

# Technology Roadmap for Grid Computing

## 1. Introduction

Grid computing is an innovative approach that leverages on existing IT infrastructure to optimize compute resources and manage data as well as computing workloads.

Currently, Grid Computing or E-Infrastructure or Cyber-Infrastructure has become a global research phenomenon. "Grid" was termed in this area and defined as below:

- Grid Computing (Grid) is a form of distributed system where computing resources are shared across networks.
- Just as Web standards and technologies enabled universal and transparent access to documents, Grid promises do so for computing resources.
- Grid enables the selection, aggregation, and sharing of information resources resident in multiple administrative domains and across geographic areas.
- These information resources are shared based upon their availability, capability, and cost, as well as the user's quality of service (QoS) requirements.

It is analogous to the electric power grid, where users do not need to know the details of the technology and the sources. They simply connect to common interfaces, subscribe and consume what they need.

## 2. KnowledgeGrid Malaysia

MIMOS, under the auspices of Ministry of Science, Technology & Innovation (MOSTI), was mandated to spearhead the KnowledgeGRID Malaysia (formerly known as the National Grid Computing Initiative) in close collaboration with local universities and industries as a testbed for Grid Computing initiative in Malaysia under the Ninth Malaysia Plan (RMK9). KnowledgeGRID Malaysia plays a pivotal role in bringing Malaysia to the next ICT evolution.

KnowledgeGRID Malaysia was launched by YAB Datuk Seri Abdullah Ahmad Badawi, the Prime Minister of Malaysia, on 20<sup>th</sup> August 2007 at Cyberview Lodge Resort and Spa in Cyberjaya. This event aimed to raise the awareness on the initiative among Malaysians as well as to invite for more participation especially the local R&D communities and industries.

KnowledgeGRID Malaysia is a key enabler for the country, driving innovations towards a Knowledge Nation.

The main objectives of KnowledgeGRID Malaysia are:

- Provide Super Computing power to the Nation beyond the research communities
- Provide highest level Cyberspace Security for critical information.
- Achieve cost efficiency on Capital Investment for Knowledge Info-Structure
- Create new web services industries through pay-per-use

In order to achieve these objectives, MIMOS has forged research collaborations with 13 local universities who serve as MIMOS virtual research centers and will undertake basic research in frontier technologies to complement MIMOS applied research to build technology competencies in driving centers of excellence.

MIMOS also partnered with multinational companies such as IBM, Altair Engineering, SGI, and Cisco to provide affordable Grid tools and resources for local researchers and industry players to jumpstart into the K-economy. MIMOS will also sign an Memorandum of Understanding (MOU) with Oracle to establish the research and development in sensor grid areas.

Leading the KnowledgeGRID Malaysia initiative, MIMOS is also mandated to draft the National Technology Roadmap for Grid Computing, in close collaboration with local universities, research agencies and industries.

### **3. National Technology Roadmap**

The objectives for developing the National Technology Roadmap are:

- To define potential key focus areas of research in Grid Computing for the whole nation.
- To identify areas where Grid Computing can be applied to further accelerate other scientific advancements and R&D related to these fields.
- To further encourage multidisciplinary R&D as well as to increase multi-institutional collaboration through the use of Grid Computing.
- To establish a proper framework and policies for the well-being of the National Grid that will support R&D in Grid Computing, deployment of its applications and other activities as well as its future directions.
- To accelerate, educate and promote the potential use and benefits of Grid Computing to the industries and public in general.

#### 4. Key Processes

The process for defining the components of the National Grid Computing Roadmap consisted of three parts:

- 1) Strategic Analysis
  - a. Trends
  - b. Applications
  - c. Considerations
- 2) Gap Analysis
  - a. Policy
  - b. Technology
  - c. Resources
  - d. Government
  - e. Institutions
  - f. Citizen
- 3) Implementation Analysis
  - a. What must be done
  - b. Who will do it
  - c. When to do it
  - d. How do we measure

This is illustrated in the following figure.

