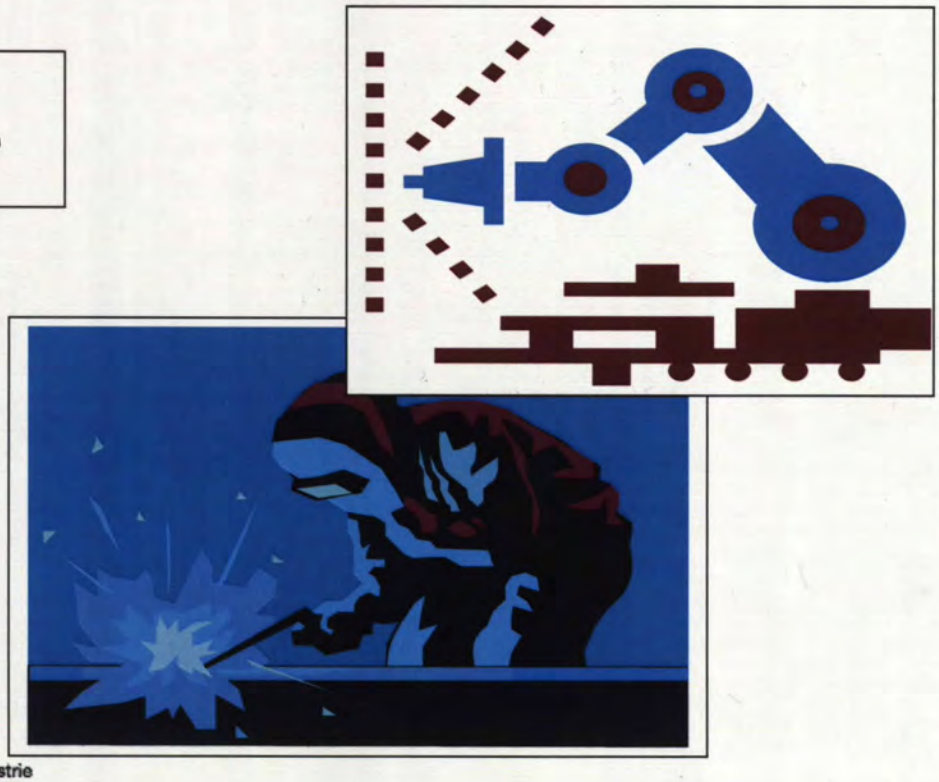
# A Technology Roadmap

*for the*

# Canadian Welding and Joining Industry

FINAL REPORT



Industry Canada Industrie Canada

FedNor

Prepared by Suthey Holler Associates

May 2006

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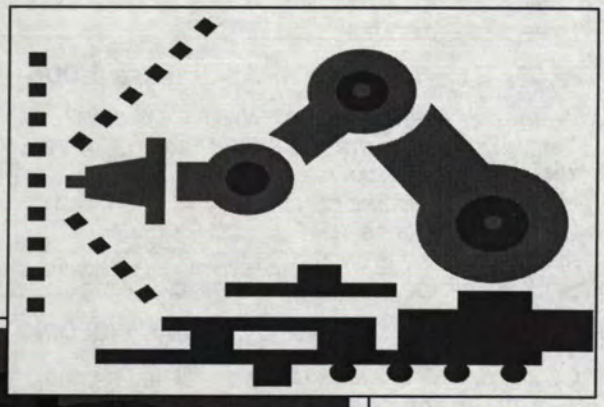



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# Table Of Contents

## *Foreword*

If you don't know where you are going – any road will get you there.

Unfortunately, this has been a well traveled road for many former participants in business and industry who are no longer around to comment on the reality of the statement.

Planning, be it strategic or business planning has become an indispensable tool that helps companies to make decisions in their allocation of resources.

On an industry-wide basis, planning is no less essential and over the last decade and a half, has increasingly taken on the form of Technology Roadmaps. The Technology Roadmap (TRM) for the Canadian Welding and Joining Industry attempts to achieve a consensus on the Goals, Vision and Plan of Action for the Welding and Joining Industry.

On a Pan-Canadian basis this TRM considers and guides future technology and product needs along with human resource requirements; future marketing opportunities; decision making on technology application and research and promotes collaboration, shared knowledge and new partnerships.

To all those who participated in the various forums of industry consultation, thank you for your support and willingness to come together to cast a Roadmap for the Welding and Joining Industry.

To the TRM Steering Committee, thank you for your enthusiasm, encouragement and your absolute commitment to the TRM process and its ensuing product that will well-serve and position the Welding and Joining Industry in Canada through the next decade.

Fred Gibbons
Steering Committee, Chairman

# A Technology Roadmap for Welding and Joining in Canada – 2006 to 2016

*In a nutshell!*

## The Problems

**Welding is a critical enabling technology for manufactured products.**

- *But senior executives often only see it as a commodity or expense.*

**Welding is a challenging scientific and technological area, globally.**

- *Yet its image to potential students is a dirty old-fashioned industry.*

**Welding education is crucial for the future of Canada's manufacturing industry.**

- *Yet we have no national standards for welders, and no international level welding engineering program.*

## The Solutions

**All players in the welding industry must recognize these problems, and provide the required leadership to:**

- *Make CEO's, senior executives and governments aware of the strategic function of welding in manufacturing excellence,*
- *Incorporate welding and joining considerations early in product design stages,*
- *Make the image of welding and joining more modern and challenging, to attract more highly talented people into the industry,*
- *Upgrade and integrate educational programs related to welding, for welders, technicians and engineers,*
- *Increase the pace of innovation in advanced welding and joining applications.*

# Executive Summary

## A Vision and a Strategy to ensure that Canada continues to play a leading role in manufacturing and construction based on the enabling technology of welding and joining

*Welding and Joining – the art, science and engineering prowess of making metals and increasingly other advanced materials join together and function as one.*

Most manufactured products require that different parts be joined. The technology for doing so continues to develop. For example, laser welding is now widely utilized in the automotive industry. Great advances in joining technology have been made, and the field keeps rolling forward, incorporating leading-edge science, information technology, robotics and advanced manufacturing materials.

*But what of the next ten to twenty-five years?* One of the negative results of the advance of the "service economy" and the "information technology revolution" has been to create the impression in the minds of young people and of many policy makers that manufacturing, and particularly welding and joining, is no longer important in today's world. Nothing could be further from reality. Welding and joining will continue to advance as the manufacturing and construction industries take on new vistas throughout the world and major new consumer societies come into play – China, India, Indonesia and a host of others. But the fundamental question is how much of the manufacturing – and the enabling welding and joining – will continue to take place in North America and, in particular, Canada?

Welding has long been fundamental to "making things". Even the Egyptians knew how to weld – items of iron and bronze that exhibit intricate forging and welding operations were found in the pyramids.

This question provides the backdrop for creating this **Technology Roadmap for Welding and Joining in Canada – 2006 to 2016**. The answer is resoundingly positive but the implementation strategy requires a clear focus and commitment of industry, government, education and research institutes.

## The primary target audience for this report is business leaders

This report is addressed first and foremost to CEO's and other business leaders of companies in industries that are users of welding and joining

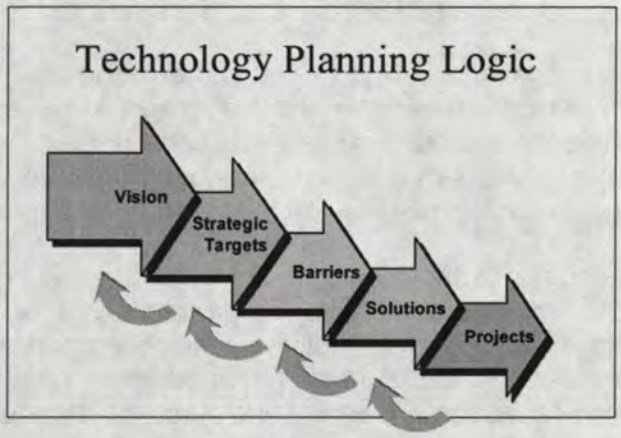
technologies. Often they see welding and joining purely as a "cost centre" and not as an enabling technology that is crucial in designing cost-competitive, quality products on the international stage. **It is also addressed to the federal and provincial governments in Canada -** to ensure that they see welding and joining as an enabling technology and that they support innovative initiatives in the sector from both a policy and financial perspective.

**In addition, the report is directed to educational institutions and research institutes** to encourage them to make their contributions to the Canadian welding and joining industry. Innovation is required to make Canada a leader in developing new design approaches and new unique joining technologies. The importance of welding and joining will require better collaboration among various educational institutions to develop a better system for education of the required personnel.

**Finally, it is also hoped that the general public will benefit** from the messages in this report which demonstrate the importance of welding and joining, and also that the welding and joining industry can provide exciting and rewarding career paths for young people at all levels of education.

### The Process of developing the Welding and Joining Technology Roadmap involved hundreds of participants across Canada!

Technology Roadmaps (TRM's) are a tool for industry, working with governments, education and research institutes to map out a strategy to accelerate industry growth and maintain competitive advantage as the future unfolds. In Canada, TRM's have been completed for a wide range of industries – Aluminum, Electric Power, Fuel Cells, Intelligent Buildings, Marine and Ocean Industries, Wood-based Panel Products. The majority of the industries that have completed TRM's rely on Welding and Joining as a critical enabling technology. As new technology platforms unfold, such as biotechnology and advanced materials, industry strategies such as logistics and welding and joining that cut across traditional single industry lines will become increasingly important.



The logic of the Technology Roadmap process moved from the Vision and Strategic Targets, through the Barriers to Solutions and Projects. The Welding and Joining TRM began with a session in Whitby, Ontario in late 2003 promoted by Industry Canada, FedNor, Northern College of Applied Arts and Technology (Kirkland Lake, Ontario), the Canadian Welding Association and numerous industry partners.

From the Vision and Strategic Goals developed at the Whitby Forum, the Welding and Joining TRM Steering Committee managed the process through numerous meetings culminating in four Regional Forums held in Montreal, Cambridge, Edmonton and Halifax in October 2005. Throughout the process more than 250 participants representing a wide range of companies, associations, educational and research institutions as well as all the levels of government participated. The entire process was documented on the website www.weldingtrm.org.

### *The Vision for Welding and Joining in Canada*

The Vision for the Welding and Joining TRM is that,

**Canada's excellence in welding and joining technology and its applications will be increasingly recognized and developed across the country and internationally over the next ten years.**

This will be achieved through the establishment and implementation of a national welding and joining strategy.

## Strategic Targets

The Strategic Targets associated with the Vision are the following:

1. Demonstrate and convince CEO's and other leaders of all manufacturing industries that welding and joining should be seen as an enabling technology that can make significant contributions to assist manufacturers who strive to put well-designed quality and cost-effective products and processes on the world marketplace.

2. Demonstrate and convince the federal and provincial governments that welding and joining is a strategic enabling technology which is required to enhance Canada's competitive position, and therefore merits both policy and financial support for world-class innovation, research, technology adoption and human resource development.

3. Develop a proactive, concerted and organized response from the welding and joining community in concert with educational institutions and research institutes, supported by government, to

increase the pace of innovation in advanced welding and joining technology and application.

The target is to ensure responsiveness to the needs of user industries particularly with respect to cost-effectiveness and constantly increasing productivity in welding and joining processes, in Canada and at the international level. Welding and joining must be integrated into the design stage for manufacturing and construction.

4. Demonstrate that welding and joining is a field of activity that spans leading-edge science, information technology and advanced manufacturing processes and materials that are integral to the future prosperity of Canada. It will provide exciting career paths at all levels of skill and education which fully safeguards life, property and the environment.

   In this context, establish Canada as one of the best education and training environments for welding and materials joining.

### *Barriers and Constraints: Downward Spiral and Leadership*

The welding and joining industry is cognizant that in order to achieve the Vision and Strategic Goals it must overcome two particular constraints.

The first constraint is the current situation of welding and joining in Canada. Welding technologies will move forward and contribute to industrial competitiveness to the extent that high quality information about new technical capabilities is available to industry leaders who have knowledge and authority to deploy them with confidence. This situation is not characteristic of the Canadian welding and joining scene. The majority of people with responsibility for design of welded products and manufacturing systems do not have advanced welding knowledge. Welding tends therefore to be treated as a commodity rather than as a strategic enabling technology. Since few senior industry executives perceive what they are missing, the result is a low demand for new technology and for engineering graduates with welding specializations. That in turn means that the capacity for advanced welding R&D in Canadian colleges and universities has remained seriously inadequate - a situation that will now take many years to correct. Initiatives in welding and joining education recently have been compromised by the retirement of experienced faculty members who have not been replaced. This "Downward Spiral" must be unwound!

