Feb. 17, 2012
Ver. 2a

KAGRA System Engineering Management Plan

System Engineering Office

Table of Contents

Preface

What is system engineering in the first place? There are so many seemingly different and wide variety of definitions in numerous textbooks and documents but we will not try here to discuss the generic definition. Instead we should define our specific system engineering focusing on our unique system that is KAGRA.

KAGRA has currently 14 subsystems and we definitely need the activity to integrate the subsystems into the whole system from the perspective which is different from that of each of the 14 elements. We will, for the time being, call this specific activity “KAGRA system engineering". If we have brilliant and competent researchers and engineers for each of the 14 subsystems - and fortunately we do - it does not automatically guarantee the success of the whole system. Something missing is to be added to the picture of bundled discrete elements of KAGRA for their successful integration and completion. We will call this “something missing to be added” as system engineering.

System Engineering Management Plan (SEMP) is a basic plan for all the management functions to be fulfilled by “our” system engineering activities as defined above. This plan is by no means a fixed code, but a living document to be updated by the KAGRA team continuously throughout the development phase of the KAGRA. In that sense, this document hopefully will be frequently referred to, evaluated, leveraged to enhance the coordination among the subsystems - contributing to the success of the KAGRA project.

One of the important objectives of SEMP is to provide the KAGRA team members with a common understanding of the system engineering management philosophy thus facilitating them to share the common idea in association with the target and the strategy with which they accomplish it.

We know that KAGRA team is challenging a difficult undertaking with limited resources and a tight schedule and also know that all the KAGRA people are extremely busy with the daily activities focusing on their own subsystems. So let me thank all of the KAGRA members who have contributed to the development of the KAGRA SEMP document by sparing their precious time. The system engineering activities at this time are all the more important because each of the team members is very busy and is occupied with the activities for his/her own subsystem.

February 17, 2012 (updated)
Ichiro Nakatani
Project Manager, KAGRA

1. Overview of KAGRA Project

KAGRA (The name has been changed from LCGT : Large-scale Cryogenic Gravitational wave Telescope), as one of the world network of gravitational wave detectors, aims at the detection of gravitational waves by a 3 km baseline laser interferometer with cryogenic mirror system placed underground at Kamioka as shown in Fig. 1.1

The development of KAGRA started as a 6.5 year project in October 2010, but later it was rescheduled as a 7.5 year project due to the suspension of the budget for the start of tunnel excavation as a result of the Great East Japan Earthquake which occurred on March 11, 2011. The KAGRA development is divided into two stages: initial KAGRA (iKAGRA) and baseline KAGRA (bKAGRA). In the 5 year iKAGRA stage the mirror system will be kept at room temperature with SAS (Seismic Attenuation System) and RSE (Resonant Sideband Extraction) not in operation while the bKAGRA is the latter 2.5 year development stage where the final goal is to be pursued with full equipment in operation including SAS, cryogenic system and RSE.

The host organization to conduct the KAGRA project is the Institute for Cosmic Ray Research, the University of Tokyo with a number of organizations both domestic and international involved. Up to now 27 Japanese and 15 overseas universities and research institutes have joined the KAGRA collaboration and still counting. The official agreements to establish international collaborations have been concluded between ICRR and 7 foreign institutes shown in Table 4.1.

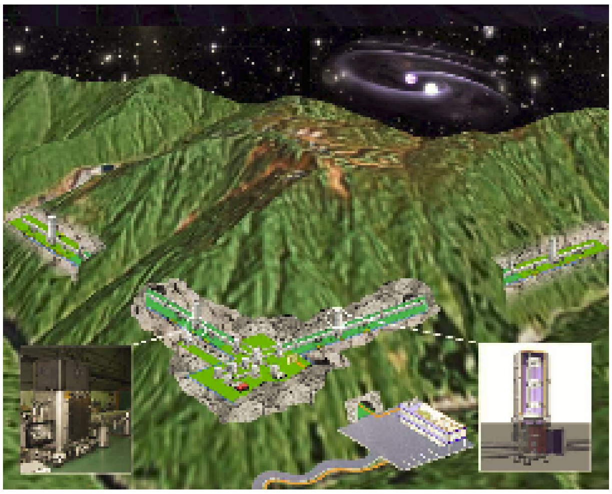

Fig. 1.1 Conceptual rendering of KAGRA

2. KAGRA Requirements

2.1 Requirements of iKAGRA and bKAGRA

KAGRA, in the final configuration of bKAGRA, is designed to achieve the aim to detect gravitational-wave signals. Among several expected gravitational-wave sources, the primary observation target is selected to be an inspiral and merger of neutron-star binary. This is because it is the most certain source: its existence has been proved by radio-pulsar surveys, and its event rate has been theoretically estimated from astronomical observation results.

So as to observe more than one gravitational-wave signal in one-year observation run, KAGRA is required to have observable range of 240Mpc for a neutron-star inspiral event, and operation duty cycle of 90%. These requirements on KAGRA sensitivity and stability are broken down into the requirements for each of the subsystems mainly based on technical feasibility.

The main purpose of iKAGRA (initial phase KAGRA) is to establish the first milestone for the steady detector construction. So, reliable and stable interferometer operation is more important in this initial phase than sensitivity for astronomical observation. The target of this iKAGRA stage, thus, is to establish a 3-km interferometer with simplified optical configuration at room temperature. The requirements are set to be moderate with minimum additional development neccesary only for this initial stage.

2.2 Requirement Allocation

The requirement for KAGRA is to be flowed down into that for each of the subsystems. In this section the basic idea for the requirement allocation is described without giving actual requirement in values which are shown in the Interface Control Document (ICD) and the corresponding interface-parameter list (JGW-T1100360, see the latest version).

Required values for the subsystem components are determined in such a way that the KAGRA target sensitivity be achieved with all the noise curves summed up in the spectrum. Some of the setup parameters are shared by multiple subsystems and those interface parameters shall be controlled by the System Engineer Office (SEO). The above mentioned ICD shall be updated each time any of the parameters is modified.

(1) Major components of each subsystem

Tunnel (TUN): 3km tunnels, center room, end rooms, entrance tunnels, water drainage system
Facility Support (FCL): buildings, power supply system, clean rooms, air conditioning, temperature control,
humidity control
Vacuum (VAC): vacuum ducts, vacuum chambers, baffles, flanges, vacuum pumps
Vibration Isolation System (VIS): Type-A/B/C SAS, suspension fibers (excl. Sapphire fibers), local controls
Mirror (MIR): core optics, MC mirrors, MMT mirrors
Cryogenic System (CRY): cryostats, heat link, Sapphire fibers, radiation shields, refrigerators
Main Interferometer (MIF): optical layout of the main interferometer
Digital System (DGS): CDS, signal transferring cables, ADC, DAC
Analog Electronics (AEL): PD, QPD, actuators, CCD, monitors
Input Output Optics (IOO): MC, OMC, Faraday isolator, EOM, MZ, BRT
Laser (LAS): laser (1064nm, 532nm)
Data Analysis (DAS): DAQ system, data analysis pipelines
Geophysics Interferometer (GIF): 1.5km interferometers, seismometers, environmental sensors

(2) Requirements and Interface Parameters

Seismic Noise

The requirement is mainly allocated to VIS and its supporting subsystems including DGS and AEL. In addition, TUN is in charge of the treatment of the floor tilt that determines the horizontal-vertical seismic-noise coupling, and CRY is in charge of seismic noise from the heat link. MIF and IOO are in charge of the beam-centering control, alignment control, etc. that are essential for the seismic-noise coupling from the auxiliary degrees of freedom. VAC and CRY are in charge of seismic noise appearing on the scattering light from the vacuum duct, cryostat, radiation shield, etc., which in fact shall be treated separately as it is rather an issue of the optical layout (see "Scattering Noise"). Namely, the allocation is summarized as follows:
[Direct Responsibility] VIS
[Indirect Responsibility] DGS, AEL, TUN, CRY, MIF, IOO