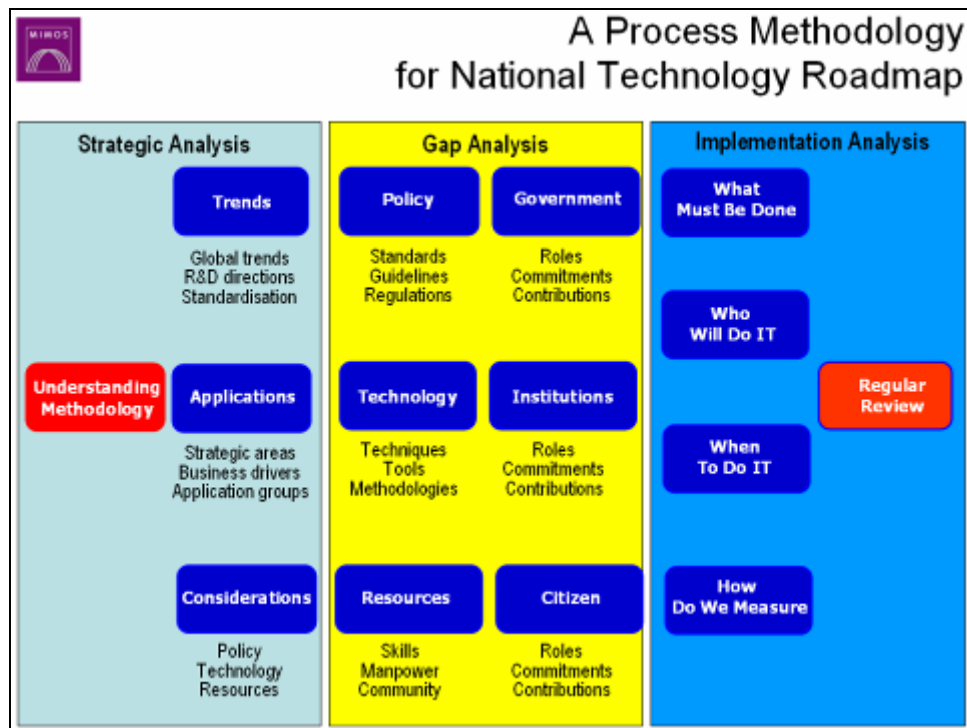


Figure 1: Development Process of Roadmap

## 5. Domain Areas

The National Grid Computing Roadmap has four main domains as shown below:

- 1) National Grid Facility, Info-structure and Security,
- 2) Grid Middleware and Tools Enablers,
- 3) Grid Applications, and
- 4) Policies & Governance.

