Singapore-MIT Alliance: SMA-2 White Paper
The White Paper should be no more than 15 pages exclusive of items 7 and 8.

1. TITLE
   Leaders in Information Systems and Architectures (LISA)

2. SUMMARY
   A summary of the teaching and research components of the academic programme, including motivation and potential benefit.

   Leaders in Information Systems and Architectures (LISA) is a collaboration among the School of Computer Engineering (SCE), Nanyang Technological University; the Engineering Systems Division (ESD), MIT; and the School of Computing (SOC), National University of Singapore. The program represents an interdisciplinary approach to large-scale information systems and architecture engineering challenges of the 21st century. It is modeled after ESD's Leaders for Manufacturing degree program.

Impact on Singapore
   The Economic Review Committee's recommendations in remaking Singapore contained a key component that aims to position the nation as a key node in the global networked economy. In order to become the hub of business operations for the region, it is imperative that Singapore supports an information grid. The services and capabilities of such a grid will enable enterprises to collaborate with global business partners. The academic program will focus on knowledge and practice in information systems and their architecture. It retains a strong flavor of existing ESD programs by providing both breadth and depth in engineering systems. The research portion will investigate issues and develop solutions relating to the information grid. Existing expertise found in the collaborating institutions provide a strong base for this research to take place. We have sought advice from the Infocomm Development Authority of Singapore (IDA) and their response is summarized as follows: “The research focus on Information Grid is in line with IDA's Strategic Infocomm Technology Roadmap from 2002 to 2007... In one sentence, the White Paper is on the right track.”

Benefits of Incorporating ESD into SMA
   ESD has a dual mission: to define and evolve engineering systems as a new field of study and to transform engineering education and practice. ESD is a priority in the MIT School of Engineering's view of the future, with a history of success in developing innovative teaching programs with a close relationship to industry. (Further background material on ESD can be found in Appendix 3.)

   The proposed program is unique and important. LISA is a visionary program that is different from traditional theoretical computer science and traditional business information systems groups. It combines the best of these programs and expands beyond the traditional views.

Benefits to Singapore Institutes
   The academic program is an ideal match with the universities' plans to provide a broad-based education and build partnerships with Singapore Research Institutes. Our proposed research team includes participants from Singapore’s Institute for Infocomm Research, Institute of Manufacturing Technology, and National Grid Office. Research institutes and university faculty will have opportunities to work with the diverse and rich pool of researchers affiliated with NTU, MIT, and NUS. As future leaders, the students will have a unique opportunity to be exposed to the systems-approach to complex engineering problems.

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3. TEACHING COMPONENT

   a. Type of degrees (Masters or PhD, and dual or certificate) offered, and planned yearly
graduation rates
b. Degree requirements at each partner university
c. Curricula and key subjects
d. Student trajectory with indication of residence and distance components (courses, projects)
e. Faculty involved, and associated teaching responsibilities
f. Teaching collaboration plan and track record (if appropriate)
g. Documentation suggesting student and industry interest, and the potential for ultimate
   financial self-sufficiency

(a) Type of Degrees and Overview of Educational Program

Degrees
LISA will be a Dual Masters Degree program of duration of 18 months. Incoming students
will earn dual Master’s degrees, one SM Degree in Information Systems from NTU/NUS and an
SM in Engineering Systems (from Information Systems track) from the ESD of MIT. We expect
to admit about 20 students a year to this program – based upon sufficiently high quality
applicants.

LISA will admit up to 8 students, who have completed the dual SM degree requirements, per
year into an NTU/NUS PhD Degree program with SMA certificate. Such students will apply to be
admitted to NTU/NUS PhD Degree before the completion of the dual degree and will be admitted
on a competitive basis.

Candidates should possess a good undergraduate degree in Engineering or Science in a field
which is related to their intended LISA thesis program. Some students with undergraduate
preparation in management or economics would be admissible, provided that they have a strong
technical background. All students in this LISA program are expected to have a solid background
in the basics of computers and information technology (e.g., programming languages, data
structures, etc.)

Student Trajectory
The dual SM degree students will spend their second semester at MIT and the rest in
Singapore. In addition to building theoretical foundations, coursework of the first semester also
establishes preliminary research interests among students. While they are at MIT, students will be
taking courses and at the same time, exploring research topics in more depth. Thesis research will
be conducted during the summer and the following third semester. This arrangement allows
students to most effectively use their residence at MIT to interact with faculty and other students
and at the same time, to promote collaborative research. The thesis research will be co-advised by
NTU/NUS and MIT faculty.

Distance Learning
Because not all MIT courses are offered in both semesters of the academic year and to get the
students ready for more advanced courses, some of the core courses will be offered via distance
teaching. For SMA-2, this could be bi-directional, i.e., some MIT courses will be taught while
students are in Singapore, and some NTU/NUS courses will be taught while students are at MIT.
We should limit the latter, though, to allow maximum use of the MIT residence.

(b) Degree requirements at each partner university

ESD Degree Requirements
The ESD Masters degree is constructed around a core set of classes. This is the same core as
the ESD PhD core. The ESD core classes are chosen to give the student competence in systems theory
and methods that can be applied to research in engineered systems to advance theory, policy or
practice.
Students must satisfy a breadth and depth requirement. A student must take a minimum of 66 units with a minimum of 12 units in each of the three breadth areas of (I) Systems Theory, Design and Architecture, (II) Socio-Technical/Enterprise Systems and (III) Research Methods. The student then takes three classes in one area of depth in Information Systems.

The program described in (c) is based upon the current structure of the ESD SM Program and existing courses. It is expected that modifications to the program will occur and new courses will be developed as part of this SMA-2 LISA effort.

**NTU/NUS Degree requirements**

For a Master of Science degree, the requirement is six courses plus one thesis. These courses include core in Systems Theory, Design and Architecture and Socio-Technical/Enterprise Systems as offered by ESD. An additional core course is required in the Research Methods together with three more electives from the following modules in the Information Systems.

