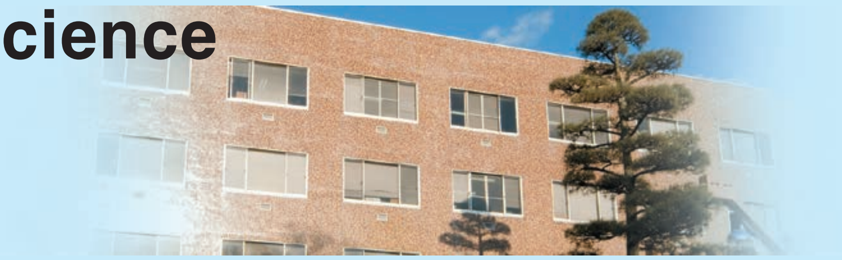
Institute of Fluid Science
Tohoku University

2022



TOHOKU UNIVERSITY

Institute of Fluid Science Tohoku University IFS

We contribute to society with world-class fluid research and education.

Director Kaoru Maruta

The Institute of Fluid Science, Tohoku University is a state of the art research center of fluid science.

Past

It all started with cavitation research

The origin of the Institute of Fluid Science was the Institute of High Speed Mechanics, established in 1943. The original purpose of the Institute was to research cavitation occurring on an object in a high speed flow. The Institute is well known to have contributed considerably to the development of the first Japanese jet engine. After World War II, the Institute supported industrial fluid application such as the development of power plant turbines, sea ship propellers, and airplane engines. In the 1980s, the research areas of the Institute expanded and diversified from flows under ordinary conditions to those under extreme conditions such as high temperature, high pressure, and high speed, including microflow dealing with molecules, complex flow accompanying chemical reactions, and blood flow through blood vessels. In line with this expansion, the Institute of High Speed Mechanics was renamed the Institute of Fluid Science (IFS) in 1989 and was reorganized into four research divisions: Advanced Flow, Intelligent Fluid System, Non-continuum and Heat Transfer, and Complex Flow. The Shock Wave Research Center also established at that time was later reorganized into the Transdisciplinary Fluid Integration Research Center in 2003. In 2013, the Institute of Fluid Science (IFS) was reorganized into three research divisions and one research center to activate interdisciplinary research collaboration further and to contribute to the solution of energy problems. In 2015, the Collaborative Research Division was launched. IFS also inaugurated the Advanced Fluid Information Research Center (AFI) in 1999, the Advanced Flow Experimental Research Center (AFX) in 2013, the Global Collaborative Research and Education Center (GCORE) in 2015, and the Aircraft Computational Science Center (ACS) in 2017. With various programs adopted by the Japanese government such as establishment of the COE Formation, the 21st Century COE and the Global COE Programs, IFS has been promoting research and education activities aggressively as a world-class advanced fluid science research center. We have also been promoting international collaborative research projects as the Joint Usage/Research Center in the field of fluid science since 2010.

Present

State-of-the-art computational and experimental research

IFS has established the Lyon Center (Integration Research Center for Materials and Fluid Sciences) in 2018 and has renewed the Collaborative Research Division, "Advanced Vehicle Technology Study (Keihin) Ⅱ." Today, IFS is a world-class advanced fluid science research center with 32 research laboratories under four research divisions and two research centers: Creative Flow Research Division, Complex Flow Research Division, Nanoscale Flow Research Division, Collaborative Research Division, Innovative Energy Research Center and Lyon Center. The Creative Flow Research Division conducts studies of creation of novel functions of flow. The Complex Flow Research Division conducts research on clarification of complex flow phenomena. The Nanoscale Flow Research Division conducts studies of clarification of Nanoscale Flow phenomena. The Collaborative Research Division conducts fundamental research of advanced vehicle technology with Hitachi Astemo,Ltd. The Innovative Energy Research Center conducts studies of utilization of unused energy by multidisciplinary fluid science. The Lyon Center conducts integration research for materials and fluid sciences. AFI is also going to replace its supercomputer system in 2018 to perform cutting-edge research such as large-scale flow simulation, measurement-integrated simulation and advanced visualization. Research is conducted using world-class experimental equipment such as a low-turbulence wind tunnel and shock wave research facilities in AFX. As a world-class center of the fluid science community, GCORE is conducting activities using its worldwide network, and have hosted an international symposium held every year since 2001. ACS academically supports the aircraft industry in collaboration with Multi-Physics Design Laboratory established in 2018 at Organization for Advanced Studies.

