CASE STUDY

CASCADE INSTITUTE

AOSTRA:

A model for funding geothermal innovation

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Introduction

The Cascade Institute envisions Canada as a global leader in geothermal electricity production, but innovation is essential to achieve this goal. Our *Ultradeep Geothermal Research and Action Roadmap* (2024) identifies four major technological imperatives that must be achieved to unlock a rapid expansion in geothermal energy: reduce drilling time, design high-temperature tools, enhance well-completion technologies, and improve heat extraction methods (Gall et al., 2024). To tackle these challenges, the Cascade Institute proposes establishing a series of in-field test sites across Canada. These sites would facilitate crucial research into hard-rock drilling, well construction, reservoir development, and surface facility technologies. This proposed program, which would cost an estimated $550 million to establish, could be funded through a variety of models, including an equal partnership between public and private sectors.

The success of public-private partnerships in supporting test centres in Canada has been demonstrated in practice. This report will examine the Alberta Oil Sands Technology and Research Authority (AOSTRA) as a funding model for the test centres proposed by the Cascade Institute, aimed at accelerating innovation in Canada's geothermal industry. The AOSTRA model revolutionized Alberta's energy industry, and could do so again at the national level by using the same skills and expertise to unlock deep geothermal power.

AOSTRA's strategic approach and sustained investment in oil sands research and development (R&D) significantly transformed Alberta's oil industry. By funding and de-risking high-risk projects like the Underground Test Facility (UTF) and adopting a shared funding model with industry partners, AOSTRA advanced disruptive technologies, most notably, steam-assisted gravity drainage (SAGD). SAGD not only unlocked previously inaccessible oil reserves but also generated substantial economic returns and established Alberta as a global leader in oil sands technology.

The ultimate success of AOSTRA illustrates the profound impact that sustained research investment, a clear mandate, technical expertise in leadership, and data-sharing between government, industry, and academic institutions can have on building a world-leading industry.

Background

AOSTRA was established in 1974 by the Government of Alberta to facilitate research and development in the oil sands industry. At the time, only 20 percent of Alberta's vast heavy oil deposits were accessible through existing surface mining techniques. The primary goal of AOSTRA was to improve extraction technologies and enhance economic viability of oil sands operations, ultimately unlocking the other 80 percent of the resource. Over its 26 years of operation, AOSTRA funded over 200 projects, leading to in-situ extraction advancements such as SAGD (Hester & Lawrence, 2010). The organization played a crucial role in transforming the oil sands industry, making extraction more efficient and sustainable.

The financial investment required to commercialize oil sands subsurface extraction in the 1970s far exceeded what the private sector was prepared to commit. So, in 1974 the Government of Alberta set up AOSTRA as a crown corporation, endowing it with $100 million ($625 million in today's dollars) from the Alberta Heritage Savings Trust Fund (Government of Alberta, n.d.-a). This funding covered the first five years of projects and operations. Wiggins (2009) estimates that the Government of Alberta invested a total of $620 million ($1.7 billion in today's dollars) through AOSTRA.

AOSTRA adopted a distinctive approach to accelerating innovation: it collaborated with private oil companies, matching their investments in research and pilot projects, and retaining ownership of any patents for new technologies developed through these projects. This shared investment distributed the risk amongst investors, allowing participating companies to test more and higher-risk projects. Any industry partner could access breakthrough technologies developed by AOSTRA for minimal cost. This approach to sharing research outcomes and distributing risk helped to massively de-risk oil sands R&D.

One of the highest-risk projects undertaken by AOSTRA began in 1983 with the construction of the Underground Test Facility (UTF), which was entirely funded by AOSTRA. Located two hundred metres below ground, UTF began operations in 1987 and demonstrated the successful operation of a horizontal SAGD well pair in its first year. Building on this success, ten companies contributed $16 million each to the second phase of UTF experimentation, buying into the project to reach 50:50 public/private ownership (Government of Alberta, n.d.-b).

By de-risking SAGD technology with the demonstration, AOSTRA sparked an industrial revolution in Alberta. In-situ capacity went from zero in the late 1980s to nearly 200,000 barrels per day (bpd) by 2001 and doubled to 400,000 bpd in 2002. By 2008, capacity exceeded 1 million bpd, eventually exceeding mined oil sands production in 2012. Today, the Alberta Energy Regulator estimates in-situ capacity is nearly 1.8 million bpd (Alberta Energy Regulator, 2024).

The economic returns from the SAGD boom are enormous. In just five years from 2017-2022, SAGD generated nearly $130 billion in gross revenue ($35 billion net revenue) and $15 billion in royalties for the government of Alberta (which does not include income and sales tax revenues). The government's $1.7 billion (today's dollars) investment in AOSTRA generated an almost 10x return for the province, simply from the royalties collected, between 2017 and 2022 (Government of Alberta, 2022).

Funding mechanism

AOSTRA was initially funded in 1974 with $100 million from the Alberta Heritage Savings Trust Fund. This funding was designed to cover the first five years of operations and projects. Seven percent of these funds were allocated to the administration of AOSTRA and were covered solely by public funding (Hester & Lawrence, 2010). All project spending by AOSTRA was intended to be matched evenly by industry investment.

