Building the knowledge base for ocean resource management – a global challenge

The Ocean Tracking Network
Strategic Plan 2013-2018

December 21, 2012
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Preface to the OTN Strategic Plan 2013-2018

The Ocean Tracking Network (OTN) is set to revolutionize the ways that oceans, and freshwater systems that feed the oceans, are monitored and understood. OTN is deploying an international grid of sensors to gather information, and is training Highly Qualified Personnel who will shape the resulting data into principles that will guide our conservation of the aquatic species on which humans depend. It is an ambitious undertaking, and OTN is now at a pivotal moment.

Since the finalization of OTN’s funding from the Canada Foundation for Innovation in March 2010, approximately 50% of the sub-sea receivers have been committed and eight formal international collaboration agreements have been signed; others are currently under negotiation. Approximately 53% of the Phase I CFI award has been spent or formally committed. The OTN Network is generating scientific results from the work of 287 researchers at institutions across Canada and internationally. The training of 116 highly qualified personnel, including postdoctoral fellows, PhD, MSc and undergraduate students, and technical staff, is advancing rapidly. And as OTN moves to full deployment, a new governing Council is being implemented under the chairmanship of Peter Harrison, Professor, Stauffer-Dunning Chair and Director of the School of Policy Studies at Queen’s University and a former senior federal government official with extensive experience in oceans, Arctic, policy, communications, and environmental issues.

This is, therefore, an appropriate time for the development of OTN’s first comprehensive Strategic Plan, and the associated Management Plan that will guide both the scientific programs supported by the OTN platform and the evolution of the platform itself over the next five years – 2013 to 2018. The new plan replaces and supersedes previous roadmaps and Conditions for OTN, and is itself subject to the natural evolution characteristic of all frontier research initiatives. Further, the new plan lays out a visionary path for OTN, one that includes a crucial capacity to adapt as circumstances change.

OTN wishes to acknowledge the Canada Foundation for Innovation, the Natural Sciences and Engineering Research Council of Canada, the Social Sciences and Humanities Research Council of Canada, and Dalhousie University for their generous support and guidance.

Fred Whoriskey
Sara Iverson
Kes Morton

The OTN Management Team
November, 2012
The Plan at a Glance

This Plan is based on a new Vision and Mission for OTN established in the autumn of 2012 with input from the OTN Strategic Plan Steering Committee, the new OTN Council, the International Scientific Advisory Committee and the Scientific Advisory Committee of OTN’s NSERC-sponsored research arm.

Vision
Enabling international sustainable management of valued aquatic species by providing knowledge of animal movements, survival, and habitats and of how all are linked to environmental conditions. Fostering technological and operational innovation that will revolutionize our management of the ocean.

Mission
To create a global partnership to construct and sustain a scientific platform and the associated trained personnel to collect, store, share, analyze, and use aquatic tracking and environmental data to support sustainable management of valued aquatic species.

Values:

- Excellence in sustained, interdisciplinary science supporting long-term management and conservation, driven by infrastructures that provide timely, high-quality, broadly accessible, global data that is interoperable with other data sets;
- Emphasis on attracting, enabling, and training top quality researchers, both nationally and internationally;
- Collaborative international partnership addressing global problems confronting ocean and freshwater conservation and management in a cost-effective manner; and
- Optimizing opportunities for development of new products and services by Canadian technology industries through the development and maintenance of the OTN state-of-the-art infrastructure.

Concept:

- OTN is the world’s aquatic animal tracking network. OTN’s underlying concept is to share costs, resources, expertise and data with global partners to enable the creation of a global acoustic telemetry network. OTN also includes work with other technologies, including satellite telemetry and data storage tags, which can contribute knowledge about animal movements and their environmental correlates. OTN’s international value proposition is to strategically make capital and data-sharing investments that build on the scientific expertise and existing infrastructure of international partners to provide larger platforms that can generate the knowledge that international end users need at an affordable price.
Planned deployments:
- Tracking will be conducted in each of the world’s five oceans, spanning seven continents, and in freshwater systems that either serve as highways to the oceans for species that migrate between fresh and salt waters, or whose size foster significant movements of valued species entirely within fresh water. OTN will deploy 2000 sonic receivers in its deployments.

Species tracked:
- The OTN will track species of scientific and strategic interest in various regions of the world, including marine mammals, sea turtles, squid and other invertebrates, and fishes including sharks, sturgeon, eels, tuna, salmon, and cod.

Why
Different species are valued by humans for differing reasons, including their contribution to food security, their cultural importance, or their protection under legislation such as that for endangered species. A well-positioned global telemetry platform must meet multiple needs for information on species that are valued for multiple reasons.

Aquatic animals are sensitive indicators of global environmental trends. Marine and freshwater systems are interconnected, and many important species such as salmonids migrate between them as a normal part of their life cycles. We cannot successfully manage or conserve such species without the necessary understanding of how they use both freshwater and marine habitats. Large freshwater systems such as the North American Great Lakes have their own unique ecosystems, with valued species undertaking large scale migrations entirely confined to fresh water.

The funding invested:
- $45 million from the Government of Canada; ~$128 million from partners.
Executive Summary

The announcement of the creation of the Ocean Tracking Network (OTN) occurred in February 2007, with finalization of the Canada Foundation for Innovation funding award occurring in November 2009. While low-level development of the OTN infrastructure commenced shortly after the 2007 announcement, major growth of the platform began following finalization in 2009. This five year plan (2013 -2018) sets out the vision, mission, strategic science goals and management priorities for the OTN.

The platform

The OTN is the world’s aquatic animal tracking network. OTN is a global partnership built on Canadian technology and the sharing of costs, resources, expertise and data internationally. OTN is focused on the use of sonic and other telemetry technologies (satellite tags, archival data-storage tags) to document the survival and movements of marine animals, and to correlate both with environmental conditions.

The OTN infrastructure has been initiated by a $35M award from the Canada Foundation for Innovation (CFI). The Natural Sciences and Engineering Research Council of Canada (NSERC) supports OTN-Canada, a $10M, five year national network of researchers that works with the OTN infrastructure. The Social Sciences and Humanities Research Council of Canada (SSHRC) funds the participation of social scientists in OTN work. Over 200 international researchers from 15 countries are currently participating in the global network, and new researchers are being regularly added. International Deployment Collaborators engage in the project by providing operation and maintenance support of international receiver lines (also referred to as arrays) deployed in their jurisdictions, as well as tagging and releasing marine animals to study their movements.

OTN’s management plan aligns strategic goals with management priorities. Governance of OTN is undertaken by the OTN Council on behalf of the University. The Council is advised by a Canadian Scientific Advisory committee that oversees the science work of the NSERC OTN network, and an International Scientific Advisory Committee that fosters collaboration of Canadian institutions and scientists with their international counterparts.

The science

For the next five years, OTN researchers globally are focusing their activities around three primary research questions, and four cross-cutting activities:

1) Research Question 1: How do oceanographic and environmental features (both physical and biological) affect animal habitat use, movement and migrations?
2) Research Question 2: How do species interactions and areas of ecological significance relate to habitat use, movement patterns, and biotic/abiotic features?
3) Research Question 3: How do anthropogenic activities and development influence animal behaviour and ecology?
4) Cross-cutting Activity 1: Assimilating animal tracking data with coastal and offshore oceanographic models
5) Cross-cutting Activity 2: Visualization and modeling of complex aquatic and marine observations
6) Cross-cutting Activity 3: Advancing animal tracking technology and tagging techniques
7) **Cross-cutting Activity 4**: Policy, stake holders and mechanisms for feeding into outreach and management; cooperation of natural and social scientists

OTN will make all its data publically available, free of charge. Under current OTN policy, public access to some animal tracking data may be delayed to protect potentially endangered animals and to permit graduate students working on OTN projects to successfully complete their thesis work. The OTN team constantly strives towards open access wherever feasible and this policy is expected to evolve to be congruent with new data-accessibility standards currently being developed for publically-funded research projects in Canada.

The OTN is sustaining research in each of the four priority ocean research clusters identified by the 2012 Council of Canadian Academies (CCA) report “40 Priority Research Questions for Ocean Science in Canada”. OTN will be a lead resource for addressing a number of key issues, and can contribute directly or indirectly to addressing 26 of the 40 priority ocean research questions identified by the CCA.

**Strategic goals**

The strategic goals addressed in this plan for OTN in 2013-2018 are:

- Enabling research excellence
- Deriving benefits for Canada
- Enabling international benefits

OTN’s logic model guides OTN in addressing these goals, and the OTN Management Plan aligns strategic objectives with management priorities.

The 20 year goals for OTN are:

- **Providing a reliable long-term global oceans perspective.** As the platform and database grow and improve, they will be of increasing value for informed decision-making and will be a necessary go-to source for end-users. The inclusion of Polar zones make this particularly important for polar countries, including Canada.

- **Enhancing Canadian capacity for adaptive oceans management.** Canadian leadership of OTN means that observations will include areas of critical importance for Canada. Canadian leadership also means that we will train highly qualified personnel with a capacity to exploit the wealth of international OTN data.

- **Making the infrastructure sustainable through a continued focus on becoming more efficient and cost-effective.** Many platforms originally intended for long-term environmental monitoring have been cancelled due to high costs. OTN will systematically work on developing novel cost-sharing agreements and on reducing operations and maintenance costs of our platform through avenues such as automation of data transfer to the data warehouse, and the use of autonomous vehicles to service OTN lines.

- **Coping with more challenging scientific questions.** Improvements in tracking technology will enable new generations of scientists to address questions that have not been tractable previously, such as changes in ecosystem function caused by distributional shifts of animals resulting from global climate change, and unanticipated cumulative impacts.

- **Ensuring faster and broader uptake of the data** generated by the platform. OTN will be built on principles of open access to the database and with an evolving suite of analytical and visualization tools. Progress in improving and downscaling oceanographic models will greatly extend OTN’s ability to link animal distributions and movements to environmental conditions.
Evolution in electronic communications and OTN’s communication skills will result in rapid and effective transmission of knowledge to the end users.

- **Becoming more flexible** as autonomous vehicles and bioprobes play an increasing role and extend OTN’s coverage and reach. A core principle of OTN is the continuous, adaptive and sophisticated evolution of OTN in response to shifting challenges and pressing needs.

- **Expanding to assist the developing world.** Less developed areas will be facing a disproportionate share of the impacts of ocean development, and will have the least resources to devote to scientific support of decision-making. OTN will assist in meeting the needs of these countries, and since the ocean is a shared global resource, that work will have direct benefits for Canadians, and will also raise the profile of Canada and Canadian Science and Technology internationally.

**The impact**

The OTN infrastructure and the research it sustains provide cost-effective science to improve our understanding of biology and ecology of aquatic species, and to provide sustainable management regimes for these valued species. Knowledge from the OTN will assist end-users from academia, government, industry and the public in the development of new management approaches and in policy development. It will also help guide the development of marine protected areas, endangered species recovery plans, and the implementation of ecosystem approaches to fisheries management.

Canada is the world leader in the design and construction of the technology for acoustic tracking of animals. OTN activities will help maintain this Canadian technological stronghold and the jobs it supports by identifying promising new products, showcasing the utility of the technology to answer critical questions for end users, and by beta-testing equipment.

Internationally, the OTN value proposition is to make strategic capital and data-sharing investments that build on the scientific expertise and infrastructure of international partners to provide larger platforms that can generate the knowledge can be used worldwide at an affordable price.