(c) **Curricula and key subjects**

**Common Curriculum for ESD and NTU/NUS SM**

I. Systems Theory, Design and Architecture
   - ESD.34J System Architecture

II. Socio-Technical/Enterprise Systems
   - ESD.565J Integrating Information Systems: Technology, Strategy, and Organizational Factors

III. Research Methods
   ESD Requirement
   - Systems Dynamics
   - ESD.74J System Dynamics for Engineers

   NTU/NUS Requirement (1 of the following)
   - Computational Intelligence, Methods and Applications
   - Modeling and Performance Evaluation of Queuing Systems
   - Linear Programming
   - Scientific Visualization

IV. Depth in Information Systems
   ESD Requirement (3 of the following courses)
   - ESD.264J Database, Internet, and Systems Integration Technologies
   - ESD.341J Web System Architecting: Building Web Services
   - ESD.355J Concepts in the Engineering of Software
   - ESD.132J Law, Technology, and Public Policy

   other possible ESD choices may include (subject to approval of faculty):
   - ESD.127 Telecommunications Modeling and Policy Analysis
   - ESD.210J Computer Algorithms for Systems Analysis
   - ESD.221J An Introduction to Intelligent Transportation Systems

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2 MIT has a peculiar unit scheme which consists of the sum of classroom lectures hours, expected laboratory hours, and expected homework hours per week. Typical MIT subjects are either 9 or 12 units and roughly correspond to 3 or 4 unit courses at other universities.
**NTU/NUS Requirement** (3 of the following courses)
- Data Mining
- Advanced Data Management Techniques
- Software Testing
- Multimedia Information Management
- Human Computer Interaction

d) **Typical Student Trajectory**

Assuming an 18 month schedule for the dual Masters degrees (starting in July):

<table>
<thead>
<tr>
<th>Period</th>
<th>Courses (NTU/NUS + MIT)</th>
<th>Milestones</th>
</tr>
</thead>
<tbody>
<tr>
<td>July-Dec (Singapore)</td>
<td>3 + 2</td>
<td>3 Courses at NTU/NUS</td>
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<tr>
<td></td>
<td></td>
<td>2 MIT SMA-2 LISA core course via teleconf.</td>
</tr>
<tr>
<td>Jan-May (MIT)</td>
<td>1 + 4</td>
<td>4 Courses at MIT (including 1 compressed in Jan)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 NTU/NUS core course via teleconf.</td>
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<tr>
<td></td>
<td></td>
<td>1 SMA-2 LISA research seminar</td>
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<tr>
<td></td>
<td></td>
<td>Identify supervisors and research topics</td>
</tr>
<tr>
<td>June-Dec (Singapore)</td>
<td></td>
<td>Full time research on thesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Apply for PhD program</td>
</tr>
<tr>
<td>Estimated to be 3 years</td>
<td></td>
<td>Confirmed PhD candidates proceed to further study at NTU/NUS</td>
</tr>
</tbody>
</table>

As mentioned in section 3(a), we project a cohort of 8 PhD candidates per year. These students will be registered in NTU/NUS under the supervision of Flagship/Inter-University research faculty, and co-supervised by an MIT counterpart working on the same project. As part of the project, such doctoral students will spend at least one semester on the MIT campus as MIT Special Students.

Planned yearly graduation rates: 20 dual Masters per year and approximately 8 PhDs per year. The former are expected to reach steady state in late 2006 while the latter would only graduate from 2009/2010 onwards.

(e) **Faculty Involved**

MIT – ESD faculty and initial teaching responsibilities (course numbers might change as they are modified to fit LISA objectives): Steve LERMAN (1.001), Stuart MADNICK (ESD.565), Joel MOSES (ESD.34J), Nancy LEVESON (ESD.355J), John WILLIAMS (ESD.341J), plus other MIT faculty.

NTU/NUS: Ee Peng LIM, Wee Keong NG, Ah Hwee TAN, Kian Lee TAN, Beng Chin OOI, Yong Meng TEO, Sourav Saha BHOWMICK, Kim Tian SEOW, Kevin Kok Wai WONG

(f) **Teaching Collaboration Plan and Track Record**

The faculty selected for this program have had extensive experience with educational efforts similar to LISA involving complex faculty collaboration, such as:
- Distance education – Systems Design and Management (SDM) and SMA-1 programs
- Dual degree programs – Leaders for Manufacturing (LFM)
- Innovative educational technology – OpenCourseWare (OCW)
Existing “Smart Classes” with video conferencing equipment will be used to facilitate distance learning. ELearning portals such as NTU’s edveNTUre will be exploited to support courseware and student/faculty communication.

(g) Student and Industry Interest

The LISA program is inline with the vision and roadmap of Singapore’s Infocomm Development Authority. This involves the educating of knowledge workers at a postgraduate level in the specific domains of engineering and information systems.

SCE/NTU has existing MOUs with multinational corporations, such as SUN and HP, in research as well as postgraduate education programs. Specifically, the Master of Science in Bioinformatics has already received warm support from the industry. Such partnerships could be extended for this SMA program. Companies such as Singapore Engineering Software of the ST Electronics group and Motorola have also expressed interests in research and manpower with software engineering skills. They could be potential partners of our research projects and provide test sites for implementing our research outcomes as well as recruiters of the LISA graduates.

4. RESEARCH COMPONENT

a. Summary of the general research theme and associated applications within which the Inter-University and Flagship projects will reside
b. Synopses of several illustrative potential Inter-University proposals: topic and personnel
c. Executive summaries of one (or at most two) specific flagship proposals: topic and personnel
d. Research collaboration plan and track record (if appropriate): shared personnel, face-to-face arrangements, proposed distance mechanisms
e. Documentation suggesting interest of industry and outside funding agencies, and the potential for ultimate self-sufficiency
f. Plans for collaboration with RIs and/or industry.

(a) General Research Theme: Information Grid

Singapore is poised to play a major role as an information and technology hub in East Asia and has aspired to build up indigenous research expertise that will be strategic in attaining and sustaining a competitive advantage in Information Systems and Information Technology. The research theme on Information Grid suggests that tremendous advantages may accrue to Singapore by taking a lead in the research, development, and deployment of an important set of integrated value-added information grid services leveraging on the excellent network and information infrastructure. These capabilities will enable Singapore to transform herself into an important information hub providing the knowledge processing capabilities critically needed by global enterprises in the information age.

This research theme will leverage on the expertise of diverse research groups from MIT, NTU, NUS, I2R, SimTech and National Grid Office through an integrated large-scale experiment to:

- Establish a shared global Information Grid environment
- Identify important application areas, with an initial focus in the financial services domain
- Research, design, and develop Information Grid tools and services
- Demonstrate the effectiveness of the theories, tools, and methodologies through technology transfer to industry.