Suspension Thermal Noise

The requirement is mainly allocated to VIS and its supporting subsystems including DGS and AEL. TUN is in charge of the horizontal-vertical coupling, and CRY is in charge of providing suspension fibers that transfer the heat from the mirror. MIF and IOO are in charge of the beam-centering, alignment control, etc. Namely, the allocation is summarized as follows.
[Direct Responsibility] VIS
[Indirect Responsibility] DGS, AEL, TUN, CRY, MIF, IOO

Mirror Thermal Noise

The requirement is mainly allocated to MIR and CRY. FCL is in charge of the cleanliness of the laboratory and mirror assembly areas, which are related to the mirror quality. MIF is in charge of the lock-acquisition system using 532nm lasers and can be related to the coating design. CRY together with VIS is in charge of the ears and the suspension clamps on the mirror. AEL is in charge of the actuators on the mirror. Namely, the allocation is summarized as follows.

[Direct Responsibility] MIR, CRY

[Indirect Responsibility] FCL, MIF, VIS, AEL

Quantum Noise

Quantum noise sets requirements on MIF, MIR, and LAS. MIF is in charge of the robust control of the interferometer and low sensing noise from the auxiliary degrees of freedom. MIR is in charge of the low optical losses, the high surface/curvature accuracy, the low birefringence, and the mass of the mirrors. LAS is in charge of the high-power laser. Associated subsystems are IOO, DGS, AEL, and FCL for the low optical loss and RF sidebands (IOO), low excess digital control noise and realization of robust control (DGS), low excess analogue control noise (AEL), and high optical quality of the mirrors (FCL). Namely, the allocation is summarized as follows.

[Direct Responsibility] MIF, MIR, LAS

[Indirect Responsibility] IOO, DGS, AEL, FCL

Residual Gas Noise

The requirement is allocated to VAC. Associated subsystems are MIF for the g-factor, CRY for the cryostat vacuum level, and AEL for excess residual gas noise at the coil-magnet actuators. Namely, the allocation is summarized as follows.

[Direct Responsibility] VAC

[Indirect Responsibility] MIF, CRY, AEL

Scattering Noise

The subsystems responsible for scattering noise are MIF, IOO, VAC, CRY, and AEL. MIF and IOO are in charge of the optical design of their system and VAC is in charge of the detailed optical layout. FCL used to be in charge of scattering light reduction but the scope has been modified. MIR is in charge of the surface accuracy of the mirrors. VAC and CRY are in charge of seismic motion of the vacuum duct and cryostat, respectively. Moreover, the scattering light does not cause observational noise but also a heat problem, which should be taken care of by MIR and CRY. AEL is associated with this requirement for the possible scattering light on the photo-detectors and/or CCDs. Namely, the allocation is summarized as follows.

[Direct Responsibility] MIF, IOO, VAC, MIR, CRY

[Indirect Responsibility] AEL

Control Noise

See “Quantum Noise” requirement allocation.

Gravity Gradient Noise

TBD

Up-conversion Noise

TBD

Schedule

The requirements above should be satisfied in the finite time. The roadmap of the KAGRA project is set by the KAGRA Roadmap Working Group (LRM) and the schedule according to the roadmap is controlled by the Project Manager (PM).

3. Schedule

3.1 Overall Schedule

A brief schedule for KAGRA development is shown in Fig.3.1 where a fiscal year starts in April and ends in March the next year. The whole KAGRA development spans 7.5 years starting in October 2010 and completing in March 2018. The KAGRA project is conducted in two stages, the initial KAGRA (iKAGRA) for 5 years and 3 months and the baseline KAGRA (bKAGRA) for 2 years and 3 months as follows:

iKAGRA (October 2010 – End of December 2015) :
- 3 km Fabry-Perot Michelson Interferometer
- mirrors at room temperature
- simplified vibration isolation system (VIS) with a 'Stack-B' (Type-B payload on a stack) to be used
- RSE (Resonant Sideband Extraction) system not in operation
- with the target to establish stable operation of large-scale interferometer
- one month engineering/observation run in the final phase

bKAGRA (January 2016 - March 2018) :

- final form of KAGRA with full spec
- engineering/observation run will follow the completion of bKAGRA starting from March 2018

Each of iKAGRA and bKAGRA incules following milestones with major events and activities:

iKAGRA:

- budget partially approved	Jun. 2010
- start of iKAGRA	Oct. 2010
- tunnel excavation and facility construction	Apr. 2012 - Mar. 2014
- installation of vacuum system	Apr. 2014 - Mar. 2015
- installation and test of cryostat	Apr. 2014 - Dec. 2015
- installation of Fabry-Perot Michelson interferometer	Apr. 2014 - Nov. 2015
- engineering/observation run	Dec. 2015

bKAGRA:

- SEC installation	Aug. 2015 - Nov. 2015
- Center interferometer up-grade/change	Jan. 2016 – April 2016
- Dual Recycled Michelson interferometer	May 2016 - Aug. 2016
- Full test of cryogenic test mass	Jan. 2016 - July 2016
- Installation of Sapphire test mass	July 2016 - Dec. 2016
- Commissioning of RSE interferometer	Jan. 2017 - Aug. 2017
- Commissioning of cryogenic interferometer	Sept. 2017 - Feb. 2018
- Engineering/observation run	Mar. 2018 -
- Observation	Sept. 2018 -

