1988's Hottest Superconductor Companies

Media hype aside, superconducting is serious business for a growing number of companies

By T. A. Heppenheimer

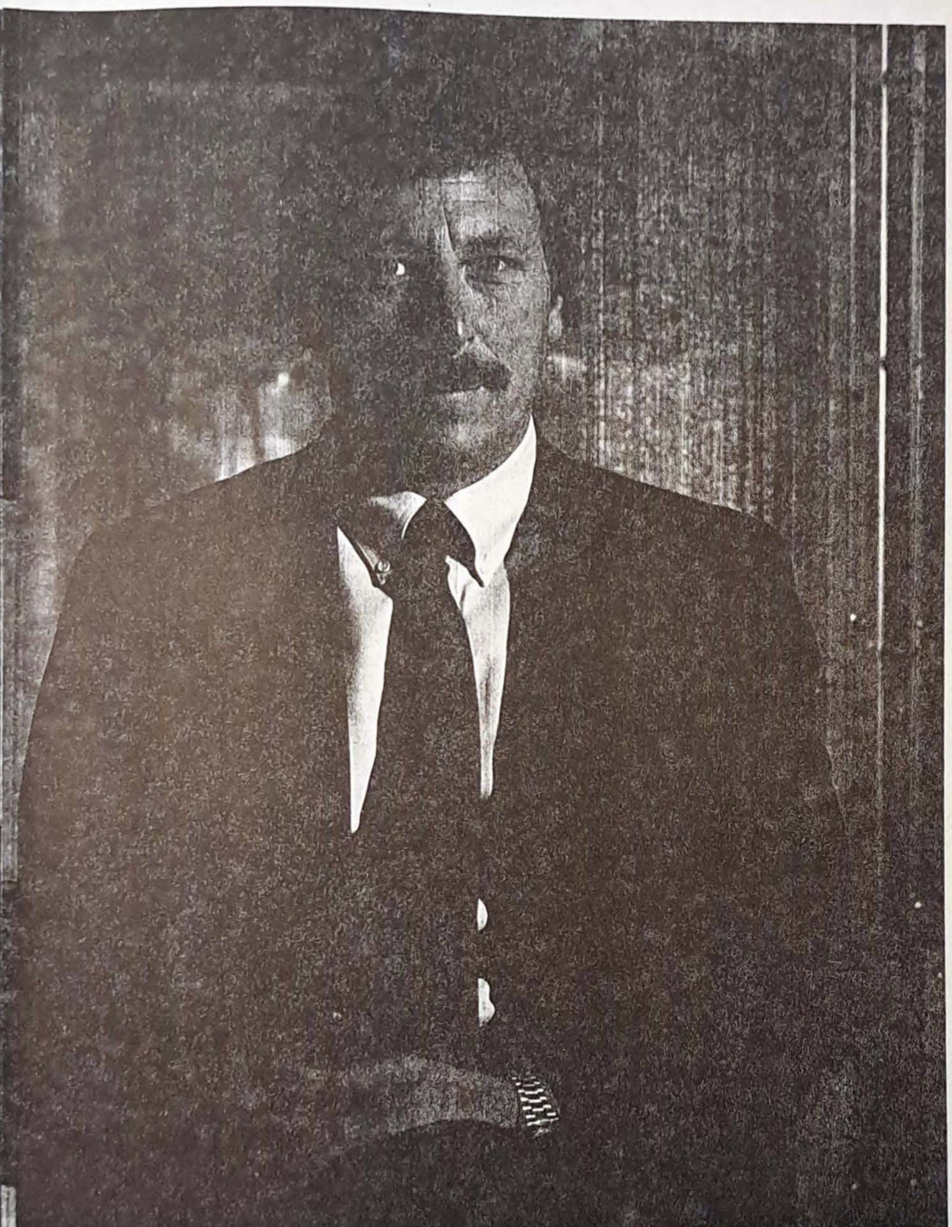
NO ONE CAN deny that superconductors were 1987's technology superstars. Dramatic laboratory breakthroughs thrust them into such prominent places as the covers of leading national magazines. But so much emphasis on breakthroughs in advanced research and the promise of a technological revolution obscures the fact that superconductors already support a growing industry.

But there is still room for expansion. Industry revenues were just $300 million in 1987, according to Strategic Analysis, a business and market-planning company. Strategic Analysis expects the 1988 superconductor market to remain at about the same level, and projects an increase to $3 billion by 2005, barring an unforeseen breakthrough in technology. That's an average growth rate of only about 10 percent, quite modest for a high-tech business.

Still, even the current market for superconductors represents sizeable potential for the 48 competitors involved worldwide. The entire commercial market is for the older niobium superconductors, largely used for making ultra-high-powered electromagnets, although electronic applications are growing. A promising potential market for niobium magnets is the proposed Superconducting Super Collider, a $4.4-billion Department of Energy project for conducting basic, large-scale physics research.

The markets for niobium superconductor products are dominated by established companies, especially General Electric and GA Technologies, leaders in producing magnetic-resonance imaging equipment used in medical diagnosis. Other companies are finding they can prosper by specializing in other areas. Hypres, for example, is carving out a dominant role in the nascent market for superconducting electronics. Biomagnetic Technologies has developed a promising new imager that can detect brain activity, and Quantum Design is marketing a superconducting device that monitors metal corrosion.

Meanwhile, there's been a recent spate of startups that hope to cash in by developing usable, high-temperature superconductors. However, this latest generation of superconductors uses ceramic materials, which are brittle and much harder to work with than metal. Most research is looking for ways to produce workable versions of these ceramics. However, experts—such as IBM senior researcher Paul M. Grant and Stanford University physicist Theodore H. Geballe—point out that the ceramics cannot yet carry enough current for practical use. Therefore, ceramic superconductors cannot significantly displace the niobium-based products now in use,



ROCKY THIES

Biomagnetic Technologies' Steven James opens a new field for established, niobium superconductors.

they contend. Hence the prospects for ceramic superconductors remain wildly speculative.

Nevertheless, money is being spent on ceramic research, and many entrepreneurs dismiss the above attitude as needlessly pessimistic. Venture capitalists have committed about $25 million to start ceramic-superconductor companies, and have poured an equal amount into niobium-superconductor companies. Other financing for superconductivity research comes from federal support, which totalled $29 million in 1987. The National Academy of Sciences recommends a boost to $100 million this year. In addition, companies such as IBM and AT&T Bell Labs are doing significant research.

