EDITORIAL

Augustine's Law Revisited

***David O. Smallwood**, Consultant*

In 1983, the American Institute of Aeronautics and Astronautics published the first edition of *Augustine's Laws* by Norman R. Augustine, then president and chief operating officer of Martin Marietta Corporation. The book is a humorous, but insightful look at the problems of managing a large corporation. The book is written from the viewpoint of managing a large aerospace corporation with large government contracts but has larger implications. Parts of the book deal in topics of direct interest to the design and testing community. These parts are the subject of this editorial, which borrows liberally from the book. I encourage you to find a copy of this book and explore the implications in today's world. The data presented are dated but still relevant. In the book, Augustine states 52 laws, one for each week of the year.

I will start with the cost of performance. Lord Kelvin once observed, "Large increases in cost with questionable increases in performance can be tolerated only for race horses and fancy women." It seems that we have forgotten this advice when purchasing military hardware, new cars, and the latest electronic toys. In the days of advancing technology, it always seems to be that by waiting a little longer we can design, produce, or buy a product that is a little bit better. So the way to get nothing is to insist on waiting for everything. The high cost of performance is illustrated by Law Number XV.

Law Number XV. *The last 10% of performance generates one-third of the cost and two-thirds of the problems.*

Managers are well aware of a similar law. Twenty percent of your employees will cause 80% of your problems.The cost of new systems follows a very predictable pattern. The per-unit cost of tactical aircraft is plotted as a function of time in Figure 1. The cost has increased by a factor of four every decade. There is no ceiling in sight. Figures 21 and 22 in the book show a similar trend for commercial aircraft and bomber aircraft. This leads to Law Number XVI.

Law Number XVI. *In the year 2054, the entire defense budget will purchase just one aircraft. The aircraft will have to be shared by the Air Force and Navy, 3.5 days each per week except for leap year, when it will be made available to the Marines for the extra day.*

We are all aware of the intrusion of electronics in every product, from toys, to automobiles and military systems. This leads to Law Number XIV.

Law Number XIV. *After the year 2015, there will be no airplane crashes. There will be no takeoffs either, because electronics will occupy 100% of every airplane's weight.*

It seems we have avoided this law, at least for a few years, because of the miniaturization of electronic hardware. However, this leads to Law Number XVII.

Law Number XVII. *Software is like entropy. It is difficult to grasp, weighs nothing, and obeys the second law of thermodynamics; i.e. it always increases.*

With this increase in software comes the cost of performance, ease of use, understanding, and lack of bug-free software. Early in my career, I actually understood what computers were doing. I defy anyone to say the same thing today. You can understand one or two layers of software but never understand all the many multiple layers of software. Next, a law close to the design and testing community.

Law Number XLII. *Simple systems are not feasible, because they require infinite testing. Or very complex systems apparently require very little testing.*

One might want to examine the amount of testing required as a function of the complexity of the system. You might expect that the amount of required testing will increase as the system becomes more complex. Apparently this is not the case. Let's assume that complexity is directly related to per-unit cost. Figure 2 plots the

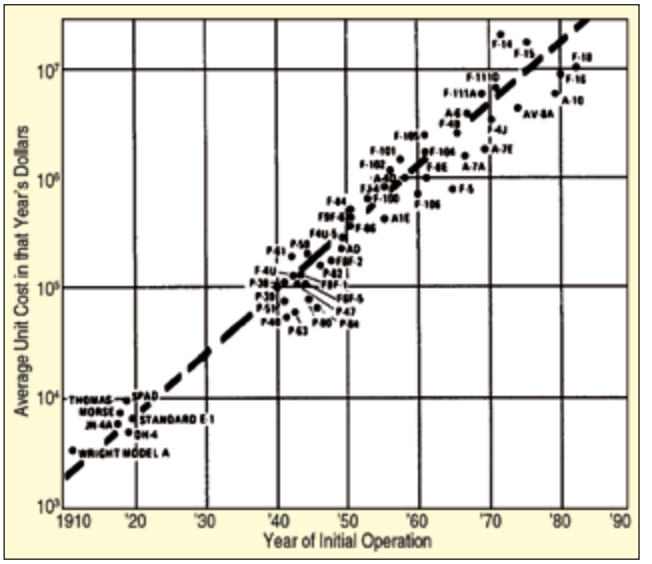

Figure 1. Unit cost of tactical aircraft has increased in a very consistent manner since aviation began. Rate of climb is a factor of four every 10 years, and no ceiling is in sight.

