9. Department of Simulation Science

Fusion plasma is a typical complex system which is characterized by multi-hierarchy, nonlinearity, non-equilibrium, and openness. It consists of multi physics and multi time/space scale processes from macroscopic process such as plasma transport through microscopic electron dynamics. For full understanding of complex phenomena in fusion plasma a holistic viewpoint is very important in addition to the investigation of fundamental processes in an individual hierarchy. Based on the recent remarkable development of the information technology such as supercomputer, network and visualization system, the conventional simulation research is now evolving to the new paradigm, "Simulation Science", which will enable us to comprehend a multi-hierarchy system holistically.

The Department of Simulation Science was established in 2007 with aiming to promote simulation science based on the studies of the dynamics of nonlinear, non-equilibrium, open systems, in which the fusion plasma system is centered. The Department consists of the Division of LHD and Magnetic Field Confinement Simulation, the Division of Fusion Frontiers Simulation, and the Rokkasho Research Center (Fig.1). Besides, the computer working group, the network working group, and the virtual reality (VR) taskforce are organized to support activities of various collaboration researches.

There are two tasks in simulation science at the Department. One is to construct the simulation methodology and simulation environment that enables us to deal with the complex multi-hierarchy system consisting of multi time/spatial scale processes and multiple physics. The second task is to understand and systemize physical mechanisms in fusion plasmas and explore science of complexity in plasma as a basic research supporting fusion plasma studies by utilizing developed methodology and simulation environment. For these tasks three simulation projects, i.e., LHD and Magnetic Confinement Simulation Project, Laser Fusion Simulation Project and Plasma Complexity Simulation Project have been launched.

In the LHD and Magnetic Confinement Simulation Project, various researches on multiple physical processes and their mutual interactions occurring in core and edge plasmas are being done based on fluid and kinetic simulations aiming at the realization of the LHD numerical test reactor. Full three-dimensional nonlinear simulations of MHD instabilities in the LHD plasma are done by using the MINOS code. For the purpose of construction of the basis of MHD and extended-MHD simulations to promote collaborative simulation research, the MHD Infrastructural code for Plasma Simulation (MIPS) is developed. The Alfven eigenmode (TAE) bursts, which cause the loss of energetic particles in the LHD plasma, are reproduced by MHD simulations with neutral-beam injection and collision taken into account. The motion of the plasmoid produced by the pellet injected into the LHD plasma is investigated by the pellet ablation code (CAP). Microinstabilities and turbulent transport in core plasmas are studied by using the Gyrokinetic Vlasov (GKV) simulation code. The GKV simulations show effective regulation of ITG turbulence by zonal flows in the neoclassically-optimized LHD configuration. A 1D two-fluid model is used for simulations of plasma profiles in the LHD edge region and PIC simulations are performed for kinetic analysis of plasma-surface interaction. An integrated modeling code for three-dimensional configurations, TASK3D, is being developed, and modules for rotational transform, radial electric fields, and NBI heating are implemented in collaboration with Kyoto University and the Department of LHD Project.

The Laser Fusion Simulation Project has been promoted to totally clarify physics of the Fast Ignition and to design targets for FIREX (Fast Ignition Realization EXperiment) project at Osaka University by the Fast Ignition Integrated Interconnecting code (FI^3) simulation under the tight collaborations with Osaka University, Setsunan University, Kyushu University, and the Japan Atomic Energy Agency. Under this project the Arbitrary Lagrangian Eulerian hydro code (PINOCO), the collective Particle-in-Cell code (FISCOF), and the relativistic Fokker-Planck code (FIBMET) are integrated with data exchanges. By analyzing the core heating characteristics for various foam parameters with FI^3 simulations, it is found that there are an optimum density of the foam and a necessary minimum thickness of the coating. In the case of 20ncr with 60μm thickness foam, the core electron can reach 2.6keV.

