INSIDE MAYO CLINIC RESEARCH

Born in a Mayo lab: GPS, CT scans and more

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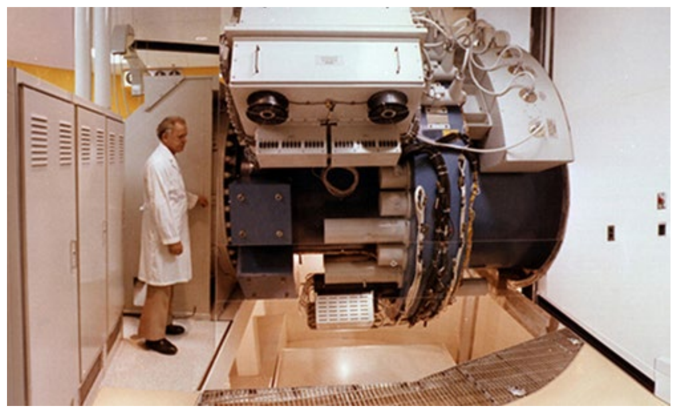


Side view of the Dynamic Spatial Reconstructor, an early contribution to the X-ray CT revolution.

Barry Gilbert, Ph.D., and the team of engineers he has led for the past 59 years have advanced technology and changed the face of healthcare. This second installment of a two-part series highlights the incredible work of a widely unknown department at Mayo Clinic: the Special Purpose Processor Development Group.

Tucked away off campus, on the other side of a secure entrance, is a row of offices — nothing out of the ordinary. But behind this scene are colleagues who have worked for more than 50 years to change the world of medical science in meaningful ways.

They work in a cutting-edge electronics research laboratory with design, assembly and test capabilities in several advanced technology areas. The Special Purpose Processor Development Group (SPPDG) in the Department of Physiology and Biomedical Engineering was created in 1971 by Barry Gilbert, Ph.D., with a mission to identify and exploit opportunities to translate technology into Mayo Clinic's research and clinical operations.

Since its inception, the now 45-member SPPDG staff, in partnership with more than 40 Mayo researchers and clinicians, has worked on several dozen projects in support of Mayo's missions, has published over 350 papers, and holds 35 patents.

From the outside in

While one usually thinks of biomedical research as taking place in labs studying cells and tissue, Dr. Gilbert and his team are engineers, IT specialists and technicians dedicated to developing next-generation electronics and computer technology. They concentrate on designing and building one-of-a-kind computers and software intended for specialized (i.e., not general purpose) applications, such as the analysis of extremely large clinical data sets, the wireless transmission of patient data from body-worn physiological monitors, and the miniaturization and ruggedization of some of these systems.

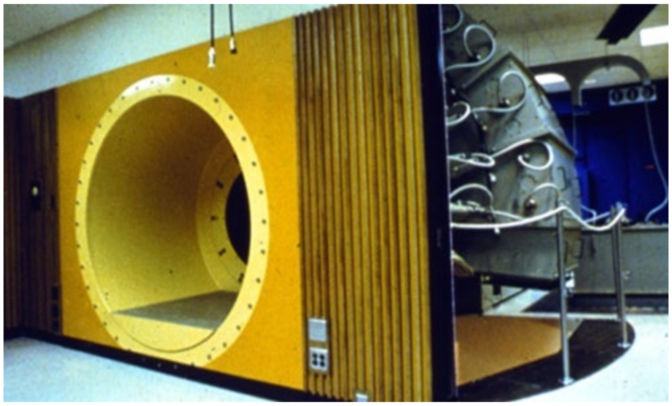
These areas may appear to be beyond understanding, but most people use these technologies every day in the form of GPS-based map displays and health wearables. In Mayo's field of healthcare, the developments of Dr. Gilbert and his team have enabled tools such as high-resolution X-ray CT and the ability to monitor patients remotely.

Some of the most notable projects from SPPDG over the decades have revolutionized the way physicians peer into a patient's body, helped to find and rescue downed military pilots, improved satellite communications, and even supported climbers atop Mount Everest. A few of these projects are described here.