Figure 1 shows AOSTRA's spending per year over the first 15 years of operations, while Figure

2 shows the cumulative shared-cost expenditures by AOSTRA and industry, broken down by technology type (Alberta Oil Sands Technology and Research Authority, 1990).

In 1975, the Government of Alberta granted AOSTRA an additional $135 million. By 1987, the initial funding for AOSTRA had been depleted and additional funding was added from the General Revenue Fund (Hastings-Simon, 2019a; Hester & Lawrence, 2010). Over the 26 years that AOSTRA was in operation, the Government of Alberta invested an estimated $620 million in AOSTRA, which was approximately matched by industry (Wiggins, 2009).

There is one notable project that deviates from the investment-matching model. The UTF (discussed later) was funded and operated 100 percent by AOSTRA with no industry partner from 1984-1990.

A key factor in AOSTRA's funding mechanism was the continuous public investment into the project, rather than a single cash infusion. Currently, most of Alberta's public-private partnership investments are short-term investments in a specific project or technology. The funding is tied to milestone deliverables and is paid out upon delivery. This model relies on the developer to secure private capital, which is then matched by public funds (Emissions Reduction Alberta, 2024). Such a model can be challenging for developers who are between initial technology development and commercial pilot testing, as this phase of R&D is viewed as high risk by private investors. AOSTRA's continuous and sustained funding of technologies helped mitigate this perceived risk and provided public funding up front for R&D. The practice of continuous public investment is an internationally recognized model for clean energy innovation (International Energy Agency, 2023; Sha et al., 2020).

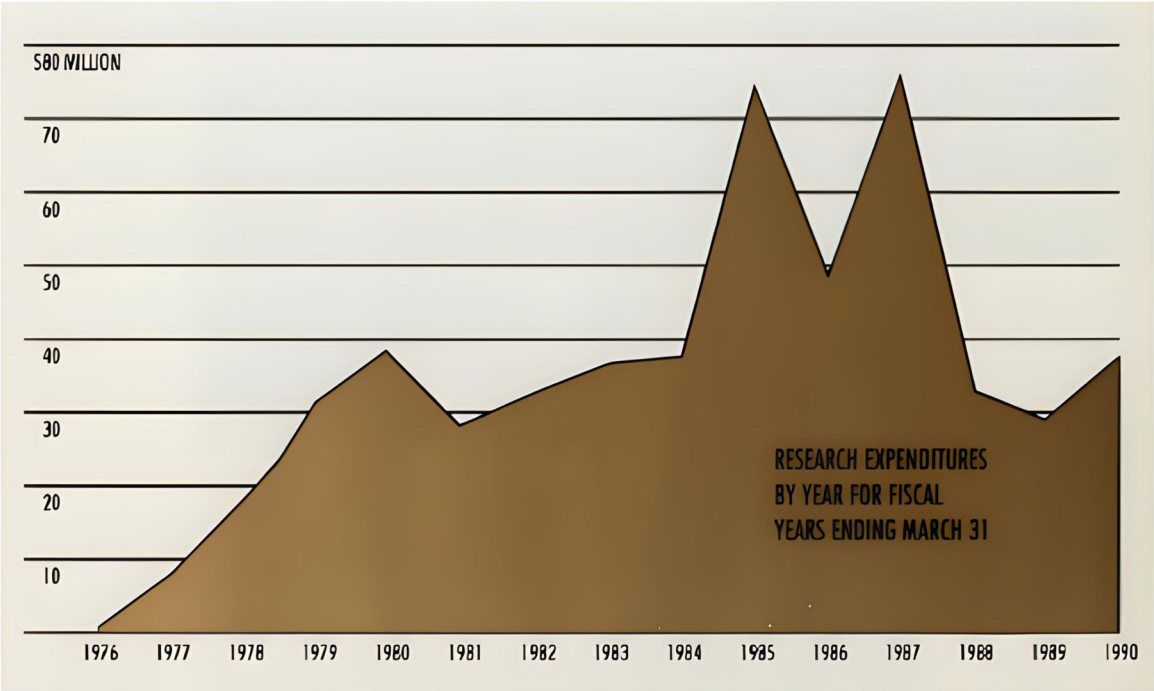

Figure 1: AOSTRA research expenditures by year, 1976-1990. The peak in 1985 is attributed to the construction of the Underground Test Facility (UTF), while the peak in 1987 is attributed to the first phase of experimentation at the UTF (Alberta Oil Sands Technology and Research Authority, 1990).

