Medical Imaging: Discussion Paper

A Report to:	Industry Canada
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Executive Summary

The Context

Health care systems around the world are under enormous pressure to maintain or improve quality of care while containing or reducing costs. The challenge to reconcile these conflicting objectives is complicated by an aging population in the developed world and by a wide differential in standards of care between developed and developing countries.

Medical imaging has great potential to help resolve this dilemma. It offers major advances in both diagnosis and precision image-guided therapy. It will be delivered over networks, in real time, bringing specialized expertise into community settings world-wide. Properly implemented, it will deliver more effective health care services with lower overhead and operating costs.

Fulfilling this promise will require new technologies and new business approaches. Canada is not currently a major player in the medical image sector, but, through a combination of advantages, it is well positioned to take advantage of this business opportunity. These advantages include:

- strong research and clinical capabilities;
- successful medical imaging niche businesses;
- expertise in innovative software development;
- sophisticated telecommunications networks and industry;
- a regulatory environment that has encouraged innovation;
- a relatively well-organized and increasingly entrepreneurial health care delivery system.

Canada's future opportunities in this sector will depend on how well we can build on these strengths. The greatest opportunities involve the development of integrated solutions which combine international technologies with new Canadian-developed enhancements into robust, flexible, and user-accessible systems. The ability to build partnerships with the health care delivery system which demonstrate the successful operation of these integrated systems, especially in a telehealth environment, will be vital to establishing a Canadian leadership position in international markets.

To project the future business opportunities in the medical imaging field requires an understanding of the underlying political, economic and social "drivers" which will shape the market in Canada and internationally. Government policy and regulatory regimes will establish the political context. Health care funders and managers will make many of the critical decisions about the pace and direction of change. The ability of our education and training institutions to provide sufficient workers with the right combination of sophisticated skills will be an important limiting factor. Finally, a variety of social considerations will affect the medical imaging sector, including: the demographics of health care; concerns about access and privacy and the potential for new health consumer attitudes to influence public attitudes.

The Technology

Medical imaging has been around since the discovery of X-rays. In more recent times a number of new or refined technologies for generating internal images of the human body have been developed. These "modalities" include: CT (Computed Tomography); ultrasound; MRI (Magnetic Resonance Imaging); and nuclear imaging (based on the tracking of ingested, inhaled or injected radioactive isotopes).

Over the years, medical imaging has spawned its own medical speciality - Radiology. Radiologists have driven the development of medical imaging. In turn, changes in medical imaging technology are now driving changes in the profession.

Recent years have seen a shift towards capturing, storing, and using these images in digital form rather than in hardcopy form (film). Digitization is the key to the future growth of medical imaging. It opens the door to the introduction of a wide range of new technologies for the storage, retrieval, transmission, analysis and visualization of medical images. The pace of the installation of PACS (Picture Archiving and Communication Systems) will be a critical factor in the growth of the sector. The most significant development here will be the integration of PACS systems into "enterprise-wide" integrated patient record data systems available over a distributed network.

The medical imaging equipment business will see innovation and refinement in the imaging modalities, but there do not appear to be any radically new image generating technologies on the horizon which will capture significant market share.

The most significant areas of new business growth are likely to be in two areas of software or software-enhanced products. These are:

- products which facilitate the integration of medical imaging into telehealth systems; and
- products which enable or facilitate a variety of new image handling, image analysis and visualization capabilities

The report which follows details these issues and opportunities. Its most important conclusion is that building the Canadian medical imaging sector will require co-ordinated action among private sector companies - both large and small; governments (policy and regulatory agencies); the medical research community; and health care delivery systems.

1. Introduction

Industry Canada, in collaboration with industry, has embarked on a program of encouraging the development of evolutionary "technology roadmaps" which identify the critical technologies required by industry to meet international market needs five to ten years into the future. The aim is to encourage industry participants, academic and research groups and governments to work together to shape an evolving strategic business plan which will guide their individual and collective ability to influence the future. Industry Canada identified medical imaging as a possible subject for such a process and convened an industry-based Steering Committee which confirmed the potential value of such a strategic exercise.

This discussion paper is the first step in developing an evolving technology roadmap in the field of medical imaging. It is intended to serve as a focus document for discussion and debate among medical imaging stakeholders in Canada by

- providing stakeholders with background information on the current global and Canadian status and future trends in the medical imaging sector; and
- providing analysis and projections of future developments and opportunities for Canadian industry.

A fundamental assumption of the document is that development of the medical imaging sector will be influenced profoundly by external political, economic and social forces over the next few years. Even the technologies developed to respond to these forces will be influenced by the growing trend to "borrow and apply" technologies from one field to another. For this reason, the document concentrates considerable attention on identifying and analyzing the external drivers which will shape the future of medical imaging.

A key fact directing this paper is that medical imaging is in a transition from an analog-local process (film-based) to a digital, distributed process. The implications of this are that instead of the radiologist interpreting a static image (film) in a fixed location, the image is a digital object with the ability to be manipulated, visualized, analyzed and communicated. This transition to digital images and its implication overshadows the entire report.

Given the short time horizon under which this paper has been prepared and its primary purpose of stimulating the active involvement of a wide range of Canadian stakeholders, the emphasis has been placed on providing a base for informed discussion rather than attempting to offer definitive solutions. Our approach has drawn upon ORTECH's expertise in market assessments for technology investors and for our own Health Sciences

Group. Our knowledge has been extended by extensive literature searches, by input from Industry Canada's Medical Imaging Steering Committee, and by interviews with knowledgeable individuals in Canada and internationally.

2. The Medical Imaging Sector

For the purposes of this discussion paper, Medical Imaging covers all aspects of the development and use of products and systems which capture, store, integrate, analyze, transmit, report on and display human body images for diagnostic and therapeutic medical purposes. The medical imaging sector stakeholders include all of those organizations and individuals engaged in or affected by the development and use of medical imaging technologies.

3. The Potential of Medical Imaging Technology

Medical imaging is about perceiving, or reconstructing, reality based on data recovered from imaging equipment (modalities).

In order to assess likely changes in the medical imaging sector over the next five to ten years, it is necessary first to identify a goal. What is the promise of medical imaging technology? What contribution might it make to the human health field?

In general non-quantitative terms, these are not difficult questions to answer. At the core of the medical imaging opportunity are two potential benefits: to greatly improve human health diagnosis while, at the same time, offering much greater flexibility in its availability and in the method of its delivery. Between these two benefits lies the potential to control or reduce health costs while improving quality and accessibility. In combination with other medical disciplines (e.g. surgery) imaging also offers the potential to radically improve patient treatment through integrated image-guided therapy. The broadest benefits, however, are likely to be seen in the improvement of diagnostic services: in both quality and accessibility.

4. The Current Situation

4.1 Global Overview

The medical imaging sector is a good example of a technology-defined market place which is shifting from an equipment focus to an information management focus. The key technologies have been developed to capture, store, retrieve, transmit and display the images generated. While the potential for applying these technologies to solve major challenges in the diagnostic component of healthcare services has been clearly identified, the shift from technology push to market pull is incomplete and fragmented. Integration and standards setting are the two greatest challenges currently being addressed.

The integration challenge involves fitting existing technologies which have been developed piecemeal into an integrated set of cost effective solutions for the emerging market.

The standards setting challenge is an essential prerequisite to integration but it also must evolve along with the technology in order to achieve the full potential of medical imaging to improve healthcare diagnostics.

At present, the use of medical imaging technologies as a direct component of medical therapy (e.g. image-guided surgery) is even less well developed.

4.2 Canadian Initiatives

Canadians have been involved in telehealth initiatives since the early 1980s and key players have included provincial governments, universities, healthcare providers and private corporations across the country. Initiatives are currently taking place in telemedicine, teleradiology, development of electronic patient records, PACS and continuing medical education. Appendix III provides a selected list of initiatives.

Key participants in the medical imaging sector in Canada are in the process of proposing a Network of Centres of Excellence - CMIST (Consortium for Medical Image Science and Technology). Key participants and partners are listed in Appendix VI.

Several groups are also looking at broad issues surrounding telehealth. CIHI (the Canadian Institute for Health Information) has organized six working groups to look at such standards issues as health information models, privacy and security, information exchange protocols, and multimedia health records. CAR (Canadian Association of Radiologists) is also looking at all professional and regulatory aspects arising out of teleradiology between organizations and across jurisdictions.

4.3 Markets

Medical imaging is an important multi-billion dollar sector of the global healthcare market. Attempts to quantify the medical imaging market are complicated by its breadth and diversity. Current statistics typically do not encompass all contributors.

Recent projections from Frost & Sullivan (see Table I) do not include X-ray or CT. Assuming that X-ray based techniques are roughly 50% of the market and CT is at least 8%, the 1998 global diagnostic imaging projection can be estimated to be more than $ 15.16 billion U.S.(assuming that the $6.37 billion U.S. total in Table I is 42% of the market). This is comparable to a more comprehensive report that was issued in 1994, that stated 1993 global diagnostic imaging revenues to be $11.61 billion U.S. (Frost & Sullivan 1994).

Table I : Value of the Global Ultrasound, MRI and Nuclear Medicine Imaging Markets, 1995-2002

($m)

Modality	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
Ultrasound	2,060	2,130	2,220	2,330	2,460	2,610
MRI	1,410	1,510	1,620	1,770	1,950	2,170
Nuclear	1,600	1,760	1,980	2,270	2,690	3,320
Total	**5,070**	**5,400**	**5,820**	**6,370**	**7,100**	**8,100**

Source: Frost & Sullivan

Medical imaging can aide physicians in detecting and treating illnesses and monitoring treatment progress. The efficiencies gained help to reduce the costs of long treatments, surgery, additional tests, and hospital stays.

The major market trends that are affecting the MI market in the developed countries include demographic factors (i.e. an aging population resulting in an increase of age-related diseases) and healthcare reforms (i.e. cost reductions) which include the trend to HMOs and in Canada regionalization.

The major markets for MI include the United States, Western Europe and Japan. The re-evaluation of the healthcare systems in these markets are profoundly affecting MI suppliers. MI suppliers are attempting to provide more cost-effective systems to meet the need to control spiraling healthcare costs. Other needs that are being expressed by these markets include upgradability, interconnectivity, and digitization.

In response to cost pressures, consolidation in the healthcare industry is occurring within the large suppliers and, particularly in the U.S., within the providers. Hospital systems have merged and large integrated health networks have formed.

The emerging markets in Asia and the Rest-of-World are expected to grow while the major markets continue to mature. The introduction of higher-quality healthcare in the developing world has resulted in an overall increase in world-wide examinations. Traditional film technology is considered to be the most cost-effective method for most of these countries and it is enjoying double-digit growth in this market. Approximately 60% to 70% of all examinations world-wide are still acquired on film (Rosenzweig 1998).

The major markets by modality (image generation equipment type) are radiography (X-ray), ultrasound, magnetic resonance imaging (MRI), computed tomography (CT) and nuclear imaging. Radiography (X-ray) is by far the largest segment of the modality market at roughly 50% followed by ultrasound at approximately 17% and with magnetic resonance imaging, computed tomography and nuclear making up the rest (See Tables I, II and III). The tables show a slow growth in revenues with minimal shifts in the relative contributions of the modalities to the total. This reflects the maturity of the modality (hardware) market.

Table II : Value of the U.S. Diagnostic Imaging (DI) market by modality, 1995-2000

($m)

Modality	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
X-ray	2,843.4	2,942.9	3,053.9	3,177.5	3,321.5	3,481.6
Ultrasound	682.0	686.8	695.3	708.6	727.5	748.0
MRI	465.0	474.3	483.8	500.7	518.2	536.4
CT	416.0	424.3	432.8	450.1	468.1	486.8
Nuclear	359.9	368.2	376.6	391.0	405.8	421.2
Total	**4,766.3**	**4.896.5**	**5.042.4**	**5,227.9**	**5,441.1**	**5,674.0**

Source: MarketLine

Table III : Value of the European (France, Germany, Italy, Spain, and U.K.) Diagnostic Imaging market by modality, 1995-2000

($m)

Modality	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**
X-ray	916.5	938.6	961.8	993.5	1,031.0	1,074.6
Ultrasound	534.4	541.4	553.5	568.6	588.9	611.9
MRI	277.6	284.2	291.0	304.9	319.6	335.0
CT	195.1	199.3	203.5	211.6	220.0	228.8
Nuclear	103.8	106.1	108.5	113.3	118.5	123.8
Total	**2,027.4**	**2,069.6**	**2,118.3**	**2,191.9**	**2,278.0**	**2,374.1**

Source: MarketLine

Although not large, the segments with strong growth potential relate to medical image management and transmission (i.e. PACS, teleradiology) as well as nuclear medicine imaging technologies (i.e. SPECT, PET). The U.S. market for PACS is estimated at $650 million, according to Toshiba America Medical Systems (Tustin, Calif.). The projected total installed base for 1998 is 500 units and more than 800 units by the year 2000, according to Meta Group (Kales 1998). PACS is moving from leading edge beta site testing to fully commercial installations.

4.4 *Technology Today*

Medical imaging involves a number of linked processes, each affected by different technologies. In order to discuss the current status and future prospects of medical imaging technology, the field has been subdivided by process as opposed to imaging modality (equipment that generates an image). The sections include: image generation, image capture, storage and retrieval, transmission, display, analysis, visualization and reporting. A final heading deals with issues of the integration of medical imaging systems.

The evolution of the medical imaging sector will be strongly effected by the trend to digital images with the resultant opportunities in integration and transmission of data. As such, medical imaging, and teleradiology specifically, will interact with telehealth initiatives in general. The topic of telehealth is covered in a recently released Industry Canada publication entitled, “The Telehealth Industry in Canada: Background Study to a Sector Competitiveness Framework” (Industry Canada 1997a). As such, telehealth is not covered in detail in this report.

4.4.1 Image Generation

Image generation modalities, as defined by the energy source used (e.g. X-rays, ultrasound, MRI, radiofrequency and radioactive decay), are well established. However, they are undergoing continual refinement as groundbreaking approaches grow out of them (e.g. inverted X-ray, functional MRI and 3D ultrasound). Modalities can be split into two groups: ionizing radiation-based modalities such as X-ray, CT (or CAT) and nuclear medicine; and non-ionizing modalities such as ultrasound and MRI. As noted in Section 4.3, a significant portion of the medical imaging market is X-ray based since it generates high resolution images and is relatively inexpensive. However, the need to expose patients to ionizing radiation is a key issue with this modality. While Medical imaging has traditionally been the domain of the radiologist, other modalities, such as fluoroscopy, endoscopy, EEG signals (not formally an image), dental X-rays, pathology sections (visual light based images) also generate similar sets of data which can be handled using the similar tools as medical images. Since many of these techniques do not fall in the conventional definition of radiology they will not have the same prominence in discussions/issues relating to medical imaging.

4.4.2 Image Capture

Conventionally, images have been stored on film or video tape, even in the case where the data was digital by nature (e.g. MRI, Ultrasound or CT). The films were physically handled by the radiologist for interpretation and ultimately filed in a library. While capture on film is still predominant, it is clear that digital capture of the images and digital storage is the direction of the future. This shift to digital images will be the rate limiting step in the development of many of the technologies described in the subsequent subsections (4.4.3-.4.4.9).

Digital capture of images has many advantages: i) reduction in the costs and environmental impact associated with film processing; ii) improved distribution and hence communication amongst consultants leading to improved diagnosis; iii) better tracking of images and iv) the ability to adjust over- or under-exposed images thus reducing the need for repeat exposures.

Modalities which are currently available with digital capture include ultrasound, nuclear medicine, fluoroscopy, MRI and CT. Indirect methods of digital X-ray capture are commercially available and range from scanning of films to produce digital images, to capturing images on a reusable phosphor plate which is scanned to form a digital image (avoiding the film step). Approaches to direct digital capture of X-rays (flat panel detectors which generate digital output from an array of pixel detectors) are in the process of commercialization. Sterling Diagnostics is the first to market with a 2D direct X-ray detector, but many others are poised to launch similar products. CCD detectors are expected, by some, to allow direct 2D capture of images at a very competitive cost.

4.4.3 Storage & Retrieval

Storage and retrieval of hardcopy images (films) is a physical process with significant labour and space requirements. Storage and retrieval of digital images is built on the foundation of technologies drawn from outside of the medical imaging field.

Digital storage considerations can be broken into two needs: short-term, and long-term. Short-term (i.e., local) storage is being achieved by using servers employing RAID technology. This capacity is required to hold images waiting to be viewed and to act as a buffer in case network connections are disrupted. Long-term, centralized storage is being achieved with CD, DVD and tape jukeboxes.

With the move to open systems, retrieval technology is migrating to web browser technology. Web-based applications allow for easy access and linking of files, and use tools and standards developed outside of the medical imaging field. They can also utilize inexpensive PC-based computer platforms.

Data compression is used to minimize the storage size of medical images and to speed up their transmission. Compression is either lossless or lossy. Lossless compression retains all the original data in the compressed version, whereas lossy compression drops out data in the compressed version in the interest of further reducing the file size. The degree of acceptable loss on compression will vary by imaging application (e.g. X-ray vs. ultrasound) as well as by the user's need (e.g. radiologist vs. referring physician). Wavelet-based compression (a lossy method used for color images and video) is gaining broader use for compressing medical images.

PACS (Picture Archiving and Communication System) is a computer network system designed to transmit, store, and retrieve digital medical images. PACS represents the "virtual film library" backend to the Radiological Information System (RIS) which stores the patient data and text versions of the radiologist's reports. PACS and the integration of various hospital information systems will be discussed in more detail under Integration.

Historically, the digital image file had a structure defined by the vendor who captured or digitized the image. As a result, the files were not easily transferred between equipment from different vendors. The industry has taken a step to solving this problem through the Digital Imaging Communication in Medicine (DICOM) standard. This standard provides a framework to allow for imaging modalities and archival systems (PACS) to communicate. This evolving standard will allow for open systems communication and enable users to get maximum value from medical images.

The movement to digital storage via PACS is unquestionable, but its rate will be limited by the transition to digital image capture discussed in the previous subsection, as well as other factors related to cost and system integration issues.

4.4.4 Transmission

In a film-based operation, transmission means physically handling images and walking (or couriering) them around to their required destination(s). The clear disadvantages to this mode of transmission include cost, time and lack of duplication of images.

As with storage and retrieval, the transmission of digital images draws upon technologies (e.g. telecommunications and networking) which are outside of medical imaging. The drivers for this technology are also outside of medical imaging, although imaging will benefit from the inevitable fruits of lower cost/higher capacity transmission.

