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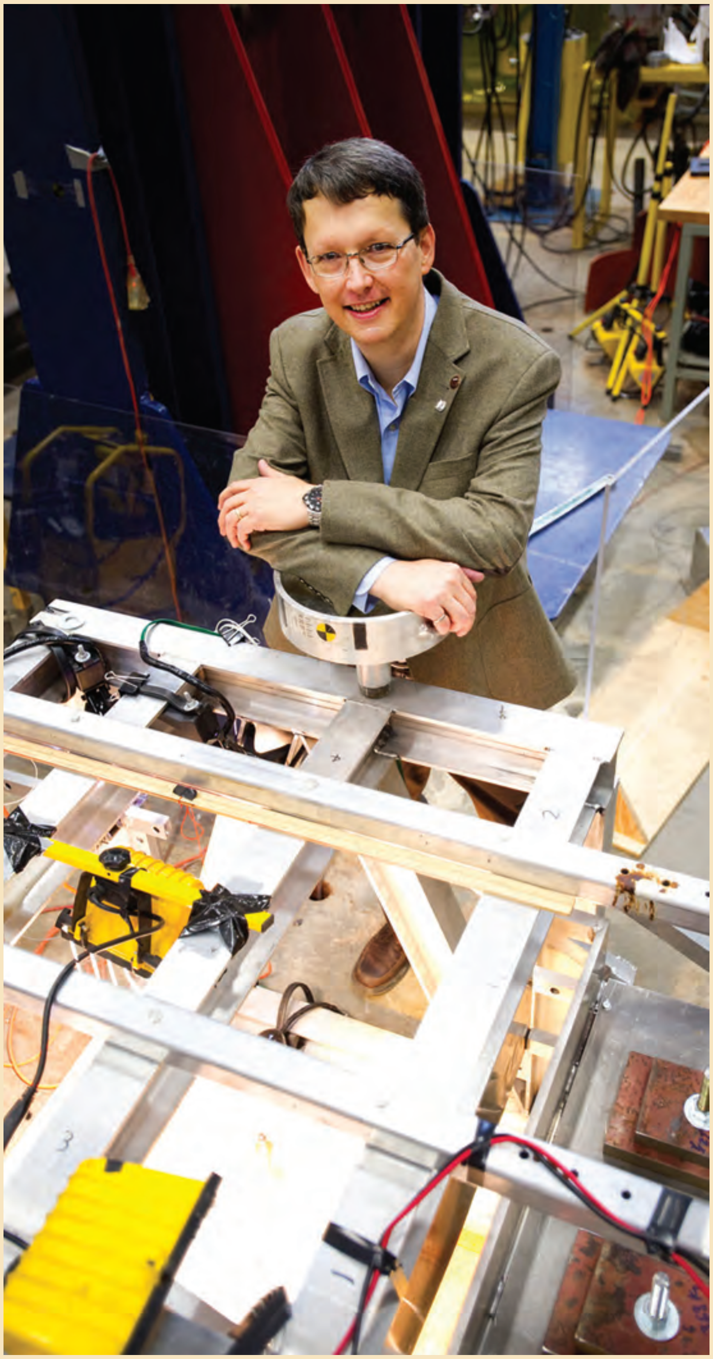
Design Toolset of the Future for

Arctic Ship and Offshore Structures

By Andrew Safer

Developing tools to design ships and offshore structures for year-round Arctic operations is the focus of a $7.2 million five-year applied R&D project at Memorial University of Newfoundland in St. John's, Newfoundland and Labrador, Canada. Husky Energy, Inc., American Bureau of Shipping (ABS), Samsung Heavy Industries Co. Ltd, Rolls-Royce Marine, and BMT Fleet Technology are the industry partners in the Sustainable Technology for Polar Ships and Structures (STePS2) project. The National Research Council's Institute for Ocean Technology (IOT-NRC) is a key technical partner in the project.

"One of our key challenges is year-round Arctic operations of very large vessels and structures, beyond current experience," reports Dr. Claude Daley, Professor of Engineering in the Ocean and Naval Architectural Engineering Group at Memorial University of Newfoundland in St. John's, and Principal Investigator of STePS2. "If we do the work needed to raise the level of our technology and lower the uncertainty, we can have a significant effect on whether Arctic oil and gas projects are seen as viable. This can help determine whether our Arctic is developed, and more importantly, how it's developed."

