INSTITUTE FOR
OIL SANDS INNOVATION
AT THE UNIVERSITY OF ALBERTA

Breakthrough Energy Research | Advanced Environmental Technologies

Imperial ALBERTA INNOVATES FACULTY OF ENGINEERING

Annual Report
2019- 2020

Prepared by Jagvir Singh

March 6, 2020

Vision

Oil sands operations with a reduced environmental footprint by minimizing water use, consuming less energy, lowering greenhouse gas and other emissions, yielding high quality products at lower cost.

Mission

To promote, to build capacities and to fund breakthrough researchwith commercialization potential that leads to environmentally, economically and socially sustainable development of Canada's mineable oil sands resources.

Values

- **Partnerships, collaboration and teamwork** – we seek to provide an environment in which ideas can surface and be acted upon. We constantly look for innovative solutions that will add value to our stakeholders and investigators. We strive to improve the efficiency and effectiveness of our Institute's operation to deliver best value services. As a learning organization, we are constantly increasing our intellectual capital and improving our business practices and procedures through teamwork and a desire to excel.

- **Effective communication** - we strive to foster a culture that stimulates free and open communication. We commit to communicating definable and measurable goals.

- **Fairness, transparency and accountability** – we take accountability for the Institute's mission and resources entrusted to us. We conduct our business operation in a fair manner that meets or exceeds all legal, ethical and public expectations.

- **Excellence** – we focus on advancing our technical competencies and delivering services of the highest quality consistent with established standards and best practices.

Executive Summary

The Institute for Oil Sands Innovation (IOSI) was established in 2006 to accelerate the innovation and revolutionize the productivity and sustainability of oil sands operations by focusing on delivering breakthrough technology for cleaner, cheaper oil sands development, while also contributing to the development of tomorrow's top-flight researchers and industry leaders. With ever changing techno-economic scenario, IOSI has been forefront in delivering groundbreaking research that has contributed tosocial, economic and environmental excellence in extraction and upgrading processes - now and for future generations.

IOSI has successfully evolved as a vibrant, multi-disciplinary institute dedicated to the development of new technology for the oilsands. Comprising of researchers from universities not only in Canada but across the globe, IOSI has demonstrated how research collaboration can makesignificant advances in the basic understanding of the chemistry, interfacial behavior, and physics of oil sandsmaterials with focus on commercial applications. IOSI continues to nurture strong partnerships with Alberta Innovates, Imperial and the Canada's Oil Sands Innovation Alliance (COSIA).

Since inception, IOSI's research has been adjusted to meet the challenges faced by the oil sands industry and currently includes four main themes of the research, namely, extraction, product cleaning and partial upgrading, online instrumentation, and tailings fundamentals. The researchers have been able to deliver groundbreaking research in each of these theme areas over the period of the last 15 years. As with any other technological area of research, oil sands research also demands continuous alignment of its focus to the emerging socio-economic challenges in order to maintain its competitiveness and provide cutting edge solutions to the industry. Keeping this in view, IOSI is in the process of redefining the theme areas to better serve the industry in ever changing technological dynamics in the oil sands industry. In each theme area, IOSI researchers are working together to advance the basic science and to explore technologies for the mineable oil sands industry.

Imperial Oil Resources Ltd. has contributed a total of $35.2 million over 15years to the Imperial Endowment fund as well as $500 thousand per year in in-kind support to IOSI. The Imperial – U of A Foundation Agreement was amended and renewed for another 5 years effective November 1, 2018 and ending on October 31, 2023. The in-kind support has included time devoted by highly knowledgeable staff from Imperial Oil Resources Ltd. who has contributed significantly to the quality of research.

The partnership has been successful in attracting significant funding and in-kind support from the Province of Alberta through Alberta Innovates (AI) with $6.0 million from the former Alberta Ingenuity Fund and $10.0 million from the former Alberta Energy Research Institute. AI has contributed $7.36M since 2013 out of which $1.5M has been received after Alberta Innovates renewed support for 5 years in April 2018 with a total funding of $2.5M to IOSI till March 31, 2023.

IOSI also receives project-related funding from the Canada Foundation for Innovation, the Canada Research Chairs program, and the National Science and Engineering Research Council (NSERC).

COSIA was launched on March 1, 2012 to foster innovation and collaboration in research and development relating to the environmental impact of oil sands development. The Tailings Environmental Priority Area (EPA) is the successor to the former Oil Sands Tailings Consortium (OSTC). Each company has pledged to share its existing tailings research and technology and to remove barriers to collaborating on future tailings R&D. The research activities on tailings fundamentals carried out by IOSI are part of the fundamental research working group of the COSIA Tailings EPA and funding is shared by the five member companies of the COSIA Tailings EPA (Canadian Natural, Imperial, Suncor, Syncrude & Teck).

Again, IOSI continues to receive project-related funding from COSIA. The total funding received from COSIA for 2019-20 was $0.85M.

IOSI has successfully attracted principal investigators (PIs) from the departments of Chemistry, Civil & Environmental Engineering, Chemical and Materials Engineering, Electrical and Computing Engineering, Geotechnical Engineering, and Renewable Resources at the University of Alberta. IOSI's PIs also include members of the Department of Environmental & Fluid Mechanics at the Delft University of Technology in the Netherlands, the Boreal Research Institute at the Northern Alberta Institute of Technology (NAIT), the Centre for Oil Sands Sustainability at NAIT, the School of Sustainable Building and Environmental Management at NAIT, the Department of Enhanced Oil Recovery and Agronomy at Purdue University, the Department of Chemistry at the University of British Columbia and the University of Montreal, the Atlantic Centre for Green Chemistry from St. Mary's University in Halifax, the Department of Chemical & Petroleum Engineering from the University of Calgary, the Department of Civil, Environmental, and Geo-Engineering at the University of Minnesota, the Department of Chemistry at the University of Ottawa, the Department of Chemical Engineering at Queen's University, Deltares (the Netherlands), InnoTech Alberta, Coanda, the National Research Council of Canada and the National Institute for Nanotechnology.

IOSI approved 11 new research projects in 2019and review process is underway for new research projects in 2020.

IOSI project leaders are able to access the world class nanotechnology research tools provided on the University of Alberta campus that are available nowhere else in Canada. IOSI's three research labs are re-located to the newly renovated chemical labs in the Chemical and Materials Engineering Building during 2019-2020.

IOIS is able to provide unique training and research experience as a result of the exceptional project leaders and facilities available. Imperial's partnership with IOSI provides invaluable industry experience to students. In all, IOSI has grown from the participation of six individuals in April 2006 to close to 130 today.

Goals and Achievements

1. Research Excellence

IOSI is committed to providing research breakthroughs enabling the long-term sustainable development of the oil sands in Alberta. Research focuses on solving some of Alberta's most pressing concerns when it comes to oil sands development. IOSI's areas of research are divided into four themes, as revised in early 2014: extraction, product cleaning and partial upgrading, on-line instrumentation, and tailings fundamentals.

IOSI's call for letters of intent (LOI) in December 2018 resulted in 75 LOIs which were reviewed by the Scientific Advisory Committee (SAC) in February 2019. SAC invited 18of the 75 LOIs for full proposals. Out of the 18 full proposals, 8 were recommended by SAC to the Executive Management Committee (EMC), which were approved as the 8new projects for 2019. These included two new extraction projects, three online instrumentation projects, one new product cleaning and partial upgrading project, and 2new tailings process fundamentals projects.