Superconductivity work falls into 10 categories. In the niobium segment, five of the activities cater to commercial markets. These markets involve small custom magnets for research; large custom magnets for electric power and energy research; production magnets, especially for magnetic-resonance imaging; electronic products; and wires, rods, and cable, usually used to make magnets.

Another niobium activity is research and development to come up with products that offer improved superconductive properties.

All ceramic superconductor activities focus on research. Studies are underway on the principles and properties of superconductivity, the production of ceramic wires and tapes, the application of superconducting coatings, and future superconducting uses. With ceramic superconductor activity still centered in research, the technological revolution is probably a lot farther away than last year's media hype would lead you to believe; the new superconductors being developed in laboratories face formidable technical barriers.

Superconductors are materials that give no resistance to electric currents. As a result, all the power that goes in one end of a superconductor comes out the other. They produce particularly strong magnetic fields, and they bring new physical principles to electronics, yielding ultra-fast circuits and very sensitive instruments.

The problem is that today's superconductors, which are made from alloys of the metal niobium, only work when they're cooled to sub-Arctic temperatures using liquid helium. That requires expensive cooling equipment and makes the technology too costly for all but special uses, such as magnetic-resonance imaging machines, and a few electronic devices for defense and industry.

Researchers are creating superconductors that work at somewhat higher temperatures, although they still must be cooled with liquid nitrogen. Because they'll be cheaper to use, these new superconductors are raising hopes that they'll bring advances such as computers that operate with unheard-of efficiency, magnetically levitated trains, and cross-country electric power lines.

This adds up to an emerging, technology-driven industry that will no doubt be subject to surprising developments. But for the near term, the business of superconductivity will focus on the following 10 areas.

Niobium production magnets

1987 SIZE: $200 million

PLAYERS: GA Technologies, General Electric, Hitachi, Intermagnetics General, Oxford Instruments, Siemens, Toshiba

Niobium production magnets. Production superconducting magnets, built by the hundreds to standard designs, represent the backbone of the industry. Last year's sales reached about $200 million. About $150 million of that was spent on magnetic-resonance imaging, a technique that uses magnetic fields and radio waves instead of X rays to look inside the body. More than 300 such systems are sold annually, a solid commercial base. Carl Rosner, president of Intermagnetics General, expects medical magnet sales to rise to $350 million by 1990.

The lion's share of this growth should go to Siemens and General Electric, current market leaders for magnetic-resonance-imaging machines. About half the niobium magnets used in these machines come from Oxford Instruments. Other major suppliers are GA Technologies and Intermagnetics General.

These companies could also get a boost in the next two years from the Super Collider, which would require about 10,000 magnets that could yield an additional $300 million in revenues each year. However, the potential Super Collider market rests on the capricious will of Congress. So far the program has generated a lot of attention, largely because the facility is expected to bring a considerable boost to the regional economy in its location. But when the Department of Energy picks a site in July, lawmakers from the 49 other states will probably lose interest in the program, and the project could be ripe for a major cutback early in the next administration.

Niobium electronics. In electronics, where the market for superconductors stood at about $40 million last year, attention focuses on the Josephson junction. Named for Nobel-winning British physicist Brian Josephson, the junction is a speedy electronic switch—the fundamental unit of a computer—that operates a thousand times faster than a transistor and uses a thousand times less energy. From 1969 to 1983, IBM invested $300 million to develop a superconducting computer, but then abandoned the effort in favor of continued development of silicon. Now Hypres owns IBM's Josephson licenses and is pursuing other uses. The first company to offer a product based on Josephson circuitry, Hypres sells an oscilloscope that does laboratory testing and is five times faster and 50 times more sensitive than comparable devices.

Such innovation puts Hypres above other market-segment contenders—the company has garnered about half the $25 million in venture capital spent on niobium technology. But two new challengers, Biomagnetic Technologies and Quantum Design, have suddenly entered the running with innovative new applications for superconducting in electronics.

Biomagnetic Technologies has developed a novel method of medical imaging to detect the weak and evanescent magnetic fields produced by the brain's neurons. This method pinpoints brain cells that cause epilepsy and promises early diagnosis of such diseases as Alzheimer's and Parkinson's, according to the company. The Food & Drug Administration recently approved the instrument, called the Neuromagnetometer, for use in research hospitals; that has prompted Biomagnetics to abandon all other work and focus on neuromagnetism. The Neuromagnetometer costs $825,000 to $1.3 million.

Quantum is marketing the Magnetic Property Measurement System to universities and research labs, many of which use it in advanced superconductivity research. The product is already a runaway success; the company has about a 16-month order backlog. But perhaps more promising is a rust detector based on the system, being developed for a research program with MIT. The device senses the weak magnetic fields resulting from the chemical reaction that occurs in corroding metal, offering substantial benefits for companies such as petroleum producers, which rely on extensive networks of pipelines. A new subsidiary, Quantum Magnetics, is preparing laboratory and industrial versions. An introduction date has not yet been announced.

Both Biomagnetic's medical-imaging product and Quantum's rust monitor rely on the superconducting quantum interference device (SQUID), which consists of two Josephson junctions. This exquisitely sensitive detector can pick up magnetic fields a billion times weaker than the

Niobium electronics

1987 SIZE: $40 million

PLAYERS: ASEA-Brown Boveri, Biomagnetic Technologies, Cryogenic Consultants, Fujitsu, General Electric, General Electric (England), Hypres, Matsushita Electric Industrial, Mitsubishi Electric, NEC, Nippon Telegraph & Telephone, Quantum Design, Sumitomo, Toshiba, TRW, Westinghouse Electric

LOGOS BY JAVIER ROMERO

High Technology Business' Guide to Superconducting 1988

The following directory lists the 48 companies active in superconductor research and sales around the world. Alphabetical listings within categories—United States, European, Japanese, or startup companies—represent the full spectrum of superconductor activity, from small entrepreneurs to large corporations doing small-scale research to major players already profiting from this growing technology. The list includes all companies our researchers could find, no matter how significant or insignificant their current programs may appear.