A broad range of transmission media are available and their use is dependent on cost and the application (e.g., real-time viewing). Typically, increased bandwidth is accompanied by increased cost. Common LAN (local area network) technologies such as Ethernet and

ATM (Asynchronous Transfer Mode) offer bandwidths in the range of 10-1,000 Mbps and 25-2,488 Mbps respectively. This is appropriate for real time image consulting.

Cable modems and satellite technology typically offer bandwidth in the low Mega bits per second range. Wireless technology (cellular and wireless modem) further extend transmission capabilities to thin clients (e.g., palm-top devices, laptops).

Transmission of data is an area where Canada has a particular strength both in terms of telecommunications companies (in the broadest sense, including supporting software and hardware) as well as a well developed communications infrastructure. CANARIE (Canadian Network for the Advancement of Research Industry and Education), a non-profit, industry lead consortium, has initiated networking programs to advance Canada's networking infrastructure and to test broadband applications. Fifteen high-speed Regional Advanced Networks (RAN) across the country provide connections to CANARIE's high performance IP/ATM network, CA*netII. CANARIE helps to fund numerous healthcare technology application development projects including teleradiology.

4.4.5 Display

In a film-based environment, display involves putting a film on a light box and examining it. Display of digital images involves the production of a *softcopy* on a monitor. The softcopy or digital image can also be printed (hardcopy).

Issues relating to monitors are dictated by the external technology environment. The monitors are typically higher resolution than conventional PC screens and are subject to issues relating to reproducibility from terminal to terminal such that an image will look the same regardless of where it is viewed DICOM standards and industrial innovations (e.g. TrueGrey® monitors) are moving this issue forward.

The present level of monitors available are acceptable. In some cases the display quality is dictated by regulation or convention. At present "2K" monitors represent the quality required for high-end radiological applications. However, lower end terminals ranging down to typical PC monitors can be used in less demanding applications and for lower end users. The advent of flat panel displays which offer the required resolution at a competitive cost would represent the next major step in monitors.

Issues associated with displays also include whether you store the raw image alone or the manipulated (with intensity variations) and annotated (with arrows/circles/text) versions created during the radiologist's interpretation process. As storage becomes less of an issue this will be less important.

4.4.6 Analysis

In a film-based environment, the radiologist carries out the analysis in his/her head. They determine how the features of an image relate to the organ being imaged, its 3D structure, and what the significance of the features are. This information is communicated to the referring physician through a report.

The current challenge with digital images is in defining an object (e.g., organ, tumor) within the image and the degree of automation that can be used to do this. Computers are not good at recognizing structures within medical images but are good at delineating them (once a radiologist has identified and tagged some aspect of a structure).

Considerable work is proceeding on the creation of expert systems to devise tools which aid the radiologist in analyzing images. The ultimate direction is for the computer to be able to identify and define the structures. The progress towards this target will vary but initial examples are emerging. Much of the research in this area involves fuzzy logic and learning from atlases and databases of reference images. Another emerging trend is the ability to integrate images from different modalities to give a view of a single object (e.g. organ).

The limitation of affordable computational power to carry out sophisticated analysis in real time (or rapidly) is a key limiting factor.

4.4.7 Visualization

The natural extension of display technologies and analysis is visualization. This refers to approaches to integrating the information and rendering it into a form (e.g. 3D object) which allows for better presentation of the information and hence interpretation.

ISG Technologies of Mississauga is a key player in the visualization field. Their products are being incorporated into a variety of modality vendors' display capabilities.

4.4.8 Reporting

Reporting is the ultimate step in the radiological process. It is where the interpretation is communicated and documented for the user of the information. In the conventional setting, a radiologist dictates a report which is transcribed by a typist, reviewed by the radiologist, corrected by the typist and then signed and approved by the radiologist. The report is then stored in the RIS (radiological information system).

Two productivity enhancements in use are speech recognition software and standardized reports. Speech recognition software is aimed at reducing the turnaround time for a radiology report from days to minutes. Recognition accuracy is reported to be between

80 to over 95% although recognition training is required to reduce errors. Given that transcription errors can be life threatening, editing by radiologists is required. Depending on initial accuracy rates, this process may be less efficient than conventional transcription. The middle ground is digital dictation where a radiologist's report is available instantly as an audio file over the voicemail/telephone system. A text report is generated by a typist (on or offsite) with the radiologist providing final verbal edits. The ultimate evolution will be full, reliable speech recognition which is expected to be in place in the coming years.

There is also a move towards standardization of reporting formats. Utilizing patient information (already entered into an information system) and use of glossaries (e.g., standard phrases for such conditions as a "normal spine") can speed up the report generation process. This is especially important with distributed readings of radiographs. Physicians can also receive notification (e.g. be paged) when a report is available, thus reducing turnaround time.

Integration

Integration represents the biggest opportunity and challenge for medical images. Integration includes the linking of both imaging modalities with archival systems (PACS) as well as the imaging information with Hospital Information Systems (which are moving towards integrated patient records and enterprise-wide systems which manage entirely electronic activities).

Two of the technical challenges facing integration are: i) the distributed and divergent nature of healthcare information (i.e., it enters in from multiple points in multiple formats), and ii) the incompleteness of existing information interchange standards.

Two standards in prominent use in healthcare-related information systems are: i) DICOM (Digital Imaging and Communications in Medicine) for imaging equipment and ii) HL7 (Health Level 7) for exchanging text-based information (e.g., patient registration, admission, lab results, discharge information) between Hospital Information Systems (HIS) and Radiological Information Systems (RIS). DICOM provides uniformity and compatibility between medical imaging equipment while HL7 provides the same between RIS to HIS.

DICOM has explicit and detailed models of how image data involved in radiology is described and related. For distribution, communication of medical images must be integrated into the RIS and HIS. However, not all old patient systems can deal with image data, not all medical equipment in use is DICOM compliant and even DICOM 3.0 compliant equipment typically needs custom interfacing.

Interface engines or "Black boxes" are now available which allow connection of non-DICOM 3.0 legacy equipment to a DICOM 3.0 compliant network. Companies like Mitra Imaging Inc. of Waterloo, are having great success filling this need. Their PACS broker systems is widely used by PACS vendors in interfacing between PACS, modalities and the RIS.

Integration with HL7 is not a straight forward process either. HL7 is a flexible standard but there are ambiguities in it that affect query transactions. These are negotiated between two parties which want to use HL7 as the standard. Hence, when implementing HL7, users define their own variations within specific applications which ends up hindering interoperability.

PACS (Picture Archiving and Communication System) is a computer network system designed to transmit, store, and retrieve digital medical images. PACS is the backend to a RIS. Evidence is accumulating that demonstrates the cost-benefit justification of PACS. Productivity gains are realized at the imaging department level and these increase as these systems are integrated at an enterprise level. Dramatic improvements in computational power and reduction in costs associated with storage and retrieval suggest that we may be at a watershed with respect to cost benefit advantage. A list of PACS initiatives is provided in Appendix III.

Challenges also exist at the hardware systems level. At present, the dominant hardware platform is UNIX. However, users are migrating to the Windows NT platform which is cheaper and offers a greater selection of software applications. The reliability of NT platforms will affect the rate of migration from UNIX.

4.5 *Stakeholders*

This section is intended to provide summary characterizations of the main participants in the medical imaging sector at an international level and to identify their motivation and clout. The text is supplemented by appendices which identify specific companies, associations, and other organizations which have been identified in each category during the preparation of this discussion paper. Given the timelines under which this paper has been prepared, it has not been possible to contact all of the organizations and individuals identified to verify current information or their correct placement on the lists.

4.5.1 Imaging Hardware Suppliers

Internationally, the current market place is dominated by a relatively small group of multinational Original Equipment Manufacturers (OEMs) of medical imaging hardware. The largest of these offer equipment using a variety of image generation technologies. Either directly of indirectly, they can provide full systems to their clients. This group of

OEMs are supported by a variety of suppliers of specialized hardware and by value added resellers (VARS) in individual markets.

OEMs consist largely of multinational electronic equipment companies that have divisions that specialize in medical equipment. Examples include: Elbit Ultrasound, Elscint, GE, Hewlett-Packard, Hitachi, Philips, Picker, Siemens and Toshiba.

In the past, OEMs have built and protected their market position through use of their own unique equipment and performance standards. As compliance with the evolving DICOM standard becomes a reality (rather than merely a general statement of direction, as is often the case at the present) the protected market place for proprietary comprehensive systems will erode and it will allow increased competition from smaller suppliers of products and services.

The OEMs in MI are adopting various strategies to maintain/increase market share. One strategy is multi-modality marketing to ensure maximum visibility. GE Medical Systems, Siemens, Toshiba and to a lesser extent, Philips Medical Systems and Picker International are following this strategy.

Another strategy is niche marketing in order to gain specific recognition in one modality or product class.

A third strategy is to diversify geographically to protect against country-specific economic and regulatory risks. The five leaders, GE Medical Systems, Toshiba, Siemens, Philips, and Picker International have adopted this strategy.

A final strategy that is considered is strategic alliances and joint ventures in order to gain access to new markets. Usually this consists of a large multinational that links up with smaller, more specialized players. For example, ALI Technologies (a Canadian ultrasound PACS provider) has alliances with various multinational OEMs to distribute their PACS and networking solutions.

4.5.2 Imaging storage (PACS) Companies

Historically the film companies (e.g. Agfa, Kodak, Fuji) have been key players in image capture. Recognizing that ultimately there would be no place for film and applying their understanding of the radiological (film) work flow allowed them to expand into digital image storage (via PACS). Players on the imaging modality side (e.g. GE, Seimens, Phillips) have also expanded into PACS.

There are a number of companies actively developing the market for the installation of

PACS into the health delivery system. To date, most of these systems have been small or have involved subsidized pilot/demonstration sites. Market penetration by PACS is estimated at 500 installations in 1998 (Meta Group). The companies installing these systems tend to have or draw upon those with system integration expertise. They are in turn draw upon by companies which have developed specific technological components (e.g., tape/CD jukeboxes, RAID servers) of the PACS systems.

While PACS systems tend to be marketed by multinationals, there are opportunities for small players. As an example Agfa's PACS system was in large part developed by Mitra Imaging of Waterloo.

Selected PACS companies are listed in Appendix V.

4.5.3 Analysis and Visualization Companies

Even though this area offers enormous potential, it is the least well-developed component of the medical image industry at the present time. This area includes all of those companies which are providing specialized enhancement tools for imaging data which is being collected and stored. These companies tend to be small, niche-focused (e.g. on a specific disease or systems problem), and depend on a combination of medical and software design expertise.

Emerging specialty software niches in the MI field include: image enhancement, data mining, graphics display, and image modelling and interpretation. In addition, the unique attributes of individual human organs and diseases tend to lead to focused software initiatives.

4.5.4 Academic & Research Centres

Canada has a well developed group of institutions involved in various aspects of Radiological research. Selected academic and research centres are listed in Appendix II.

The research community has also come together to develop a proposal for a Network of Centres of Excellence entitled Consortium for Medical Imaging Science and Technology (C-MIST). The goal is to promote the development and commercial exploitation of Canadian innovations in medical imaging through cross-Canada integration of research programs (within targeted themes), training to stimulate developments, and partnerships with the medical community, knowledge based companies and venture capital organizations. A summary of the research and industrial partners involved in the C-MIST proposal are listed in Appendix VI.

The National Research Council Institute for Biodiagnostics in Winnipeg is also involved in medical imaging research and several start-up companies have spun off from the organization.

4.5.5 Associations

Researchers and other stakeholders come together under a variety of organizations. A number of medical imaging associations are listed in Appendix II. Four key associations which represent various constituents within the continuum from developers to implementors of both imaging and image (data) handling, are:

SPIE-Medical Imaging -The Society of Photo-Optical Instrumentation Engineers had its 25 anniversary symposium in medical imaging in 1998. Early stage academic content.

SCAR - The Society for Computer Applications in Radiology focuses on digital imaging and issues arising out of it.

CAR - The Canadian Association of Radiologists represents Canadian clinicians.

RSNA - The Radiological Society of North America represents clinicians.

HIMSS - the Healthcare Information and Management Systems Society focuses on more global enterprise communication issues with which digital imaging and PACS must be integrated.

Each of these organizations hold conferences annually where new technologies and approaches are reported.

4.5.6 Medical Practitioners

Up to the present time, radiologists and researchers have been the main driving force in the development of medical imaging technology. As a profession, radiologists have been setting the objectives and have increasingly been pushing for the development of a common standard (e.g. DICOM) for medical imaging equipment. While the cost savings and immediate clinical improvements are initially less obvious to referring physicians, the transition to digital images is almost universally viewed as the direction to go for its long term benefits.

While the development of medical imaging has been supported by other medical specialties where particular applications have been involved (e.g. cardiology, neurosurgery), the primary role of referring physicians has been as the “customer” who commissions and uses the imaging information.

This model has provided a strong and medically focused approach. Its weakness has been a tendency to concentrate heavily on developments from within the medical community and to focus on immediate challenges rather than on the longer term possibilities of digital images and electronic integration of all hospital records.

An important issue as the medical imaging field evolves is the impact on the specialty of radiology. Opinions vary from it vanishing (as a distinct profession) to it growing in importance. Historically, the radiologist's role has intensified and expanded in response to the information explosion and rapid growth of the power and sophistication of imaging technologies. However, as the respective roles overlap the distinction between the radiologist (image interpreter/consultant) and the clinician (who acts on the information) is less clear. It is clear that radiologists will continue to take on a more active therapist role while some therapists will access and interpret medical images specific to their specialty. The use of images by clinicians becomes increasingly important as one moves toward real-time imaging and image guided therapy particularly in certain subspecialties where the therapist views and uses the imaging information in real time, bypasing the radiologist. Thus the current role of the radiologist will be challenged by the inevitable restructuring that will redefine the traditional turf between specialties.

The above evolution may impact on the general radiologist: Will the role of the general radiologist contract or expand? Will there be a move to far more sub-specialization? And in particular, will the area of interventional radiology increase and become more specific and defined?

4.5.7 Hospitals & Delivery Services

The role of the hospital within the healthcare system is undergoing radical transformation, but the importance of hospitals to the healthcare delivery system has not been decreased. Hospitals provide the institutional heart for any new integrated community or regional delivery system. They provide the infrastructure to implement and manage system-wide services - especially those which require sophisticated development and support.

The existing involvement of hospitals in the medical imaging field is mostly an artifact of their autonomous past. With a few notable exceptions, hospitals have tended to act individually on acquiring and implementing medical imaging technology. In many cases, capital acquisitions have been funded by extraordinary means including specialized government grants, private sponsorships, and community fund-raising. This approach has tended to re-enforce the pattern of local decision-making by hospital boards and staff.

This situation is, however, rapidly changing with the pressure on healthcare expenditures throughout the developed world. Hospitals are increasingly acting together on a community or regional basis and their associations are becoming more active as true costs and benefits of using advanced medical imaging technologies are becoming better understood.

4.5.8 Health Delivery System Managers

Healthcare delivery involves large and increasingly visible costs. How these costs are funded varies by political jurisdiction, but the need to control costs is universal. Since most of the population (at least in the developed world) rely on health insurance, the need for cost control places a heavy responsibility on the managers of healthcare delivery systems whether these are public or private agencies. In some respects, provincial medicare systems in Canada are the ultimate HMOs operating without competition but with a complex set of political influences.

In order to provide a standard of care within limited resources, health management authorities need to understand the changing medical technology environment and attempt to shape and direct technology to serve their service/cost objectives (e.g. in the implementation of enterprise PACS systems and the concentration of specialized radiology resources). While there are exceptions, it would appear that most systems managers have not yet fully understood this need.

4.5.9 Governments

Governments in jurisdictions like Canada which administer publicly funded medical care systems have a direct responsibility in setting the medical and financial standards which the system managers will follow. Even where this is not the case, however, government health authorities maintain an overall responsibility for health policy and the health regulatory framework. Their interest would definitely encompass the introduction of new technology which has the potential to radically alter the delivery of healthcare services.

From an industrial point of view, governments in all western economies maintain an interest in the development of the healthcare industrial sector since it is such a large component of domestic expenditures and an equally important export trade opportunity.

The involvement of governments in Canada is complicated by the jurisdictional divisions. Setting regulatory standards for telecommunications and for medical devices is a federal responsibility while the rules which govern the funding and use of medical imaging systems come for provincial jurisdictions. Within governments, there is also a need for coordination between those agencies responsible for healthcare and those responsible for the promoting the industrial opportunities inherent in the healthcare sector.

4.5.10 Consumer/Patient Advocates

There is no clear evidence of a strong patient advocacy or consumer interest in the MI field at the present time. However, there are consumer/patient issues that will effect medical imaging.

Obtaining specialty imaging equipment for local hospitals is a key public issue. Acquisition of CT or MRI equipment has often come as the result of community campaigns at local hospitals. Accessibility of the equipment is also a key issue. Waiting lists for equipment can be over half a year while funding constraints can mean that in some cases the equipment is only used 40 hours a week (sitting idle 16 hours a day and all weekend). As the availability and accessibility issues ferment, community (patient) discontent may strengthen.

Exposure to ionizing radiation in X-ray and nuclear medicine is another issue which has the potential to result in consumer concerns. In some cases, such as CT, the radiation dose is increasing while the recommended exposures are dropping. The presence of ionizing radiation also tends to minimize the use of imaging as a low risk screening mode.

Another issue which could increase consumer/patient concern is the impact on patient privacy of new data storage and retrieval systems. This issue is likely to be hotly debated as centralized digital information systems are introduced and as current changes in the delivery of healthcare de-personalize the system or reduce the relationship of trust between the patient and the physician (and the physician and radiologist). This issue is in fact larger than medical images and relates to electronic patient records and telehealth in general.

4.5.11 Canada’s Medical Imaging Sector

Canada’s medical imaging sector tends to be located in metropolitan areas including: Toronto, London, and Montreal. There is also activity in other areas including Winnipeg, Vancouver and Dartmouth. Industry Canada’s recent publication “Canadian Capabilities in the Medical Imaging Sector” (Industry Canada 1997b) posted on their website “Strategis” (strategis.ic.gc.ca) provides a list of known Canadian manufacturers of imaging and related products. Many are innovative niche players in the hardware and software sides of the industry which evolved as outgrowths of the research universities/teaching hospitals in their respective regions. Most of the multinational MI equipment manufacturers are represented in Canada by sales and marketing subsidiaries. There is no significant manufacturing operation by these firms in Canada. Appendix VI provides selected lists of both academic and industrial players in this sector.