Besides above, during 2019, three projects (two projects under Extraction and one project under Online Instrumentation theme) of strategic priority were approved under "Technology Accelerator" scheme. Funding support was also approved by EMC to "NSERC Senior Industrial Research Chair in Control of Oil Sands Processes" in the area of Online Instrumentation.

LOIs in the theme areas of Online Instrumentation and Extraction and Full Proposals under Tailings theme were invited in December 2019. A total of 11 LOIs and 28 Proposals were received which are under review at the moment by SAC.

The following are the highlights of progress in each of the four themes:

Theme One: Extraction

Current extraction technologies are based on mining the oilsands then contacting it with warm water, which generates large volumes of high water content tailings. These tailings are expensive to store in ponds, there are technical challenges associated with effective dewatering, and the tailings ponds are a risk to the environment. IOSI supports research leading to water-free processing of oil sands, and technologies that use a significantly smaller volume of water.

The technology for oil sands recovery and processing is controlled by the behavior of the bitumen and its interactions with the minerals and water present in the ore. Understanding this behavior is challenging because the oil sands are an extraordinarily complex mixture of components that, so far, defy complete analysis. In order to provide a foundation for new non-aqueous technology, IOSI supports research on bitumen composition, molecular behavior such as aggregation of the asphaltene components, interfacial interactions between bitumen components and mineral surfaces. Although this theme is focused on non-aqueous technology, water is always present in the oilsands ore, and in small quantities can be useful in binding the fine solids to the sand. Research on bitumen behavior at oil-water interfaces supports this effort.

Highlights of the research

Project IOSI2016-04: Biodegradation of cyclohexane under different redox conditions

PI: Tariq Siddique (University of Alberta)

Accomplishments:

The project has successfully cultivated cyclohexane degrading microbial communities originating from fluid fine tailings under aerobic conditions. There is evidence of degradation of both cyclohexane and cyclopentane in microcosms containing non-aqueous solids. These active bottles have been inoculated with fluid fine tailings and biostimulated with nitrogen and phosphorus.For additional treatments under nitrate-, sulfate-iron-reducing and methanogenic conditions, no significant microbial degradation was observed. These findings will be valuable in future biotechnologies wherein scaled up bioreactors may be used to manage the dry tailings derived from non-aqueous extraction processes and ensure that these bioreactors have adequate supplies of nitrogen, phosphorus, and oxygen, as well as microbial cultures from FFT.

Project IOSI2016-05: Removal of hydrophobic bitumen-coated fine solids from NAE bitumen using water droplets with modified interfacial chemistry and bio-inspired polymers

PI: Hongbo Zeng (University of Alberta)

Accomplishments:

Investigated the settling process of bitumen-coated fine solids in cyclohexane with different additives that included the water droplet, amphiphilic polymers, polymers with functional groups and their combinations. Modified interfacial bio-inspired polymers with specific functional groups were designed and synthesized to further reduce the content of fine solids in solvent diluted bitumen using water droplet.

Also, interaction mechanisms among water droplet, fine solids and amphiphilic polymers in cyclohexane were investigated using a colloidal/drop probe AFM technique. Interfacial tension (IFT) of w/o emulsion or between oil (i.e. cyclohexane) and amphiphilic polymer solutions using a goniometerwere studied.

Project IOSI2019-02 (TA):Maltene recovery from TSRU tailings

PI: Qi Liu (University of Alberta)

Accomplishments:

This research was aimed at investigating the interactions of different chemical additives with maltene and asphaltene contained in the TSRU tailings of Imperial Oil's Kearl operation, and utilizing the knowledge to separate and recover maltene from the TSRU tailings. The project started from April 1, 2019. Three batches of TSRU tailings sampleswere collected from Imperial Oil, and 47 batch flotation tests were carried out using Denver D-12 flotation machine and so far tested a dozen chemicals and solvents have been tested. Some chemicals were observed to have the desired selective interactions with maltene versus with asphaltene.

Project IOSI2019-04: Micro/Nanobubbles (MNBs) for Enhanced Bitumen Recovery

PI: Xuehua Zhang (University of Alberta)

The project was approved in 2019. The PI has started the project and initiated the application for matching fund from NSERC in the Alliance Option 2 program, which has opened up recently.

Project IOSI2019-09: Application of High-Pressure Slurry Ablation Technology for Energy Efficient Lump

PI: Sanja Miskovic (University of British Columbia)

Objective:

This project aims to investigate applicability of a new lump ablation and slurry conditioning technology, called high-pressure slurry ablation (HPSA), in oil sands lump ablation and bitumen extraction circuits. The technology already exists and has been proven effective for the disassociation of hydrocarbons from contaminated sands (oil spill site material), a structurally similar material to oil sands. In HPSA, lump ablation is achieved by intensive lump to lump and lump to plate collisions provided by the high-pressure pump moving slurry through a set of nozzles. The research will be performed using a range of laboratory and pilot-scale demonstrations on available 10tph HPSA unit, and lab PSV, and froth flotation units. Research will encompass not only demonstration of HPSA lump size reduction efficiency, but will also aim to evaluate if the technology has the ability to create a conditioned slurry that can be phase separated efficiently using conventional PSV and bitumen flotation processes.

Accomplishments:

The project has been recently approved and contracting is in progress. The contracting process was delayed as although research provider is UBC but technology patent owner is DISA. UBC-UofA category A project contract did not give DISA co-ownership of new IP. DISA objection led to revision/re-negotiation of contract. The matter is being handled by RSO and expected to be resolved soon.

Theme Two: On-line Instrumentation for Oil sands

This is IOSI's newest theme. Research will investigate the development of novel sensors or adaptation of existing sensors from other industries for the rapid real-time online measurements of pertinent operational parameters in oilsands mining, extraction and froth treatment process streams. These sensors must be capable of maintaining performance while operating in a challenging process environment such as streams with high solids contents, bitumen fouling, heterogeneous flows, erosive flows, among other conditions. Examples of such operational parameters include particle size distribution with capabilities to detect ultrafines (less than 0.5 microns) even when mixed with water and/or bitumen; mineralogical composition including clay minerals; tailings stream density (water, clay, bitumen); asphaltene content; viscosity of multiphase flow systems; water chemistry (pH, soluble ions); froth quality; slurry composition (water, bitumen, solids, clays); and ore composition by non-contact methods.

Highlights of the Research

Project IOSI2017-02: Ultra-wideband microwave imaging system for rock and metal detection upstream of the crusher

PI: Rambabu Karumudi (University of Alberta)

Accomplishments:

Lab measurements are successfully conducted to estimate the system specifications. Components and sub-systems were designed, fabricated, and tested including Gaussian pulse generator circuits and their topologies to generate radiated pulses in the order of 40 ps, which is the state-of-the art design. Signal

processing algorithms for 2D and 3D SAR imaging are developed and validated and the proto-type integrated system is developed, and its testing is in progress.

Project IOSI2017-16: Reflective Optical Response of Tailings Flocculation Processes

PIs: Heather Kaminsky (NAIT), Ted Garver (InnoTech Alberta)

Accomplishments:

A full cycle of development for the flocculation analyzer has been completed including specification and use of a camera with illumination system and evaluation of different analysis methods including calculation of flocculation image descriptors. Calculations tested include intensity variation (standard deviation), calculation of the Fourier transform of the images with reduction by summation over different frequencies and calculation of the frequency-dependence of intensity. Also, spatial autocorrelation has been evaluated. These image analysis tools will be implemented into the final software. Fractal dimension analysis was evaluated as a tool for characterization of the flocculation process by imaging, but it did not meet the criteria for inclusion in the next prototype. The changes include improved illumination, improved stirring. Currently InnoTech and NAIT are working on optimize the apparatus and analysis module by testing on various flocculation conditions (FFT types, mixing conditions, and flocculants). Innotech Alberta is working on improvements to the system for delivery to NAIT.

