cost mainframes that compete with the low-end IBM mainframe market. Although Amdahl retired from CDS in 1998, he remains part-owner of the company and notably helped it promote its machines as millennium bug-fixing tools.

Throughout his career, Amdahl has remained an enthusiastic supporter of the mainframe model of computing, arguing that distributed computing (using networked personal computers) has displaced only a fraction of the mainframe market. Maintaining that the mainframe is a better platform for many applications, he commented to *Computerworld* in 1997: "People often have no idea what was done before on the mainframe and oftentimes they are decades behind technology already put on the mainframe."

BIOGRAPHY

Gene Myron Amdahl. Born 16 November 1922 in Flandreau, South Dakota. Served in the U.S. Navy during World War II. B.S. in engineering physics from South Dakota State University, 1948. Ph.D. in theoretical physics from University of Wisconsin, 1952. Joined IBM and designed mainframes, 1952–56. Worked for Ramo Wooldridge and Aeronutronic, 1956–60. Resumed IBM career, worked as principal architect of System/360, 1960–70. Left IBM to start Amdahl Corporation, 1970; resigned as chairman, 1979; and left entirely, 1980. Founder of Trilogy Systems Corporation, 1980; Andor International, 1987; and Commercial Data Servers, 1996. Recipient of numerous honors, including Information Processing Hall of Fame, 1985; ACM/IEEE Eckert-Mauchly Award for outstanding innovations in computer architecture, 1987; and four honorary doctorates.

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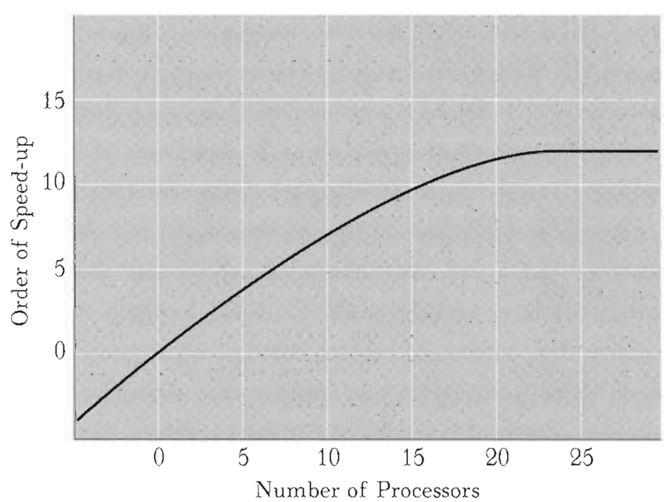
—*Chris Woodford*

Amdahl's Law

Amdahl's law can be stated as: Overall system speed is governed by the slowest component. There are two main variations of the law; the first refers to the total speedup obtained when the number of processors of a **multiprocessor** is increased systematically. The second refers to the speedup achieved when some part of a computer is enhanced while leaving the rest unchanged.

Gene Amdahl (1922–) was an engineer at **IBM** in the 1960s; he served as the main architect of the IBM System/360 series, and later he became one of the first builders of IBM **clones**. Amdahl noticed that a multiprocessor machine duplicating the number of processors does not lead automatically to a machine that runs twice as fast (i.e., one that cuts execution time by half). He observed diminishing returns every time that extra processors were added. The first processors cut execution time significantly, but after a certain threshold was reached, additional extra processors did not make the machine much faster. This meant that not all parts of conventional real-world programs can be parallelized



Amdahl's law of parallel processing.

and distributed among several processors. There is always a certain sequential component that cannot be eliminated and represents the effective bottleneck of the entire computation. The accompanying figure shows the speedup increase (i.e., by what factor the programs run faster) when processors are added. The slope of the curve decreases at some point and the increase in speedup flattens out. This is Amdahl's law of **parallel processing**.

The second variation of Amdahl's law has been popularized by David Patterson and John Hennessy. They argue that adding an enhancement to a processor that makes some part of the machine run twice as fast does not lead automatically to programs running in half the time. Consider, for example, the case of accelerating the multiplication operation by a factor of 5. The processor won't be five times faster when processing normal programs, since multiplication is only a small fraction of the total operations being executed. If multiplication is used 5 percent of the time in a program, and if the running time of the program was 100 seconds, the enhanced multiplication unit will cut the running time of all multiplications in the program from 5 seconds to 1 second. The rest of the program continues running in 95 seconds, so the total running time is 96 seconds—almost the same as before, despite the fact that the new multiplication unit could be very expensive.

Amdahl's law can even be illustrated with examples from daily life, like the ones used by Patterson and Hennessy. Assume that you had to cross a desert, where you can walk half the distance and drive the other half. If it takes 20 hours to walk, you could possibly drive the other half of the way in 1 hour. That makes 21 hours of total travel time. Using a faster car that cuts the driving time to half an hour does not radically improve the total time: It goes from 21 hours to 20.5 hours. Even if a rocket were used and the "driving" time dropped to zero, the total travel time flattens out and cannot be reduced to less than 20 hours. This is Amdahl's law: The total improvement or speedup is limited by the fraction of the task that can be covered with the improved design (i.e., the rocket). Computer engineers must therefore evaluate the total benefit of an enhancement to a computer before doing the actual investment. It could be that the enhancement is barely used, and in that case, the price/performance ratio of the entire machine could deteriorate instead of improving.

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—*Raúl Rojas*

American National Standards Institute

The American National Standards Institute (ANSI) is a nonprofit, nongovernmental organization in the United States that approves American National Standards (ANSs) and accreditates their developers. ANSI does not develop standards itself; its chief function is that of a bridge between industry, government, and international standardization organizations, striving to foster voluntary adherence to the standards.

Originally formed by three federal agencies and five engineering societies in 1918, ANSI has over 1300 members today, including both national and international firms, academia, labor representatives, trade associations, consumer organizations, and governmental agencies. Accredited developers can submit possible standards to ANSI for approval. In 2000 there were approximately 175 accredited entities and over 14,000 approved ANS guidelines. Although a purely private organization, the U.S. government has come to rely on use of the voluntary ANSs: Many standards approved by ANSI have been adopted by the government.

ANSI acts not only as a neutral forum in which its members from the public and private sectors cooperate and collaborate, it also serves as a sentinel—assessing the conformity of manufacturers to the requirements of a particular standard. Although standards are voluntary, it is useful to check the adherence of accredited manufacturers to the pledged standard. This, in turn, assures that U.S. products are competitive in foreign markets. ANSI also plays an important role in the computer industry, as hardware and even software can receive the ANSI seal. Software developers can write