What is perhaps most remarkable about Canada's commercial medical imaging sector is its potential for expansion. This potential is latent in the Canadian entrepreneurial talent available with medical, software, and telecommunications skills. The path has already been mapped out by several innovative niche players as mentioned above, but their numbers could be greatly expanded by closer contact among the medical and IT communities in exploring commercial opportunities. The irony is that it is very difficult to identify potential interest that does not yet exist - either by existing companies operating in other IT fields, or by the creation of new companies. In this fluid and evolving situation, the biggest challenge is to find ways of improving the level of contact and collaboration among a wide range of potential medical and IT interests so that they can begin to identify and actualize specific medical imaging opportunities.

5. Identification of External "Drivers"

To date, medical imaging has developed along lines which have been strongly guided by the medical profession, radiologists in particular, and by relatively few large international companies which dominate the complex and expensive medical imaging equipment market. Will this pattern continue into the future? If not, what will likely be the changes? How will these external forces affect the ability of medical imaging to achieve the potential outlined above?

To answer these questions, it is essential to identify and to analyze the external forces which will affect the medical imaging sector.

5.1 Political Drivers

Healthcare is a major political issue in every jurisdiction in the developed world since it intimately affects every citizen at many points in their lives. How governments address this issue will affect the paths by which technologies are developed and commercialized.

5.1.1 Healthcare Policy

Healthcare policies in the industrialized world are being heavily influenced by cost considerations. The cost of the healthcare system, whatever its foundations, is however essentially an "insiders" issue. For the general population, accessibility, quality and affordability are the prime concerns. Medical imaging has the potential to assist with all of these concerns. The challenge is that it will take up-front investment in both financial and change management terms to achieve the benefits.

Health research and pilot project funding will be important but the most important public policies will likely be those which establish and govern the management of healthcare delivery. In the United States, the private sector (and increasingly the HMOs) will perform this function. In a jurisdiction with public healthcare, like Canada, the growth of medical imaging will depend on the extent to which public policy makers can understand and commit to this solution among the many that are offered to them. In Canada itself, the situation is further complicated by the fact that healthcare delivery falls under provincial rather than federal government jurisdiction.

At the delivery level, especially in the United States, the slogan “Managed Care” is increasingly being used. Observers believe that its use is evidence of a system which has lost sight of its primary objective - quality care - in its enthusiasm for cost control. The implications for medical imaging are mixed: strong interest where a cost-effectiveness case can be made, but a reluctance to invest in solutions which do not have an immediate financial pay-back.

At the heart of the healthcare policy dilemma is the reality that innovative new programs which have the potential to contribute to better care at lower cost require capital investment and some acceptance of risk in adopting new approaches. The current health policy climate in most developed countries is not only risk averse but it is heavily influence by a “spending cap” approach to financing which inhibits any ability to spend now for future benefit. There is little evidence that governments will quickly develop more sophisticated methods of determining the value of public healthcare investments.

5.1.2 Industry and Technology Development Policies

In addition to the healthcare support policies of governments, the future of medical imaging will be affected by public policies supporting economic development -particularly the development of advanced technology industries. There is considerable debate in Canada and elsewhere as to the effectiveness of such policies, but there is no doubt that industry location can be affected by a combination of policies including: tax incentives; access to research capabilities; the availability of a talented workforce; and quality of life issues.

Canada has traditionally operated at a disadvantage in R&D. For many years the United States has used defense spending as a massive pump-primer for the commercialization of technology. Public expenditures by Japan and European countries on pure and applied research infrastructure have also exceeded those in Canada for many years. On the other hand, while Canada has a low per capita spending on R&D, it has the lowest cost of R&D in the G7 as a result of R&D tax credits and other incentives.

In the political and financial environment of the approaching Millennium, there does not appear to be any significant potential for a strongly interventionist approach in this area. The risk for Canada as a small player internationally is that Canadian industry will be fragmented and leaderless in a world of larger, more organized national industries.

Regulatory Environment

The regulatory environment created by governments both affects and is affected by healthcare and industrial development policies. Regulation can have a strongly negative effect when it fails to address the differences among governments' objectives.

The sale of medical devices in Canada is regulated by the Health Protection Branch of Health Canada. Canada's regulatory system for medical devices has been seen as less rigid than that of the US, allowing sufficient latitude for experimentation that a number of the large multinational OEMs have piloted new technology in hospital settings and research institutes within Canada ahead of its introduction in the United States. Contributing factors to conducting these trials in Canada have also included the excellence of Canadian researchers and the absence of extreme litigiousness such as exists in the U.S. healthcare environment.

Health Canada is in the process of converting to a system of regulation based on risk classification of the device, with higher-risk devices being subject to relatively greater regulatory scrutiny. This change is in keeping with international trends, and is an enabling factor in the Mutual Recognition Agreement which has been negotiated with the European Union for the regulation of medical devices, as well as a number of other product areas.

At the same time, Health Canada proposes to introduce a second phase of cost recovery for the regulation of medical devices.

Critics have expressed the view that the system as proposed is too expensive for the size and low profit margins of the cost-squeezed Canadian medical devices market. This factor, combined with uncertainty and higher barriers to market entry relating to proposed changes, has resulted in concerns that the program will inhibit the adoption of medical technology innovation and investment in Canada.

Proponents of the proposed system say that cost recovery will put the regulatory system on a more efficient, business-like basis, and that the revenue is needed to support the risk-based system, which in turn assists with international harmonization efforts and reciprocal agreements.

The trend in telecommunications regulation is almost entirely in the opposite direction. The CRTC is pursuing a policy of deregulation in the cost of long distance telecommunications services which are needed to match the situation in other countries where competition has had a dramatic effect on pricing and competition. The implications of this development are positive in terms of the trend for the pricing of the broadband services that medical imaging requires. It also means that Canadian developments will be increasingly sensitive to international competitive forces in this field.

5.2 Economic Drivers

The economic forces which will shape the evolution of the medical imaging sector over the next five to ten years are closely connected to the political drivers, especially through the issues of cost and affordability, but they extend beyond them to cover the questions of international competitiveness and labour force availability.

5.2.1 The International Marketplace

The trend towards reduced trade barriers of the last few years shows no signs of changing. This means that the marketplace for medical imaging technology is likely to be subjected to even more international competition than it is at present.

Multinational companies are likely to continue to dominate the imaging equipment marketplace through their access to the investments required to introduce sophisticated new hardware and their world-wide distribution capabilities.

This dominance will be affected by the evolution of performance standards, notably the DICOM standard, which will reduce the dependence of purchasers on a single supplier. The result may be some volatility within the large multinational supplier group, with the evolution of a very small group of world dominating players and another group of aggressive “wannabees” ready to move up if the leaders falter. This will make innovative technology breakthroughs a potentially critical factor for this group of international players. It will also likely lead the dominant OEMs to spread their risk in the same way multinationals have done in other sectors by concentrating on their own core businesses and partnering with other smaller companies to provide a broader range of services.

The evolution of borderless commerce will also affect the smaller players as it becomes easier to compete in foreign markets at the expense of facing competition at home. Business and product reputations will increasingly have to be developed on the international stage.

For the very smallest companies, including start-ups with innovative technology, the opportunity - and the potential necessity - of forming international partnerships will increase.

5.2.2 Paying for Healthcare

The trend internationally is towards reducing hospital stays ($500-900/day/patient) due to cost savings and evidence of positive effects on patients (they tend to take more responsibility for their recovery). The need is for faster decisions. Faster decisions will occur when access to information is readily available. Information management is a huge cost - 1/3 of hospital personnel's time is spent tracking information. PACS is expected to provide cost savings. The major hurdle is the need for capitalization.

With all of the focus on affordability, the funding of medical imaging developments will increasingly have to provide well documented cost savings over existing systems. This will affect both operational and capital budgets. This does not mean that the money will not be available for innovation, but that the researcher/clinical enthusiast will not be driving the pace of innovation.

Operating budgets are likely to be particularly constrained in a "managed care" model system. The problem is that often "best practices" are seen to be in conflict with cost control, especially where caps or arbitrary cost reductions are imposed. This current unhealthy environment for the introduction of new technology is unlikely to moderate until pilot situations provide hard evidence of the short term financial benefits of technological innovations and as ongoing pressures on the health delivery system makes it ever more dependent on the contributions of technology to provide cost and quality performance.

One major opportunity to demonstrate reduced costs will be in getting the patient the right treatment the first time. For example, a study of patients from rural communities who were transported showed that 25% of transfers were not necessary and transportation costs for these transfers alone could total millions for some health districts, not to mention reducing trauma to the patient. The drive to best practices is in conflict with the narrow departmental view imposed by cost cutting and non-interacting jurisdictions. For example, if the best practice involves a larger expenditure from "your budget", you may favor an alternative mode which shifts the financial burden to another part of the healthcare system.

Telemedicine is expected to play a major role in reducing costs and improving efficiencies. Actualizing this vision will provide significant opportunities to the industry, especially those that offer networking expertise, consulting experience, data storage, etc. The roll out of teleradiology will depend on the availability of decentralized equipment to allow for remote imaging. This will be less of an issue for lower cost (e.g. ultrasound) and widely available (e.g. X-ray) technologies, but will be more of an issue for MRI, CT and nuclear medicine where installation of the equipment is very limited and long waiting lists already exist. In the short term, moving the patients instead of the digital images may be the only alternative.

As the benefits of medical imaging applications (e.g. enterprise-wide electronic information including PACS installations) are documented, it should become easier to acquire the capital necessary to make the investments that will yield long term operational cost reductions. Given the preoccupation of governments with expenditure and debt reduction, for the foreseeable future this capital is more likely to come from private investment than from public sources. If funding is not available for new systems implementation, development of new product will slow. For example, teleradiology cannot be introduced unless medical imaging equipment is distributed across the network.

Most of the early PACS implementations have been analyzed to examine the cost effectiveness and other savings compared to staying with film. The studies are complex and some early implementers found the initial costs high and payback lengthy; currently the cost justification of PACS has been well established, thus it is clear that PACS implementations will accelerate.

Investment in new technology will also be facilitated by the full implementation of common standards, which will make it possible to add and upgrade between suppliers rather than be tied to a single company's products.

5.2.3 Outcomes Analysis

The digitization of medical images and the entire patient record enables the ability to perform outcomes analysis which will allow one to do cost-benefit and productivity-effectiveness analyses. On a microscale, the quality of a radiologist's diagnoses can be monitored by following patient outcomes. On a macroscale, the effectiveness components of the therapeutic process can be determined by data mining electronic databases of patient records.

The outcomes analysis approach will allow one to examine healthcare delivery in its entirety and look for interactions which can drive improvements. In that healthcare is paid for by the governments in Canada there is greater potential for outcomes analysis to drive the system. In the US, the insurer pays for the treatment but may not receive the benefit (e.g. a healthy patient who returns to the work force). In that Canada pays for both healthcare and other aspects of the social safety net, improving patient outcomes in the broadest sense benefits the insurer (the government).

5.2.4 Workforce Requirements

A critical factor in the evolution of the medical imaging sector will be the availability of a trained workforce.

The most critical workforce shortages are likely to occur at the level of senior scientists and engineers engaged in product design and engineering. As with almost every other high tech industry, the medical imaging sector will increasingly rely on software expertise to exploit the potential of the technology. Currently, medical and software design skills are rarely combined in the same individual. In the short term, this means that successful innovation will require the formation of close working relationships among individuals with very different skill sets and backgrounds. In the longer term, training institutions in the medical imaging field will have to come to grips with the same challenge facing many other sectors which are being profoundly affected by the use of information technology. They will have to produce subject experts who also have advanced IT skills.

Skill shortages will be less of a problem at the user level. The issue here will likely not be one of absolute shortages but of imbalances between jurisdictions. For example, radiologists are currently in short supply in the U.K. but not in North America. These imbalances may also lead to increased pressure for the development of skilled non-medical image specialists (called "Radiographers" in the U.K.), which in turn will further complicate the workforce situation.

In addition, many new radiologists are still being trained entirely on film-based technologies as opposed to digital images. This training gap is likely to be overcome within the next several years as teaching hospitals are able to upgrade their equipment, but it will mean a further lag time in changing the skills and the culture of many existing radiology facilities.

As teleradiology systems are introduced, they are likely to reduce the number of radiologists required by providing the services of image diagnostic specialists over a wide area by centralizing them in a single pool or distributing them among member communities with centralized access.

5.3 Social Drivers

5.3.1 Demographics

In the developed world, an aging population is increasing the need for healthcare. Life expectancy, doctors per population, and per capita healthcare spending are all generally higher in more affluent countries and directly affect the costs to the healthcare system. As the developing countries become more affluent, they will similarly place increased demands on their healthcare systems.

The Third World tends to have a much younger population and is still underserved by medical imaging technology. It is likely that demand for traditional radiography will continue longest in developing countries because they offer high resolution images at low cost. It has been suggested that the other modality which best meets the needs of Third World medicine is ultrasound. As developing countries find themselves able to invest in medical imaging technologies, integrated ultrasound systems may be the route that they choose.

Access and Timeliness of Care

As noted above, healthcare cost is really an issue for government and management. It is an abstraction for the general population of actual or potential patients. In the current environment of deficit and debt reduction, patients and their families may put up with poorer service for a time, but the motivation and the latent demand for accessible and timely service remains. As people's perceptions of the severity and the success of cost cutting change and as popular images of the potential value of new technologies grows, there will likely be a strong resurgence of demand for more and more widely available medical imaging. In other words, there is likely to be a shift in the public perception of advanced medical imaging technologies from being experimental luxuries to becoming basic essentials.

Emphasis on community based healthcare services is likely to stimulate this trend as communities, even remote ones, accept the idea that access to the most advanced services is not only technologically possible but a right.

5.3.3 Healthcare Consumerism

At the same time as public expectations of medical imaging increase, they are likely to be matched by a growing tendency of patients to understand, influence and even control their personal healthcare services. Doctors and other health professionals have retained their credibility levels with the general population longer than most other professional groups, but there are strong signs of change. Evidence includes the enormous growth in popularity of homeopathic and other non-traditional forms of medicine and the phenomenon of the popularity of health based internet sites. Stories of the detailed interrogation of physicians by their patients based on in-depth surfing of the Internet have become modern clichés.

Much of the change has been fuelled by real or perceived loss of service and of personal connections between patients and their doctors. These trends are likely to continue as the healthcare systems in every developed country continue to face massive change.

The implications of these developments for medical imaging are not clear, in large part because medical imaging has had the reputation as being a complex, esoteric field inaccessible except through expert medical interpretation.

While it is hard to be precise about the implications of healthcare consumerism for the medical imaging sector, it is not difficult to foresee that radiologists will have patients and their families looking over their shoulders at the same images that they are interpreting. Communicating the rationale for a diagnosis may become as critical a skill as forming that diagnosis. There may be an important market for the development of interpretative and communications tools to enable the patient/family to make treatment decisions.

Privacy Issues

The issue of personal privacy is already and will remain a critical external driver wherever sensitive health information is involved. This stated, neither the issue nor its potential solutions are primarily contained within the medical imaging field.

Medical images by themselves are not especially sensitive. It is when they are identified with a person and integrated with other forms of patient related information that they become an issue. This means that privacy will be a major challenge in the move to enterprise systems which integrate medical images with the rest of the patient record. The solutions to this challenge are certain to fall outside medical imaging and are likely to come from outside of the healthcare field. Other sectors are already much further advanced in addressing confidentiality. These include national defense, major corporations and the banking community. Assuring security of information is already a major limiting factor in the development of internet based commerce. These technologies as they evolve will undoubtedly require adaptation to the healthcare sector, but they are not likely to provide a severe impediment in a society which is already heavily committed to develop the safeguards that are needed for a networked society.

5.4 Technology Drivers

5.4.1 Innovation Overview

Information and communications technologies are advancing quickly. Issues around storing, processing and transmitting large data files (images) are important to many sectors and should be resolved shortly.

As imaging techniques become more “real-time”, their therapeutic application will increase. As the cost of the techniques decrease, their application as screening technologies will increase.

5.4.2 Image Generation

Besides optical imaging techniques, no radically new energy forms for image generation can be seen on the horizon. Advancements and refinements in current technologies is more likely. For example: i) reducing the cost of MRI, which currently offers high resolution images and is safe; ii) expanding the use of MRI as an interventional (therapeutic) tool; iii) improving the resolution of ultrasound, which is safe and inexpensive, via contrast agents; iv) development of CT scanners into 2D and 3D; v) tissue characterization; vi) inverted X-ray imaging, and vii) developments in PET.

Passive detection via MEG/EEG systems is also gaining acceptance and competing with MRI and CT technology.

Image Capture

Several developments are taking place in this area. Direct Radiology (DR), which involves converting X-ray patterns directly to digital information without the need for cassettes, is just emerging. Flat panel digital detection is almost commercial (although the dose is still a bit high). Ultrasound is moving towards 2D arrays. PET detection technology needs improvements in speed and signal-to-noise ratio (faster electronics or better images at the current speed). CT is moving towards multiple detectors and 3D CT systems are expected to revolutionize image acquisition.

5.4.4 Storage & Retrieval

This area will be driven by non-medical (mass market) developments. Since the technology available elsewhere will be used by the medical imaging field, this area will not be discussed in detail for this report. Speed and cost remain the biggest issues for high volume data applications such as medical imaging.

ALI Technologies has been successful in the development of mini-PACS focused on a single modality (ultrasound), while others such as Mitra have focused on interface engines to facilitate connectivity between modalities, RIS and PACS. In general, the cost effectiveness of PACS goes up with the size of implementation and integration with the other hospital records systems. As the implementation size goes up, so do the difficulties.

5.4.5 Display

Developments in this area will be driven by other markets and thus not discussed in detail.

Image fusion and surgical applications are and will continue to be made possible by advances in other information technology areas, particularly entertainment, where 3D visualization and virtual reality developments are taking place.

5.4.6 Transmission/Connectivity

Centralization of high-tech diagnostic resources is the model being followed the most. Medical imaging really pushes the envelope in terms of the amount of data involved and the speed at which it is required. Cost per byte (not bandwidth availability) is a dominant issue. Thin client technology will also change the accessibility of information.

DICOM and HL7 standards are key to the development of the medical networking sector. The continued development of the industry hinges on vendors continuing to co-operate in the development of common International standards.

Several questions remain outstanding:

- How quickly will HL7 and DICOM merge/integrate?
- How will the competition between CORBAmed and ActiveX play out? These are competing solutions. CORBAmed supports CORBA, IIOP, and Java and has been adopted by Sun, Oracle and Netscape. Microsoft's Healthcare User Group (MS-HUG) - is using ActiveX technologies (an alternative to Java) to develop a standard to ensure compatibility between Microsoft programs. ActiveX creates OLE protocols for application-to-application information exchange and communication
- What about the role of interface engines (e.g., AWG's developments)?
- How will production of 3, 4 and 5 dimensional image datasets and the increasing need to combine images from different modalities be addressed in the standards. The Montreal Neurological Institute has developed an image format and processing environment which addresses these issues and it may serve as a starting point for the development of an appropriate standard to be used in conjunction with DICOM.
- How will we handle intercity/provincial networking - what systems will be used (satellite links, microwave links), what needs to be in place?