Project IOSI2018-01: Online Monitoring of Bitumen Contents Using Differential Light Radar

PI: Keng Chou (University of British Columbia)

Accomplishments:

The researcher has developed LiDAR with a larger stand-off distance, using a laser with a higher output power to collect signal intensity that is inversely related to the square of the distance between the LiDAR and the sample used. Two possible approaches were studied to compensate for the signal lost. Firstly, the diameter of the telescope was increased. Secondly, the laser power was increased. Optimization of the sensitivity using various wavelengths was accomplished by using signal intensity and penetration depth test. A 2D scanning for bitumen map was created by setting up a scanning unit to image the spatial distribution of bitumen content. The scanning unit consists of two oscillating mirrors and a high-speed signal digitizer records the signal to construct the 2D map.

Project IOSI2019-01(TA): Testing and Implementation of UAS Surveys into Mine Operations at Imperial Oil's Kearl Mine

PI: Ken Whitehead (SAIT)

Accomplishments:

The reconnaissance visits and mine safety training and orientation for all SAIT personnel has been completed; operational visits to Kearl was undertaken; 500% improvement in efficiency of mapping active mine faces has been achieved; development of optimized photogrammetric processing algorithms to rapidly and effectively process the imagery produced from UAS surveys and production of manual of operational procedures for UAS surveys at Kearl. The project is a demonstration of the successful application of the UAV mapping and imaging technology in commercial operation at Kearl. The project also entailed 320 field students-days training of SAIT students and personnel at the Kearl site.

Project IOSI2019-03(TA): Evaluation of Non-Destructive Ore Characterization Technologies

PI: Andrea Sedgwick (NAIT)

Accomplishments:

The researchers conducted Laboratory characterization process at NAIT's Centre for Oil Sands Sustainability and Centre for Sensors and System Integration, for the development of a database representing 100 homogenized ore samples from Kearl oil sands mine. Scanning with Enersoft technology was performed on these samples and was the basis for a chemometric model. In the second phase, additional candidate technology testing and expansion of the ore database was completed. Candidate technologies were tested on the remaining ore samples stored at NAIT's Productivity and Innovation Centre.

Project IOSI2019-08: NSERC Senior Industrial Research Chair in Control of Oil Sands Processes

PI: Biao Huang (University of Alberta)

Accomplishments:

This NSERC-Industry Research Chair in Control of Oil Sands Processes is a partnership among the University of Alberta, Syncrude Canada Ltd., Suncor Energy Inc., Spartan Controls and Emerson.

Focus of this Chair program is to achieve sustainability through improved process control technologies. Process control systems are critical because they allow for steady and safe process operations, efficient production, consistent product quality, less waste, and better control of emissions. Control systems in the oil sands industry operate under challenging circumstances: fewer operations and technical support personnel, uniqueness of oil sands operations, harsh environment for instrument and control systems, and less availability in measurement of key process variables. As a result, there is greater demand for real-time measurement of key variables, earlier detection of process system abnormalities, and more efficient operations. The goal of this Chair program is to address these challenges and provide effective solutions through research on new technologies on estimation, monitoring, data mining and optimization.

Project IOSI2019-07: Multi-Sensor Dean Stark Alternative for Online Bitumen/Solids/Water Estimation

PI: Vinay Prasad, Rambabu Karumudi, Arno de Klerk (University of Alberta)

Accomplishments:

This project addresses an issue that is central to the extraction of bitumen from oil sands - compositional identification of the process streams. The bitumen recovery from the oil sands and the processability of the ores depend strongly on the composition. Compositional identification primarily involves the characterization of the bitumen and clay content in these streams. The presence of clays in oil sands is known to directly impact the bitumen recovery in the extraction process due to the interactions between the bitumen and the clays wherein water chemistry is a major influence on the processability of the ores.

The project is approved but has not started as the PI has applied for NSERC Alliance funding and is awaiting the decision.

Project IOSI2019-11: Fouling-Resistant Surfaces for Oil Sands Applications

PIs: Xuehua Zhang, Qi Liu, Daniel Dan (University of Alberta)

Accomplishments:

This project focuses on understanding the role of micro/nanobubbles (MNBs) in assisting and accelerating bitumen recovery from water-based oil sands extraction. The goal is to search for feasible techniques in commercial oil sands operation for enhanced bitumen recovery. After establishing experimental setup for the

nanobubble generation, conditions affecting the bitumen-flotation bubble interactions will be explored to find out optimal operating conditions. The sizes, population, and stability of the generated MNBs will be determined using advanced instrumentation.

The project is approved and is starting.

Project IOSI2020-01: Integrating Borehole Data with Mine-Face Photography to Improve Geological Models, Imperial Oil's Kearl Mine, Alberta

PI: Paul Durkin (University of Manitoba)

Accomplishments:

The Athabasca Oil Sands deposit is actively mined at surface and produced from wells in the subsurface. While mining, photographs of the mine face are collected; this provides an opportunity to integrate this data with pre-mining borehole data to gain a better understanding of variations in oil distribution that impact production efficiency. Learnings from surface exposures can also be applied to the subsurface to extract oil more efficiently. The proposed project will provide a student with a fully funded Master's thesis project, the opportunity to be engaged in an oil and gas company, and ultimately high-quality training in geoscience techniques and skills.

The project is approved but has not started. The contracting process is in progress.

Theme Three: Product Cleaning and Partial Upgrading

Processing of the bitumen from the oil sands adds to its value, enables transportation by pipeline, and makes it more attractive to many petroleum refineries. The current technologies use heat to break up the largest molecules in the bitumen and high-pressure processing with catalysts and hydrogen to remove the sulphur and other contaminants. These technologies require very large capital investments and give significant emissions of greenhouse gases. We support research on new approaches to separate desirable from undesirable components, reaction of bitumen feeds, catalysis, and production of value-added products. The emphasis of the research is to improve value and at the same time reduce energy consumption and the release of greenhouse gases. The theme includes fundamental research on the molecular structure of bitumen components, on new catalysts for processing bitumen and derived distillates, and new reaction pathways.

Highlights of the Research

Project IOSI2015-03: Multifunctional non-precious upgrading catalysts

PI: Natalia Semagina (University of Alberta)

Accomplishments:

Earth-abundant catalysts were developed as an alternative to the conventional hydrotreating catalysts. In addition to sulfur and nitrogen removal, they possess enhanced hydrocracking activity to single rings.
A series of niobium catalysts promoted with copper were shown to be active not only in hydrodesulfurization but also in hydrodenitrogenation. Mechanistic insights in nitrogen inhibition of olefin hydrogenation were obtained.

Project IOSI2016-06: Non-thermal plasma assisted catalytic bitumen partial upgrading under methane environment

PI: Hua Song (University of Calgary)

Accomplishments:

This research proposed to develop a novel partial-upgrading technology to increase the mobility of the bitumen extracted from surface minable oil sands, and identify the role played by plasma and catalyst individually as well as how they jointly contribute to the bitumen partial upgrading.

Investigations on the plasma reactions with the heavy oil model compounds including cyclohexane, toluene, dodecane and decenehave been carried out. The results showed that the ring alkylation is the major reaction in the conversion of cyclohexane or toluene, while cracking, C-C coupling, and hydrogenation are the dominant reactions for the transformation of dodecane or decene. The investigations of simulated natural gas and liquified petroleum gas showed that light hydrocarbons (C1-C4) are effectively converted into C6-C9 branched-paraffins with low coke formation. The statistically significant synergetic interactions between the catalyst and plasma are observed during the conversion of light hydrocarbons into liquid chemicals. One unique photocatalyst Ti-Ga/UZSM5 has been developed, which could utilize UV/Visible light generated from plasma, thus significantly increase the conversion and liquid yield, and control the coke formation.