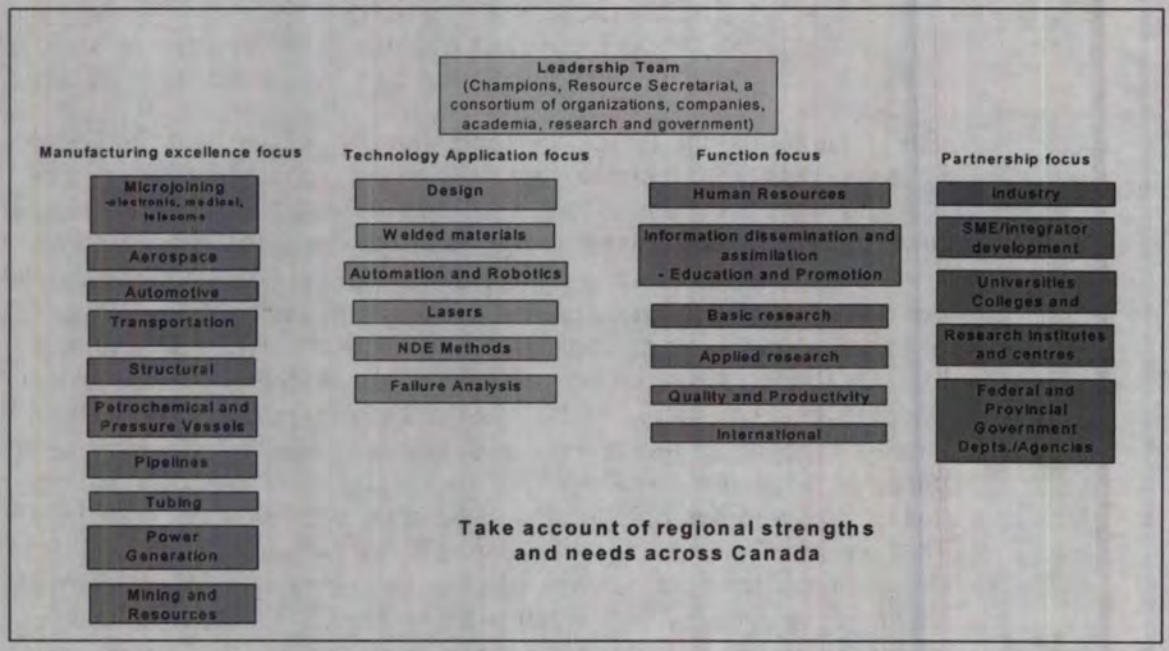
The second constraint is related to the first. Because welding and joining is "embedded" in many user industries and because the industry is widely dispersed across Canada, a clear and dynamic leadership focus is

lacking. While a number of industry associations related to welding and joining are active, they lack the resources and the commitment of senior executives and the commitment of government support to present a visible and highly respected image of the industry. No widely recognized research and development centre or information sources for welding and joining exist in Canada.

## Solutions – A Leadership Team and a Solutions Matrix

In order to implement the Vision and Strategic Targets and to overcome the Constraints, the following Solutions Matrix is recommended.

1. The first element of the Solution is the creation of a strong funded Team of at least three Welding and Joining Champions supported by a Resource Secretariat. The purpose of the Team is to develop a strong, comprehensive national welding and joining consortium capable of developing and implementing the TRM welding and joining solutions matrix and specific projects.




The working philosophy of the Team will be the acronym DREAM. Clearly identify DESIRES, assign RESPONSIBILITY, ensure ENGAGEMENT that leads to ACTION in accordance with a clear METHODOLOGY.

The Matrix identifies the key user industries that will continue to be a strength of Canadian manufacturing and for which welding and joining must provide enabling solutions. It also identifies the key technology applications that must be advanced and the industry and enterprise focus through which the technology applications need to be pursued. And finally it identifies the Partnerships through which the solutions must be presented, advanced and implemented.

## Projects

The Leadership Team and Resource Secretariat will implement inter-connected projects based on the Solutions Matrix. The four identified priority project themes are indicated below. As the Leadership Team undertakes further analysis the individual project themes may be implemented as stand-alone elements or combined in a form conducive to achieving the best results.

1. Design and implement a funded, Canada-wide campaign – directed at leaders in industry, government, education and the research community - to create a positive, **energetic image of the welding and joining industry**, why it is important for Canada's prosperity and how it can contribute to increasing the competitive position of Canadian manufacturing and construction over the next 10 years.

2. Implement a funded **manufacturing excellence and technology application** program for the Canadian welding and joining industry, based on the following elements:

    a) Create a Canadian **Welding and Joining Productivity Network** with complementary locations in the Maritimes, Ontario, Quebec and Alberta with the mandate to:

        I. Design and apply lean manufacturing concepts, one of several sustainable manufacturing practices, to welding and joining.

        II. Integrate welding and joining into manufacturing excellence, particularly at the design stage.

        III. Conduct welding technology application assessments in major companies and create a "Best Practices" technology application database.

        IV. Develop and advocate policies to governments, such as tax incentives, for investment in automation and productivity improvement.

V. Develop an "Integrator" capacity among companies in Canadian industry capable of supplying complete sub-assemblies, not just individual parts.

VI. Sponsor specific welding/joining technology demonstration projects or workshops in all regions of the country.

b) As a complement to the Productivity Network, establish and strengthen **Welding and Joining Centres at educational institutions** across the country, and develop better communications between them and industry to provide information for small and large Canadian companies for the testing and application of welding solutions. Create an associated Innovation Fund.

3. Implement a funded comprehensive research innovation and advanced technology adoption program for welding and joining that will encourage,

   a. Greater research capacity for innovative welding and joining process applications and adoption for all user industries.

   b. Greater research capacity for new materials with improved joining capabilities, and their efficient use in welding and joining applications.

4. Implement a funded comprehensive **education and training response** for the Canadian welding and joining industry, based on the following elements:

   a) Create a **Human Resource Sector Council** for welding and joining, supported by a Canadian Welding Accreditation Board.

   b) **Standardize and harmonize education, qualifications, training and apprenticeship** across Canada – harmonized with ISO, IIW and TWI.

      I. Make Red Seal obligatory across Canada for certain types of welding (a compulsory apprenticeable trade).

      II. Define a basics skills ladder.

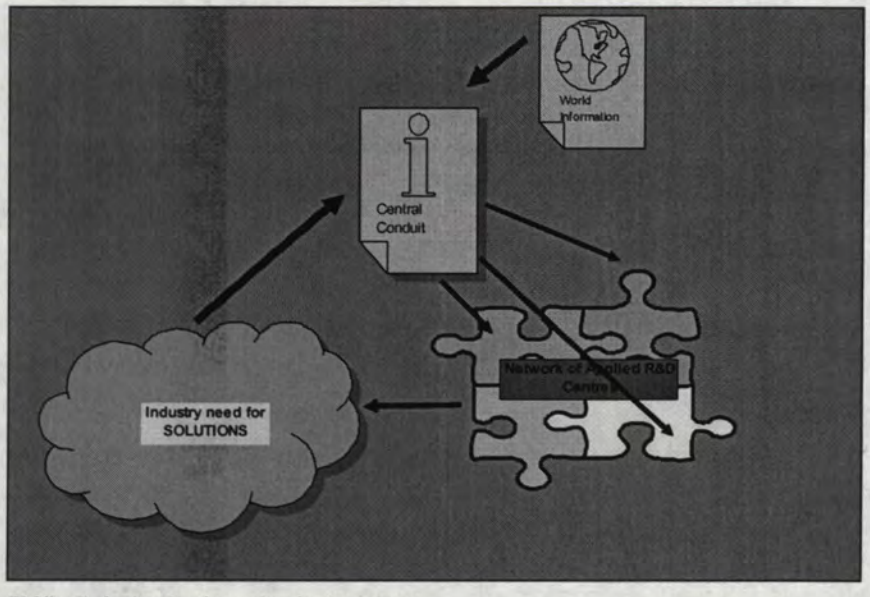
      III. Promote the coordination of college welding training across Canada applicable for students, apprentices and current workforce.

IV. Develop/support/revamp University welding engineering programs.

V. Showcase welding and joining careers with schools, industry and academia across Canada.

c) Outline a "Value-chain for investment in human intellectual property" – an explanatory report on how investment in human resources is at the base of achieving the Vision of the Welding and Joining industry.

5. Implement a funded **welding and joining Information Clearing House,** based on the schematic below:




Welding Technology Roadmap – Steering Committee

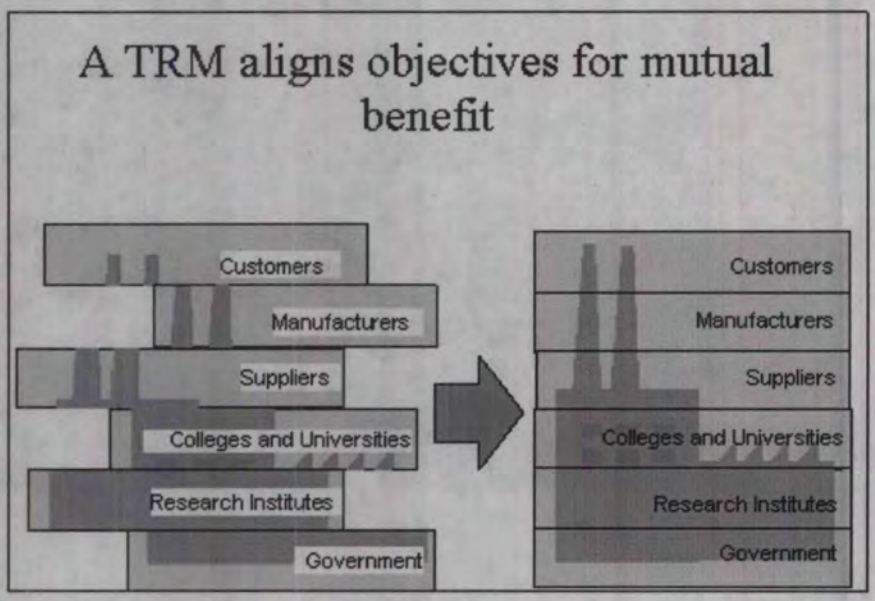
The purpose of the Clearing House is to act as a central information conduit for welding and joining:

- Providing an access point for industry to submit its needs for solutions to welding and joining issues,
- Providing access to the international knowledge base for welding and joining, and
- Providing the opportunity for the Welding and Joining Productivity Network and the Welding and Joining Centres at educational institutions to find the best solutions to industry needs.

# Introduction

**What are Technology Roadmaps?**

Technology Roadmaps (TRM's) are a collaborative, industry-led strategic planning exercise for developing innovative products and processes to meet emerging market demands and international competitive pressures. The process of development provides a tool for industry, working with governments, education and research institutes to align objectives for mutual benefit.




The process has become more and more popular over the course of the last fifteen years with governments across the world actively partnering with industry to encourage the kind of forward thinking and innovation that is required to succeed in the 21st Century.

In Canada, TRM's have been completed for a wide range of industries – Aluminum, Electric Power, Fuel Cells, Intelligent Buildings, Marine and Ocean Industries and Wood-based Panel Products. The majority of the

industries that have completed TRM's rely on Welding and Joining as an enabling technology. As new technology platforms unfold, such as biotechnology and advanced materials, strategies that cut across traditional single industry lines will become increasingly important. For instance, apart from welding and joining, a recent TRM that has spanned traditional industry profiles is Lean Logistics/Supply Chain Management.

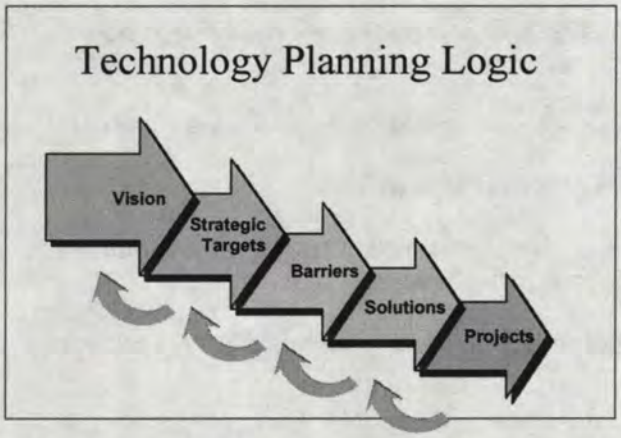
**Industry Canada and FedNor contributed to the development of this TRM**

Industry Canada plays a very important role in initiating and supporting Technology Roadmaps and has contributed both financially and through technical support to the preparation of this Welding and Joining TRM. In addition, the economic development program for Northern Ontario, FedNor, which is part of Industry Canada, also made an important financial contribution. The FedNor contribution recognizes that the initiative for the roadmap emerged in Northern Ontario as part of the business planning process by the Kirkland Lake campus of Northern College of Applied Arts and Technology to create a "Materials Joining Innovation Centre."

**Technology Roadmaps in the United States**

Like Canada, United States has also strongly supported the development of technology roadmaps by a wide range of industries. In 2000, A Welding Technology Roadmap was prepared for the United States Department of Energy, Office of Industrial Technologies in cooperation with the American Welding Society and the Edison Welding Institute.

**The Canadian welding and joining TRM process**

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The logic of the Technology Roadmap process moved from the Vision and Strategic Targets, through the Barriers to Solutions and Projects.

From the Vision and Strategic Goals developed at the Whitby Forum, a Welding and Joining TRM Steering Committee (*see Appendix A for a list of Members*) managed the process through numerous meetings culminating in four Regional Forums held in Montreal, Cambridge, Edmonton and Halifax in October 2005.

Throughout the process more than 250 participants representing a wide range of companies, associations, educational and research institutions as well as all the levels of government participated (*See Appendix B for a full list of process participants*). The entire process, inclusive of resource materials, has been documented on the website www.weldingtrm.org.

**Expected outcomes**

A TRM is really only the beginning of a long process for an industry and has only limited use unless it is followed by implementation. While some immediate benefits are expected, results are more likely to occur over a long time-frame thereby making them hard to track. On the other hand, through the process, collaborative efforts are often established outside the formal TRM framework and these are not always attributed to the TRM effort.

In general the expected outcomes of the TRM are to:

- Define the "road" to compete successfully in tomorrow's markets,
- Guide an industry and firms to predict future technology and product needs along with skills requirements,
- Guide the industry and companies to seize future marketing opportunities,
- Guide the industry and companies in making decisions on technology application and research,
- Increase collaboration, shared knowledge and new partnerships.

