naturally, they got the help they needed from the very talented scientists whom Langham had recruited, and the resulting detector was used to make the first observation of the neutrino. Fred Reines was awarded the 1995 Nobel Prize in Physics for that discovery. In a totally different vein, that large detector became the forerunner of the whole-body counter for *in vivo* monitoring of radioactive fallout from nuclear testing.

This volume is filled with history. It also surveys our present understanding of radiation and the risks associated with radiation exposure. When the story of the human radiation experiments reached the media in the fall of 1993, all kinds of numbers were being quoted to describe the events—picocuries of radioactive iron, 100-millirem doses of iodine-131, microgram quantities of plutonium. Only the experts knew what those numbers meant, and everyone else was baffled. Were those numbers big or small? What radiation exposures are considered acceptable, and how are they measured? What are the known risks from radiation exposures, and how do they depend on the level of exposure? Perhaps the most valuable contribution of the present volume is a three-part primer summarizing what we know about radiation and risk. The first part, "Ionizing Radiation—It's Everywhere!," introduces the physical properties of radiation in a way that should be engaging even to young students and describes various sources of natural background radiation, of which many of us are mostly unaware. The second part, "Radiation, Cell Cycle, and Cancer," presents the latest knowledge regarding the molecular mechanisms of cancer, the mechanisms of radiation-induced cancer, and the body's natural molecular and cellular defenses against radiation damage and cancer induction. That area of research is evolving very rapidly, and the story researched and written especially for this volume has not been told anywhere else at the same level of accessibility. The last part of the primer is a review of all the epidemiological data on radiation effects in humans. The article is entitled "Radiation and Risk—A Hard Look at the Data," and it is just that. We see data for the Japanese atomic-bomb survivors that form the basis for estimating the risk of radiation-induced cancer, we learn the hypothetical risks derived by extrapolating the high-dose risk factors to low doses, and we learn about the epidemiological data that have been gathered at low doses. The data are clearly presented so that anyone can make their own judgement about what is known and where the uncertainties lie concerning the effects of low-level exposures. We hope this volume will take its place on the shelf beside two important reports on the human radiation experiments: the Department of Energy's "Roadmap to the Story and the Records" and the "Final Report" of the President's Advisory Committee on Human Radiation Experiments.

Tara O'Toole helped us to get on this path. Despite considerable discomfort, the Human Studies Project Team took on the task of assessing the science and the ethics of the human radiation experiments. Their openness and commitment can serve as an example for all of us in the Laboratory and elsewhere. It is now up to us to continue. ■