5.4.7 Analysis

There are tremendous opportunities in this area for Canadian companies in image enhancement, image integration and modelling. Image recognition is highly modality and organ/region specific. It is not something that will likely be addressed by a single software application. There are huge opportunities for the development of niche software applications in this area and the multinationals are unlikely to develop their own software products beyond general tools.

As computing power and storage capacity increase, the use of PACS and three-dimensional images will also increase, creating tremendous opportunities for the analysis side of medical imaging. For well-defined organ systems or where a history (expectation) exists, computerized recognition might be possible, thus enabling a move towards computer diagnosis rather than simply computer-aided diagnosis.

Applications such as functional MRI require a tremendous amount of data analysis combining statistics, anatomical atlases, and the challenge to link what has been stimulated within the patient to the measured outcome. These capabilities also need to be packaged for use by the clinician.

The holy grail of image analysis would be computerized diagnostics where the system interprets the medical image without the need for radiologist/clinician intervention. While this goal is a distant target in the global sense, there will undoubtedly be progress towards it to varying degrees in specific modality/organ/disease niches. This progress will typically be in tools which will aid and direct radiologists and others in the identification and delineation of medical images.

Security Technology

Security is a major issue for all integrated systems which contain confidential information. Since this technology will be driven by forces outside of medical imaging and are encompassed by discussions on such topics as telehealth and enterprise-wide information systems, it will not be discussed in detail in this report.

5.4.9 Year 2000 Issues

The Year 2000 problem transcends all information technology applications. It refers to a family of problems relating to the inability of legacy (old hardware and software) systems to deal with the turn of the century due to 2 digit coding of years. Its implications to the development of medical imaging are only tangential but it may still have an impact. Ensuring Year 2000 compliance of all hospital systems will consume significant hospital IT resources and hence draw attention away from electronic integration issues which will be required to enable the progress of digital implementation in hospitals. Conversely, it could conceivably increase the adoption of new equipment and technology if replacement is the major route to addressing this problem. The replacement option is hampered by its high cost. While the effect of the Year 2000 problem may be to slow implementation, it will not affect opportunities and issues raised in this report in the long run.

6. Analyzing the Drivers

The previous section has identified the various forces which will shape the future of medical imaging. This section attempts to build a framework for assessing the ways in which this is likely to occur.

Projecting the future of rapidly evolving technologies is never an easy task. It becomes increasingly difficult the further into the future the projection is extended. For this reason, we have taken two different approaches to projecting the future of medical imaging. The first looks at changes to the current situation based on the potential introduction of new technologies during the next five years. It involves reviewing the potential technology-driven developments which were identified in Section 5.4 against the political, economic and social drivers identified in Sections 5.1, 5.2, and 5.3 to answer three questions:

1. Will the *technology* be mature within the five year horizon?

2. Will the *market* be ready to use the available technology?

3. How *significant* would be the impact of the introduction of the new technology?

The second approach to analysing the future of medical imaging concentrates on the longer term, five to ten year time horizon. It builds upon the likely developments of the next few years, but introduces a larger scale, more speculative approach based on how technology might be expected to evolve beyond its existing horizons in response to external needs. In effect, this approach is the reverse of the previous one, in that it starts with selected external scenarios and speculates upon how technology might evolve to meet these needs. It would be foolhardy to suggest that such an analysis can be comprehensive in its scope since it is inherently speculative. Its purpose is to stimulate discussion of overall directions rather than to attempt to make firm predictions.

6.1 One to Five Year Horizon

The analysis which follows is divided on a similar basis to the discussion of the future of the technology drivers in Section 5.4. At the end of each discussion there is a summary ranking of the answers to each of the three questions listed above. The ranking scale (H-high, M-medium, L-low) is a subjective assessment based on the text analysis.

4. For ***Technology Availability,*** the ranking estimates the likelihood of the new technology discussed in that section being mature (or at least reliably and widely available) within the five year horizon.

5. For ***Market Readiness***, the ranking estimates the probability of the marketplace being ready to exploit the new technology if it is available during the five year horizon.

6. For ***Overall Significance***, the ranking indicates how significant the implications for the whole medical imaging sector would be if the technology was widely adopted in the marketplace.

<u>Interpretation of Rankings:</u>

By way of example, a ranking of :

Technology Availability	Market Readiness	Overall Significance
L	**M**	**H**

would indicate that the technology under discussion is still not close to commercialization although there is already some need for it in the market place and it will likely have a very significant impact when it does become available. This might represent a technology which is still in a research institution but which would gain market acceptance at a reasonable rate and have an enormous impact when fully commercialized. The expectation for 2-D direct X-ray detectors a couple of years ago serves as an example.

Conversely, a ranking of:

Technology Availability	Market Readiness	Overall Significance
H	**M**	**L**

would indicate that the technology is or will shortly be readily available, that there is some demand for its application in the marketplace, but that it will not have a significant effect upon the development of the medical imaging sector as a whole. High resolution monitors would be a specific example.

6.1.1 Image Generation

There do not appear to be any entirely new technologies on the horizon which would expand the current set of imaging modalities (radiography, CT, nuclear imaging, MRI, and ultrasound). This being the case, the short term future is likely to involve continued development of these existing modalities and changes in their use based upon these improvements (e.g., fMRI, 3D ultrasound).

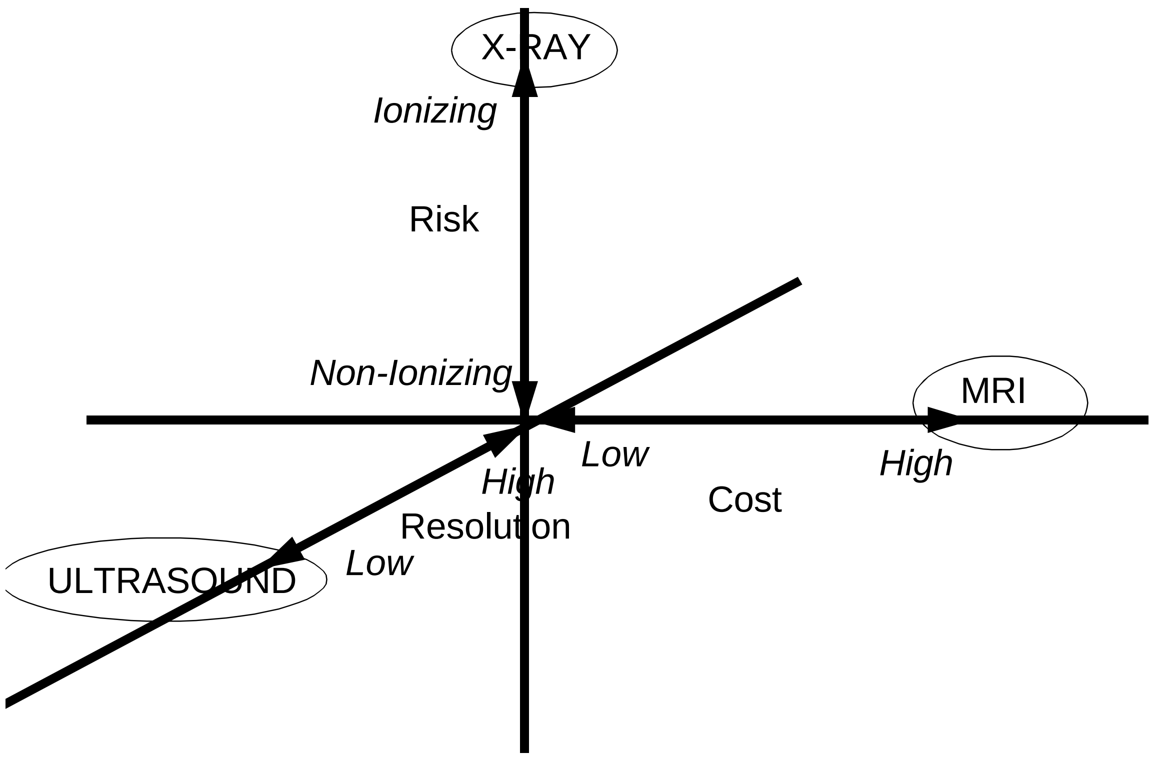
Effect of External Drivers

The external issues affecting improvements in image generation can be summarized on a three dimensional graph which plots cost, resolution, and risk (as shown on the next page).

It would appear that the longer term future potential lies most strongly with MRI and ultrasound - the two modalities that do not involve ionized radiation with its potential for negative effects on the patient.

The challenge with MRI technology is to reduce the cost of the hardware and the complexity of its use. It can be anticipated that current improvements in the design and performance of so-called midfield scanner systems (0.1 - 0.5 Tesla) will continue to reduce costs and expand the use of this equipment.

The challenge with ultrasound is to improve resolution. Improvements in the design of scanning heads and in the introduction of new contrast media are likely to be the key developments which will occur.



It would be simplistic to rule out the potential for improvements in the other ionizing media. The development and use of new organ specific contrast media which improve image capture at lower doses of radiation will reduce if not eliminate the adverse impact on the patient. While improvements in MRI and ultrasound technologies may gradually replace much of general radiography, this process will not be complete within the 1-5 year time frame - especially in parts of the world where low cost X-rays provide the only affordable option.

Ionized radiation based systems will not disappear. In fact, recent market history and projections do not show significant shifts in the industry mix for imaging. Efforts will continue to find ways to reduce dosage levels for traditional radiography and continued and increasingly specialized roles will likely be developed for CT and nuclear medicine technologies.

Commentary

The foreseeable future for image generation likely involves significant improvements to existing image modalities, both to reduce costs and to increase the resolution of the images generated. These changes are not expected to have a fundamental impact on the direction of the sector as a whole, but they will provide the improved image base which will allow the further development of the sector.

Technology Availability	**Market Readiness**	**Overall Significance**
H	**M**	**M**

6.1.2 Image Capture

The most immediate issue related to the technology of image capture is the conversion of radiography systems to direct digital capture. A second issue involves the improvement of detection devices to allow for multi-dimensional data input to support the display of three dimensional images in real time.

Effect of External Drivers

The pace of conversion to direct digital capture will be driven in the short term by cost/effectiveness considerations. The funding of healthcare systems internationally no longer allows for major investments in new or upgraded technology without strong justification. In practical terms, this means that the move to digital capture will be governed by the implementation of broader PACS storage and retrieval systems.

The development of improved detection devices will be encouraged by the move toward using 3D (and up) analysis and display technologies. There will likely be considerable room for the introduction of innovative technologies in this field.

Commentary

In summary, technologies in the image capture field can be expected to move ahead but at a slower pace than most researchers would wish. The shift to direct or indirect digital capture should be more than half complete within five years.

Technology Availability	Market Readiness	Overall Significance
H	**M**	**H**

6.1.3 Storage and Retrieval

The underlying technology for storage and retrieval is not unique to the healthcare sector. Database technologies are expected to advance rapidly and should not impose any impediment to the implementation of health applications.

Implementation of PACS systems at the hospital-wide level is already accepted as current technology. The major opportunity for significant change in this field within the time horizon will be with the large scale implementation of "enterprise systems" which involve the full integration of image storage and retrieval within a comprehensive electronic patient record system.

Changes affecting this aspect of medical imaging are likely to be incremental, yet the creation of comprehensive digital image databases is another essential precondition for further development of medical imaging technology.

Continued progress in the elaboration and use of the common DICOM standard is an essential requirement for the development of improved storage and retrieval systems.

Effect of External Drivers

The pace at which new systems are introduced will depend on the capacity of hospitals and healthcare systems to cost justify implementation of digital-based image storage and retrieval systems. The issue is complicated by the fact that the strongest justifications will be for those broad-based systems which are costly and complex to implement on the broadest base possible. The availability of the capital required to implement these systems (direct or financed) will obviously be a restraining factor.

While the cost effectiveness of PACS was questioned in the past, new installations are emerging as commercially viable. Whereas many of the old implementations were discounted supplier alpha and beta sites, today suppliers are including assurances of cost saving over film and/or the ability to pay as you use the system in their sales approach, which indicates that there is a high degree of supplier confidence in the cost effectiveness.

Another factor which may affect the pace of implementation is the need to demonstrate control of access to information, especially when linked to a specific patient. Like database technology generally, data security technology is also being driven by forces much broader than the healthcare system and will provide a range of innovative solutions, but public sensitivity to *perceived* issues of confidentiality and privacy are particularly acute in the health sector. To date, there has not been any significant public concern expressed about the security of the few centralized image storage and retrieval systems which exist, but, as implementation spreads, a few high profile cases could change this picture.

Commentary

Implementation of institution-wide PACS systems is likely to be substantially complete within the five year time horizon where digital images are available. By that time, full integration of medical images into electronic patient records will be an accepted next step, but implementation may still be spotty.

Technology Availability	Market Readiness	Overall Significance
H	**M**	**H**

6.1.4 Transmission/Connectivity

The potential for sharing medical images over networks holds enormous implications for the development of the sector. As with database technology, the incentives for the development and implementation of telecommunications technology are much broader than just the healthcare community.

Effect of External Drivers

Introduction of networks which will share medical images over large geographical distances is not a technology issue. The technology is available today and pilot teleradiology systems are currently underway across Canada. The critical factors are standards, pricing, and the structure / incentives of the healthcare system.

The standards issue is much the same as for other aspects of medical imaging. It involves the ongoing development of medical imaging standards (DICOM) and integration of these standards into the evolving standards of the telecommunications world.

Pricing is a matter of control by national telecommunications regulators. In general, deregulation of services and prices is occurring but the policy framework and the pace varies from one jurisdiction to another. In Canada, the Canadian Radio, Television and Telecommunications Commission is adjusting the regulatory environment at a pace which many find to be too slow to allow the rapid introduction of innovative services, especially those which require high bandwidth. For this reason, many of the existing pilot networks are extended local or "campus" installations which do not use public telecommunications services.

The organization of the healthcare system is a more serious problem. The structure and incentives built into the healthcare delivery system must be such as to encourage and reward the adoption of cost-effective teleradiology. The process is more advanced in the United States (half of the world market) than in Canada, but issues of regional co-ordination of service, incentives for cost reduction, and the availability of front-end funding to implement new systems remain important issues in all jurisdictions.

It is worth adding a specific note on the use of standard bandwidth Internet technology for medical imaging purposes. It is possible now for doctors to receive medical images on their home computers using dial-up connections. The potential for expanding this capability as the technology improves rapidly over the next few years is very strong. The incentive will be to improve the diagnostic service and opportunities for medical consultation while also respecting the lifestyle of overworked professionals.

Commentary

Use of broadband telecommunication networks to transmit and link healthcare sites will become widespread over the next few years, but the necessary changes in the organization of the health delivery system - and particularly the incentives for cost effective use of broadband networks will continue to be a limiting factor.

Technology Availability	**Market Readiness**	**Overall Significance**
H	**M**	**H**

6.1.5 Image Integration (Image Fusion)

Image integration involves forming objects out of multiple images. It allows them to be compared and assembled into composite views which can then be modelled and manipulated in multiple dimensions. Real time integration and manipulation of objects offers particular opportunities for "practice" surgery and image guided therapy.

Effect of External Drivers

The nature and pace of improvements in the integration of medical images will be affected indirectly by the growth of image databases and networks which will facilitate more sophisticated analysis.

Commentary

The development of specialized software-based tools for the analysis of medical images holds great potential for the next few years. This potential is based on the relatively low cost of developing such tools and their ability to add high value to the use of medical images for diagnostic and therapeutic purposes. The pace of these developments will be somewhat dependent on the implementation of the underlying image collection, storage and transmission systems.

Technology Availability	Market Readiness	Overall Significance
M	**M**	**H**

6.1.6 Object Identification

With object identification, the aim is to improve the ability of the technology to automatically locate and identify objects (e.g. organs, tumours, blood vessels) within images. This is not a simple task since it is often difficult to differentiate boundaries, membranes and subtle tissue changes contained even in high resolution images. The recognition of objects within images is one of the quintessential functions of a trained radiologist.

As noted in previous sections, computers excel at refining and elaborating information. Their weakness has been in recognizing significance. Nevertheless, there exists a considerable platform of experience in computer-aided mapping of objects once a radiologist has identified an object.

Progress in this area will be dependent on advances in the field of artificial intelligence which, when perfected, will greatly increase the potential for the development of a host of specialized (organ and disease specific) object identification capabilities. Hopes for breakthrough developments in the artificial intelligence field are less optimistic, at least for the short term, than they have been in the past several years.

Effect of External Drivers

The prospect of automating the identification of objects in medical images is likely to be seen as a threat by those whose livelihood involves the identification and interpretation of medical images. Their opposition combined with the immaturity of the underlying technology is likely to act as a significant drag on innovation in this area.

Commentary

The effect of a breakthrough in automating the identification of objects in medical images would be very significant. It would enable vast amounts of information to be read and compared. It would alter - but probably never eliminate - the role of the expert human image reader. It would allow medical images to be much more widely used and understood, at least within the medical profession. However, given the slow progress of fundamental research in Artificial Intelligence, practical breakthroughs are not likely in the next few years.

Technology Availability	**Market Readiness**	**Overall Significance**
L	**L**	**H**

6.1.7 Visualization

In many respects, visualization (or user interface technologies) are the least developed component of medical imaging. This is not surprising given the film-based origin of the field and the fact that the radiology profession has concentrated on developing 3D interpretative skills based on 2D film and film-like displays. While experimentation is occurring in the field, it is estimated that the majority of radiology students are still being trained on interpreting the shades of grey in film-based technology.

Technology is not a limiting factor in this situation. Many other industry sectors are using sophisticated display technologies that use 3D, colour, real time, interactive display capabilities on a routine basis for design and animation of models. Enriching the user interface even further - for example by adding auditory and tactile data - is within the capability of current virtual reality display technology. In order to exploit these opportunities, development will be required in data gathering and data interpretative software, but even these changes are beyond the technology horizon.

The greatest impediments to taking advantage of the full range of available - and rapidly evolving - display technologies lies with the user interface.

Effect of External Drivers

The direction and pace of change in MI display technology will be driven by two human-dependent factors: changes in the way image interpreters are trained and the introduction of standards for the uniform presentation of these new rich forms of information.