Examples of outcomes from other Canadian TRM's include:

- A commitment of over $200 million from the government of Canada to accelerate full-scale commercialization of fuel cells.
- The creation of the Aerospace Manufacturing Technology Centre in Montreal.
- Creation of the Intelligent & Integrated Buildings Council (IIBC).
- Creation of a Logistics Sector Council for human resource development

- Identification of over 1200 specific technologies relevant to marine and ocean industries.
- Forecast of technology needs in the area of medical imaging.

# A Profile of the Materials Joining Industry

## What is materials joining? What is welding?

*Welding and Joining – the art, science and engineering prowess of making metals and increasingly other advanced materials join together and function as one.*

Most people take it for granted that cars, trains, refrigerators, computers, pipes and a wide range of other articles that we see everyday simply "exist". As a society we appear less and less curious as to how things are made. And yet, joining basic materials and shapes to achieve something new is fundamental to our lives.

Welding is part of this broader concept of "materials joining". This is the process of bonding one material to another to create new products and innovative shapes and designs – for both product manufacturing and product maintenance/repair. The range of materials that can be joined is ever increasing and includes metals, polymers, ceramics and emerging composites. Some materials are joined with a wide variety of adhesives, as is used in the lamination of wood products or the attachment of ceramic tiles to the Space Shuttle

In spite of the wide range of materials that are now being joined, the joining of **metals** remains the largest industry segment. Metal joining techniques may include mechanical fastening such as riveting and bolting, often seen in the construction of bridges. But from an economic point of view, **welding** is the preferred method for joining metal parts.

*Advanced technology is now the norm*

Welding, as a manufacturing process, is the act of joining a range of material components to form an assembly to satisfy one or more functions. To accomplish atomic or molecular bonding, welding may involve heat, pressure or a combination of both. More than 100 welding processes are in use today from the very common arc welding to more exotic types such as advanced laser or friction-stir.

Most manufactured products require that different parts be joined. The technology for doing so continues to develop. For example, laser welding is now widely utilized in the automotive industry. Great advances in joining technology have been made, and the field keeps rolling forward, incorporating leading-edge science, information technology, robotics and advanced manufacturing materials.

**The welding "industry" is a community of different industries – a critical enabling technology for many**

Welding is not just one industry but a community of many different industries across Canada. The industry is comprised of

- User industries - manufacturing, fabrication, construction and repair industries.
- Welding and welding-related equipment and product manufacturers.
- A wide range of service industries that include engineering consultants, regulatory agencies, research and development organizations and education and training institutions.

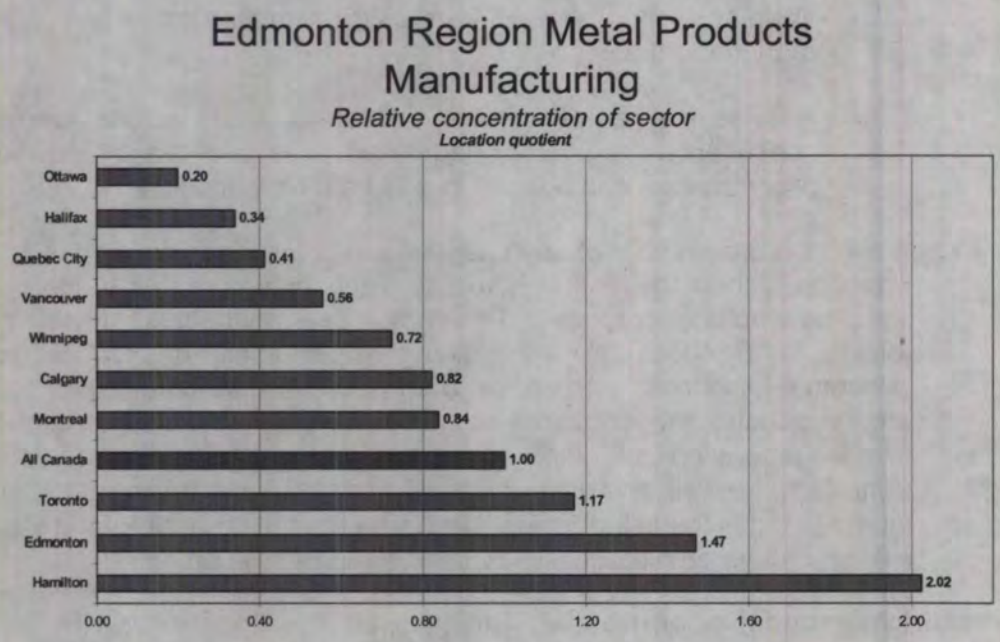
Canada has a number of key user industries for which welding is a "critical enabling technology" – that is to say a technology that is fundamental to the manufacturing process. The major user industries of welding and joining in Canada are microjoining (electronics, medical equipment, telecommunications), aerospace, automotive and transportation, structural steel products, petrochemical and pressure vessels, pipelines and tubing, power generation and the resource industries of mining, forestry and agriculture as well as a wide range of other light and heavy manufacturing industries. It is these industries that represent the strength of the Canadian manufacturing advantage.

**Welding's economic contribution - one-third of the Canadian GNP**

When all of the above user industries of welding and joining are taken into account, the contribution to the Canadian GNP is indeed huge. Using the benchmarks identified in a study of the welding industry in the United States (***American Welding Society**: Welding-Related Expenditures, Investments and Productivity Measurement in U.S. Manufacturing, Construction and Mining Industries*) the following estimates have been calculated for Canada for the year 2000.

- The revenue of the user industries in Canada for which welding is a critical enabling technology represents one-third of the Canadian Gross National Product (GNP).
- Welding-related expenditure in the key user industries is over $5 billion, of which payments to employees represent 70% ($3.7 billion).
- The Canadian market for the sale of welding materials to user industries is about $800 million.

By its very nature, the welding industry is widely dispersed across Canada – as are the industries for which welding is an enabling technology. However, certain segments of the industry are more localized than others. For instance, a report by the Edmonton Economic Development Corporation on the *Needs and Developments in Alberta Welding and Joining Technology Services* demonstrates the relative concentration of metal products manufacturing in Canada.




This exhibit demonstrates the importance of centres such as Hamilton, Edmonton, Toronto and Montreal but, in fact, all regions of the country have some form of specialized welding and joining activity such as shipbuilding/repair and offshore platforms in the Maritimes, aerospace in Quebec, automobiles in Ontario and, oil and gas in Alberta.

## Up to 300,000 jobs

In Canada, welding represents about 75,000 jobs at the technician and welding operator level. By including occupations where welding is either a specialized skill or an integral part of the operation, as well as occupations associated with the welding process such as design engineers and managers, the welding-related workforce in Canada is in the range of 300,000. The largest industry segment is metal and machinery manufacturing, followed by construction and motor vehicles.

**Manufacturing is undervalued**

One of the negative results of the advance of the "service economy" and the "information technology revolution" has been to create the impression in the minds of young people and of many policy makers that manufacturing is no longer important in today's world. Nothing could be further from reality. While it is true that direct employment in the North American manufacturing sector has been declining over the past 25 years, the value of output has been constantly increasing – keeping pace with the overall growth in GDP. Furthermore, many analysts often fail to recognize the myriad jobs that are created in marketing, selling, distributing and transporting "manufactured products" so that they become available "goods" throughout the country. This is indeed "value added" by the manufacturing sector for the benefit of society as a whole. Indeed many of the "service economy" companies such as Intel are also manufacturers who expend a great deal of energy in improving the entire manufacturing value chain.

An added factor is that welding and joining will continue to advance as the manufacturing and construction industries take on new vistas throughout the world and major new consumer societies come into play – China, India, Indonesia and a host of others.

**Still in need of a "serious makeover"**

Welding itself is further disadvantaged by an unattractive image often limited to a picture of a welder in a mask with sparks flying everywhere. For many, welding is stereotyped as a hazardous, labour-intensive occupation.

However, what most people do not realize is that modern welding is characterized by a wide range of science-based skills that stretch from the skilled welder putting together a major pipeline to the engineer, scientist, computer-assisted industrial designer and the international business executive, selling Canadian welding "solutions" worldwide. The fact is that the welding industry employs increasing numbers of highly educated people that are both well-paid and motivated to move the industry forward in a technology-driven world.

So while welding and joining is indeed an integral part of the manufacturing process that produces goods for society, it faces a multitude of challenges over the next ten years – even beyond its overall image and the limited perception of the importance of manufacturing. The key challenges are outlined in the next section.

# The Challenges to the Canadian Welding and Joining Industry

*The fundamental question is how much of the manufacturing – and the enabling welding and joining – will continue to take place in North America and, in particular, Canada? Three mega-trends facing the Canadian welding and joining industry are:*

- *Competitive pressures from globalization*
- *Creating a technology critical mass*
- *Investing in human resources and education*

**Globalization creates competitive pressures... and opportunities**

As with many industries in Canada, the most important mega-trend facing the welding and joining industry is the globalization of business. All of the industries for which welding is an enabling technology are becoming increasingly global in nature and competition is worldwide. The pressure of markets and customers fuels the drive for increased productivity in manufacturing and forces supplier industries to be more cost-competitive. Although the demand for welding would appear to be very strong for the coming decade given the overall development needs for worldwide manufacturing and infrastructure projects, Canada will face increased competition from new competitors.

China and other Asian countries present the most serious challenge as a competitor to industry in Canada and North America in general. Not only are such countries "catching up", but are now - in many instances - "leap-froging" in terms of the technology that they are able to use and apply cost-effectively.

When this is combined with the continued absence of world-wide free trade, Canada's market share of manufacturing and hence welding and joining worldwide is threatened. But, at the same time that globalization presents challenges to the Canadian welding industry, it also presents opportunities. Competition forces all industries to attempt to shorten the new product development cycle and to integrate increased performance and enhancements in product quality – and all of this at more affordable prices.

**Technology critical mass must grow**

In a globalized world Canada needs to stay well ahead of others on the welding technology development and applications curve. This includes dealing with the "unknowns" and developing strategies to react to emerging technologies in the user industries.

The challenge for the Canadian welding industry in the next decade will be:

- To maximize the application of existing technology, and
- The development, integration and implementation of new technologies that reduces the "time to market".

*A consensus in industry exists that the level of Research and Development is far too low in Canada and that the critical mass must grow exponentially.* This requires both a greater R & D investment by industry itself and commitment by the federal government and provincial governments to support such investment.

**Human resources and education are critical**

***There is a shortage of skilled welders everywhere in the world, and it is only getting worse as each year passes.***

Job prospects for welding-related employment in the coming years are excellent – resulting not only from growth in user industries – particularly oil and gas projects in Alberta - but also because of the need to replace an ageing workforce.

Given the task of the Canadian welding industry to gain a competitive edge over the next ten years and drive innovations in technology, clearly the attraction of new entrants into welding and welding-related professions is a priority for the future. This will require a greater commitment by both industry and government to invest in labour force development. Changing the image of the welding industry to make it an exciting and attractive career choice for young people – both male and female - is crucial.

**But is the Canadian welding and joining community in a downward spiral?**

A background paper was prepared for the regional welding and joining TRM Forums in Montreal, Cambridge, Edmonton and Halifax. In that paper the author suggested that a "downward spiral" existed in the Canadian welding and joining community. The majority of participants in the Forums agreed with this assessment. The essence of the argument is as follows.

*Underlying assumption*

If responsible individuals have ready access to high quality information about the technical capabilities of processes such as welding, the vast majority of decisions about product technology content, manufacturing and repair can be distilled down to simple questions of money. That is, those product configurations and manufacturing methods will be selected that are likely to generate the highest ratio of value in the marketplace or at use, relative to the input costs.

*An example*

For instance, an exemplary version of the way in which welding stakeholders could position themselves may be taken from the educational publications of the Lincoln Electric Co in the 1930-1950's era. Their Welding Procedure Handbooks discussed in detail the technical and economic benefits of replacing castings with welded fabrications. They then went on to provide detailed instructions for the design and the fabrication of welded products. Today, the world of welding is much more complex, diverse and rapidly changing, certainly no longer susceptible to being captured in a handbook. But the principle remains that the penetration of a particular technology is intimately tied to the successful dissemination of high quality technical information (to executives, students and current practitioners) that will allow them to make good decisions and deploy the technology confidently.

*The issue – welding is not treated as a strategic technology*

Availability of superior scientific, engineering and practical knowledge in forms usable by decision makers appears to be the key to facilitating contributions to competitiveness by a technology like welding. **A consensus exists that welding and joining in Canada and generally in North America currently tends not to be treated in education or in industry as a strategic technology for competitiveness**. Its visibility and impact is actually waning, and a heroic effort will be needed to turn this negative trend around. The nuts and bolts of the problem are approximately as follows.

*How the downward spiral has been generated and sustained*

Most design engineers get some limited educational exposure to design of joints that could require welding. For those that need more information, quite a bit of detailed cookbook information is available in CSA, ASME, AWS, SAE[1] and other standards, and through copying of prior welded product designs. For execution of the welded joints specified by the

[1] CSA – Canadian Standards Institute; ASME – American Society of Mechanical Engineers; AWS – American Welding Society; SAE – Society of Automotive Engineers

designer, the availability to manufacturing system designers of support from welding equipment and consumable manufacturers is actually extremely good in North America. The end result is that that **most welded products and the systems that build them can be and are created by teams that don't include any welding specialists**. That doesn't mean the resulting products are bad – in fact the persistence of this kind of status quo suggests that senior business executives are not dissatisfied with this generic approach to design and manufacturing engineering.

Only where welding has a really big role in the product, or in rare cases where **executives have deliberately decided to create a strategic** advantage by acquiring leading know-how, do we tend to see welding specialists employed.