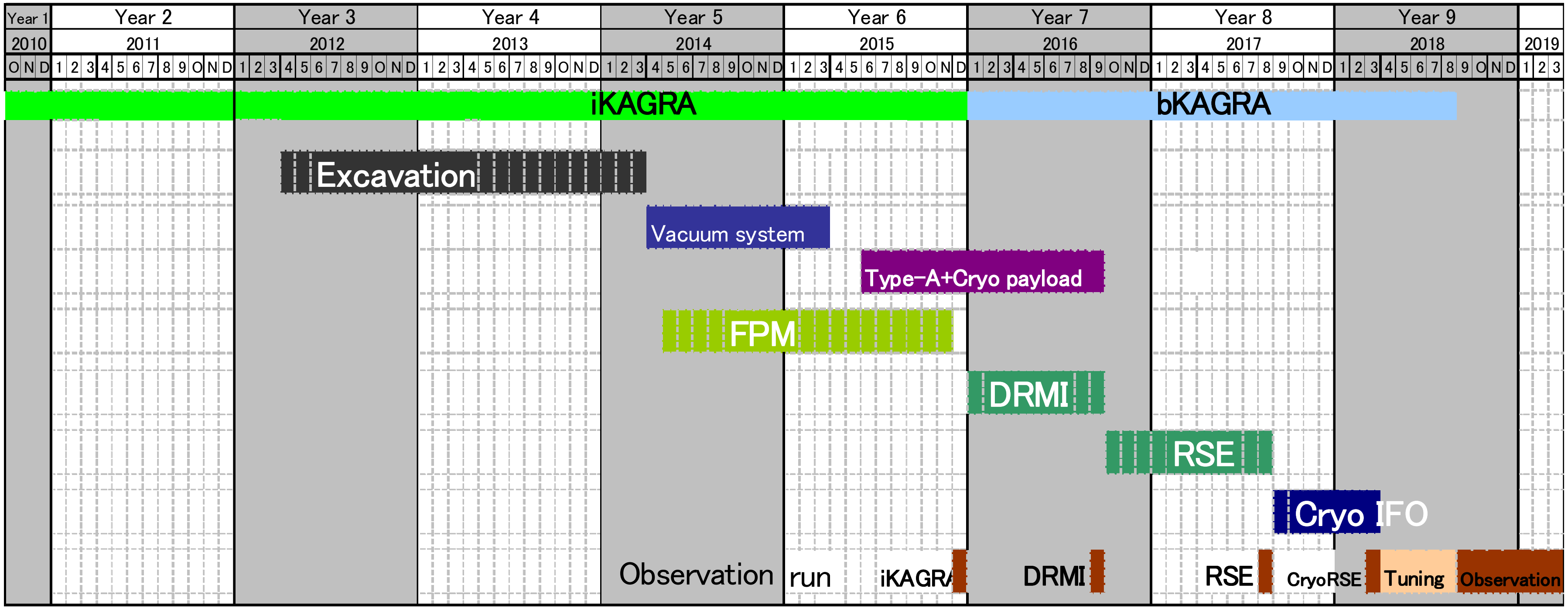

Fig.3-1 KAGRA Schedule

3.2 Schedule Management

The overall schedule of the KAGRA project shown in the previous section is based on the collection of the detailed planning by all of the 14 subsystem working groups. The System Engineering Office (SEO) is in charge of continuously tracking the progress of the activities of each of the subsystems thus confirming the progress of the KAGRA project as a whole. The procedure for the KAGRA schedule management is briefly summarized as follows:

1) Each of the subsystem is requested to work out a detailed plan which conforms to the overall schedule of the KAGRA project. This will require a close dialogue between the subsystem and the SEO.

2) The above mentioned detailed plan is described using a tool shared by all the subsystems in a common form. This plan will hereafter be called a bottom-up schedule.

3) Major milestones are to be indicated in the bottom-up schedule for achieving the goal of each subsystem. The measure of the progress is to be clearly shown for each of the milestones. The number of the necessary milestones may depend on the nature of each subsystem, but typically some 10 milestones for each subsystem are recommended.

4) Bottleneck milestones for each of the subsystems are to be shown in the bottom-up schedule through indicating the order of the schedule sequences using arrows. The effects of the delay in the completion of any milestones upon other activities is to be easily grasped by looking at this chart.

5) If the SEO finds any delay in achieving a certain milestone which affects the timely start of other activities, immediate action is to be taken to coordinate the activities of related subsystem(s). If it needs additional budget or human resources or any other serious action, it is to be recommended to the Executive Committee.

4. Organization

4.1 KAGRA Collaboration

The KAGRA project as shown in Fig 4.1 is conducted by the Institute for Cosmic Ray Research (ICRR), University of Tokyo as a host organization together with two other co-host organizations: National Astronomical Observatory of Japan (NAOJ) and High Energy Research Organization (KEK). Researchers from 27 Japanese and 15 overseas universities and research institutes are participating in KAGRA as collaboration members.
The total number of the collaboration is currently 120.

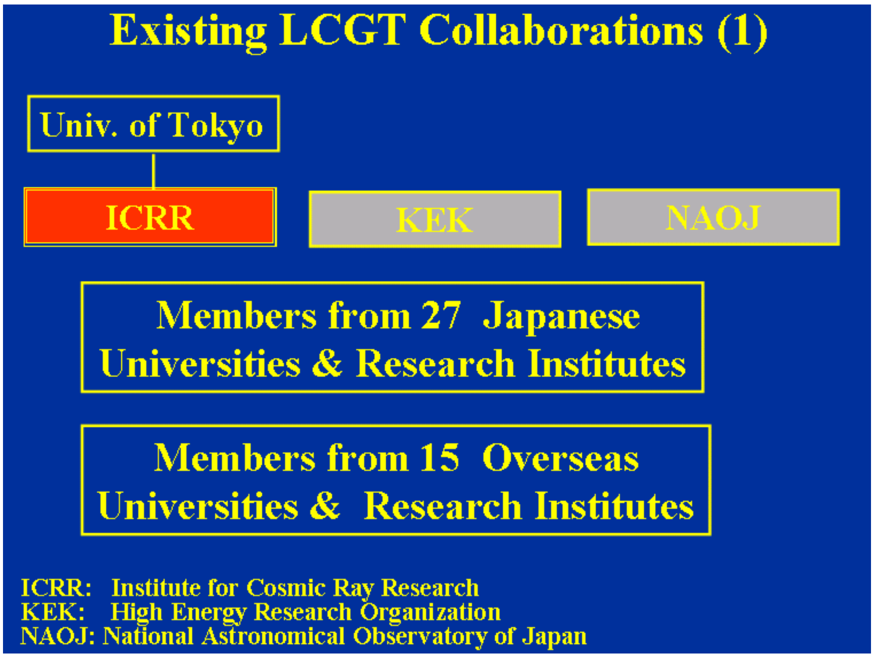

Fig.4.1 LCGT Collaboration Structure

4.2 Project Organization and Task Definition

Fig.4.2 shows the KAGRA project organization chart where each of the 14 Working Groups is in charge of its respective subsystem: Data Analysis, Tunnel, Facility, Vacuum, Vibration Isolation, Cryogenics, Mirror, Main Interferometer, Digital System, Analog Electronics, Input/Output Optics, Laser, Auxiliary Optics and Geophysics Interferometer. It is to be noted that every member involved with the KAGRA project as shown in the organization chart is on a voluntary basis with no official position assignment given, which keeps the morale of the team members very high, while it is not possible to force any team member to accept assignments without his or her full understanding of its purpose.

The task for each position is defined as follows:

Principal Investigator (PI)

Principal Investigator supervises the whole program, plays a role of a contact point for MEXT and chairs the Executive Committee

Executive Committee (EC)

Executive Committee with 6 members is chaired by Principal Investigator and makes top level decisions as a collegial body. Each of the 6 members is charged with the following tasks:

- Project Management
- KAGRA Collaboration and External Affairs
- Finance
- Review Implementation (the member and the alternate)
- Other Items

Program Advisory Board (PAB)

Program Advisory Board is comprised of outside senior peers and is charged with the task of reviewing the overall KAGRA status and giving advice, where "overall status" covers such items as setting of science goals, project management, organization, construction status and future plans. The PAB meeting as a rule is held twice every year where the project status is reviewed based on the presentations by the KAGRA management and working group members.

International Board of Representatives (IBR)

The International Board of Representatives is comprised of the KAGRA Executive Committee members and the Principal Investigators from abroad representing each country or region to request budget in his/her own region. The board is to discuss a long term KAGRA policy and also to coordinate the scope of the activities of the international partners and the schedule of the meetings. The board meeting is to be held twice a year or more – typically at the Face-to-Face Meetings.

Project Manager (PM)

The Project Manager is responsible for the smooth progress of the project with the following activities to be covered:

- coordinating the subsystem activities with a particular emphasis on interface control
- configuration control of the subsystems through oversight of modifications with timely work-arounds
- assignment of work packages to the different subsystems
- monitoring and tracking the performance of each subsystem against its schedule, and technical target
- supervising System Engineering Office activities to fulfill above responsibilities

Project Management Support (PMS)

Executive Support Group assists Executive Committee members in managing the project. The members are the Systems Engineering Office members and the leaders of the Working Groups.