**The future**

OTN is working with international partners to insure continued support of the global telemetry network beyond 2018.
OTN – a unique international observatory led by Canada

The Ocean Tracking Network (OTN) was established by Dalhousie University and its partners as a global ocean research and technology development effort headquartered at Dalhousie University, Halifax, Nova Scotia. Starting in 2008, OTN began deploying global acoustic telemetry infrastructure using Canadian state-of-the-art acoustic receivers and oceanographic monitoring equipment in key ocean locations. Appendix 2 outlines the number of OTN collaborations that have been established by partner institutions and countries as of November 2012, including the number of receivers and tags deployed.

OTN is focused on filling the present gap in ocean observing systems by directly monitoring the movements and survival of valued aquatic animals over extended periods and by linking them to biological and physical oceanography. The ability to address these questions arises from rapid advances both in acoustic telemetry technology, and in internet-linked computing technology, which allows rapid communication and data-linking among geographically-dispersed international scientific teams. The OTN platform is unique by virtue of a special combination of factors:

- We fill a notable gap in present ocean observation systems in monitoring the movements and survival of marine animals in the context of their environment.
- Our platform deployments are global in scale, capable of operating in polar to tropical environments.
- We are an enabler, not a competitor. We collaborate and partner to enable institutions and agencies to address their core problems and mandates.
- Our infrastructure is robust and agile. It can monitor fixed stations for extended periods and also be rapidly redeployed to address new issues and questions.
- We have a globally distributed group of national and international expert marine scientists utilizing the platform and contributing to the science outcomes.
- We are a Canadian initiative, built on Canadian technology.

Canada Foundation for Innovation (CFI)-supported OTN deployments are planned for each of the world’s five oceans and selected freshwater sites; they span seven continents. Many are already in place. Acoustic tags can be fitted on animals as small as seven cm, permitting the tagging of varying life-stages of up to 85% of the world’s fishes. The Natural Sciences and Engineering Research Council of Canada (NSERC) supports OTN-Canada, a national network of researchers that works with the OTN infrastructure. The Social Sciences and Humanities Research Council of Canada (SSHRC) funds the participation of social scientists in OTN work, which will focus on getting the knowledge into the hands of end-users. Over 200 international researchers from 15 countries are currently participating in the global network using OTN infrastructure together with research resources from their home countries.

By developing a platform that provides direct observation of valued aquatic animals, OTN will enable the critical science necessary for effective fisheries conservation and management, ecosystem management, and the documentation of the outcomes of interactions among different species.

OTN hosts a Data Warehouse repository for data collected by OTN researchers, and is working to develop interpretation and visualization tools for tracking data. The warehouse will provide foundational information for the development of Marine Protected Areas and the design of recovery plans for endangered species. It will document the responses of valued species to changes in environmental conditions. It will allow decision-makers to operate in an adaptive management context, and enable global communities to meet their goals for marine conservation.
OTN owns two autonomous vehicles (Webb “Slocum Electric Gliders”) to support oceanographic and tracking research. The fleet is used in targeted ocean areas to profile the water column, providing empirical data to help create and/or validate oceanographic models whose output is used to link animal tracks and survival to environmental conditions. The gliders can also be fitted with acoustic receivers and used as mobile telemetry platforms in areas where fixed receivers are contraindicated (e.g., areas with heavy trawl fishing). OTN is exploring ways to integrate its glider operations with those of other glider centres including Rutgers University, the University of Maryland, and Defence Research and Development Canada in Halifax. The oceanographic data obtained in our work will be freely available to the global community. OTN is committed to establishing the infrastructure and making it fully operational over the period 2008-2014. At the same time, OTN Management is negotiating international research partnerships and fostering further international integration of the Canadian OTN research activities supported by NSERC and SSHRC.

OTN has begun compiling a list of organized acoustic telemetry monitoring observatories in the various ocean regions and of their respective databases. A high level overview of that inventory is provided in the following table. The OTN uses Vemco acoustic receivers, and according to the manufacturer’s estimate, 20,000 such receivers are currently deployed globally. OTN plans to deploy 2000 receivers by the time it has completed its rollout in 2014. A majority of the global owners of deployed receivers have not provided information on their deployments (Table 1). As part of OTN’s international strategy we will continue to reach out to these owners and encourage them to coordinate their efforts with us.

Table 1. Documented current global receiver deployments.

<table>
<thead>
<tr>
<th>Location</th>
<th>No. of documented receivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>100</td>
</tr>
<tr>
<td>Asia</td>
<td>NA</td>
</tr>
<tr>
<td>Australia</td>
<td>1,195</td>
</tr>
<tr>
<td>Middle East</td>
<td>60</td>
</tr>
<tr>
<td>Europe</td>
<td>40</td>
</tr>
<tr>
<td>North America</td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td></td>
</tr>
<tr>
<td>Atlantic Cooperative Telemetry</td>
<td>900</td>
</tr>
<tr>
<td>Florida Cooperative Telemetry</td>
<td>150</td>
</tr>
<tr>
<td>Gulf of Mexico</td>
<td>NA</td>
</tr>
<tr>
<td>California Fish Tracking Consortium; Pt. Reyes</td>
<td>500</td>
</tr>
<tr>
<td>Puget Sound/Juan de Fuca</td>
<td>224</td>
</tr>
<tr>
<td>Alaska</td>
<td>22</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
</tr>
<tr>
<td>West Coast (OTN-POST; Kintama)</td>
<td>100</td>
</tr>
<tr>
<td>Arctic</td>
<td>125</td>
</tr>
<tr>
<td>East Coast</td>
<td>489</td>
</tr>
<tr>
<td>Total documented all regions</td>
<td>3,905</td>
</tr>
<tr>
<td>Total estimated global receivers</td>
<td>20,000</td>
</tr>
</tbody>
</table>
Global Challenges and Opportunities for OTN

Marine and freshwater species are critical to assure global food security and to provide employment and social benefits for the nations accessing these resources worldwide. Human impacts, both direct (e.g., fisheries) and indirect (e.g., climate change, ocean acidification, oxygen depletion), are pressuring these resources, and their future sustainable use will require management regimes informed by the best possible science.

Many fisheries species migrate across international borders. As a consequence, nations share the resource, which greatly complicates the task of sustainable management, especially if we do not understand the migratory behaviour or the non-fishery mortality rates during the movements. Impacts from the removal of the targeted fisheries species upon ecosystem structure and function are frequently unpredictable, and can change the biological production of ecosystems with great socioeconomic and biological consequences.

Future restoration, conservation, and management of fisheries and their supporting ecosystems will depend on scientists providing appropriate information to the managers and decision makers. We must be able to monitor the movements, survival and habitats of fish species if we are to achieve successful fisheries management, design marine protected areas, safeguard endangered species, and protect critical habitats for marine species.

Acoustic telemetry is used world-wide to document local-to-global scale movements and survival of marine animals. The equipment detects movements of aquatic animals fitted with acoustic tags (“pingers”), and then associated monitoring of environmental conditions allows researchers to link movements and survival to environmental stressors. The worldwide growth in the use of such techniques is premised on a Canadian technology produced by Vemco/Amirix, a Halifax company founded in 1979 that currently employs approximately 90 people. It is also built on the pioneering scientific work by Canadian researchers; a partnership between the Department of Fisheries and Oceans and the Atlantic Salmon Federation deployed the first large-scale (46 km) coastal acoustic array across the Bay of Fundy in 2000. Results from that study then stimulated the Pacific Ocean Shelf Tracking (POST) project on the West Coast of North America in 2002. POST deployed multiple acoustic arrays across the continental shelf of the west coast of North America with the objective of documenting long-distance movements and survival of fishes from “Baja California to the Bering Sea.”

The early success of projects on such a scale then did two things: it set the stage for even grander ambitions; and it highlighted the need to systematically track and link the movement of marine animals/fish across national and regional boundaries, and to establish a single data warehouse or a system of linked data warehouses so that the results of the many separate acoustic array initiatives can be collated and compared.

The obvious need for the information made possible by acoustic telemetry, coupled with the success scientists have had with the technology has resulted in a rapid increase in activity. As noted, there are now more than 20,000 active Vemco/Amirix receivers deployed in the globe’s marine and fresh waters. These units are seamlessly compatible with each other, and the opportunity is enormous.

In the beginning the investigators working with the equipment proceeded independently and focused on specific local research questions. In some instances, regional-scale networks of investigators agreed to share detections of tagged animals that moved outside of localized study areas into neighbouring
arrays (e.g., the Pacific Ocean Shelf Tracking Project). Such cooperation permitted the scientists to address much bigger science questions than could be answered by individual investigators, and it raised the tantalizing prospect that ever-wider collaborations could generate ever-greater returns. The largest such collaboration to date has occurred in Australia, where a continental network of receivers is coordinated by the Australian Animal Tagging and Monitoring System (AATAMS). At present, the USA is proceeding with organizing its independent telemetry lines, existing regional networks, and work with satellite telemetry into an integrated Animal Tracking Network (ATN) that will find a home in the US Integrated Ocean Observing System (IOOS). Canada’s acoustic telemetry efforts are now being coordinated by the OTN, and OTN is working to incorporate Canadian lines into a continental array for North America in collaboration with the USA and Mexico.

**OTN’s Value Proposition**

OTN’s international value proposition is to make strategic capital and data-sharing investments that build on the scientific expertise and infrastructure of international partners to provide larger platforms that can generate the knowledge can be used worldwide at an affordable price. To document and monitor animal movements on a global scale requires a worldwide network of scientists and a global tracking platform which is too expensive for any one group to achieve. What is required are partnerships of governments, academic institutions, industry and public sector groups to build a global tracking capability that affordably provides the information that serves all. OTN is positioned to coordinate these independent ventures, resulting in exponential increases in the scientific power of infrastructure and results. Members of OTN gain access to the OTN data warehouse, which provides them with a bigger return on their local investment.

Canada also benefits from this investment. OTN deployments in Canada are being linked to those in the USA to build a continental capability that serves the knowledge needs of Canadian end users. As a Canadian-led telemetry research platform that leverages Canadian-designed and built interoperable sensor arrays around the world, OTN enables Canadian researchers and ocean technology providers to take a leadership role in domains with critical economic and public policy impacts. Such leadership enables Canada to attract and retain the best talent for Canada and to reinforce its competitive market position in ocean technologies. **Made-in-Canada technology – including oceanographic sensors and acoustic detection stations** – is being deployed by OTN in ocean and freshwater systems across seven continents to achieve these ends. OTN is well on the way to implementing the full global platform. At present 24 lines have been deployed or are in progress, and over 13 of these involve international partnerships (Figure 1). Additional international research collaborations are in the planning stages; still others are being executed.
The OTN International Strategy

OTN’s strategy for building a global platform is predicated upon leveraging partner assets and capabilities, and coming to formal agreement with the partners on formats for data storage and sharing. For example, OTN’s deployments in Australia complemented existing tracking infrastructure there, and built on the coordinated scientific and technical expertise already present. The OTN Perth and Tasmania lines filled important gaps by covering southern portions of boundary currents on both the east and west coasts of Australia. They significantly enhanced the critical mass and resolution power of telemetry capacity, helping to create a continent-wide capability. The ways that the resulting data are shared is governed by a formal Collaboration Agreement signed between OTN and the Australian partners. On the other side of the world OTN’s upcoming deployment in the Strait of Gibraltar will serve the interests of all coastal nations of the Mediterranean Sea, and complement their existing deployments in coastal waters.