Future

World center of fluid science where world researchers gather

IFS has amended VISION2030 in September, 2021. Based on research, technology, and international networks we have been developing, IFS will become the world center of the fluid science by 2030, aiming to realize and improve the safety, security, and health of people and society and to explore a comfortable and rich future. Every researcher at IFS arbitrarily belongs to these research clusters: "environment and energy," "nano-micro," "health,welfare,and medical cares(life science)," and"aerospace." The goal of this endeavor is to enhance researchers' interactive activities particularly addressing resolution of challenges faced by society. We also plan to develop new international research and education through the activities of the Lyon Center. IFS strives continuously to foster the development of students and to conduct cutting-edge research to meet the demands of our rapidly evolving society.

Organization Chart (Research Divisions and Laboratories)

【Creative Flow Research Division】

The Creative Flow Research Division was established to create and to apply novel functions in flows in fluid systems. The development of fluid science and the creation of innovative engineering are pursued through elucidation of flows and creation of novel functions in electromagnetic fluids, living body flows, and flows in aerospace conditions.

- Creation of novel flow functions using an electromagnetic field
- Development of next-generation intelligent fluid control devices and systems
- Development of advanced medical devices based on measurement-integrated simulation
- Clarification of flow dynamics in a living body
- Innovation, safety, and manufacturing of aerospace systems
- Creation of innovative thermal and fluids control systems for next generation spacecraft
- Harmonic design of energy systems with nature
- Creation of optimal, robust, and intelligent fluid machinery systems

【Complex Flow Research Division】

The Complex Flow Research Division was established to explore and to apply complex flow phenomena related to various physical and chemical processes that constitute the foundation of fluid science. Development of fluid science and the creation of innovative technologies are pursued through investigation of combustion reaction flows, heat and mass transfers in complex systems, cavitation, shock waves, turbulent flows and universal principles of heat and material flow phenomena, as well as construction of mathematical models.

- Combustion phenomena in aerospace propulsion systems and energy apparatuses
- Nano-to mega-scale heat and mass transfer in complicated systems
- Complex flow accompanied by cavitation and advanced fluid machinery systems
- Study on elucidation of complex propagation phenomena in gas-liquid-solid three-phase and its interdisciplinary application
- Theoretical modeling for universal and specific complex flow phenomena

【Nanoscale Flow Research Division】

The Nanoscale Flow Research Division was established to advance basic science and to explore new R&D areas related to nano/microscale thermal and fluid phenomena and thermophysical properties. Creation of novel medical technologies and development of innovative nanoscale thermal and fluid devices are pursued through the progress and deepening of science, as well as investigation of mass–momentum–energy transfer mechanisms on scales of electrons–molecules and new discoveries of nanoscale flow characteristics in living bodies and nano-devices.

- Physical and transport phenomena in non-equilibrium gas flow and their applications
- Nanoscale flow and interfacial phenomena governing macroscopic thermal and fluid properties
- Physical mechanism of the quantum effect of fluid molecules on flow dynamics
- Reactions, thermal flow dynamics of plasma flow and their application for medical engineering
- Transport phenomena in large-scale composite systems governed by molecular physics and their applications
- Development of novel flow devices utilizing unique nanoscale flow and interfacial phenomena