KAGRA Council

LCG Council is comprised of the directors representing three co-hosting organizations, ICRR, NAOJ and KEK plus leaders of gravitational wave experiments in these organizations and senior researchers who dictate research laboratories of gravitational wave physics in other institutes. The KAGRA Council meeting as a rule is held once a year where advices will be given mainly to establish financial plan.

System Engineering Office (SEO)

1. <<SEO Objective>> System Engineering Office is in charge of checking, implementing and evaluating the KAGRA project activities through looking over the whole system from the scientific, technical and strategic viewpoints thus supporting the Project Manager in leading the project to success.

2. << Major Activities of SEO>> To attain the objective listed above, SEO will conduct following activities for managing the project activities.

(1) Taking the initiative in formulating schedule, baseline strategy and development of roadmap for the project.

(2) Continuously confirming the smooth progress of the project subsystem activities to identify problems which require quick resolution through recommendations, discussions, implementations and evaluations. Refer to Section 3.2 for schedule management.

(3) Coordinating the subsystem interface from the standpoint of overlap, lack or conflicts among the subsystem interface items in parallel with conducting Configuration Control of the subsystems.

(4) Proposing, conducting and organizing the Type-A(internal) and Type-B(external) reviews.

(5) Facilitating the information sharing among the subsystem WG's and/or between the Executive Committee and subsystem WG's including the document control.

3.<<Miscellaneous>> The SEO activities are conducted as follows:

(1) The assistance by the KAGRA Support Group or other project members is to be requested as necessary.

(2) Recommendations on the issues which affect project budget, schedule and personnel are to be proposed to the Executive Committee.

Data Analysis (DAS)

Data Analysis Working Group is in charge of data collection, analysis, distribution and archiving covering the following:

- raw data spool and transfer
- primary data processing (pre-processing) to generate and re-pack the calibrated data
- storage of raw and calibrated data
- computing platform (hardware)
- computing environment (software)
- data distribution among KAGRA collaborators
- data sharing with international gravitational wave detectors
- search for gravitational waves
- collaborations with counterpart observations (e.g. X-ray or gamma-ray observatories),
- analysis of gravitational wave events leading to gravitational physics and new astronomy.

Tunnel (TUN)

The KAGRA interferometer will be constructed in a large experiment room placed in the underground site of Kamioka mine. The experiment room needs access tunnels from the outside. The experiment room and the access tunnels consist of a lot of tunnels which will be newly excavated for KAGRA. The experiment room consists of three areas (Center, X end and Y end) and two 3km arm tunnels. Two access tunnels will be provided for each area access.

The Tunnel Working Group is in charge of:

1) design of the tunnels for KAGRA
2) construction and maintenance of the tunnels

Facility (FCL)

Facility Working Group is in charge of installation and operation of internet, power line, water drainage and the facilities for providing clean environment; being a liaison to the local community; controlling safety and environment.

Vacuum (VAC)

Vacuum system is to provide vacuum environment for the entire interferometer system to be operated in a vacuum for avoiding any noises due to in-space molecules and adsorbed molecules on the mirrors. The material choice and surface treatment for almost all of the components are to be discussed form the view point of vacuum performance.

Vacuum Working Group is in charge of development the following:

- vacuum system
- drawing the detailed layout of components and optical instruments

Vibration Isolation (VIS)

Vibration Isolation Working Group is in charge of the development of vibration isolation system for all the optical systems covering the following:

- Type-A system for the main mirrors, ITM1, ETM1, ITM2 and ETM2. It consists of an Inverted Pendulum (IP), four stage Geometrical Anti-Spring (GAS) filters and a cryogenic mirror suspension.
- Type-B system for the core optics, BS, PRM, PR2, PR3, SRM, SR2 and SR3. It consists of an IP, two stage GAS filters and a mirror suspension.
- Type-C system for small optics such as MCF, MCE, PD, etc. It consists of three stage stack and a mirror suspension.
- mechanical design for the cryogenic suspensions for the test mass mirrors which are cooled to 20K through heat links.

NB: The final stage consisting of a sapphire mirror, sapphire wires and heal links are covered by the cryogenic subsystem.

Cryogenics (CRY)

Cryogenics Working Group is in charge of development of cryogenics system of KAGRA listed in the followings:

- Cryostat
  - Vacuum chamber.
  - Radiation shields. The temperature of the outer shield is 80 K and that of the inner shield is 8 K.
  - Heat conduction path on the radiation shields.
  - Support of radiation shields with high mechanical stiffness and low thermal conductance.
  - Flexible heat links between the inner shield and the platform of SAS.
  - Heat conductor to the cryocooler units.
  - Position adjustable connection to type-A SAS.
  - Connection to the vacuum ducts.
  - Access holes with an enough openings.
  - Low outgas thermal insulation.
  - View ports for optical monitors of mirror position.
- Low vibration cryocooler unit for the cryostat.
  - CLIO-type vibration isolator for 2-stage pulse-tube cryocooler.
  - Double heat conduction path with low outgas thermal insulation.
  - Solid conduction path with a flexible connection made of high-purity aluminum.
  - Support of the conduction path with high mechanical stiffness and low thermal conductance.
  - Soundproofing of compressors.
- Shield duct
  - Baffles for stopping thermal radiation from the vacuum duct at room

temperature. Baffles are designed to reflect or absorb obstacle radiation
 - Optimal design of baffles for both configuration and surface treatment.

- Vibration isolator of cryocooler for cooling shield duct.
  - CLIO-type vibration isolator for single stage pulse-tube cryocooler.
  - Thermal insulator with low outgassing.
  - Soundproofing of compressors.
- Sapphire mirror suspension.
  - Connection method between the mirror and the support rods.
  - Connection of rods to the Intermediate mass of type-A SAS.
  - Auxiliary support of the mirror and the rods.
- Monitoring of cryogenic system.
  - Temperature distribution inside of cryostats and shield ducts.
  - Status of cryocoolers.
- Transportation and installation of instruments belonging to the cryogenic system.

Mirror (MIR)

Mirror Working Group is in charge of the development of mirrors for iKAGRA and bKAGRA as listed below.

Input Test Mass of X-arm (ITMX), Input Test Mass of Y-arm (ITMY), End Test Mass of X-arm (ETMX), End Test Mass of Y-arm (ETMY), Mode Cleaner1 (MC1), Mode Cleaner 2 (MC2), Mode Cleaner 3 (MC3), Mode Matching Telescope 1 (MT1), Mode Matching Telescope 2 (MT2), Power Recycling Mirror (PRM), Power Recycling 1 (PR1), Power Recycling 2 (PR2), Signal Recycling 1 (SR1), Signal Recycling 2 (SR2) and Signal Recycling Mirror (SRM)

The items to be developed are:

1. Materials
   - Silica for room temperature mirrors
   - Sapphire for cryogenic mirrors
   - Their optical absorption, homogeneity and birefringence affect the interference performance of the interferometer.
   - Their optical absorption of Sapphire determines the lowest temperature of the cryogenic mirrors.
   - Their mechanical loss determines the mirror thermal noise.
2. Polish
   - Shape of the polished surface determines the interference performance of the interferometer.
   - Roughness of the polished surface determines the scattering loss that may degrade the sensitivity of the interferometer.
3. Coating
   - Roughness of the coated surface also determines the scattering loss that may degrade the sensitivity of the interferometer.
   - Their optical absorption affects the interference performance of the

interferometer.

- Their optical absorption of the coating on Sapphire also determines the lowest temperature of the cryogenic mirrors.
- Their mechanical loss of the coating also determines the mirror thermal noise.