The Internet and the World-Wide-Web have collectively provided the basis for an important infrastructure for connecting enormous amounts of computing and information resources on a global scale. It is increasingly obvious, however, that this kind of “physical connectivity” alone is not sufficient – this complex system must be effectively managed and vastly enhanced, through an Information Grid, to provide maximum value. This proposal suggests that tremendous advantages may accrue to Singapore and beyond by taking a lead in the research, development, and deployment of such an Information Grid.
The Information Grid has certain parallels and analogies to an Electric Power Grid:
- There are many different heterogeneous information sources.
- The consumers of the information should not care which source provides its needed information and in what form or which language.
- The information should be easily transformable to serve the specific needs of the diverse users and applications.
- The Grid should be dynamic and resilient to changes. It should be able to dynamically and automatically substitute alternative information sources for inaccessible or damaged information sources.
- The Grid should be able to balance and effectively manage its resources.
- High degrees of local autonomy should be allowed and supported. On the other hand, in the event there are situations where autonomy can be meaningfully traded for efficiency and quality, sources can opt for a quasi-autonomy mode by adopting some specific service protocols that facilitate management and sharing of computing computation and information resources.

Background and Related Work

Before we proceed on to describe the individual information grid services, we would like to examine the motivations for building an information grid. Two questions to pose are:
1) Is a grid infrastructure necessary, as opposed to just using the Internet?
2) Do current web-based technologies suffice for building our proposed information services?

Both questions can be rephrased with respect to Figure 1 as follows:
1) How far along the y-axis should the Information Grid be positioned?
2) How far along the x-axis should the Information Grid be positioned?

To answer the first question, we feel that although the computational and bandwidth requirements of the Information Grid at present may not be as high as some scientific grid applications which require as much as 100Gb/s data throughput and few hundred years worth of computational resources, they are still way beyond the current capabilities of the internet. For instance, the world’s largest computer maker, Dell computer, logs several tens of gigabytes (GB) of online transaction data daily. The world’s largest retailer, Wal-Mart, maintains an up-to-date massive 7.5 terabytes (TB) central database of purchase transaction logs culled from 2,900 stores in 6 countries. Further, an industry for credit-card fraud prevention (also known as credit risk management) currently exists in the US dedicated to the collection and aggregation of detailed credit card transaction data (including lists and dollar amounts of purchased products, addresses, etc.) from a consortium of participating merchants. In all of these examples, real time data-mining analysis is not performed on the collected data precisely due to the lack of an adequate information grid infrastructure.

Imagine the number of enhanced applications enabled by the information grid: real-time fraud detection across multiple online and/or brick-and-mortar merchants (currently hard to detect based solely on the credit-card history perspective of the issuing bank), real-time recommendation of
products and services based on the current buying trend data-mined from the information grid, decision support for credit/loan application based on real-time classification of an applicant into several demographic groups. In fact, the data and real-time computational requirements of the information grid will increase by leaps and bounds when multiple merchants and financial institutions around the world begin to collaborate on mutually-beneficial and computational-intensive tasks such as global risk-management analysis. Further down the road, when ubiquitous computing becomes “pervasive”, only our proposed Information Grid will be capable of providing the personalized information access and delivery to the plethora of devices and individuals based on their locations, preferences, histories/logs, and similarity to other persons/devices.

With regards to the second question, while numerous intelligent information analysis tools/services have been developed for the Internet/web, most of them are ad-hoc, and do not assume a distributed computing metaphor, and therefore are not designed to operate optimally in a grid environment. On the other hand, at a lower level, the web-services specification, originally designed for the Internet, has been adopted by the OGSA (Open Grid Services Architecture) [Foster2002], and forms an integral part of any solutions developed on top of it.

Singapore’s National Grid Project aims to create a permanent inter-grid between the major Universities and research institutes in Singapore and abroad. This initiative will provide the infrastructure upon which the proposed information grid can be built. Most of the currently existing grid initiatives around the world focus on raw data-crunching applications for a particular domain such as earth-sciences, genomics, etc. The closest resemblance to our proposed information grid architecture is the knowledge grid [Cannataro2003] and the semantic grid [Roure2003], both of which are also still unproven research efforts. The first proposes an abstract grid architecture for applying classical data-mining techniques, while the second is a grid version of the still non-existing semantic web. To the best of our knowledge, there are no other research efforts into applying information grid technology to the financial market. All in all, our proposed Information Grid provides significant semantic enhancement over the traditional web and grid architecture, and yet retains a practical and reasonable scope.

Information Grid Architecture

Figure 2 shows a set of seven information grid services built on top of a basic grid and network services layer, which provides low-level OGSA compliant services such as security, raw resource allocation and management, data transfer, etc. OGSA is a widely adopted grid architecture that has become the de-facto basis of the majority of international grid-computing initiatives including NASA’s Information Power Grid[HiNo00] and the Discovery Net at Imperial College[CG*2002].

The actual architectural design and specification of the Information Grid, including the functionality and interfaces of each of the services, is an important part of this research effort. Furthermore, the overall management of the research team to insure the interoperability of these services in support of our flagship project is another important goal of this research effort. That is, although the individual research sub-projects (some described in more detail in Appendix 5) will be pursued independently and in parallel, much like the design and manufacture of the various components that make up a car, they are intended to fit together to provide an integrated Information Grid infrastructure.
The seven core information grid services are described in more details below:

1. **Information Access & Delivery Services**
   - Provides personalized multi/cross-lingual information retrieval and query services over vast number of autonomous/quasi-autonomous and heterogeneous data sources
   - Provides conversion/transformation/wrapper services to access and deliver diverse data formats
   - Provides smart deployment services for publishing/pushing/advertising information

2. **Information Integration & Exchange Services**
   - Provides collation services for resolving data heterogeneity
   - Provides brokering, contracting, and negotiation services for smart information barter/trade/collaboration

3. **Semantics & Ontology Services**
   - Provides collaborative ontology and rules management and maintenance services over different domains, thereby allowing domain-experts to collaboratively maintain ontologies and rule-bases
   - Provides services for the convenient and rapid acquisition of new ontology and rules
   - Provides tools to semantically enrich (mark-up) data/services using ontologies and rules
   - Provides translations between heterogeneous forms of ontologies and rules
   - Provides inferencing services (both query-answering/backward and data-driven/forward) for ontologies and rules