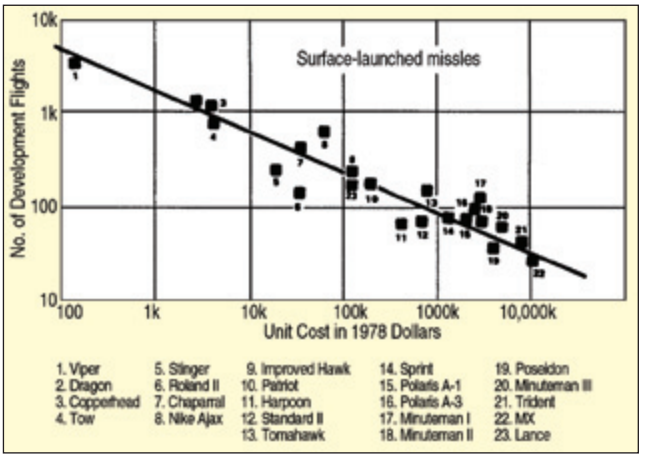

Figure 2. Very simple products often require literally thousands of test articles; very complex items apparently require very little system test hardware..

number of development flights for surface-launched missiles as a function of unit cost. The amount of required testing seems to be inversely correlated with the complexity (unit cost). The more complex the system, the fewer development flights required. Apparently relatively simple unguided artillery rounds demand literally thousands of test rounds, while a new intercontinental ballistic missile needs only a few handfuls of tests.

As I recall, the trend continues. One of the most complex systems ever built, the space shuttle, required less than five development flights.

We find ourselves more reliant on models to validate performance instead of tests. And the more complex the system, the less the model can predict actual performance. As the old saying goes, "all models are wrong, some are useful," and "when testing is performed, the model is exact, but we usually are unaware of the exact test we have run." It is very difficult to explore the complete range of all the variables in a complex system. Does it come as a great surprise that more problems are discovered as the system goes into service?

Another annoying property is exhibited by hardware even after

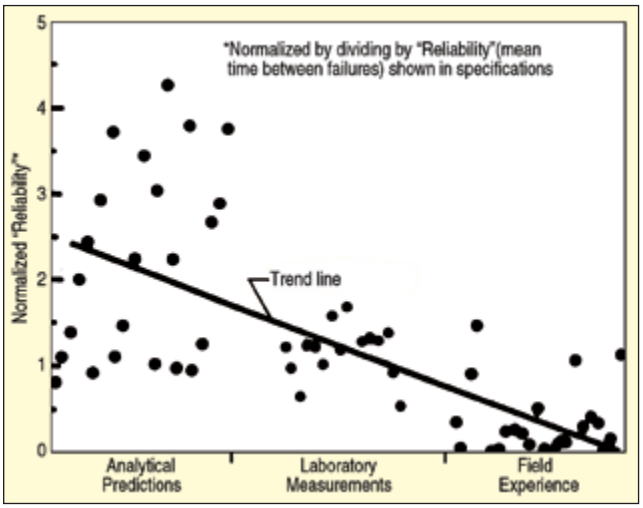

Figure 3. Initial analytical estimates of a system's reliability, as measured by its mean time between failures, have traditionally been several times more favorable than the value specified by the customer. Actual customer experience, on the other hand, has correspondingly been several times less favorable. [Basic data sources: (1) G. Kern, "Operational Influences on Avionics Reliabiity;" (2) Defense Management Journal, "7 Mid 70s systems;" (3) author's data collection.]