4. Measurement system

   The above mentioned parameters must be measured before the mirrors are installed. Since the requirements for these parameters are quite severe, commercial measurement systems sometimes cannot be used. It is, hence, also the MIR Working Group's responsibility to develop dedicated measurement systems.

Main Interferometer (MIF)

The Main Interferometer (MIF) includes two arm cavities, the power recycling cavity and the signal recycling cavity. The MIF subsystem also provides specifications for output mode cleaner which will be developed by the input/output optics group. The MIF subsystem also includes the control system to keep the interferometer safe and at an optimal operating point. This subsystem provides no hardware because all the hardware which constitutes the main interferometer is provided by other subsystems: e.g. mirrors are provided by the mirror subsystem. What this subsystem provides is a design of the interferometer, which is transferred to other subsystems as specifications for their components. MIF Working Group is also responsible for the commissioning of the interferometer once components are installed.

Main Interferometer Working Group is in charge of the following:

- Determination of the optical parameters of the main interferometer, except for the ones already determined by the detector configuration group
- Determination of the detailed optical layout of the main interferometer
- Design of robust length and alignment sensing schemes which do not contaminate the target sensitivity
- Design a robust lock acquisition scheme
- Make a commissioning plan to achieve the target sensitivity
- Coordination of the activities related to the surveillance and control of the equipment to keep the stable operation of the telescope covering such items as remote monitoring, logging of the status, autonomous/manual shutdown of the instrument at the time of anomalies.
- Coordination of the activities related to the Detector Characterization which will support the judgement on the detection/ non-detection of a gravitational wave through interpreting the telescope noise.

Digital System (DGS)

Digital System Working Group is in charge of development of digital system to provide a flexible human interface for a km scale interferometer through introducing digital system to all subsystems for controls, monitors, switches and diagnoses.

Digital System has the functions of:

- digitalizing analog sensing signals extracted from the interferometer and subsystems

- providing signals to the computers
- conducting control, monitoring and data acquisitions
- re-producing analog signals to actuate the interferometer

Digital System has following development items:

- Development of real-time (RT) control computer
  - (a) Signal input/output using ADC/DAC modules
  - (b) Binary switch using BO modules
  - (c) Real-time software for monitor/diagnosis
  - (d) Real-time communication network interface
- Development client workstations (RT system monitor) for monitor/diagnosis
- Network design and development for following data transfer
  - (a) Real time control
  - (b) Timing
  - (c) Data acquisition (DAQ)
  - (d) General network
- Producing frame data for data storage/analysis

Each of the subsystems is responsible for developing its own application software such as real-time interferometer control model, data analysis software using frame data and so on.

Analog Electronics (AEL)

The Analog Electronics Working Group is in charge of development of analog electronics which here is defined as the analog electronic part of KAGRA except for the digital control system and AC power line infrastructure. Also the AEL Working Group is to provide EMC criteria which all the subsystems are required to comply with.

Input/Output Optics (IOO)

Input/Output Optics Working Group is in charge of the development of input/output optical system where the input optics covers all the optics systems between the laser source and the recycling mirror while the output optics includes all the optics systems between the signal extraction mirror and the gravitational signal output terminal.

Auxiliary Optics (AOS)

Auxiliary Optics Working Group is in charge of coordinating the efforts of designing, tesing, and manufacturing all the auxiliary optics items including the optics for the scattered light issue. The actual purchase of items shall be done by appropriate subsystem groups. In other words, AOS will distribute the AOS works (and also human resources for that, if required) to the other appropriate subgroups.

Laser (LAS)

Laser Working Group is in charge of development of laser system which is comprised of the following:

- laser oscillator
- power supply
- cooling system

- control elements for frequency and intensity stabilization

Two sets of laser system will be prepared for continuous operation of KAGRA

Geophysics Interferometer (GIF)

Geophysics Interferometer Working Group is in charge of development and operation of geophysics interferometers, which measure crustal deformation for the purpose of geophysical observation as well as correction of the KAGRA baseline. The group is also responsible for environment monitoring, such as temperature, barometric pressure, and vibration.

Theory

Theory Working Group in charge of calculating analytical and numerical form of templates for data analysis.

R&D for Future System

R&D for Future System Working Group is in charge of developing new technology and theoretical challenges for possible improvement of sensitivity and observational performance for the next generation KAGRA .

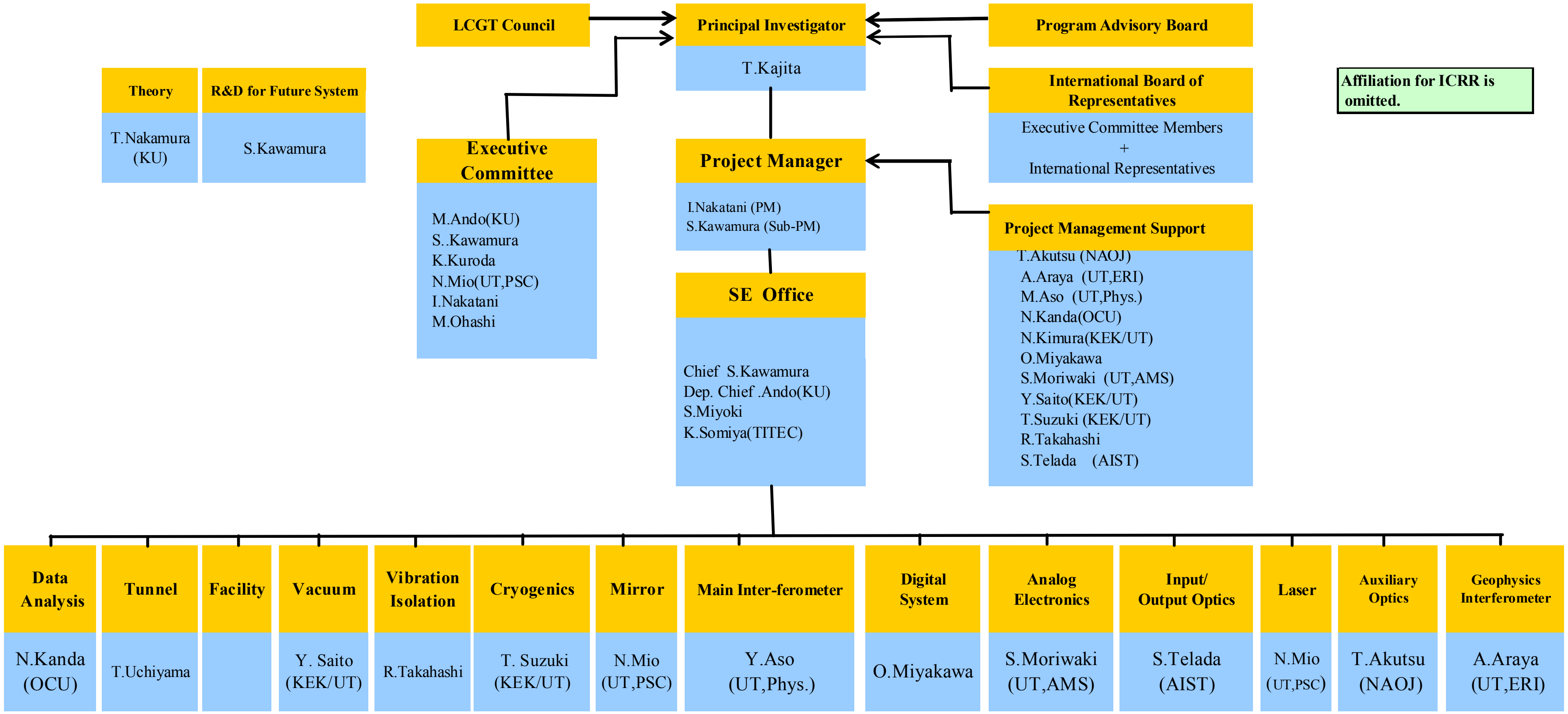

Fig. 4.2 KAGRA Organization Chart

4.3 International Collaboration

KAGRA aims at playing the role as one of the nodes for the world network of gravitational wave detectors and so it is essential to have close collaborations with overseas institutions. Table 4.1 shows the status of the MOU/Agreements between the Institute for Cosmic Ray Research (ICRR) and other research institutes abroad showing that some agreements have already been concluded while others are in preparation.