Clearly, if no welding specialists are employed, there will be nobody prepared to take knowledge-based responsibility for implementing radical, possibly risky advances in product or manufacturing technology that go beyond standard marketplace offerings. That in turn will result in low demand for advanced welding processes, materials and equipment, which **reinforces the view of welding as a commodity technology like bolts or adhesives, and results in the installation of nearly cookie-cutter copies of welding systems across whole industry segments.**

The small number of post-secondary educational institutions in Canada with a significant stake in welding technology, welding engineering and/or welding research are acutely aware of the prevalence of the commodity attitude to welding technology in Canada. Every day, new painful examples appear of sub-optimal joining technology being deployed in industry by people who lack the knowledge to demand more from their processes and suppliers.

*No incentive for educating technologists, engineers and researchers*

As part of this syndrome, the demand for newly graduated technologists, engineers and researchers with specialized welding knowledge remains scattered and has shown little growth in the past decade. That in turn has made it difficult for academic departments faced with pressures from many directions to devote increased resources to welding-related activity. Relatively little growth in student throughput also implies lack of growth - and in some cases even shrinkage - of capacity for welding R&D in Canadian universities and colleges. Therefore, the platform from which a welding vision for Canada is to be launched is at best seriously inadequate - mostly stretched to the limit just to maintain some sort of status quo. Even with a major injection of new resources into higher education and R&D in the short term, it will take a number of years to grow a new generation of sufficient people in industry and academe with advanced

welding knowledge and confidence to lead Canada towards realizing the vision.

## Moving forward

Certainly the existence of such a downward spiral in the welding and joining community does not provide a strong platform for moving forward. On the other hand, recognition of the problem is the first step in making change happen. Canada cannot accept that this spiral should continue and all of the players in manufacturing and welding/joining must come together to implement a Vision and a Strategy not just to stop the spiral but to reverse its direction and move back to a position of strategic advantage.

# Vision and Goals

The purpose of setting a Vision is to reflect a set of agreed beliefs or values that will serve as a beacon light from the future shining back into the present and drawing us towards it. While it may not always be possible to achieve the full Vision, the statement sets the heading on which the industry must navigate.

**Vision for the welding and joining industry**

The Vision that has been set for the Canadian welding and joining industry is the following:

***"Canada's excellence in welding and joining technology and its applications will be increasingly recognized and developed across the country and internationally over the next ten years."***

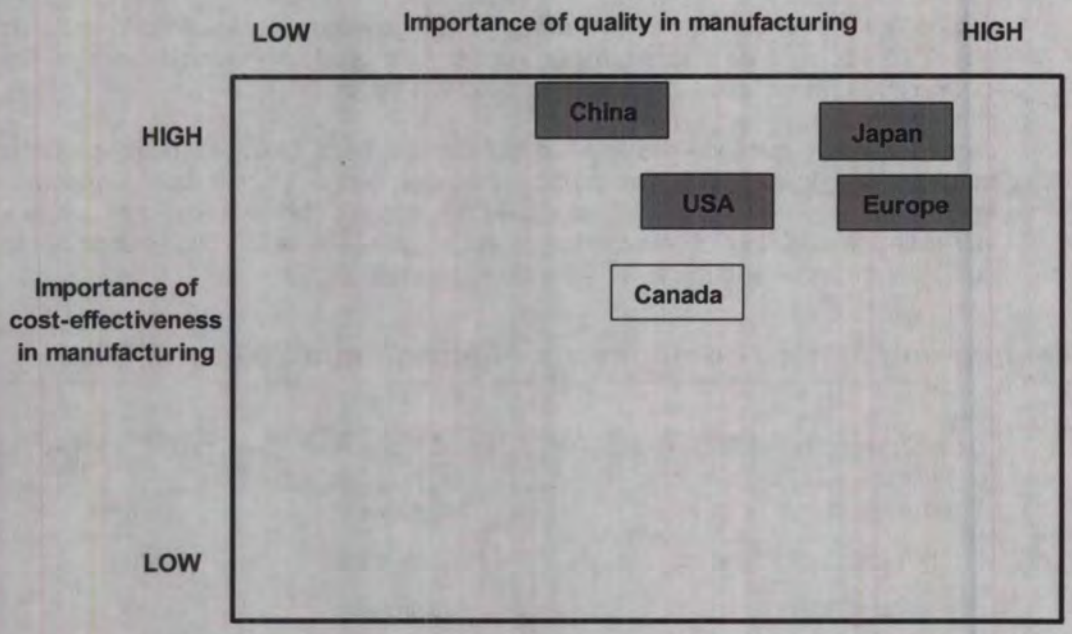
Even if we may question the level of our current "base of excellence", we know that Canada does have a reasonable base on which to build and constantly improve upon. The following chart shows the various components of excellence in welding and joining, an evaluation of where we are now in 2006 (compared to other jurisdictions) and the level we want to reach in 2016.

## *Welding and joining components of excellence 2006 and 2016*

| Component of excellence | 2006 Status | 2016 Target |
|---|---|---|
| Technology R & D | Medium | High |
| Technology application | Medium-Low | High |
| Innovation and responsiveness | Medium | High |
| Cost effectiveness | Medium | High |
| Integration in design process | Low | High |
| Rigorous client quality standards | Medium | High |
| Quality workforce | Medium-Low | High |
| Safeguarding life, property and the environment | Medium | High |

During the course of the regional forums held in Montreal, Cambridge, Edmonton and Halifax participants attempted to characterize where Canada stood in the drive for quality and the drive for cost-effectiveness in manufacturing processes and the associated welding and joining applications. The result was the schematic below which places Canada in the "middle of the pack". It does not reflect scientific or objective evidence but it does reflect a common assessment from a wide range of industry participants of where Canada currently fits in the worldwide competitive picture.

## *Canada in the manufacturing quality and cost-effectiveness dynamic*




### Strategic targets

The strategic targets represent the four major audiences – in order of importance – to which the welding and joining industry must forcefully speak to implement its Vision. "Speaking" includes explaining, convincing, co-opting and moving to action. The strategic targets are as follows:

1) Demonstrate and convince **CEO's and other leaders of all manufacturing industries** that welding and joining should be seen as an enabling technology that can make significant contributions to assist manufacturers who strive to put well-designed quality and cost-effective products and processes on the world marketplace.

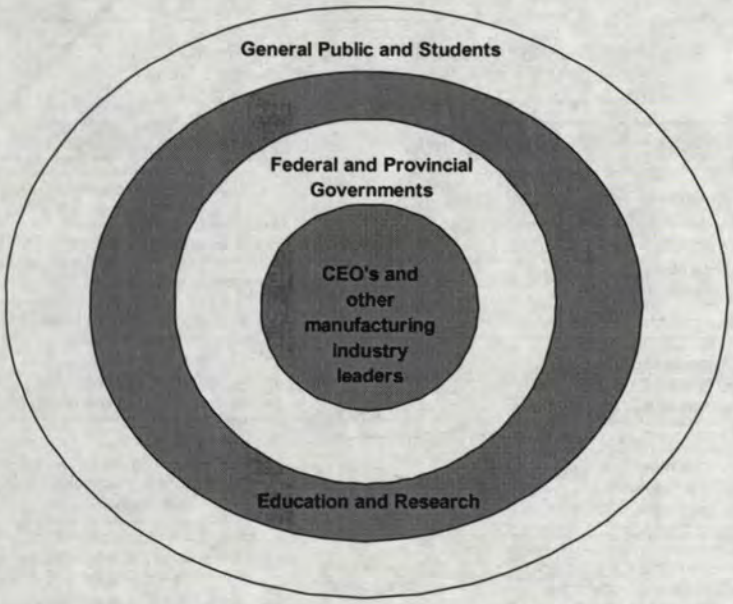
2) Demonstrate and convince **the federal and provincial governments** that welding and joining is a strategic enabling technology which is required to enhance Canada's competitive position, and therefore merits both policy and financial support for world-class innovation, research, technology adoption and human resource development.

3) Develop a proactive, concerted and organized response from the welding and joining community in concert **with educational institutions and research institutes**, supported by government, to increase the pace of innovation in advanced welding and joining technology and application.

   The target is to ensure responsiveness to the needs of user industries particularly with respect to cost-effectiveness and constantly increasing productivity in welding and joining processes, in Canada and at the international level. Welding and joining must be integrated into the design stage for manufacturing and construction.

4) Demonstrate to the **general public and students** that welding and joining is a field of activity that spans leading-edge science, information technology and advanced manufacturing processes and materials that are integral to the future prosperity of Canada. It will provide exciting career paths at all levels of skill and education which fully safeguards life, property and the environment.

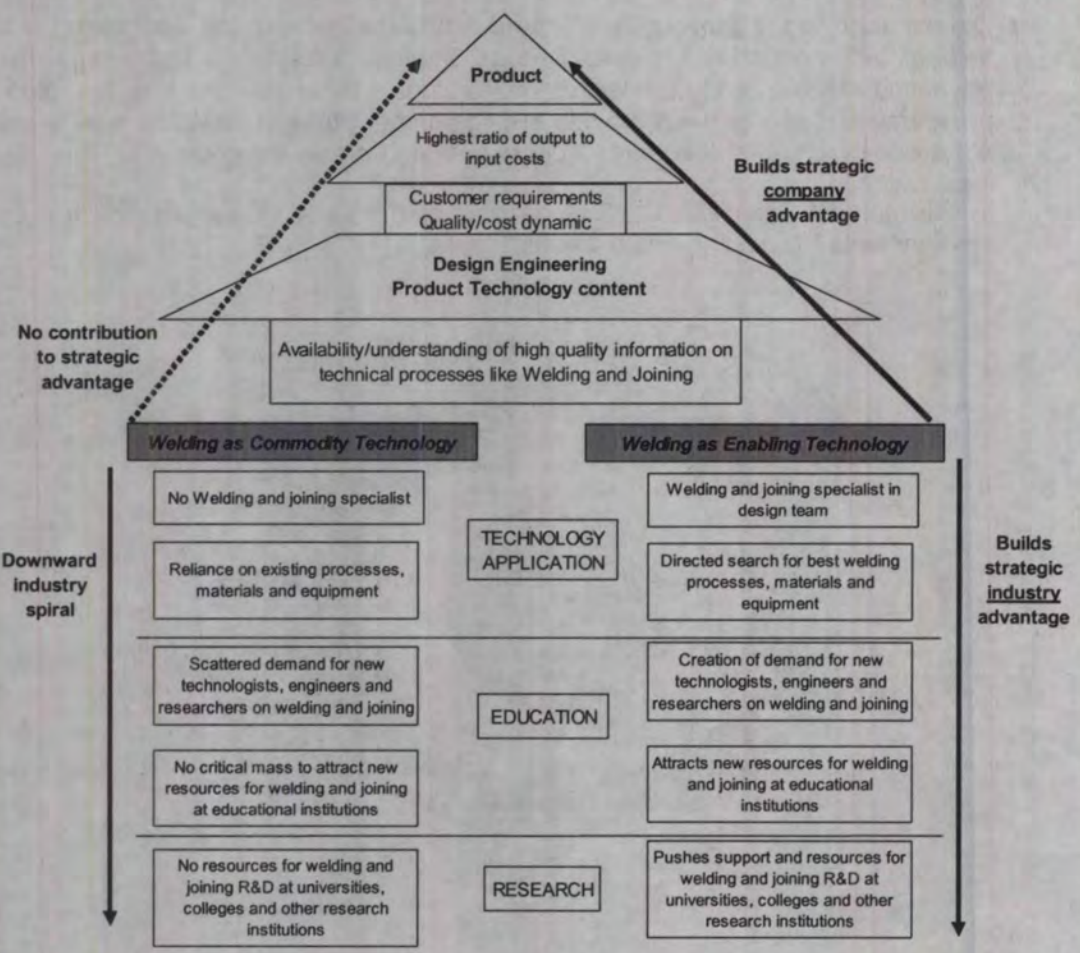
   In this context, establish Canada as one of the best education and training environments for welding and materials joining.



# Applying the Vision to Unravel the Downward Spiral

The key to moving forward with the Vision is to find the way to unwind the downward spiral of the welding and joining industry in Canada, to identify the points at which the positive pressure can be applied and then to build a framework for moving forward. The exhibit below demonstrates the product development process seen from the point of view of welding as a commodity technology and welding as an enabling technology.

## *Welding and joining as an enabling technology: strategic advantage*



It is clear that when welding and joining is seen as an enabling technology, the result is a strategic advantage for individual manufacturing companies and for the welding and joining industry – and hence Canadian manufacturing – as a whole.

In developing a new product, re-engineering a product or repairing a product, a company is looking to achieve the highest ratio of output value to input costs consistent with customer requirements. This usually means achieving a specified level of quality at the least cost. A particular "product technology content" is associated with any product and is the result of design choices that are made by design teams, usually consisting of engineers supported by a variety of other product specialists.

If welding and joining is seen as an enabling technology, then a directed search will take place for the best welding processes, materials and equipment that can be incorporated in the product technology content to meet the company-wide goal of achieving the highest ratio of output value to input costs, thereby building a strategic advantage for the company.

When this process is repeated across a wide range of companies in user industries, the result is the creation of demand for technologists, engineers and researchers on welding and joining. This in turn creates a demand at the level of colleges and universities to provide the necessary learning programs and resources for welding and joining and also attracts funding, usually from governments and industry, to respond to the educational demand. Once colleges and universities are providing the appropriate welding and joining programs, this in turn pushes the support and resources for welding and joining research and development at the same institutions and in specialized research institutions.