4. **Quality/Reliability/Performance Services**
   - Provides services to incorporate domain-specific metrics/methods/notions for the automatic or semi-automatic assessment/rating of service quality
   - Provides capabilities for measuring and improving data quality
   - Provides approaches to improve software quality and reduce or eliminate system failures
   - Provides monitoring, tuning, and fault-tolerant mechanisms for achieving desired performance and/or quality
   - Provides capabilities for monitoring execution and validating services relevant to negotiated agreements
5. Directory & Discovery Services
   • Provides indexing services to create and maintain a distributed smart information and service directory (yellow page) based on intelligent data-mining of resources
   • Provides match-making services to discover relevant consumers and publishers alike

6. Policy, Authority & Resource Management Services
   • Provides fine-granularity security services for the access of information and services
   • Provides authority aggregation/inference services for multiple resources of varying authority
   • Incorporates mechanisms to address and support regulatory policies on information reuse and repurposing

7. Agent Services
   • Provides intelligent agent services for automating/aggregating various (where applicable) Information Grid functionalities or realizing new and novel functions

Potential Applications

The need for Information Grid is especially important to information-intensive global applications, such as Financial Services (e.g., Global Risk Management), Transportation/Logistics (e.g., In-Transit Visibility), Military (e.g., Total Asset Visibility), Government (e.g., Terrorist Information Awareness), Biotechnology (e.g., Distributed Bioinformatics) and Manufacturing (e.g., Integrated Supply Chain Management). Although all of the above areas are important and can benefit greatly from the proposed technology, it is necessary to select an initial focus. It is proposed that the initial application focus be on financial information. Despite our initial emphasis of using the Information Grid infrastructure services for the financial services industries (e.g., banks, investors, etc.), this focus is actually quite encompassing since every organization, whether it be manufacturing, transportation, government, or military, has complex financial information and applications that can benefit vastly from the Information Grid.

It is our intention to make the generic Information Grid infrastructure being developed by LISA available to other possible SMA-2 programs, such as in Manufacturing and Biotech, for possible use by them in applications such as supply chain management and distributed bioinformatics.

We refer to our flagship research effort (described in more detail below) as the SMA Financial Information Grid (FIG). It is to be an intense collaborative effort involving NTU, MIT, and NUS. This collaboration will result in an Information Grid architecture together with its functional components to support complex financial applications. The research findings and experience will also be highly relevant to the construction of information grids for applications in other domains, and will result in the transfer of critical technological know-how and expertise to the IT industry in Singapore. The innovations and expertise that are developed through this research collaboration will play a significant role in shaping and supporting efforts in the development of a national information infrastructure and Singapore’s transformation to an intelligent island. In the long run, these can be critical factors in shaping a long-term sustainable competitive advantage for Singapore.

(b) Inter-University Proposals:

Proposal topics and personnel

Given that there are broader research issues not confined to the financial services industry for three of the Information Grid services, they are proposed here in this section to be Inter-University Research Projects. A more detailed description of possible sub-projects in these areas is suggested in Appendix 5.
1. Directory & Discovery Services -- Ee-Peng LIM, Francis Bu Sung LEE, Wee Keong NG, Xueyuan TANG, Stuart MADNICK, Michael SIEGEL

The proposed project explores efficient distributed indexing mechanisms for Information Grid resources using distributed data-structures such as hash tables. It investigates how an index can be optimally located, applied to data replicas, efficiently updated, and adapted to user access patterns to achieve improved performance and reliability. The distributed indexing mechanism will also be applied to application services, thereby enabling service search & discovery.

The project will also automate data source selection by discovering and applying knowledge about data sources and updating them as the sources and usage patterns evolve.

2. Agent Services -- Angel GOH, Chunyan MIAO, Kiam Tian SEOW, Ah Hwee TAN, Benjamin GROSOF, John WILLIAMS

Agents are software components that demonstrate autonomy, adaptiveness and goal-driven behaviors. This proposed research will investigate how agents can help to semi-automatically gather up-to-date and personalized information from a dynamically changing grid environment. To facilitate multiple agents to co-ordinate and collaborate with one another to achieve a common goal quickly and effectively, inter-agent interfaces and protocols will be investigated. The use of advanced rule-bases will be explored as well as emerging web services technologies. Furthermore, ways to create trusted agents as effective intermediaries will be explored.

3. Policy, Authority, & Resource Management Services -- Tok Wang LING, Wee Keong NG, Sourav Saha BHOWMICK, Mun Kew LEONG, Stuart MADNICK

In this proposed research, fine and coarse grain access-control will be studied in a distributed grid environment. Distributed security policies and their implementation will also be addressed for the update, display, and access of grid resources.

Different approaches and views towards information re-use and re-purposing are emerging around the world. Extreme positions have emerged with a movement toward regulation coming from the European Union Data Base Directive while the United States has taken a much more benign approach. We need to understand the implications of these directions as well as the position for Asian nations and develop recommendations for meaningful policies and regulations.

(c) Flagship Proposal: SMA FINANCIAL INFORMATION GRID (FIG)

This flagship proposal has a focus on addressing the complex design, systems and policy issues pertaining to the development of a SMA Information Grid (FIG) over the financial sources on the Internet. The characteristics and trends of financial sources and applications are as follows:

- Information is the core asset of financial services in any enterprises.
- Up-to-date financial information is required to support both strategic and operational decision making.
- Large volumes of data are collected electronically and are made available on the internet. Examples are online financial data, company and financial news, internet banking, etc.
- Both general and specialized financial services and tools can be made available on the Internet to support cross-enterprise financial services.
- Computation and data intensive information analysis applications are needed, e.g. global risk monitoring and management, credit card transaction analysis, etc.
- Financial data are distributed at different nodes and are in heterogeneous formats.
- The computation of financial data may only be done at designated nodes as they may be owned by different enterprises or individuals.

Simple Example

As an illustration of the problems created by the disparities underlying the way information is provided, represented, interpreted, and used, consider the example depicted in Figure 3 below. It assumes a collaborative effort, somewhat like the SMA programs, whereby various groups maintain
financial information sources (in this case simple budget and expenditure information, depicted on the left-hand side of diagram) – but using their own local and heterogeneous practices and information systems.

There are also multiples users of these information sources located in various countries around the world with their own information systems and practices (depicted on the right-hand side). What if each of these users wished to answer a fairly common, but important, type of question: “How much funding is left for project A?” The calculation in this case is conceptually quite simple, merely subtract the expenses incurred by the 3 regions from the amount of funds that had been allocated (these are all shown on the left side under the heading labeled “Sources”). There are multiple challenges to be overcome; a few key ones are summarized below.