THE U.S. COMPANIES

COMPANY	OFFICERS	FINANCING	STAFF (SUPERCONDUCTING)	SUPERCONDUCTOR ACTIVITY
1. American Magnetics Box 2509 Oak Ridge, TN 37831 (615) 482-1056	Kenneth Efferson, president Robert Jake, v.p., general manager E.T. Henson, v.p., marketing and sales	Privately owned; sales of $1 million to $5 million	20	Building custom niobium superconducting magnets and instruments for research use; pursuing the specialty-magnet market.
2. AT&T Bell Labs/Bell Communications Research (Bellcore) 600 Mountain Ave. Murray Hill, NJ 07974 (201) 582-3000	Robert Dynes, director, chemical physics research Donald Murphy, head of solid-state chemistry research Paul E. Fleury, director, physical research lab	AT&T subsidiaries; Bell Labs has an annual budget of $2.25 billion, 10 percent dedicated to basic research	40	In superconductivity research since 1950; developed niobium alloys, did early work on Josephson junctions. Made major contributions to the discovery of high-temperature ceramic superconductors. Currently pursuing basic research.
3. Bechtel National Box 3965 San Francisco, CA 94119 (415) 768-1234	Robert J. Loyd, project manager, Superconducting Magnetic Energy Storage (SMES)	Privately held; sales of $140 million. SMES contract worth more than $10 million	6 (more expected in early 1988)	Developing SMES as part of the Strategic Defense Initiative; may use experience to enter commercial utility market.
4. Biomagnetic Technologies 4174 Sorrento Valley Blvd. San Diego, CA 92121 (619) 453-6300	Stephan O. James, president, CEO William C. Black, senior v.p. Eugene Hirschkoff, v.p., operations	Privately held. Raised $5.2 million in first-round financing in 1985, $4.2 million in second round, 1987. Projected 1987 revenues, $3.7 million	85	Marketing SQUIDs and related equipment, including its Neuromagnetometer for observing brain functions. Seeking partnership with medical-equipment company to sell and support products.
5. E. I. Du Pont de Nemours 1007 Market St. Wilmington, DE 19898 (302) 774-1000	Edward Mead, manager, superconductor business development Rudolph Pariser, director, advanced materials research Arthur W. Sleight, research leader	Listed on New York Stock Exchange. 1986 earnings, $1.1 billion; sales, $29.4 billion	30	Attempting to apply its expertise in chemical processing to the large-scale production of superconductors. Wants to supply high-temperature superconductor markets as they emerge.
6. Energy Conversion Devices 1675 W. Maple Rd. Troy, MI 46084 (313) 260-1900	Stanford R. Ovshinsky, president, CEO Stephen J. Hudgens, v.p., R&D Rosa T. Young, sr. scientist, group leader	Traded on NASDAQ. Fiscal 1986 net loss of $27.9 million on revenue of $21.1 million; superconductivity work internally funded at $1 million	About 10	Studying ceramic and niobium-based superconductors. Developed a process for mixing fluoride with ceramic for higher-temperature superconductivity, but process not independently verified. Plans to license fluorination technology if a market develops.
7. Eriez Magnetics/Eriez Manufacturing Asbury Road at Airport Erie, PA 16514 (814) 833-9881	Chester F. Giermak, president Jerry Selvaggi, consultant/engineering manager	Privately held; $40 million in sales	10	Designed and installed the first superconducting magnet for industrial use, a separator that removes impurities from clay. Plans to compete with conventional separators that remove particles from wastewater.
8. Ford Motor Box 1899 Dearborn, MI 48121 (313) 322-3000	John McTague, v.p., research Marga Roberts, director, chemistry and physical sciences Craig L. Davis, manager, physics dept.	Traded on New York Stock Exchange. 1986 earnings of $3.3 billion on sales of $62.7 billion	5	Working with Detroit's Wayne State University on high-temperature superconductors. Looking for electronic applications that would be pursued by its Aeronutronic Division in Newport Beach, Calif.
9. GA Technologies/Applied Superconetics Box 85608 San Diego, CA 92138 (619) 452-3400	Tihiro Ohkawa, vice chairman Kenneth Partain, president, Applied Superconetics John Alcorn, manager, Superconducting Magnet Group	Privately owned; 1986 sales of $154 million	100	Designing and building specialized magnets. GA's subsidiary, Applied Superconetics, sells magnets for use in magnetic-resonance imaging. Strong candidate to supply magnets for the Super Collider.

THE U.S. COMPANIES (Continued)