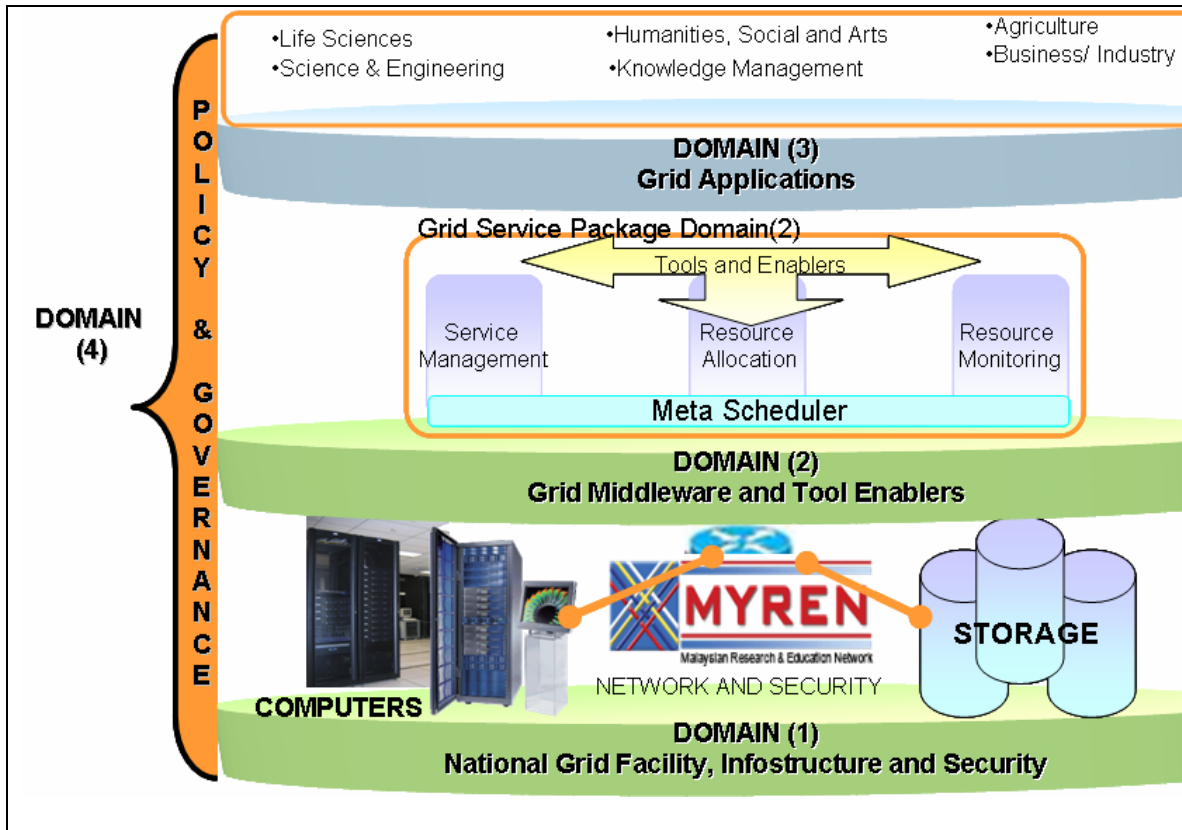


Figure 2: The Key Domains in National Grid Computing Roadmap

### Domain 1: National Grid Facility, Info-structure and Security

This domain is a combination of three major sub-domains namely National Grid Facility, Infostructure and Security. This identified grid infrastructure will form the core foundation for successful grid applications.

In doing so, the implementation plan for the three sub-domains is outlined below:

Sub-domain	Description
National Grid Facility	<p>The National Grid Facility is actually a testbed for grid applications. The purpose of its setup is to allow various grid applications to be tested, deployed and demonstrated to various parties including decision makers, general public and the industries. It will consist of a National Grid Nucleus (housed at MIMOS) as well as Satellite Centres or Grid Nodes.</p> <p>The National Grid Nucleus and Satellite Centres will form the National Grid Facility that consists of physically distributed computation and storage elements with high speed network (through MYREN) to enable distributed and parallel data processing and applications.</p> <p>The network availability will leverage on MYREN with plans to migrate to IPv6 and wireless technologies.</p>
Info-structure	<p>It is a non-physical structure (software or applications) that allows users to manage and monitor the computational elements, data storage and information based systems as well as supporting other activities such as collaborations, virtual organisations and so on in the grid environment. Among the main focus areas are to setup the Access and Data Grid.</p> <p>Access Grid aims to enable access and share applications, data and software in heterogeneous environment.</p> <p>Data Grid aims to establish data grid management (data application, recovery, storage management, distribution, load balance).</p>
Security	<p>It is a set of tools used to ensure the protection of the physical and non-physical components from any interruption and intrusion, in the heterogeneous of the grid nature of resources and the security policies.</p> <p>This sub-domain aims to establish Grid security standards, network device compliance to security standards, assurance and audit, and multilevel control mechanisms.</p>

Table 1: Description of Sub-domains in Domain 1

## Domain 2: Grid Middleware and Tool Enablers

Grid Middleware & Tools concerns with providing a standard platform for services to operate, coordinate and manage grid services for resource integration, monitoring and allocation in order to create a uniform and flexible middleware level interface in Grid environment.