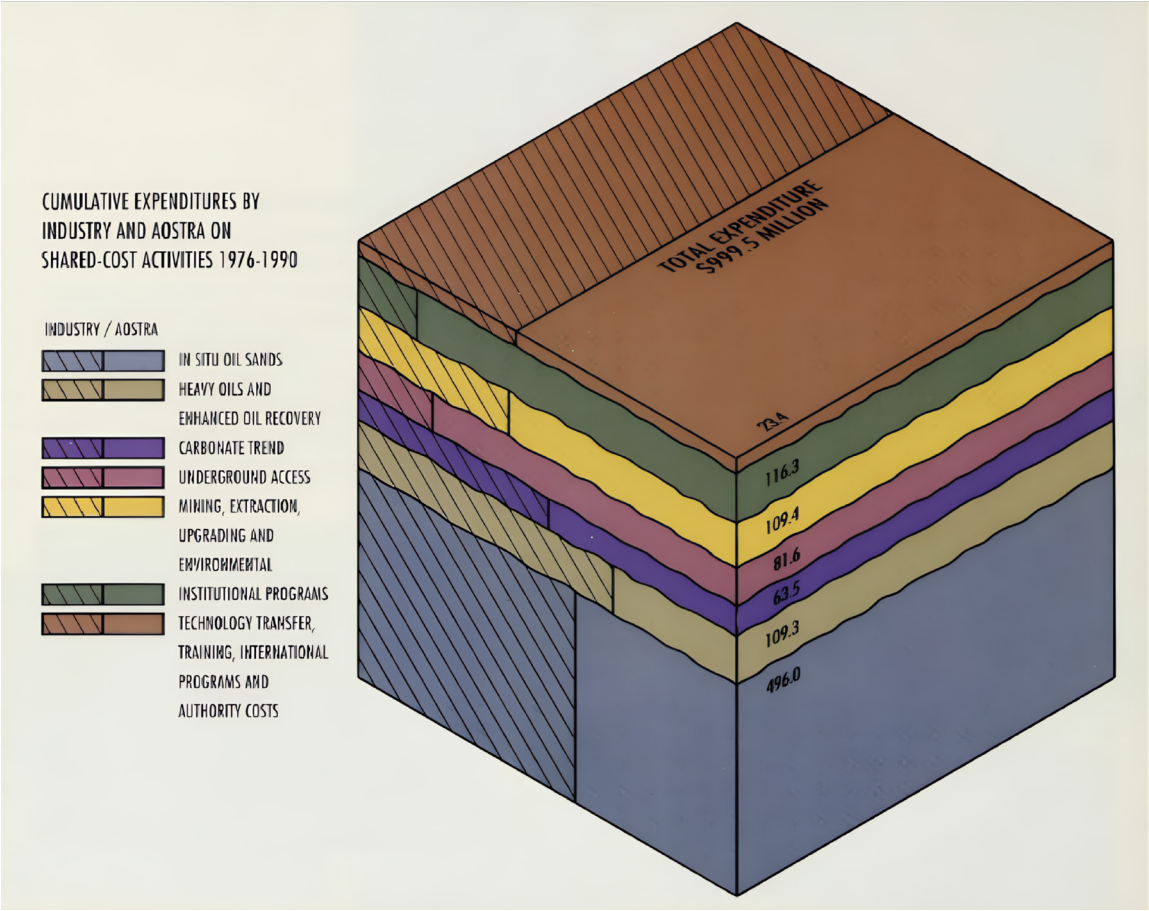

Figure 2: Cumulative expenditures shared by AOSTRA and industry, 1976-1990 (Alberta Oil Sands Technology and Research Authority, 1990).

Governance model

Leadership and staffing

When AOSTRA was founded, it used an executive search firm to hire the chair of the AOSTRA Board of Directors. While the Government of Alberta originally intended the board to have between three and seven board members, it eventually expanded the board to nine. The Government of Alberta and the chair appointed the first board members, which included petroleum industry experts, academics, and a government representative. The government representative was a sitting member of the Alberta legislature and was responsible for reporting on the activities of AOSTRA to the Minister of Energy on an annual basis. The board was responsible for making investment decisions that aligned with AOSTRA's primary goal of unlocking the economic potential of the oil sands (Hester & Lawrence, 2010).

Most board members were hired as consultants with project-specific staff positions embedded in AOSTRA member companies. These staff positions were paid by AOSTRA through project-specific funding (split 50:50 between AOSTRA and the company) (Alberta Oil Sands

Technology and Research Authority, 1990; Hastings-Simon, 2019a). At its largest, AOSTRA consisted of 30 staff, most of whom were embedded employees related to specific projects (Hester & Lawrence, 2010).

Towards the end of AOSTRA's operations, the Government of Alberta took a greater role in making appointments to the board, which diluted its technical and scientific expertise and altered the arms-length approach that had made AOSTRA successful (M. Dusseault, personal communication, August 1, 2024; Hester & Lawrence, 2010).

AOSTRA demonstrated the importance of scientific and technological expertise in the leadership team. Expert representation on the board and leadership team ensured that organizational decisions aligned with the overarching R&D goals. It also ensured that no single group (public, private, or academic) had excessive influence over decisions.