Going forward, OTN will continue to implement the deployments outlined in its original grant proposal, and will adopt a two-pronged approach to developing additional international capacity through:

- Working with new partners of varying experience where the availability of local resources permits the initiation of, or significant enhancement to, local/ regional/continental acoustic telemetry capabilities. OTN will primarily contribute technical expertise and data services to these efforts, with limited capital investments;
- Making strategic investments of OTN capital resources in geographic areas of scientific and socioeconomic priority interest, in collaboration with local partners.
Linking to the Global Ocean Observing System (GOOS)

The Intergovernmental Oceanographic Commission of the United Nations has created the Global Ocean Observing System (GOOS; www.ioc-goos.org) to stimulate international collaboration and coordinate global ocean monitoring efforts. GOOS uses data from national authorities and attempts to produce accurate descriptions of the present state of the ocean and forecasts of future conditions. GOOS is implemented by member states via their government agencies, navies and oceanographic research institutions working together in a wide range of thematic panels and regional alliances.

GOOS has historically focused on physical/chemical oceanography, but is now adding biological monitoring to its activities. OTN is a pilot project of GOOS, and will bring into it data on animal migration and marine habitat use; no other international program offers this advantage.
Opportunities and Benefits for Canada

Canada’s oceans policy context
Fisheries and Oceans Canada (DFO) has the lead federal role in managing Canada's fisheries and safeguarding its waters. Its work is guided by three key pieces of legislation:

- The Oceans Act that entrusts the Minister with leading integrated oceans management and providing Coast Guard and hydrographic services.
- The Fisheries Act that gives the Minister responsibility for the management of fisheries, habitat, and aquaculture.
- The Species at Risk Act that gives the Minister responsibilities associated with the management of aquatic species at risk.

The presence of the OTN platform and the research sustained by it provides science to improve the understanding of biology and ecology of aquatic species. This will influence the design of new management approaches and policies as the technology and knowledge matures, and will assist with day-to-day operational management. OTN will thus assist DFO by informing policy and management decisions relating to these three framework acts and in delivering on the three strategic objectives for DFO: Economically Prosperous Maritime Sectors and Fisheries; Sustainable Aquatic Ecosystems; and Safe and Secure Waters.

OTN data are one of many data sources that are available from government and academia that describe Canada and Canadian natural resources in valuable ways. Many of these data streams, including OTN, are geo-spatial in nature. The need for Canada to improve the inter-operability of such geo-spatial records and enhance their availability through publicly-accessible portals has been recognized.

Discussions about how best to improve such access for Canadians are underway, and include the idea of a common geo-spatial standard and platform. OTN recognizes the opportunity that such developments would represent and would look forward to such an initiative.

In addition to national considerations, DFO manages Canada’s adherence to international agreements that provide a policy framework for effective management of transboundary fisheries and global oceans. Amongst them are:

- The United Nations (UN) Convention on the Law of the Sea (UNCLOS) that establishes jurisdiction and governance parameters of key issues related to the world’s oceans.
- The UN Fish Stocks Agreement (UNFSA) that provides the framework for the conservation and management of straddling and highly migratory fish stocks in high seas areas.
- The Convention on Biological Biodiversity.
- A number of Food and Agricultural Organization (FAO) of the UN agreements relating to the management of fishing capacity, the prevention, deterrence and reporting of illegal, unreported and unregulated fishing and the conservation and management of sharks.
- The Pacific Salmon Treaty (PST), signed by Canada and the United States in 1985, that provides the framework through which the two countries work together to conserve and manage Pacific salmon.
- The International Boundary Water Treaty between the US and Canada managed by the International Joint Commission (IJC).
OTN and Canadian priorities

While a number of federal and provincial departments have a mandate that could usefully be informed by the outcomes of the research that will be supported by the OTN platform, the federal Department of Fisheries and Oceans (DFO) is pre-eminent among those users. As such, its current priorities will inevitably help shape the OTN science planning activity, both Canadian and international:

- **Efficiency and effectiveness in the provision of day-to-day decision support for oceans management.** This is a pragmatic agenda in which DFO is seeking new technologies and methods to assess such events as the strength of a salmon run or a migratory event in near- or real-time with technologies and approaches that augment or replace current technologies at lower cost and higher efficiency and effectiveness. Technologies developed over time for the OTN platform should seek to serve a pressing need for more cost-effective monitoring.

- **Maintaining a relevant longer-term strategic research agenda within DFO.** The longer-term focus of DFO’s interest in OTN is on those areas of activity that allow it to better understand ocean processes, and in particular on processes that could alter current management and policy paradigms. DFO seeks to maintain a long-term strategic research program premised on providing the resource manager with a better understanding ocean processes. Key management issues include fisheries habitat, species at risk, ecosystem-based management, risk management for human developments in the ocean, and creation and management of marine protected areas. Departments associated with the inter-departmental agenda on climate change are also potential receptors for OTN research. For these Departments, the focus is increasingly on the development of adaptive strategies to mitigate climate change impacts.

- **International commitments and issues.** Canada is a signatory to a number of international commitments that carry certain expectations of Canada; hence there is a need for forefront research to inform decisions. There is a potential for alignment of the species tracked through OTN with Canada’s international commitments, as well as for meeting biodiversity objectives and identifying the factors influencing biodiversity changes. There is also a very pragmatic interest on the part of Canada in better understanding the location and numbers of commercial species such as tuna and halibut in trans-boundary zones, in support of trans-boundary resource sharing arrangements.

As OTN matures, it will assess how to balance the interests of research users who may be satisfied with two or three data collection sessions per year with the needs of operational managers who frequently need data more often and more rapidly for real-time management. With the integration of gliders, continued miniaturization and better technology, OTN should be able to provide relevant data delivered in a timely manner to DFO and its partners.

Managing a constructive knowledge flow and interface between the OTN platform and DFO will be crucial. DFO, a large federal department with research and operational activities widely distributed across Canada, is an important collaborator in OTN’s forward agenda. This collaboration will be achieved through DFO participation in all levels of OTN committees, by DFO researchers using the platform for priority studies, and through researcher-to-researcher contacts including DFO scientific involvement in co-creating research topics. Another effective means of interface is the issue-focused workshop similar to the one held in late 2011 on the science relevant to DFO that had been undertaken using the Pacific Ocean Shelf Tracking (POST) infrastructure on the West Coast.
The Council of Canadian Academies report
Acting on a commission from the oceans-related research-intensive universities, in 2011-2012, the Council of Canadian Academies applied a well-established methodology for collaboratively identifying research priorities and emerging issues in science and policy to define a set of questions that, if answered, would have the greatest impact on oceans understanding and management relevant to Canada. That report, entitled “40 Priority Research Questions for Ocean Science in Canada,” classified the broad priority research issues in four clusters:

- improving fundamental scientific understanding
- monitoring, data, and information management
- understanding impacts of human activities
- informing management and governance

The OTN will sustain research in each of these four clusters; indeed it will be a critical resource for tackling many of the specific questions and can contribute directly or indirectly to address 26 of the 40 questions.

The Council’s report also highlighted several key research issues that structure international frameworks on oceans management:

- the ocean is affected by global environmental change through its impacts on ocean processes and marine ecosystems
- the rate of change is accelerating in the ocean
- the Arctic is of particular importance to Canada
- the world’s oceans are interconnected
- socio-economic systems and ecosystem management must be better integrated.

Three of the infrastructure capacity questions included in the Council’s report that are worthy of particular attention.

23. How can autonomous and networked platform infrastructures and sensors be developed to deliver comparable ocean data and data products for observation, monitoring, analysis, and decision-making?

24. How can a network of Canadian ocean observations be established, operated, and maintained to identify environmental change and its impacts?

25. What indicators are available to assess the state of the ocean, what is the significance of changes observed in those indicators, and what additional indicators need to be developed?

In each case, the OTN provides a substantive answer. Furthermore, OTN is operating within a global or “one ocean” contextual framework emphasized by the Council (see text box). The “one-ocean” context is unique to OTN among Canadian oceanographic platforms:

<table>
<thead>
<tr>
<th>The interconnected nature of the world’s oceans has prompted some researchers to adopt a “one ocean” perspective (O’Dor et al., 2009): marine species migrate between countries; ocean currents transport energy, nutrients, and contaminants over immense distances; and the ocean is linked to global climate through a complex web of atmosphere-ocean interactions and feedback mechanisms. Thus, research in ocean science must extend beyond national boundaries to develop a coherent and holistic model of ocean processes.</th>
</tr>
</thead>
</table>

40 Priority Questions for Ocean Science in Canada: A Priority-setting Exercise by the Core Group on Ocean Science in Canada Council of Canadian Academies 2012 |

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1 Professor Ron O’Dor was OTN’s first Principal Investigator.
Canada’s ocean industries
While a compilation of the ocean industry sector for all of Canada is not currently available, recent regional studies highlighting the importance of the industry have been carried out, including two for Nova Scotia (Gardner Pinfold Consulting Economists, Ltd 2009. Economic Impact of the Nova Scotia Oceans Sector, 2002-2006; Government of Nova Scotia 2011. Defined by the Sea). In Nova Scotia, in 2006, 15.5% of annual GDP ($4.9 Billion) came from the oceans sector, which created 60,000 jobs (13.9% of the provincial work force). This sector is growing at twice the rate of other components of the economy. With regards to the Ocean Technology sector, Nova Scotia is home to more than 200 companies, mostly Small and Medium Enterprises, of which 60 are innovators of new high-technology products. In 2009, these technology companies generated revenues of more than $500M, twice the value compared to 2003; they accounted for about one third of all R & D investment by companies in the province. Markets for Nova Scotia ocean technology companies are primarily in international exports, where the global market for ocean-related sales and services is estimated to approach $3 trillion (US) per year — double the value in 2005.

The Defined by the Sea report explicitly recognizes the leadership role of the Ocean Tracking Network in the NS oceans industry sector. Canada is the world leader in the technology of acoustic tracking of animals, and the manufacturing centre for this equipment is located in Nova Scotia. Support by NSERC for the OTN Canada Network demonstrates the high level of international competitiveness of the Canadian scientists involved with OTN.

Industrial developments in the ocean, such as oil and gas exploration and production, shipping and aquaculture are accelerating, and the impacts of such activities will also need to be carefully managed to meet regulatory requirements and sustainable development goals. The information provided by OTN will assist industry by providing information that supports the management of ecological risk, while permitting the socioeconomic benefits that flow from successful projects. For example, knowledge of the timing and routes of migration for valued fisheries species could permit oil exploration to be planned for periods when the species are not present in the target areas. Understanding migration routes also means that shipping routes can be altered to avoid the potential for encounters with endangered marine mammals or turtles. Similarly, charting the migration routes of wild fishes could allow the siting of aquaculture facilities in ways that minimize encounter probabilities and the attendant risks of disease transmission to wild stocks.

In addition to their importance in research, international connections and collaborations are also valuable assets in international business and trade. Such connections help the already strong ocean sensor industry in Canada benefit from progress made in research all over the world, especially in the design and marketing of new products and services that respond to the evolving needs of researchers and the public they serve.
The 20 Year Vision

Global oceans will be subjected to increasing stress over the next 20 years, driven by human population growth and of the demands it will make on the planet’s resources. The oceans will be under increasing pressure to provide secure food supplies, as well as social and economic development opportunities. The ocean’s fisheries will be fully utilized, with decision-makers faced with constant demands to permit additional exploitation. The ocean will be required to accommodate rapidly expanding aquaculture, as well as other development activities. The receding ice in the Arctic will open up new trade routes and resource development that will in turn create as-yet unknown impacts on ocean biological resources and human populations in the Arctic and elsewhere. All of this will occur in the face of rising pollution, and systematic shifts in the global climate. Unanticipated cumulative impacts from these activities are likely; they will confound predictions of system behaviour and will require a rapid adaptive-management capability.