Table 4.1 Agreement status

Partners	**Agreement Status**
LIGO-Laboratory/CALTECH	concluded
EGO/Virgo	concluded
GEO/Albert Einstein Inst.	in preparation
GEO/Glasgow University	concluded
Shanghai United Center for Astrophysics /Shanghai Normal Univ.	concluded
LIGO Collaboration/Virgo Collaboration/GEO Collaboration	under discussion for data sharing
Faculty of Life and Physical Sciences/ University of Western Australia	concluded
Department of Physics/ Tsinghua University	concluded
SICCAS-GCL Research Development Center/ Shanghai Institute of Ceramics	concluded
School of Science/ Louisiana State University	in preparation
Engineering Department/ University of Sannio	condluded
Adelaide University (between universities)	under discussion

5. Project Cost

There are four budget categories for the KAGRA project classified as follows.

a) Leading-edge Research Infrastructure Program (production cost)
b) State Budget (excavation, cryogenics)
c) Operational Expenses
d) Grant-in-Aid for Scientific Research (general research).

The total of 15.7 billion yen will be necessary for the construction of KAGRA. We have to acquire these budgets in a timely way, and have to distribute appropriately so that the KAGRA project can proceed most efficiently and productively.

N.B. Some of the requested budget has already been approved, but for keeping the fairness for the participants of the open bidding, the amount and its allocation for the subsystem are not described here.

6. Project Phase and Test

It is crucial to make the best design of KAGRA by taking into consideration all the knowledge and experiences that we have gained with all the prototypes we have built so far, that we have learned from other projects such as LIGO, Virgo, and GEO, and that we will learn by building and evaluating prototypes and first articles of all the subsystem.

In a normal project, the proper procedure of the design and test should be 1) to establish the requirement for each subsystem, 2) to make a preliminary design that meets the requirement, 3) to build and evaluate a prototype, 4) to make a final design based on the outcome of the prototype test, 5) to build and check a first article for the final validation of the design, and 6) if necessary to implement minor modification into the real systems. A proper review should be conducted in each step .

Unfortunately, however, KAGRA has an unusual development plan due to the limited budget and the tight schedule. For example, the design of some subsystems for iKAGRA should be finalized as soon as possible even before the design of the whole bKAGRA is finalized. Thus we may or may not afford a full prototype test for all the subsystems for iKAGRA. Nevertheless we should accommodate as much test as possible to evaluate the design of iKAGRA and bKAGRA, by sometimes relying heavily and only on a first article test, and sometimes conducting a test for bKAGRA in parallel with the commissioning of iKAGRA.

7. Project Reviews

KAGRA, roughly speaking, has 3 types of reviews as follows:

(1) Type A: Internal Peer Review
(2) Type B: External Review
(3) Type C: Program Advisory Board Review

The overview of these 3 types of review is summarized in Table 7.1.

The first series of Internal Peer Reviews (Type A) were conducted from Nov. 8 ’10 through Fev. 7 ’11 for each of the subsystems.

The External Reviews (Type B)listed above, generally speaking, are to be held at major milestones of the KAGRA and the first External Review was conducted from February 28 through March 4, 2011 just before starting the construction of the iKAGRA project. It is the equivalent of the Final Design Review (FDR) of LIGO or the Critical Design Review (CDR) at major space development agencies. It is to be noted that for a few of the subsystems dedicated to bKAGRA, the Review is the equivalent of the Preliminary Design Review (PDR).

The Program Advisory Board Review

Table 7.1 Three Types of Reviews

Category	**Type A Review**	**Type B Review**	**Type C Review**
Name	Internal Review	External Review	Program Advisory Board Review
Objectives	-Understanding detailed design/development status of other subsystems -Identifying potential problems with other subsystems -Clarifying the interfaces among subsystems	-Confirming detailed design/development status of the subsystems -Identifying potential problems with each subsystem -Recommendation on go/no-go for proceeding to the next development phase	-Confirming the KAGRA development status
Reviewees	subsystem leaders	subsystem leaders	KAGRA management and members
Reviewers	internal peers (External peers if necessary)	mostly external peers and a few internal reviewers	Program Advisory Board members
Frequency	at each milestone	at major milestones	once a year
Language	Japanese	Japanese (English if necessary)	English
Presentation materials	Japanese/English	English	English
Participants	any KAGRA members	any KAGRA members	any KAGRA members
Presentation materials	Japanese/English	English	English

8. Information Management

The LCG project team is comparatively small with 14 Working Groups corresponding to 14 subsystems to which 120 collaboration members belong, but still providing necessary and sufficient communication among the members facilitating the project going along smoothly is not an easy task for the project to achieve. In this section three most important ways for exchanging information are described: meetings, documents and Wiki.

One of the most serious problems for the KAGRA project is the shortage of human resources, so the information management is to aim at establishing the most efficient way of running the project.

8.1 Meetings

The number of the meetings should be optimum considering the following two conflicting requirements:

(1) Adequate number of meetings should be held so that sufficient information is to be delivered to the project members both in the top-down and bottom-up directions. Lack of the information in the top-down direction could make the team members act with blinkered view sometimes resulting in sectionalism or loss of commonly shared project goal, while the lack of the information flow in the bottom-up direction of course could lead to wrong decisions by the management.

(2) Minimum number of meetings should be held so that the burden on the team members should be minimized thus reducing time and energy for the team members to spend.

Currently the meetings held at regular intervals are as follows which are also summarized in table 8.1.

Executive committee meeting

Top level decisions on political and technical issues are made. It is held once every week by 6 executive members chaired by Principal Investigator.

Executive committee + support group meeting

The objective of this meeting is the information exchange between the executives and the leaders of the Working Groups executing the project tasks. It is held every week by the executives, system engineering office members and the leaders of the WG's which are currently in the process of purchasing facilities and equipment.

Face-to-face collaboration meeting

This meeting is for the face-to-face exchange of the project information among the KAGRA collaboration members and also for making decisions on the KAGRA policy regarding the collaborations. The participants are expected to be all the collaboration members both domestic and international. It is held twice a year chaired by the executive in charge of collaboration and external affairs.

International collaboration meeting

This meeting is exactly the same as the Face-to-face meeting except that the participation via internet is permitted. The participants are expected to be all the collaboration members both domestic and international. It is held twice a year chaired by the executive in charge of collaboration of external affairs.

Domestic collaboration meeting

This meeting is for the exchange of the project information among the domestic KAGRA collaboration members and also for making decisions on the KAGRA policy regarding the domestic collaborations. The participants are expected to be all the collaboration members both domestic and international. It is held four times a year chaired by the executive in charge of collaboration and external affairs.

Chiefs meeting

This meeting is for the exchange of information among the subsystems. In the design phase, it is held once every week chaired by the project manager. The participants are expected to be the leaders of the Working Groups for the subsystems and any other KAGRA members. The frequency of the Chiefs Meeting will change depending on the stage of the development.