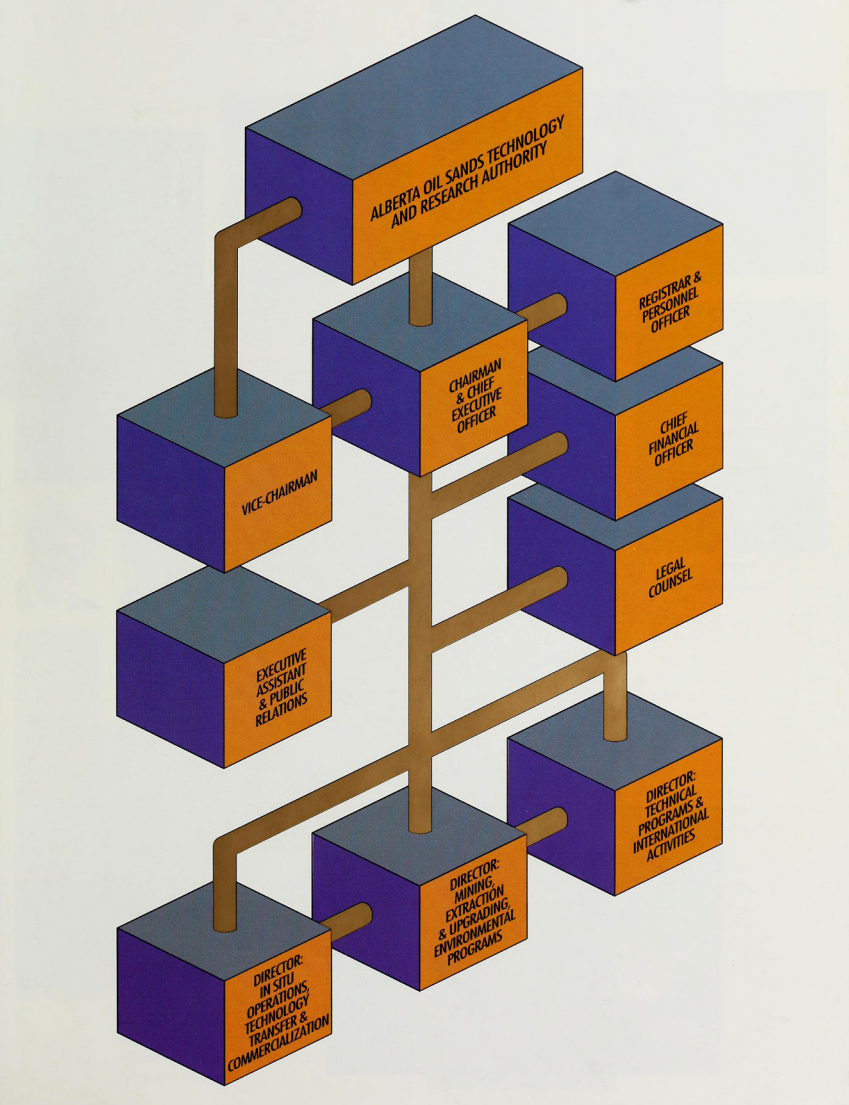

Figure 3: The leadership organizational structure of AOSTRA in 1990 (Alberta Oil Sands Technology and Research Authority, 1990).

Project selection

AOSTRA was formed with the overarching goal to improve extraction technologies and enhance economic viability of oil sands operations. While in operation, the board met extensively with industry, academia, and interest groups to solidify AOSTRA's goals and project principles (Hester & Lawrence, 2010). Relevant principles included (Alberta Oil Sands Technology and Research Authority, 1990):

- AOSTRA would not construct or operate any of its own facilities (the UTF was a notable exception).
- All research concepts would be considered, regardless of source.
- Early-stage research could be carried out anywhere, but an effort would be made to bring advanced technologies to Alberta.
- Contractors and consultants would be sought in Alberta first, then in Canada, then internationally.
- AOSTRA would accumulate, retain, and license oil sands technology on a commercial basis to all that would benefit from it, at reasonable rates, and in the best interest of Alberta.

In 1975, AOSTRA issued the first request for proposals and received 21 submissions. Of these proposals, five were selected, and AOSTRA requested an additional $135 million of funding from the Alberta government (Hester & Lawrence, 2010).

The board met regularly to review written project proposals. Projects were selected based on the recommendation of an internal selection committee (comprised of board members with expertise in technology and business) that was supplemented by external experts as needed. If a member of the selection committee had a conflict of interest on a proposed project, that member would recuse themselves from the selection process. To be selected, a project had to align with AOSTRA's overall priorities and goals. All projects with the potential for technological breakthroughs were evaluated, regardless of the source or cost.

Selected projects were implemented through formal agreements between AOSTRA and the project developer. These projects were normally carried out with a 50:50 funding split between AOSTRA and the developer. In the case of field-based pilots, the project would take place on the developer's lease, with the developer acting as the operator (Alberta Oil Sands Technology and Research Authority, 1990).

