place. New applications were explored as scientists realized that the SXRS could potentially be used in industry and medicine in addition to laboratory analysis. Commercialization of the SXRS began in 1965, primarily to university, Government, and corporate laboratories. Between 1970 and 1973, trace-element analysis improvements were made at Lawrence Berkeley Laboratory (LBL). Improvements were also made in the speed of analysis such that a complete analysis of a typical sample now took less than 1 minute.

Approximately 8300 commercially manufactured SXRS units are presently in use in the United States. Of these, 2500 units are stand-alone analysis systems that include the radiation source, detector, and processor. The users of these systems fall into three categories: (1) industry; (2) commercial laboratories; and (3) Government, academic, and medical laboratories. The remaining 5800 SXRS units are attached to scanning electron microscopes.

About 350 of the 2500 stand-alone SXRS systems are used in the scrap metal, steel and metal manufacturing, and durable manufacturing industries. All of these units are located in the production area and are used as part of the production process. Approximately 1000 SXRS systems are used in commercial laboratories where they are typically one of many elemental analysis instruments used away from the actual production process.

The remaining 1150 of the stand-alone systems are used both for research and analysis of trace elements in patient specimens in National, university, and hospital laboratories.

The SXRSs attached to scanning electron microscopes assist the microscope in plotting a "map" of a surface; the elemental composition of each small area is determined separately, and the peaks and valleys are identified. These instruments are widely used in both commercial and Government/university/medical laboratories. They are used frequently in quality control of ball bearings, airplane bodies, and machine parts, as well as in new materials research.

Eight factors are responsible for the large number of SXRS units in use and the wide variety of uses.

1. The SXRS analyzes all elements of a given sample simultaneously, thereby providing a complete elemental composition of the sample.
2. The SXRS's measurement accuracy is tenths of parts per million.
3. The SXRS provides information rapidly, typically in 10 to 30 seconds.
4. The SXRS is nondestructive.
5. The SXRS is flexible and can be programmed to analyze single elements in less than 5 seconds.
6. The SXRS can use portable detector attachments, and even the non-portable units require little floor space.
7. The SXRS system requires little additional maintenance.
8. The SXRS does not usually require skilled personnel.

Benefits The benefits of SXRS development are twofold: (1) reduction in the cost of analyzing materials compared with other elemental analysis techniques and (2) availability of information not otherwise obtainable.

The cost savings accumulated through 1982 by industrial and commercial users provide some indication of the benefits of SXRS development. SXRS users were contacted and asked to estimate the 1982 cost savings that could be attributed to the SXRS. Average annual savings for five user groups—scrap, steel/metals, manufacturing, commercial (nonresearch), and commercial (R&D)—were estimated to total $88 million/year in 1982.

High-resolution Gamma-ray Spectrometry Gamma-ray spectrometry is a method of detecting, characterizing, and monitoring gamma radiation. The development of lithium-drifted germanium [Ge(Li)] and high-purity germanium [Ge(HP)] solid-state semiconductor detectors and improvements in the associated electronics have revolutionized the field of gamma-ray spectrometry, particularly with respect to energy applications.

As a result of their much higher resolution (the ability to distinguish between gamma rays of different energies), germanium spectrometers have replaced other types of gamma-ray spectrometers in many uses. They are now commonly used in nuclear power plants, industry, and research institutions for identifying the elements in reactor cooling waters that cause radioactivity, logging oil wells, studying distant planets, and analyzing biological and laboratory samples.

History Until about 1970 the device most frequently used for gamma-ray spectrometry was the scintillation spectrometer. The most widely developed scintillator is a sodium iodide crystal that emits light when penetrated by gamma rays. The light is collected and converted to an electrical signal by a photomultiplier tube. The scintillation spectrometer is an efficient detector of gamma rays. However, the resolution of the scintillator is not fine enough to distinguish between isotopes emitting gamma rays of very similar energies. The need for a spectrometer with higher resolution in physical and biological basic research was the primary impetus for germanium spectrometer development.

The first germanium gamma-ray detector was developed in 1962 as a result of Federal (non-OHER), private, and foreign-sponsored research. The original instrument was inferior to the scintillator in both resolution and efficiency. Improved resolution was achieved in 1963 through OHER-sponsored research at LBL, BNL, and ORNL.

By 1971 the results of OHER research were twofold. First, the process of drifting the germanium crystal with lithium was improved, which considerably enhanced the resolution of the detector. Second, the associated signal processing