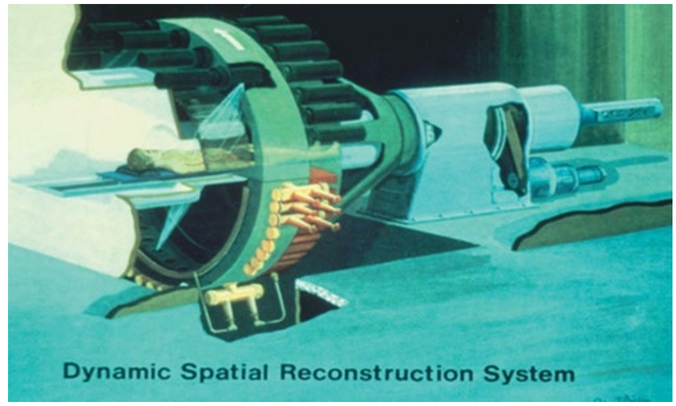
1970: Dynamic Spatial Reconstructor

From 1970 to 1979, SPPDG worked on developing the Dynamic Spatial Reconstructor (DSR) under the directorship of Dr. Earl Wood. This was an early contribution to the X-ray CT revolution.

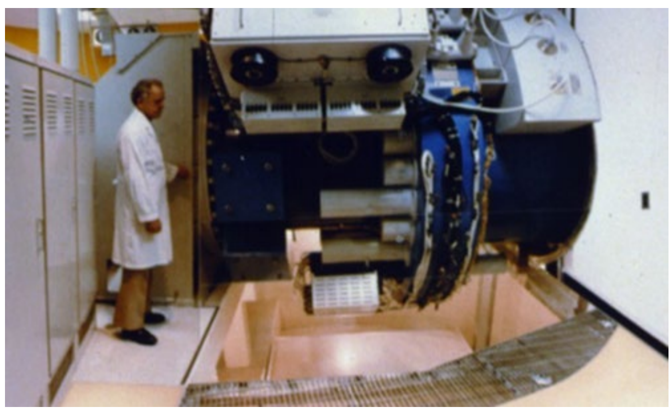
The basic concept of the DSR was a gantry, or frame, that held the X-ray tubes, image intensifiers and X-ray detectors, and rotated around the patient. The machine was fabricated by Bath Iron Works in Maine and shipped by rail to the Rochester campus. At that time, Bath Iron Works was the only company with a large enough milling machine to create the gantry structure. The lineage of all modern rotating-gantry X-ray CT machines can be traced to the DSR, a project funded by the National Institutes of Health and Mayo Clinic, costing more than $75 million in 2023 dollars. (Read more about Dr. Wood: “New book highlights a prominent Mayo researcher.”)



The patient “portal” part of the DSR design, before the patient table was installed.



An illustrated design concept of the DSR.



A side view of the DSR, with a member of the DSR team to illustrate the machine’s scale

1989: Mayo One helicopter GPS and ‘downed pilot’s radio’

Beginning in 1989 with funding from the Defense Advanced Research Projects Agency (DARPA), SPPDG began working with Motorola to create the world’s smallest GPS receiver. The team in 1993 incorporated those tiny receivers into the Air Force’s “downed pilot’s radio” to aid in the recovery of combat pilots shot down over hostile territory. More than 30,000 of these “GPS-enhanced downed pilot’s radios” were distributed to military flight crews for more than a decade.

In parallel with the development of the miniature receiver, the group created a GPS-guided moving map display, which was first installed in the Mayo One helicopter in 1989, in a collaboration with David Claypool, M.D., and Scott Zietlow, M.D., of the Saint Marys Emergency Department. The GPS system in Mayo One allowed the helicopter to fly directly to accident scenes using communications and navigation pathways established between GPS satellites, Mayo One, Saint Marys Hospital and handheld GPS receivers used by county law enforcement officers at the accident scenes. This system demonstrated savings of about 20 minutes from the “golden hour,” or the time immediately after an injury when lifesaving medical intervention can offer the highest chance of survival for a trauma patient. This project was funded by DARPA, with additional funding from the Office of National Drug Control Policy and NASA.