Three sub-domains have been identified with priority areas as described in the following table:

Sub-domain	Description
Service management	<p>Focuses on the provision of the high level services in managing and administrating the existing grid services to provide virtualization, federation of domains, utility computing and service discovery and matching. It should not reinvent the existing grid middleware that has been commonly used.</p> <p>Prioritized areas are :</p> <ul style="list-style-type: none"><li>▪ Grid Accounting &amp; Billing</li><li>▪ Virtual Organization Management</li><li>▪ Grid Security</li><li>▪ Service Brokering</li><li>▪ Service Directory</li></ul>
Resource management	<p>Attempts to further extend the present resource monitoring capability by including resource prediction and fault tolerance capabilities and to optimize the usage of grid resources in order to achieve better performance and quality.</p> <p>Prioritized areas are :</p> <ul style="list-style-type: none"><li>▪ Grid/Meta Scheduler</li><li>▪ Grid Fault Management / Tolerance</li><li>▪ Grid Resource Monitoring</li><li>▪ Resource Allocation</li><li>▪ Data Management</li></ul>
Tools & Enablers	<p>Focuses on the provision of the high-level services in managing and administrating the existing grid services to provide virtualization, federation of domains, utility computing and service discovery and matching.</p> <p>Prioritized areas are :</p> <ul style="list-style-type: none"><li>▪ Grid Performance Measurement</li><li>▪ Grid Information Profile</li><li>▪ Communication Management: User Interactive Connectivity for the Grid</li><li>▪ Grid Portal Technology</li><li>▪ Workflow</li><li>▪ Visualization</li><li>▪ Grid Simulators</li></ul>

Sub-domain	Description
	<ul style="list-style-type: none"> <li>▪ Grid Application Enabler</li> <li>▪ Grid Enable API</li> </ul>

Table 2: Description of Sub-domains in Domain 2

### Domain 3: Grid Applications

The success of Grid Computing lies not just on the infrastructure and the middleware but more importantly, on the availability of Grid enabled applications. The applications are classified as follows:

- 1) Short Term applications (2007 – 2008)  
These are applications that are already in use or at the prototype stage and ready to be grid enabled.
  
- 2) Medium Term applications (2009 – 2010)  
These are applications that are important for Malaysia but the technologies and enablers need more time to develop and mature.
  
- 3) Future applications (beyond 2010)  
These are potential grid applications that may not have any mainstream player and the technologies and enablers are yet to be developed or do not exist yet.

The projects are prioritized in sub-domains as follows:

Sub-domain	Description
Life Science	<p>This sub-domain will have the biotechnology as one of the key focus areas under the RMK9.</p> <p>Life Science areas shall include but not limited to:</p> <ul style="list-style-type: none"> <li>▪ Bio-Medical</li> <li>▪ Ambient Intelligence</li> <li>▪ DNA and Protein Modeling</li> <li>▪ Bioinformatics</li> <li>▪ Tissue Engineering</li> <li>▪ Bio-Chemistry &amp; Cheminformatics</li> <li>▪ Human Disaster Management</li> <li>▪ Biological – Technology Interface</li> <li>▪ Genomics</li> <li>▪ Bio-Forensics</li> </ul>