The Plasma Complexity Simulation Project aims to clarify magnetic reconnection phenomena, which are controlled by various physics from micro to macro-scale, in solar and magnetosphere plasma and fusion plasma, and to clarify the physics of plasma-material interaction in compound physics system. Innovative simulation methods called multi-hierarchy, multi-scale, and multi-physics models are now being developed under domestic and international collaborations. Preliminary model for multi-hierarchy simulation of magnetic reconnection phenomena has been developed, which is designed to interlock three different simulation models based on domain decomposition method. Generation mechanism of C_2H_2 from the chemical spattering on a graphite surface is clarified by using molecular dynamics simulation model with an interaction potential function between carbon and hydrogen developed based on the Brennar potential. Multi-hierarchy simulation scheme called a primal Equation-Free Projective Integration (EFPI) scheme is developed and applied to simulate the ion sound wave paradigm.

The present activity of the Rokkasho Research Center communicates with organizations related ITER/ITER-BA such as JAEA, Aomori prefectural office and Rokkasho village office and gathers information, and quickly reports the necessary information to researchers in domestic universities as the Inter-University Research Institute.

The Department will further promote a large-scale simulation research which will lead to the construction of the LHD Numerical Test Reactor predicting overall behaviors of fusion plasmas, while assembling simulation methodologies developed in various applications into our simulation models and improving them under intensive international and domestic collaborations. In order to make these collaboration researches more effective the hardware and software simulation environment should be improved furthermore.

Two large-scale computer systems, the Plasma Simulator and the LHD numerical Analysis System, have been installed and periodically upgraded to support various research activities under the NIFS collaboration program. The Plasma Simulator is a high-performance computer system to support the studies in confinement physics of fusion plasmas and their theoretical systematization, the exploration of science of complexity as the basic research, and other collaborative researches to advance and establish simulation science. The LHD numerical Analysis System serves mainly for the LHD Experiment Project and its related simulation projects, and the research collaboration with worldwide universities and institutes. The previous Plasma Simulator, NEC SX-7/160M5, was replaced by HITACHI SR16000 with the total peak performance 77TFlops and the total main memory 16TB on March 3, 2009. Furthermore the main system will be upgraded to total peak performance 315TFlops and total main memory 32TB with 2.0PB storage in October 2012.

The computer working group and the network working group have continuously worked to support various collaboration research activities with utilizing the large-scale computer systems and the NIFS campus network under the NIFS collaboration program. In addition, the network working group provides various network services in steady and secure condition. A large-scale numerical simulation creates a huge amount of numerical data. In order to analyze such a huge data and extract a physical essence we need to develop innovative analysis tools as a task of simulation science. The Virtual Reality (VR) taskforce has continuously developed scientific visualization technologies, which work on NIFS VR System "CompleXcope", as powerful tools to explore the science of complexity in plasma.

The social events and other academic activities including two public lectures, the simulation science symposium, the Toki lectures on simulation science, and various workshops were hosted to provide the opportunity for scientists to exchange opinions and academic information on simulation science and for students and citizens to lean simulation science.

We hope that the Department of Simulation Science will promote the collaboration researches on theory and simulation more intensively and contribute toward constructing simulation science.

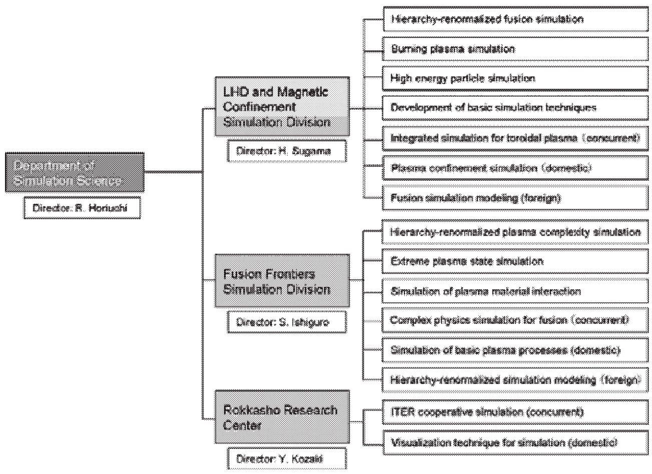

Fig.1. Organization of the Department of Simulation Science as of April 1, 2009.

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