One fundamental issue is how - or whether - the radiology profession will adapt to this challenge. There is already pressure from two different directions. On the one hand clinical specialists are becoming increasingly sophisticated in their use of current images. Additional display features that enable them to recognize and manipulate images will be attractive to many of them. Surgeons are already beginning to understand the value of imaging-based virtual reality tools for diagnosis, for virtual practice before engaging in surgery, and for risk-free training of students. On the other hand, advances in telecommunications already provide opportunities for the development of specialized "image interpreters" operating in a central location. Such "radiographer" operations would be strong consumers of improved display technologies which would facilitate the speed and accuracy of their piecework production.

The development of standards for the introduction of advanced display technologies raises a host of other questions which have not yet begun to be addressed. By their nature, advanced display technologies offer the user a host of ways of displaying and interacting with the data. How will standard diagnostic procedures be developed? How will individuals be trained?

Commentary

The above analysis would indicate that, while tremendous opportunity exists for the introduction of advanced display technologies into the medical imaging field, the context for the acceptance and implementation of these developments does not yet exist. Given the regulatory, professional, and cultural barriers, it is likely that real progress over the next few years will be slow.

Technology Availability	Market Readiness	Overall Significance
H	**L**	**H**

6.1.8 Integration

The greatest opportunity for progress in the medical imaging field lies in the integration of the individual developments outlined above into working systems which will effectively and unobtrusively provide healthcare delivery systems with a comprehensive array of advanced imaging services.

As noted in previous sections, integrated systems are also where the greatest cost savings are to be found - and the most profound impacts on the evolution of healthcare systems themselves.

Effect of External Drivers

If those who control health service budgets are already struggling with investment decisions that go beyond the immediate environment, commitments to the development of integrated systems for the generation, storage, transmission and use of medical images are not likely to find favour in the short term. This is likely to change over the next few years as the potential for major improvements in cost effectiveness becomes clearer.

Unfortunately, even with champions and funding available, integrated systems will not be easy to implement. Most if not all of the retarding factors identified for individual developments apply even more strongly to large scale, high profile, integrated projects. In addition, the complexity of managing and implementing such projects pose an additional hurdle.

Commentary

Implementation of integrated medical imaging systems offers enormous potential but it will take a number of years before such projects become routine.

Technology Availability	Market Readiness	Overall Significance
L	**M**	**H**

6.2 Five to Ten Year Horizon

In terms of the development of a technology strategy for medical imaging, the five to ten year horizon provides the opportunity to harvest the investments made in the near term - if the right direction has been chosen. The problem is that predictability is low, especially in an area like medical imaging where both the technology and the context of its use are expected to see major changes. Under these circumstances, planning must be kept very flexible and choices have to be adjustable to events as they unfold.

The approach of this section of the analysis is to select a limited number of scenarios which could profoundly affect the medical imaging sector and sketch the circumstances and implications which would likely surround them. The scenarios are extreme cases. They are not necessarily intended to be fully achievable - even beyond the ten year horizon. Their purpose is generate debate and to assist in identifying the elements which should be addressed in the strategic technology planning exercise.

6.2.1 Telemedicine

Description

A telemedicine scenario might involve the delivery of most or all specialized medical services remotely by advanced multi-media telecommunications systems. This would be combined with a complete restructuring of community care to include all services which would continue to require physical delivery. Under such a scenario, the patient in a large urban centre and the patient in a remote location anywhere in the world (as long as the complementary community infrastructure was in place) would receive equal - in fact, identical - healthcare services. Given the sophisticated and accessible telecommunications infrastructure required by this scenario, it would be technically possible to have specialized medical services centralized in a few locations or as widely distributed as the user communities.

Implications

In addition to the availability of advanced telecommunications networks, this scenario would also require continued exponential growth in computation power and storage capability. Under these circumstances, medical imaging would be an essential element in the success of the system. It would gather and store images locally, uploading them to specialists for review. It would provide real-time consultation, seamlessly integrating a real time medical imaging, document transfer and teleconferencing into a "virtual" examination with a remote specialist. It would allow the use of real-time imaging to support the participation of a remote specialist in a complex surgical procedure.

For these events to be possible, the availability of most of the technological advances described in this paper would be required. More importantly, it would require their *integrated* deployment. Integration can be expensive and time consuming. It would take a firm commitment to a clear direction motivating all of the participants. Finally, this scenario would require a massive shift in the training of community-based health professionals to deliver or assist in the delivery of an integrated telemedicine service.

Commentary

From the brief description above, it is evident that the technology for implementing a telemedicine scenario is available. Pilot projects are already demonstrating many of the components, including medical imaging. The limiting factors would be political, economic and social. The key questions include: How would the vision be defined clearly enough to be actioned? Who would set the standards? How would commitment be achieved? Who would fund the up-front costs of integration? How would the operating costs of the system be provided? Who would determine which services are "remote" and which "local"? What facilities would be required locally and at the remote location? How would delivery be co-ordinated and quality assured?

Patient Centred Medicine

Description

A patient centred scenario would greatly extend the current tendency toward "consumerism" and loss of confidence in medical professionals. It might involve the empowerment of patients to manage and decide their own healthcare and treatment. While much of the rhetoric of today's healthcare system pays lip service to patient control, most of the emphasis to date has been on involving the patient in preventative healthcare and "wellness" programs. This scenario would extend this approach to include treatment.

It would require the wide availability of easily accessible and understandable information so that patients could determine and even implement their own therapies. Doctors and other healthcare professionals would function purely as advisors and implementors of the patient's wishes. Under this scenario, it is conceivable that patients would not only manage but deliver much of their own treatment with limited physical assistance from healthcare professionals. In effect, under such a system the patient not the doctor would be the customer in every healthcare transaction.

Implications

The challenge of such a scenario for medical imaging systems would be considerable. It would involve concentrating the development of the sector on providing greatly improved accessibility and understanding. The aim would be readily available, easily interpreted images. Self-administered imaging might be a component of this scenario.

Commentary

This scenario is an extreme case which is certain to send shivers down the spines of most health professionals! Its aim however is to encourage exploration of the extent to which medical imaging can be made more directly patient accessible.

6.2.3 The Fragmentation of Radiology

Description

It has been said that Radiology is the only medical speciality to have been created by technology. This scenario explores the notion that what technology creates it can also destroy.

A recent series in The Lancet , entitled, "Issues in Imaging" contained some interesting speculation. One of the articles in the series discusses distance radiology and includes the following quotation (Hynes, Stevenson, and Nahmias, 1997):

> Teleradiology may also change the way in which radiologists work, and not always in ways they will welcome. Radiology physicians have spent decades climbing out of the darkened basement to become "real doctors", performing interesting procedures, both diagnostic and therapeutic, and enjoying the clinical contacts and consultations that go with such activities. There is already evidence that the availability of digital images in the intensive-care unit leads to reduced consultation with the radiologist, and teleradiology may put the radiologist back in the basement.

While this quotation does not predict the elimination of radiology as a profession, it starkly poses the two divergent directions which the profession may follow. In the first, radiologists become "radiographers" - remote technical specialists reading images on demand. In the second, radiology merges into the various medical disciplines that it supports. In either event, the extreme outcome may be that radiology ceases to exist as a separate speciality.

Implications

There are significant implications for the medical imaging sector if either one (or a combination of both) of these developments occur. While traditional radiology has developed from a fairly narrow base in film technology, radiologists have been the dynamic that has driven the growth of medical imaging and its expansion through the introduction of new image generation technologies, PACS installations, and other innovations. If radiologists are deprofessionalized or fragmented into the medical specialities, there is a serious question as to who will replace their vital role as champions for the broad development of medical imaging technology.

A second implication is in the area of training. As medical imaging becomes more and more incorporated into medical practice, how will all of the professionals involved be trained to a minimum level of competence? If the "basement specialist" image is the result, how will these people be trained - and in what?

Commentary

As medical imaging develops, it is inevitable that it will create major shifts in the roles of those professionals and organizations that use it. Researchers will continue to press forward with innovations and industrial suppliers will seek to serve the market as it evolves, but it remains to be seen how the vision for the direction and use of medical imaging can be transferred from a relatively small and well-defined group of professionals to the healthcare system as a whole. Who leads and how clear their mandate is will be a vital factor in the direction and pace of change.

6.2.4 Molecular Medicine

Description

Medical imaging operates at the physical level and at human scale. The Human Genome project points to another reality. It raises the potential to enhance the identification of disease chemically at the microscopic and molecular level. The pharmaceutical industry is already taking advantage of these new opportunities in drug discovery. This scenario raises the question of the implications of molecular-based medicine for medical imaging.

Another article in the Lancet series quoted above poses this challenge in an interesting fashion (Hillman 1997):

> The origins of radiology are in gross anatomy and pathology and these remain the primary foci of the specialty even today. However, further advances in medicine that will significantly improve health are likely to require innovations that detect and treat disease at the level of early functional changes, perhaps even before any microscopic morphological alterations. Research in molecular genetics, cellular engineering, pharmacokinetics, and information technology is facilitating the transition of medicine from the macroscopic to the microscopic or even molecular level, by identifying genes that appear to control the likelihood of disease, by discovering new intrinsic transmitters of biological information and their sites of action, and by developing new drugs to take advantage of this information.

Implications

The implications of molecular medicine are not nearly as clear as the issue posed by this scenario. Medical imaging will be an increasingly valuable source of information available to doctors in making diagnoses or in guiding therapy. But medical imaging is only one source of information. As new sources develop - and molecular medicine is obviously an important example - how will the medical imaging sector adapt to include these other inputs?

Commentary

Biopharmaceutical companies are already beginning to explore the edges of the challenge posed by this scenario. In the field of nuclear medicine, for example, computational chemists have been designing radio pharmaceuticals - "hot" ligands which will carry gamma emitting substances to specific body targets.

6.2.5 Virtual Reality-Enhanced Medicine

Description

In the discussion of visualization in Section 6.1.7 above, the potential for introducing emerging virtual reality technologies to medical imaging was introduced. This scenario explores the implications of embracing these technologies fully and applying them both to diagnosis and to therapy.

Implications

The full introduction of current or emerging virtual technologies to medical images would have a profound effect on the sector. Instead of 3D images displayed on a flat screen or even in real time video, the radiologist or clinician would be able to enter into and interact with the image itself in real time. The combination of vision, auditory, and tactile devices (e.g. electronic gloves) would enable diagnosis or therapy to be practiced interactively in the virtual world.

Commentary

Introducing virtual reality medicine is not just a matter of improving display technology. In order for this scenario to be realized, additional kinds and huge additional amounts of data would have to be captured, manipulated and displayed in real time. As with many of the other opportunities outlined in this paper, the most difficult challenge is likely to be in the seamless integration of all the diverse components of the system.

7. Identifying Canadian Opportunities

The previous section attempted to sketch out the short and medium term opportunities in medical imaging which evolved out of identifying the drivers. This section attempts to draw the focus back to opportunities for Canadian industrial exploitation of medical imaging.

Canadian Owned Versus Canadian Based

Medical imaging is a global market dominated by the U.S. both in terms of supply and demand. While multinational OEMs have distribution and marketing in Canada, they tend not to do significant manufacturing or development in Canada. The OEMs are important to the development of medical imaging in Canada in two ways: they use Canada as a testing ground for new technologies prior to their introduction into the U.S. market; and, through partnerships, they represent the distribution route for technologies developed and/or manufactured in Canada.

Both of these activities provide significant benefits. The early introduction of new technologies benefits Canadian researchers and clinicians. It also enables Canadian companies to get a jump start in the development of the niche opportunities which result from the introduction of new technologies. The related role of multinational firms in supporting the development and international marketing of the innovative products of Canadian companies is even more important.

Opportunities do exist for Canadian companies, but alliances with OEMs may be necessary to take full advantage of them. Examples of Canadian companies which have developed medical imaging technologies and are bringing them to market in conjunction with multinationals would include: ISG, ALI and Mitra. Noranda's Advanced Material Research Group is also working with flat panel X-ray detector developers to use selenium-based materials that they have developed.

Providing an environment to attract OEMs as partners and investors continues to represent an important goal. While elements of an overall medical imaging solution may be developed by Canadian companies, they will often be bundled into products sold by OEMs and sold through partnerships with them. Canadian companies bringing technologies to market without significant interactions with multinational OEMs face an uphill challenge in the world marketplace. The challenge is to maximize the benefit to the Canadian company.

The continued use of Canada for clinical trials is another important way that OEMs can contribute to the development of medical imaging in Canada. Spin-offs of clinical trials include assistance in maintaining an active pool of researchers and clinicians who will go on to develop other technologies. The implications of new regulations (e.g. TPP program) in terms of diminishing the advantages of carrying out clinical trials in Canada may negatively impact this area.

7.2 System-Wide Integration

The generation and capture of images (imaging modalities) is mature (not growing rapidly) and dominated by the multinationals. There may be opportunities for the Canadian development of niche modalities but we are unlikely to capture significant marketshare on the imaging hardware side. With the inevitable shift to digital images and electronic patient records there is a family of “software” opportunities relating to the integration, analysis and transmission of the data. These opportunities are just starting to grow as the shift to digital occurs and they represent a tremendous opportunity. In the following subsection a variety of niche opportunities will be described. This subsection focuses on the opportunity of developing integrated, modular, scaleable, turnkey solutions to managing and using distributed medical images (and medical records in general). This would involve the building of a consortium (or consortia) including:

- Healthcare funding agencies
- Hospitals and related groups
- Government
- Medical Imaging OEMs
- Communications companies (both hardware suppliers and carriers)
- Software developers
- Technology applications and integration experts
- Business system integrators

Strengths that Canada would bring to the table include the fact that the first three consortium partners ultimately fall under the banner of government. This is in contrast with the U.S. where the healthcare payers (insurers) and hospitals are a mix of private and public players with competing agendas. Canada (or a province) acting as a single healthcare entity to push forward a consortium initiative would be a key enabler. This would of course require policy co-ordination within and between government departments.

In addition, Canada has particular strengths in the telecommunications and software industry. CANARIE provides an advanced networking infrastructure along with support for applications development. Major telecom-related companies that could be part of the consortium might include Nortel, BCE, Stentor, provincial telecoms, cable companies, and Newbridge Networks. Various other software and systems integration firms are also available in Canada. Industry Canada’s recent Telehealth Sector Competitiveness document (Industry Canada 1997a) summarizes these companies and Canada’s communications resources in more detail.

Should a consortium as outlined above be pulled together, it would not be difficult to encourage the participation of medical imaging OEMs including modality vendors and PACS suppliers.

This sort of an opportunity would build upon Canada’s strengths in telecommunications, software and health delivery to develop a medical imaging industry which concentrates on the highest growth opportunities in the field.

While there are currently limited niche initiatives taking place in Canada (e.g., New Brunswick’s teleradiology initiative), analogies to the sort of consortium the we have proposed already exist in the U.S. The U.S. Veterans Administration is probably the closest American analogy to the Canadian healthcare system. It manages the healthcare of a huge group of veterans across the U.S. through 170 distributed hospitals. The VA is actively engaged in putting a distributed enterprise-wide system in place.

An example of a private sector approach would be the BJC Health System’s Project Spectrum integrating 15 sites and 6,000 physicians. It draws together an HMO with IBM Global Healthcare, Motorola, Kodak and OEMs and telecom/network providers to deliver an architecture that supports both the business and health delivery processes across the continuum of care.

7.3 Niche Opportunities

The previous section describes a broad initiative drawing upon, but also extending beyond, Canadian medical imaging expertise. This subsection focuses on more narrow opportunities which combine Canadian medical imaging expertise in the research and clinical setting with the innovative technological skills of Canadian companies. These opportunities tend to be niche-based and small in scale - at least initially - which makes them ideal for exploitation by existing or new SMEs.

Critical to the development of such companies is the continued vitality of the research and clinical communities which support them. Government support through programs like the Networks of Centres of Excellence would appear to be a crucial and effective way of maintaining fertile ground for new Canadian enterprises in this field.

Niche opportunities divide roughly along the segmentation used in this report. Most of the niches centre around modality and organ/disease specific opportunities. The specific nature of the opportunities lend themselves to SME-based commercialization.

Image Generation and Capture
While the major imaging modalities are well defined, there is a constant flow of novel innovations flowing out of our research institutions. Harnessing these innovations and converting them to business ventures is a major opportunity. Examples of innovations which have evolved into Canadian companies includes LIS’ 3D ultrasound imaging system (via Robarts)and IMRIS’ magnetic resonance imaging system (via NRC Winnipeg).

Integration Tools

Digital images and their integration with the other hospital information system components represent a complex task. Tools will need to be developed to carry out a variety of custom integration tasks for an almost infinite variety of configurations and legacy systems. DICOM, HL7 and other standards will ultimately simplify the process, but systems integration will remain a niche which requires both software background as well as an appreciation of medical imaging and hospital information flow issues. Mitra of Waterloo is an example of a company which has developed tools to broker information transfer between PACS, modalities and other hospital information systems. It offers products directly to the market (e.g. PACS Broker) as well as developing custom products for world-wide distribution by OEMs (e.g. Agfa's IMPAX).

Imaging Display and Fusion

Issues relating to the display of images and especially the reconstruction of 3D images are very modality and application specific. As a result, there are a variety of opportunities for companies developing custom software to display and manipulate image data. ISG of Mississauga is an example of a company which has developed significant expertise in image display. Their products have been incorporated by a variety of multinational OEM systems. The extension of image display is to fuse the images from different modalities which bring different information into a single image which can better direct diagnosis or therapy.

Image Guided Therapy

Advances in the speed of acquisition and display of images creates new opportunities for image guided therapy where the image is displayed in real time and is used to guide the progress of the procedure. In this case, the imaging equipment must often be adapted to smaller less cumbersome forms so that it can be used in conjunction with surgical (or minimally invasive) intervention. Opportunities range from adaptation of existing modalities to image display. Examples would include the kind of neurosurgical MRI techniques which have been developed at the Montreal Neurological Institute.

Image Analysis

Beyond image display and fusion there is the development of tools to identify structures with little or no radiologist input. As discussed, full automation represents a very long term objective but there are significant opportunities for the development of improved aids to analysis as we progress toward this goal. Other opportunities relate to the development and mining of image databases which can be used for training as well as image recognition using artificial intelligence techniques. As image analysis techniques evolve they will augment the capabilities of conventional image display software.

7.4 Research Driven Opportunities

Canada has a well developed fundamental research infrastructure primarily centered in universities. This represents an ongoing source of innovative concepts and trained staff. Conversion of this raw intellectual property and talent to successful commercial ventures remains the weak link. While successes can be identified they represent the exception, not the rule. A focused effort to convert research innovations into Canadian-based businesses which will employ trained staff will be required. To not focus on this opportunity and to allow these creative, educated minds and their ideas to migrate to the U.S., is to squander any potential to develop commercial value in Canada.