【Collaborative Research Division】

The Institute of Fluid Science, Tohoku University, and Hitachi Astemo, Ltd. have established a joint research department and have been able to obtain results in the first and second phases. In the third phase, as "Fundamental research of advanced vehicle technology (Hitachi Astemo)Ⅲ", the next-generation inverter that drives the motor will be ultra-compact, lightweight, and high-performance for future vehicle electrification toward the realization of a low-carbon society. We will promote the fundamental research to realize those kinds of basic technologies. The research conducted by the Collaborative research division is related mostly to the enhancement and the application of the simulation technology based on computational fluid dynamics and experimental verification. By conducting collaborative research between Hitachi Astemo, Ltd. and Institute of Fluid Science, Tohoku University, aims to create new value directly connected to development of appealing products with excellent environmental performance based on the research of such next-generation technology.

- New Cooling System Construction and Element Technology Research for Next-Generation Inverter
- Numerical Elucidation of Laser Fusion Bonding Technology
- Elucidation of Solder Void Generation Prediction Technology
- Construction of an Optimization Method for New Cooling Technology and Laser Melting Technology

【Innovative Energy Research Center】

The objective of this center is to realize a highly efficient, economical, and innovative energy utilization system through research and development related to conversion of unrealized energy, which has been achieved heretofore only slightly using conventional technologies, by the adaptation of improved storage, transportation, and maintenance of energy in basic energy and new energy fields based on fluid science.

- Innovative green nanodevices based on intelligent nanoprocesses
- Deep subsurface systems for the resolution of environmental and energy issues
- Combustion with higher exergy efficiency based on new concept combustion technology
- Optimization of maintenance activities using advanced sensing and material evaluation
- Innovative multi-phase flow technology and realization of sustainable energy systems
- Science and technology, and energy policy to contribute to the solution of energy problems
- Advanced energy related technologies
- Theoretical design of innovative batteries based on the analysis and control of nanoscale flow

【Lyon Center (LyC) — Integration Research Center for Materials and Fluid Sciences】

The Lyon Center (LyC) was established to promote international joint research activities which the IFS faculty members and graduate students staying at Université de Lyon (INSA Lyon, École Centrale de Lyon) carry out. Especially, we explore interdisciplinary science based on materials science and fluid science to answer current social challenges in the fields of transportation, energy and engineering for health.

- Intelligent sensing and evaluation of mechanical systems
- Design of smart materials and fluids system
- Spatiotemporal multiscale clarification of flow dynamics

【Advanced Flow Experimental Research Center (AFX)】

Specially Appointed Associate Professor Kiyonobu Ohtani
Senior Fellow Yasufumi Konishi