So it can be seen that the result of many companies in a range of industries seeking a competitive advantage from welding and joining is the creation of a strategic advantage for the industry as a whole that begins to unwind and reverse the observed downward spiral.

The Vision Statement correctly places the emphasis on "recognition and development" of Canadian welding and joining technology and applications. The statement underlines the notion that excellence exists in Canada but that in needs to be better organized and packaged so that it is first recognized and used and then secondly further developed.

## Design team

The key to "recognition" and unwinding the downward spiral of the welding and joining sector is the inclusion of welding and joining in the product design team as well as the availability of high quality information on technical processes. This is most likely to occur through the inclusion of a

welding and joining specialist directly in the design team. For companies that already have such a specialist, inclusion in the design team should not be a big step. But many companies may not immediately be prepared to hire such a person - if in fact they can find one – so that the availability of high quality information on technical welding and joining processes to the rest of the design team is an absolute necessity. At the present time, such information is scattered in different places and not readily available in an understandable format for design team members that are outside of welding and joining. A full science exists in relation to industrial design and also integrated product and process design so that welding and joining does not have to invent some new process – simply to integrate with existing management processes.

The importance for companies to have dedicated welding and joining specialists cannot be over-emphasized. It is not simply a question of bringing key knowledge to the table. It is also a question of having welding and joining people who are prepared to take knowledge-based responsibility for implementing radical, possibly risky advances in product or process technology that go beyond standard marketplace offerings. This is the essence of innovation.

This is probably the most important pressure point that needs to be tackled, in particular with the primary strategic audience – CEO's and other business leaders. But to be effective, it will be necessary to demonstrate how in fact the strategic company advantage can be achieved and how it can be quantified in terms of price and/or quality.

Other positive pressure points may exist at the Education and Research levels. In other words, by creating a world-class welding and joining engineering program in Canada it may be possible to influence the way welding and joining is viewed and integrated in the industrial design process. Similarly, it may be possible to "kick-start" the process by convincing governments to invest heavily in a Canadian research centre for welding and joining. But such efforts have been attempted in the past and while they may cause a blip on the screen in the short term they will be unlikely to make a sustainable impact on recognition of the welding and joining industry. The key to implementing the Vision really is to focus on the user industries and on top management in those industries to fully integrate welding and joining into the product design process.

## Leadership

This will take leadership. Much more than is currently evident in the Canadian welding and joining community. And we are not speaking here simply of industry associations and organizations. The leadership required is that of key individuals in the user industries that are already convinced of the strategic advantage that welding and joining can bring to

manufacturing and who are ready to work together to "spread the gospel". But that team of key leaders in the user industries is going to require a strong resource group from welding and joining that is capable of systematically developing the tools that will be required to fully integrate welding and joining into product design – design checklists, flow charts, matrices, life-cycle analysis, economic contribution analysis etc. This task involves taking the current body of knowledge on welding and joining in Canada and recasting it in terms of product design and manufacturing excellence and also ensuring that knowledge from other jurisdictions is constantly brought into the Canadian knowledge base.

Beyond simply organizing the knowledge, leaders from the user industries and the welding and joining resource team will need to find innovative ways to demonstrate welding and joining technologies and systematic methods to implement those technologies in Canadian companies and to quantify the benefits of doing so. For this a formal Solutions Matrix is required.

# A Solutions Matrix for Welding and Joining in Canada

A Solutions Matrix is a "mind map" for taking a global view of the elements that are key to applying resources to specific projects that will build momentum in achieving an overall Vision.

**A Solutions Matrix for welding and joining**

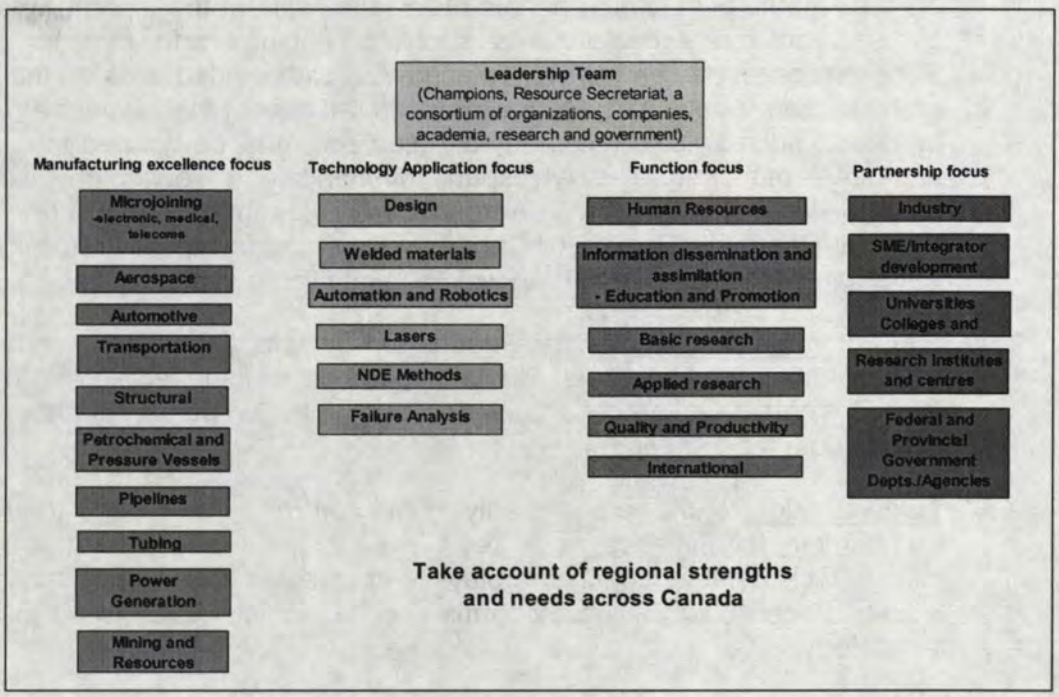
The Solutions Matrix that emerged from discussions in the regional forums held in Montreal, Cambridge, Edmonton and Halifax is set out below. The critical focus is on the development of a Leadership Team consisting of Champions from user industries supported by a Resource Secretariat from the welding and joining industry. The purpose of the Leadership Team is to implement the Vision using the Solutions Matrix.

The four pillars of the matrix are the following:

- Manufacturing excellence in 10 industries for which welding and joining should represent an enabling technology and for which Canada has an opportunity to establish, continue or extend a competitive advantage on the world stage.
- Six technology application categories that define the areas in which welding and joining technology is capable of advancing and contributing to competitive advantage.
- Six key functions for the welding and joining industry.
- Five entities on which to focus in partnership development.

The concept of the Solutions Matrix is that a wide range of possible initiatives and projects can be pursued using a mix of elements from the four pillars. For instance, an applied research initiative could be undertaken on automation and robots in petrochemical and pressure vessels working in cooperation with industry and the University of Alberta. Naturally, each region of the country may have a particular set of projects that it wishes to pursue based on the Solutions Matrix and that relate to its industry strength.

It would be up to the Leadership Team and regional specialists to define the areas and projects that should be pursued and that will contribute to an overall advance in the recognition of Canadian welding and joining expertise.




## Manufacturing excellence

The industries or sectors which are included in the manufacturing excellence focus are not all necessarily mutually exclusive. For instance, pressure vessels are used in power generation and microjoining will be used in a variety of aerospace and automotive components. However, each of the ten themes represents a consensus of the industries or sub-industries in which Canada has a particular expertise and for which welding and joining is an important activity. Also, the sub-industries that make up a larger industry may not be located in the same area. For instance, the industry that builds pressure vessels may be located in Ontario, but major projects using pressure vessels may be located in the Maritimes or Alberta.

The following is a brief description of each of the manufacturing excellence sectors:

Microjoining is the joining together of very small parts (sometimes no larger than the width of a hair) used in the electronic, medical and telecommunications applications. Real-time monitoring of the physical

conditions during joining and numerical modeling is closely associated with microjoining.

Aerospace covers both aircraft and spacecraft. While rivets are the most obvious methods of joining panels used in the skin of the aircraft, welding is used on many components such as engines and landing gear. Research continues on how to replace rivets with welded joins on the skin of the aircraft. Spacecraft are similar to aircraft except that a wider array of materials, such as ceramics, may be used and must be bonded to metals and other materials. The Aerospace Manufacturing Technology Centre and the Institute for Aerospace Research, part of the National Research Council of Canada and based in Montreal is a major Canadian centre for research on welding and joining in aerospace.

The Automotive sector centred in southern Ontario is highly developed in the use of automation and robots applied to welding and joining and indeed, contrary to aerospace, welds play a major part throughout the vehicle both for components and for the body.

Transportation refers here primarily to railroad rolling stock and to ships. Bombardier, for instance, is a key player in the fabrication of railroad rolling stock. While shipbuilding plays a decreasing role in the Canadian industrial scene, oil drilling platforms require similar welding and joining technology.

Structural refers to large structures such as buildings and bridges in which steel is a major materials component, and for which welding is critical.

Petrochemical and Pressure Vessels refers to large metal containers (usually circular) that are either used for storage or for an industrial/energy process that uses air, gas or liquid under pressure. For instance, highly critical pressure vessels are used in nuclear reactors.

Pipelines and Tubing are hollow items, also normally circular, that are used for transmitting gases (e.g. natural gas) or for liquids (e.g. oil). They are also used in structural, mechanical or decorative functions. Some tubing is also used in conjunction with pressure vessels to transmit fluids or gases at elevated temperatures or pressures or both.

Power Generation is an industry that in fact uses many of the products from other sectors described above, for instance, pressure vessels for turbines; tubing; microjoining for instrumentation and various structural elements.

Mining and Resources includes mining, forestry, oil and agriculture. Once again, these industries use a wide array of welding products in plants and equipment.

## Technology application focus

The Solutions Matrix includes six areas as the priority for welding and joining technology application in the manufacturing excellence industries described above. The six areas are:

- Design of products to take the best advantage of welding and joining technology as well as the best design of specific weldments
- Welded materials that are continually evolving including composites and alloys and that require special welding processes and procedures
- Automation and robotics that are well-entrenched in the automotive industry but that are gradually being employed in other industry sectors
- New laser technologies for welding and joining
- Non-destructive examination (NDE) methods that monitor, probe and measure materials response
- Failure analysis of welded structures and weldments (including corrosion) including wear-resistance

The Industry Advisory Group on Welding and Joining of the Edmonton Economic Development Corporation[2] has identified a number of forces that inhibit innovation and the adoption of new welding technology (apart from human resource issues). These include:

- The lack of current welding process knowledge at design level of project development.
- The "myth" of the history of failure by early adopters of new processes and consumables.
- Welding procedure development may be proprietary which may limit technology transfer possibilities
- Limited opportunities for smaller fabricators to employ automated processes as setup and capital costs may not justify increases in productivity.

The same group has also calculated that on $70 billion in northern Alberta resource development projects, estimates of potential savings from welding innovation are in excess of $2 billion, and that innovation and

[2] From preliminary presentation of draft report on Welding and Joining Opportunities in Alberta

automation will increase the capability of the fabrication sector and allow more of the forecast projects to be completed with the limited labour and fabrication resources available.

## Function focus

Within the Solutions Matrix, the Function focus refers to six issues or factors that are of critical importance to individual companies and to the industry of welding and joining as a whole:

- Human resources
- Education and promotion of the industry as a whole through the dissemination and assimilation of industry
- Basic research on welding and joining
- Applied research on welding and joining
- Quality and productivity improvement, and
- International harmonization of standards

## Human resources are a critical issue

Certainly the issue of human resources has been front and centre since the first session in developing the Vision for the Canadian welding and joining industry at the Forum in Whitby in late 2003. It was reemphasized at each of the Regional Forums in Cambridge, Montreal, Edmonton and Halifax. The quote that we used in the Vision document continues to hold true and will likely be an issue throughout the ten-year implementation period of this Technology Roadmap – 2006 to 2016.

*"There is a shortage of skilled welders everywhere in the world, and it is only getting worse as each year passes."*

Within Canada, this shortage is being felt particularly in Alberta. The Industry Advisory Group on Welding and Joining referred to earlier has identified the supply of welders, technologists and welding engineers as the most critical force inhibiting innovation. The suggestions on how to address the shortage emanating from the first Vision Forum were re-emphasized and expanded upon at the Regional Forums. These included:

- Recognize and develop an articulated "career ladder" going from skills to science to management with a recognized continuum of credentials.

- Promote employer buy-in for both apprenticeship and co-op training and education.

- Make Red Seal obligatory across Canada for certain types of welding (a compulsory apprenticeable trade).

- Stress the benefits of careers, skills and technology at the level of the senior primary grades and ensure the provision of suitable instructors, particularly at the high-school level.

- Address the need for increased numbers of welding engineers as welding automation becomes more prominent. The lack of engineers with expertise in welding and welding process applications can result in the adoption of design and manufacturing practices that limit, rather than increase the productivity of welding and the value that it is able to add to the final product.

- Promote the coordination of college welding training across Canada applicable for students, apprentices and the current workforce.

- Develop/support/revamp University welding engineering programs.

- Continue to develop a common national and international system of standards, assessment and certification of welding professionals such as those of the International Institute of Welding (IIW).

At several of the Regional Forums a renowned educator in welding and joining presented a global view of the current welding education scene. He reviewed programs in Canada, Japan, Australia, United Kingdom and USA, concluding with the following observations:

- Canada lags behind both Europe and Asia in welding engineering education.

- The International Institute of Welding (IIW) has developed qualification standards for the International Welding Engineer (IWE) level as well as for the levels of International Welding Specialist and International Welding Technologist – these standards are expected to rapidly become the norm around the world.