Programs to support these sorts of opportunities would include the Network of Centres of Excellence proposal currently being developed that deals with the medical imaging sector, C-MIST. This proposal focuses on the imaging science aspects of the opportunities which flow out of institutions focused on radiology. The broader image communication and telehealth opportunities will require a more interdisciplinary approach and should be co-ordinated with other telehealth initiatives.

7.5 Telehealth

The opportunity in telehealth is closely related to the system-wide integration option discussed in Section 7.2 . There are also smaller scale opportunities in teleradiology. The integration of readily available tools (e.g. video conferencing, networking, etc.) with the transmission and simultaneous use of images provides opportunities for the development of custom solutions to meet individual distributed users' needs. The biggest challenges in developing these business opportunities are not in the development of the technology but in the provision of robust and intuitive interfaces. Companies which are able to provide credible initial solutions to these human-technology interface issues are likely to build a reputation on which to undertake the development of much more sophisticated telehealth systems.

While individual teleradiology opportunities exist, viewing the communication needs of a healthcare organization (or province or country) in a broader context leads to larger opportunities. The reader is referred to the Industry Canada's Telehealth paper (IC 1997a) for additional background.

7.6 Healthcare for Export

The medical imaging market is international in scope. To exploit it, Canadian companies will need innovative technologies (a Canadian strength); access to markets (already discussed under Section 7.1) and distinctive products. One of the most obvious ways of ensuring the distinctiveness of Canadian products is through partnership with the healthcare delivery system.

Despite our constant agonizing about medicare, viewed from the outside the Canadian system is an impressive success. It also brings together (at least potentially) integrated decision-making on health policy and funding with a relatively uniform, high quality delivery system. How can this system contribute to the distinctiveness of Canadian medical imaging products?

The answer has several parts. First, the involvement of Canadian hospital-based researchers and clinicians can lend impetus and credibility to the development of Canadian products. Second, supporting innovative pilot applications in Canadian healthcare settings will enable Canadian businesses to develop the credibility for export sales - especially where proof of cost-effectiveness is a critical part of the purchase decision. Third, the development of advanced networks in Canada offers the potential for the direct export of healthcare services, especially in the distance education delivery of training and upgrading to health professionals.

The fact that the cost and productivity of Canada's healthcare system is under such pressure can only increase the motivation of healthcare administrators and professionals to find ways of increasing the return on their expertise.

8. Building a Technology Roadmap

As noted in the introduction, this paper is one step toward the preparation of a technology roadmap for medical imaging which will serve to co-ordinate the activities of the private sector, governments, and the healthcare community in developing this important sector.

The purpose of a discussion paper is to promote dialogue and debate. To encourage this process, we have included a set of "draft" recommendations which arise from the evidence collected to this point. These recommendations are intended to challenge the reader to think through the actions which need to be taken to develop Canada's medical image sector over the next decade.

We have also included a section entitled "Next Steps" which sketches the process which might be followed to push forward to elaborating a Medical Imaging Technology Roadmap.

8.1 Draft Recommendations

A. **Research:**

Public support for research in the development and application of medical imaging technologies is crucial to the growth of Canadian business opportunities in the field. This support must encourage the pooling of expertise and collaboration among medical imaging research centres across the country. This is an appropriate role for the Federal Government to undertake and support through various mechanisms such as the Networks of Centres of Excellence program and federal granting councils (NSERC, MRC).

B. **A Funding Policy Framework:**
In order for the medical imaging sector to grow in Canada, there must be a much greater awareness of the opportunities and implications among the provincial authorities who establish the rules for healthcare funding. This awareness must encompass research, capital investment and the funding rules under which medical imaging services are funded. A task group reporting to the Canadian Council of Ministers of Health should be established to address this issue.

C. **Co-ordination with Telehealth Initiatives:**
The medical imaging sector is closely inter-related with telehealth, which encompases all aspects of the application of information and communications technologies to the health field. Medical imaging technologies depend on and provide vital contributions to advances in information management in health delivery. In particular, medical imaging is a critical component in the distance delivery of health information (whether within a "campus" situation or world-wide). A number of telehealth pilot initiatives are already underway in Canada. It will be of critical importance for governments, institutions and the private sector to ensure that medical imaging developments are included in these plots so as to ensure that opportunities and resources are not wasted and to provide compatibility across provincial and national enterprises.

D. **Therapeutic Products Program:**
If the regulatory mechanisms are designed properly, strong health safety regulation need not be incompatible with the pursuit of legitimate economic development objectives. There is sufficient unresolved concern about the impact of announced changes to Health Canada's Therapeutic Products Program to require an additional effort on the part of the Federal Government (including <u>both</u> Health Canada and Industry Canada) to allay fears. If this is not done, there is a strong risk that current perceptions may adversely affect the climate for medical imaging technology in Canada.

E. **A Canadian Medical Imaging Showcase:**
The key to long term growth of the Canadian medical imaging sector is to promote increased collaboration and association amongst Canadian companies and healthcare organizations. This collaboration must not only include the present players, but those who have unrealized potential to contribute. One way of achieving this objective would be through the sponsoring of a broadly-based annual showcase in Canada to bring together the latest in technology research with experimental applications of

technology and with the business opportunities which they create.

Such a showcase would be a natural outgrowth from the process used to complete the Technology Roadmap (see Section 8.2, below). It should be organized and held jointly with the telehealth field (see Recommendation C above).

F. **Demonstration Projects**:
As outlined in this paper, the greatest opportunities and the biggest challenges lie in the development of integrated solutions. The challenge is increased by the need to demonstrate cost-effectiveness for medical imaging technology investments.

If Canada is going to translate its existing research, entrepreneurial and healthcare delivery strengths into an international leadership position in the medical imaging field it will be essential to create world-leading demonstration projects. In order to be effective in attracting international attention and the commercial opportunities which flow from that attention, these demonstration projects will have to be both technologically innovative and of sufficient scale to provide significant results.

Most of the funding required to mount projects of this kind is potentially already available from a combination of public sources and private investment. The biggest problem is in the co-ordination of these resources and in achieving a willingness by financial decision makers to invest in developmental solutions.

Industry Canada is probably in the best position of any organization in Canada to act as a facilitator for the creation and pump-priming of consortia which can develop innovative demonstration project proposals.

8.2 Next Steps

8.2.1 Use of This Discussion Paper

In order for this discussion paper to be effective, it should be distributed as widely as possible among all those with an actual or potential role to play in the sector. This should include health policy and delivery organizations.

Given the short time frame of this project there will undoubtedly be amendments and additions required. These changes should be encouraged as part of a dialogue and refinement process leading up to the preparation of the actual technology roadmap. This process will be facilitated if Industry Canada provides a central point for the incorporation of new material.

8.2.2 Proposal to Hold a Medical Imaging Forum

In commissioning this discussion paper, Industry Canada indicated that one of its uses could be as a background document for a proposed medical imaging Forum which would bring together a wide range of participants and potential participants in the sector to provide input into what will eventually become the final Roadmap document. In preparing the discussion paper, ORTECH was also requested to provide feedback on this proposal.

In preparing this document, it has become very apparent to us that the medical imaging sector is fragmented and disconnected. At the same time, there is widespread interest in pursuing opportunities in the field through greater collaboration. Our comments about the vital importance of pursuing integration opportunities (Section 7.2) reflect and are re-enforced by this interest.

We believe that the holding of a Medical Imaging Forum is an essential step toward engaging sector participants in the roadmap exercise. The forum should be designed on a national basis to bring as many interests (actual and potential) together as possible. It should be short enough not to inhibit attendance, but long enough to allow for the development of real dialogue. An evening plus a full day would probably be ideal. The program should include up-to-date information on both Canadian and international developments in the field.

In fact, Industry Canada may wish to seriously consider a multi step process as follows:

- An initial broadly-based forum of all potentially interested stakeholders as outlined above. This forum would be designed to raise awareness and identify serious participant interest.

- A second “working” meeting might then be held. It would concentrate on debating the key elements to be covered by the proposed Roadmap. It would likely involve a smaller but representative group of those participants with an active commitment to the sector.

- This second forum might spawn an ongoing body to oversee final drafting of the Roadmap and the initiation of annual showcase events as outlined in Recommendation E in Section 8.1 above.

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APPENDIX II: SELECTED INTERNATIONAL ORGANIZATIONS

This appendix provides lists of associations and societies involved with or relating to medical imaging. This information has been extracted from two main references:

- www.healthnet.com/associations/assocdefault.html
- www.medmark.org/rad/rad.html

Those associations and societies which are prominent in this report are listed under the title “Selected” while the remainder are listed under “Others”.

Selected International Associations and Societies

Healthcare Information and Management Systems Society (HIMSS)
Radiological Society of North America (RSNA), USA
Society for Computer Applications in Radiology (SCAR), USA
International Society of Photo-Optical Instrumentation Engineers (SPIE)
Canadian Association of Radiologists (CAR)

Others Identified

American Association of Physicists in Medicine
American College of Nuclear Physicians (ACNP), USA
American College of Radiology (ACR), USA
American Health Information Management Association, USA
American Healthcare Radiology Administrators, USA
American Institute of Ultrasound in Medicine, USA
American Medical Informatics Association, USA
American Nuclear Society (ANSWER)
American Registry of Diagnostic Medical Sonographers, USA
American Roentgen Ray Society, USA
American Society for Therapeutic Radiology and Oncology (ASTRO)
American Society of Head and Neck Radiology (ASHNR)
American Society of Interventional and Therapeutic Neuroradiology
American Society of Neuroradiology
American Society of Nuclear Cardiology
American Society of Pediatric Neuroradiology
American Society of Spine Radiology (ASSR)
American Telemedicine Association, USA
Arizona Society of Echocardiography (Main)
Asian and Oceanian Congress of Radiology (AOCR), USA
Association for the Advancement of medical Instruments (AAMI), USA

Association of Educators in Radiological Sciences
Associazione Italiana di Medicina Nucleare
Associazione Italiana di Neuroradiologia
Australian Sonographers Association
British Nuclear Medicine Society
Cardiovascular and Interventional Radiological Society of Europe
Center for Healthcare Information Management, USA
Clinical Magnetic Resonance Society
Dansk Radiologisk Selskab
Dutch Society of Radiation Protection
Eastern Neuroradiological Society
European Congress of Radiology (ECR), Austria
European Society of Neuroradiology
Florida International Medical Expo , USA
Florida Radiological Society
Health Industry Manufacturers Association (HIMA), USA
Health Physics Society, USA
International Cyber-Society Of Radiology Professionals
International Radiation Protection Association (IRPA)
International Society for Computed Aided Surgery, Germany
International Society for Magnetic Resonance in Medicine, USA
International Society of Magnetic Resonance in Medicine, British Chapter
International Society of Radiology
Interventional Radiology Society of Australasia
Israel Society for Medical and Biological Engineering, Israel
Italian Association of Radiology (S.I.R.M.)
Japan Radiological Society
Japan Society of Magnetic Resonance in Medicine
Los Angeles Radiological Society (LARS), USA
Medical Device Manufacturer's Association, USA
Medical Image Perception Society
National Association for Medical Equipment Services (NAMES), USA
National Association of Portable X-ray Providers, USA
National Brain Tumor Radiosurgery Association, U.S.
National Electrical Manufacturers Association (NEMA), USA
New York State Radiological Society
North American Society for Cardiac Imaging (NASCI)
Northeastern Ohio Association of Vascular and Interventional
Nova Scotia Association of Radiologists, Canada
Pennsylvania Radiological Society

Radiological Society of South Africa
Radiology Business Management Association, USA
S.I.R.M. Associazione Italiana di Radiologia Medica
Sociedad Nuclear Espa ola
Society for Imaging and Technology (IS&T), USA
Society for Pediatric Radiology (SPR)
Society of Cardiovascular & Interventional Radiology
Society of Diagnostic Medical Sonographers, USA
Society of Nuclear Medicine, USA
Society of Skeletal Radiology
Society Of Thoracic Radiology
South West Radiologists' Association
Southeastern Neuroradiological Society
Spanish Nuclear Medicine Society (SEMN)
SPIE: Medical Imaging 1998, USA
Swedish Society of Radiation Physics
Swiss Society for Medical Radiology, USA
The Society for Minimally Invasive Therapy, USA
Western Neuroradiological Society

APPENDIX III: SELECTED INITIATIVES

This appendix provides a selected list of provincial initiatives relating to medical imaging, followed by a selected list of Canadian and international PACS initiatives.

SELECTED PROVINCIAL INITIATIVES

The primary sources for these initiatives were:

- "Telehealth in Canada Clinical Networking Eliminating Distances", CANARIE July 1997 (http://strategis.ic.gc.ca/SSG/it04122e.html)
- Canadian Initiatives on Networking Clearing House (CINCH). Select the telehealth category. (http://strategis.ic.gc.ca/sc_indps/itt/cinch/search/srchcinche.html)

Alberta

- developing a province-wide health information management and technology initiative and has established a Senior Reference Committee and Technical Coordinating Group
- Health Information Protection Act is undergoing public scrutiny and consultation.
- Telehealth Working Committee
- Rural-Urban Telehealth. Telehealth trial involved one rural site and 55 cases over 10 months.
- province-wide Information Management/Information Technology telehealth plan - planning development of networks to service 17 regions with telehealth services.
- Telepsychiatry Service, Provincial Mental Health Advisory Board
- Foothills General Hospital telehealth trial - assessed scope of telehealth for emergency medicine and identifying situations where it is effective and cost-efficient. Remote consultations included video and X-ray transmissions.
- Remote Consultative Network - allows interactive consultation services between rural healthcare providers and specialists in urban centres

British Columbia

- Healthnet/BC
- Northwest Teleradiology Pilot Project

Manitoba

- Manitoba Health Information Network
- Draft privacy legislation concerning health information (Spring 1997)
- Drug Program Information Network
- Home Care Project

New Brunswick

- Atlantic Health Sciences Association, NBTel interActive and Sterling Diagnostics' DR (Direct Radiology) and VITAL (Virtual Interactive Telehealth Assertive Links) projects - testing direct radiology (displaying X-rays, MRI scans and other information on computer screens rather than film).
- Teleradiology - linkages present in half of the province's regional Hospital Corporations.

Newfoundland and Labrador

- Newfoundland and Labrador Centre for Health Information (NLCHI)
- Child Telepsychiatry Project. Piloted remote psychiatric consultations with 23 cases.
- Telemedicine Centre at Memorial University

Nova Scotia

- Home Care Nova Scotia program
- Dalhousie University's Division of Medical Education, Digital Image F/X, and the Fraunhofer Center for Research in Computer Graphics - Trying to expand use of TeleVivo in Canadian medical schools. TeleInViVo (Interactive Visualizer of Volumized data) allows physicians and patients to view two-dimensional images like CTs, MRIs, and ultrasound in three dimensions.
- Nova Scotia Rural Physician Network. In 1996, completed a 12-month pilot project connecting Halifax to four rural sites. Consultations in radiology and dermatology, as well as continuing medical education were provided via PC-based videoconferencing. It linked the province's main hospital in Halifax (Queen Elizabeth II Health Sciences Centre) with hospitals in the eastern region of the province, using technology developed by TecKnowledge Healthcare Systems Inc. of Dartmouth.

Ontario

- University of Ottawa Heart Institute's satellite broadband networks for cardiac consultation. Project will produce remote satellite consultation workstations, software and evaluate the financial and educational aspects of using satellite ATM technology to transmit diagnostic information.
- Smart System (coordinated by the Government of Ontario, Program Management Office)
- Hospital for Sick Children, Toronto - teleradiology or 'video clinics' for consultations with children primarily in Thunder Bay. Transmissions included X-ray images and MRI scans which were analyzed by a specialist at the Hospital.
- HealthLink - connection of 20 health institutions (hospitals, home care sites)
- Telemedicine Canada - a non-profit corporation operating amongst University of

Toronto and Toronto Hospital, providing live continuing medical education

PEI
- Island Health Information System

Quebec
- preparing for the implementation of a health and telecommunications network
- Quebec Inter-regional Telemedicine Network - tested videoconferencing for continuing medical education and multidisciplinary staff meetings. Next phase will add teleconsultations through to March 1998.
- Hôtel-Dieu, Montreal - conducts consultations and education seminars with regional hospitals, and conducts real-time international consultations (including exchange of radiographs, CAT scans and other medical images) using ISDN technology.
- Telediagnosis in a Clinical Setting Pilot Project (CHUL-Rimouski)

Saskatchewan
- Saskatchewan Health Information Network

Northwest Territories
- Health and Social Services Telemedicine Trials

Selected CANADIAN PACS IMPLEMENTATIONS
- Victoria General Hospital, Victoria - with Siemens
- Sick Kids Hospital, Toronto - with GE Medical
- Montreal General Hospital - ultrasound filmess since 1995, CT/MR filmless since 1997

Selected INTERNATIONAL PACS INITIATIVES
- UCLA Radiology
  Extensive work in radiology R&D. Have had PACS system for over 10 years
- BJC Group in MN
  Project Spectrum integration of all hospital record systems into a Healthcare Enterprise System. Academic and industrial partners.
  Shand Hospitals in Florida - key contact. Carried out PACS cost analysis was breakeven but quality was up.
- Baltimore VA Medical Centre
  One of the first filmless hospitals. Group of local VA hospitals linked for telemedicine. VA's early adopters of nationwide telemedicine linking
- Hammersmith Hospital in UK
  One of the first filmless radiology departments. Extensive cost/benifit analysis carried

out in conjuction with the UK government via Buxton University

APPENDIX IV: SELECTED RESEARCH ORGANIZATIONS

This appendix provides lists of selected Canadian and international research organizations involved in activities relating to medical imaging.

CANADIAN INSTITUTES (AND SELECTED PROJECTS)

The main references used for Canadian institutes and research organizations were:

- "Canadian Capabilites in the Medical Imaging Sector", Industry Canada December 1997 (http://strategis.ic.gc.ca/SSG/hi01349e.html)
- "Research Centers and Services Directory", Gale Research Inc., 1995.

British Columbia Cancer Research Centre

- Medical Biophysics, studying biological effects of ionizing radiation and improvements in radiotherapy;
- Medical Oncology-Laboratory Operations, developing new methods of diagnosis and advances in the administration of chemotherapy;
- Cancer Endocrinology, investigating application of hormonal therapy to various cancer sites;
- Terry Fox Laboratory, evaluating diagnosis and treatment of cancers of the blood and lymphatic system;
- Cancer Imaging, performing computerized screening of cancer cells;
- Epidemiology, Biometry and Occupational Oncology, studying geographic mappings of cancer in British Columbia, epidemiology of breast cancer in British Columbia, risk factors for melanoma, and incidence of brain tumors in airline pilots.