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**Figure 3. Example of Challenges to be addressed by Information Grid**

**Overall Architecture of the Information Grid**

It is increasingly apparent that to exploit the proliferation of information sources that are becoming available, we require an Information Grid so that the information can be obtained from disparate sources and can be meaningfully assimilated. In Figure 3, we can see how four of the Information Grid services interrelate and coordinate with each other to derive a solution for the simple example (as elaborated below). Furthermore, the Information Grid must be scaleable, adaptable, and extensible to provide decision makers with the appropriate services in an efficient and timely manner in their environments and their applications. Thus, the overall architectural design of the Information Grid is an important goal of this project (referred to as project category 8 in Appendix 5).

**1. Information Access and Delivery Challenges**

**Access:** Even assuming that all the necessary information is available electronically and connected via the Internet, they may be in different media and meaning. In this example, the allocated funds are in an Oracle relational database in Singapore, the expenses for Region 1 (USA) are available from an XML web site, the expenses for Region 2 (UK) are in an Excel spreadsheet, and the expenses from Region 3 (Japan) are provided via a semi-structured electronic mail message. In order to
compute the desired answer, the information must be extracted from these varying sources and gathered together.

**Delivery:** Similarly, the actual request may originate in many ways (these are shown on the right side under the heading labeled “End-User Environments & Applications”). A user in the USA may be making this request from a Web browser, a user in the UK may have this request originating from an “embedded SQL query” in a spreadsheet, a user in Singapore may be collecting this information for data warehousing purposes. Furthermore, this information may be requested and used as part of calculations in different application programs (e.g., preparation of budgeting reports, generation of exception reports, etc.)

**(2) Information Integration and Exchange and (3) Semantics and Ontology Challenges**

Merely subtracting the numbers shown in the Figure 3 expense sources on the left from the allocated number does not produce the “right” answer because different sets of assumptions underlie the representation of the information in the sources. These assumptions are often not explicit. We call these the meaning or “context” of the information [BGLSS2000, GBMS1999]. In this case, the source contexts are indicated at the far left in Figure 3.

For the example shown in Figure 3, the allocated funds are expressed in 1000’s of Singapore dollars, the expenses in Region 2 are expressed in 1’s of British pounds excluding 10% VAT charges, and Region 3 reports its expenses in 100’s of Japanese Yen.

Likewise, the receivers’ may have their own unique context, shown at the far right in Figure 3. A USA user may expect the answer in 1’s of US dollars, whereas the Singapore user may wish the answer in 1000’s of Singapore dollars. The UK user may want the answer in 100’s of British pounds including 10% VAT charges. Under these circumstances, answering even the “simple” question in Figure 3 is not so simple. If fact, auxiliary information sources may be needed, such as currency conversion rates, as well as rules on how such conversions should be done (e.g., as of what date).

Contextual issues can be much more complex in other situations. For example, the meaning of “net sales” may vary – with “excise taxes” included for government reporting purposes in one context, but excluded for security analysis purposes in another. Furthermore, there may be multiple users (see right side of Figure 3) who might want an answer to such a question, each with their own desired media and meaning (user context profile). Note that a “user” might be a person, an application program, or a consolidated database, such as data warehouse or data mining application.

The use of language semantics and ontology is one approach to solving the aforementioned contextual issues. Ontology is a formal description of the concepts and relationships. Ontologies can be created manually or extracted semi-automatically for each domain. We will enhance existing knowledge discovery techniques, e.g. classification and clustering, etc. by exploiting the ontological knowledge of the underlying data. We will also investigate semantic extensions to the XML data model making the knowledge an exchangeable resource within the information grid. Ultimately, with the help of financial ontologies, the goal is to improve data and service quality by providing the appropriate context for preparing and interpreting the results.

**(4) Quality, Reliability and Performance Services**

Due to the fact that information is backed by different authorities, with varying levels of quality, we will investigate how the various authorities and quality can be combined to reflect the authority and quality of the returned query result. Change management is another area in which quality is important, i.e. a piece of information is no good if it is stale, nor will it be acceptable if a complete downloaded is required to make it up-to-date. We will investigate the detection of changes in data databases with different implementations models. To deliver optimal performance for the Information Grid, the tuning and coordination among processing entities in the grid will be investigated. In this regards, new metrics for calibrating performance and the extent of autonomy required by the Grid entities will be investigated.
Example FIG Applications

The Information Grid to be developed as part of this research effort comprises a set of generic services (sometimes referred to as “horizontal grid”). These services, as depicted in Figure 2, can be customized and utilized to address a range of applications. To demonstrate and test these capabilities, we have decided to apply these services to a specific application domain (sometimes referred to as “vertical grid”) – that is, financial services. To demonstrate the FIG capabilities, two possible applications are described below.

Example FIG Application 1 (Financial Service Integration)

Banks and other financial services organizations are faced with a requirement to support and interoperate with multiple standards for critical business functions. For example, IFX, OFX, and SWIFT all cover payment transactions with different data structures and representations [Coates01]. In addition, firms must do significant work to interface internal systems with these multiple standards. IFX, OFX and other standards are in a period of rapid evolution, resulting in a continuing need to make repeated changes to interface software to keep abreast of changing standards. Even within stable standards, extensibility features or “user defined” fields require multiple interpretations for some parts of standardized messages. The net result is that a significant amount of systems maintenance resources are required to cope with different and changing standards. Due to the rapidly changing landscape of electronic banking processes and practices these expenses can recur cyclically.

One specific initial FIG application would be to support inter-organizational (and intra-organizational) payment systems. Several major financial organizations (listed in Section 4(c) below) have already indicated interest in participating in this effort.

Example FIG Application 2 (Financial Transaction Analysis)

With the growing popularity of online-shopping, online credit card fraud is also increasing at a staggering rate. According to the European Commission, online credit card fraud in the European Union increased 50 percent from 2001 to 2002, ringing up a total of US$553 million in illegal transactions. Online merchants have to shoulder the lion’s share of the losses as the credit card holders’ liability is limited. Herein lies a real and urgent opportunity for online merchants to cooperate by allowing their transaction information to be anonymously mined over the proposed information grid in real-time for the purpose of fraud-reduction. For instance, a fraudster successively making a string of single large-ticket-value item purchases from different online stores each using a different stolen credit card number may not raise any red flags at each of the individual store. However, if this information is aggregated and data-mined over the information grid, and compared to the current buying statistics of similar demographic groups, a fraud alert may be generated and sent to all of the involved merchants to halt the transactions just in time.