Project IOSI2017-15: CO_2 assisted paraffinic froth treatment

PI:Qi Liu (University of Alberta)

Accomplishments:

PFT process was developed in the oil sands industry to clean the bitumen froth generated from water-based extraction process. In PFT, a paraffinic solvent (pentane or hexane) is used to blend with the bitumen froth (at S:B ratio of about 1.6-2:1), which causes the precipitation of the majority of the asphaltene from the bitumen froth. Although PFT causes losses of hydrocarbon (precipitated asphaltene to the froth treatment tailings), the asphaltene precipitates bring with them the water and fine clay contaminants and clean the bitumen froth very nicely. One major problem is the high volume of paraffinic solvents used. This project aims at lowering the solvent volumes required as well as to only precipitate the truly undesirable asphaltene.

The postdoc and MSc student continued to work on the project for the entire year in 2019. After accurately determining the onset of asphaltene precipitation in PFT, CO_2 was injected at different pressures and temperatures, and observed that the CO_2 indeed assisted and increased asphaltene precipitation. The presence of water in the feed stream was found to have the beneficial role in promoting the effect of CO_2. Control tests showed that the injection of nitrogen gas at the same pressure did not have the same beneficial effect as CO_2

Project IOSI2018-02: Low-cost Process of Converting Asphaltene into Valuable Graphene-like Materials

PI: Zhi Li (University of Alberta)

Accomplishments:

This project explores the low-cost processes to convertasphaltene into valuable graphene-like materials that support and provide information to stakeholders on carbon emission reduction and improve energy

storage efficiency. Asphaltenes are being utilized as valuable building blocks to construct graphene-like carbon nanomaterials for energy storage and conversion. The researchers were able to process asphaltene into solid carbon with no carbon emission. Three (3) salts were evaluated as the low-cost template, with the NaCl template delivering the most promising results. Energy storage prototype devices are being developed including, supercapacitator, pseudocapacitators, Li-on batteries and Na-ion batteries.

Project IOSI2018-03: In-situ study of asphaltene precipitation by using total internal reflection fluorescence microscopy

PI: Xuehua Zhang (University of Alberta)

Accomplishments:

The aim of this project is to develop techniques to lower the volume of solvents used in Paraffinic Froth Treatment (PFT) that significantly reduces the energy consumption for recycling the solvents and labor capacity needed for the transportation of bitumen. The researchers have been able to build and test a diffusion-driven mixing chamber to optimize asphaltene solvent/ bitumen ratios. They also tested the dynamical effect from mixing flow rates and diffusion-driven process on asphaltene precipitation at room temperature and at elevated temperatures. the project explored the effects of water droplets and temperature on asphaltene precipitation at room and elevated temperatures. The results and insight provided by this project will serve as the foundation for technology innovation based on optimization of the solvent supply system by using less solvent in PFT.

Project IOSI2018-13: Asphaltene Enhanced Removal by Oscillating Interfaces

PI: Giovanni Natale (University of Calgary)

Accomplishments:

This project aims to develop an innovative method to enhance coalescence to generate larger flocs and achieve more rapid settling within the Paraffinic Froth Treatment (PFT) process. The potential benefits from the research include reduction of solvents, energy and GHG emissions. The researchers have been able to modify the pendant drop apparatus used to measure the interfacial tension of water/model oil systems with oscillatory electric field. They have also measured and assessed the new system using the electric field induced coalescence via bulk emulsion stability tests. Since the oscillating interface method has not yet been tested on complex systems with impurities and multiple stability mechanisms, these results are important for the industry as this process is expected to be low-cost in comparison to current equipment requirements.

During the few months since the project started, the amplifier and oscilloscope necessary to generate AC fields have been purchased. Sameer Mhatre, the research associate hired for the project, has been working on the rheological characterization of the PFT bitumen previously received by IOSI. There are plans perform bulk tests to test the frequency and amplitude of the AC field, amount of solvent, asphaltene concentration, presence of fine solids, and temperature during the first half of 2020.

Project IOSI2019-10: Partial Upgrading of Bitumen

PI: Tariq Siddique(University of Alberta)

Objectives

This proposed research aims to develop enrichment cultures from mature fine tails to partially upgrade bitumen in bitumen froth by breaking the carbon heterocycles and linkages and removing the heavy metals.

As high molecular weight compounds are converted into lighter hydrocarbon fractions via microbial activities, it will reduce viscosity, minimize carbon loss due to asphaltene precipitation in froth treatment tailings and help in transporting bitumen and overall upgrading process. Microbial activities will also enhance water and solids separation from bitumen simultaneously and aid in final upgrading process.

Accomplishments:
The project is slated to start from April 1, 2020.

Theme Four: Tailings Process Fundamentals

Warm water is a low-cost medium for extracting the bitumen from the oil sands, but the clays in the oil sands ore become suspended in water. When these fine particles settle, they form wet tailings which contain the fine particles along with about 70% water by weight. The high water content of the tailings makes the current mining operations net consumers of water, and water used for extraction processes is not returned to streams and rivers.

The oil sands industry faces new regulations that require much more rapid treatment of the tailings, giving a significant reduction in the volume of tailings associated with each mine. IOSI supports the development of new methods for the rapid dewatering of tailings, and integration of extraction and tailings management. Rather than optimizing the water chemistry and additives to maximize bitumen recovery, at the expense of tailings management, we seek an integrated approach.

In the future, the industry will need to treat the water released from tailings and mining sites. New processes are needed to remove the water-soluble components from the oil sands to enable the safe release of this process water. In addition to demonstrating proof of concept on new processing options, the theme includes work aimed at a more fundamental understanding of the interactions of aqueous phase components, minerals, and residual bitumen with additives such as polymers.

The oil sands industry has placed such a high priority on new technology for handling tailings that all of the companies agreed to share all intellectual property in this area, and collaborate on future research and development efforts. The growing importance of tailings is leading to growth of this theme within IOSI in collaboration with the COSIA Tailings EPA. Representatives of the Tailings EPA are actively involved in selecting the new projects within this theme.

Highlights of the Research

There are 25 projects underway in this theme area.

Project IOSI2015-01: Connecting microstructure and rheology for enhanced oil sands tailings reclamation
PI: Milana Trifkovic (University of Calgary)
Accomplishments:
Investigated the correlation between the microstructures of flocs measured by confocal laser scanning

microscope and the rheology of the flocculated system. With non-invasive imaging, the understanding has been developed about the tailings system and optimized flocculation, transport of flocculated samples and optimal design of flocculants. Interaction of cationic polymers with tailings components has been studied and also examined the effect of polymer aggregation on the flocculation efficiency.

Project IOSI2015-02: Novel hyperbranched functionalized polyethylenes for densification of oil sands tailings

PI: João Soares (University of Alberta)

Accomplishments:

Synthesized several highly branched co-polymers based on polyethylene backbone and tested their flocculation effect on diluted mature fine tailings. The branched polymers worked more effectively than the straight chain polyethylene.

