What is eminently missing is a discussion of how to physically implement any of these algorithms or protocols, which indeed is a whole field by itself. Even the obligatory double-slit experiment or Mach-Zender interferometer is absent from the introduction, which must be a first in books on quantum computing. It no doubt shows Mermin's experience in thinking about the foundations of quantum mechanics that he feels comfortable talking about quantum computing in such an abstract way—an experience that has prepared him well for conveying the essential ideas behind quantum computing, without getting sidetracked by hundreds of years of experimental physics.

Instead, Mermin uses the introduction to carefully explain that the power of quantum computing should not be thought of as a straightforward corollary of the miracle of "quantum parallelism" with its exponentially sized superposition of states and computations, but rather as a more subtle consequence of the superposition principle and its constraints combined with the effects of interference between the probability amplitudes of the states. He is keen to remind us that it is an illusion to think that we have access to all the information used to describe a system of quantum bits and that we should be careful not to expect unreasonable benefits from storing information quantum mechanically. Although no proper textbook would disagree with that assertion, it is the strength of this book that it makes the point as explicitly and convincingly as it does.

Also missing is any reference to Turing machines, computational complexity theory or lower bounds. This decision, if it was one, is less fortunate. The excitement about quantum computing among computer scientists does not stem from the mere fact that we have found some efficient algorithms and novel ways of doing cryptography; new algorithms and cryptographic protocols are invented on a regular basis, and only a few of them will get noticed outside a small community of researchers. What *does* make quantum computing a revolution in theoretical computer science is the fact that it gives a whole new model of computation—only the third one after the deterministic and probabilistic models, and seemingly the first one that violates the strong Church-Turing principle, which states that any process that can be implemented on a physical device can be simulated efficiently on a Turing machine (the violation being that Shor's algorithm gives strong evidence that a quantum computer would be impossible to simulate efficiently on a classical computer).

Quantum Computer Science does not share this excitement about the field; it presents quantum computing more as a collection of quantum tricks. Readers with some knowledge of computational complexity will find no answers to obvious questions, such as what Shor's factoring algorithm implies for the hardness of simulating quantum systems, or whether Grover's search algorithm can be improved to solve NP-complete search problems efficiently on a quantum computer.

This last omission is an especially dangerous one. A significant part of the research in quantum computation is devoted to proving that even quantum computers cannot solve certain problems beyond certain bounds. Such "lower bounds" provide powerful no-go theorems telling us that quantum computers, like classical computers, have their limits. In conjunction with Grover's discovery of a quantum algorithm that searches a function over N items in $\sqrt{N}$ steps, it is also known that such a quadratic speedup is the best possible, ruling out once and forever the hope for generic exponential speedups for similar problems. To not bring this to the attention of readers learning about Grover's algorithm for the first time seems downright irresponsible. (Think of all the time wasted by ambitious students who, after reading this book, will try to find a log N algorithm for searching.)

Despite such omissions, *Quantum Computer Science* will be hard to beat for theoretically oriented self-learning, because its selection of topics will keep the attention of readers from beginning to end. Those interested in the experimental side of quantum computing should look elsewhere, however. *An Introduction to Quantum Computing*, by Phillip Kaye, Raymond Laflamme and Michele Mosca (Oxford University Press, 2007) is more complete than Mermin's textbook, but it is also more detailed and more technical. This makes *Quantum Computer Science* one of the two best books currently available for an introductory course on the theory of quantum computing. Readers who have a quantum computer scientist (who might or might not "know little or nothing about quantum physics") available to field follow-up questions will get the most benefit.

Wim van Dam is an assistant professor in the departments of computer science and physics at the University of California, Santa Barbara.

ASTRONAUTICS

The Rise and Fall of the Space Shuttle

Roger A. Pielke, Jr.

FINAL COUNTDOWN: NASA and the End of the Space Shuttle Program. Pat Duggins. xii + 249 pp. University Press of Florida, 2007. $24.95.

Since NASA's creation in the 1950s, its history has followed a course that calls to mind the Greek tragedies—tremendous early success, followed by a series of catastrophes and failures, which share the same root cause. Nearly 40 years have passed since NASA had its most notable successes, which culminated in Neil Armstrong's walk on the lunar surface. Since then, the agency has struggled to come up with meaningful goals that could take advantage of the sustained political support the agency has enjoyed over the decades. NASA has a rich tradition and employs the world's best scientists and engineers. Yet in recent decades its most notable moments have come in the form of disasters and their aftermath. And the institutional and cultural problems that led to the explosion of the space shuttle *Challenger* in 1986 went largely uncorrected for 17 years and contributed to the *Columbia* accident in 2003. The agency's identity crisis continues and will stretch into the next presidential administration and perhaps beyond. How the story of its space shuttle program will end remains highly uncertain.