In 20 years, the OTN will contribute to meeting these challenges by:

1) **Providing a reliable long-term global oceans perspective.** As the platform and database grow and improve, they will be of increasing value for informed decision-making and will be a necessary go-to source for end-users. The inclusion of Polar zones make this particularly important for polar countries, including Canada.

2) **Enhancing Canadian capacity for adaptive oceans management.** Canadian leadership of OTN means that observations will include areas of critical importance for Canada. Canadian leadership also means that we will train highly qualified personnel with a capacity to exploit the wealth of international OTN data.

3) **Making the infrastructure sustainable through a continued focus on becoming more efficient and cost-effective.** Many platforms originally intended for long-term environmental monitoring have been cancelled due to high costs. OTN will systematically work on developing novel cost-sharing agreements and on reducing operations and maintenance costs of our platform through avenues such as automation of data transfer to the data warehouse, and the use of autonomous vehicles to service OTN lines.

4) **Coping with more challenging scientific questions.** Improvements in tracking technology will enable new generations of scientists to address questions that have not been tractable previously, such as changes in ecosystem function caused by distributional shifts of animals resulting from global climate change, and unanticipated cumulative impacts.

5) **Ensuring faster and broader uptake of the data** generated by the platform. OTN will be built on principles of open access to the database and with an evolving suite of analytical and visualization tools. Progress in improving and downscaling oceanographic models will greatly extend OTN’s ability to link animal distributions and movements to environmental conditions. Evolution in electronic communications and OTN’s communication skills will result in rapid and effective transmission of knowledge to the end users.

6) **Becoming more flexible** as autonomous vehicles and bioprobes play an increasing role and extend OTN’s coverage and reach. A core principle of OTN is the continuous, adaptive and sophisticated evolution of OTN in response to shifting challenges and pressing needs.

7) **Expanding to assist the developing world.** Less developed areas will be facing a disproportionate share of the impacts of ocean development, and will have the least resources to devote to scientific support of decision-making. OTN will assist in meeting the needs of these countries, and since the ocean is a shared global resource, that work will have benefits for Canadians, and will also raise the profile of Canada and Canadian Science and Technology internationally.
Achieving the long-term vision will require continued Canadian leadership by OTN to expand the Canadian user community, push the technology to greater capabilities, broadly engage the international community through OTN’s science advisory structure and through international collaborations among Canadian and international scientists, strengthen linkages with policy users in Canada and worldwide, and ensure effective data management and access. This, in turn, will require core funding. OTN looks forward to working with CFI, NSERC, SSHRC and other funders to develop approaches to sustainability and continued leadership.

The Plan 2013-2018

The platform
OTN equipment can be positioned at specific locations to provide long-term monitoring of animal movements and oceanographic parameters yet can be rapidly and cost-effectively redeployed to meet changing needs. While in most instances, data from the equipment is retrieved at planned intervals, OTN is actively working with industry to develop mechanisms to provide real-time and near-real-time retrieval capabilities. This will open up new research opportunities, and could significantly increase management capabilities for valued marine living resources.

A critical deliverable for OTN is the deployment of its global network of tracking systems, which will leverage and complement deployments being made by international partners. The following charts provide an overview of existing and forecast OTN deployments in Canada and internationally. Management of these deployments is a key priority in 2013-2014.
Existing OTN Deployments – locations and sequencing of Canadian (red) and International (purple) lines

- Halifax
- Cabot Strait
- Antigonish
- Minas Basin
- Vancouver Fraser
- Resolute 1 (seasonal)
- Resolute 2
- Cumberland Sd (Pang.)
- Strait of Belle Isle
- Venus (Pacific)
- N Strait of Georgia
- Integration of POST infra

- Australia (Perth)
- Cape of Good Hope (SA)
- Azores (Portugal)
- Tasmania
- Strait of Gibraltar
- Hawaii
- Norway
- Puerto Rico

- First deployment
- NSERC award
- OTN Canada
- CFI IJVP
- First funding
- New Governance system implemented
Forecast OTN Deployments

Prince William Sound AK
Indian Ocean

Great Lakes Fishery (pool)
West Africa (Angola (pool))
Indian Ocean

Graves Harbour AK
Unimak Pass AK
Greenland
Mid Atlantic Bight
Bermuda
Chile
Antarctica
Mexico
Grey seals as bioprobes

Researchers from Dalhousie University, and the Department of Fisheries and Oceans have been tagging grey seals on Sable Island, Nova Scotia, with Vemco Mobile Transceivers (VMTs), a unique technology that acts both as a sonic tag for the seal, and also as a receiver to record any other tagged animal that the seals might encounter. The seals are also fitted with satellite positioning systems that let the researchers know where the seals are as they interact with other animals, turning the animal into a “bioprobe”. The seals have been encountering tagged cod, but have not been consuming them. Instead, both the cod and the seals seem to be drawn to “hotspots” in the ocean where productivity is high and where the high-fat prey species (capelin and sand lance) that they prefer congregate. This information is important as Canadian legislators are considering a controversial proposal to cull grey seals to try and boost the recovery of depleted cod populations. At present, the researchers need to get their VMT back from the seal to acquire its data. New work involving Vemco who manufactures the VMT and the Scottish Sea Mammal Research Unit is creating a way to feed the VMT data back to researchers via satellite, providing the information in near-real time. This will be a major technological advance.

The science and technology plan

The scientific context

Sustainable management of ocean resources will be required if we are to conserve the benefits that the oceans biological resources bring to us. Managers and decision makers will require a profound understanding of interconnected marine systems if they are to mitigate the potential for harmful human impacts. This can only be achieved by providing a strong scientific base to underpin management activities. In addition to food security through commercial fisheries, marine species are also the basis of recreational fishing and tourism industries (e.g. whale watching, shark diving) worth billions of dollars globally per year, and are important culturally for First Nations and other aboriginal peoples. Considering the importance of many of these species, surprisingly little is known about their migration patterns and habitat use, survival rates, and how they respond to changes in the ocean environment. Therefore a global monitoring network provides the scientific foundation for sustainable management.

The scientific objective of OTN is to better understand changing ocean dynamics and their impact on ocean ecosystems, animal ecology, and oceans resources, with the aim to address critical issues in resource management and implications for ocean governance. Ocean ecosystems are hugely varied, ranging from polar to tropical, and abyssal to pelagic. Species of interest may confine themselves to restricted local movements, or be highly migratory. Within this overarching, shared objective, the international corps of OTN scientists is working in all parts of the ocean, on a broad array of valued species with widely differing behaviour. The scientists are also focused on strategic science issues critical to their nations and regions. Thus the scale and scope of the research undertaken by OTN’s national and international partners and supported by the OTN platform will necessarily be tailored to meet the needs of the geographic areas in which the platform operates, and the species of interest. This is a great scientific strength, as the work of the network will provide a powerful opportunity to compare and contrast the responses of many different species from differing ecosystems to common stressors such as human exploitation and climate change. The comparative approach across many ecosystems provides the potential for a quantum leap in our understanding of ecosystem structure and function, which in turn will inform new management regimes predicated upon ecosystem-based approaches.

The conceptual framework

In order to achieve the aims of OTN, it is important to establish a conceptual framework of scientific questions necessary to strategically align the related research activities within that framework and to inform ocean governance. Details of the science planning process are outlined in Appendix 3. In the short-term (over the next five years), the research questions being addressed
across OTN will be broadly structured around three major integrated “framework questions” (FQ), under which projects will be organized and coordinated. Additional scientific activities will be structured under four major “cross-cutting activities” (CCA) (Table 2). CCAs are activities that cut across two or more FQs and/or projects and subprojects, which include methodologies and approaches that can inform the three framework questions. This overall organization ensures a conceptual understanding of how projects are interrelated, illustrates how best these can be integrated across countries and investigators to best address OTN’s mission, and allows rapid dissemination to interested parties of all individual research projects and programs.

- **Framework Question 1**: How do oceanographic and environmental features (both physical and biological) affect animal habitat use, movement and migrations?

The main objectives of this framework question and its associated projects are to understand valued or keystone species in ecosystems and species at risk, and how their movements change in relation to oceanographic features and variability. Many animals are dependent upon extensive movements through the ocean, ranging from simple drifting to annual migrations to reach highly productive sites for feeding (growth), reproduction and to reduce predation risk. Understanding movements and migrations—and the physical and biological conditions that drive them—is crucial to conservation, economic development, and prediction of how animal distribution patterns will alter with climate variability and change.

- **Framework Question 2**: How do species interactions and areas of ecological significance relate to habitat use, movement patterns, and biotic/abiotic features?

The primary aims of projects relating to FQ#2 are to expand knowledge of predator and prey distributions in time and space in relation to ocean characteristics and to test hypotheses concerning predator and other impacts on prey populations, including economically important commercial fish stocks.

- **Framework Question 3**: How do anthropogenic activities and development influence animal behaviour and ecology?

Research related to FQ#3 aims to better understand the direct and indirect effects of anthropogenic activities and infrastructure on animal populations and their movements, migrations and habitat use and survival, in the face of changing ocean environments. Many human activities impact marine animals and their movements, distribution and survival, both directly and indirectly. Examples include harvesting and discarding, and their impact on food webs and functional relationships, habitat alteration, aquaculture, pollution, ship traffic, advent of alternative power sources such as tidal power plants, and ocean acidification and climate changes including loss of sea ice.

- **Cross-cutting Activity 1**: Assimilating animal tracking data with coastal and offshore oceanographic models

Models of the three dimensional, time-varying oceans have a critical role to play in understanding the movement and distribution of marine animals, and also in projecting how they will change with a warming climate. Such models are used to fill in the gaps between geographically sparse ocean observations and also to extrapolate to locations and times (especially the future) for which observations are not available. Used in this way, models can transform the OTN’s point observations (e.g., detection of a fish crossing a line of acoustic receivers, measurement of temperature and salinity from a glider) into
products that can be used for practical applications such as ecosystem-based management and the setting of marine policy. This CCA spans different species, geographic regions and disciplines and leads to results that will impact management and policy.

- Cross-cutting Activity 2: Visualization and modeling of complex aquatic and marine observations

This activity addresses the rapidly growing and critical need for visualization and modeling tools that will allow us to deal effectively with OTN (and other) tracking data and with the ensuing large complex data sets that will arise as we begin to link oceanographic features with animal migrations and movements. The growing data warehouse that OTN has created to house and link tracking data across the globe will be useful here.

This cross-cutting activity will initially draw on the OTN’s international network of scientists from the USA, Australia and South Africa, where expertise currently exists. A new International Visualization and Modeling Team being developed within the Canadian OTN network (currently funded by NSERC) will form an important nexus for this activity. The visualization and modeling tools developed will be shared with the international tracking community. The vision is to eventually establish a distributed international Aquatic Animal Telemetry Centre of Excellence (AATCE, pronounced “At Sea”) and to build ever-increasing membership from the international OTN community.

- Cross-cutting Activity 3: Advancing animal tracking technology and tagging techniques

Although OTN already employs cutting-edge technology, it also uses the needs of its investigators to drive collaborative R & D into new technology and the innovative use of the technology to permit scientists to answer next-generation questions. Thus a key activity of OTN internationally, relevant to all FQs and CCAs, must be a continued focus on technological advances, refinement of techniques in animal tagging including the development of best practices for animal capture and tagging, receiver array placement, improvement of line efficiencies, and development of completely new products. Technology development will occur throughout the OTN programs, building on Canada’s technological leadership in this field and fostering international collaborations with industry and scientists.