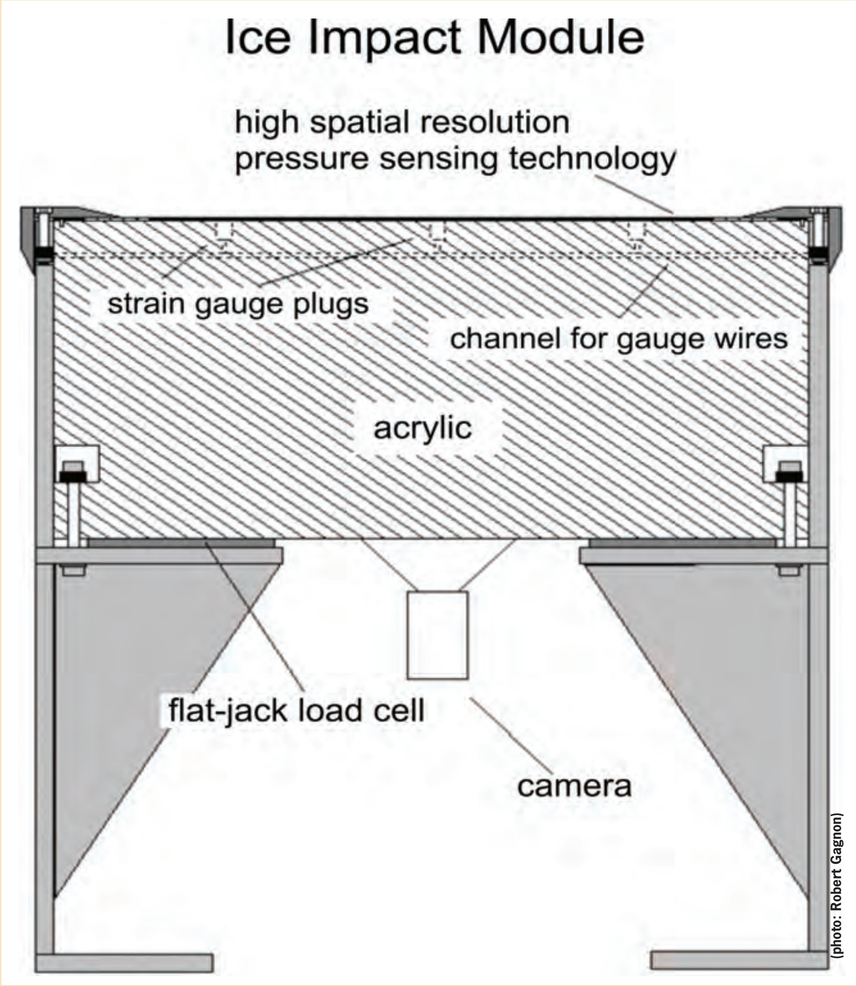


Dr. Claude Daley and the small double-pendulum ice impact apparatus.

There is a 50 percent chance of finding 83 billion barrels of oil north of the Arctic Circle, according to the US Geological Survey. At $100 per barrel, that is valued at $8.3 trillion, plus the value of natural gas and minerals. The potential of the vast petroleum and mineral deposits in the Arctic make the business case for STePS2.

Static and dynamic ice-crushing experiments, and hydrodynamic ice-ship hull interaction tests will be conducted in the Faculty of Engineering structures lab to better understand the impact pressures ice exerts on steel. Based on these findings, the researchers will then develop numerical models that will be validated in a high-performance computing environment and modeled as full-scale field scenarios involving interactions between water, ice, and steel. "The ice class rules for ships include requirements to strengthen the deep wet parts of a hull below the ice belt, and experience shows that without strengthening there will be damage in the deep areas," Daley notes, "but there is a lot of uncertainty about the precise cause of these ice loads."

ABS established a Harsh Environment Technology Center at Memorial University in 2009, and currently has a company researcher onsite working on STePS2. Dr. Roger Basu, Director of Shared Technology at Houston-based ABS, adds that "for traditional ships of a certain size and shape that have been operating in the Arctic, we're comfortable with the rules we have, but there are gaps in knowledge regarding significantly larger ships." An LNG ship that displaces ten times that of a small Arctic ship would be an example. "Where we don't have experience, we need tools to evaluate those kinds of ships and structures," Dr. Basu notes. "The more novel the concept, the bigger the physics component is. This is what STePS2 is addressing in a systematic, integrated way, and we find it very attractive." He adds that numerical tools have only become viable in the last five years or so, and sees their application in STePS2 as significant because they provide the flexibility in assessing a broad range of configuration of offshore structure. "If the work done on STePS2 proves these tools can be used, then industry might start to use them in a design tool mode," he observes. "That would give industry confidence in the applicability of using numerical tools directly for design purposes and designers wouldn't have to rely entirely on existing empirical models."