It wasn't until 1997 — when the demonstration project had been completed — that the GPS-enabled moving map display system was implemented by the Garmin Corporation as a commercially available product.

An image of the Mayo One helicopter in flight, illustrating communications and navigation pathways established between GPS satellites, Mayo One, Saint Marys Hospital and officers at an accident scene.

The GPS-enabled moving map display located in Mayo One's cockpit to show the helicopter's location on the displayed maps.

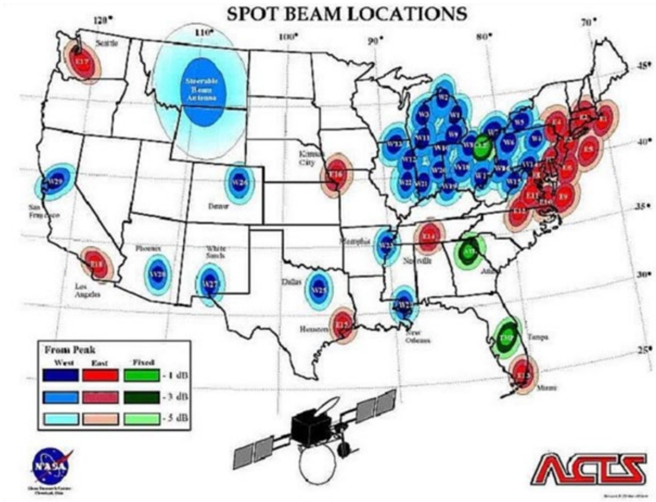
The Motorola Traxar handheld, six-channel GPS receiver distributed to law enforcement officers in initial work on the Mayo One helicopter project.

1993: Advanced communications technology satellite demonstration

In the early 1990s, SPPDG was approached by the Air Force to be the biomedical project lead organization on a new "intelligent" satellite with improved communications capabilities. At that time, all communication satellites were "dumb," only providing general communications from Earth to satellites, and from those satellites to the entire U.S. (i.e., not location-specific), with no on-satellite data processing.

The Advanced Communications Technology Satellite (ACTS) spacecraft launched by NASA and employed in Mayo projects.

With the Air Force's and NASA's creation of the Advanced Communications Technology Satellite (ACTS), individual message streams could be received by the satellite separately, decoded and processed separately, and retransmitted selectively to ground stations at specific locations called spot beam locations. (See the figure below.) SPPDG and Mayo physicians Bijoy Khanderia, M.D.; Joseph Duffy, M.D.; Bruce Kottke, M.D.; and Michael Wood, M.D., conducted three demonstration projects: two voice and video clinical consultations to the Pine Ridge Indian Reservation in South Dakota, and one to an oil platform in the Gulf of Mexico. These demonstrations were revolutionary for their time and demonstrated the huge benefits of selective satellite transmission capability. All modern commercial communications satellites now work on this principle of selective bidirectional communications.



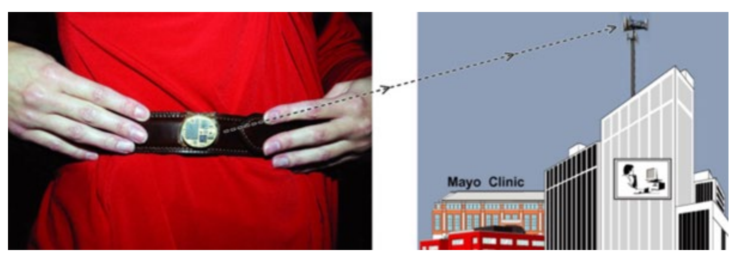
A graphic depicting the spot beam locations from the ACTS satellite