COMPANY	OFFICERS	FINANCING	STAFF (SUPERCONDUCTING)	SUPERCONDUCTOR ACTIVITY
10. Garrett Box 92248 Los Angeles, CA 90009 (213) 776-1010	Anil Trivedi, assistant manager, advanced applications	Parent company, Allied-Signal, on New York Stock Exchange; Garrett had 1986 sales of $2.15 billion	10 to 20	Developing a fine-grained superconductor ceramic powder for electronics and industrial use.
11. General Dynamics Space Systems Division 5001 Kearny Villa Rd. San Diego, CA 92123 (619) 573-8000	David Walker, chief, R&D designs Robert Johnson, program manager, energy programs	Traded on New York Stock Exchange. 1986 revenues, $8.9 billion; loss of $63 million due to $420-million write-off of purchase price of Cessna Aircraft	60 at peak; now only a few preparing proposals	Built large magnets for Department of Energy research programs; may use expertise to supply magnets for the Super Collider.
12. General Electric Medical Systems Group Box 414 Milwaukee, WI 53201 (414) 544-3011	John Trani, sr. v.p., group executive Michael J. Jeffries, R&D manager, GE R&D Center	Traded on New York Stock Exchange. 1986 earnings of $2.5 billion on sales of $35.2 billion	20 at R&D Center; the Medical Systems Group employs several hundred	Supplying magnetic-resonance-imaging equipment. The R&D Center developed superconducting generators and is working on high-temperature ceramic superconductors.
13. General Motors Technical Center 30200 Mound Rd. Warren, MI 48090 (313) 575-1188	Donald J. Atwood, vice chairman Robert Frosch, v.p., GM Research Laboratories	Traded on New York Stock Exchange; 1986 earnings of $2.9 billion on earnings of $102.8 billion	5	GM Research Labs is developing ways to deposit thin films of ceramic superconductors on silicon wafers. Has demonstrated a metallo-organic deposition technique that lays down films without the use of vacuum.
14. Hypres 500 Executive Blvd. Elmsford, NY 10523 (914) 592-1190	Sadeg M. Faris, president, CEO Gerald M. Haines, v.p., CFO Eric Hanson, v.p., product development	Privately held; venture funding of $2.2 million in August 1983 and $6.4 million in December 1985	75	Produces a commercial Josephson-junction microchip that it uses in electronic instruments. Plans to introduce more such devices; seeks partner to develop and market a computer.
15. IBM Watson Research Center Box 218 Yorktown Heights, NY 10598 (914) 945-3000	Prauveen Chaudhari, v.p., physical-science research Alex Malozemoff, coordinator, superconductivity program	Traded on New York Stock Exchange. 1986 earnings of $4.8 billion on revenues of $51.2 billion; 1986 R&D and engineering budget, $5.2 billion	Not available	Studying high-temperature materials to achieve superconductivity at room temperature.
16. Intermagnetics General Charles Industrial Park Box 566 Guilderland, NY 12084 (518) 456-5456	Carl Rosner, chairman, president C. Richard Mullen, sr. v.p., operations Bruce A. Zeitlin, v.p., materials technology	Traded on NASDAQ. Lost $3.9 million on revenues of $14.3 million in 1987; 1986 profit of $1.6 million on revenues of $21.2 million	More than 300, including production workers	The leading U.S. maker of wire and cable, and magnets for commercial and research markets. Saw 1987 loss after its largest customer, Johnson & Johnson, discontinued product line. Positioned to be leading supplier of magnets for the Super Collider.
17. Microelectronics and Computer Technology 3500 W. Balcones Center Dr. Austin, TX 78759 (512) 343-0978	Grant A. Dove, chairman, CEO Barry Whalen, v.p. Harry Kroger, technical director, packaging and interconnects	Owned by consortium; $75-million operating budget	7	Coordinates research efforts of electronics companies that own it. Developing high-temperature superconductors for electronics packaging and interconnects. Seeking new participants.
18. Quantum Design 11578 Sorrento Valley Rd. San Diego, CA 92121 (619) 481-4400	William B. Lindgren, president, general manager Michael B. Simmonds, v.p.	Privately held; recently topped $1 million in annual sales	22	Making instruments that measure magnetic properties, using SQUIDs from Biomagnetics Technologies. A subsidiary, Quantum Magnetics, will market additional SQUID-based instruments, including a rust detector.
19. Supercon 830 Boston Turnpike Rd. Shrewsbury, MA 01545 (617) 842-0174	James Wang, president Eric Gregory, v.p., general manager	Privately held; annual sales of $1 million to $5 million	30	Manufacturing niobium-alloy wire and cable. Supplies research labs, GE, and GA Technologies. Maneuvering to supply the Super Collider.
20. Teledyne Wah Chang Albany Division Box 460 Albany, OR 97321 (503) 926-4211	Al Riesen, president Chet Leroy, v.p., technology	Traded on New York Stock Exchange. Earned $129 million on sales of $1.6 billion for the first half of 1987.	10 in R&D; many more in production	Leading supplier of niobium-alloy wire for magnets made by companies including Oxford, Intermagnetics, and Supercon. Plans to be major supplier of wire for magnets in the Super Collider.
21. TRW 1 Space Park Redondo Beach, CA 92077 (213) 535-4321	William Simmons, director, group research Arnold Silver, head, superconducting electronics	Traded on New York Stock Exchange. 1986 earnings of $217 million on sales of $6.4 billion	About 20	Researching Josephson-junction circuits for the Defense Department. Will develop products for military and aerospace markets.

COMPANY	OFFICERS	FINANCING	STAFF (SUPERCONDUCTING)	SUPERCONDUCTOR ACTIVITY
22. Westinghouse Electric Research and Development Center 1310 Beulah Rd. Pittsburgh, PA 15235 (412) 256-1352	John Hulm, director, research; Richard D. Blaugher, manager, cryogenic technology and electronics; Alex Braginski, manager, superconducting materials	Traded on New York Stock Exchange. 1986 earnings of $671 million on revenues of $10.7 billion	7	Researching high-temperature ceramic superconductors; developing Josephson-junction technology for the Air Force. Well positioned to be a major magnet supplier for the Super Collider. Superconducting generator technology may interest the Navy.

THE STARTUPS

COMPANY	OFFICERS	FINANCING	STAFF (SUPERCONDUCTING)	SUPERCONDUCTOR ACTIVITY
23. American Superconductor 21 Erie St. Cambridge, MA 02139 (617) 499-2600	George McKinney, president; Terry Loucks, v.p., technology; Francis Hughes, treasurer	Privately held; $4.35 million from American Research & Development, Rothschild Ventures, and Venrock	4	Holds a license on an MIT process for making ceramic wire and tape; plans to open pilot plant in 1988 to produce wires and ribbons, windings for magnets, and possibly thin wires for electronics. Significant profits not expected for 7 to 10 years.
24. AppliTech of Indiana 8150 Zionsville Rd. Indianapolis, IN 46200 (317) 872-6109	N. Quick, founder	Privately held; financial data unavailable	4	Developing a process for making very high-quality ceramic; testing a laser process for eliminating flaws. Pilot plant expected in two years.
25. Arch Development 1115-25 E. 56th St. Chicago, IL 60637 (312) 702-7417	Steven Lazarus, president, CEO; Brian R.T. Frost, director, Technology Transfer Center, Argonne National Laboratory; Janett Truhatch, associate v.p. for Research, University of Chicago	Nonprofit; funded by Argonne National Laboratory and University of Chicago	50 scientists and technicians at Argonne	Setting up a company to develop a way to make ceramic wire. Plans to license patents, form cooperative R&D partnerships, and create new companies.
26. Ceramics Process Systems 840 Memorial Dr. Cambridge, MA 02139 (617) 354-2020	H. Kent Bowen, chairman; Clayton M. Christensen, president, director; George A. Neil Jr., exec. v.p., operations	Common stock traded on NASDAQ. 1986 revenue, $2.6 million; net loss, $4.1 million	As many as 12	Developing metal-ceramic layered packages for integrated circuits. Wants to link marketing with other companies. Focusing on developing products that can be made using micro-smooth sheet forming, metal-ceramic laminates, and molding.
27. Conductor Technologies 1001 Connecticut Ave. N.W. Washington, DC 20036 (202) 452-0900	Stephen J. Lawrence, president; Laurence Storch, v.p.	Privately held; undisclosed amount from private sources	None full-time	Supports the work of MIT researchers who are developing electronic devices made from ceramic superconductors; seeking priority in licensing resulting patents.
28. Conductus 2275 E. Bayshore Rd. Palo Alto, CA 94303 (415) 494-7836	John Shoch, president, CEO; Tony Sun, CFO	$6 million in first-round financing	None full-time	Developing fabrication methods using thin-film techniques similar to those used to produce semiconductors. Exploring very high-speed digital devices, magnetic field detectors (SQUIDs) and other sensors, and high-speed electronic interconnections.
29. Electro-Kinetic Systems 701 Chestnut St. Tranier, PA 19013 (215) 497-4660	Jack Reilly, chairman, CEO; Burton Lederman, director, R&D	Listed on NASDAQ. Sales of $2 million, earnings of $65,000	2	Developing ceramic-based materials that can be applied as coatings and which superconduct at liquid-nitrogen temperature. Working with MIT.
30. Guernsey Coating Labs 4464 McGrath St., Unit 106 Ventura, CA 93003 (805) 642-1508	Peter Guernsey, president; Sam Pellicori, consulting physicist	Privately held; sales of $500,000 in optical coatings; seeking $500,000 in venture capital	1 part-time	An established optical-coating lab, diversifying into custom coating with ceramic superconductors.
31. Monolithic Superconductors Box 1654 Lake Oswego, OR 97035 (503) 684-2974	Lawrence E. Murr, owner, founder; Alan Hare, owner, founder	Privately held; financial data unavailable	6	Developing a way to produce bulk ceramic material by using shock waves to bond particles. Seeking venture capital and cooperative research to help commercialize the technique.