London Regional Cancer Centre

- radiation oncology, including 3-D imaging
- portal imaging

McGill University, Montreal Neurological Institute

- 3D imaging for neurosurgery

McGill University, McConnell Brain Imaging Centre

- Investigates cerebral function using positron emission tomography (PET) and magnetic resonance imaging (MRI) on healthy volunteers and patients with brain tumors, epilepsy, movement disorders, and other acute and chronic neurological illnesses. Research areas include radiochemistry, imaging physics, mapping of cognitive functions in the brain, kinetic analysis, and modeling of biological systems.

McGill University, Medical Physics Unit
- Medical imaging, including resonant cavity imaging, filter functions (computer tomography), positron-emission tomography, nuclear magnetic resonance imaging, and electronic processing.
- physical aspects of radiation oncology and radiation dosimetry, radiosurgery, radiation hazards and protection, physical aspects of nuclear cardiology, and dosimetry in diagnostic radiology.

McGill University, Neuro-Isotope Laboratory
- Uses multitracer autoradiographic methods and positron emission tomography (PET) to study brain tumors and cerebral ischemia.

University of Alberta, Department of Biomedical Engineering
- In Vivo Nuclear Magnetic Resonance (NMR)
- Magnetic resonance imaging of peripheral nerves
- simultaneous transmission/emission of CT
- affordable teleradiology
- absolute quantification by planar imaging
- ultrasound properties of bone

University of British Colombia, Division of Critical Care Medicine
- Positron Emission Tomography (PET)

University of Calgary, Joint Injury and Arthritis Research Group
- definition of the degree of concordance between MRI and arthroscopy
- region-based image processing
- restoration of nuclear medicine images
- directional imaging analysis

University of Calgary, Neuroscience Research Group
- non-invasive computer imaging of cortical activity

University of Manitoba, Institute for Biodiagnostics
- biosystems (using MR, IR to understand and treat physiological and disease processes)
- magnetic resonance technology

University of Manitoba, The Andrei Sakharov Magnetic Resonance Imaging Facility
- provides on-site scanning

University of New Brunswick
- Magnetic Resonance Imaging of Foreign Objects in the Human Hand

University of New Brunswick, Institute of Biomedical Engineering
- applications of electronic instrumentation in orthopedics, medical imaging, ergonomics, exercise physiology, and biomechanics.

University of Ottawa, Cardiac PET Centre, Ottawa Heart Institute
- nuclear cardiology
- comparison of perfusion SPECT imaging with FDG glucose metabolic imaging

University of Montreal, Ecole Polytechnique, Systems, Signaux et Images Biomedicaux
- instrumentation (hardware and software) for image acquisition and processing
- tissue characterization using ultrasound

University of Saskatchewan, Reproductive Biology Research Unit
- reproductive ultrasonography, three-dimensional ultrasonography, and computerized image processing.

University of Sherbrooke
- positron emission tomography
- condensed phase low-energy radiation physics

University of Toronto, Department of Medical Imaging
- abdominal imaging
- breast imaging
- cardiothoracic imaging
- musculoskeletal imaging
- neuroradiology imaging
- pediatric imaging
- vascular and interventional radiology

University of Toronto, Imaging Research Program at Sunnybrook Health Sciences Centre
- ultrasonic biomicroscopy
- digital mammography research
- use of MRI for image guidance for minimally invasive therapy

University of Toronto, R.B. Holmes Radiological Research Laboratories
- Develops medical imaging methods and studies X-ray imaging systems.
- Operate Two-Tesla small-bore magnetic resonance imaging and spectroscopy unit for neurological, musculoskeletal, and cardiovascular animal research.

University of Toronto, Institute of Biomedical Engineering
- Doppler ultrasound techniques
- imaging techniques in nuclear medicine and microcirculation

University of Western Ontario, Lawson Research Institute
- diagnostic imaging
- development of new diagnostic imaging techniques and approaches
- magnetic resonance (MR) spectroscopy

University of Western Ontario, John P. Robarts Research Institute, Imaging Research Laboratories
- Medical imaging systems and techniques, including diagnostic X-rays, computed tomography, ultrasound, and magnetic resonance imaging.
- Evaluates existing technology and develops new diagnostic imaging systems, focusing on vascular imaging research in neurological diseases, three dimensional image processing and display and multimodality display.

University of Western Ontario, Computer Science Department
- Logic programming, formal languages, distributed computing, database management, software methodologies, cryptography, computational linguistics, computer graphics, and medical imaging.

INTERNATIONAL

Selected

University of California, Los Angeles: i) Center for Advanced Accelerators, ii) Reed Neurological Research Center and iii) Crump Institute for Biological Imaging (former/alternate name: Crump Institute for Medical Engineering)

Mallinckrodt Institute of Radiology, USA

Mayo Clinic, Ultrasound Research Laboratory, USA

Univerisity of Pennsylvannia: i) Pendergrass Diagnostic Radiology Laboratories and ii) W.D. Miller General Clinical Research Center

Duke Unviersity, Engineering Research Center for Emerging Cardiovascular Technologies

Stanford University: i) Information Systems Laboratory and ii) Radiological Research Laboratory

City College of City University of New York: i) Institute for Ultrafast Spectroscopy and Lasers, and ii) Mediphotonics Laboratory (former/alternate name: Photonic Application Laboratory)

John Hopkins University, Medical Imaging Lab

Others Identified

3M (former/alternate name: Minnesota Mining and Manufacturing Co.)
American Institute of Physics: The Physics Information NETsite
American Institute of Ultrasound in Medicine
AML Information Services
Applied Technology Associates
Australian Institute of Radiography
Australian Institute of Ultrasound:
Biomedical Technology Center
British Institute of Radiology
Cambridge University, Wolfson Brain Imaging Center
Cancer Center
Carnegie Mellon University, Center for Light Microscope Imaging and Biotechnology
Carnegie Mellon University, Science and Technology Center (former/alternate name: Center for Fluorescence Research in Biomedical Sciences)
Center for Devices and Radiological Health (CDRH)
Center for Imaging and Pharmaceutical Research
Center for Molecular Imaging Research
Center for Photographic Images of Medicine and Health Care
Center for X-Ray Optics
Cincinati Children's Hospital, Imaging Research Center

CIT Institute of Biotechnology
Emory-Georgia Tech Biomedical Technology Research Center
Energy Laboratories, Lawrence Berkeley Laboratory Center for Functional Imaging
Ernst-Moritz-Arndt-Universit t Greifswald, Diagnostische Radiologie
Fox Chase Cancer Center
Frederik Philips Magnetic Resonance Research Center
Georgia Institute of Technology, Bioengineering Center
Georgia Institute of Technology, Graphics, Visualization & Usability Center
Gustave-Roussy Institute, Institut Gustave-Roussy
Guy's and St Thomas' Hospital, Clinical PET Centre, Guy's and St Thomas' Hospital
H. Lee Moffitt Cancer Center and Research Institute
Harvard Medical Center, Joint Center for Radiation Therapy (JCRT
Heinrich-Heine-University, Institut of Diagnostic Radiology
Illinois State Psychiatric Institute
Indiana University Medical Center, Radiology Research Laboratory
Institute for Biophysical and Biomedical Research (formally/alternate name: Institute for Structural and Functional Studies)
Institute for clinical PET
Institute of Applied Physiology and Medicine
Institute of Physics
Institute of Physics and Engineering in Medicine
Julius Silver Institute of Biomedical Engineering
Klinikum Innenstadt der LMU, Institut f r Radiologische Diagnostik
Laboratory for Medical Imaging Research
Lawrence Berkeley Laboratory, Center for Functional Imaging (former/alternate name: Lawrence Berkeley Laboratory, Research Medicine and Radiation Biophysics Division)
Mammography Research Group, Biomedical Engineering Network
Massachusetts General Hospital, Center for Imaging and Pharmaceutical Research
Massachusetts General Hospital, Center for Morphometric Analysis
MAX-Lab, Lund University, Sweden
Medical College of Wisconsin, MCW Research Foundation
Michigan State University, A.H. Case Center for Computer-Aided Engineering and Manufacturing
MSB Systems, Inc.
National High Magnetic Field Laboratory, U.S.
National Institute of Standards and Technology, Physics Laboratory, National Institute of Standards and Technology
National Radiation Laboratory
National University of Singapore, Center for Information-enhanced Medicine, CieMed (ISS), National University of Singapore

Naval Surface Warfare Center Dahlgren Division (NSWCDD)
New England Medical Center, Image Analysis Laboratory
New Mexico Institute of Neuroimaging
Ohio State University, Biomedical Engineering Center (former/alternate name: Bio-Medical Engineering Program)
Oklahoma State University, Oklahoma Center for Equine Research
Physical Electronics Institute, Institut fur Physikalische Elektronik
Polaroid Corp.
Radiation Oncology Research & Development Center
Research Biochemicals, International (RBI) (former/alternate name: Research Biochemicals, Inc)
Rochester Institute of Technology, Center for Imaging Science
RSF International Group, Inc. (former/alternate name: Robert S. First, Inc.)
Scottish Agricultural Statistics Service (SAAS)
Signal Processing Laboratory, Signaalinkasittelyn Laitos (formally/alternate name: Computer Systems Laboratory)
South Fork Technological Consultants
SRC Medical Biophysics Programme
St. Jude Children's Research Hospital
State University of New York Health Science Center at Stony Brook
Synchrotron Radiation Reseach Center
Thomas Jefferson University, Office of Research Administration (former/alternate name): Office of Director of Sponsored Programs)
Turku PET Center
U.S. Public Health Service, National Institutes of Health, Lister Hill National Center for Biomedical Communications
U.S. Public Health Service, National Institutes of Health, National Cancer Institute, Division of Cancer Treatment, Radiation Research Program
U.S. Public Health Service, National Institutes of Health, National Cancer Institute, Division of Cancer Treatment, Radiation Research Program, Diagnostic Imaging Research Branch
UCI/AMI Magnetic Resonance Imaging Center (former/alternate name(s): AMI Medical Center)
University of Arizona, Arizona Cancer Center
University of Arizona, Nuclear Medicine Research Group
University of Arizona, Optical Sciences Center
University of Arkansas, Biomedical Visualization Center
University of California, Irvine. Beckman Laser Institute and Medical Clinic
University of California, Irvine. Brain Imaging Center
University of California, Irvine. Laser Microbeam Program (LAMP)

University of California, San Francisco, Osteoporosis Research Group
University of California, San Francisco. Magnetic Resonance Laboratory
University of Chicago, Cancer Research Center
University of Chicago, Center for Imaging Science (CIS)
University of Colorado, Center for Human Simulation,
University of Florida, Center for Structural Biology
University of Maryland, Medical Biotechnology Center
University of Maryland, Neuroscience Center for Research in Schizophrenia
University of Maryland, Vocal Tract Visualization Laboratory
University of Michigan, Artificial Intelligence Lab
University of Minnesota, Center for Magnetic Resonance
University of Palermo, Institute of Radiology
University of Pavia, Istituto di Radiologia
University of Pittsburg, Pitt Chemistry X-ray Crystallography Lab
University of Rochester, Center for Advanced Optical Technology
University of Rochester, Rochester Center for Biomedical Ultrasound
University of Southern California, Signal and Image Processing Institute
University of Texas MD Anderson Cancer Center Levit Radiologic-Pathologic Institute
University of Texas, Austin, NMR Imaging Laboratory
University of Texas, Southwestern, Radiology Imaging Research Center
University of Virginia, Department of Biomedical Engineering
University of Washington, Diagnostic Imaging Sciences Center
University of Washington, Madison, Radiation Calibration Laboratory
Wadsworth Center (former/alternate name: New York State Hygienic Laboratory; New York State Department of Health, Division of Laboratories and Research)
Washington University, Applied Research Laboratory
Wayne State University, MR Center
Westf lischen Wilhelms Universit t Mnster, Institut f r Klinische Radiologie
X Data Corp.

APPENDIX V: SELECTED INTERNET LINKS

Connectivity
http://www.xray.hmc.psu.edu/dicom/dicom_home.html
http://www.mcis.duke.edu/standards/guide.htm
http://dumccss.mc.duke.edu/standards/HL7/hl7.html

Healthtechnet:
www.healthtechnet.com Comprehensive links to healthcare technology industry information (including associations, societies, conferences, expositions, government, regulatory).

MedMark Radiology:
www.medmark.org/rad/rad.html

Radiology Terminology:
www.bih.harvard.edu/radiology/Headings/glossary.html

Information Technology Terminology:
www.techweb.com/encyclopedia

PACS:
www.charm.net/~efinegan/pacspage.html
http://www.erols.com/veader/general.htm

OEMs

ADAC Laboratories	http://www.adaclabs.com
Agfa	http://medical.agfa.com
Elscint	http://www.elscint.co.il
GE Medical Systems	http://www.ge.com/medical
Hewlett-Packard	http://www.hp.com
Hitachi	http://www.hitachi.com
Philips Medical Systems	http://www-eur.philips.com/ms
Picker International	http://www.picker.com
Siemens	http://www.sms.siemens.com
Toshiba	http://www.toshiba.com

CT

Shimadzu	http://www.shimadzu.com

Toshiba America Medical Systems http://www.toshiba.com/tams/

Nuclear Medicine

ELGEMS (Elscint and
GE Medical Systems) http://www.elscint.co.il
SMV America http://www.smvnet.com/
Toshiba America Medical Systems http://www.toshiba.com/tams/

Ultrasound

ATL Ultrasound http://www.atl.com
Acuson Corp. http://www.acuson.com/
Diasonics Vingmed Ultrasound Ltd.
Elbit Ultrasound
Shimadzu http://www.shimadzu.com
Toshiba America Medical Systems http://www.toshiba.com/tams/

X-ray

Canon USA Inc. http://www.canon.com
DpiX Inc.
Eastman Kodak Co. http://www.kodak.com
Fischer Imaging http://www.fischerimaging.com/
Odelft Corp. of America
OEC Medical Systems Inc. http://www.oecmed.com
PGI
Shimadzu http://www.shimadzu.com
Shimadzu http://www.shimadzu.com
Sterling Diagnostic Imaging Inc. http://www.sterlingdi.com/
Swissray International Inc. http://www.swissray.com/
Toshiba America Medical Systems http://www.toshiba.com/tams/
Trex Medical Corp. http://www.thermo.com/subsid/txm.html
Trixell S.A.S.
Varian Associates Inc.'s Imaging Products Division http://www.varian.com/

MRI
Toshiba America Medical Systems http://www.toshiba.com/tams/

Endoscopy

Smith&Nephew http://www.smithnephew.com

PACS Companies

ADAC Laboratories	http://www.adaclabs.com
Advanced Technologies Laboratories	http://www.atl.com
Agfa	http://medical.agfa.com
ALI Technologies (Can)	http://www.alitech.com
Cifra Médical Inc.(Can.)	
Diffracto Ltd. (Can.)	http://www.netcore.ca/~diffract
Dynamic Healthcare Technologies	http://www.dht.com
Elscint	http://www.elscint.co.il
Fuji	http://www.fujimed.com
GE	http://www.ge.com/medical
I.S.G. Technologies Inc. (Can.)	http://www.isgtec.com
IDX	http://www.idx.com
Imation/Cemax-Icon	http://www.imation.com
IMNET Systems Inc.	http://www.imnet.com
Kodak	http://www.kodak.com
Mitra Imaging (Can.)	http://www.mitra.com
PACS LTD. (Can.)	
PACS Marketing Solutions Inc. (Can.)	
Phillips	http://www-eur.philips.com/ms
Picker International	http://www.picker.com
Siemens	http://www.sms.siemens.com
Sterling Diagnostic Imaging	http://www.sterlingdi.com
Toshiba	http://www.toshiba.com

Additional PACS vendors can be found at
“http://www.charm.net/~efinegan/pacsvend.htm”

APPENDIX VI: C-MIST PARTICIPANTS

The following names have been provided by C-MIST, the Consortium for Medical Imaging Science and Technology, being lead by Dr. Aaron Fenster of the Advanced Imaging Research Group at the Robarts Research Institute located at the University of Western Ontario.

The goal of C-MIST is to promote the development and commercial exploitation of Canadian innovations in medical imaging through cross-Canada integration of research programs (within targeted themes), training to stimulate developments, and partnerships with the medical community, knowledge based companies and venture capital organizations.

C-MIST is in the process of developing a proposal for a Network of Centres of Excellence.

Calgary
Dr. G. Sutherland, Professor of Neurosurgery, University of Calgary; Chief of Neurosurgery, Foothills Hospital Calgary. Expertise: Neurosurgery, Image-guided Surgery.

Dr. A. Buchan Neurologist, University of Calgary; Foothills hospital.
Expertise: Neurology.

Dr. R. Sevick Associate Professor, Department of Radiology, University of Calgary, Radiologist, Foothills Hospital. Expertise: MRI.

Edmonton
Dr P. Allen, Chairman, Department of Applied Sciences in Medicine, University of Alberta, Edmonton. Expertise: NMR, MR imaging and spectroscopy

Dr. R.E.Snyder, Professor, Biomedical Engineering, University of Alberta. Expertise: MR imaging, Neuroscience.

Dr. A. H. Wilman, Assistant Professor, Biomedical Engineering, University of Alberta.

Expertise: MR vascular imaging.

Dr. Z. J. Koles, Professor, Biomedical Engineering, University of Alberta. Expertise:

Brain Electrical Tomography.

Dr. R. Cabeza, Assistant Professor, Psychology, University of Alberta.

London
Dr. A Fenster Director, Imaging Research Laboratories, J. P. Robarts Research Institute; Professor, Department of Radiology and Nuclear Medicine, UWO. Expertise: Ultrasound.

Dr. R. Menon, Scientist, J. P. Robarts Research Institute; Assistant Professor, Department of Medical Biophysics, UWO. Expertise: Functional MR imaging

Dr. T. Lee, Scientist, J. P. Robarts Research Institute, Investigator, Lawson Research Institute; Assoc. Professor, Medical Biophysics, UWO. Expertise: Functional CT imaging.

Dr. T. Peters, Scientist J. P. Robarts Research Institute; Professor, Radiology and Nuclear Medicine, UWO. Expertise: Surgical image-guidance, MR Imaging.

Dr. M. Drangova, Scientist, J. P. Robarts Research Institute; Assistant Professor, Medical Biophysics, UWO. Expertise: MR Imaging.