Sub-domain	Description
	<ul style="list-style-type: none"> <li>▪ Sequencing and Pattern matching</li> </ul>
Science and Engineering	<p>Existing scientific and engineering applications that are compute intensive or data intensive and ready to be grid-enabled.</p> <p>Science and Engineering areas shall include but not limited to:</p> <ul style="list-style-type: none"> <li>▪ Computational Engineering,</li> <li>▪ Computer Aided Engineering(CAE)</li> <li>▪ Micro-electronics</li> <li>▪ Pseudo science</li> <li>▪ Nanotechnology</li> <li>▪ Artificial Intelligence</li> <li>▪ Control Engineering</li> <li>▪ Wireless application</li> <li>▪ Sensor Network</li> <li>▪ Advanced Manufacturing</li> <li>▪ Signal and Image Processing</li> <li>▪ Disaster Management</li> <li>▪ Space Science</li> <li>▪ Material Science and Engineering</li> <li>▪ Physics (Atomic Studies)</li> <li>▪ DNA Computing</li> <li>▪ Quantum Computing</li> </ul>
Knowledge Management	<p>Collaborative E-Learning applications across various types of communities that require not just high-speed bandwidth but storage and methods to federate various contents.</p> <p>In the near future, one may further venture into R&amp;D of datamining, knowledge management, ontology, context awareness, semantic web/grid and other related knowledge and information based technologies.</p> <p>Knowledge Management areas shall include but not limited to:</p> <ul style="list-style-type: none"> <li>▪ Knowledge Repository <ul style="list-style-type: none"> <li>• Tele-Medicine</li> <li>• Islamic Digital Library</li> </ul> </li> <li>▪ Information Retrieval and Storage <ul style="list-style-type: none"> <li>• Search Engine</li> </ul> </li> <li>▪ Ontology <ul style="list-style-type: none"> <li>• Islamic</li> </ul> </li> </ul>

Sub-domain	Description
	<ul style="list-style-type: none"> <li>• Industry</li> <li>• Medical</li> <li>▪ Language Translation</li> <li>▪ E-Learning</li> <li>▪ Knowledge Dissemination <ul style="list-style-type: none"> <li>• Online Seminar/Training</li> </ul> </li> </ul>
Humanities, Social and Art	<p>Humanities, Social and Art applications that make use of high-end ICT technologies. Applications in this area can be used for preservation of our cultural and heritage, arts, historical data and so on.</p> <p>Humanities/Social/Art areas shall include but not limited to:</p> <ul style="list-style-type: none"> <li>▪ Computer/Graphic Art <ul style="list-style-type: none"> <li>• Interactive Art</li> <li>• Electronic Art</li> <li>• Animation</li> </ul> </li> <li>▪ Religion and Islamic civilization <ul style="list-style-type: none"> <li>• Digital Islamic Library</li> </ul> </li> <li>▪ History</li> <li>▪ Culture</li> <li>▪ Law</li> <li>▪ Linguistic</li> <li>▪ Politics</li> <li>▪ Visual Art</li> <li>▪ Sound Art</li> <li>▪ Performing Art</li> <li>▪ Poetry &amp; Literature</li> </ul>
Agriculture	<p>Agriculture areas shall include but not limited to:</p> <ul style="list-style-type: none"> <li>▪ Ambient Intelligence</li> <li>▪ Super Distributed RFID Infrastructure (SDRI)</li> <li>▪ Precision Agriculture <ul style="list-style-type: none"> <li>• Sensor Technology</li> </ul> </li> <li>▪ Weather Climate</li> <li>▪ Natural Disaster Management</li> <li>▪ Biological – Technology Interface</li> </ul>
Business / Industry	<p>Use of Grid facilities and resources by businesses and industries to become more competitive as Grid enables resource sharing of data storage, expensive and compute-intensive applications.</p>

Sub-domain	Description
	Business / Industry areas shall include but not limited to: <ul style="list-style-type: none"> <li>▪ Multimedia Industry</li> <li>▪ Animation</li> <li>▪ Financial</li> <li>▪ Stock Market/Share</li> <li>▪ Online Banking</li> <li>▪ Automotive Industry</li> <li>▪ Design and Manufacturing Support / Services               <ul style="list-style-type: none"> <li>- Crash Simulation Analysis</li> <li>- Product Design</li> <li>- Manufacturing</li> </ul> </li> <li>▪ Other Industries               <ul style="list-style-type: none"> <li>• Shipping</li> <li>• Aerospace</li> <li>• Defense</li> </ul> </li> <li>▪ SME Support               <ul style="list-style-type: none"> <li>• Rural Industry (One Product for One Village/District eg: e-Halal Portal)</li> </ul> </li> </ul>

Table 3: Description of Sub-domains in Domain 3

#### Domain 4: Policy and Governance

The issues on policy and governance need to be addressed as well to make sure that all the aspects in the roadmap such as implementation, infrastructure, projects evaluation and monitoring, roadmap evaluation, resource allocation and so on can be executed properly and must be in line with the nation's goals and needs.