Intellectual property and licensing

As outlined in AOSTRA's original policies, one of its mandates was to "accumulate, retain and make available oil sands technology on a commercial basis, so that the best technology would be available to all who could benefit from it, at reasonable rates, bearing in mind the best interests of Albertans" (Alberta Oil Sands Technology and Research Authority, 1990). Initially, some oil and gas companies resisted this approach (Hastings-Simon, 2019b; Hester & Lawrence, 2010). However, the model prevailed and AOSTRA adopted the following key technology ownership policies (Alberta Oil Sands Technology and Research Authority, 1990):

- AOSTRA contributes 50 percent of the project funding and maintains 50 percent management control.

- The project developer is responsible for project execution and operations, with annual reporting to AOSTRA.
- AOSTRA owns all new technology, keeps this technology confidential, obtains patents, and is the exclusive Canadian licensor of the technology.
- AOSTRA and the developer can jointly or individually license technology internationally.
- All licensing income is shared in proportion to the financial contribution of the technology development.
- AOSTRA licenses third parties at a fair market value, or failing that, by arbitration.
- AOSTRA can include a developer's prior technology when licensing but would adjust licensing income accordingly.
- AOSTRA, the Government of Alberta, and the developer can use technology free of charge, but all other users must pay a licensing fee—this fee was minimal for industry partners (Hester & Lawrence, 2010).
- AOSTRA can place staff within the developer's office (at the project's expense) to acquire and license new technology developed by the project.
- AOSTRA and the developer share the project's physical assets and revenues resulting from disposition or sale of products.
- AOSTRA requires repayment of its investments in a project from commercial operations on a "time value of money" basis.

While AOSTRA owned all emerging data, it never made these data publicly available. It sought to create a balance between the protection of intellectual property (IP) and the benefits of data access. To achieve this balance, **AOSTRA made its data available to any legitimate industry user.** This model encouraged collaboration between developers and allowed Alberta to build a world-class oil sands industry (Alberta Oil Sands Technology and Research Authority, 1990; R. Chalaturnyk, personal communication, August 6, 2024; M. Dusseault, personal communication, August 1, 2024).

There were two key exceptions to AOSTRA's data ownership model: the Inventors Grant Assistance Program (described below) and demonstration projects for existing technologies. **AOSTRA would fund demonstration projects where patent ownership would remain with the technology owner.** In these cases, AOSTRA would recover its investment through a share in proprietary rights or a share of licensing or sales revenue (Alberta Oil Sands Technology and Research Authority, 1990).

Inventors Grant Assistance Program

Within AOSTRA, the Inventors Grant Assistance Program was designed to help inventors with limited funding develop their ideas to the point where they could obtain patent protection and commercial funding (Hester & Lawrence, 2010). AOSTRA did not take ownership in technologies or intellectual property (IP) developed through this program and only required technical and financial reports upon completion of the project. AOSTRA would provide up to $50,000 for any one invention (Alberta Oil Sands Technology and Research Authority, 1990). **This program was designed to support technology R&D in its earliest stages** and advance commercially promising technologies to field-scale testing.

Institutional Research and University Program

AOSTRA contributed over $116 million over its 18 years of operation to universities and research institutions (Figure 2). The Alberta Research Council was one of the primary institutions to receive AOSTRA funding and used this money to create the Oil Sands Research Centre, the Oil Sands Information Centre, the Geology Project, and an Oil Sample Bank (Hester & Lawrence, 2010).

AOSTRA also funded many university research projects, professors, post-doctoral fellows, and scholarships. It accepted applications for research from all Canadian universities, but most funding was awarded within Alberta. University researchers conducted research projects with technical support from AOSTRA and consultation with industry, ensuring that projects aligned with the goals of AOSTRA. Researchers were permitted and encouraged to publish their results but had to submit papers to AOSTRA for prior approval. Any patents developed through the University Program were owned by AOSTRA with an honorarium paid to the researcher. Funded university researchers were required to report to AOSTRA annually (Alberta Oil Sands Technology and Research Authority, 1990).

AOSTRA's support of academic and research institutes created a pipeline of highly knowledgeable experts feeding Alberta's oil sands industry. This pipeline of industry experts is still influencing the oil sands industry today. AOSTRA hired students and researchers from within the University Program and employed them during their first few years of oil sands industry work. This practice helped preserve and commercialize the knowledge created through the University Program in Alberta (H. Chhina, personal communication, July 25, 2024).

Underground Test Facility

The Underground Test Facility (UTF) was a unique and notable divergence from AOSTRA's typical shared-ownership model. Researchers within AOSTRA believed that horizontal drilling and SAGD technologies needed to be tested in an underground facility. They presented the project proposal to oil sands companies to secure an industry partner. The AOSTRA researchers proposed that the Government of Alberta would cover all initial construction costs (an estimated $50 million). Industry partners could then pilot their technologies in collaboration with AOSTRA while half the pilot funding would retroactively cover the industry's share of the construction cost.

The project was viewed with skepticism, as the industry was in a downturn. As a result, no industry partners were willing to participate. **AOSTRA leadership made the decision to go ahead with the construction of the UTF, funded entirely by AOSTRA** (H. Chhina, personal communication, July 25, 2024; Hastings-Simon, 2019a).