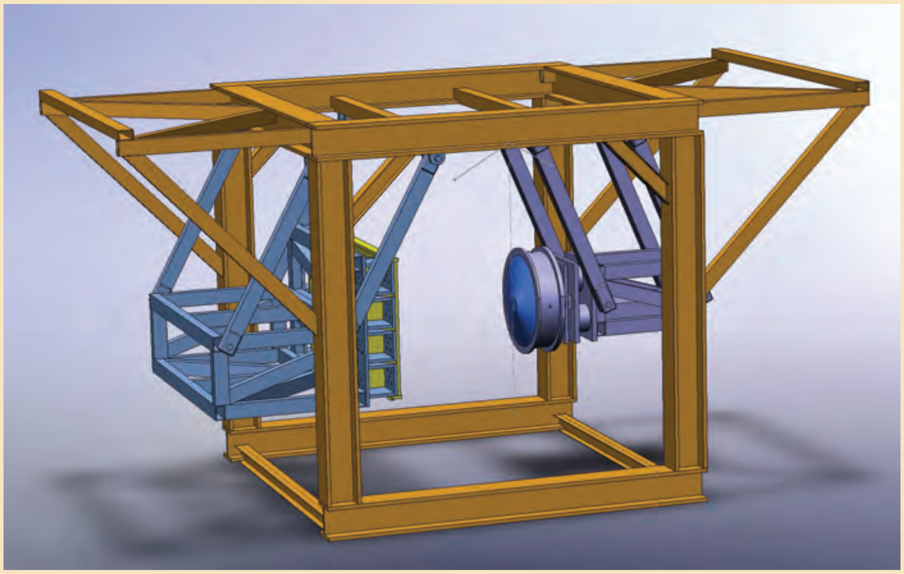


Students assisting with proof tests of the IOT/NRC Ice Impact Module in a high-capacity steel frame at Memorial's Structures Laboratory

Now in its second year, 35 people are working on STePS2: that include 10 undergraduate students, 12 graduate students, five faculty members, and four staff. In addition IOT-NRC has four principal researchers participating in the project. An estimated 40 to 50 graduate and work-term students will be involved over the course of the project. So far, Dr. Daley's team of researchers has built a small double-pendulum ice impact apparatus and are now building one four times the size, to be operational within the next year. A new clear tank has been constructed that will permit the observation of underwater ice loading scenarios on ships. An extensive program of ice mechanics tests is underway. And on the computational front, several large numerical simulation tools are under development using modern cluster computers and 'massively parallel' GPU technology.

BMT Fleet Technology established the BMT Ocean and Arctic Structures Research Program at Memorial University and this funding has become one of the components of the STePS2 project. From an operational perspective, Andrew Kendrick, Chief Technical Officer of Kanata, Ontario-based BMT Fleet Technology, outlines some of the unknowns that oil companies face when contemplating Arctic projects. He points out that designers of floating production storage and offloading units and drillships still have difficulties identifying what load levels to design against. This impacts the types of mooring systems that may be required, the amount of thrust that propulsion and stationkeeping systems have to provide, and how much active ice management may be needed around these structures. "Estimates can be an order of magnitude different," he observes. "Someone says 2,000 tons and someone else says 20,000 tons. We're that far apart in our definable knowledge. There are still a lot of areas where our understanding is not really very mature." Another knowledge gap he identifies is the ability to create a finite element model of ice. "We have to keep it really simple to avoid making mistakes," Mr. Kendrick adds.

There are several oil companies that would be drilling in the Arctic right away if they could get permits, Mr. Kendrick reports, indicating there is an urgent need for better information to assist in project planning. "We can work with the information we have now, but what we can't do is work as cost-efficiently as we're sure we could if we knew more. It's all about reducing the cost of doing these projects." Compared to 30 years ago when oil companies conducted exploratory drilling in the Beaufort Sea, today—particularly after Deepwater Horizon—there are demands for enhanced safety, projects proceed with a significantly greater degree of caution, and regulations are more stringent, all of which equates to higher costs. Mr. Kendrick figures reducing the uncertainty by 100 percent could save 50 per cent of the structural design costs, adding, "I hope that's where we may be able to get to with STePS2."



Design drawing of the large double-pendulum ice impact apparatus. The apparatus is 12 feet tall and capable of impacting ship structural panels with a 1-meter diameter ice mass.