Project IOSI2016-01: Laboratory investigation of transport, segregation and deposition of TSRU tailings in subaerial beach environments

PI: Jeffrey Marr (University of Minnesota)

Accomplishments:

The project focused on conducting flume experiments with TSRU tailings material to observe the transport and deposition processes associated with the particles within the TSRU. The facility was constructed in 2017 and has been used to carry out six experiments using a surrogate tailings material. The test run had been conducted on TSRU tailings. The results provided insights on ways to improve the capture of fines within TSRU tailings and improve reclamation of tailings ponds. The project has been completed and the team is in the process of submitting final report.

Project IOSI2016-08: Optimizing the usage of Tubifex to enhance densification and strength of oil Sands tailings: building on recent laboratory test success, towards pilot

PI: Miguel de Lucas Pardo (Deltares, The Netherlands)

Accomplishments:

The project has demonstrated with data that Tubifex can live and reproduce in oil sands tailings when kept under the correct and cost effective circumstances. As well, the project demonstrated that Tubifex improved the dewatering properties (i.e. higher solids content and higher permeability) significantly in lab environment, when compared to conventional treatment.

Project IOSI2016-09: Bugs and veggies as tailings management tools

PI: Amanda Schoonmaker (NAIT)

Accomplishments:

Tailings samples were analyzed for hydrocarbon content and the microbial community assessed. Hydrocarbon concentration was highly variable between treatments and no conclusions could be drawn. The microbial community was affected by the presence of willows, the sampling location in the column (top vs middle), and the presence of hydrochar. The greatest effect on plant biomass was observed in hydrochar amended treatments, this may have been in-part due to the shift in the microbial community where the growth of

Bacilli (Planococcaceaei) and Clostridiales (Clostridiaceae) were stimulated. These bacterial groups are known to contain plant growth promoting rhizobacteria and nitrogen fixing bacteria. Hydrochar as a biostimulant will be further examined in future projects.

Project IOSI2016-10: Technology for in-situ real time measurements of solids content in settling tailings

PI:Ying Tsui (University of Alberta)

Accomplishments:

Lab bench measurements of the scattering of laser light at various angles and at various wavelengths have been carried out and an optimum wavelength for measuring solids content has been determined. Fouling tests have been carried out on various plastic and glass windows and the best "anti-fouling" optical material has been determined. The ability to measure inorganic solids content at a few percent accuracy in test samples of kaolinite and FFT has been demonstrated using two low-level x-ray sources. A specially designed compact, portable, and economical gamma ray detector has been fabricated. The custom-made gamma ray detector can be fabricated at a significantly lower cost than a typical commercial gamma ray detector.A first principle modeling code based on GEANT4 has been developed for the low-level x-ray scattering measurements and compared to the measurements obtained in kaolinite and FFT for different setups. The calculations accurately model the x-ray source and measurement system giving good agreement with the experimental results to within a few percent. Scattering and low-level x-ray measurements were used to track the temporal change of solids content in a settling column filled with a Kaolin and water mixtures and shown consistent results.

Project IOSI2016-12: Development of rapid screening methods to screen and classify mature fine tailings

PI: Cliff Johnston (Purdue University)

Accomplishments:

The project team is developing optical and thermal analysis methods to predict key performance indicators with an aim to develop rapid methods to predict bitumen and water content, along with mineralogical proxies. The emphasis has been on sample presentation, sampling, mixing and statistical analysis.

A new characterization tool based on mid-IR method was developed to rapidly screen and predict key MFT properties based on analysis and benchmarking of 34 different MFTs. Key results were prediction of MBI, weight % bitumen, and weight %solids with reasonable accuracy: RMSEV values of 0.8, 0.4 and 1.53,respectively (same as units of measure).Mid-IR is a promising complementary method to NIR and may offer some advantages in detecting bitumen and differences in clay mineralogy, possibly water quality.

Project IOSI2017-04: Maintaining permeability for continuous mature fine tailings dewatering

PI:Qi Liu, Xiaoli Tan (University of Alberta)

Accomplishments:

The project started from May 2019 after delays in getting the NSERC CRD matching. Mature fine tailings (MFT) were collected and characterized. An ultrafine component of clay and residual bitumen was separated from MFT by centrifugation. After removing the ultrafine component, the MFT was found to respond well to pressure filtration. When the ultrafine component was added to a kaolinite slurry, it severely affected the pressure filtration of the kaolinite slurry. The ultrafine component contains both clays and residual bitumen. At this point it is not clear whether they both had the detrimental effects. According to the project scope,

bitumen flocculants were purchased, and a series of jar tests have been performed to screen appropriate bitumen flocculants.

Project IOSI2017-05: Physical and numerical modeling of progradation of segregating tailing beaches into MFT and associated depositional mechanisms

PI: Jeffrey Marr (University of Minnesota)

Accomplishments:

The project has taken off after modifying the scope to address the most relevant problemsin consultation with project stewards. The research focuses on revealing important processes to avoid or take advantage of when applying co-deposition of two separate tailings streams.

Project IOSI2017-06: Minimization of GHG emissions in froth treatment tailings by manipulation of electron acceptors

PI: Juliana Ramsay (Queen's University)

Accomplishments:

Project aims at reducing greenhouse gas (GHG) emissions in froth treatment tailings ponds via manipulation of electron acceptors. It focuses on using fluorescence spectrometry as a rapid tool to quantify naphtha. Results of earlier experiments are being analyzed and new experiments are in progress such as measuring the abiotic effect of adding phosphate and ammonium nutrients to MFT and GHG production in other MFT samples. Nutrients added are removed abiotically and generate CO2, the impacts of which are being investigated.

Project IOSI2017-07: Partially Hydrophobic and Natural Graft Polymers for the Efficient Treatment of Mature Fine Tailings

PI:Joao Soares (University of Alberta)

Accomplishments:

The project started in Jan 2020 and is in early stages. It plans to synthesize polymers in 1st stage by combining the AP-based polymers with varying graft type, density and length and partially hydrophobic polymers with varying molecular weight, comonomer type and fraction.

Project IOSI2017-10: Effects of shearing on dewatering and compressibility of treated tailings

PI: Clara Gomez (Coanda, Vancouver)

Accomplishments:

The current study aims to link the shear explored in the laboratory setting to realistic field scenarios in a systematic way. The results will provide a more comprehensive understanding of the effects of shear on treated tailings than was previously available, with a particular emphasis on the geotechnical ramifications of tailings transport.Geotechnical testing to determine compressibility and permeability properties of treated and sheared tailings samples was completed, along with the conclusion of the monitoring periods for various geotechnical settling columns. Various analyses were performed on the final consolidated samples following monitoring. Data was analyzed and a conference paper, presentation and final project report were prepared.

Project IOSI2017-11: Evaluation of granular cap success conditions and failure potential on treated fine tailings

PI:Philip B. Solseng (Barr Engineering, Calgary)

Accomplishments:

The project aimed to develop a numerical model to show failure mechanisms and assess anticipated behavior of oil sands fine tailings as a sand and coke cap is hydraulically placed on top and identify critical factors for commercial scale-up. The project was completed in March 2019. Physical experiments were conducted with additional modeling and analysis. Tailings behavior was identified when supporting specific cap geometry along with the factors that are most critical for cap success.

Project IOSI2017-12: From slurry to soil: creating soil from oil sands tailings

PI: Heather Kaminsky (NAIT)

Accomplishments:

The project was completed in 2019. The objective of this study was to develop and compare artificial soil prototypes from oil sands tailings through amendment with nutrients and sand, which can better support the growth of native plant species (Slender wheatgrass, sandbar willow, western dock). Through a mixing study, it was shown that none of the nutrient amendments tested had an adverse effect on tailings flocculation, which indicates a potential for the amendments to be added in-line. Sand addition at an SFR of 1.5 was not problematic to produce, and conducive for plant growth. SFR 0.0 and 3.0 did not meet target. Compost, as the only tested amendment offering a range of micro/macronutrients, most consistently supported plant growth. A mixing study assessed the impacts of nutrient amendments and sand addition on flocculation performance. A six-week growth trial assessed the growth response of three native species to combinations of amendments and sand content.