Flagship Project Personnel

MIT: Stuart MADNICK (MIT Coordinator), Kevin AMARATUNGA, Benjamin GROSOF, Nancy LEVESON, Joel MOSES, Michael SIEGEL, Richard WANG, John WILLIAMS

NTU: Wee Keong NG (NTU Coordinator), Ah Hwee TAN, Kuiyu CHANG, Kim-Wai HO

NUS: Kian Lee TAN (NUS Coordinator), Beng Chin OOI

I2R: Hwee Hwa PANG

SimTech: Eng Wah LEE

National Grid Office: Hing Yan LEE

(d) Research Collaboration Plan and Track Record

The MIT researchers, with informal collaboration with colleagues from Singapore, have developed an initial theory, architecture, and prototype for such an initial set of Information Grid services, referred to as COntext INterchange (COIN) [BGLSS2000, GBMS1999] through funding
from the USA Defense Advanced Research Projects Agency (DARPA) and corporate sponsors. Research groups in Singapore, such as the Electronic Commerce & Database Research Laboratory at NUS and the Center for Advanced Information Systems at NTU, have also been engaged in related research.

All of the researchers involved in this effort have had significant experience and success with such large-scale collaborative projects.

(e) **Interest of Industry and Funding Agencies**

Discussions have begun with several major financial organizations to cooperate in our Flagship research effort. We expect that this list will evolve as the research plan is further developed.

**MAJOR BANKS**
- Citibank
- Wells Fargo
- ABN AMRO

**MAJOR FINANCIAL INTERMEDIARIES**
- Check Free
- SWIFT – operates world-wide payment network
- Mastercard
- ClearCommerce – online payment and fraud-prevention system vendor

(f) **Plans for Collaboration with RIs and/or Industry**

**Research Institute Collaboration**

The following Singapore Research Institute collaborators have been identified and are playing a major role in the development of this White Paper:

- Institute of Infocomm Research (I2R) ([http://www.i2r.a-star.edu.sg](http://www.i2r.a-star.edu.sg)), previously the Laboratories for Information Technology (LIT), Kent Ridge Digital Labs (KRDL), and Institute of Systems Science, has related activities in database research. Primary contacts:
  - Dr Hwee-Hwa PANG, Division Director, Services & Applications
  - Dr Mun-Kew LEONG, Manager, Media Semantics

  - Dr. Yee Hsun U, Principal Scientist & Group Manager, Production and Logistics Planning (PLP Group)
  - Dr. Eng Wah LEE, Senior Scientist and in-charge Java Smart Services Lab, PLP.

- National Grid Office ([http://www.ngp.org.sg](http://www.ngp.org.sg)) has overall responsible for the development of Grid infrastructure for Singapore. Primary contacts:
  - Dr Hing-Yan LEE, Deputy Director

**Other Possible Singapore Research Institute Collaborators**

- Bioinformatics Institute (BII) ([http://www.bii.a-star.edu.sg](http://www.bii.a-star.edu.sg))
  - Distributed Computing in Biomedicine ([http://www.bii.a-star.edu.sg/dcbg](http://www.bii.a-star.edu.sg/dcbg))
  - Medical Informatics ([http://www.bii.a-star.edu.sg/mig](http://www.bii.a-star.edu.sg/mig))
  - Advanced Computing
    - Software and Computing ([http://www.ihpc.a-star.edu.sg/research_advcom_sc.htm](http://www.ihpc.a-star.edu.sg/research_advcom_sc.htm))
Intelligent Engineering Systems (http://www.ihpc.a-star.edu.sg/research_advcom_ies.htm)

Interest from Industry and Other Organizations

As explained in Sections 2 and 4, the LISA program and the Information Grid research can have a significant impact in industry in Singapore and around the world. Current and past sponsors of related research eventually might become sponsors of the LISA research program. That includes: Citibank, Merrill-Lynch, Microsoft, MITRE, Suruga Bank (Japan), DARPA (US government), etc.

5. QUALIFYING CRITERIA

An indication that all the qualifying criteria of Section 3.1 can plausibly be satisfied at the time of full-length proposal submission.

All of the elements of the Qualifying Criteria are met by this proposed program. See more specific notes in Appendix 2.

6. SUMMARY OF PROGRAMME MANAGEMENT PLAN

A summary of the programme management plan, including liaison with the relevant university units.

Steering Committee: The proposed LISA program will be managed by an 8 member Steering Committee, co-headed by Professor Stuart Madnick from MIT and Professor Angela Goh Eck Soong from NTU to manage day-to-day operations of the program. Two faculty members from each side will be selected to serve on the committee. In addition, the administrations of MIT and NTU will be represented on the committee by Professor Daniel Roos, Director of ESD at MIT, and Professor Seah Hock Soon, Dean of Computer Engineering at NTU.

The committee will meet once a year in person, alternating between Singapore and USA, and three additional times a year (or as needed) via video conference. The committee will be responsible for overall management of the education and research efforts of the program, e.g., admissions, curriculum development and improvement, review of research projects, budgeting and planning, and coordination with industry and government sponsors.

Advisory Board: We also plan to create an external advisory board that will include representatives from the A*STAR research institutes, Singaporean industry, and other relevant parties (such as representatives from international industry that are collaborating with either the LISA educational or research programs). The composition and operation of this Advisory Board will be determined as part of preparing the full proposal.

Administrative Office: An administrative office will oversee the day-to-day operations and maintain liaison with external partners. The office will be located at the School of Computer Engineering, NTU. Upon start of the program, the students will be located in NTU before and after spending the mid-period at MIT. However, as teaching and research will take place in MIT/NTU/NUS, facilities at all three sites will be provided. Selected students will be confirmed as PhD candidates; these students will be located in the research centers of their respective advisors.
## 7. BUDGET (US$)

**MIT ESD Leaders in Information Systems & Architectures (LISA) 7/1/2005 - 6/30/2010**

### Inter - University Projects

<table>
<thead>
<tr>
<th></th>
<th>Year 1</th>
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<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
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<td>$10,143</td>
<td>$10,650</td>
<td>$11,183</td>
<td>$11,742</td>
<td>$53,378</td>
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<td>-</td>
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<td>$10,650</td>
<td>$11,183</td>
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### Flagship Project

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<th>Year 1</th>
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<th>Year 4</th>
<th>Year 5</th>
<th>Total</th>
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<tr>
<td><strong>Salaries &amp; Wages</strong></td>
<td></td>
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<td>$73,500</td>
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<td>Travel - 4 trips to S'Pore for 2 wks apiece</td>
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## Inter-University Projects