THE JAPANESE

COMPANY	SUPERCONDUCTOR ACTIVITY
32. Fujitsu Marunouchi Building 6-1 Marunouchi, 1-chome Chiyoda-ku, Tokyo 100, Japan (03) 216-3211	Researching high-temperature ceramics, with particular interest in thin films. Working on Josephson junctions to develop a superconducting computer.
33. Furukawa Electric 2-6-1, Marunouchi Chiyoda-ku, Tokyo 100, Japan (03) 286-3001	Major electrical cable maker; developing a ceramic-based, ring-shaped superconducting magnet.
34. Hitachi Central Research Laboratory Kokubunji, Tokyo 185, Japan 0423-23-1111 x 3217	Leading developer of niobium-based Josephson junctions. Also developing ceramic-based superconductors for electronics. Hitachi Cable division makes niobium-based wire.
35. Kawasaki Steel 2-2-3, Uchisaiwaicho Chiyoda-ku, Tokyo 100, Japan (03) 597-3111	Developing an experimental superconducting wire made of ceramic.
36. Matsushita Electric Industrial 1-1-2, Shibakoen Minato-ku, Tokyo 105, Japan (03) 437-1121	Working on ceramic thin films for silicon wafers, possibly leading to a process that uses superconductors in integrated circuits.
37. Mitsubishi Electric 2-2-3, Marunouchi Chiyoda-ku, Tokyo 100, Japan (03) 218-2111	Researching superconductivity since 1958; experimenting with ceramic-based, high-temperature materials. Makes superconducting tape.
38. NEC 5-33-1, Shiba Minato-ku, Tokyo 108, Japan (03) 454-1111	Researching Josephson-junction technology for computers and other electronic applications.
39. Nippon Steel 2-6-3, Otemachi Chiyoda-ku, Tokyo 100, Japan (03) 242-4111	Developing ceramic-based, superconducting wire.
40. Nippon Telegraph & Telephone 1-6-1, Uchisaiwaicho Chiyoda-ku, Tokyo 100, Japan (03) 509-5035	Pursuing Japan's largest development effort in Josephson-junction technology; also experimenting with techniques for producing ceramic crystals and films.
41. Sumitomo Electric Industries 3-12-1 Moto-Akafaka Minato-ku, Tokyo 107, Japan (03) 423-5111	Has more than 400 Japanese patent applications in ceramic superconductors. Affiliate Sumitomo Heavy Industries is building a superconducting synchotron, expected by 1989, to etch chips.
42. Toshiba 1-1-1, Shibaura Minato-ku, Kawasaki 105, Japan (03) 597-7111	Developing experimental ceramic wire and tape by bonding superconducting powders inside a metal capillary.

THE EUROPEANS

COMPANY	SUPERCONDUCTOR ACTIVITY
43. ASEA-Brown Boveri S-721 83 Vafteraf, Sweden 021-10 00 00	Researching high-temperature superconductors for use in high-powered magnets and generators.
44. Cryogenic Consultants Metrostore Building 231 The Vale London W3 7QS, England 01-743-6049	Designing and manufacturing superconductor and superconductor-cooling equipment, including magnets for research, mineral separators, SQUIDs, and related electronic devices.
45. General Electric 1 Stanhope Gate London W1A 1EH, England 01-493-8484	Makes magnetic-resonance-imaging equipment with magnets from Oxford Instruments. Researching high-temperature superconductors for use in large magnets, electrical machiners, and electronics.
46. Oxford Instruments Group Eynsham Oxford OX8 1TL, England (0865) 881-437	Has about 50 percent market share in magnets for magnetic-resonance imaging; also makes niobium-alloy wire and cable. Expected to become major supplier of wire and cable for magnets used in the Super Collider.
47. Plessey Vicarage Lane Ilford, Essex IG1 4AQ, England 01-478-3040	Developing ceramic superconductors; studying applications in electric-power cables, Josephson-junction circuits, SQUIDs, and thin films.
48. Siemens Wittelsbacherplatz 2, Muenchen Postfach 103, D-8000 1 Federal Republic of Germany (089) 234-10	A leading builder of superconductor magnet systems and magnetic-resonance imaging equipment. Developing test magnets for medical market.

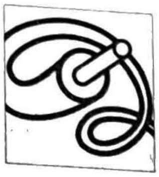
earth's. Almost all electronic uses for superconductors involve SQUIDs.

For instance, the Defense Department buys SQUIDs, primarily from TRW, Westinghouse, and General Electric. The Navy is studying SQUIDs as submarine detectors, and the devices are also being used in the Terahertz Initiative, an offshoot of the Strategic Defense Initiative that seeks to develop Josephson-based technology for radar and communications. However, this effort has a modest $4-million budget.

Niobium rods, wires, and cable. The $10-million annual supply line for rods, wires, and cable provides the basic electrical conductors used in superconducting magnets. Teledyne Wah Chang is the industry's chief producer of niobium-alloy rods. It sells them to wire-fabrication houses—mainly Intermagnetics General, Oxford Instruments, and Supercon—

which pull the rods to produce wire, which in turn may be wound into cable. New England Wire & Cable specializes in making cable only, from wire supplied by other companies.