Table 8.1 KAGRA Regular Meetings

Meeting	Objective	Attendees	Frequency	Language
Executive committee meeting	Top-level decisions on political & technical items	Executive committee members	1/week	Japanese
Executive Committee + Project Management Support group	Exchange of information between executive committee and support group	Executive committee members + Project Management Support group	1/2 weeks	Japanese
Face-to-face collaboration meeting	Sharing information among international KAGRA members	All KAGRA members	2/year	English
International collaboration meeting	Sharing information among international KAGRA members	All KAGRA members	2/year	English
Domestic collaboration meeting	Sharing information among domestic KAGRA members	All domestic KAGRA members	4/year	Japanese
Chiefs meeting	Sharing information among KAGRA subsystems	Leaders of subsystem WG	1/2 weeks	Japanese

8.2 Documents

8.2.1 Document Categories

There are three categories of KAGRA documents as follows:

(1) Prime Documents
- shared by all the KAGRA members
- updated as frequently as practical
- open to the KAGRA collaboration
- written in English
- posted on the Wiki
- limited to the following 4 documents
  1) KAGRA Design Document
  2) KAGRA System Engineering Management Document (SEMP)
  3) KAGRA Interface Control/Configuration Management Document (ICD/CMD)
  4) KAGRA Environment and Safety Document

(2) Milestone Documents
- issued at major milestones
- not updated (with the exception of correction of errors)
- open to the KAGRA collaboration
- written in English
- posted on the Wiki
- examples are as follows:
  1) Preliminary Design Documents
  2) Final Design Documents
  3) Official Agreement with other Institutes

(3) Ad hoc documents
- shared by some of the Working Groups and management
- all the following items are up to each of the document author(s):
  1) to which group(s) the document is open
  2) how often it will be updated
     (whether it is to be updated or not in the first place)
  3) in which language it is written
  4) whether it is posted on the Wiki / with a pass word or not
- examples are as follows:
  1) handout at major interface meetings
  2) copy of power point for major conferences
  3) copy of power point for internal reviews (Type A reviews)
  4) handout for the meetings among Working Groups

8.2.2 KAGRA Prime Documents

The KAGRA human resource is extremely tight, so the number of the documents should be bare minimum to reduce the burden of team members. Four formal documents are to be developed as described below all of which are living documents to be updated throughout the KAGRA project.

(1) **KAGRA Design Document**

Detailed design of each subsystem is described where the process of selecting a system with various parameters is explained.

(2) **KAGRA System Engineering Plan (SEMP)**

SEMP is a basic plan for all the management functions to be fulfilled by KAGRA system engineering activities. It will also provide all the management information which the project members are expected to share.

(3) **KAGRA Interface Control Document (ICD)**
==> KAGRA Configuration Management Document (CMD)

KAGRA ICD is the document that lists the interface parameters among all the subsystems while KAGRA CMD covers all the major parameters defining each subsystem; which means it is possible to define the ICD as a subset of CMD. We will, hence, start with ICD which will be later expanded to cover CMD. The CMD will, in the course of project progress, be updated frequently and the data should be shared by all the KAGRA teams. It should never happen that certain parameters which could affect other subsystems are changed without being noticed by other team members.

These documents do not describe the reason why a certain parameter has been selected, but just the result is given. The process of selecting parameters is described in the KAGRA Design Document.

(4) **KAGRA Environment and Safety Management Document**

KAGRA Environment and Safety Management Document will cover following items:

- safety rules and regulations to be observed by KAGRA team members and other related personnel
- environment standard to be kept for the personnel
- environment standard to be kept for the equipment and facilities
- environmental impact assessment

8.2.3 Document Management

In a big project it is very important to manage various documents written by many people to share information. The major objectives of document management are:

- to provide an easy way to search, collect and distribute documents thus facilitating the sharing of the information among project members
- to keep the documents updated in order to make the best of the existing information
- to facilitate the transfer of the accumulated knowledge to newcomers who will be interested in this field.

In the KAGRA project, following tools are available to manage the documents related to KAGRA.

(1) Document database

A document database is sometimes a very important tool to collect documents related to the project. In the KAGRA project, web based document database named as 'JGWdoc' is being operated at the following addresses;

Public: http://gw.icrr.u-tokyo.ac.jp/cgi-bin/DocDB/DocumentDatabase
Private: http://gw.icrr.u-tokyo.ac.jp/cgi-bin/private/DocDB/DocumentDatabase

The public address is open to all the people in the world including those outside the KAGRA collaboration, while the private address is open only to the KAGRA collaboration.
It is useful and convenient if all the documents related to KAGRA are archived at one location. JGWdoc has enough capability and flexibility to deal with a huge number of documents for a long-term big project. JGWdoc has following management functions:

(a) Document storage: Any documents can be uploaded from anywhere on web browser.
(d) Numbering: JGWdoc automatically provides an individual number with category indication character and year information when the document is uploaded.
(c) Categorizing: Character on the head of document number represents its category as follows;

T - Technical notes, M - Management or Policy, P - Publications, D - Drawings, G - Presentations (eg. Graphics)

(d) Document version control: Last digit of document number shows a version number.
(e) Additional information archiving: Title, abstract, keywords, notes and changes, file name and description, submitters, authors, topics, related documents, journal references, other public information.
(f) List and search: Making a document list by date, author, topic etc. Strong search engine is available including contents search inside the documents.

For example uploaded documents have such numbers;

JGW-T0900123-v2 (Techical notes, year of 2009, 123th document, version 2)
JGW-G1100456-v1 (Presentation file, year of 2011, 456th document, version 1)

(2) Wiki

Wiki is being operated as the name of 'JGW wiki' with the following address;

Public: http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA
Private: http://gwwiki.icrr.u-tokyo.ac.jp/JGWwiki/Private/ KAGRA

Public address is open to anybody and private address is open to only KAGRA collaborators.

One of the main functions of wiki is to provide the means for communication especially for the items currently under discussion – for example recently obtained data, preliminary calculation results, meeting schedules or meeting minutes. In fact, this wiki is able to store files like document database but the function for storage is very limited. The file storage function of wiki should be used temporarily, and once the discussion has been settled, all the related documents should be fixed and posted to JGWdoc.

(3) SVN

SVN is used to manage documents or source codes. It sounds similar to the document database above, but the main function of SVN is especially version controls for developments of software, and documents written by many people for example ICD or SEMP. Here is an explanation how to use;

http://gw.icrr.u-tokyo.ac.jp/JGWwiki/KAGRA/SVN

SVN has a limited function for explanation or attached information. Wiki or JGWdoc should be used for providing auxiliary explanation.

8.2.4 Mailing List

Mailing list is a tool to communicate in a small group like sub-working group. Currently following mailing lists related to KAGRA project exist.

General:
KAGRA2008 (KAGRA general, English)
KAGRAj (KAGRA general, Japanese)
gw_comm (Announcement for monthly gravitational wave seminar)

Management based:
KAGRAexe (KAGRA executive committee)

KAGRApms (KAGRA executive committee + support group)

Subgroup based:
KAGRA-isc (Main interferometer, Japanese)
KAGRA-digital (Digital system, Japanese)
KAGRA-seis (Vibration Isolation, English)
KAGRA-vi (Vibration Isolation, Japanese)
KAGRA-data (Data analysis, Japanese)

Special working group based:
KAGRA_roadmap (KAGRA Roadmap, Japanese)

CLIO:
cliocore (For core members of CLIO project)

Those who want to join the above ML are requested to send an e-mail to:
{each ML name}-ctl@icrr.u-tokyo.ac.jp
with their e-mail address on "From" tag, with the word subscribe in the message.