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<th>Year 1</th>
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<td><strong>Salaries &amp; Wages</strong></td>
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<tr>
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## Flagship Project

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<td><strong>Salaries &amp; Wages</strong></td>
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<td>$60,000</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$300,000</td>
</tr>
<tr>
<td><strong>Operating Expenses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials &amp; Services</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$100,000</td>
</tr>
<tr>
<td><strong>Sub-Total Operating Expenses</strong></td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$20,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Equipment</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$60,000</td>
<td>$300,000</td>
</tr>
<tr>
<td><strong>TOTAL BUDGET</strong></td>
<td>$582,200</td>
<td>$589,500</td>
<td>$598,000</td>
<td>$606,000</td>
<td>$634,300</td>
<td>$3,010,000</td>
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</tbody>
</table>
8. CURRICULUM VITAE OF ALL PERSONNEL INVOLVED (Teaching and Research)

Please see Appendix 4 for detailed Curriculum Vitae

MIT Teaching and Research Faculty

Senior Faculty:

Steven LERMAN, Class of 1922 Professor of Civil and Environmental Engineering, MIT School of Engineering
Nancy LEVESON, Professor of Aeronautics and Astronautics and Professor of Engineering Systems, MIT School of Engineering
Stuart MADNICK, John Norris Maguire Professor of Information Technology, MIT Sloan School of Management and Professor of Engineering Systems, MIT School of Engineering
Joel MOSES, Institute Professor of Computer Science and Engineering and Professor of Engineering Systems, MIT School of Engineering
John WILLIAMS, Associate Professor of Civil and Environmental Engineering, MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering

Note: may add faculty who are teaching other ESD course subjects in this program, once we finalize curriculum.

Junior Faculty:

Kevin AMARATUNGA, Associate Professor of Civil and Environmental Engineering, MIT School of Engineering
Benjamin GROSOF, Douglas Drane Assistant Professor in Information Technology, MIT Sloan School of Management

NTU-NUS Teaching and Research Faculty

Angela Eek Soong GOH, Professor and Vice Dean, NTU School of Computer Engineering
Ee Peng LIM, Associate Professor and Head, Division of Information Systems, NTU School of Computer Engineering
Francis Bu Sung LEE, Associate Professor and Head, Division of Computer Communications, NTU School of Computer Engineering
Wee-Keong NG, Associate Professor and Director, Center for Advanced Information Systems, NTU School of Computer Engineering
Ah-Hwee TAN, Associate Professor, NTU School of Computer Engineering
Narendra CHAUDHARI, Associate Professor, NTU School of Computer Engineering
Kim Wai HO, Associate Professor, NTU Nanyang Business School
Sourav Saha BHOWMICK, Assistant Professor, NTU School of Computer Engineering
Chunyan MIAO, Assistant Professor, NTU School of Computer Engineering
Kevin Kok Wai WONG, Assistant Professor, NTU School of Computer Engineering
Xueyan TANG, Assistant Professor, NTU School of Computer Engineering
Yew Soon ONG, Assistant Professor, NTU School of Computer Engineering
Kiyu CHANG, Assistant Professor, NTU School of Computer Engineering
Kiam Tian SEOW, Assistant Professor, NTU School of Computer Engineering

Beng Chin OOI, Professor and Vice Dean (Academic Affairs and Graduate Studies), Dept of Computer Science, NUS School of Computing
Tok Wang LING, Professor, Dept of Computer Science, NUS School of Computing
Kian-Lee TAN, Associate Professor and Deputy Head, Dept of Computer Science, NUS School of Computing
Yong-Meng TEO, Associate Professor, NUS School of Computing

I2R/SIMTECH/National Grid Teaching and Research Associates

Hwee Hwa PANG, Director of the Services and Applications Division, Institute for Infocomm Research
Mun Kew LEONG, Manager of the Media Semantics Department, Institute for Infocomm Research
Yee Hsun U, Principal Scientist & Group Manager, Production and Logistics Planning (PLP Group)
Eng Wah LEE, Senior Scientist, Singapore Institute of Manufacturing Technology (SIMTECH)
Hing Yan LEE, Deputy Director, Singapore National Grid Office

MIT Principal Research Associates
Michael SIEGEL, Principal Research Associate, Information Technologies Group, MIT Sloan School of Management; co-head MIT PROductivity from Information Technology (PROFIT) Program
Richard WANG, Principal Research Associate; Director, MIT Information Quality Program, Center for Technology, Policy, and Industrial Development (CTPID), MIT School of Engineering and Co-director, Total Data Quality Management (TDQM) Program, MIT Sloan School of Management.

MIT Teaching Program Administration (Head, ESD Education Committee)
Richard DE NEUFVILLE, Professor of Civil and Environmental Engineering, MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering

MIT Research Program Administration (Director, CTPID)
Fred MOAVENZADEH, James Mason Crafts Professor of Systems Engineering and Civil and Environmental Engineering, MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering

MIT Overall Program Administration (Co-Directors of ESD)
Dan HASTINGS, Professor of Aeronautics and Astronautics and Engineering Systems, MIT School of Engineering and Co-Director, Engineering Systems Division, MIT School of Engineering
Dan ROOS, Japan Steel Industry Professor of Civil and Environmental Engineering, MIT School of Engineering and Associate Dean of Engineering Systems, Director of Engineering Systems Division, MIT School of Engineering
APPENDICES
1 – References
2 – SMA-2 Qualifying Criteria
3 – Background on MIT’s Engineering Systems Division (ESD)
4 – Individual Curriculum Vitae
5 – Brief Descriptions of Possible Sub-Projects

APPENDIX 1 – REFERENCES

Successful programmes must meet the following qualifying criteria for each of the participating universities:

1. The programme must significantly advance the agenda of the Alliance universities with respect to teaching, degree programmes, and research. The final proposal must be approved by the heads of the relevant academic units of the Alliance universities.
   YES

2. The programme design as regards student trajectory and Alliance university collaboration must adhere to all the regulations, expectations, and values of the participating universities. Any degrees must already be approved at the Alliance universities, or the proposal must include a reasonable plan to secure such approval.
   YES

3. The programme must involve a sufficient number of faculty members and students at the Alliance universities to have significant impact on teaching and research. The majority of the faculty members involved should participate in both the teaching and the research collaboration aspects.
   YES

4. The rewards and compensation to faculty members for their participation in SMA-2 must be (a) consistent with their home institution’s usual compensation mechanisms, and (b) commensurate with their contributions to the programme.
   YES

5. Faculty members participating in either Inter-University or Flagship grants must be present at the collaborating university for two or more contiguous weeks each year.
   OK. Schedules to be worked out.