Project IOSI2018-04: Treating Mature Fine Tailings using Environmentally Safe Engineered Bacteria

PI: Larry Unsworth (University of Alberta)

Accomplishments:

Bacterial strains have been identified; the anchor system for generating the biopolymers and transporting them to the bacterial cell surface was defined. DNA sequences for this anchor system and biopolymers were designed and synthesized. The biopolymer DNA sequences were concatemerized to create numerous highly-repetitive sequences then inserted into the anchor sequences. DNA sequencing has confirmed that the final biopolymer products are correct and ready for biopolymer production.

Project IOSI2018-05: Geotechnical Modeling of Surface Strengthening for Soft Tailings Capping

PI: Jed Greenwood (Barr Engineering)

Accomplishments:

The research team has designed a memorandum summarizing the basis for FLAC modeling. Using the FLAC model and FISH functions, they developed the FLAC model and associated FISH functions for granular capping over a surface straightened material. A new memorandum was developed summarizing the results from the FLAC simulations and recommendations for a surface strengthening material to achieve a stable advancement of capping material over soft tailings and recommendations for capping methods to avoid unstable

conditions. A final report comparing the modeling outcomes with and without surface strengthening, including modes of failure for comparable strengths of the tailings, slope of the cap, thickness of the cap and type of material was drafted.

Project IOSI2018-06: Modeling the Cap Placement with Tailings Deformation and Consolidation

PI: Jim Langseth (Barr Engineering)

Accomplishments:

The team has designed the model on the basis for FLAC modeling, including the model functions to account for "in-filling" as the tailings settle and the advancing delta slope slows. Likewise, they developed a straightforward model (2D) to represent the delta advance and infilling where cap settlement has occurred. They have recorded the results from the FLAC and Delta infill simulations and provided recommendations for tailings strength to achieve a stable advancement of granular capping over soft tailings, and recommendations for capping methods to avoid unstable conditions.

Project IOSI2018-07: Comparison of Rapid Centrifuge Test, geotechnical Beam Centrifuge Test, and Large Strain Consolidation Test for Oil Sands Tailings

PI: Trempess Moore (Thurber Engineering)

Accomplishments:

The researchers have identified key assumptions and lessons learned for the centrifuge consolidation test method to compare centrifuge consolidation test methods. They performed program laboratory tests on three tailings materials and consolidated the test results to compare conventional and centrifuge consolidation tests.

Project IOSI2018-08: Modeling the Cap Placement with Tailings Deformation and Consolidation

PI: Mauricio Pinheiro (Thurber Engineering)

Accomplishments:

Laboratory testing on tailings materials at different fines contact have been done to assess the static liquefaction of unsaturated soils subjected to future saturation. The tests included, initial index testing to study pertinent aspects of the tailings materials, soil water characteristic curve determination to correlate moisture content to suction and improve interpretation of results, as well as miniature cone penetration testing.

Project IOSI2018-09: Effect of Dispersants on Dispersion and Flocculation of Oil Sands Tailings

PI: Marek Pawlik(University of British Columbia)

Accomplishments:

The researchers have completed an assessment of partition of dispersants between the solids and the solution phase and determination of adsorption characteristics of dispersants on tailings. Then a determination of the dispersing capabilities of the tested dispersants was established through measurement of suspension turbidity and solids content in the supernatant as function of dispersant dosage. Lastly, the effect of dispersants on flocculation of tailing suspensions was assessed by characterizing flocculated sediments using laser light backscattering in terms of root-mean-square scattering, signal mean, and aggregation index to quantify the extent of aggregation/flocculation of the sediment.

Project IOSI2018-10: Mechanics of Methane Bubbles in Tailings Ponds

PI: Ian Frigaard (University of British Columbia)

Accomplishments:

The project focuses on single axisymmetric static bubble computations and collinear axisymmetric multi-bubble configurations. The study includes wide experimentation with different methods for bubble nucleation/growth, identification of promising methods and selection, as well as specification of visualization methodology. Currently, the researchers are developing the initial estimates of bubble array behavior by working on axisymmetric computations of steady gas displacement, fitting of results to closure expression, 2D arrays of bubbles in different configurations/interaction of stress fields and conducting exploratory computations.

Project IOSI2018-11: Rheology of Froth Treatment Tailings

PI: Savvas Hatzikiriakos(University of British Columbia)

Accomplishments:

Methodology included setting up of the high-pressure cell (pressures up to 5 MPa that corresponds to depths of ponds of 400 m based on a density of 1200kg/m3) on the rotational rheometer to study the rheological properties of a model fluid and tailings from the field in terms of temperature (-25o C to 100o C – upper limit can be as high as 220o C). A model fluid has been developed based on Kaolinite powder mixed with deionized water and bitumen and appropriate amount of naphtha and rigorous mixing for model fluid experiments. The viscosity of this model fluid will be matched with oil tailings from the field if possible. Using this model fluid enables controlling the variables of interest in a systematic manner and facilitates the measurement of bubble size and morphology with respect to suspension characteristics and flow field.

Project IOSI2018-12: Pipeline Transport of Flocculated Tailings Materials

PI: Clara Gomez (Coanda)

Accomplishments:

Project aims to create a dimensional analysis to explore the adequate parametric space for testing during the pipeline experiments. Potential pipe line configurations have been evaluated to propose a final design for the rig. The researchers have also built and assembled the pipeline configuration. Pipeline experiments were performed with a selected range of well flocculated materials produced in the inline mixer to investigate the pipe flow behavior as well as the impact of the resulting pipe shear rate and pipe length on degradation over varying lengths.

Project IOSI2018-14: Combining Worms and Vegetation to Enhance Tailings Dewatering: Building with Nature on Successfully Tested Methods

PI: Miguel de Lucas Pedro (Deltares)

Accomplishments:

The *Lumbriculus Variegatus* (LV – wetland worm) was introduced into saturated columns filled with thickened tailings. Additional columns included a plant-only treatment as well as untreated control. All columns were saturated for 8 weeks to ensure that LV survives in the tailings. After the 8 weeks passed, 3 replicates of each treatment were destructively harvested prior to surface drying. The remaining 5 replicates were allowed to dry and the mudline, survival of plants and total aboveground biomass data was analyzed. Finally, a bench

scale study on bacteria to measure survival rate was conducted by combining different bacteria and hydrochars into 1L containers of tailings containing LV worms.

Project IOSI2019-05: Constitutive Model Development and Experiment Scale-Up for Fines-Dominated Tailings Deposit Capping

PIs: Jed Greenwood, Jim Langseth, Branko Damjanac, Luca Sittoni, Claudio Tamagnini (Barr Engineering)

Accomplishments:

The proposed work is a key aspect of the ongoing development of an innovative approach to hydraulically place a sand cap on relatively soft treated fine tailings deposits. If successful, this capping approach (called "deltaic capping") will provide a safe, efficient way to cap soft tailings. Deltaic capping promises to be the lowest-cost method of capping large areas for reclamation.

The project has been approved but not started, the contract in progress.