2001: Autonomous body-worn physiological monitoring units

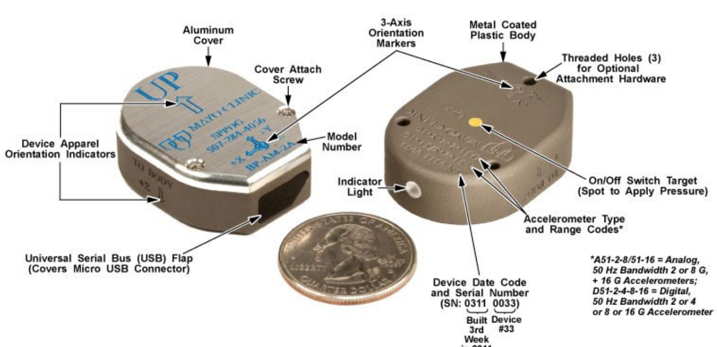
The early development of autonomous body-worn physiological monitoring units in 2001–2012 allowed patient data to be recorded and transmitted to a distant location. The ultimate goal of these monitoring systems was to allow patients to live freely while medical information and critical medical alerts were transmitted continuously to their providers.

As the research and development of the autonomous body-worn physiological monitors continued, more advanced units were developed and used in other projects. In 2011, a much smaller unit the size of a quarter was used in a gait and balance study conducted by Kenton Kaufman, Ph.D., of Mayo's Department of Orthopedics. In 2012, Mayo sponsored a climb of Mount Everest, where a more heavily instrumented, body-worn unit was used to monitor professional mountain climbers over the entire duration of their two-week journey, in a collaboration with Orhun Kantarci, M.D., and Ivana Croghan, Ph.D.


Mount Everest expedition climbers wearing the SPPDG's ECG and motion recording units in 2012.



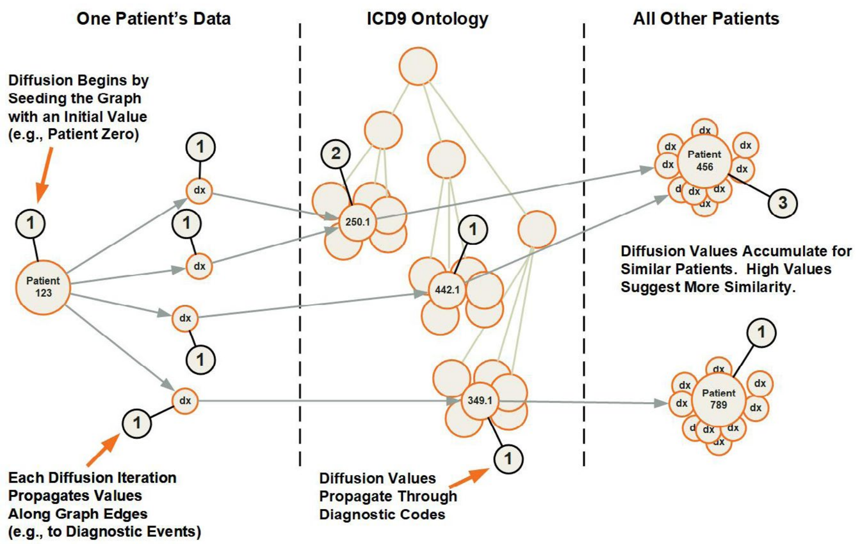
A patient wears an early version of the monitoring system that consisted of on-body sensors incorporated into a wearable device, which transmitted data to an antenna on the Mayo Building.



SPPDG's design of the biomedical platform activity monitor used in a 2011 study conducted by the Department of Orthopedics.

2012: The Rochester Epidemiology Project

The Rochester Epidemiology Project (REP) stores more than a million medical records across multiple Mayo providers, making it possible to conduct population-based descriptive, case-controlled, historical cohort studies of most diseases and medical conditions. Starting in 2012, in collaboration with Walter Rocca, M.D., and Jennifer St. Sauver, Ph.D., SPPDG prepared and employed specially written software in a demonstration project to explore very rapid, deep data mining for the REP. The algorithm created by SPPDG was installed on a Mayo-owned supercomputer and could perform one- to five-minute targeted searches across the entire patient population in the REP database (495,000 patients and 1.2 million records at that time).



A chart depicting the graph diffusion algorithm developed by SPPDG and applied to the Rochester Epidemiology Project database to identify a similar patient cohort.