【Aircraft Computational Science Center (ACS)】

【Advanced Fluid Information Research Center (AFI)】

【Global Collaborative Research and Education Center (GCORE)】

* Concurrent
** Cross-Appointment

	(Professor)	(Associate Professor)	(Assistant Professor)
【Electromagnetic Functional Flow Dynamics Laboratory】	Hidemasa Takana		
【Intelligent Fluid Control Systems Laboratory】	Kaoru Maruta*		
【Integrated Simulation Biomedical Engineering Laboratory】	Makoto Ohta*	Kenichi Funamoto	
【Biomedical Flow Dynamics Laboratory】	Makoto Ohta	Hiroyuki Kosukegawa**	Hitomi Anzai
【Aerospace Fluid Engineering Laboratory】	Shigeru Obayashi		Aiko Yakeno
【Spacecraft Thermal and Fluids Systems Laboratory】	Hiroki Nagai		Xinyu Chang
【Design of Structure and Flow in the Earth Laboratory】	Takatoshi Ito*	Anna Suzuki	
【Fluids Engineering with Data Science Laboratory】	Shigeru Obayashi*	Koji Shimoyama	
【High Speed Reacting Flow Laboratory】	Hideaki Kobayashi Hirohide Furutani (Visiting Prof.)	Akihiro Hayakawa	Sophie Colson
【Heat Transfer Control Laboratory】	Atsuki Komiya		Yuki Kanda
【Advanced Fluid Machinery Systems Laboratory】	Yuka Iga	Junnosuke Okajima	
【Complex Shock Wave Laboratory】	Hiroki Nagai*	Kiyonobu Ohtani*	
【Computational Fluid Physics Laboratory】	Yuji Hattori	Makoto Hirota	
【Non-Equilibrium Molecular Gas Flow Laboratory】	Taku Ohara*		
【Molecular Heat Transfer Laboratory】	Taku Ohara		Donatas SURBLYS Hiroki Matsubara
【Quantum Nanoscale Flow Systems Laboratory】	Takashi Tokumasu		Takuya Mabushi**
【Biological Nanoscale Reactive Flow Laboratory】	Takehiko Sato		Siwei Liu
【Molecular Composite Flow Laboratory】	Taku Ohara*	Gota Kikugawa	
【Nanoscale Flow Application Laboratory】	(Visiting Professor)		
【Fundamental Research of Advanced Vehicle Technology (Hitachi Astemo) Ⅲ】	Jun Ishimoto*		
【Green Nanotechnology Laboratory】	Seiji Samukawa		Daisuke Ohori
【Energy Resources Geomechanics Laboratory】	Takatoshi Ito		Yusuke Mukuhira Liu Bailong
【Energy Dynamics Laboratory】	Kaoru Maruta	Hisashi Nakamura	Youhi Morii
【System Energy Maintenance Laboratory】	Tetsuya Uchimoto*		
【Multiphase Flow Energy Laboratory】	Jun Ishimoto		Ippei Oshima
【Energy Science and Technology Laboratory】	(Visiting Professor)		
【Advanced Energy Engineering Laboratory】	(Foreign Visiting Professor)		
【Novel Battery Nanoscale Flow Concurrent Laboratory】	Takashi Tokumasu*		
【Mechanical Systems Evaluation Laboratory】	Tetsuya Uchimoto		Sho Takeda
【Advanced Materials and Fluids Design Laboratory】	Jean-Yves Cavaillé (Visiting Prof.)	Kaori Yuse** Lucile Joly-Pottuz** Carole Frindel**	
【Flow Dynamics Laboratory】	Makoto Ohta* Atsuki Komiya* Hidemasa Takana*		Aiko Yakeno* Sophie Colson*
【Division for the Establishment of Frontier Sciences of the Organization for Advanced Studies Multi-Physics Design Laboratory】	Shigeru Obayashi* Tomonaga Okabe*		Yoshiaki Abe

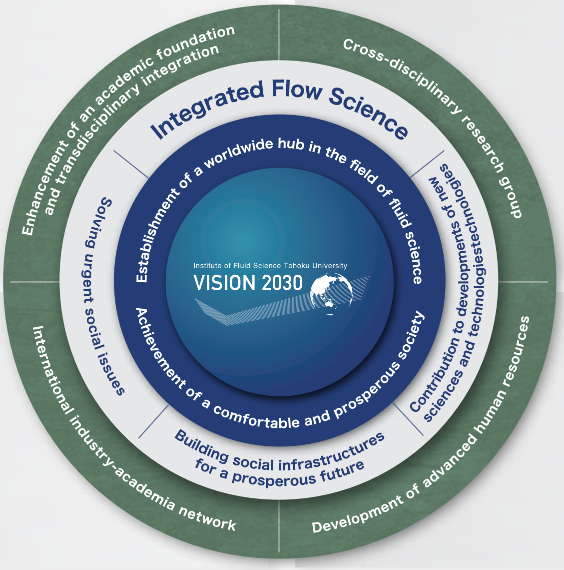
The Mission of the Research Cluster

In September 2021, the Institute of Fluid Science amended its VISION2030 to reflect the tumultuous changes in social conditions in recent years. Under this new vision, it has reorganized into four research clusters, which are unique interdisciplinary research groups in the fields of “environment and energy,” “nano-micro,” “health, welfare, and medical cares (life science),” and “aerospace.” From now on, the work of these clusters will form and advance a new academic foundation of integrated flow science, to contribute to the building of a comfortable and affluent society.