Project IOSI2019-06: The Role of Bubble Ebullition on the Vertical Transport of Fine Solids in End-Pit Lakes

PI: Morris Flynn (University of Alberta)

Accomplishments:

End-pit lakes offer a cost-effective method for tailings disposal but the technology has not yet been given governmental approval in the Athabasca oil sands context. Securing such approval requires not only that key water quality targets be met but that the end-pit lakes satisfy a minimum aesthetic standard. Water turbidity plays an obvious role in either case. Although turbidity is influenced by many factors, there is mounting evidence that bubble release from sediment is of particular importance. This project will investigate more closely the ability of bubbles to resuspend significant quantities of fine solids material. This will be achieved by (i) running laboratory-scale experiments using field material, and, (ii) deriving a complementary theoretical model that is to be validated by comparison with measured data. The development of a predictive model is especially important insofar as providing meaningful guidance to both industry and regulators, both of whom would benefit from having further tools to assess end-pit lake performance.

This project just started in Jan 2020 and is in the early stage.

2. Funding and Partnerships

Funding

IOSI has received a total of $35.2M by the end of 2019 through Endowment Fund from Imperial with spendable allocation of $1.6M for the year 2019. The Foundation Agreement of IOSI between Imperial and University of Alberta was amended and renewed for another 5 years, effective from November 1, 2018 to October 31, 2023.

Besides Imperial contribution, IOSI has received funding from the Government of Alberta's *Access to the Future Fund* that has provided a total of $8.16M as an endowment since 2007. The spendable allocation from this endowment has partially supported the institute's operational overhead.

Over the period of 5 years, Alberta Ingenuity Fund (now part of AI) provided IOSI an investment of $6.0Mand the Alberta Energy Research Institute (also part of AI) contributed $10M commencing in February 2008. AI

has invested a total of$7.36M of funding till date since 2013. In April 2018, AI renewed its commitment for $2.5M over 5 years from April 1, 2018 to March 31, 2023 out of which $1.5M has been received.

For the year 2019-2020, out of total expenditure of $5.97M, $5.78M went into directly supporting research and innovation projects through various project leaders, representing 97 % of IOSI's total annual expenditure. Also, IOSI was able to attract $1.2M of NSERC funding during the period through leveraging research funds.

Personnel Support

Getting high priority support from key stakeholders has been one of the critical factors behind the success of IOSI. It was able to receive strong engagement from Imperial through the Vice President of Upstream Research, Dr. Cheryl L. Trudell and the Heavy Oil Mining Research Lead Dr. Christopher Lin in the governance of the institute. Dr. Trudell chairs IOSI's Executive Management Committee (EMC), while Dr. Lin co-chairs the Scientific Advisory Committee (SAC) and is a member of the EMC. Further emphasizing their commitment, Dr. Lin has deployed 14 research scientists from Imperial and ExxonMobil to help steward IOSI research projects. This has been a very important partnership between University faculty and students and the Imperial staff, who have the knowledge and the vested interest to fully interact with each of IOSI's projects and project personnel.

Alberta Innovates has also placed a high priority on the Institute with Mr. Bryan Helfenbaum, Executive Director, Advanced Hydrocarbons – Clean Energy and Dr. Shunlan Liu, Director, Partial Upgrading all sitting on IOSI's Executive Management Committee. Dr. S. Liu also sits on IOSI's Scientific Advisory Committee.

Canada's Oil Sands Innovation Alliance (COSIA) Tailings EPA has partnered with IOSI to bring together the shared experience, expertise and financial commitment to find new technologies and solutions to tailings. Mr. Dave Corriveau, Director of the Tailings EPA, along with Mr. Abu Junaid and Babak Derakhshandeh who are the Chair and Co-Chair of the Tailings Research Working Group, respectively, participate in the selection of IOSI tailings projects. The tailings EPA has also deployed fifteen individuals from the industry members of COSIA Tailings EPA, including Canadian Natural, Imperial, Suncor, Syncrude, Teck, to help steward IOSI tailings research projects. As with Imperial, this has been a very important partnership between the researchers, students and industry personnel who have the knowledge and expertise to fully interact with IOSI's tailings projects and personnel.

IOSI was able to receive strong support from the University of Alberta. Dr. Fraser Forbes, Dean of the Faculty of Engineering, and Dr. Ken Cadien, Chair of the Department of Chemical and Materials Engineering, sit on the Executive Management Committee. Dr. Qi Liu, the Scientific Director of IOSI, co-chairs the Scientific Advisory Committee. Dr. Natalia Semagina serves as the Associate Director of IOSI and also sits on the SAC. Drs. Ying Tsui, Associate Dean of Research for the Faculty, and João Soares also sit on this committee.

Additionalresearch personnel come from St. Mary's University in Halifax, NS, University of British Columbia, University of Calgary, University of Ottawa, Université de Montréal, the National Institute of Nanotechnology in Edmonton, National Research Council in Ottawa, Northern Alberta Institute of Technology (NAIT), Southern Alberta Institute of Technology (SAIT), Queen's University, Deltares, Coanda, Barr Engineering, Purdue University, University of Minnesota, and Delft University of Technology, in Delft, Netherlands. In addition, the

University provides all of the research facilities used by IOSI in its operations.

Research Partners

Authentic research partnerships always result into better quality and validity of research. Over the period of its existence, IOSI has been able to forge some great partnerships across the academic and industry realm beyond the geographical boundaries. This has resulted in the sharing of world class research facilities amongst the partners thus enhancing the capacity to conduct quality research. Some of the prominent evolved partners include - National Institute for Nanotechnology, nanoFAB, Canada Excellence Research Chairs, NSERC Industrial Research Chairs, more than 50 research scientists, graduate students, undergraduate students spread across more than 15 universities, institutions and companies. Some prominent partners include - TUDelft, Deltares, Barr Engineering, Coanda, NAIT, SAIT, NINT, NRC, InnoTech Alberta, Purdue, SMU, UBC, Queens, UofA, UofC, CarltonU, UofT, UVic, UofMinn and UofO.

Though IOSI is located at University of Alberta, it has attracted a large number of researchers from universities across Canada and beyond who are essential to its mandate. IOSI is expanding Canada-wide, with research projects being conducted at campuses across the country. These include NAIT, SAIT, St. Mary's University, the University of British Columbia, University of Calgary, Université de Montréal, University of Toronto, University of Victoria, Queens University, Carlton University and University of Ottawa. Internationally the institute partners with the Technical University of Delft, Purdue University and University of Minnesota.

IOSI continues its partnership with InnoTech Alberta, the National Research Council, the National Institute for Nanotechnology, and at CANMET Energy Technology Centre in Devon, Alberta. IOSI currently partners with Deltares, an independent institute for applied research in the Netherlands, and two engineering companies: Barr Engineering and Coanda.

3. Training and Development

Research at IOSI provides unique opportunities for training and development of HQPs across the engineering and science disciplines that can be embedded within the study programs. At the University of Alberta, the departments of Chemistry, Chemical and Materials Engineering, Earth and Atmospheric Science, Electrical & Computer Engineering, Renewable Resources and the National Institute for Nanotechnology are currently involved in the program.

IOSI provides an outstanding environment for training of graduate and undergraduate students in oil sands research. In addition to the direct supervision provided by the project investigators, students gain the following experience:

- Direct interaction with industry researchers
- Opportunity to work onsite for the research projects
- Exposure to research methodology and project monitoring process.
- Participation in interdisciplinary conferences and workshops.
- Leadership development activities.

- Training on research equipment in the IOSI Analytical Lab, supervised by the IOSI technical staff.

Through active participation in research the students have been able to achieve a high level of scientific exposure combined with a significant understanding of the research needs of the oil sands industry.