Parnters in the (STePS2) Project

- **Memorial University of Newfoundland in St. John's, Newfoundland and Labrador, Canada**
- **Husky Energy, Inc.**
- **American Bureau of Shipping (ABS)**
- **Samsung Heavy Industries Co. Ltd**
- **Rolls-Royce Marine**
- **BMT Fleet Technology**

Between 1992 and 2008, Dr. Daley helped develop the structural standard for the polar class rules, an international safety framework for ships operating in polar waters. STePS2 evolved as a result of large shipbuilding companies asking Dr. Daley and his colleagues to help them understand the structural capacity that would be needed to withstand ice loads in the Arctic. "We said we can use the tools we have, but we need new tools," recalls Dr. Daley. "Developing new tools will let people evaluate the new concepts as per ABS's Novel Concepts Guide." He explains that for existing constructions, the load is averaged over the structural layout, but there are only guidelines for designing ships and offshore structures to withstand substantially higher loads. What is unknown is whether the pressure zones get bigger as the loads increase. The current offshore code, he notes, is based on the premise that pressures won't increase in impacts above 100 mega Newtons. (For reference, the Hibernia platform offshore Newfoundland was designed for about 500 mega Newtons, and the highest controlled impact measured in a field program was about 17 mega Newtons.) "I believe that the whole event will scale up, and the total force will get larger, though I know there are differing views and healthy debate on the subject," he says.

Another view is that the size of the high-pressure zone is determined by the strength of the ice. "This is why we need to do research," Dr. Daley adds. "This needs to be sorted out."

In the 1980's, impacts were measured during major ice-loading events on platforms in the Beaufort Sea, but the high-pressure zones were not recorded due to the low spatial resolution technology that was available at the time. In STePS2, the ice-structure interactions will be measured using an advanced technology impact module capable of withstanding the loads and capturing the pressure distributions at high resolution.

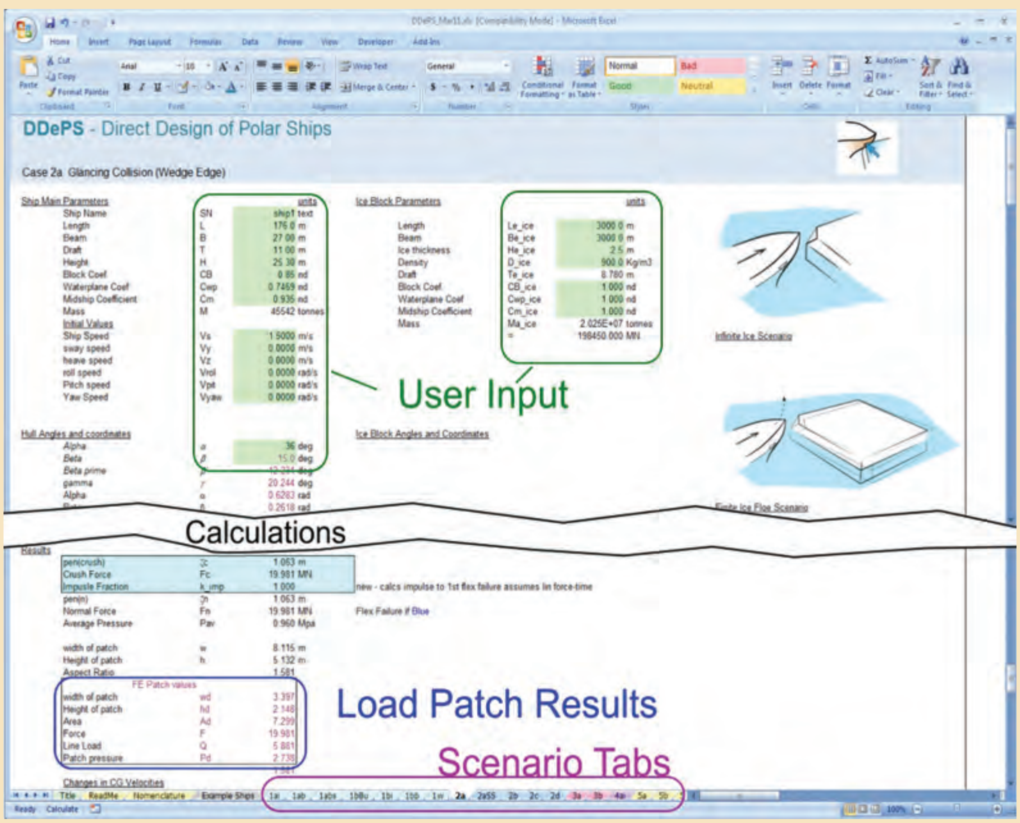
Developed by physicist Dr. Robert Gagnon at the National Research Council's Institute for Ocean Technology (located next door to Memorial University's Ocean and Naval Architectural

Engineering structures lab in St. John's), the impact module consists of a high spatial resolution array of pressure sensors covered by a thin metal sheet, against which the force is applied.