Construction on the UTF began in 1984 on government-leased land. AOSTRA assumed the role of operator (in a contract with the Government of Alberta) and created an industry steering committee to provide advice on field tests (Alberta Oil Sands Technology and Research

Authority, 1990). The UTF began its Phase A operations in 1987 by testing three horizontal well pairs (Figure 4). Oil recovery by SAGD was successful within the first year (Government of Alberta, n.d.-b). This breakthrough opened the 80 percent of deposits that were inaccessible through surface mining at the time.

Phase A of pilot testing ran until 1990 and proved the feasibility of SAGD bitumen extraction. However, by the end of Phase A, the Government of Alberta had spent $65 million and AOSTRA faced pressure to meet their 50:50 shared-ownership model (H. Chhina, personal communication, July 25, 2024; Hastings-Simon, 2019a). To remedy this, AOSTRA allowed six industry partners to retroactively buy into Phase A at a reduced rate (this rate was never made public) and another ten to join Phase B for $16 million each. With these partners in place, AOSTRA was able to move forward with Phase B testing with 50 percent industry ownership (Government of Alberta, n.d.-b; Hastings-Simon, 2019a). Phase B showed the same success as Phase A and proved the commercial viability of SAGD technology. Of the more than 200 projects (and 116 patents) created during AOSTRA's operations, **SAGD, developed at the UTF, was the disruptive breakthrough responsible for unlocking Alberta's oil sands.**

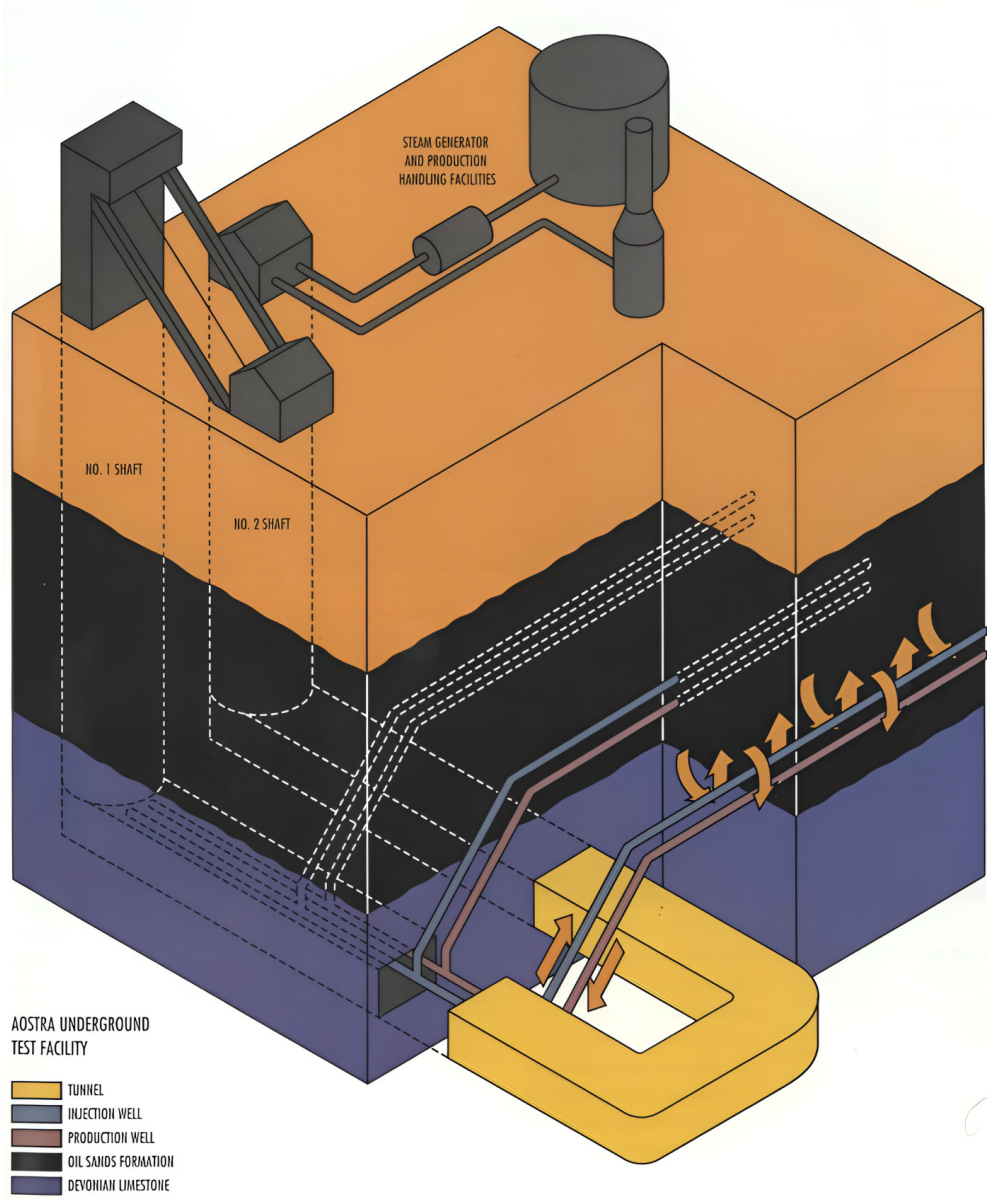

Figure 4: A schematic diagram of the Underground Test Facility (UTF). The access tunnels were located 200 metres below the surface in limestone underlaying the oil sands deposits