Workshops

Workshops provide great opportunity for the researchers to interact and share their research results in a stimulating and learning environment. IOSI organized twoworkshops on oil sands processing during 2019, and invited researchers from various universities, industry, laboratories and academia. These workshops were designed to bring together current IOSI researchers with prospective researchers and industry experts to identify specific knowledge gaps and research needs for oil sands and share the research results. These workshops were:

1. Workshop on Innovations in Bitumen Upgrading: This workshop was held on June 17, 2019 in Edmonton and was jointly organized by Alberta Innovates, Canmet, IOSI and Suncor. The objective of the workshop was to review current scientific understanding of bitumen composition, identify future directions for value addition on carbon-based fuels and develop research projects to address high-priority knowledge gaps in upgrading technologies. More than 45participants from government (Alberta Innovates, InnoTech, NRCan- CanmetENERGY Devon), academia (University of Alberta, University of Calgary, McGill University), and oil sands companies (CNRL, Imperial, Suncor, Syncrude Canada) attended the workshop. The research gaps were discussed and announcements were made regarding funding opportunities.
2. IOSI's "Tailings Project Stewardship and Knowledge Dissemination Review" Workshop (November 21, 2019, Calgary). Researchers from University of Alberta, Deltares, Purdue University, University of Calgary, Coanda, NAIT, University of Minnesota, Barr Engineering and Queen's University reported results of 11 ongoing or just-completed tailings projects to COSIA member companies and industry stewards.

4. Governance and Management

The IOSI management structure consists of two committees, the Executive Management Committee (EMC) and the Scientific Advisory Committee (SAC).EMC is chaired by Dr. Cheryl L. Trudell, Vice President Upstream Research of Imperial. The EMC provides strategic direction, monitors progress, approves budgets, research plans and intellectual property proposals, and recommends research areas for faculty appointments to the Dean of Engineering. Mr. Bryan Helfenbaum from Alberta Innovates and Christopher Lin from Imperial joined EMC; Natalia Semagina from the University of Alberta has been appointed as IOSI's Associate Director from November 19, 2018 and serves as a SAC member as well as an ex-officio member on EMC. All other members on both EMC and SAC have remained the same.

The EMC held two strategic meetings in July 2019and November 2019 and conducted environmental scan to identify changes in the sector, assess external factors and determine current oil sands research needs. The group discussed ways to align research with industry needs, opened the discussion on one of the theme area - Product Cleaning and Partial Upgrading. Need was felt to refocus

and rename the theme to *Value Added Products* keeping in view the industry priorities and changed scope and provide value addition to research. Also need was emphasized to maintain the inventory of trained HQPs in the area.

In February 2019, the SAC reviewed 75 letters of intent and invited 18of them to submit full proposals. Eight of the 18full proposals were recommended by SAC to the Executive Management Committee for funding as 8 new IOSI projects for 2019. Besides these, three new projects were recommended under "Technology Accelerator" scheme taking the tally of new projects in 2019 to 11.

The committee conducted multiple stewardship meetings over the last year to review the progress of, and provide guidance to the research projects. The formal stewardship meeting was held in May and the informal stewardship meeting was held in November. The feedback following the stewardship reviews continues to indicate their value to the research process.

Governance Structure

Executive Management Committee Membership:

CHAIR	MEMBERS:	EX-OFFICIO
Cheryl L. Trudell, Imperial	Christopher Lin, Imperial Fraser Forbes, U of A Ken Cadien, U of A Bryan Helfenbaum, Alberta Innovates Shunlan Liu, Alberta Innovates	Qi Liu, Scientific Director Natalia Semagina, Associate Director Jagvir Singh, Manager Research Operations

SAC organizes calls for research proposals from universities across Canada, reviews and screens proposals, and works with researchers to align proposals with existing work and strategic direction and areas. The SAC proposes projects to the EMC to be funded, and conducts "gate reviews" on research projects. At the initial stages of a project, these reviews help ensure that each research proposal is aligned with the objectives of IOSI and the business needs of the oil sands industry. As research progresses, these reviews will determine which projects are ready for further technology development.

Scientific Advisory Committee Membership:

CHAIR:	MEMBERS:	EX-OFFICIO
Qi Liu, U of A	Christopher Lin, Imperial (Co-chair) Shunlan Liu, Alberta Innovates Natalia Semagina, U of A Ying Tsui, U of A João Soares, U of A Babak Derakhshandeh, COSIA (Tailings) Abu Junaid, COSIA (Tailings)	Jagvir Singh, Manager Research Operations

Dave Corriveau, COSIA (Tailings)

Institute Staff

Jagvir Singh, Manager Research Operations
Xiaoli Tan, Research Associate and IOSI Lab Manager
Lisa Brandt, Research Technician
Brittany Mackinnon, Research Assistant
Lynette Hussain, Administrative Financial Assistant

Research Support

The IOSI technical team consists of a research associate and two research technicians who provide general laboratory support to researchers and scientific support to research projects. Sixty per cent of time is spent on general laboratory support and the remaining 40 per cent on specific research support.

The IOSI technical team manages laboratory resources and provides a safe environment for researchers working in the laboratory. The facilities in the IOSI laboratory include:

- bench-scale separation and preparation equipment for solvent extraction of oil sands, minerals separation, tailings treatment, reactors for upgrading of bitumen, asphaltene separation, and chemical reactions
- extensive analysis capability at molecular level for fundamental research by advanced equipment including: intelligent gravimetric analyser (IGA), gas/residual solvents analyzer (DSMS, QIC), particle size analyzer (Mastersizer 3000, FBRM G400), thermogravimetric analyzer (TGA), Infrared spectrometer (Nicolet 6700), gas chromatograph (Sim Dist, SRI, GC-MS), liquid chromatograph (HPLC, Flash), elemental analyzers (CHNS, CHNS/O), rheometer (Marlvern Kinetic Lab+), tensiometer (Krüss K100), atomic force microscopy (Bruker Innova), and TAM III isothermal microcalorimetry (TA Instruments).
- a series of high temperature/pressure reactors for bitumen product cleaning projects (funded by Future Energy Systems), which expands capacity for bitumen treatment up to 5.5 liters per batch at high temperature and pressure (up to 500°C and 5,000 psi) with an incorporation of novel in-situ hot pressure filtration unit (up to 400°C and 300 psi).

The main activities of the IOSI technical team include set-up and maintenance of labs and equipment; training researchers in analytical equipment and experimental methods; sample inventory and preparation of the IOSI samples bank; procuring research materials; and reciprocal service to other oil sands research groups in the Faculty of Engineering.

In 2019, more than 40 researchers including graduate students, postdoctoral fellows, research technicians and research assistants have been working in the IOSI laboratory to carry out different research projects.

The IOSI technical team also contributes expertise by carrying out high-level, complex research activities under the direction of the IOSI director and principal investigators. These activities included designing

experiments, research methods, data collection protocols and standards; setting research activities; assisting and coordinating the analysis of results; supervising graduate students and research assistants; proposing new research directions under the IOSI theme areas and research scope; and fostering communication with off campus partners.

Promotion of the Institute and its Research

As part of the D.B. Robinson Distinguished Speaker Series in the Department of Chemical and Materials Engineering, IOSI sponsors the Andrew Main Lecture. Each year, the Andrew Main Lecture features an internationally-renowned engineer and/or scientist who inspires students and faculty members alike. This lecture combines exemplary scholarship and industrial relevance—befitting Dr. Andrew Main.

Dr. Dongyuan Zhao from Fudan University, China is scheduled to present the 2019 Andrew Main Lecture on "Multi-Level Architectured Functional Mesoporous Materials: Synthesis and Application on Catalysis" on April 16, 2020.