The following table describes some potential components that need to be established and their probable roles and responsibilities respectively:

Components	Roles and Responsibilities
National Grid Coordinating Committee	<p>The NGCC is the main body that will help coordinate the activities around the National Grid with 2 external bodies i.e. National Steering Committee and International Advisory Panel. The Chairman of NGCC is the KSU of MOSTI.</p> <p>The NGCC will establish the necessary guidelines on implementing the National Grid among others :</p> <ol style="list-style-type: none"> <li>1) Appointment of Steering Committee</li> <li>2) Appointment of International Advisory Panel</li> <li>3) Membership in the National Grid</li> <li>4) National Certificate Authorities</li> </ol>

Components	Roles and Responsibilities
	<ul style="list-style-type: none"> <li>5) Grid Authorization</li> <li>6) Grid Authentication</li> <li>7) Liability</li> <li>8) Accounting</li> <li>9) Intellectual Property</li> <li>10) Software Licensing</li> <li>11) Disruptive Recovery</li> <li>12) Project evaluation, monitoring and management</li> <li>13) Resource allocation, management, monitoring and costing</li> <li>14) Regular review of National Technology Roadmap</li> <li>15) Etc.</li> </ul>
Grid Technical Committee	<p>The Grid Technical Committee members consist of the following entities. (New members subject to approval):</p> <ul style="list-style-type: none"> <li>1) MOSTI</li> <li>2) MOHE</li> <li>3) KTAK</li> <li>4) MIMOS</li> <li>5) Local universities : <ul style="list-style-type: none"> <li>a. Universiti Kebangsaan Malaysia (UKM)</li> <li>b. Universiti Malaya (UM)</li> <li>c. Multimedia University (MMU)</li> <li>d. Universiti Tenaga Nasional (UNITEN)</li> <li>e. Universiti Putra Malaysia (UPM)</li> <li>f. Universiti Teknologi MARA (UiTM)</li> <li>g. Universiti Malaysia Sarawak (UNIMAS)</li> <li>h. Universiti Kuala Lumpur (UniKL)</li> <li>i. International Islamic University of Malaysia (IIUM)</li> <li>j. Universiti Sains Malaysia (USM)</li> <li>k. Universiti Teknologi Malaysia (UTM)</li> <li>l. Universiti Utara Malaysia (UUM)</li> <li>m. Universiti Malaysia Sabah (UMS)</li> <li>n. Universiti Malaysia Terengganu (UMT)</li> <li>o. Universiti Tun Hussein Onn Malaysia (UTHM)</li> <li>p. Universiti Malaysia Pahang (UMP)</li> <li>q. Universiti Teknikal Malaysia Melaka (UTeM)</li> <li>r. Universiti Malaysia Perlis (UNIMAP)</li> <li>s. Universiti Malaysia Kelantan (UMK)</li> </ul> </li> <li>6) Public Research Institutes <ul style="list-style-type: none"> <li>a. Malaysia Nuclear Agency</li> <li>b. Malaysian Centre for Remote Sensing (MACRES)</li> <li>c. National Hydraulic Research Institute of</li> </ul> </li> </ul>