Even though these companies have a relatively stable footing, technical innovation is still the key to market dominance. Competitive development centers on niobium-tin compounds, which show the best commercially available superconductivity properties, but which have been too brittle for practical use. Intermagnetics General has experimentally produced continuous, thin strands 90,000 feet long. Also, the company's "internal tin" multifilament conductor, which relies on particles of the compound rather than continuous strands, is fast becoming an industry standard.



Niobium rods, wires, and cable

1987 SIZE: $10 million

PLAYERS: ASEA-Brown Boveri, Furukawa Electric, Intermagnetics General, Mitsubishi Electric, Oxford Instruments Group, Supercon, Teledyne Wah Chang

Small niobium magnets for research. Last year, companies spent about $10 million on small, custom-made niobium magnets for experiments. This research seeks to find new uses for magnets and to improve existing uses.

Major suppliers to this market are Intermagnetics General and Oxford Instruments. But the field also includes GA Technologies, American Magnetics, and Cryogenic Consultants.

Promising new uses for this research include:

■ X-ray lithography, a largely experimental method for creating more finely detailed computer chips than can be made with established technology. Superconducting magnets steer intense X-ray beams that lay down microscopic circuit patterns. Oxford Instruments, in a three-year, $15-million effort for IBM, is building a prototype of such a device.

Small niobium magnets for research

1987 SIZE: $10 million

PLAYERS: American Magnetics, ASEA-Brown Boveri, Cryogenic Consultants, Eriez Magnetics, GA Technologies, Hitachi, Intermagnetics General, Oxford Instruments Group, Siemens, Sumitomo, Toshiba

■ Powerful industrial magnets made from superconductors. These magnets could be used to treat wastewater or remove impurities from oil or coal. Eriez Magnetics, aided by GA Technologies and Cryogenic Consultants, recently sold a $2-million prototype superconducting magnetic separator to J.M. Huber Corp. of Wrens, Ga., which will use it to remove impurities from clay. The product's liquid-helium cooling system is computer controlled, so Eriez claims the system requires no special skills to operate. Thus the prototype demonstrates that niobium superconductors may have a future in standard industrial settings.

■ Improved medical imagers. Already the largest single use for superconductors by a wide margin, these devices will yield better results if stronger magnets can be produced. The West German company Siemens has built an experimental magnet with more than twice the strength of those used today, and Oxford Instruments is building similar test magnets.

R&D of niobium materials. As last year's headlines touted ceramic superconductors, Teledyne Wah Chang quietly developed a more homogeneous form of the compound niobium titanium, the basic material for superconducting wire and cable used in magnets. This new form generates stronger magnetic fields when charged with an electric current, and therefore is being applied to development of the Superconducting Super Collider.

Such work makes Teledyne the clear leader in this activity. It is developing another promising compound, niobium tin, which produces even stronger magnetic fields while retaining its superconductivity even through brief temperature increases. The compound is unpopular because it is brittle, but Teledyne Wah Chang is working on improved versions.

Teledyne's niobium research funding of about $1 million is relatively modest. But as the Super Collider work illustrates, the potential payback can be huge, because such metallurgical advances may quickly find commercial use in high-strength magnets.

R&D of niobium materials

1987 SIZE: About $2 million

PLAYERS: Energy Conversion Devices, Intermagnetics General, Supercon, Teledyne Wah Chang

Large niobium magnets for energy programs. The general slowdown in U.S. energy programs effectively curtailed market activity for large niobium magnets in 1987. Earlier, both General Electric and Westinghouse had worked on superconducting electric generators, and the Department of Energy bought large niobium magnets for its fusion-energy development program.

According to analyst C.B. Whichard predicts that Business Technology Research, large niobium magnets for storing electricity represent the most promising large-scale application for the near term, because they offer electric utility companies a way to store energy for peak load periods. In 1986, Bechtel, GA Technologies, and General Dynamics, work-

Large niobium magnets for energy programs

1987 SIZE: Negligible

PLAYERS: Bechtel National, Eriez Magnetics, Garrett, General Dynamics, Hitachi, Mitsubishi Electric, Sumitomo, Toshiba ing with Los Alamos and Lawrence Livermore Laboratories, demonstrated the feasibility of such devices. Although the market does not yet exist, Whichard predicts that it may grow to between $50 million and $100 million by 1997. He expects General Dynamics to emerge as the leader in this field.

The market for large magnets could stir as early as this year. Intermagnetics General and General Dynamics have fabricated test magnets for the Super Collider, demonstrating that the government's demanding designs can be met by private industry. Also, electric-energy storage systems for the Strategic Defense Initiative are growing into another new market. A dominant player is GA Technologies, which has built a powerful magnetic coil to store and rapidly release electricity for the Air Force-sponsored High-Voltage Homopolar Generator experiment at the University of Texas at Austin. Bechtel International recently won a contract to build a much larger energy-storage system for the Defense Nuclear Agency.

R&D of ceramic materials. Although many companies in the superconductor industry have great expectations for high-temperature ceramic materials, they are still plagued by two problems. Superconducting ceramics are very brittle and hard to work with, and they cannot carry large electrical currents, which is the key to generating strong magnetic fields.

Several companies are working to improve the current-flow of ceramic superconductors, but with limited success. IBM and Nippon Telegraph & Telephone (NTT) have made very thin films, a micron or less in thickness, with current capacities comparable to niobium alloys. However, the usefulness of such films as bulk current-carriers is very doubtful.

R&D of of ceramic materials

1987 SIZE: None

PLAYERS: Applitech of Indiana, ASEA-Brown Boveri, AT&T Bell Labs/Bellcore, Ceramics Process Systems, Du Pont, Energy Conversion Devices, Ford, Fujitsu, Garrett, General Electric, General Electric (England), IBM, Misubishi, Nippon Telephone & Telegraph, Plessey, Sumitomo, Supercon, Teledyne Wah Chang, Westinghouse Electric

As a result, materials research increasingly focuses on learning more about the properties of ceramics' high-temperature superconductivity. Because of its hefty cost, such fundamental research will remain primarily with large companies, including IBM, AT&T Bell Labs, and NTT in Japan. In addition, Du Pont is working on techniques for large-scale production of superconducting ceramics.

Nevertheless, small companies with a novel technology can find a place among the giants. For example, Energy Conversion Devices is in the forefront of materials research with a process for replacing some of the oxygen in a ceramic with fluorine. Tests show that this raises the superconducting temperature.