- As yet, no University in Canada has committed to conforming its programs with IWE, although the University of Waterloo Welding Specialization is close to IWE requirements.
- The status of the University of Alberta welding engineering program is unclear in terms of future direction.
- The Canadian Welding Bureau (CWB) has modules, but is not yet at the IWE level.
- Northern College as a strong 3-year program and Conestoga College is strengthening its 3 year program.

**Basic research**

The Welding Technology Roadmap prepared in 2000 for the United States Department of Energy, the American Welding Society and the Edison Welding Institute describes the transition that welding should make by 2020 from "an empirical-based to a physical-based process." The description is as follows:

*Welding processes based on engineering analysis, numerical modeling, and computer-based automated manufacturing will be widely used in 2020. The industries using welding hope to create a "virtual factory" in which welding technologists go outside the traditional scope of welding to better understand, control and automate welding processes.*

*.....Information technology will play a key role; the core of the transformation is a comprehensive knowledge-based model incorporating data on weld properties, processes, materials, and applications. The welding industry is optimistic that it can match the success of the gas turbine industry, where scientific advances led to the gradual replacement of empirical data with hard physical data. This requires parallel knowledge building in the physical, chemical, mechanical and materials sciences that support welding science.*

*The comprehensive physical-based model would cover the entire life-cycle of the welded product. Robust knowledge on historical applications feeds into the initial experience-based model; as more scientific and engineering data are obtained, the underlying nature of the model shifts. The model itself is not the end point; it captures knowledge which is then disseminated as needed.*

Many of the presentations made in relation to welding technology and the associated research during the Regional Forums dealt with aspects of this transition and highlighted the need for greater research on the fundamental physics of the materials used in welding. Again, as stated in the United States Welding TRM, "*The variety of materials is vast, and little*

*is known about the relationships between material behavior (in terms of melting and solidification) and material properties, especially high-temperature properties."*

Key issues relating to research on materials science were made by members of the Canadian Aerospace Manufacturing Technology Centre in Montreal to the Regional Forum but are not reported here because of their proprietary nature. But certainly, the Centre is at the forefront of welding and joining technology research in Canada. Although the Centre is focused on aerospace, much of the research being undertaken will find applications in the other key user industries of the Solutions Matrix. Other Canadian centres of research (either existing or potential) were referenced during the Forums.

Other technology-related presentations made during the Regional Forums included:

- Lastron Beam Technology (PAVAC Industries)
- Elimination of Residual Stresses and Distortion in Weld Zones by Ultrasonic Preening (Integrity Testing Laboratory Inc.)
- Welding Solutions (Liburdi Automation Ltd.)
- Aerospace proprietary technology of Pratt & Whitney Canada
- Scientific Research & Experimental Development (SR&ED) Program (Canada Customs and Revenue Agency)

Also at the Montreal Forum an excellent presentation was made by the Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ) that could provide an organizational model for welding and joining research related to other industries. CRIAQ provides leadership for collaborative research projects involving companies from the aerospace sector and university and other research centres in Quebec. One of the major successes of CRIAQ has been to thoroughly negotiate the intellectual property issues that often complicate collaborative research. The CRIAQ Board has recently approved the broadening of its mission to undertake projects across Canada in collaboration with universities and companies outside of Quebec.

While a definite platform for basic welding and joining research does exist in Canada, it does not appear to be nearly as well-developed as in other jurisdictions including United States, Japan and Europe. However, the Canadian Aerospace Manufacturing Technology Centre as well as the Materials Technology Laboratory of Natural Resources Canada are exceptions and their work is in the "world class" category. The challenge is

to extend that welding and joining research excellence to the all of the identified user industries.

## Applied Research

Much of what is described above as Basic Research naturally spills over into the term Applied Research, particularly with respect to research carried out at the individual company level.

However, participants in the Welding and Joining Technology Roadmap Process were thinking particularly of centres at the college level when referring to applied research. For instance, Northern College of Applied Arts and Technology has developed a business plan for a "Materials Joining Innovation Centre (MAJIC)" that would see part of its mandate extend to applied research.

The **Mission** of MAJIC is as follows:

> *The mission) is to provide solutions to the Canadian welding industries to assist them in advancing their competitive position. The products and services of MAJIC are rooted in the innovative application of technologies.*
>
> *MAJIC will foster the development of a materials joining cluster in Northern Ontario to the benefit of suppliers of welding materials and services and the welding user industries. In so doing, it will act as a catalyst for economic development.*
>
> *MAJIC will accomplish its mission through participation in a wide range of networks of institutions and organizations that focus on welding as well as on the wider field of manufacturing and construction processes.*

The creation of MAJIC builds upon the expertise of Northern College in welding technology and the trust that has been built up with industry through the College's Welding Engineering Technology program. MAJIC also responds to the challenge of Canada's Innovation Strategy, creating a "kernel" innovation centre for applied welding technology.

While MAJIC will be the only Centre in Canada completely focused on the workplace application of welding technology, it is meant to be a node in wider networks of complementary centres and institutes that are active in research and development and technology application to manufacturing, materials and construction processes. For instance, during the Regional Forums, colleges in Alberta (Northern Alberta Institute of Technology (NAIT) and Southern Alberta Institute of Technology (SAIT) and the Maritimes (Nova Scotia Community College and New Brunswick

Community College) were identified as offering potential for the creation of additional applied welding technology centres.

## Quality and productivity improvement

Quality and productivity improvement is at the heart of manufacturing excellence that all of the ten identified user industries are seeking. The Solutions Matrix focuses on this function at both the enterprise and industry level.

In all of the ten sectors, manufacturing excellence has already or is becoming a key element of competitiveness. And today, the concepts of "Lean manufacturing" and "Agile manufacturing" have almost become a religion in North America. Lean manufacturing really grew out of attempts to improve quality and productivity in Japan, particularly at Toyota. Lean manufacturing is also part of the broader concept of Total Quality Management (TQM). TQM and Lean manufacturing are really attempts to change the "culture" of manufacturing enterprises. Empowerment, flatter management structures, teamwork and continuous improvement become crucial to success in a total systems approach that links manufacturers with their suppliers and their customers.

Concepts of lean manufacturing gained significant momentum in North America when the world automotive industry jumped on board and began emulating Toyota. A five-year study by the Massachusetts Institute of Technology (MIT) was very influential in this regard, concluding that plants using the Toyota system significantly outperformed traditional plants – whether located in Japan or not. From this, the definition and components of lean became widely understood by senior management across a wide segment of the manufacturing industry.

One of the tools used to effect the transformation to lean is the "kaizen" event. Kaizen is a cross-functional team event, consisting of six to ten members focusing for two to five days on a defined area of the plant. Using standardized tools and techniques, they analyze, brainstorm, implement changes, measure effect, and document the new "lean" system that must emerge.

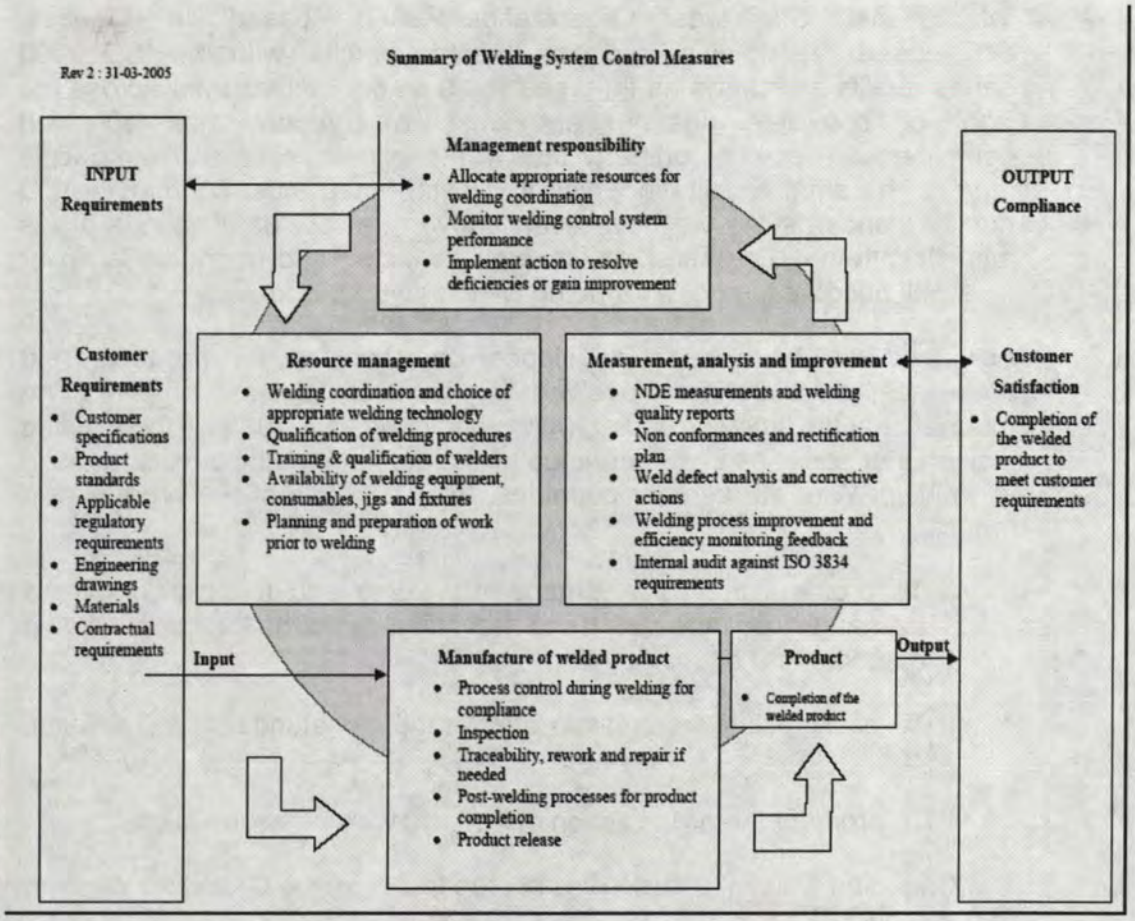
It has not been uncommon for such teams to achieve significant gains in productivity, reductions in work-in-progress (WIP), reductions in floor space and distance traveled. However, gains from kaizens can be short-lived unless they are integrated into an overall company plan or "culture change". Nelson Teed, writing in Advanced Manufacturing has provided a good summary of the lean concept and how it needs to be pursued within a manufacturing enterprise. He has observed:

*"Most practitioners now recognize that all lean conversions need a road map. Analyzing the operation's unique combination of products, equipment, materials, processes, and links with suppliers and customers prior to the kaizens helps ensure success. What's needed is a clear understanding of where the operation stands today compared with the lean vision of a continuous stream of value-added steps stretching from the first supplier to the end user. Value-stream mapping is one method to achieve this.*[3]"

During the regional forums in Cambridge, Montreal, Edmonton and Halifax, the issue of lean manufacturing came up repeatedly and many stressed the need for welding and joining to be integrated into the process. One of the tools to do this is the ISO 3834 standard for quality welding that is similar to the ISO 9001/9004 standard but is specifically designed to address welding fabrication (See exhibit below). The standard was just adopted in September, 2005. The following points were stressed, in relation to the standard:

- Welding is to become reliable and not a hit and miss joining process, as is the often current perception of CEO's.
- More monitoring of the welding processes, before, during and after welding will be required to ensure compliance.
- Senior management will be involved in resource allocation and technology selection, based on welding performance towards continuous improvement.

[3] Nelson J. Teed, Advanced Manufacturing (www.advancedmanufacturing.com)




Using tools such as the ISO 3834 standard, kaizens and value-stream mapping of lean manufacturing, an opportunity exists to develop a specific approach to manufacturing excellence that focuses on welding and joining applicable to each of the ten industry sectors identified.

## International

International standards are becoming increasingly more important in nearly every area of business. The process of developing international standards grew initially out of a desire to harmonize technical and business practices in order to facilitate international exchange. However, more and more international standards are being incorporated in regulations of national and regional authorities and in the performance

requirements of multinational corporations. As such, compliance with such standards is a pre-requisite for doing business.

This has become evident in the area of quality standards of the International Standards Organization (ISO), based in Geneva, Switzerland. Nearly everyone has become familiar with the ISO 9000 series quality standards as they see the banners emblazoned across the front of corporate headquarters when a company has achieved compliance. Today, a company that wants to do business on any scale beyond the small locality in which it is established must conform to ISO quality standards. As we have seen above, the ISO 3834 standard has just recently been established for quality welding and undoubtedly, over time, will become the norm for doing welding work world-wide.

As standards have been developed and evolved for products and processes, so have they evolved for professional qualifications. The International Institute of Welding (IIW) was founded in 1948 by the welding institutes or societies in 13 countries to promote international collaboration in welding. With 43 member countries, the objectives of the organization are:

- To promote the development of welding and to provide for the exchange of scientific and technical information on welding research and education,
- To assist in the formulation of international standards for welding, and
- To promote the organization of national welding associations.

The Canadian Council of the IIW is hosted jointly by the Canadian Welding Bureau (CWB) and the Materials Technology Laboratory of Natural Resources Canada, part of the federal government. The Canadian Council will be hosting the Annual Assembly of the IIW in Quebec City from 27 August to 2 September, 2006.

The Qualification and Authorisation System of the IIW has developed standards for the following professional qualifications:

- International Welding Engineer (IWE),
- International Welding Technologist,
- International Welding Specialist, and
- International Welding Practitioner.

To date, in Canada, no University or College has been accredited to offer the education programs required to meet the standards of the above categories. However, the CWB does indicate transitional arrangements on how to meet the qualifications.