Action 01

Enhancement of an academic foundation and transdisciplinary integration

Creation of a new field of study by the transdisciplinary integration of different research fields in fluid science while enhancing the academic foundation of fluid science research.



Action 02

Cross-disciplinary research group

Contribution to society and industry through organizational studies by the construction of four research clusters including “environment and energy”, “nano-micro”, “health, welfare, and medical cares”, and “aerospace” and one research team as an “IFS task force for urgent social issues”.

Action 03

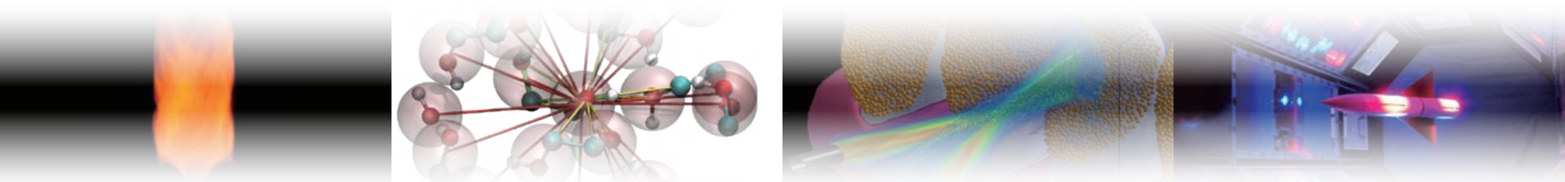
International industry-academia network

Establishment of a hub of international collaborative research by actively transmitting research results both within Japan and overseas through an international industry-academia network.

Action 04

Development of advanced human resources

Creation of an attractive environment and research and education system, and development of advanced human resources that can play active roles in domestic and international research institutions and industries.



Environment and energy

We aim to develop integrated flow science to realize a decarbonized society and create a new energy system

The COP26 "Glasgow Climate Pact" reaffirmed the need for the entire world to tackle global warming issues with specific numerical goals, and the need to control greenhouse gas emissions and create new energy sources have become urgent issues. In order to solve these urgent issues while maintaining and improving industrial activities and quality of life, to weave together the creation of knowledge from entrance to exit are required, along with an awareness of green growth strategies. It is essential to secure new sources of energy with low environmental impact, promote the introduction of self-sufficient renewable energy, further develop energy-saving technologies, and so on. With the environment and energy cluster, we will rethink the conversion and creation of energy, which is essential for human activities and sustainable development, and promote a wide range of research and development, from basic to applied technologies, to solve environmental and energy problems in a wide range of time and space.

Nano-micro

We aim to build an integrated flow science in which we analyze the phenomena that arise on a nano-micro scale and apply them to technological development in all fields

Recent developments in science and technology have made it possible to design and manufacture equipment with nano and micro-scale structures. Moreover, owing to the increased precision and miniaturization of the processing technology, new types of devices which apply functions which arise on these scales are being built actively in all fields. The purpose of nano-micro cluster is to analyze such nano-micro scale phenomena using supercomputers and large-scale experimental facilities, and to build an academic field that comprehensively understands them from the perspective of fluid science. We will also develop innovative devices and processing technologies that utilize these phenomena to improve the function and performance of equipment in various industrial fields.

Health, welfare and medical cares

We aim to realize a healthy and comfortable society through integrated flow science

The social environment is changing drastically due to the rapidly aging society and declining birthrate. The creation of advanced health, welfare, and medical technologies is necessary in order to realize and keep a healthy, secure, and affluent life. This cluster aims to construct new theories of integrated fluid science by clarifying transport phenomena in living organisms and interaction phenomena between living organisms and physical stimuli. Specifically, we aim to develop methods for diagnosis, prediction, measurement, and modeling related to humans; data-driven prediction and conservation related to the living environment and health; recovery and addition of human functions; application to the treatment of stroke and heart disease through the development of biomodels; prevention, treatment, diagnosis, and prediction related to infectious diseases and cancer; plasma medicine; and regenerative medicine. We are also working on the development of protein and cell processing technologies.