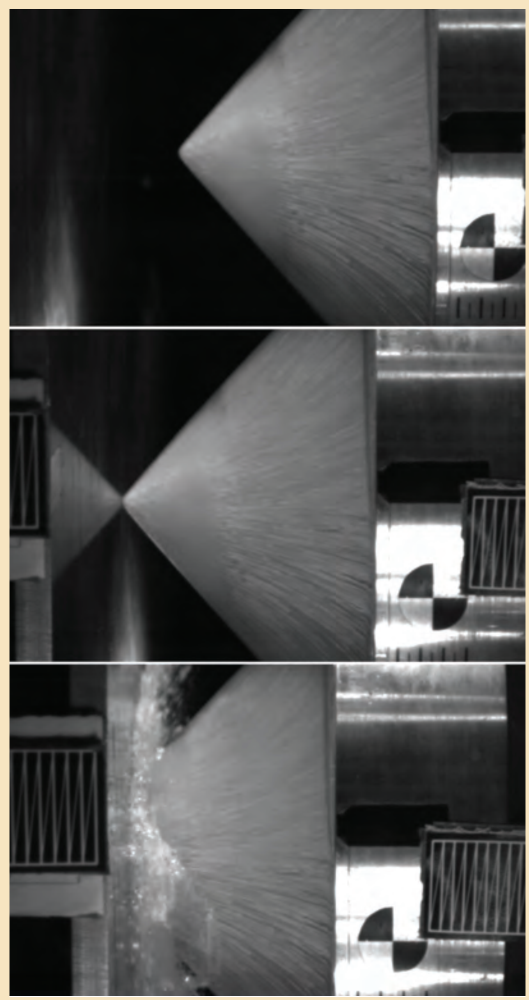
These patented sensors rest on an 18-inch-thick block of clear acrylic that has a high-speed camera mounted behind it to capture the pressure information. Dr. Gagnon designed this unit following a field trial he and colleagues conducted offshore Newfoundland in 2001 that acquired data from 178 impacts on 18 ice masses ranging from 40-ton growlers (chunks of ice less than one meter above the surface) to a 22,000-ton iceberg at ship speeds up to 13 knots for the smaller masses.

The impact module was developed in part to validate the design of a much larger impact panel intended to be mounted on the front of a vessel and rammed into icebergs during field trials. The impact module and preparations for the field study have cost about $1,000,000. If the rest of the required funding is secured, Dr. Gagnon plans to have the large impact panel mounted on the Canadian Coast Guard Services Terry Fox icebreaker for trials possibly in 2012, the centennial of the sinking of the Titanic. Dr. Gagnon has for several years been developing technologies for measuring load and pressure, formulating new experimental techniques to study ice crushing behavior and developing numerical simulations of ice/ship collisions. Dr. Daley was able to capitalize on these strong and complementary backgrounds when drafting the proposal.

In the experiments using the double-pendulum apparatus, the impact module will measure the impact force and pressure distribution



The 'Direct Design of Polar Ships' (DDePS) spreadsheet program--used to evaluate ice loads in a variety of ship-ice interactions.



(photo: Claude Daley)

Series of high-speed images taken from the small double- pendulum ice impact test with 25-cm diameter ice cone.