9. Risk Management

The risk management is another critical issue for the success of KAGRA. There should
be a proper risk management plan both for the whole KAGRA and for each subsystem. We should use our full imagination in advance to predict what could go wrong and in what way. Then we should evaluate the possibility and severity of each potential risk. We should focus on the risk with higher product of the possibility and severity to prepare for a proper risk management plan.

10. Interface Control and Configuration Management

It is often pointed out that a significant portion of system failures arise from the problems with the interface between subsystems. Clearly defined subsystem compartmentalization with the interface parameters kept always updated is crucial to the consistency of the design of the whole system which is the integration of all the subsystems. For this purpose, efficient and reliable exchange of information among the subsystem teams is essential including meetings, documents or Wikis.

There are variety of meetings - either ad hoc or regular - to facilitate a smooth exchange of information. Too many meetings will pose a heavy burden on the team members who are already so busy and are suffering from the lack of human resources, so we should reduce the frequency of meetings to bare minimum while enough information exchange and sharing is to be ensured. The regularly held meetings listed in Table 8.1, however, seem to be bare minimum at the design stage. In the construction phase, more frequent brief meetings will be necessary.

As for a document, Interface Control Document (ICD) for the bKAGRA already exists which is to be updated with more frequency so that everyone can reliably refer to. Also the ICD for iKAGRA is to be prepared soon.

A detached document on Configuration Management will be developed as described in Chapter 8.3. It is the extension of Interface Control Document which is a subset of the Configuration Document, so both will merge to reduce the number of documents.

11. Safety and Environment Management

As described in chapter 8.3, a document dedicated to environment and safety management is to be prepared which will cover the following 4 items:

(1) safety rules and regulations to be observed by KAGRA team members and other related personnel
(2) environment standard to be kept for the personnel
(3) environment standard to be kept for the equipment and facilities
(4) environmental impact assessment

Each of the above 4 items are described below.

11.1 Safety Rules

KAGRA laboratory is placed in an underground mine where much more stringent safety management system is indispensable compared with that for ordinary laboratories. We have a good example of underground Kamioka observatory with a long history of operation from which we can learn a lot and with which KAGRA can share its heritage of safety management procedures.

For the safety of the personnel in the underground laboratory, following 2 items are specifically important:
- Controlling the personnel going in and out
- Monitoring the environment in the mine

which will be described below.

(1) Controlling Entrance and Exit

The personnel going into the mine are requested
- to be qualified in advance,
- to use specified transportation for the mine and
- to be equipped with mobile phone for the mine, helmet and flashlight.

For the safety control for the personnel following items are required:

- Safety training for the personnel, qualification procedure and safety management plan are to be established.
- Management system of the transportation in the mine and the license for its operation are to be provided.

- Management system is to be developed for monitoring the personnel going in and out for checking if the personnel have come out at the planned time. A new section responsible for confirming the safety of the personnel in the mine is to be established. In the case of Super Kamiokande, guards are on duty 24 hours a day.
- The rules for the emergency of injuries, fire or power outage are to be developed and the drills are to be conducted assuming emergency situations. The safe evacuation routes are to be specified in advance depending on the different locations of the fire breakout. Enough number of emergency lights are prepared in preparation for power outage.
- The emergency rules should also cover the case for visitors and also the accidents outside the mine (e.g. rockfalls or snow accumulation).

(2) Monitoring the Environment

It is important that the following items can be confirmed prior to entering the underground laboratory.
- Oxygen density which is measured at each location of the laboratory rooms
- Output of the fire detecting device which is set at each location of the laboratory rooms

(3) Others
- High power laser (class 4) used for KAGRA requires its designated area where researchers are requested to wear goggles. The operation of the high power laser is to be monitored from outside the designated area.
- High pressure gas and crane are to be operated by personnel with license designated by law and are subject to periodic inspection.
- The subsystem equipment, specifically those of vacuum and low temperature, are to be designed so that the damage caused by power outage be minimal.

11.2 Environmental Standard for Personnel

Oxygen density is to be maintained above 20%.

11.3 Environmental Standard for Equipment and Facilities

(1) Each subsystem is requested to put together the requirements for temperature, humidity and cleanliness of its equipment. If there is no requirement, the common standard is as follows:
- temperature: 20 +/- 2 degree C
- humidity: <50 %

(2) For the equipment radiating heat, it is suggested to check the possibility of keeping them inside a thermally shielded space with a water-cooling system.

(3) For the equipment emitting acoustic noise it is suggested to check the possibility of keeping them inside an acoustic shield room.

11.4 Environmental Impact Assessment

It is prohibited to discharge water contaminated with heavy metal from Kamioka mine. Those who discharge water are requested to consult in advance with Kamioka Mining & Smelting Co., Ltd. for checking the water quality.

12. Public Outreach

Exploring the universe by KAGRA would surely stimulate interests in natural mysteries among the general public - specifically among younger generation - inviting them to the world of science. Natural science would make mankind not only mentally rich but also help mitigate the conflicts among different cultures through eliminating prejudices.

Meanwhile, big science project like KAGRA needs public support for using large amount of tax as described in the report entitled "Evaluation of large scientific projects, KAGRA and B-factory" submitted from a working group discussing large scientific projects in the Ministry of Education, Culture, Sports, Science and Technology on September 7th 2011 (see the following sites : http://www.jahep.org/files/report1.pdf and http://www.jahep.org/files/report2.pdf).

Public outreach which KAGRA is conducting covers the following three activities,

(1) Scientific and strategic activity mainly for physics, astronomy and technology society:

(a) Output presentations in domestic and international academic meetings and conferences on physics, astronomy and technology.
(b) Awards for young and/or outstanding scientist activities.
(c) Guidance for undergraduate and graduate students and post-doctoral fellows to invite them to KAGRA.
(d) Recruiting new collaborators in other domestic and international universities and institutes to accelerate KAGRA progress.
(e) Press release about significant progress and results on KAGRA development and scientific topics.

(2) Educational activities conducted in cooperation with the ICRR public relations office mainly for school students, teachers, supporters who are interested in science and the general public (tax payers):

(a) Public lecturers (regional): Lectures on general relativity, gravitational waves, meanings of GW detection and GW detection techniques in a plain style in a public hall.

(b) Public exhibition (regional): Presentations about GW and demonstrations of a simple Michelson interferometer (MI) or other equipment.
(c) Institute or university open house (regional): Poster presentation and demonstration of MI in a special room (atelier).
(d) Guided tour at CLIO and TAMA (for the general public) sites: Guide and show of the proto-type GW detectors CLIO and TAMA sometimes in cooperation with commercial companys' event (GSA) and educational outreach programs of Kamioka Observatory (Super Science High School) and so on.
(e) Participatory Events: Public offering of new KAGRA name and logo mark to develop a bond between researchers and the public.
(f) Accountability through mass media (nationwide): Dope story about KAGRA projects on newspapers, broadcasting and science journals.
(g) Contents preparation: To help the public to understand GW physics and KAGRA
project, movies, graphical figures and booklet are prepared.

(3) Web page maintenance:
A web page about KAGRA will bring together all the information in Japanese and English. In addition to this, pages for miscellaneous KAGRA related items such as scientific internal and international meeting information, document archive links and collaborators information are prepared and presented for collaborators for convenience.

HP server maintenance, reform, SSL, twitter function and article post are contracted out to commercial companies. On the other hand, articles and graphical figures are provided by KAGRA staff.

At present, formal contact to KAGRA project is ICRR public relations office.