The SAGE computers processed information in real time, presenting the result to operators on circular screens. The user could ask for more details about a specific object by touching the screen with a light gun and could also enter commands in the same way. Each computer was enormous, needing a full megawatt of power to drive its 55,000 vacuum tubes, making SAGE the largest vacuum-tube system ever built. SAGE was operational until 1983.

The SAGE system was designed to be triggered by an alarm from early warning radar installed at the U.S. borders, in Canada, or even on top of offshore oil platforms (the shortest route for Soviet missiles was over the North Pole). The warning was sent through telephone lines to a direction center, which notified interceptors and headquarters. SAGE then tracked the bomber or missile and calculated the interception parameters, which were sent to ground-to-air missiles and other interceptors.

Although the work done for SAGE was classified, much of the technology eventually became available and was used in civilian air traffic control systems. **Joseph Licklider** (1915–90), who worked on the development of SAGE, later became the director of IPTO (Information Processing Techniques Office) at **ARPA**, and started research that culminated in creation of the **ARPANET**.

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—*Frank Darius*

SAP

SAP is one of the largest **software** companies in the world, and one of the few European global players in the software industry. The name is an acronym for *Systeme, Anwendungen, Produkte in der Datenverarbeitung,* or in English, *Systems, Applications, and Products.* SAP was founded in Germany in 1972 by five former **IBM** employees who later became multimillionaires. The original name of the company was *Systemanalyse und Programmentwicklung* (*System Analysis and Program Development*).

In the 1970s, most business data processing was done off-line, using punched cards to hold the data, processing the programs overnight in special computer centers. The founders of SAP, who did consulting for IBM clients, noticed that many companies were developing the same types of programs for their business needs and immediately saw a business opportunity. Their idea was to provide those companies with a generic solution, which could be customized and would allow interactive online data processing using time-shared computers.

During the last 25 years, SAP has marketed two main products, R/2 and R/3. Both systems are packets of program modules that provide all the functionality required for business computing. R/3 provides a user interface that separates the user from the **operating system** (OS) so that it seems to be the OS from the user's perspective. R/2, introduced in 1979, was targeted for mainframes with a time-sharing operating system, whereas R/3, introduced in 1992, is based in the server–client model so effective in local area networks. The server is the main computer where the data are kept; the clients are the individual workstations or personal computers that allow retrieval or modification of the data.

SAP software became popular in the first half of the 1990s, and the company opened distribution offices in all major industrial countries in the world. At one point, SAP was the second- or third-largest software company in the world. However, the success of R/3, a closed proprietary system, led the company to ignore the **Internet** and the emerging **electronic commerce** business. While startups were introducing new products for networks, SAP was locked with its proprietary strategy. After having enjoyed 60 percent yearly growth rates, the company reached a sales plateau in the late 1990s and SAP shares fell in the stock market.

SAP countered by embracing the Internet and starting specific **portals** for the business community, such as "mySAP.com". Companies get information and support through the portal and can even make use of the *application hosting service*—companies provide the data, which is processed in external computers. The SAP software makes the process transparent for the user.

At the end of 1999, SAP had worldwide revenues of more than U.S.$5 billion. It employs more than 20,000 persons in 50 countries. The main competitor of SAP in the enterprise computing marketplace is **Oracle**, which has a more diversified product range.

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—*Raúl Rojas*

Satellite Networks

Satellite networks were first proposed by British science-fiction writer Arthur C. Clarke (1917–) while serving as a lieutenant in the Royal Air Force during World War II. In just 50 years, communications satellites have evolved from science fiction to a key component of global networks.

Clarke set out his ideas in a short article called "Extra-Terrestrial Relays," which appeared in the October 1945 issue of the magazine *Wireless World.* In four pages, Clarke outlined most of the principles of modern satellite communications, including the microwave radio frequencies that could be used, the rocket technology required to reach orbit, and the need for a parabolic reflecting dish to receive signals. He also calculated the power necessary to transmit signals through Earth's atmosphere, explaining that this could be acquired through solar energy.

Clarke's most useful insight was his discovery of what is now called the *geostationary orbit,* a precisely circular trajectory that exactly matches Earth's rotation. It had been known for more than 200 years that the orbital period of a satellite depends on its distance from Earth, and the period increases as it gets higher. For example, the Space Shuttle uses a relatively low orbit of no more than 400 kilometers (km), circling Earth in around 90 minutes; the moon is 1000 times more distant and takes nearly a month. Clarke calculated that at 35,784 km the orbital period would be exactly 24 hours. This means that if a satellite is placed at this altitude above Earth's axis of rotation—the equator—it will not move at all relative to the ground, appearing to hang in the sky. Users could simply point an antenna up toward a fixed spot without having to track orbits or worry about satellites disappearing over the horizon.

Although Clarke feared that many readers would find his ideas "too far-fetched to be taken very seriously," satellite development actually progressed even faster than he predicted. The relays envisaged by Clarke required continuous maintenance and so had to be mounted on space stations with a permanent human crew. This was rendered unnecessary by miniaturization, in particular the invention of the **transistor** in 1948.

One scientist who did take Clarke's ideas seriously was John R. Pierce (1910–), an electronics researcher at **Bell Labs**. He began more detailed research into satellite communications in 1954, but his work was largely ignored until the Soviet Union launched their *Sputnik* satellite in October 1957. As well as showing that a rocket could blast an object into low orbit, *Sputnik* also carried two battery-powered radio transmitters that bleeped for 21 days, proving that communication from space to Earth was possible.

The first satellite intended solely for communication was launched by the United States in December 1958. Known as the *Signal Communication by Orbital Relay Experiment* (SCORE), it grew out of a U.S. Navy project that had originally tried to bounce radio signals off the moon, using it as a natural communications satellite. SCORE managed to transmit prerecorded Christmas greetings from President Eisenhower for 21 days, but it could not be used for the type of immediate communication envisaged by Clarke and Pierce.

Two years later, Pierce saw an opportunity to test a real-time satellite system. The newly formed National Aeronautics and Space Administration (NASA) planned to launch an inflatable sphere 30 meters across, intended for atmospheric study. Pierce persuaded the agency to coat the balloon in reflective