

## The Tools That Jack Built

**H**umans are not the only animal species that makes and uses tools. Wikipedia has a photo of what appears to be a gorilla using a stick to gauge water depth. Likewise, elephants use rocks for various tasks. If using tools is a measure of intelligence, these animals are clearly intelligent. Although most animals use no tools other than their paws and teeth, some of them, such as squirrels and dogs, seem pretty smart as well.

Mechanics and machinists typically have large collections of tools, ranging from tiny screwdrivers to huge wrenches. These technicians cherish their tools, keeping them in cabinets with carefully arranged drawers, where each item has a designated place. Every tool must be accounted for, and no tool is ever abused.

Physical tools are used to assemble, disassemble, and fabricate devices as well as to make other tools. Beyond wrenches and screwdrivers, specialized tools are often needed. If you've done any repair work on your car, you probably own a few. Specialized tools complement the machine for which they're made. The machine cannot function without the tools, and the tools may be worthless without the machine.

But the tools that we develop for systems and control don't reside in neatly arranged drawers, and they rarely have any physical presence at all. We implement some of our tools on green circuit boards with dull black and shiny silver components, but these boards don't convey what the tools are about. Rather, our nonphysical tools are based on mathematics that we use



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to create algorithms that are embedded in computer programs that reside on circuit boards that run machines and processes that everyone depends on.

If your goal is to develop a walking robot, then you seek tools that facilitate design, fabrication, and implementation.

knife can cut many different things, we seek tools that pay unlimited dividends. A good tool can find useful applications that were not conceived of by the developer.

But tool developers must be application driven—at least to some extent.

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Driven by necessity and provided with enough time and resources, you might develop new systems and control tools—and this sometimes happens. But the ultimate goal of application-driven research is not tool development; in fact, application-driven research rarely allows that luxury, which may be viewed as a distraction.

While specialized tools have narrow usefulness, what we ultimately wish to develop are tools that have broad application. Just as a sharp

We need to understand a problem that requires innovative tools and use that insight to invent effective tools. Indeed, it's often necessary to solve real problems to develop new tools—that can solve real problems. And long after the specific application is no longer of interest, the tools we develop will find new applications. With or without drawers.

**Dennis S. Bernstein**