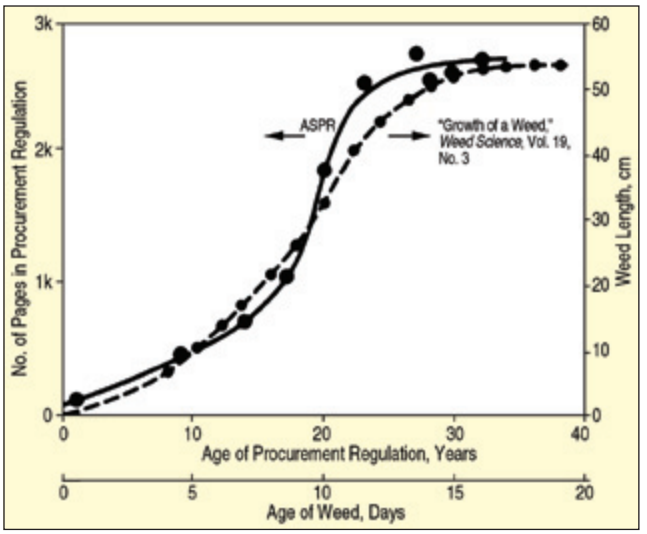

Figure 4. Volume of regulations imposed on participants in engineering and production activities has grown rapidly with time, paralleling behavior of certain natural phenomena. Imposing regulations can sometimes be quite subtle, for example, flowing down references to subordinate regulations. In one such case, a court held a contractor liable for failure to comply with a regulation at the fifth level of an indentured tree of specifications cite only in references. Data shown here apply to the armed services procurement regulations but generally parallel most corporate purchasing manuals as well.

the cost has been established and after the design has been finalized. The hardware seems to malfunction when the malfunction is most harmful, failing at the most inopportune times. As we say in testing, "the probability of a test failure in inversely related to the number of people watching, and inversely related to the square of the importance of the viewers." The trend is illustrated in Figure 3. The reliability of the system tends to decrease as development, testing, and field experience progresses. This leads to law number XLIII.

Law Number XLIII. *Hardware works best when it matters the least.*

For some reason, when dealing with multiple-million-dollar hardware, the part that fails is something like a 70-cent bolt or a seven-cent solder joint. This leads to the next law.

Law Number XLIV. *Aircraft flight in the 21st century will always be in a westerly direction, preferably supersonic, crossing time zones to provide the additional hours needed each day to fix the broken electronics.*

We seem to believe that all procurement problems can be solved with regulations. The problem with regulations is that if a person, manager, or organization can ignore an old regulation, they can ignore the new one also. Despite the profusion of rules, skillful people find a way around or a loophole, which requires new rules. Of course, the old rules are never discarded. This continues until the whole system collapses under its own weight, and a new set of regulations is written. In 1971, the number of umbrella defense procurement policy documents was 15 but by 1980 had grown to 114. In recent years, the number has decreased, but each individual paragraph has become more ominous. Apparently not only nature abhors a vacuum. Figure 4 suggests that the volume of regulations grows quite rapidly with time, somewhat like the growth of a weed.

Law Number XLIX. *Regulations grow at the same rate as weeds.*

If the federal government's regulatory operation were a business, it would be one of the 50 biggest in the country in terms of revenues, and the third largest in terms of employees, with more people working for it than McDonald's, Ford, Disney and Boeing combined.

This short editorial is just a sampling of the insight of Norm Augustine. We will never correct all these problems; they are systemic to large organizations and projects. Readers are encouraged to seek solutions in their area of work to at least mitigate the negative impact of these insights.

Norman R. Augustine, *Augustine's Laws*, Penguin Books, 1987, New York, NY. Numerous other editions have been published. SV

The author can be reached at: dosmallwood@q.com.