Lessons from AOSTRA

Although much has changed since AOSTRA was founded in the mid-1970s, there are still lessons to be learned from AOSTRA's successful disruption of the oil sands industry. By leveraging public funding to distribute risk, AOSTRA encouraged private investment in oil sands R&D, which stimulated all four stages of technology innovation (Figure 5). The Inventors Grant Assistance Program funded prototypes, the Institutional Research and University Program funded prototypes and demonstrations, and AOSTRA's industry partnerships funded a wide range of projects from demonstrations all the way to mature technologies.

AOSTRA illustrates the importance of continuous funding across all stages of innovation. After ten years of operation, AOSTRA had still not discovered a breakthrough technology, but persevered with R&D (Hastings-Simon, 2019a). AOSTRA was ahead of its time; its approach aligns with current recommendations for funding energy innovation (Sha et al., 2020).

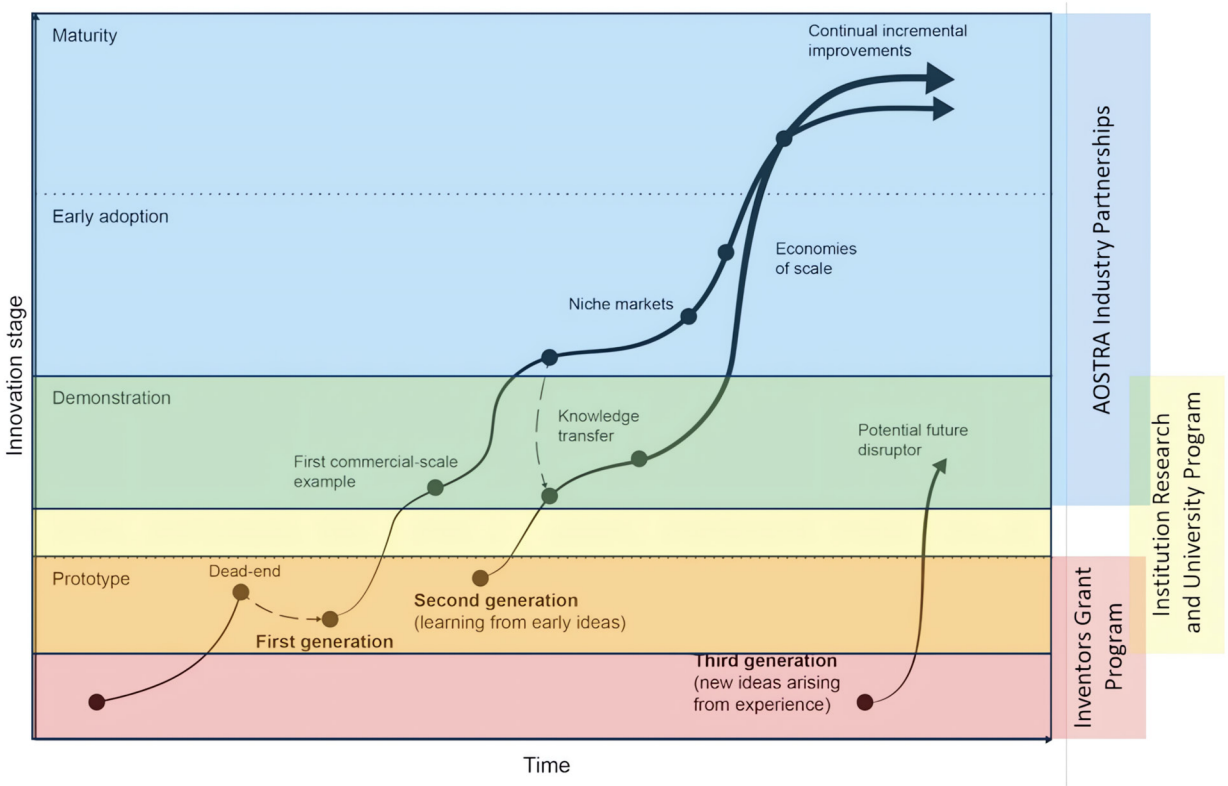

Figure 5: The four stages of technology innovation and the feedbacks and spillovers that improve successive generations of designs (modified from: Sha et al., 2020).

AOSTRA-funded projects were thoughtfully selected by a group of scientific and industry experts. Projects had to align with AOSTRA's goals of improving extraction technologies and enhancing the economic viability of the oil sands. Another key factor of AOSTRA's success was its clear—but non-prescriptive—overarching goal. These factors encouraged AOSTRA to select projects and technology with the greatest potential for breakthroughs.