Ceramic wires and tapes

1987 SIZE: None

PLAYERS: American Superconductor, Arch Development, ASEA-Brown Boveri, AT&T Bell Labs/Bellcore, Conductor Technologies, Fujitsu, Furukawa Electric, General Electric (England), IBM, Kawasaki Steel, Mitsubishi Electric, Monolithic Superconductors, Nippon Steel, Sumitomo, Toshiba

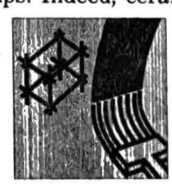
Ceramic wires and tapes. Wires and conducting tapes are essential if ceramic superconductors are to become useful products. Therefore a number of companies are attacking this problem, including the startup Arch Development, plus IBM and AT&T Bell Labs, and the overseas companies ASEA-Brown Boveri, General Electric (England), Fujitsu, Hitachi, Furukawa, Mitsubishi, Sumitomo, and Toshiba. The startup American Superconductor appears to be closest to delivering a commercial product.

American Superconductor makes flexible ribbon from superconducting materials by mixing them with molten silver, then putting the mixture onto a chilled, spinning wheel. The molten metal rapidly solidifies and rolls off the wheel as continuous ribbon. Backed by $4 million in venture-capital funding, the company is now running a pilot plant and plans to begin selling its superconducting tape early this year. However, skeptics such as IBM researcher Paul Grant point out that, as of late last year, American Superconductor had not yet produced even laboratory samples that can do what it claims its production tapes will.

At Arch Development, a joint venture of Argonne National Laboratory and the University of Chicago, researchers mix ceramic powder with a binder and form it into thread-like fibers that can be wound into wire before heat treatment turns the powder into a superconductor and makes it brittle. AT&T Bell Labs uses a similar approach to make flexible tapes. Toshiba encapsulates ceramic powder in a metal tube that can be formed into wire or tape before heating.

Ceramic coatings, thin films, and electronics. Ceramics can easily be formed into coatings and thin films that can be processed with standard microelectronic-fabrication techniques used to make silicon chips. Indeed, ceramic coating processes are so straightforward that AT&T Bellcore, which has demonstrated thin-film deposition using lasers, declines to patent its technique.

Because applying coatings is a relatively simple process, small companies that want to explore the technology are having trouble raising the money needed for research and development. For instance, Guernsey



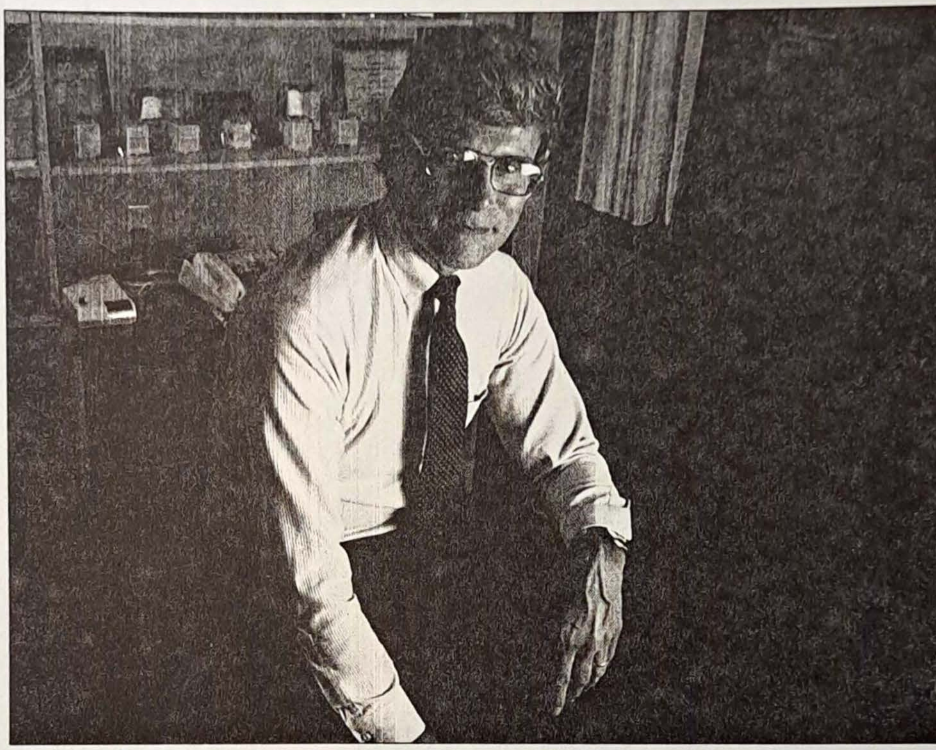
Ceramic coatings, thin films, and electronics

1987 SIZE: None

PLAYERS: AT&T Bell Labs/Bellcore, Ceramics Process Systems, Conductor Technologies, Conductus, Electro-Kinetic Systems, Energy Conversion Devices, Garrett, General Electric (England), General Motors, Guernsey Coating Laboratories, IBM, Matsushita Electric Industrial, Microelectronics and Computer Technology, Nippon Telegraph and Telephone

Coating Labs, an optical-coating company in Ventura, Calif., has been unable to attract venture dollars to support basic research in superconductor coatings. Venture capitalists are willing to back only proprietary techniques. However, president Peter Guernsey complains that, without research funding, the company cannot develop a proprietary process.

Ceramic coatings already have been used to produce electronic devices such as SQUIDs in laboratories by IBM, AT&T Bell Labs, Matsushita, NTT, and Energy Conversion Devices. But many technical difficulties remain. For example, ceramic SQUIDs are as much as 1,000 times less sensitive than their niobium counterparts.



JOAN SEIDEL

Led by entrepreneur George McKinney, American Superconductors aims to be first with new ceramic products.

Microelectronics & Computer Technology, which is setting up a consortium of 20 companies to support superconductor-electronics research, is studying the use of ceramics not in chips, but in electronic interconnects that would tie conventional computer chips together. Superconducting ceramics would provide much faster signal transmission between chips in a multiple-chip device.

In yet another attempt to apply superconducting ceramic to electronics, Electro-Kinetic Systems is developing coatings that would provide electronic shielding for computers. The coating would absorb signals generated by the computer which, when picked up by an outside receiver, can be deciphered to reveal its computations—a threat to security. Electro-Kinetic is developing a shield for the ETA-10 supercomputer from ETA Systems of St. Paul, Minn. The computer already uses liquid nitrogen to chill its circuitry, setting up the perfect environment for ceramic superconductor coating. Because of this synergism, shielding is expected to be one of the earliest commercial products for the new ceramics.