Components	Roles and Responsibilities
	<p>Malaysia (NAHRIM)</p> <p>7) MDeC/MYREN</p> <p>8) Industries:</p> <p style="padding-left: 20px;">a. PROTON</p> <p style="padding-left: 20px;">b. Les Copaque Sdn. Bhd.</p> <p>It can be further expanded to include:</p> <p style="padding-left: 20px;">1) Other ministries/agencies (e.g. MOH, MINDEF and MITI)</p> <p style="padding-left: 20px;">2) Private Research Centres</p> <p style="padding-left: 20px;">3) Trade Associations</p> <p>The main task of the Grid Technical Committee is to discuss and agree to a common rules and regulations that will be used to define the guidelines and policies for the National Grid.</p> <p>In addition, the committee will also need to regularly review the National Technology Roadmap and recommend any necessary refinement to it. This subsequently will further identify potential projects that will be recommended or approved for funding under different funding mechanisms from different ministries.</p>
International Advisory Panel (IAP)	<p>Members for this panel are expected to be invited based on their technical experience and international reputation and recognition in the field of Grid Computing. They can be either from either academics or industry.</p> <p>Similar to the Steering Committee, the IAP members will evaluate and provide advice/recommendations on the National Technology Roadmap.</p> <p>They also will provide insights on future technologies that will shape the National Technology Roadmap thus may also recommend potential projects that need to be done or new technologies that the nation should focus on.</p>

Table 4: Description of Various Components and Their Roles and Responsibilities in Domain 4

## 6. The Roadmap

As a summary for the activities described in the respective domain areas, the KnowledgeGRID Malaysia roadmap is depicted in its pictorial form as shown in Figure 3 with the accompanying timeline.