While AOSTRA successfully produced disruptive, breakthrough technologies, it also created room for experimentation and failure. Over its 26 years of operations, AOSTRA was involved in over 200 projects. Failure is an expected part of the R&D process, which AOSTRA and its partners understood. AOSTRA prioritized data collection, not only to collect IP, but to ensure industry could learn from both failures and successes. By expecting inevitable project failures, AOSTRA researchers were able to learn from them and minimize their cost. This approach is uncommon today, with most R&D funding being awarded through project-specific grants with set timelines and deliverables. To facilitate innovation, funders need to be flexible and patient. AOSTRA is proof that when the technology environment and incentives are properly aligned, the breakthrough will come.

In-field testing at the Underground Test Facility (UTF) was crucial for technological breakthroughs in the Alberta oil sands. Initially met with skepticism, AOSTRA proceeded with the UTF's construction without industry partners, funded by the Government of Alberta. This decision allowed the testing of horizontal drilling and SAGD technologies. SAGD opened up access to the 80 percent of oil sands deposits that had been unreachable. This breakthrough led to industry partnerships in subsequent phases, and ultimately proved the commercial viability of SAGD. The in-field testing at UTF was pivotal in developing SAGD, a disruptive technology that unlocked Alberta's oil sands potential.

Key lessons from AOSTRA:

1. Consistent and sustained public funding at all stages of R&D is key to unlocking disruptive technological breakthroughs.
2. A clear mission and goal must guide R&D decisions.
3. Leadership needs to be comprised of technical experts.
4. The operating model must reflect an understanding that failure is a natural part of the R&D process.
5. Data must be accessible to accelerate innovation.
6. Collaboration between government, industry, and academic institutions accelerates innovation and creates a skilled, knowledgeable workforce.
7. In-field testing is essential for proving the feasibility and commercial viability of technologies.

Limitations of the AOSTRA model

While the 50-year-old AOSTRA model is remarkably relevant for the energy technology innovation ecosystem today, it has a few limitations. For instance, environmental considerations focused on minimizing the surface footprint of the oil sands. Modern test centres must align with current environmental standards and seek to minimize their environmental impact. The mandate of test centres should also reflect a commitment to Indigenous reconciliation, community participation, and social impact.

AOSTRA illustrates the strengths of the public-private partnership (PPP) funding model. However, there may be the opportunity for test centres to attract additional capital from philanthropic funders, which would further distribute risk. While the public-private-

philanthropic partnership (PPPP) approach is still new, the finance community is increasingly recognizing it as an effective model for funding R&D (World Economic Forum et al., 2024).

In addition to using a PPPP model to attract additional funding, test centres should include global collaboration. The oil sands targeted by AOSTRA are geographically unique to Alberta and few similar deposits exist in other parts of the world (University of Calgary, 2024). However, the technological advances stimulated by a modern geothermal test centre would not be geographically constrained. International collaboration will further accelerate technological innovation for Canada.

One of AOSTRA's unique features was its ownership model for IP. AOSTRA owned all data and technology developed through AOSTRA-funded projects. It shared these data and results freely with the oil sands industry but never made them available publicly—an approach that some industry partners initially resisted.

A similar model could face the same resistance today. IP makes up a significant portion of many companies' value (Heer et al., 2023). It could be challenging to attract participants without properly balancing corporate IP interests with those of a publicly funded test centre. AOSTRA achieved this balance by allowing developers to test their existing technology and maintain ownership of their IP, but any new IP emerging from AOSTRA projects belonged to AOSTRA. Ultimately, the Government of Alberta's financial success from AOSTRA was the result of oil sands royalties, not the licensing of patents. However, the ownership of data and IP by AOSTRA facilitated collaboration and unlocked a level of innovation that would not have been achieved under the conventional IP model.

Conclusion

AOSTRA's 50-year legacy highlights the effectiveness of a public-private funding model in driving technological innovation. By providing continuous financial support across all stages of technology development, AOSTRA created an environment where experimentation and learning from failures were integral to success. The creation of an in-field test centre played a key role in significant technological breakthroughs, such as in-situ production methods. AOSTRA's commitment to data accessibility and long-term funding exemplifies how patience and flexibility can lead to R&D breakthroughs.

The geothermal test centres proposed by the Cascade Institute could benefit from adopting a similar model, along with the principles of environmental stewardship, Indigenous reconciliation, community participation, and social impact. Embracing public-private-philanthropic partnerships and global collaborations could further enhance innovation and attract diverse investment. Balancing IP rights with public interests will be crucial, but AOSTRA's experience shows that strategic data management and collaboration can accelerate progress and drive industry advancements. To address the current technical challenges that geothermal energy is facing, Canada needs a Geothermal Science and Technology Research Authority (GEOSTRA). This would not only position Canada's existing energy industries to compete in tomorrow's opportunities, but provide a new pathway for Canada to improve competitiveness and productivity through innovation.

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Institutional partner

Collaborating partners

Alberta Drilling Accelerator
Accelerating Community Energy Transformation
Grantham Foundation for the Protection of the Environment
ReThink Charity Foundation's RC Forward Climate Change Fund
Founders Pledge's Climate Change Fund
Ivey Foundation

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