Research into uses for ceramic superconductors. The major electrical companies, plus nonprofit organizations such as the Electric Power Research Institute in Palo Alto, Calif., are studying potential applications for ceramic superconductors. These include magnetically levitated trains, long-distance power transmission, and superconducting motors and generators. However, such research isn't expected to bear fruit before the year 2000, if then.

Nitrogen-cooled superconducting wires or tapes, with properties that can compete with established niobium alloys, are needed to get such work beyond the early stages. So far, developments have not been promising. Wire made by Arch Development and Toshiba, for example, shows only poor current capacity and magnetic strength. George McKinney, president of American Superconductor, says he will sell a ceramic-based tape with high current capacity and a strong magnetic field early this year.

The most significant breakthrough for commercial superconductivity—for the near term at least—is not the discovery of high-temperature superconducting ceramics. More immediate payback is likely to come from developments such as Eriez' clay-purifying magnet, which demonstrates that superconductors can be applied to ordinary industrial tasks, and from Biomagnetic Technologies' medical imager.

The ceramic superconductivity community remains in a state of vigorous research activity, helped by federal funding and venture capital, but its present market prospects are rather cool. Unless researchers can overcome the technical difficulties, 1987's springtime of hope for ceramic superconductors may give way to a long winter of discontent. ■

T.A. Heppenheimer is a journalist and author specializing in aerospace and other technologies.

Research into uses for ceramic superconductors

1987 SIZE: None

PLAYERS: ASEA-Brown Boveri, Garrett, General Electric (England), Mitsubishi Electric, NEC, Nippon Steel, Oxford Instruments Group, Sumitomo, Toshiba

SECRET

IN REPLY PLEASE QUOTE
No. HQ 8932-4 (DEP 2b)

CANADA

Department of National Defence
Army

P2A.

ARMY HEADQUARTERS
OTTAWA 4, Ont., 16 Apr 64

Referred to D Phys R
File DRBS 4200-30
Chgd. to CLC 31/3/64.

Defence Research Board
Ottawa, Ontario

Attention: Directorate of Physical Research

Radar Absorbing Techniques

1. Attached is a copy of a letter received from our CLO at USAEPG which explains a discussion with representatives of North American Aviation pertaining to their company's development of a radar absorbing material. This information undoubtedly will be of interest to both the DRB and the RCAF.

for (GRA Coffin)
Colonel
Director of Equipment Policy

ATT

cc:

Chief of the Air Staff (ATTN: DADSO)

SECRET

HEADQUARTERS
U. S. ARMY ELECTRONIC PROVING GROUND
Fort Huachuca, Arizona
Office of the Canadian Liaison Officer

CAS(W) 8932-5 (AEPG)
3 Apr 64

Commander
Canadian Army Staff
2450 Massachusetts Avenue, N. W.
Washington, DC, 20008

Radar Absorbing Techniques
North American Aviation

1. Representatives of North American Aviation visited Fort Huachuca recently and described in a very guarded manner their company's development of a radar absorbing material. This material is called HIDE (High Absorption Integrated Defense system). The work to date has been done under a USAF contract out of Aeronautical Systems Division, Patterson AFB, Dayton, Ohio. Characteristics of the material and process are SECRET and on a "need-to-know" basis, and references to any military application or existence of such a research programme is at least CONFIDENTIAL. No mention of this work has been published in technical literature.

2. Although details are meagre, it was learned that this is a honeycomb type of material that possesses good structural strength and can be produced in special configurations. Sections of wings, cowlings, and fuselages apparently can be made entirely of this material or it can be integrated into designs.

3. The representatives would not answer specific questions but one can speculate on the properties of HIDE because it was indicated that the following applications and questions were not unreasonable:

a. Might be applied to reducing radar cross section of mortar bombs (Picatinny are investigating this).

b. Can be made reflective at certain frequencies and, hence, offers possibilities for decoys.

c. Might be applied to vehicles.

d. Can be used to absorb lobes from radar antennae.

e. Can be considered for radomes.

f. Possible applications to clothing and reduction of radar returns from troops.

4. It is evident from the above that our conversations were not very productive. It was agreed with Mr John R. Miller, Information Systems, Advanced Programs Development, North American Aviation, Inc., Space and Information Systems Division, 2000 North Memorial Drive, Tulsa 2, Oklahoma, that we should contact Mr CL Moore, Davis Bldg, K Street, Washington, who is their Washington representative. It was suggested that Australia has already

SECRET

obtained a clearance to discuss details of the programme and it was expected we would have no difficulties if we requested a clearance. Undoubtedly, conversations with Mr Moore would reveal how a clearance should be obtained and in what areas we should express an interest.

5. This development will be of interest to the RCAF and to DRB. The company appears to be willing to make their development as widely known as security permits and indicated they would undertake to brief an audience in Ottawa.

6. From other sources it is learned that the HIDE system is in limited production now and consideration can be given to using it in designs now. In addition to this particular product, North American Aviation are knowledgeable in complementary systems and alternative techniques in the field of radar absorbing materials. While HIDE is not an acoustical material, the honeycomb structure apparently acts as a reflector for sound and, being light in weight, could be applied to certain areas where acoustical levels are a problem.

7. HIDE at present is an S to X band material but consideration can be given to some applications in the L band region. It is also possible that special designs using HIDE material would permit relatively narrow frequency band windows in radomes and that this might help to reduce manual interference or sighting problems. It is known that performance figures are available on the attenuation at various frequencies and on the thickness and configuration of material most suited for specific applications. In addition to contacting Mr Moore, there is a Mr Eric Linden employed by the Army at Fort Monmouth who is said to be one of the most knowledgeable people in the Army on the HIDE programme. Unfortunately, his address is not available but it is thought that he works at USAELRDL.

8. The North American Aviation representative also advised that they had received an Army contract out of Huntsville, Alabama, for the sonic and supersonic target drone called the Red Headed Road Runner. This is launched from a carry aircraft and provides five minutes sonic and three minutes supersonic endurance. In its present configuration it has no surveillance capability but it is thought that the company is investigating possibilities of a drone based on their present product but adapted to provide the endurance and range needed for sensors.

(J T Bradley)
Major
Canadian Army Liaison Officer