In order for welding engineers and other levels of the welding profession to be able to work on projects in Europe and certain other jurisdictions, it is or will soon become mandatory to achieve the IIW professional qualifications.

**Partnership Focus**

The final column of the Solutions Matrix is the Partnership Focus – those partners with whom the welding and joining industry must work in order to achieve its Vision.

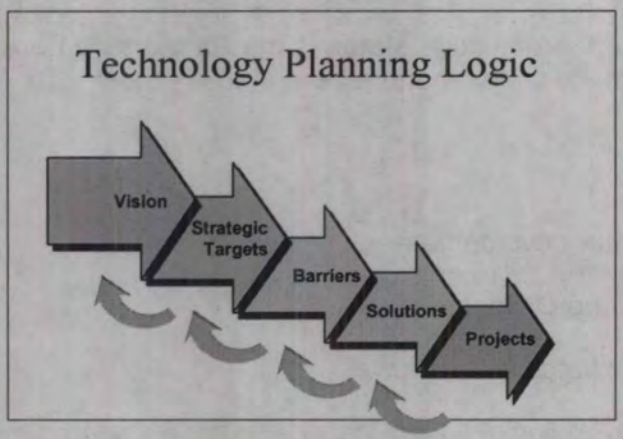
- Industry
- SME/Integrator development
- Universities and Colleges
- Research institutes and centres
- Federal and Provincial government departments and agencies.

In most cases, the Strategic Targets of the Vision coincide with the Partners. The nuance is that before a practical partnership can be established, the particular partner has to have a common understanding and commitment to welding and joining as an enabling technology. Thus, to have a good working relationship with enterprises in the ten identified user industry sectors, the CEO's of those industries and companies must first of all be convinced that a strategic advantage can be gained through the relationship.

Within the industry partnership focus, a subset of industry referred to as "SME/Integrator development" is singled out. This arose in particular reference to the aerospace sector where the need has become evident to encourage more small and medium-sized enterprises to act as suppliers of integrated welded systems and not simply individual components of these systems. The example given in the Regional Forum held in Montreal was in reference to welded systems used in the manufacture of aircraft engines.

# Projects – Making the Vision Happen

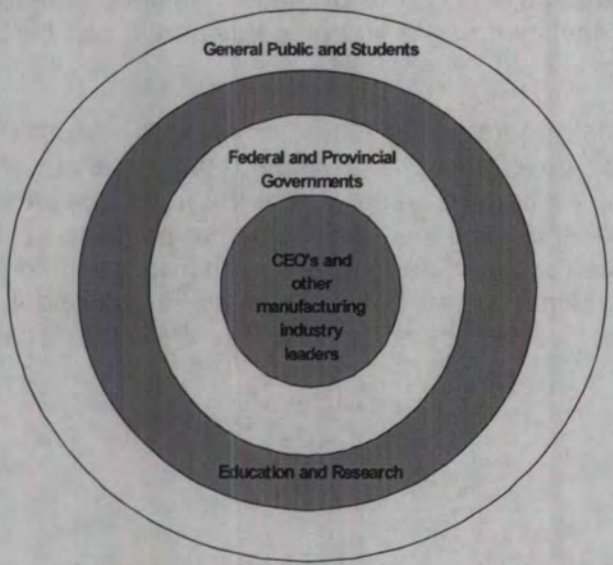
In introducing the Welding and Joining Technology Roadmap we earlier indicated the process of moving from a Vision to Projects. The exhibit below recalls that process.




We first of all identified the Vision,

*"Canada's excellence in welding and joining and its applications will be increasingly recognized across the country and internationally over the next ten years."*

We then identified the Strategic Targets to whom the Vision has to be sold, emphasizing CEO's and other manufacturing industry leaders.



Subsequently, we identified the barriers and constraints that had to be addressed in order to implement the Vision. This included all of the challenges at the international level because of the increasing pressure on the competitive position of North American manufacturers coming from China, India and other parts of Asia. But it also addressed the apparent "downward spiral" that was evident in the Canadian welding and joining community.

We concluded that the downward spiral had to be unraveled and reversed. The key to doing this is to convince industry leaders to see welding and joining as an "Enabling Technology" that can provide strategic advantage at the manufacturing company level and at the welding and joining industry level. It is essential to ensure that welding and joining specialists are included in product/project design teams and that welding and joining fully integrates itself with processes of manufacturing excellence (e.g. lean manufacturing).

From this, we identified a Solutions Matrix that would carry the theme of Enabling Technology across 10 industry sectors, 6 welding and joining technology applications, 6 industry functions and with 5 sets of partners. But we stressed that the Matrix was "a set of possibilities" for a wide range of specific projects and initiatives across Canada over the next ten years.

We have now reached the point of identifying the priority themes and projects for welding and joining in Canada over the next few years so that other projects drawn from the Solutions Matrix can be developed within the full ten-year framework for the TRM. The priorities are:

- Create stronger industry leadership
- Create an exciting image of the industry
- Institute a Quality and productivity advantage for manufacturing industries based on welding and joining as an Enabling Technology.
- Implement a stronger research innovation and technology adoption program.
- Create a strong Education and Training base for welding and joining
- Create a Clearing House for welding and joining information

**Create stronger industry leadership**

Throughout the TRM process the issue of industry leadership has been front and centre. Without strong leadership, implementation of the Vision

will not be achieved. The leadership required is that of key individuals in the user industries that are already convinced of the strategic advantage that welding and joining can bring to manufacturing and who are ready to work together to "spread the gospel" to increase the strategic advantage of Canadian manufacturing as a whole.

Suggested principles to be followed in creating the Leadership Team include:

- A minimum of 3 CEO's or other senior leaders drawn from the industry sectors of the Solutions Matrix and from leading welding and joining companies.
  - That are already convinced that welding and joining is an Enabling Technology that can provide Canadian manufacturing with a strategic advantage.
  - That have the time to commit to the initial implementation of the Welding and Joining TRM, at least over a 2-year period.
  - That represent a balance between the regions of Canada.
- A Resource Team of about 5 members drawn from the welding and joining sector that may represent industry, associations, universities and colleges, research or government.
  - That understands and is committed to implementation of the Welding and Joining TRM.
  - That can support the CEO's and other industry leaders in the directions they determine.
  - That represent a balance between the regions of Canada.

Once the Leadership Team has been initially constituted the first task will be to ensure that sufficient funding for the operation of the Team (Leaders and Resource Team) is in place for a minimum 2-year period. Such funding would be expected to come from industry and from government.

The second task for consideration would be the convening of a forum of the leading associations, institutions and government agencies to achieve a working agreement on a common approach to implementing the TRM. An example of such an approach is that taken by the forest and wood products industry in Finland where "Wood Focus Finland" emerged as a central structure to promote the industry while leaving existing organizations and associations with a large measure of independence to implement their specific and/or renewed mandates.

The third task would be to secure the funding required to implement the other recommended actions of the TRM as described below – and as confirmed or modified by the forum referred to above. Such funding would be expected to come from industry and government.

In its approach the Leadership Team would draw guidance from the acronym D.R.E.A.M.

- Identify DESIRES
- Assign RESPONSIBILITY
- Ensure ENGAGEMENT
- Take ACTION
- With a clear METHODOLOGY

**Image of the industry**

The first project in the TRM implementation is to undertake a Canada-wide campaign directed at the four strategic targets – industry, government, education and the research community – to create a positive, energetic image of the welding and joining industry, why it is important for Canada's prosperity and how it can contribute to increasing the competitive position of Canadian manufacturing and construction over the next ten years.

This project will require professional assistance from marketing and corporate relations specialists with experience in designing industry campaigns and will needed to be fully funded. The main objective of the campaign is to "open doors and minds" so that industry leaders will be receptive to the concept of welding and joining as an enabling technology. Messages and campaigns will need to be carefully crafted for each of the strategic targets and communication channels and venues clearly defined to transmit the message. The elements of the campaign may include:

- Broad media messages through marketing and advertising.
- Directed media messages at key industry events.
- Showcase companies to illustrate the messages.
- Corporate and government presentations.
- Follow-up practical tools providing leaders with the means to "drill down" the message into their companies, institutions and organizations.

- A specific campaign crafted for schools and students at the primary, secondary and post-secondary levels.

**Manufacturing excellence and technology application**

This project has two components:

1. A welding and joining productivity network.
2. Welding and joining centres at educational institutions.

**1. A welding and joining productivity network**

The concept of the Welding and Joining Productivity Network is to create at least four centres across Canada that would work together on a program that would provide ongoing support to the messages transmitted during the campaign to change the image of the industry and particularly, to further the concept of welding and joining as an enabling technology.

Centres are envisaged in the Maritimes, Ontario, Quebec and Alberta and might be attached to existing institutions or organizations, possibly at the education or research levels. The overall mandate would include the following:

- Design and apply concepts of manufacturing excellence, such as lean manufacturing to welding and joining. Each of the centres might develop a specialized approach in accordance with the industry focus of their region.
- Integrate welding and joining into manufacturing excellence, particularly at the design stage. This would require the articulation of welding and joining into the existing concept of product, project and process design so that design teams are fully aware of welding and joining as an enabling technology and have the necessary information and tools to incorporate it into design.
- Conduct welding technology application assessments and create a "Best Practices" technology application database. Such a database would be one of the tools required by design teams.
- Develop and advocate policies to governments, such as tax incentives for investment in automation and productivity improvement. It may be that one of the welding and joining productivity centres becomes specialized in the economic and policy analysis of welding and joining enabling it to be at the forefront in advocating incentive measures to government that would promote the use of the best welding and joining processes in industry.

- Develop an "Integrator" capacity among companies in Canadian industry capable of supplying complete sub-assemblies, not just individual parts. This integrator capacity is particularly required in the aerospace sector and the Aerospace Manufacturing Technology Centre in Montreal has an incubator program and facility in place to encourage SME's to move into integration. It is possible that, over time, each of the proposed centres in the Welding and Joining Productivity Network would have an associated Incubator.

- Sponsor specific welding and joining technology demonstration projects or workshops in all regions of the country. The concept here is that rather than just being places to which industry would come, all of the centres in the Welding and Joining Productivity Network would have an outreach program to demonstrate welding and joining technologies in specific applications.

**2. Welding and joining centres at educational institutions**

The concept of the welding and joining centres at educational institutions is patterned on the example described earlier of the Materials Joining Innovation Centre (MAJIC) proposed for Kirkland Lake, Ontario by Northern College of Applied Arts and Technology.

The main function of such applied research centres, likely located at colleges across Canada, is to be responsive to industry needs to solve specific problems relating to welding and joining. As such, the services offered would likely include:

- Information dissemination and technology transfer, based on databases
- Education and training
- Consulting, contract engineering and lab services, and
- Contract applied research.

The Welding and Joining Productivity Centres and the Welding and Joining Applied Research Centres would act in a complementary fashion. The Productivity Centres would be responsible for moving the yard sticks forward for welding and joining to be used as an enabling technology through a number of funded and directed projects, but they would not provide services at the enterprise level. The Applied Research Centres, on the other hand, would make use of the tools developed by the Productivity Centres to respond to the problem-solving needs of individual enterprises. It is possible, however, that a Productivity Centre and an Applied

Research Centre could be co-located and be under a single governance structure.

**Implement a stronger research innovation and technology adoption program**

This TRM implementation projects stems from the consensus that an insufficient critical mass of basic research on welding and joining exists in Canada and that two aspects need to be strengthened:

- Greater research capacity for innovative welding and joining process applications and adoption for all user industries.
- Greater research capacity for new materials with improved joining capabilities, and their efficient use in welding and joining applications.

It is likely that this goal will be met by funding a greater number of specific projects at existing Universities that have a welding and joining specialization and at existing research institutions, such as the Aerospace Manufacturing Technology Centre. However, consideration in implementing this project should be given to the model of the Consortium for Research and Innovation in Aerospace in Quebec (CRIAQ), described earlier. A Consortium for Research and Innovation in Welding and Joining might be created that would draw industry and all of the basic research centres across the country into a cooperative and coordinated venture.

**Create a strong Education and Training base for welding and joining**

The issue of human resources was indeed prominent throughout the Welding and Joining TRM process and, at times, tended to overshadow some of the more technology-related issues. A shortage of skilled welding and joining specialists exists, particularly at the basic qualified welder level for oil and gas projects in Alberta and in other parts of the country. Three specific projects are recommended:

- Create a Human Resources Sector Council.
- Standardize and harmonize education, qualifications, training and apprenticeship across Canada – harmonized with standards of the International Standards Organization (ISO) and the International Institute of Welding (IIW).
- Describe a "Value-chain" for investment in human intellectual property – an explanatory report on how investment in human resources is at the base of achieving the Vision of the Welding and Joining industry.

The key element is the creation of a Human Resources Sector Council in which work on the other two elements can be pursued. For this, the Leadership Team would need to present a request to the federal government's Sector Council Program.

The Government of Canada's Sector Council Program (SCP) works to enable partnerships that address skills and human resource issues by establishing, developing and supporting national partnerships and the capacity of partners to address both pressing and emerging skills and human resources issues. Sector Councils, Sectoral and Occupational Studies, Industry Profiles, Sectoral Career Information, Grant and Contribution programs and other sectoral activities are a part of the Sector Council Program. The initiative is managed by the Human Resources Partnerships Directorate of the federal government's Department of Human Resources and Skills Development (HRSD).

The five main objectives of the Human Resource Sectoral Program are the following:

- Increase sectoral capacity

  Work with national sectors to help increase their ability to identify and meet their human resources needs.

- Understand and describe skills

  Support activities to understand and describe skills Canadians need in today's labour market.