Pat Duggins's timely and thoroughly enjoyable book *Final Countdown: NASA and the End of the Space Shuttle Program* is a hard-hitting account of the post-Apollo human spaceflight program, focusing primarily on the space shuttle. Duggins is a senior news analyst at public radio station WMFE in Orlando, Florida, and has followed the space program closely for many years. That he is a very knowledgeable observer is evident in this short but well-written book. Although he doesn't hesitate to criticize NASA, his perspective is ultimately optimistic.

The book is organized more or less chronologically. The bulk of the text is devoted to the space shuttle program, which began in the early 1970s, well before the first shuttle flight in 1981. Tellingly, 5 of the book's 13 chapters are about the *Challenger* and *Columbia* accidents and their repercussions. The facts will be familiar to most observers of U.S. space policy, but Duggins, drawing on his own original reporting, brings his account to life with colorful anecdotes, stories and photographs. Thus the book is far more than a review of secondary sources; it is a primary contribution to the history of the space program.

I estimate that U.S. taxpayers have spent about $170 billion (in 2008 dollars) on the shuttle program since its inception, at an average cost per flight approaching $1.5 billion. One central question that repeatedly came to mind as I read Duggins's history is "What purpose has the shuttle served?" Duggins never directly addresses that question, probably because it has no easy answer, but several possible answers can be deduced from his account.

In the early years the shuttle was an unwelcome compromise, something that NASA settled for when its ambitious desire to build on the Apollo manned moon program with a mission to Mars was rejected in the political process. The shuttle was supposed to become a reliable and low-cost means of getting to space and delivering satellites for the military and private companies. This goal was never met, however; the shuttle's eventual flight rate (the number of flights per year) approached only 5 percent of what was initially expected, and costs soared far above original projections.

Once the program was mature, the shuttle's existence became its own justification, and a space station was added to serve as its destination. Politics came into play as well. Duggins asserts that the Clinton Administration favored using the human spaceflight program as a means of conducting foreign policy, noting that critics called it "foreign aid with spacesuits." But there has been a long-term trend across administrations of using the space program for a variety of political purposes. The *Challenger* and *Columbia* accidents provided their own motivations for continuing the program—the rallying call "return to flight" became a mission unto itself. Duggins discusses the common institutional and cultural factors that were found to be behind both shuttle accidents and hints that NASA is still dealing with them. He quotes the husband of one of the astronauts who perished on *Columbia* (who happened to be a NASA flight surgeon himself):

> "I've learned hard lessons in aviation. That you have to stop and say, 'Wait a minute.' Things like Mission Completion Syndrome or get-there–itis can make you do things you wouldn't ordinarily have done before."

The book also brings home the fact that the experience of being an astronaut is less than glamorous and can sometimes even be harrowing. U.S. astronaut Jerry Linenger, recalling his time on Mir, the Russian space station, says, "Part of the time we were working to keep the station alive, and part of the time to keep ourselves alive."

The considerable risks of spaceflight were reinforced in April 2008 by the uncontrolled reentry of a Soyuz capsule that was carrying an American, a Russian and a South Korean back to Earth from the International Space Station. The capsule's reentry problems and its hard landing some 260 miles off target (which the astronauts survived) received little attention in the press and remain poorly understood.

Final Countdown is neither an academic history nor a political analysis; it draws on almost none of the scholarly literature on the U.S. space program. Nonetheless, with only a few minor exceptions, Duggins's account is largely consistent with the analyses of historians and policy researchers. However, the book's focus is clearly on the space shuttle program and its participants, and not on the broader sociopolitical context of the program. Academic quibbles aside, *Final Countdown* offers a first-rate journalistic history of the space shuttle program.

When investigators pieced together the debris from the wreckage of the space shuttle *Columbia*, they loaded the gray reinforced carbon-carbon (RCC) heat shields from the leading edge of the left wing in a plastic frame and determined that falling foam had punched a hole in shield number 8 (shown above). This allowed superhot gases to flow past the breach during reentry, leading to the disaster. From *Final Countdown*.

Looking to the future, Duggins is optimistic, perhaps more so than circumstances warrant. "Retiring the space shuttle program may give NASA a chance to forget its troubled past and pursue the genuine mission it has lacked for years," he says early in the book. In the epilogue, though, he warns that NASA has a number of hurdles to overcome before it can move on—most notably the possibility of the loss of another orbiter or of a serious accident on the International Space Station. The story of the space shuttle is far from over. The program has impressive support from members of the public, civil servants and private contractors. One can only hope that no more catastrophes are in store and that the shuttle program, and indeed NASA itself, avoids coming to a tragic end.

Roger A. Pielke, Jr., is professor and director of environmental studies, and a fellow of the Cooperative Institute for Research in Environmental Sciences, at the University of Colorado at Boulder; he is also an associate fellow of the James Martin Institute for Science and Civilization at the University of Oxford. His most recent book is The Honest Broker: Making Sense of Science in Policy and Politics *(Cambridge University Press, 2007).*