- Cross-cutting Activity 4: Policy, stake holders and mechanisms for feeding into outreach and management; cooperation of natural and social scientists

The new knowledge generated by OTN researchers will inform a number of pressing legal and social issues. Additionally, the technological innovations have the potential to significantly change the ways local, national, and international management systems are implemented, and thereby to generate more effective and sustainable coastal and ocean governance. OTN findings will be articulated through publications of modelling tools that will be made available to fisheries managers and stakeholders and that will be informed by the work of those same people. One result of such information exchange will be harvest management “prescriptions” that are consistent with the logistic and regulatory constraints of fisheries. The objectives under this CCA are to examine the adequacy of existing laws, management policies, socioeconomic patterns, and harvesting practices for protecting marine species, with a particular emphasis on those that are at risk or are keystone species in their ecosystem. The ultimate intent is to suggest ways to weave a stronger, more successful protective net informed by increasing scientific information.
Table 2. The Ocean Tracking Network Scientific Research Framework Questions (FQ) and Cross Cutting Activities (CCA)²

<table>
<thead>
<tr>
<th>Cross-Cutting Activity (CCA)</th>
<th>FRAMEWORK 1: How do oceanographic &amp; environmental features (both physical &amp; biological) affect animal habitat use, movement &amp; migrations?</th>
<th>FRAMEWORK 2: How do aquatic species interactions &amp; areas of ecological significance relate to habitat use, movement patterns, &amp; biotic/abiotic features?</th>
<th>FRAMEWORK 3: How do anthropogenic activities &amp; development influence aquatic animal behaviour &amp; ecology?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Assimilating animal tracking data with coastal &amp; offshore oceanographic models</td>
<td></td>
<td></td>
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<tr>
<td>2: Visualization &amp; modeling of complex aquatic &amp; marine observations</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>3: Advancing animal tracking technology &amp; tagging techniques</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4: Policy, stake holders &amp; mechanisms for feeding into outreach &amp; management; cooperation of natural &amp; social scientists</td>
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</tbody>
</table>

² Associated with each project and subproject will be information about end users and national and international collaborators (e.g., academic, government, first nations, industry, other), activities related to international information exchange, and opportunities for exchange of highly qualified personnel (HQP).
Data acquisition, management and access

The OTN Data

The data generated by OTN includes the geographic positions for tagged animals at the times they are detected and additional information such as the animal’s depth or speed if the tag is fitted with specialized sensors necessary to measure these parameters. Tags can also carry environmental sensors that will report the temperature or salinity the animal is experiencing. Larger animals such as grey seals can be fitted with oceanographic monitoring instruments and specialized mobile transceivers that function both as a tag and a receiver (animals equipped this way are called “bioprobes”). Bioprobe animals typically cover large distances during their ocean movements, and are very good at finding areas of high ocean productivity where many species from different trophic levels will congregate to feed. Their instrumentation permits the acquisition of a wealth of information on oceanographic conditions, especially from deep diving animals, as well as providing the opportunity to record interactions among different species of tagged animals.

OTN also deploys benthic pods and Slocum electric gliders for oceanographic sampling. These instruments record temperature, salinity, conductivity, oxygen and depth. The gliders carry an additional optical sensor package that permits investigators to estimate the primary productivity of the ocean. Gliders can also be fitted with acoustic receivers to become mobile detection platforms for tagged animals.

All data are securely stored (see below), and used to generate products for end users.

OTN data principles

OTN will make all its data publically available, free of charge. Oceanographic data is quality controlled prior to being posted to National Ocean Data Centres. Under current OTN policy, public access to some animal tracking data may be delayed for up to two years in order to protect potentially endangered animals and to permit graduate students working on OTN projects to successfully complete their thesis work. This policy is expected to evolve to be congruent with new data-accessibility standards currently being developed for publically-funded research projects in Canada.

Data challenges

A first priority for an international project sharing data from many partners is to create standardized formats for data storage. OTN oceanographic data is formatted for National Ocean Data Centres, and its data team has been instrumental on the international scene in developing standardized formats for tracking data. Work on these standardized formats for tracking data is ongoing.

The knowledge required for quality assurance and quality control of OTN data lies in the geographic areas where the data is collected. Thus we envisage the creation of regional nodes where the data is stored, with the OTN Data Centre providing links and tools to fetch and analyze regional data. In some instances (Australia, USA), regional nodes are already operational. In others (e.g., South Africa and the Indian Ocean), the nodes will have to be developed. The OTN will provide model nodes and expertise to our partners who do not yet have the necessary data capacity.
OTN data flows from a broad array of international partners, and these partners may have different, legally enshrined, data access policies than those towards which Canada is evolving. OTN will have to negotiate agreements with international partners to deal with data conflicts.

The OTN Data Centre

An essential component of the OTN platform is the Data Centre (DC) which:
- develops and implements the data and metadata policies for OTN platform users;
- manages interactions with other related, large-scale marine data systems and the regional nodes of OTN;
- achieves inter-operability with other international and Canadian data centers and among diverse marine databases;
- ensures the reliability of data acquisition and the effectiveness of data archiving, security and storage provisions;
- provides efficient and effective means of access to quality-assured data and metadata, with appropriate documentation support.

In addition, the Data Centre works closely with field and research scientists to identify and meet user needs for new and enhanced techniques for data visualization and analysis.

Details on the links of the OTN Data Centre to other large databases, and on OTN data policy, are available in Appendix 4.
Measuring the OTN

This Strategic Plan uses the following logic model framework to link to the higher level strategic goals with the more detailed operational plans necessary to achieve those goals. In addition to identifying the key components and linkages between inputs, activities, outputs, outcomes, and impacts it provides a framework for monitoring and evaluating the performance of the platform and the science it sustains. Inevitably, the interplay of inputs, activities, outputs and outcomes are more interdependent and time dependent than can be represented on a simple two-dimensional diagram; however, this is a useful construct for clarifying the key elements of the management plan.

Inputs are the assets that OTN has at its disposal by virtue of the CFI, NSERC, SSHRC and partners support and the established national and international partnerships. They will evolve over time.

Activities are the operations of OTN which draw upon its assets to produce outputs and outcomes. Some will be constant over time; some will evolve according to the research opportunities and partner interests.

Outputs are the direct result of the activities of OTN – e.g., what the platform personnel and its functionalities are expected to achieve through their activities.

Outcomes are the results enabled by the knowledge created by the platform.

Impacts are the Canadian and global benefits deriving from the existence of the platform.
## Figure 2 – The OTN Logic Model

<table>
<thead>
<tr>
<th>Impacts: Canadian and global benefits from OTN</th>
<th>Knowledge benefits:</th>
<th>Economic benefits:</th>
<th>Social benefits:</th>
<th>Environmental benefits:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Better understanding of aquatic species and their management in a changing climate</td>
<td>- Sustainable revenues from living aquatic resources</td>
<td>- Sustainability of coastal communities</td>
<td>- Conservation of living aquatic resources</td>
</tr>
<tr>
<td></td>
<td>- Canadian global leadership in acoustic telemetry</td>
<td>- Enhanced global presence of the Canadian technology stronghold in acoustic telemetry</td>
<td>- Better public safety in marine environment</td>
<td>- Better understanding of aquatic ecosystem processes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Canadian developed technology becoming the international standard in the commercial market for ocean sampling</td>
<td>- Better knowledge of and capability to adapt to effects of climate change</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- Support of Canadian sovereignty in the Arctic</td>
<td></td>
</tr>
<tr>
<td>Outcome: Results by others enabled by OTN</td>
<td>Scientific:</td>
<td>HOP:</td>
<td>Industrial:</td>
<td>Reputation:</td>
</tr>
<tr>
<td></td>
<td>- Excellent science</td>
<td>- Increased numbers and quality of ocean-telemetry professionals</td>
<td>- New technology development by Canadian industry</td>
<td>- National and international support for OTN activities and upgrades into the future</td>
</tr>
<tr>
<td></td>
<td>- International scientific leadership</td>
<td>- Skills and international experience of HOP valued by employers</td>
<td>- Expanded global markets, jobs, revenues in Canadian industry involved in acoustic telemetry design and manufacture</td>
<td>- Recognition of Canadian stewardship of its marine resources</td>
</tr>
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<td></td>
<td>- Game-changing discoveries</td>
<td></td>
<td></td>
<td>- Transformed ocean conservation and fisheries management practices</td>
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<td></td>
<td>- Advances in knowledge</td>
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</tr>
<tr>
<td></td>
<td>- Global networks of collaborating research teams</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outputs: Produced by OTN through activities using inputs and that in turn enable outcomes</td>
<td>Infrastructure, data and services:</td>
<td>Expertise:</td>
<td>Empowered users and stakeholders:</td>
<td>Reputation:</td>
</tr>
<tr>
<td></td>
<td>- Largest acoustic telemetry network in the world</td>
<td>- To install and operate an integrated global monitoring system &amp; global ocean observing system</td>
<td>- Unique and specialized staff and infrastructure</td>
<td>- The OTN establishes its “brand” as the pre- eminent global source of data and technology for understanding the migratory behaviour of marine animals and the impacts of physical, biological and chemical changes in their marine environment</td>
</tr>
<tr>
<td></td>
<td>- Interoperable subsea receivers deployed globally</td>
<td>- Innovative use of existing technology and innovation in new technologies supporting conservation and sustainable use of ocean biological resources</td>
<td>- Identification of research questions that trigger new technology development by industrial partners</td>
<td>- Confidence and respect for the effectiveness, governance, management, data management and quality work within OTN</td>
</tr>
<tr>
<td></td>
<td>- Trusted, relevant, high-quality knowledge products, data and metadata</td>
<td>- To catalyze the formation of international science teams to use/expand the infrastructure to address big science questions</td>
<td>- Access to highly relevant, timely global data and information that is not available through other means</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Fast and reliable internet data delivery system.</td>
<td></td>
<td>- OTN enabled global linkages among researchers and between researchers and other stakeholders</td>
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<tr>
<td></td>
<td>- Support to partners preparing grant proposals and facilities upgrades</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activities: What OTN does</td>
<td>Operations:</td>
<td>Marketing and public relations:</td>
<td>User/Community relations:</td>
<td>Management:</td>
</tr>
<tr>
<td></td>
<td>- Implement and manage a reliable yet flexible global ocean observation system, to meet present and adapt to future needs</td>
<td>- Provide beta-testing capabilities for new products</td>
<td>- Convene meetings of research users – national and international partners’ communication and community relations efforts</td>
<td>- Ensure an efficient, professional and productive organization (e.g., through planning, financial management, monitoring, reporting)</td>
</tr>
<tr>
<td></td>
<td>- Trigger the development of new technology to meet network and global needs</td>
<td>- Identify new opportunities for Canadian industry</td>
<td>- Support international partners’ communication and community relations efforts</td>
<td>- Support a world class OTN governance system that engages the international community</td>
</tr>
<tr>
<td></td>
<td>- Manage a world class IT system - data archive, preservation, repository and access system</td>
<td>- Link Canadian partners with international collaborators (industrial and scientific opportunities)</td>
<td>- Create/exploit opportunities to recruit/involve researchers, students, industry and the public</td>
<td>- Engage in fund-raising</td>
</tr>
<tr>
<td></td>
<td>- Develop data analysis and visualization tools</td>
<td>- Outreach to and engagement of end users, and the public, nationally and internationally, on the outcomes of OTN enabled research and its implications</td>
<td>- Catalyze collaborative Canadian- international efforts using the OTN platform to address important science questions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Provide first-class support to users of the network</td>
<td></td>
<td>- Serve as a hub for interactions among researchers, end-users and the public on relevant ocean, ocean management and ocean industry issues</td>
<td></td>
</tr>
<tr>
<td>Inputs: Materials and resources OTN has to build with</td>
<td>Relationships:</td>
<td>Core HOP:</td>
<td>Governance:</td>
<td>OTN infrastructure:</td>
</tr>
<tr>
<td></td>
<td>- Canadian OTN network.</td>
<td>- OTN management, operations and IT staff (funded by CFI, NSERC, and Dalhousie)</td>
<td>- Newly restructured OTN Council and ISAC</td>
<td>- Fixed (sensors) and mobile (gliders, vessels, bioprobes) equipment, with a global distribution</td>
</tr>
<tr>
<td></td>
<td>- International network of scientific collaborators</td>
<td>- Professional expertise accessed through Dalhousie, including PR capacity</td>
<td>- Dalhousie oversight</td>
<td>- IT infrastructure for data storage, data product generation, and internet delivery capacity</td>
</tr>
<tr>
<td></td>
<td>- Canadian partners from government and industry</td>
<td></td>
<td></td>
<td>- PR capabilities</td>
</tr>
</tbody>
</table>
Measures of success: the science and technology development plan