- Encourage learning systems to be more responsive to the labour markets

  Help create and maintain national partnerships between the private sector and learning systems that can help educators provide students with the skills needed in today's labour market.

- Promote the workplace as a learning place

  Support lifelong learning by promoting learning in the workplace.

- Develop labour market transition mechanisms

  Encourage labour mobility programs that promote recognition of workers' skills across Canada.

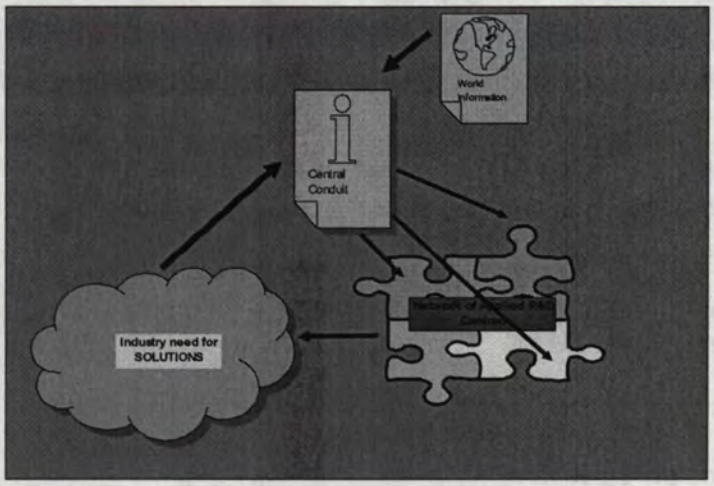
The specific projects that the Welding and Joining TRM recommends under the heading of standardizing and harmonizing education, qualifications, training and apprenticeship include the following:

1. Make Red Seal obligatory across Canada for certain types of welding (a compulsory apprenticeable trade).
2. Define a basics skills ladder.
3. Promote the coordination of college welding training across Canada applicable for students, apprentices and current workforce.
4. Develop/support/revamp University welding engineering programs.
5. Showcase welding and joining careers with schools, industry and academia across Canada.

**Create a Clearing House for welding and joining information**

The concept of this recommendation is the creation of a Clearing House to act as a central information conduit for welding and joining:

- Providing an access point for industry to submit its needs for solutions to welding and joining issues,
- Providing access to the international knowledge base for welding and joining, and
- Providing the opportunity for the Welding and Joining Productivity Network and the Welding and Joining Centres at educational institutions to find the best solutions to industry needs.




Welding Technology Roadmap – Steering Committee

As the exhibit shows, the concept of the Clearing House is closely linked to the Welding and Joining Productivity Network and Welding and Joining Applied Technology Centres.

The Productivity Network will generate interest in the application of welding and joining as enabling technologies in Canadian manufacturing industries and will – with education and research institutions - establish a Canadian knowledge base. At the same time, work on welding and joining from other international jurisdictions will also be advancing. A system is needed that ensures the Canadian knowledge base and the international knowledge base is available for the solutions that industry needs. The Welding and Joining Applied Technology Centres need to be able to access this complete knowledge base, and indeed, add to it, as they work on specific problems for companies.

The Leadership Team will need to determine the best location and structure to host the Clearing House or to ensure that it is part of a Canada-wide distributed system.

# Concluding Remarks

The Canadian Welding and Joining Technology Roadmap (TRM) described in the previous sections of the report represent the efforts and contributions of many people over the last two years – those who participated in the first Vision Forum held in Whitby, Ontario in late 2003, the Steering Committee that guided the TRM process and all of those who participated in the Regional Forums held in Cambridge, Montreal, Edmonton and Halifax in the autumn of 2005.

The List of Members of the Steering Committee can be found in Appendix A. The List of Participants in the original 2003 Whitby Forum and in the 2005 Regional Forums can be found in Appendix B.

The contribution of the industry, education and research representatives to this TRM process has been tremendous. But the contribution of the Government of Canada has been critical – not just in providing funding to undertake the TRM, but in participating with the other representatives to ensure that welding and joining becomes a recognized enabling technology capable of providing a strategic advantage to the Canadian manufacturing and construction sectors on the world market. Thank you to Industry Canada and to FedNor, the federal government's economic development program for Northern Ontario.

We have made the recommendations on how the Welding and Joining TRM can best be implemented. Furthermore, we have already begun the journey to identify potential members of the Leadership Team. The next steps will depend on how quickly the Leadership Team can "take up the reins" and begin to move forward to the Vision for 2016.

# APPENDIX A ---- WELDING AND JOINING TRM STEERING COMMITTEE MEMBERS

| | |
|---|---|
| Fred Gibbons | Northern College of Applied Arts and Technology |
| Mohammad Jahazi | Aerospace Manufacturing Technology Centre |
| Dan Kennedy | Promatek Research Centre, Magna International Inc. |
| Hugh Kerr | University of Waterloo |
| Joe Kubes | Kubes Steel Ltd. |
| Scott Lawson | University of Waterloo |
| John Levi | Canadian Welding Association |
| Brian Newman | Babcock & Wilcox Canada Ltd. |
| Geoff Nimmo | Industry Canada |
| Jack Pacey | Northern College of Applied Arts and Technology |
| Frank Palmer | Industry Canada |
| Mick Pates | Michael J. Pates, Project Consulting |
| Brian Pichette | AMEC Dynamic Structures Ltd. |
| Christopher Rees | Suthey Holler Associates |
| David Taylor | TransCanada Pipelines Ltd. |
| Viwek Vaidya | Air Liquide Canada Inc. |
| Michael Vuchnich | Lincoln Electric Company of Canada Ltd. |
| Edward Whalen | Canadian Welding Bureau |

# APPENDIX B ---- WELDING AND JOINING TRM FORUM PARTICIPANTS

Participants in the Regional Forums - Cambridge, Ontario; Montreal, Quebec;
Edmonton, Alberta; Halifax, Nova Scotia

| | |
|---|---|
| Stewart Henderson | Advanced Welding |
| Andy McCartney | Air Liquide Canada |
| Bob Olmstead | Air Liquide Canada |
| Bob Van Deelen | Air Liquide Canada |
| Viwek Vaidya | Air Liquide Canada |
| Barry Yerex | Alberta Apprenticeship Industry Training |
| James Cleland | Alberta Economic Development |
| Galen Wright | Arc Innovations |
| Terry Condon | Argus Machine Co. |
| Brian Newman | Babcock and Wilcox Canada |
| Wayne Hubick | Bantreg |
| Robert Lazor | BMT Fleet Technology |
| Elgin Hartsell | BOC Canada |
| Peter Bonarrigo | Bombardier |
| Sam Ighani | Canadian Revenue Agency |
| John Levi | Canadian Welding Association |
| Bruce James | Canadian Welding Bureau |
| Darcy Yantz | Canadian Welding Bureau |
| Dave Ellsworth | Canadian Welding Bureau |
| Ed Whalen | Canadian Welding Bureau |
| Jim Reid | Canadian Welding Bureau |
| Yvon Sénechal | Canadian Welding Bureau |
| Mac Braid | Canmet-MTL |
| Stephen Sanfacon | Cessio Fabrication |
| Cam Oberg | CNRL |
| Dan Galbraith | Cogeco |
| Muhammad Arafin | Concordia University |
| Jim Galloway | Conestoga College |
| Karsten Madsen | Conestoga College |
| Tam Nguyen | Conestoga College |
| Andre Bazergui | CRIAQ |
| Rex Whiteway | CSC Bowden Institute |
| Rick Stoesz | CSC Bowden Institute |
| Ilker Kara | CTS Containers |
| Scott Foster | CTS Containers |
| Simon Durham | DAC Aviation |
| Justin MacNeil | Dacro Industries Inc. |

| | |
|---|---|
| Marvin Kossowan | Dacro Industries Inc. |
| Al Lundrigan | Dafasco Inc. |
| Andy Lee | Dafasco Inc. |
| Lori Schmidt | Edmonton Economic Development |
| Scott Ironside | Enbridge Pipelines Inc. |
| Martin Noel | Fanuc Robotics |
| John Camara | GDLS-C |
| Len Henderson | GDLS-C |
| Rocco Varano | Heroux-Devtek |
| Bob Atkinson | Industry Canada |
| Frank Palmer | Industry Canada |
| Geoff Lewis | Industry Canada |
| Jim Castellano | Industry Canada |
| Claude Michel | ISQ |
| Jacob Kleinman | ITL Inc. |
| Keith Roy | JV Driver Projects |
| Darren Trembecky | Lakeland College |
| Laura Wall | Laura K. Wall |
| Robert Tollett | Liburdi Eng. |
| Brent Mallett | Lincoln Electric |
| Kevin Vadori | Lincoln Electric |
| Margie Charland | LJP Skills Training Inc. |
| André Rocheleau | Mancor Canada |
| Dean Michael | Metal Fabricators and Welding LTD |
| Gary Keen | Metal Fabricators and Welding LTD |
| Norman Marchand | MHT-Tech |
| Bob Muir. | Muirtec Inc. |
| Jerry Cook | MWP&P Magazine |
| Darcy Corcoran | NAIT |
| Ken Nelson | NAIT |
| Jim Tingsley | New Brunswick Community College |
| Larry Watt | New Brunswick Community College |
| Kevin Hewitt | Niagara College |
| Lorrie Irvine | Northern College |
| Chad Plant | Northern College |
| Jack Pacey | Northern College |
| Randy Mitchell | Nova Scotia Community College |
| Ron Noel | Nova Scotia Community College |
| Tony Rose | Nova Scotia Community College |
| Donald Landry | Nova Scotia Department of Environment and Labour |
| Ali Merati | NRC-AMTC |
| Francois-Olivier Gagnon | NRC-AMTC |
| Mohammad Jahazi | NRC-AMTC |
| Priti Wanjara | NRC-IAR-AMTC |
| Xinjin Cao | NRC-IAR-AMTC |
| Dennis Lacroix | NRC-IRAP |
| Ralf Edinger | PAVAC Industries Inc. |

| | |
|---|---|
| Graeme Housser | Petro-Canada |
| Jean Fournier | Pratt & Whitney Canada |
| Dan Tadic | Praxair |
| Dennett Netterville | QED Consultants LTD. |
| Robert Moore | QGI Consulting |
| Darrell Lucas | R.K.O. Steel |
| Alex Gontcharov | Rolls Royce Canada |
| Norm Ferguson | Ryerson University/Massiv Automation |
| Jill Fleming | Skills Canada – Ontario |
| Farazan Jamarani | SR&ED |
| Leo Parent | Suncor Energy |
| Alain Brandon | Suthey Holler Associates |
| Christopher Rees | Suthey Holler Associates |
| Jim Mitchell | Syncrude Canada |
| Mike Anderson | Syncrude Canada |
| Brian Lade | Syncrude UE-1 |
| John Oxenford | Titanium Corporation |
| Tiejun Ma | Tregasskiss Ltd. |
| Fraser Forbes | University of Alberta |
| Reg Eadie | University of Alberta |
| Laure Ojo | University of Montreal |
| Hugh Kerr | University of Waterloo |
| Jan Huissoon | University of Waterloo |
| Michael Kuntz | University of Waterloo |
| Scott Lawson | University of Waterloo |
| Rob Wright | Waiward Steel |
| Drew Brandow | Welding at its Best |
| Claude Choquet | 123 Certification Inc |

## Participants in the Visioning Session - Whitby, Ontario

| | |
|---|---|
| Mike McCormick | Air Liquide |
| Bill Eccles | BOC Canada |
| John Davidson | Canadian National Railway |
| John Levi | Canadian Welding Association |
| Douglas R. Luciani | Canadian Welding Bureau |
| Bruce James | Canadian Welding Bureau |
| Richard Bonneau | Canadian Welding Bureau |
| Winston Revie | CANMET |
| Glenn McMillan | Canspec Group Inc. |
| Brian Laite | CB Horton |
| Paul Kovosi | Centerline Ltd |
| Jim Galloway | Conestoga College |
| Karsten Madsen | Conestoga College |
| Blaine Robbins | Deco Automotive |
| Charmaine Rodrick | Durham College Skills Training Centre |
| Ross Brindle | Energetics Inc. |
| Richard Bonneau | GCIC |
| John Camara | General Dynamics Land Systems |

| | |
|---|---|
| Len Henderson | General Dynamics Land Systems |
| George Saxby Holding | George Saxby |
| Mel Allison | GM Electro Motive |
| Gerald Bellehumeur | GRB School of Welding |
| Frank W. Palmer | Industry Canada |
| Micheal Vuchnich | Lincoln Electric |
| Frank Langenecker | Ludwig and Associates |
| Bert Lux | Lux Consulting Services |
| Harvey Pellegrini | Materials and Manufacturing Ontario |
| Craig Hughson | Ministry of Natural Resources |
| Ken Nelson | NAIT |
| Glen Campbell | National Research Council |
| Marcel Desjardins | National Steel Car Ltd. |
| Larry Watt | New Brunswick Community College- Moncton |
| Chad Plant | Northern College |
| Fred Gibbons | Northern College |
| Jack Pacey | Northern College |
| Jacques Goudreau | Northern College |
| Jane Blackwell | Northern College |
| Lorrie Irvine | Northern College |
| Peter Maclean | Northern College |
| Jim Prince | Ontario Power Generation |
| Alain Brandon | Suthey Holler Associates |
| Christopher Rees | Suthey Holler Associates |
| Peter Hodge | TIW Western |
| Bruce Cormier | TransCanada Pipelines |
| Dave Weckman | University of Waterloo |
| Dr. Scott Lawson | University of Waterloo |
| Bernie Altshuller | Welding Consultant |
| Kevin McWhirter | Yakasawa Motoman Ltd. |