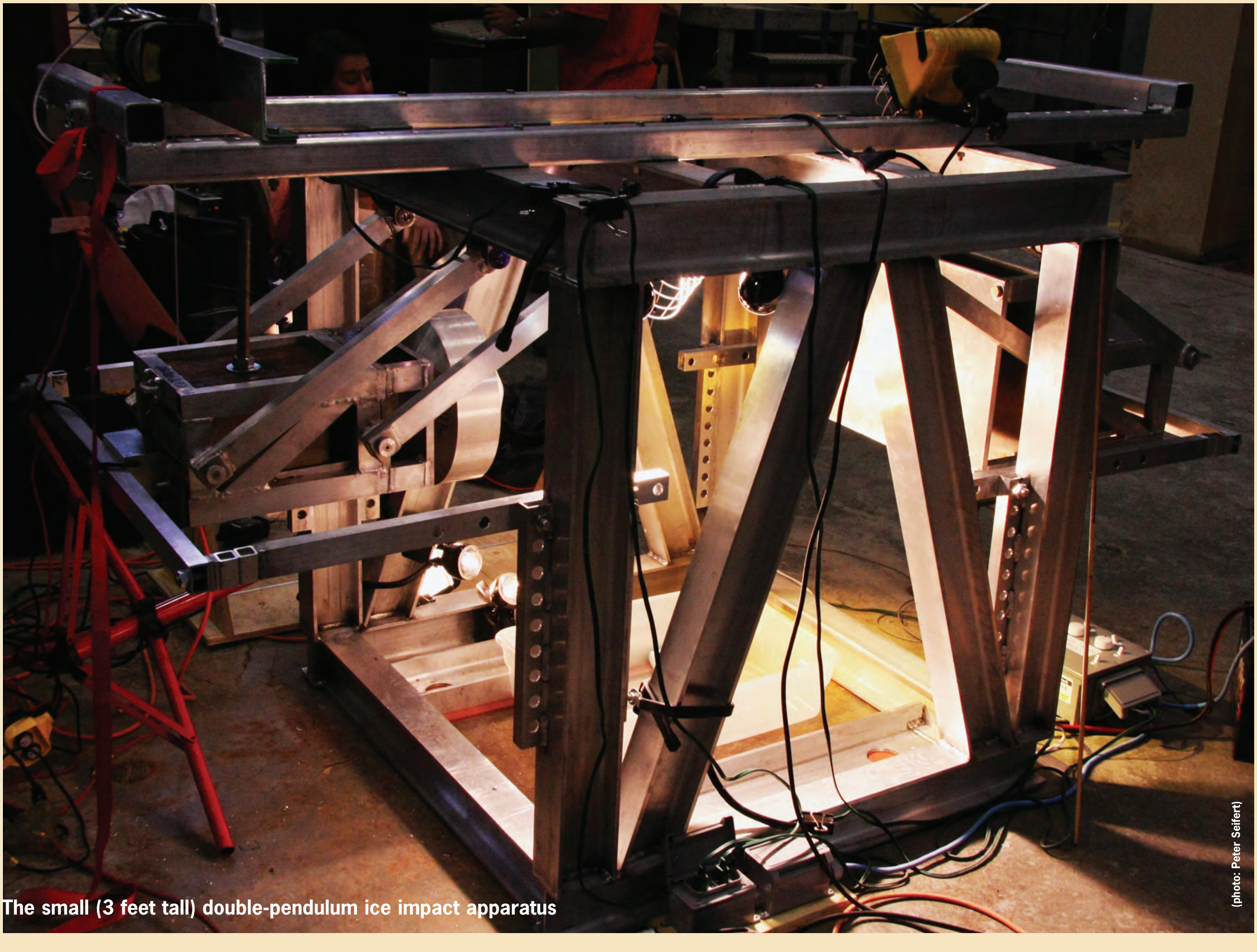
when a five-ton steel pendulum collides with another equally massive one that has a 1-metre diameter ice sample attached to it, with forces up to 5 mega Newtons and at speeds up to 15 knots. The impact module will also record the stationary experiments, in which ice blocks will be crushed against a steel frame.

In addition to the $1.2 million private-sector investment, STePS2 has also received $3 million through the Atlantic Canada Opportunities Agency's Atlantic Innovation Fund.

The Research and Development Corporation Newfoundland and Labrador is investing $800,000 through the Collaborative R&D Academic Program. Memorial University is contributing approximately $130,000 for student bursaries through the School of Graduate Studies. Research funding agencies such as MITACS and NSERC are expected to provide approximately $500,000 through various programs that fund graduate student support. IOT-NRC is a research partner. In-kind partner contributions total $1.59 million.

When the project concludes in 2015, the deliverable will be a design tool that enables Arctic ship and offshore structure designers, operators, and engineers to model a range of scenarios involving water, ice, and steel interactions, to specify optimal design parameters.

Reflecting on STePS2, Mr. Kendrick said, "I think St. John's is a really exciting place for this type of work right now. Nobody that I know of is doing directly comparable things. Others are looking at aspects of the same problems in similar ways, but what Claude (Daley) is doing is, to my knowledge, unique."



The small (3 feet tall) double-pendulum ice impact apparatus

(photo: Peter Seifert)