Metrics for the success of the science plan will include:

**Science metrics**
- Number of international and strategic scientific collaboration arrangements
- Creation of an internationally integrated global tracking collaboration
- Number of national and international scientists using the platform
- Number of animals and species being tagged
- Number of scientific papers, reports, and presentations produced
- Number of HQP being trained
- Number of HQP exchanged among international laboratories
- Number of citations of OTN data and data products

**Platform usage and capacity metrics**
- Retrieval of the tracking and oceanographic data from the platform
- Growth in the global receiver coverage accessible to the scientific community. The end goal is creation of continental scale telemetry arrays for each continent.
- Number of adjustments of the platform dictated by new challenges and designed to enhance strategic science capabilities
- Growth in the number of data records accessible via the OTN database
- Number of analysis and visualization tools developed
- Number of new technologies introduced

**Profile metrics**
Number of web hits
- Number of media reports (national and international) on OTN research results
- Number of meetings with officials involved in oceans policy development
- Number of community stakeholder meetings
- Number of white papers and briefing documents provided

**Outcomes**

The primary outcome of OTN is the generation of knowledge that leads to well-informed, effective, relevant and innovative oceans resource management policy and practice, both nationally and internationally. This requires measurement of human behaviour patterns, and such metrics will be both quantitative and qualitative in nature. Metrics for the outcome could include:

- Direct consultations with end-user groups, to identify short- and long-term concerns to be addressed and to develop confidence in the process and results of telemetry;
- A raised knowledge base among all stakeholder groups participating in management and policy issues;
- Creation of participatory management regimes involving broad stakeholder groups brought together by the knowledge provided by the OTN platform;
Acceptance in coastal communities of the necessity for unpalatable restrictions on current activities based on the information provided from the platform;

Creation of “mobile” marine protected areas that track inter-annual variations in target species distributions.

Objectives and strategies
This Strategic Plan articulates ambitious goals designed to realize return on the federal investment in OTN. With the platform migrating from the implementation to the operational phase over the next three years, managing the remainder of the first phase deployment, together with the evolution to an operating platform presents a management challenge. It requires a portfolio of activities focused on catalyzing effective use of the research platform, growing international science collaborations, enhancing commercial opportunities, interfacing with GOOS, and ongoing interactions with end-users, including translation of research outcomes. To ensure effective management of all aspects of these challenges, three strategic goals have been established:

- Enabling research excellence
- Deriving benefits for Canada
- Enabling international benefits

Under each strategic goal, sub-objectives have been identified to define what aspects of the OTN activities would support the overarching goal. The “Management Priorities” articulate the actions required to achieve the goals and sub-objectives (the “how”). A separate Management Plan lays out the specific set of management actions that are being implemented or planned to deliver on the priorities, the time line and responsible parties, as well as the measures that will be used to assess performance against these objectives. This framework will be used to report on progress and issues arising at each meeting of the OTN Council.

The following table provides an overview of the macro and meso level priorities.
## Strategic Goals and Sub-objectives
*(What — macro level)*

### Management Priorities
*(How — meso level)*

### Enabling research excellence

<table>
<thead>
<tr>
<th>The type of research</th>
<th>Management Priorities</th>
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<tbody>
<tr>
<td>Enable world-class research</td>
<td>Develop and sustain a robust and integrated, global monitoring platform using Canadian- led technology implemented across five oceans and seven continents</td>
</tr>
<tr>
<td>Promote and support innovative and integrative global-scale research initiatives</td>
<td>Design and sustain the OTN platform for long-term monitoring, to address fundamental questions related to climate change</td>
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</table>

### How research is done

<table>
<thead>
<tr>
<th>The research training environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivate interactions among different discipline communities dealing with marine issues (including the social sciences and humanities)</td>
</tr>
<tr>
<td>Expand Canadian engagement in international oceans consortia and collaborations</td>
</tr>
<tr>
<td>Foster the translation of discovery to application, policy and governance</td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance research training opportunities, especially in the use of acoustic telemetry and analysis of animal tracking data</td>
<td></td>
</tr>
<tr>
<td>Expand international interactions and exchange between research institutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop and implement the use of new tools needed to mine the database.</td>
<td></td>
</tr>
<tr>
<td>Enhance, empower and support the user community and its global inter-sectoral integration</td>
<td></td>
</tr>
<tr>
<td>Establish effective communications and outreach capabilities to assist end users with data uptakes and attract new users to the platform</td>
<td></td>
</tr>
<tr>
<td>Recruit and retain highly qualified personnel; Inspire and support research trainees</td>
<td></td>
</tr>
<tr>
<td>Pursue and secure sustained funding and other essential resources</td>
<td></td>
</tr>
<tr>
<td>Strategic Goals and Sub-objectives (What — macro level)</td>
<td>Management Priorities (How — meso level)</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td><strong>Deriving benefits for Canada</strong></td>
<td><strong>Public policy</strong></td>
</tr>
<tr>
<td>• Provide new tools that enable the transformation of conservation and fisheries management practices in Canada</td>
<td>• Promote, enhance and support the use of OTN data and research results for management and Canadian public policy development</td>
</tr>
<tr>
<td>• Promote Canadian sovereignty in the Arctic</td>
<td>• Ensure access to time-series data on global and national movements and survival of marine animals, and data on how these are related to environmental conditions</td>
</tr>
<tr>
<td>• Enable Canadian adaptation to climate change and its effects on the deep ocean and coastal regions</td>
<td>• Foster international collaboration for Canadian researchers, institutions and partner organizations</td>
</tr>
<tr>
<td>• Enable Canada to take the lead in managing its Exclusive Economic Zones</td>
<td>• Attract and engage private sector partners, facilitating their access to front-line research to enable continued evolution of their products and services</td>
</tr>
<tr>
<td>• Inform the application of three key pieces of federal legislation — the Oceans Act, the Fisheries Act and the Species at Risk Act —and DFOs strategic priorities</td>
<td>• Champion the continued development and use of Canadian oceans monitoring technologies</td>
</tr>
<tr>
<td>• Inform a longer term strategic marine research agenda for Canada</td>
<td>• Promote the use of OTN-supported research data and findings in products and activities that engage educators and the public</td>
</tr>
<tr>
<td>• Foster the sustainability of coastal communities</td>
<td>• Establish effective communications and outreach capabilities</td>
</tr>
<tr>
<td><strong>Industrial competitiveness</strong></td>
<td><strong>International profile</strong></td>
</tr>
<tr>
<td>• Position Canadian industry to retain and grow its capacity to design, build and supply advanced technology for application in the oceans environment</td>
<td>• Augment international recognition for Canadian capabilities in oceans research and technology development</td>
</tr>
<tr>
<td>• Enable private sector leadership in next generation acoustic telemetry and related technologies</td>
<td><strong>Public engagement</strong></td>
</tr>
<tr>
<td>• Enable Canadian technology to be the global industrial standard</td>
<td>• Inform, excite and engage educators and the public</td>
</tr>
<tr>
<td><strong>Public engagement</strong></td>
<td><strong>Public policy</strong></td>
</tr>
<tr>
<td>• Inform, excite and engage educators and the public</td>
<td>• Provide new tools that enable the transformation of conservation and fisheries management practices in Canada</td>
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<td></td>
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<td>• Enable Canadian adaptation to climate change and its effects on the deep ocean and coastal regions</td>
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<td></td>
<td>• Enable Canada to take the lead in managing its Exclusive Economic Zones</td>
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<td></td>
<td>• Inform the application of three key pieces of federal legislation — the Oceans Act, the Fisheries Act and the Species at Risk Act —and DFOs strategic priorities</td>
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<td></td>
<td>• Inform a longer term strategic marine research agenda for Canada</td>
</tr>
<tr>
<td></td>
<td>• Foster the sustainability of coastal communities</td>
</tr>
</tbody>
</table>
### Strategic Goals and Sub-objectives (What — macro level)

**Understanding**
- Revolutionize the way oceans are viewed and understood

**Capacity**
- Make the platform and the research it sustains an integral and permanent contributor to the international Global Ocean Observing System.
- Broaden and deepen the extent of international collaborations on marine animal migration, distribution and survival.

**Application**
- Underpin a paradigm shift in conservation and sustainable management of marine living resources.
- Enable international partners to address pressing management and policy needs in their regions.

### Management Priorities (How — meso level)

- Catalyze international/global research collaborations utilizing acoustic telemetry and related technologies in the ocean environment.
- Coordinate international science teams to work on common problems, leading to development of a toolbox of innovative approaches to address the problems.
- Creation of a seamlessly interchangeable global ocean observing system for animal movements, capable of documenting regional-to-global displacements of valued marine animals in the global oceans commons, to address the need for international collaboration in marine conservation
- Ensure breath and ease of access to the OTN data warehouse.
- Promote international exchange of user-friendly tools for mining the data and visualizing significant relationships.
- Participate actively in GOOS and other international forums.
- Assist with the development of region-specific international science plans.
- Outreach to potential government users of OTN data in other regions.

**Enabling international benefits**

OTN has carried out a risk analysis that identifies the major risks inherent in its operations and science activities, and the mitigation strategies in place or required. This is a component of the Management Plan.
Organization and management

Governance
The OTN governance structure ensures effective stewardship of the platform and oversight of the research it supports. The OTN Council governs OTN. It is an international group of 12 people with diverse skills and talents in: management of large platforms and databanks, public policy, private sector innovation, governance and management, societal perspectives, and international experience. Reporting to the OTN Council, the OTN International Science Advisory Committee (ISAC) provides independent advice on opportunities for international collaboration, the direction of the research sustained by OTN and the evolution of the platform. The Science Advisory Committee (SAC) is mandated to provide oversight to the NSERC-supported OTN Strategic Network activities and has cross membership with the ISAC. While not formally mandated to report to the OTN Council, the Council is regularly briefed on SAC activities. The Deployment Committee provides expert reviews of proposals for new infrastructure deployments, or for changes to previously approved deployments. The ISAC is informed of Deployment Committee activities, and the Deployment Committee formulates recommendations to the Council for Council votes on whether or not to approve proposed deployments or changes to deployments. The Governance and Policy Committee is presently in development and will be a committee of the Council. It is intended to draft policy for OTN in areas not covered by existing Dalhousie University Policies, and to assist with identifying potential candidates to serve the OTN in various capacities. Ongoing communications with Dalhousie University are managed through routine meetings to ensure any interface issues are addressed without delay.
**Corporate structure**
The Executive Team involves the OTN Executive Director who leads the platform component, the Scientific Director who leads the science component and the Senior Project Manager who oversees all operational activities and financial transactions. For efficiency and effectiveness, the personnel associated with OTN function as an integrated team. They support various committees such as the Deployment Committee, the Data Management Committee and the Governance and Policy Committee.
The partnership structure

OTN relies on a diversity of partnerships and collaborations to achieve the ambitious scientific and technical goals articulated for the international platform and the research it sustains. Those partnerships and collaborations are intended to be dynamic, rather than static, and fall primarily into the following categories:

1. Core OTN Platform Partnerships
   - Groups that are deploying CFI-funded receivers. These require formal agreements to ensure effective stewardship and exploitation of the core platform equipment.