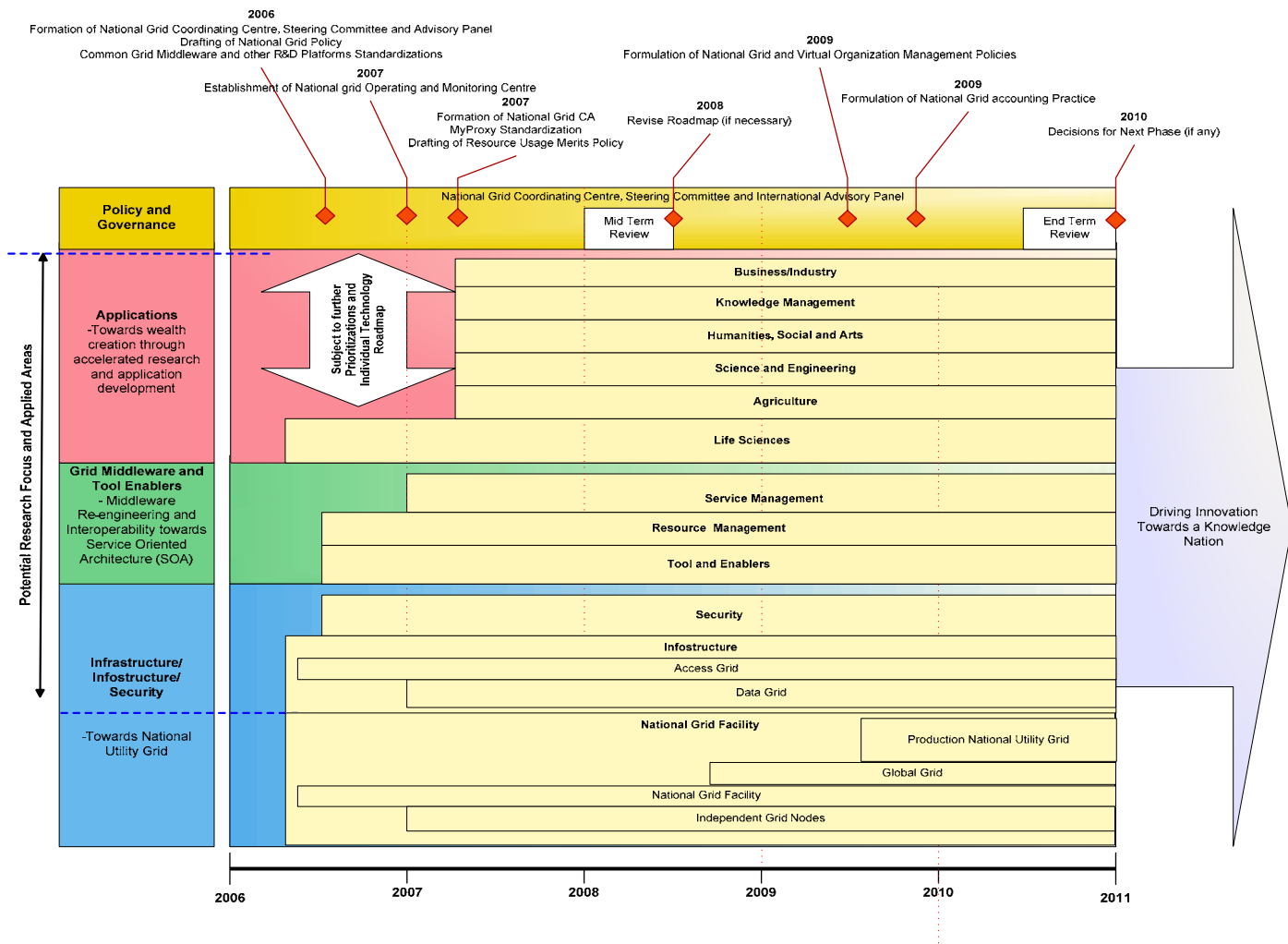


Figure 3: National Technology Roadmap for Grid Computing

## 7. Recommendations

To close the gaps amongst the regional partners in the area of grid computing, it is essential that this national grid roadmap is implemented with commitment from all stakeholders. This includes proper funding, appropriate operation model, right prioritized projects and competency of all members.

Among the steps proposed are:

- 1) Implementation of the National Grid Facility.
  - a. Linking Satellite Centres which are ready to connect to National Grid Nucleas.
  - b. Ready Grid enabled black box for new Satellite Centre.
- 2) A representative from the KnowledgeGRID Malaysia technical committee to participate in all MOSTI grant evaluation process related to Grid research.
- 3) Obtain MOSTI approval to pilot cluster projects comprising of several key projects. The proposed cluster projects include:
  - a. AgriGRID
  - b. GeoGRID
  - c. AutomativeGRID
  - d. AnimationGRID
  - e. FinanceGRID
- 4) Determination and prioritization of short term projects or applications that need to be R&D and to be demonstrated or deployed on the National Grid Facility.
  - a. For Life Sciences, the National Technology Roadmap for Bioinformatics will be used as the primary guideline.
  - b. Other applications areas will need more technological evaluation and prioritization based on criteria such as (subject to Steering Committee's approval):
    - i. Multi-institutional collaboration
    - ii. Outputs, outcomes and impact must be clearly defined.
    - iii. SWOT analysis
    - iv. Accessibility to other members of the Grid Computing research cluster.
  - c. Availability of effective project management at all levels by MOSTI.
  - d. Development of projects following a standard software development practices (e.g. SEI CMMI), where applicable.
  - e. Effective communication amongst stakeholders.
  - f. Integration with other projects and applications from other domains for example Knowledge Management Project from Application Domain

may require integration with Data Grid Project from Grid Middleware and Tools & Enablers domains.

- g. Prepare ground work for Grid security related projects.
  - h. Start ground work to get agreement on a common middleware platform and other open standards so that the Grid Computing research cluster can work more cohesively and reduce chances of portability, operability and compatibility issues on the National Grid Facility.
- 5) Establish partnership among the technologists, subject-matter experts and the industries in roadmap development and reviews.
  - 6) Grid Technical Committee (GTC) must include technologists and subject-matter experts.
  - 7) Organize annual Malaysia Grid Forum for recognition, rewards and knowledge sharing among the members of KnowledgeGRID Malaysia.
  - 8) Initialization of KnowledgeGRID Malaysia Book for annually distribution.
  - 9) Meeting with Grid Technical Committee(GTC) and all domain experts from KnowledgeGRID Malaysia should be held quarterly.

However, bear in mind that the National Grid Technology Road Map is a living document that will be regularly reviewed, refined and should be a long term strategy to further improve Malaysia's competitiveness.