errors are the product of improper human reasoning," Butler says.

Unless they are caught, software errors persist throughout a system's lifetime. That makes conventional methods of risk assessment difficult to apply.

The problem is further compounded by the high degree of reliability required for life-critical applications. Historically, manufacturers of aircraft and other systems in which faults could threaten human lives have accepted a reliability level that corresponds to a failure rate of about 1 in a billion for every hour of operation.

Butler and Finelli demonstrate that techniques often used by computer scientists and programmers to quantify software risk take too long to be practical when used to assess systems that require such high reliability. For example, software design often involves a repetitive cycle of testing and repair, in which the program is tested until it fails. Testing resumes after the cause of failure is determined and the fault repaired.

But it generally takes longer and longer to find and remove each successive fault. To establish that a complicated computer program presents minimal risk would require years, if not decades, of testing on the fastest computers available, Butler says.

In an attempt to reduce the risk of failure, computer-system designers sometimes use multiple versions of a program, written by different teams, to perform certain functions. The idea is that although each version may contain flaws, it's highly unlikely that all or even a majority of the programs would contain the same error. However, experiments have shown that computer programs independently written to do the same thing often contain surprisingly similar mistakes.

Many computer experts at last week's meeting pointed to these findings as evidence that limits should be placed on the complexity of computer programs that go into life-critical applications. "Do we want to run with systems that are not as demonstrably safe as we say they are ... when we cannot demonstrate ultra-reliability before deployment?" asks Martyn Thomas of Praxis plc, in Bath, England.

"We should build only those systems that rely on software to a degree that can be assessed," contends Bev Littlewood of City University in London, England. That means accepting a higher risk or building simpler computer systems.

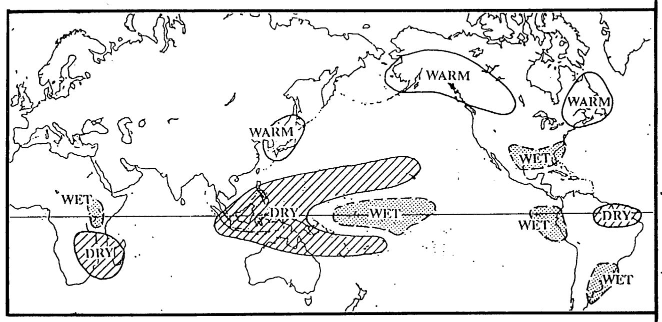
A few remain optimistic. "Maybe we're being a lot more demanding than we need to be," says John D. Musa of AT&T Bell Laboratories in Murray Hill, N.J. "There are risks in everything we do in engineering."

He adds that software developers have a variety of tools and techniques that can help them deliver — if not assess — highly reliable systems. *— I. Peterson*

'Tis the season for an El Niño warming

After more than a year of perplexing signals, the Pacific Ocean has generated an El Niño warming that promises major changes in the world's weather through much of 1992, bringing floods to some regions and droughts to others. The emergence of this temporary oceanic fever signals a success for computer models that predicted when the event would occur and, perhaps more important, when it would not.

Typical temperature and precipitation patterns for November through March when El Niño warmings occur in the central Pacific.



Climate Analysis Center/NMC

In the past month, meteorologists have observed a number of El Niño traits that did not exist earlier in the year. In particular, a large region of the central equatorial Pacific has warmed enough to generate thunderstorms, which carry ocean heat into the atmosphere, warping the jet stream's flow.

"From the observations, it looks as though we're in the middle of a warm event," Chester Ropelewski said this week at the American Geophysical Union meeting in San Francisco. "These things are important for [altering] rainfall patterns around the world, and they're also important for temperature," explains Ropelewski, a researcher at the National Meteorological Center (NMC) in Camp Springs, Md.

Generated by a complex interplay between the Pacific Ocean and the atmosphere, El Niños recur at irregular intervals of four to seven years. They are associated with a pattern of atmospheric pressure called the Southern Oscillation. The name El Niño (Spanish for "the child") refers to the warm water's tendency to appear off South America's coast around Christmastime, ruining the region's anchovy harvest.

Although these coastal waters have yet to warm, scientists say the most important traits of the El Niño have already developed. The National Weather Service has factored the new evidence into its winter forecast for the United States. For instance, it calls for above-normal precipitation in the Southeast, in part because that region tends to receive increased rainfall during El Niños, says Gerald Bell of the NMC.

Other countries can also use the El Niño in predicting weather. In certain dry areas of Peru, Ropelewski says, farmers might plant crops that would survive the heavy rains that drench the coast during these warmings.

Scientists have theorized that El Niños originate because the size and shape of the Pacific basin provide just the right conditions for water and air masses to slosh from west to east and back again, creating a natural engine that generates the warmings.

The last El Niño ran from late 1986 through 1987. Warm water began appearing in the central Pacific early in 1990, leading some meteorologists to expect a full-fledged El Niño later that year. While nature fooled those forecasters, some machines fared better. One computer model at the Lamont-Doherty Geological Observatory in Palisades, N.Y., has forecast for two years that an El Niño would develop now rather than in 1990, says Stephen Zebiak, who developed the model with Mark Cane. Zebiak discussed the prediction at this week's meeting.

"That's really amazing. Even that far back, it was calling for the event to be now," he told SCIENCE NEWS. The Lamont-Doherty model resembles a simplified version of the atmospheric general-circulation models used for short-term weather forecasting. Unlike the weather models, however, this version includes an ocean that interacts with the atmosphere.

A statistical model run at the NMC also predicted an El Niño for late 1991, but that forecast did not emerge until early this summer. The NMC model, derived from one created at the Scripps Institution of Oceanography in La Jolla, Calif., uses past patterns to predict how the weather will evolve.

The modest success of these and other El Niño models offers hope that scientists can develop versions with even more predictive power. "Ten years ago, if anyone said we would have climate models that would give a handle on what will happen six months, nine months or a year ahead, people would have dismissed it," Ropelewski says. "We're really on the brink of a new era." *— R. Monastersky*