2. Extended OTN Platform Collaborations
   - Groups that have deployed monitoring systems supported from sources other than the CFI-funded equipment pool, but are willing to coordinate their deployments with those of other investigators to create interoperable regional-to-continental scale arrays.

3. OTN Technology Partnerships
   - Canadian firms that design and manufacture data receivers, tags, and other technology used in the OTN platform (including gliders)

4. OTN Data Partnerships
   - International ocean monitoring projects generating data, and providing innovative analytic capabilities that enhance the value of the OTN data warehouse and its services
   - Organizations that curate, manage, archive and house data on behalf of OTN

5. OTN Research Collaborations
   - Researchers and research groups that mount projects utilizing the core and extended OTN platform, including the data housed and managed in the data warehouse
   - Researchers and research groups translating the scientific outcomes into insights for marine resource management frameworks, policy and practice

6. OTN End User Collaborations
   - Users of the outputs and outcomes of research carried out on the OTN platform

The Management Plan provides details of the partnership characteristics, considerations and criteria for selection, strategies and governance.

Technology transfer and knowledge translation

In addition to an enhanced international profile for Canadian capabilities in oceans science and technology, OTN has identified three key receptors for the outcomes of its research and platform development activities:

- Public policy and resource management structures
- Industrial competitiveness
- Public engagement

For each, there are targeted but interrelated outreach strategies.
**Public policy**

OTN activities will inform new policy development relating to conservation and fisheries management at federal, provincial and international levels, and foster the implementation of new technologies that will enable more efficient and cost effective conservation and fisheries management regimes through the monitoring of animal species prevalence, migration and response to environmental variables. This will be done through:

- engagement of senior policy officials in the governance structure of OTN;
- regular newsletters and communications with government officials on international science outcomes and Canadian technology developments;
- provision of results from OTN scientific investigations of relevance to policy and management decisions;
- specific policy workshops involving government agencies;
- policy briefs addressing priority ocean policy issues (and framed by both fisheries priorities and Canada’s international oceans commitments);
- demonstration of new technologies;
- providing Canadian international leadership in the global use of acoustic animal telemetry.

**Industrial competitiveness**

OTN is committed to working with its prime Canadian partner VEMCO and other Canadian ocean technology firms to grow their capacity to design build and supply advanced technology for application in the oceans environment. This will be done through:

- providing access to the technology requirements of world-class research, thereby informing new product development;
- purchasing prototypes of new equipment models for beta validations;
- testing new receivers and other equipment on OTN deployments;
- identifying new opportunities for deployment of Canadian acoustic telemetry equipment;
- assisting industrial partners with trade shows;
- fostering commercialization of innovations and applications developed through the OTN researchers and/or the Data Management Centre;
- providing Canadian leadership in the applications of acoustic telemetry, thereby enhancing the world product market and positioning Canadian technology as the global standard.

**Public engagement**

Data and scientific insights from research using the OTN platform has already generated increased public interest in oceans and their sustainable management and has the potential to ignite an interest in STEM education and careers in Canadian youth. OTN will pursue public engagement through:

- an interactive educational component of the OTN website;
- assisting with or developing learning materials for use in museums, schools, and the general public;
- providing OTN speakers to public venues;
- frequent release of news stories;
- interaction with local, national and international media (print, radio, TV, and www) to ensure pick-up and media coverage of OTN research outcomes and technology developments;
- social media.
The Halifax Marine Research Institute (HMRI)

The HMRI exists to foster partnerships among industry and researchers in the ocean sector for the commercialization of discoveries and the development of technology. The HMRI offers a window to the OTN to deliver its results and promote itself to the ocean technology sector.

While not a formal component of the OTN governance and management system, there is a plan to integrate various Dalhousie University-led oceans initiatives under a larger umbrella of the Halifax Marine Research Institute (HMRI). This will also entail the co-location of the offices of OTN with HMRI and the recently announced Marine Environmental Observation Prediction and Response Network (MEOPAR ) Network of Centre of Excellence led by Doug Wallace, Canada Excellence Research Chair, in the new Dalhousie Ocean Sciences Building to be completed in Spring 2013. This clustering of expertise and converging interests will catalyze increased operational and research synergies, and enable cross-training of technical staff and efficiencies of operation.

Financial sustainability considerations

OTN has been launched with infrastructure support from CFI, and NSERC research support for Canadian investigators participating in the network. Future support from these agencies will depend upon OTN meeting its objectives throughout the durations of these awards, and also upon attracting new sources of support.

The OTN is committed to maintaining its current sources of funding and securing new and diversified sources for future cycles of the OTN. The OTN’s approaches over the first cycle’s duration vary depending on the nature of the partner and whether they are international or Canadian.

With respect to international collaborators who have agreed to provide funding to deploy, operate and maintain OTN equipment in return for the loan of the equipment, a formal Collaboration Agreement outlining the time frame and amount of operation and maintenance resources (O&M) that will be provided is signed prior to the shipping of the equipment to the Deployment Collaborator. These Collaborators in turn use the provision of the OTN equipment to leverage funding from various funding sources for the O&M of the international lines, and to purchase tags for target species they wish to follow.

For Canadian deployments, the CFI-IJVF OTN Award included partial operation and maintenance funding up to 2015-2016. The amount allocated among sites varied according to the number of receivers that were to be deployed and the number of years that the deployment would be operational. However, the funding budgeted for the Canadian lines does not meet all of the operation and maintenance needs of the Canadian collaborators. These collaborators have used the OTN O&M funding to leverage additional O&M services from a variety of partners. This support is quantified on an annual basis, and during the first year of operation (2010 – 2011) of OTN Canada totalled more than $800,000. Similar contributions are expected in the future.
In order to secure new and diversified sources of funding, the OTN will assist its partners in their applications for research and O&M support, as well as seeking funding itself. A key activity will be to use communications capabilities to inform government, the scientific community, corporations and the public of the capacities of the OTN infrastructure, its utility for marine conservation and policy development, and to demonstrate the scientific and socio-economic benefits of supporting the infrastructure. The new ISAC and council will undoubtedly provide the OTN with a clear understanding of end users’ needs, enabling constructive knowledge exchange and interface.

These communications will include: peer-reviewed scientific publications and scientific technical reports as well as presentations at relevant national and international conferences. We will also produce broad-interest publications and presentations generally aimed at raising awareness of the OTN capabilities in the general public, government and industry, and targeted publications and meetings specifically designed to bring new collaborators and funders into the network.
Appendices

Appendix 1. Acronyms

AATAMS – Australian Animal Tagging and Monitoring System
AATCE – Aquatic Animal Telemetry Centre for Excellence
AVs – Autonomous Vehicles
AZMP – Atlantic Zonal Monitoring Program
CCA – Cross-Cutting Activities
CFI – Canadian Foundation for Innovation
CMEP – Centre for Marine Environmental Prediction
DC – Data Centre
DFO – Department of Fisheries and Oceans Canada
FAO – Food and Agricultural Organization
FQ – Framework Questions
GOOS – Global Ocean Observing System
HMRI – Halifax Marine Research Institute
HQP – Highly Qualified People
IJVF – International Joint Venture Fund
IMOS – Integrated Marine Observing System
ISAC – International Scientific Advisory Committee
MEOPAR – Marine Environmental Observation Prediction and Response Network
NERACOOS – North East Region Association of Coastal and Ocean Observing Systems
NSERC – National Sciences and Engineering Research Council of Canada
O&M – Operation and Maintenance
OBIS – Oceanographic Biogeographic Information Service
OECD – Organization for Economic Co-Operation and Development
OTN – Ocean Tracking Network
POST – Pacific Ocean Shelf Tracking
PST – Pacific Salmon Treaty
SAC – Scientific Advisory Committee
SMEs – Small and Medium Enterprises
SNG – Strategic Network Grant
SSHRC – Social Sciences and Humanities Research Council of Canada
STEM – Science, Technology, Engineering, and Mathematics
TOPP – Tracking of Pacific Predators
UNFSA – United Nations Fish Stocks Agreement
Appendix 2. OTN Partners and Deployments

Partner institutions of the OTN, listed by country. The number of receivers deployed represents the current total of active deployments. Projects utilizing some OTN receivers are highlighted. The number of tags deployed represents the total number of tags deployed since start of the project(s). *Estimated by VEMCO (Denise King, pers. comm.)*

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Number of Projects</th>
<th>Number of Receivers Deployed</th>
<th>Number of Tags Deployed</th>
</tr>
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<tbody>
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<td>USA</td>
<td>Barrow Arctic Science Consortium</td>
<td>1</td>
<td>26</td>
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</tr>
<tr>
<td></td>
<td>Delaware State University</td>
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<td>NA</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Great Lakes Fisheries Commission</td>
<td>1</td>
<td>99</td>
<td>698</td>
</tr>
<tr>
<td></td>
<td>Maine Dept. of Marine Resources</td>
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<td>30</td>
</tr>
<tr>
<td></td>
<td>NOAA, NMFS, Northeast Fisheries Science Center</td>
<td>2</td>
<td>7</td>
<td>920</td>
</tr>
<tr>
<td></td>
<td>Pacific Islands Ocean Observing System</td>
<td>1</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>POST</td>
<td>37</td>
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</tr>
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<td></td>
<td>Stanford University</td>
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<td></td>
<td>US Geological Survey</td>
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<td>NA</td>
<td>1974</td>
</tr>
<tr>
<td></td>
<td>Total USA</td>
<td>46</td>
<td>187</td>
<td>10669</td>
</tr>
<tr>
<td></td>
<td>Total OTN Partners</td>
<td>135</td>
<td>1212</td>
<td>28487</td>
</tr>
<tr>
<td></td>
<td>Total VEMCO Receivers Deployed Globally</td>
<td>20,000†</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 3. Strategic review of science directions and the science planning process

Science planning — assessing and shaping the directions of the research sustained by the OTN platform — is carried out in an ongoing manner involving all Canadian projects associated with OTN Canada and all international partners that have lines deployed. It is carried out more formally at five-year intervals, with the ISAC playing a central role.

Ongoing

Working in the context of the overarching framework research questions outlined in Section I and the vision, mission and values for OTN, the ISAC reviews all annual reports from existing non-Canadian deployments and sets standards for proposals for new deployments with a view to ascertaining:

- the extent to which the research is driven by one or more of the OTN framework questions or cross-cutting activities;
- how the proposed or ongoing research and deployment contributes to the larger OTN goals;
- the expertise and research credentials of the deployment and research teams (especially for new initiatives). See the later section on the partnership structure and strategy;
- the extent and adequacy of collaboration with Canadian researchers;
- how effectively HQP is involved;
- the adequacy of plans for, or implementation of, research dissemination, translation of discovery to application and engagement with a wider public.

The ISAC will also receive reports on the OTN Canada SAC discussions. This ongoing oversight role equips the ISAC with the wherewithal to identify particular opportunities for new collaborations and deployments and priority directions for the evolution of the OTN platform driven by priorities for OTN research.