Aerospace

We aim to contribute to the development of the aerospace field by clarifying the phenomena in the flow field related to spacecrafts and aircrafts through integrated flow science

The development of innovative spacecrafts and aircrafts for the next generation requires an understanding of a wide variety of flow fields, including flows in extreme environments such as high-temperature, high-pressure, cryogenic temperature, and rarefied atmosphere, multi-phase flow with phase change and plasmas/combustion flow with chemical reactions, and nano/micro/macroscale spatiotemporal flow. In addition, the development of highly efficient airframes and engines is necessary for green growth strategies to achieve a carbon-neutral international society, and the flow fields associated with spacecrafts and aircrafts must be controlled with high precision. Aerospace cluster aims to establish an academic field that comprehensively understands the phenomena from the viewpoint of integrated flow science, including flow field analysis using wind tunnels and supercomputers and mathematical and data science approaches.

Number of Full-time Staffs (2022.5.1)

Professors	Associate Professors	Assistant Professors	Specially Appointed Associate Professors	Specially Appointed Assistant Professors	Specially Appointed Research Fellow	Administrative Staffs	Technical Staffs	Limited Regular Employees	Total
16(1)	11(4)	10(2)	3(0)	5(1)	5(0)	9(2)	13(0)	11(10)	83(20)

※Numbers in parenthesis represent the number of females, and are included in the totals

Number of Students (2022.5.1)

B3	B4	M1	M2	D1	D2	D3	Total
1(0)	36(3)	62(9)	60(5)	10(1)	17(2)	24(2)	210(22)

※Numbers in parenthesis represent the number of females, and are included in the totals

Expenses (FY2020)

(Units: Million yen)

Operational Grants 1,663		External funding 679					
Personnel Expenses	Operation Expenses	Grants-in-Aid for Scientific Research	Sponsored Research Fund	Joint Research Fund	Sponsored Project Fund	Grants	Scholarship Donations
663	1,000	160	366	117	18	5	13

Academic presentations (2020)

Journal papers (International)	Journal papers (Domestic)	Presentation in international conferences	Presentation in domestic conferences	Total
164	9	303	256	732

Building

Total building area 13,167m^2

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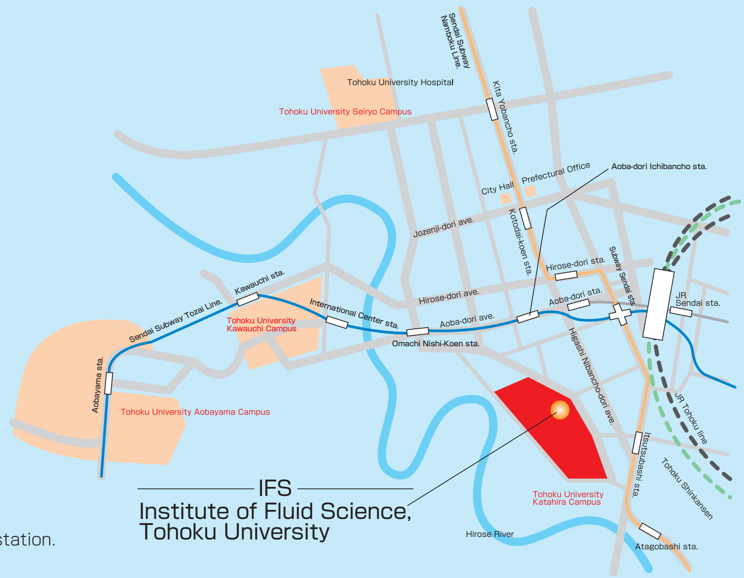

25 mins. by train from Sendai airport to Sendai station.
20 mins. walk from Sendai station to IFS.