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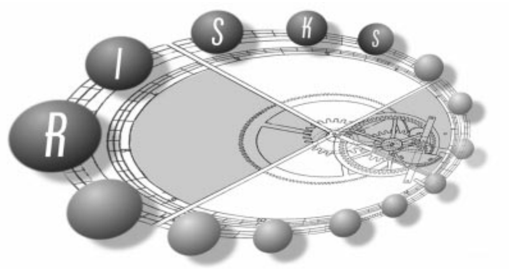

Fred B. Schneider

Toward Trustworthy Networked Information Systems

When today's networked information systems (NISs) perform badly or don't work at all, lives, liberty, and property can be put at risk (see "Inside Risks," Jan. 1998).

Interrupting service can threaten lives and property; destroying information or changing it improperly can disrupt the work of governments and corporations; disclosing secrets can embarrass people or harm organizations.

For us—as individuals or a nation—to become dependent on NISs, we want them to be *trustworthy*. That is, we want them to be designed and implemented so that not only do they work but also we have a basis to believe they will work, despite environmental disruption, human-user and operator errors, and attacks by hostile parties. Design and implementation errors must be avoided, eliminated, or the system must somehow compensate for them.

Today's NISs are not very trustworthy. A recent Computer Science and Telecommunications Board (CSTB) study (see www2.nas.edu/cstbweb/index.html) observed:

- Little is known about the primary causes of NIS outages today. Moreover, few people are likely to understand an entire NIS much less have an opportunity to study several, and consequently there is remarkably poor understanding of what engineering practices actually contribute to NIS trustworthiness.
- Available knowledge and technologies for improving trustworthiness are limited and not widely deployed. Creating a broader range of choices and more robust tools for building trustworthy NISs is essential.

The study offers a detailed research agenda with hopes of advancing the current discussions about critical infrastructure protection from matters of policy, procedure, and consequences of vulnerabilities towards questions about the science and technology needed for implementing more-trustworthy NISs.

Why is it so difficult to build a trustworthy NIS? First, the transformation of informal characterizations of system-level trustworthiness requirements into precise requirements that can be imposed on system components is beyond the current state of the art. Second, employing "separation of concerns" and using only trustworthy components are not sufficient for building a trustworthy NIS—interconnections and interactions of components play a significant role in NIS trustworthiness.

One might be tempted to employ "separation of concern" and hope to treat each of the aspects of trustworthiness (such as, security, reliability, ease of use) in isolation. But the aspects interact, and care must be taken to ensure that one is not satisfied at the expense of another. Replication of components, for example, can enhance reliability but may complicate the operation of the system (ease of use) and may increase exposure to attack (security) due to the larger number of sites and the vulnerabilities implicit in the protocols to coordinate them. Thus, research aimed at enhancing specific individual aspects of trustworthiness courts irrelevance. And research that is bound by existing subfield demarcations can actually contribute more to the trustworthiness problem than to its solution.

Economics dictates the use of commercial off the shelf (COTS) components wherever possible in building an NIS, which means that system developers have neither control nor detailed information about many of their system's components. Economics also increasingly dictates the use of system components whose functionality can be changed remotely while the system is running. These trends create needs for new science and technology. For example, the substantial COTS makeup of an NIS, the use of extensible components, the expectation of growth by accretion, and the likely absence of centralized control, trust, or authority, demand a new look at security: risk mitigation rather than risk avoidance, add-on technologies and defense in depth, and relocation of vulnerabilities rather than their elimination.

Today's systems could surely be improved by using what is already known. But, according to the CSTB study, doing only that will not be enough. We lack the necessary science and technology base for building NISs that are sufficiently trustworthy for controlling critical infrastructures.

Therefore, the message of the study is a research agenda and technical justifications for studying those topics. C

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