At Five-year Intervals

In order to maintain the scientific strength and dynamism of OTN, there will be a formal review and long-term planning process undertaken in 2017 and at five-year intervals thereafter.

Questions at five-year science planning points:

- What have we learned from the research program?
- What are the implications of the research outputs for policy and governance?
- Are our framework questions still robust and appropriate for the next five years or have they changed and if so with what result?
- What are the pressing questions globally?
- Are there certain target areas that require more intensity of study (for example the Arctic)?
For 2017 the review process will involve:

- **Retrospective assessment** – external peer review of the outputs, outcomes and impacts of the research sustained by OTN – Canadian and international. The source material for this external review will be: i) the wrap-up report from OTN Canada; and ii) the most recent reports from the international partners. OTN will request that the reports submitted at this time describe the overall portfolio of outputs and outcomes since the launch of the OTN lines, including citation and impact data. The External Peer Review Committee will report to the ISAC, which will integrate this evaluation with recommendations from the prospective assessments (see below) in formulating recommendations for revision of the science and strategic plans.

- **Prospective assessments** - prior to the ISAC review meeting, OTN will solicit short “Concept Papers” that focus on what changes might be required in the evolution of the OTN platform in the context of “big questions” facing the research and policy-user communities.

The ISAC will recommend to the OTN Council future opportunities and directions for OTN, integrating the retrospective and prospective assessments. This process is shown schematically in the following diagram.

**The 2017 Science Planning Process**
Appendix 4: Links to Global Databases and OTN Data Policy

The key principles underpinning the work of the Data Centre are that the data must be:
1. **Authoritative** – locations and organisms are described using unambiguous and reliable names and hierarchical classifications;
2. **Discoverable** – project and data descriptions are comprehensive and listed in searchable online catalogue (metadata) systems;
3. **Geo-referenced** – observation data are downloadable via geo-referenced ocean information systems on marine species and their environments;
4. **Inter-operable** – data are capable of being visualized and analyzed using a wide variety of software and hardware configurations;
5. **Accessible** – data are openly accessible to the international research community, subject to the provisions in the data access policy;
6. **Secure** – data are protected against loss resulting from human error, natural disaster, technical obsolescence, or other causes.

Among the international projects and databases that the Data Centre interacts with are:
- Ocean Biogeographic Information System (OBIS)
- Tracking of Pacific Predators (TOPP)
- Centre for Marine Environmental Prediction (CMEP)
- Pacific Ocean Shelf Tracking Project (this database is now fully hosted by OTN)

OTN’s website ([www.oceantrackingnetwork.org](http://www.oceantrackingnetwork.org)) is indexed via commercial search engines such as Google ([www.google.ca](http://www.google.ca)) and integrated with existing open standards-based systems and facilities. All OTN data will be centrally stored at International Oceanographic Commission ([ioc.unesco.org](http://ioc.unesco.org)) recognized national facilities such as the Canadian Marine Environmental Data Services ([www.meds-sdmm.dfo-mpo.gc.ca/meds](http://www.meds-sdmm.dfo-mpo.gc.ca/meds)) and the Bedford Institute of Oceanography ([www.bio.gc.ca](http://www.bio.gc.ca)). End usage and public download services are conducted via global access portals such as the Ocean Biogeographic Information System ([www.iobis.org](http://www.iobis.org)) and the Global Biodiversity Information Facility ([www.gbif.org](http://www.gbif.org)). The Species 2000 ([www.sp2000.org](http://www.sp2000.org)) and Integrated Taxonomic Information System ([www.cbif.gc.ca](http://www.cbif.gc.ca)) are being used to control species names and taxonomic hierarchies; the Canadian Geospatial Data Initiative ([www.geoconnections.org](http://www.geoconnections.org)) and Global Change Master Directory ([www.gcmd.nasa.gov](http://www.gcmd.nasa.gov)) are being used to provide metadata services. The Open Geospatial Consortium ([www.opengeospatial.org](http://www.opengeospatial.org)) specification provides the basis for interoperability.

**The data access policy**

OTN provides free and generally open public access to all discovery, deployment and release metadata and detection data. Present limitations to the open access policy are:
- Identification of tags where the OTN DC has received manufacturers’ and trackers’ metadata will be subjected to a 2-year renewable embargo (release date + life of tag + 2 years). This is intended to give the originator of the data sufficient time to complete his or her analysis and publish the resulting scientific work, and is regarded by the scientific community as necessary to protect the thesis work of highly qualified people (HQP) in training.
- Full release metadata and IDs of tags where the OTN project coordinator has received proof of an official scientific license permitting the tagging of endangered species will be subjected to a 10-year renewable embargo. This is intended to provide reasonable protection to the endangered species.
Investigators may through written notice waive some or all of the limitations applied to their data. They are also free to provide the data directly to credible sources requesting access. A review of the OTN compliance with the Organization for Economic Co-operation and Development (OECD) principles and guidelines for access to research data from public funding is given in Appendix 5.

In using the OTN data, end users are required to acknowledge use of specific records from contributing databases and the OTN facility as a whole. End users are expected to provide the full citation of any publication citing the OTN, providing a record of the impact and use of the data. It is expected that usage patterns and citations will provide a sound basis for rationalizing system development activities as well as provide an effective means for users to recognize and understand the limitations of the data.

A mid- and long-range plan for the evolution of the Data Centre’s activities is under development and will form part of the Management Plan.
## Appendix 5. Compliance with OECD Data Policy

<table>
<thead>
<tr>
<th>Clear- full compliance</th>
<th>Yellow - near full compliance</th>
<th>Orange - partial compliance</th>
<th>Red - non compliance</th>
</tr>
</thead>
</table>

### a. Openness
- The data system is user-friendly, Internet-based and timely.

### b. Flexibility
- Accounts for changes in information technologies, characteristics of each research field and diversity of research systems.

### c. Transparency
- Documentation on data and conditions of use is available on Internet.
- Applies existing data management standards.
- Communicates among data archives and data producing institutions.

### d. Legal conformity
- Effectively deals with trade secrets, intellectual property rights and protection of or endangered species.
- Delayed and or partial release of data allows primary participants to fully exploit the research data without unnecessarily shutting off access.
- Facilitates access to restricted data for public research and or other public-interest purposes.

### e. Protection of Intellectual property
- Has rules and regulations, regarding the responsibilities of the various parties involved in data-related activities.
- Research data sharing arrangements are negotiated at the initial proposal stage.
- Variations in the origin or type of data are taken into consideration when establishing data access arrangements.
- Research institutions and government organizations have been identified to ensure formal long-term sustainability of the infrastructure required for data access.

### f. Formal Responsibility
- Mutual trust between researchers, and trust between researchers, their institutions and other organizations is encouraged.
- Initial data-producing researchers / institutions are rewarded with temporary exclusive use of the data.
- Data issues and technical assistance for essential organization and curation of data are expressly acknowledged and taken into consideration as part of the funding process.
- There are incentives and development of professional expertise in all areas of research data management.

### g. Professionalism
- Attention is given to relevant international data documentation standards and co-operate with international organizations charged with developing new standards.
- There is explicit mention of standards being employed as well as promotion / adoption of most advanced practices.
- Works with organizations engaged in setting general information and communication technology standards.

### h. Interoperability
- Develops and employs methods and techniques for the collection, dissemination and accessible archiving of data.
- Origin of data sources are documented and specified in a verifiable way, readily available to all and incorporated into the metadata accompanying the data.
- Data sets and copied data sets are linked to the original research materials.
- Develops and employs appropriate practices with respect to citation of data and recording of citations in indexes.
<table>
<thead>
<tr>
<th>j. Security</th>
<th>Uses techniques to guarantee the integrity and security of research data.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uses procedures to ensure the completeness of data and absence of errors.</td>
</tr>
<tr>
<td></td>
<td>Protects against intentional or unintentional loss, destruction, modification and unauthorized use.</td>
</tr>
<tr>
<td></td>
<td>Protects from environmental hazards such as heat, dust, electrical surges, magnetism, and electrostatic discharges.</td>
</tr>
<tr>
<td>k. Efficiency</td>
<td>Conducts periodic cost-benefit assessments to ensure that data with the greatest potential utility are preserved and made accessible.</td>
</tr>
<tr>
<td></td>
<td>Has retention protocols and documentation to reduce unnecessary duplication as well as to provide necessary selectivity.</td>
</tr>
<tr>
<td></td>
<td>Collaborates with non-academic specialists and engages with data management specialist organizations.</td>
</tr>
<tr>
<td></td>
<td>Develops reward structures including recognition of data management activities in tenure and promotion review.</td>
</tr>
<tr>
<td>l. Accountability</td>
<td>Periodic evaluation by user groups, responsible institutions and research funding agencies.</td>
</tr>
<tr>
<td></td>
<td>Determines the extent of reuse of the data and publications generated from the reuse of the data.</td>
</tr>
<tr>
<td>m. Sustainability</td>
<td>Has identified administrative responsibility for the measures to guarantee permanent access to data that have been determined to require long-term retention.</td>
</tr>
<tr>
<td></td>
<td>Long-term preservation of data was considered at the outset of project including determination of most appropriate archival facilities for the data.</td>
</tr>
</tbody>
</table>

Notes:

1. *Openness means access on equal terms for the international research community at the lowest possible cost...* Since inception, OTN staff have worked with technology services professionals at the Dalhousie University computer centre to develop and operate an open-source and user-friendly Internet-based system. Early offerings included web mapping services (WMS) based on Google Earth flyover showing all projects and stations. More recently (Nov 2012) full public access was granted on all discovery metadata (information about the data) and to station and mystery tag records.

2. *Information on data management and access conditions should be communicated among data archives and data-producing institutions, so that best practices can be shared...* Since this report card was prepared (August 2012) the OTN has had numerous communications and visits with our counterparts at ISDM in Ottawa and at BIO in Dartmouth. More recent discussions with DFO indicate that this will improve in the near future.

3. *Access arrangements should promote explicit, formal institutional practices, such as the development of rules and regulations, regarding the responsibilities of the various parties involved in data-related activities...* OTN’s public data policy document has been vetted through the national and international partners and is referenced in all collaboration agreements. Data management clause(s) are therefore only included in collaboration agreements in cases where the formal public policy is unworkable.
Research institutions and professional associations should develop appropriate practices with respect to the citations of data and recording of citations in indexes... Discovery metadata records include preformed standardized data citations, thus enabling anyone accessing or using OTN data to easily give proper attribution to all of the data providers and to OTN.

Specific attention should be devoted to supporting the use of techniques and instruments to guarantee the integrity and security of research data... Project data are stored in controlled access data folders/schemes. The relevant principal investigator and or data managers therefore control access to these folders by other OTN members. With regard to guaranteeing the integrity of a data set, every effort should be made to ensure the completeness of data and absence of errors... OTN and various manufactures have implemented procedures whereby collaborators can authorize to manufacturers to provide equipment specifications metadata directly to OTN as part of their routine shipping practices.

Determines the extent of reuse of the data and publications generated from the reuse of the data ... We are both encouraging end users to cite the database and also experimenting with doing systematic literature searches to determine reuse of the data.

Taking administrative responsibility for the measures to guarantee permanent access to data that have been determined to require long-term retention... All Unrestricted Data held by OTN will be routinely copied to an International Oceanographic Data Exchange (IODE) / Global Ocean Observing System (GOOS) recognized facility such as the Department of Fisheries and Ocean Canada for long term archiving and reported to international biodiversity facilities such as the Ocean Biogeographic Information System (www.iobis.org) and Global Biodiversity Information Facility (www.gbif.org).