Dr. B. Rutt, Scientist J. P. Robarts Research Institute; Professor, Department of Radiology and Nuclear Medicine, UWO. Expertise: MR Imaging, MR instrumentation

Dr. I. Cunningham, Scientist, J. P. Robarts Research Institute; Physicist, London Health Sciences Centre; Associate Professor, , Department of Radiology and Nuclear Medicine, UWO. Expertise: X-ray imaging, CT

Dr. D. Holdsworth, Scientist, J. P. Robarts Research Institute; Assistant. Professor, Department of Medical Biophysics, UWO. Expertise: X-ray imaging, CT

Dr. D. Steinman, Scientist, J. P. Robarts Research Institute; Asst. Professor, Medical Biophysics, UWO Expertise: Computer modelling

Dr. R. Mitchell, Scientist, J. P. Robarts Research Institute; Physicist, London Health Sciences Centre; Assistant Professor, Department of Medical Biophysics, UWO. Expertise: MR imaging.

Dr. M. Goodale, Professor, Department of Psychology, UWO. Expertise: Neuropsychology, vision, motor control.

Dr. P. Williamson, Associate Professor, Dept of Psychiatry, University of Western Ontario. Expertise: Functional imaging, schizophrenia.

Dr. T. Vilis, Professor, Dept. of Physiology, UWO. Expertise: Visual motor control.

Dr. F. S. Prato Director, BioElectroMagnetics Western, Chair, Imaging Division, Lawson Research Institute; Chair, Division of Imaging Sciences, London Health Sciences; Professor, Diagnostic Radiology & Medical Biophysics, UWO. Expertise: Biomagnetics.

Dr. D. J. Drost Investigator, Lawson Research Inst; Associate Professor, Medical Biophysics, UWO. Expertise: MR imaging.

Dr. M. A. Persinger, Director, Behavioral Neuroscience Program, Professor, Psychology Department, Laurentian University. Expertise: Biomagnatics, Neuropsychology.

Dr. K-P Ossenkopp, Professor, Psychology and Neuroscience, UWO
Expertise: Bioelectromagnetics, Statistics, Behavioural Neuroscience.

Dr. B. J. Kemp, Investigator, Lawson Research Inst; Assistant Professor, Medical Biophysics, UWO. Expertise: SPECT Imaging, Computer simulation.

Dr. R. T. Thompson, Investigator Lawson Research Institute, Associate Professor, Medical Biophysics UWO. Expertise: MR Spectroscopy, Muscle Metabolism.

Dr. P. Slomka Assistant Professor, Diagnostic Radiology and Nuclear Medicine, UWO.

Expertise: SPECT Imaging

Dr. M Kavaliers, Professor, Dentistry, Psychology and Neuroscience, UWO. Expertise: Bioelectromagnatics, Opioid peptides, Behavioral Neuroscience.

Montreal

Dr. A.C. Evans, Director, McConnell Brain Imaging Centre, Montreal Neurological Institute; Professor, Neurology and Neurosurgery, McGill University.
Expertise: Brain Mapping, Functional Imaging

Dr. G.B. Pike Scientist, Montreal Neurological Institute; Asst. Professor, Biomedical Engineering, McGill University. Expertise: MR Imaging.

Dr. D. Arnold Scientist, Montreal Neurological Institute; Professor, Neurology & Neurosurgery, McGill University. Expertise: MR Spectroscopy.

Dr. C. J. Thompson Scientist, Montreal Neurological Institute; Professor, Neurology & Neurosurgery, McGill University. Expertise: PET instrumentation.

Dr. M. Petrides, Scientist, Montreal Neurological Institute; Professor, Neurology & Neurosurgery, McGill University. Expertise: Neuropsychology, Brain mapping.

Dr. R. Zatorre Scientist, Montreal Neurological Institute; Professor, Neurology & Neurosurgery, McGill University. Expertise: Neuropsychology, Brain mapping.

Dr. T. P us, Scientist, Montreal Neurological Institute; Assistant. Professor, Neurology & Neurosurgery, McGill University. Expertise: Neuropsychology, Transcranial Magnetic Stimulation.

Sherbrooke
Dr. R. Lecomte, Scientist, Centre d'Imagerie M,tobolique et Fonctionelle, Centre Universitaire de Sant, de L'Estrie, Professor, Dept of Nuclear Medicine and Radiobiology, Universit, de Sherbrooke. Expertise: PET instrumentation.

Toronto
Dr M. J. Bronskill, Director Imaging & Biomedical Engineering, Sunnybrook Health Sciences Centre, Professor, Medical Biophysics, University of Toronto.
Expertise: MRI, Surgical image guidance.

Dr. R. M. Henkelman Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Professor, Medical Biophysics, University of Toronto.
Expertise: MRI, Surgical image guidance.

Dr. J. A. Rowlands, Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Professor, Medical Biophysics, University of Toronto. Expertise: X-ray detectors.

Dr. M. J. Yaffe, Scientist, Imaging and Biomedical Engineering, Sunnybrook Health

Sciences Centre, Professor, Medical Biophysics, University of Toronto. Expertise: X-ray Mammography.

Dr. G. Wright, Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Asst. Professor, Medical Biophysics, University of Toronto. Expertise: MR Imaging.

Dr. P. Burns, Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Associate Professor, Medical Biophysics, University of Toronto. Expertise: Ultrasound.

Dr. D. Plewes Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Professor, Medical Biophysics, University of Toronto. Expertise: MR Imaging.

Dr. F. S. Foster, Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Professor, Medical Biophysics, University of Toronto. Expertise: Ultrasound.

Dr. S. Black, Senior Scientist, Imaging and Biomedical Engineering, Sunnybrook Health Sciences Centre, Associate Professor, Dept of Medicine (Neurology), University of Toronto. Expertise: Neurodegenerative diseases, MRI, SPECT.

Vancouver
Dr. A. Mackay, Professor, Radiology and Physics, UBC. Expertise: MRI.

Dr. P. Liddle, Professor, Jack Bell Chair in Schizophrenia, Psychiatry, UBC, Expertise: Functional Imaging.

Dr. D. Li, Professor, Radiology, UBC. Expertise: Clinical trials, MRI.

Dr. Bruce Forster, Assistant Professor, Radiology, UBC.
Expertise: Vascular imaging, fMRI.

Dr. D. Paty, Professor and Head, Neurology, UBC. Expertise: Clinical Trials.

Winnipeg
Dr. I. Smith, Director General, National Research Council Institute for Biodiagnostics; Professor, Department of Chemistry, University of Manitoba. Expertise: NMR.

Dr. M. McIntyre, Professor Psychology, University of Winnipeg; Dept of Physiology, University of Manitoba; Program Leader, Functional Neuroimaging, National Research Council. Expertise: Functional Imaging

Dr. J. Saunders, Head, MR Technology, National Research Council. Expertise: MR Imaging Technology.

Dr. J. Peeling, Professor of Chemistry, University of Winnipeg; Professor of Radiology, University of Manitoba. Expertise: Functional MRI, Pulse sequence development

Dr. C. Power, Dept of Neurology, Faculty of Medicine, University of Manitoba. Expertise: Clinical Trials, degenerative diseases.

Dr. P. Koslowski, National Research Council. Expertise: MR imaging.

Dr. R. Somorjai, Head, Informatics, National Research Council, Professor, Dept of Physics, University of Manitoba. Expertise: Image analysis.

Dr. B. McClarty, Professor of Radiology, Faculty of Medicine, University of Manitoba. Expertise: Clinical Trials.

Partners

Canadian Industrial Partners –

Start-up companies formed as a direct result of research activities of Network members.
Enhanced Visualization Systems, London ON. – Holdsworth, Drangova, Fenster
IMRIS, Winnipeg MB. - Saunders, Smith
Image 2000, Winnipeg MB. - McClarty
Life Imaging Sciences Inc, London ON. - Fenster
NeuroMRIS, Winnipeg MB. - Saunders, Smith
Neurovision Imaging Sciences Inc, Montreal QC. - Evans, Peters, Pike, Arnold

Other Canadian Industrial Partners

Alex Informatique inc
Astray
Berlex Canada
CTF Inc, BC
EG&G Opto,lectronique

Eli Lilli Canada
General Electric Canada
ISG Technologies Inc
Image 2000
Hoechst Marion Roussel
Jansen Ortho,
Mallinckrodt Canada
Millenium Technologies
Noranda Advanced Materials, QC
Northern Digital, Waterloo, ON
Parke Davis,
Pfizer Inc (Canada)
Siemens Canada,
Smith-Kline
Varian Canada

International Industrial Partners
ATL Inc Seattle WA
AutoImmune
CTI, Inc. Knoxville, TN
Magnex Scientific Ltd. UK.
Nuclear Diagnostics AB, Stockholm, Sweden
Novartis, Basel, Switzerland
NeuroCrine
Shering AG, Berlin Germany
Siemens Germany.
S.M.I.S. Surry, UK.

Canadian Government Partners.
National Research Council of Canada
NCE-Institute for Robotics and Intelligent Systems
Medical Research Council of Canada
National Science and Engineering Research Council of Canada

Non-Government Canadian Granting Agencies
Brain Tumour Foundation of Canada
Heart and Stroke Foundation
National Cancer Institute of Canada
Ontario Mental Health Foundation
MS Society of Canada

International Funding Agency Partners
National Institutes of Health (US)
National Science Foundation (US)
McDonnell-Pew Foundation
The Whitaker Foundation

International University Partners
University of California
University of Texas
University of Michigan
Stanford University

APPENDIX VII: GLOSSARY OF TERMS

This appendix provides a selected glossary of acronyms, medical and computer terms used in this report. Unless otherwise provided, the sources for this glossary are:

i) Techweb online encyclopedia (http://www.techweb.com/encyclopedia/)
ii) Harvard Medical School, Radiology Glossary of Terms (http://www.bih.harvard.edu/radiology/Headings/glossary.html)

2K monitors - High resolution monitors typically used in reading x-ray images.

ActiveX - A brand name from Microsoft for various technologies based on its Component Object Model (COM), many of which are targeted for the Internet.

ATM - Asynchronous Transfer Mode. A network technology for both LANs and WANs that supports realtime voice and video as well as data.

AWG - Hewlett Packard's Andover Working Group. An industry group which is developing standard software for exchanging healthcare information between healthcare systems, devices, applications and instruments. See also MS-HUG.

CANARIE - Canadian Network for the Advanceemnt of Reserach Industry and Education

C-MIST - Consortium for Medical Image Science and Technology

CT - Computerized tomography. Also known as CT scans or CAT scans (for Computer Assisted Tomography). This technique uses X-rays to generate computerized images (pictures) of all parts of the body. The technique can create pictures in 2D and 3D.

CAT - See CT.

Contrast media - A radiopaque substance used during an X-ray exam (or some MRI exams) to provide visual contrast in the pictures of different tissues and organs. Can be given orally or intravenously (by injection).

CORBA - Common Object Request Broker Architecture. A standard from The Object Management Group (OMG) for communicating between distributed objects. CORBA provides a way to execute programs written in any language no matter where they reside in the network or what platform they run on. It enables complex systems to be built across an entire enterprise. CORBA is suited for widely disbursed networks, where an event occurring in one location requires services to be performed in another.

CORBAmed - A Healthcare Domain Task Force formed by the Object Management Group (OMG) which supports the use of CORBA, the Internet interoperability protocol (IIOP) and Java in healthcare applications.

DICOM standard - Digital Imaging Communication in Medicine standard

DR - Direct Radiology. The process of capturing a digital radiological image directly (without the need for an intermediate, analogue step).

DVD - Digital VideoDisc or Digital Versatile Disc. The next-generation video CD and high-capacity CD-ROM. It can hold up to 17GB, the equivalent of 28 CD-ROMS.

EEG - Electroencephalography. EEG refers to the continuous recording of brain electrical activity. This can be recorded onto a paper chart or, more commonly these days, digitised into a computer for freqency analysis. The continuous EEG is made up of waves of different frequencies which each relate to different aspects of mental life. (http://www.bhs.mq.edu.au/~tbates/imaging_techniques/EEG/EEG.html)

endoscopy - Endoscopy is a technique that allows examination of an area of the body by means of an endoscope, a tubelike instrument with lenses and a light source attached. The endoscope provides visual examination of the interior of the body through a natural body opening such as the throat or through a small incision into the body. A camera or video recorder is often used during an endoscopic procedure to provide permanent records of internal organs which may be used for later reference. (http://patient-info.com/endoscopy.html)

fMRI - functional Magnetic Resonance Imaging. Functional MRI is based on the increase in blood flow to the local vasculature that accompanies neural activity in the brain. Using an appropriate imaging sequence, human cortical functions can be observed without the use of contrast enhancing agents on a clinical strength scanner. Functional activity of the brain determined from the magnetic resonance signal has confirmed known anatomically distinct processing areas in the visual cortex, the motor cortex, and Broca's area of speech and language-related activities. (http://www.fmri.org/fmri.html)

HL7 - Health Level 7 or High Level 7. A prominent standard used for exchanging text-based information (e.g., patient registration, admission, lab results, discharge information) between Hospital Information Systems (HIS) and Radiological Information Systems (RIS).

HMO - Health Maintenance Organization.

IIOP - (Internet Inter-ORB Protocol) The CORBA message protocol used on a TCP/IP network (Internet, intranet, etc.). CORBA is an industry standard for distributed objects, which allows programs (objects) to be run remotely in a network. IIOP links CORBA's General Inter-ORB protocol (GIOP), which specifies how CORBA's Object Request Brokers (ORBs) communicate with each other, to TCP/IP.

IP - Internet Protocol. It addresses and instructs computer network switches on what to do with the data

Java - A programming language for Internet (World Wide Web) and intranet applications from Sun. Java was modeled after C++, and Java programs can be called from within HTML documents or launched stand alone. Java was designed to run in small amounts of memory and provides its own memory management.

jukebox - A storage device for multiple sets of CD-ROMs, tape cartridges or disk modules. Using carousels, robot arms and other methods, a jukebox physically moves the storage medium from its assigned location to an optical or magnetic station for reading and writing.

LAN - Local Area Network. A communications network that serves users within a confined geographical area. It is made up of servers, workstations, a network operating system and a communications link.

legacy system - A mainframe or minicomputer information system that has been in existence for a long time.

lossless compression - A compression technique that decompresses data back to its original form without any loss. The decompressed file and the original are identical. Contrast with lossy compression.

lossy compression - A compression technique that does not decompress data 100% back to original. Lossy compression provides high degrees of compression and results in very small compressed files, but there is a certain amount of loss when they are restored.

MEG - Magnetoencephalography. MEG is a non-invasive technique that measures the intercellular currents of the neurons in the brain giving direct information about the brains activity, spontaneously or to a given stimulus. (http://www.ctf.com/)

MI - Medical Imaging

MRI - Magnetic Resonance Imaging. This technique uses radio waves and a strong magnetic field to generate images in 2D and 3D.

Mbps - Mega bits per second

MRC - Medical Reserach Council (Canada)

MS-HUG - Microsoft's Healthcare Users Group. An industry group which is developing standard software for exchanging healthcare information between healthcare systems, devices, applications and instruments. See also AWG.

NCE - Networks of Centres of Excellence (Canada)

NRC - National Research Council (Canada)

NSERC - Natural Sciences and Engineering Research Council (Canada)

Nuclear medicine - Dozens of different examinations are performed in the Nuclear Medicine Department. The patient gets an intravenous injection of a minute trace of radioactive material which attaches to a certain type of molecule. The type of radioactive tracer and the type of molecule vary, depending on which part of the body is to be examined. Scans are obtained with a gamma camera, which unlike some other radiology devices does not itself emit radiation.

OEM - Orginal Equipment Manufacturers. Manufacturers that sell equipment for resale under an end-equipment manufacturers' trademark or name.

OLE - Originally known as "Object Linking and Embedding”. A compound document technology from Microsoft that is based on its Component Object Model (COM). OLE allows an object such as a spreadsheet or video clip to be embedded into a document, called the container application. When the object is double clicked, the application that created it, called the server application, is launched in order to edit it.

OMG - Object Management Group. An international organization founded in 1989 to endorse technologies as open standards for object-oriented applications.

PACS - Picture Archiving and Communication Systems, is a computer network system designed to transmit, store, and retrieve digital medical images.

PET - Positron Emission Tomography. It is a scanning technique which allows one to measure in detail the functioning of distinct areas of the human brain while the patient is comfortable, conscious and alert. The PET scanner utilizes radiation emitted from the patient to develop images. Each patient is given a minute amount of a radioactive pharmaceutical that closely resembles a natural substance used by the body. Gamma radiation produced from the breakdown of the radioactive component is detected by the PET scanner and shows in fine detail chemical activity in the brain. (http://www.triumf.ca/welcome/text_only/petscan.html)

RAID - Redundant Array of Independent Disks. A category of disk arrays (two or more drives working together) that provide increased performance and various levels of error recovery and fault tolerance. RAID can be implemented in software using standard disk controllers, or it can be designed into the disk controller itself.

RAN - Regional Advanced Networks. These provide connections to CANARIE’s high performance IP/ATM network, CA*netII.

RIS - Radiological Information System

SPECT - Single Photon Emission Computed Tomography. A nuclear medicine procedure in which the gamma camera rotates around the patient and takes pictures from many angles, which a computer then uses to form a tomographic (cross-sectional) image. The calculation process is similar to that in X-ray Computed Tomography (CT) and in Positron Emission computed Tomography (PET).

TCP/IP - Transmission Control Protocol/Internet Protocol. A communications protocol developed under contract from the U.S. Department of Defense to internetwork dissimilar systems. It is a de facto UNIX standard that is the protocol of the Internet and widely supported on all platforms.

Tesla - the standard unit for measuring magnetic flux density and magnetic polarization.

ultrasound - This technique uses sound waves to make pictures of the body organs. Since no ionizing radiation (X-rays) are used, it is ideal for looking at pregnant women and their fetuses, but also has many other uses. It is often used for the neck, abdomen, pelvis, and soft tissues including blood vessels in the arms and legs.

VAR - Value-Added Reseller. An organization that adds value to a system and resells it. For example, it could purchase a CPU and peripherals from different vendors, graphics software from another and package it all together as a specialized CAD system. Although VARs typically repackage products, they might also include programs they have developed themselves. The terms VAR and ISV are often used interchangeably.

WAN - Wide Area Network. A communications network that covers a wide geographic area, such as state or country.

wavelet compression - A lossy compression method used for color images and video. Instead of compressing small blocks of 8x8 pixels (64 bits) as in JPEG and MPEG, the wavelet algorithms compress the entire image with ratios of up to 300:1 for color and 50:1 for gray scale. Wavelet compression also supports nonuniform compression, where specified parts of the image can be compressed more than others.

Year 2000 problem - The year 2000 presents a problem for many legacy systems whose databases were designed with two-byte year fields. Years ago, saving two bytes in a record meant a lot more than it does today. A "00" in the year field is assumed to mean the year 1900, and calculations that deal with aging will be incorrect.