6. There must be a satisfactory plan for the management and internal review of the programme within each university and across the Alliance universities including, as appropriate, advisory councils representing different viewpoints.
   YES. Discussed in Section 6.

7. In the doctoral component, programmes must make provisions for (a) research co-supervision of SMA students by MIT and NUS/NTU faculty members, and (b) residency of SMA students in MIT research laboratories for one or more semesters.
   YES

8. In the research component, programmes must make provisions for the joint appointment of SMA Post-doctoral Fellows. Within any programme there should be a balance of shared SMA Post-doctoral Fellows and graduate-student Research Assistants from each of the universities co-hosting the programme. These shared Post-doctoral fellows would be co-supervised by MIT and NUS/NTU faculty members, and must be resident at both MIT and NUS/NTU for significant periods each year. Such SMA Post-doctoral Fellows may be considered later for appointment to NUS/NTU as faculty members.
   YES. Included in Budget (see Section 7). Details of schedule to be worked out.
APPENDIX 3 – BACKGROUND ON ESD

ESD is the first new educational division at MIT in over a quarter of a century — but the faculty that constitute ESD have been responsible for many important developments and innovations. This section briefly summarizes some of them.

MIT created ESD to tackle the large-scale engineering challenges of the 21st century. ESD creates and shares interdisciplinary knowledge about complex engineering systems through initiatives in education, research, and industry partnerships. ESD broadens engineering practice to include the context of each challenge as well as the consequences of technological advancement.

ESD has a dual mission: to define and evolve engineering systems as a new field of study and to transform engineering education and practice.

As a division, ESD establishes an intellectual home for key academic programs and research centers, engages faculty across departments and disciplines, and fosters discourse about engineering innovation. Through ESD's affiliated faculty, students, and researchers, the Division fosters a new synthesis of knowledge and practice.

Academic: ESD’s current academic programs include Master’s Degree programs in: Engineering Systems; Leaders for Manufacturing; System Design and Management; Transportation; and Technology and Policy. Ph.D.s are offered in Transportation and in Technology, Management, and Policy. The academic component of this SMA-2 Program will be a new track in Information Systems in the existing ESD Engineering Systems Master’s Degree.

Research: ESD includes four research centers with an annual research volume of nearly $20 million: the Center for Technology, Policy, and Industrial Development (CTPID); the Center for Transportation and Logistics (CTL); the Industrial Performance Center (IPC); and the Center for Innovation in Product Development (CIPD). The research component of this SMA-2 Program will be administered by CTPID.

Relation to LISA: Information technology and computer science plays an increasingly critical role in modern societies. Although there are important areas of strictly technology, the complex “systems” aspects are becoming even more difficult and crucial. The LISA program is intended to provide an educational program that will prepare the student to be effective in dealing with these issues. The research program will be closely aligned and lead to innovations both in practice and to the teaching materials.

Some ESD highlights:
- MIT believes that Engineering is going to change in the 21st century. ESD will help revolutionize, re-define, and re-invent the future. ESD is a priority in the MIT School of Engineering’s view of the future.
- ESD has a history of success with innovative teaching programs and close relationship to industry, such as in distance education, Systems Design and Management (SDM), and dual degree programs, such Leaders for Manufacturing (LFM).
- ESD has had many successes in large-scale research, such in the Machine that Changed the World and Lean Aerospace Initiative (LAI).
- The ESD Knowledge Network will offer many benefits to this effort.
APPENDIX 4-- INDIVIDUAL CURRICULUM VITAE

MIT

Kevin AMARATUNGA, Associate Professor of Civil and Environmental Engineering, MIT School of Engineering


Dr. Amaratunga is an Associate Professor of the Information Technology group of Civil and Environmental Engineering Department at MIT. He holds a PhD from MIT. His research has been in the area of wavelets, filter banks and their applications to the modeling and management of large scale engineering systems. This includes multiscale wavelet approaches for partial differential equations in high performance computer simulation as well as multiscale wavelet signal processing techniques that are suitable for sensing, imaging and spatial data processing applications. Dr. Amaratunga also develops tools for performing large-scale engineering simulations, handling complex data sets and processing sensor signals in a real-time or distributed environment. Dr. Amaratunga’s recent research looks into ways of incorporating these advanced data processing techniques into grid computing to improve performance, service quality and agent capability.

Benjamin GROSOF, Douglas Drane Assistant Professor in Information Technology, MIT Sloan School of Management

[See http://ebusiness.mit.edu/bgrosof/]

Benjamin Grosof is the Douglas Drane Assistant Professor in Information Technology (IT) at MIT Sloan School of Management. His research is to create and study knowledge-based IT for e-commerce applications. He focuses especially on the technologies, business applications, and strategies for Semantic Web Services (SWS), the convergence of Web Services and Semantic Web. SWS is the next major generation of the Web, in which e-services and business communication become more knowledge-based and agent-based. The pioneer of inter-operable XML business rules, he co-leads the RuleML emerging industry standards effort. His research also includes several application areas for rule-based SWS in business process automation: e-contracting, which he has pioneered; financial information and reporting; and business policies, e.g, for trust and security. He is Principal Investigator and Rules co-lead in the DARPA Agent Markup Language (DAML) program, and a core participant in the newly formed Semantic Web Services Initiative that is creating emerging SWS standards. He interacts extensively with industry, including consulting in areas related to his research and standards activities.

He joined MIT Sloan in July 2000. Previously, he was a senior research scientist, in software, at IBM T.J. Watson Research Center (for 12 years), where most recently he conceived and led IBM CommonRules and co-led its application piloting for rule-based XML agent contracting in EECOMS, a $29 Million NIST industry consortium project on manufacturing supply chain management. His notable technical contributions also include fundamental advances in rule-based intelligent agents, conflict handling for rules, rule-based security authorization, and integration of rules with machine learning. He is author of over 30 refereed publications, two major industry software releases, and a patent. His background includes two years in software startups, PhD in Computer Science (specialty AI) from Stanford University, and a BA in Applied Mathematics from Harvard University.

Dan HASTINGS, Professor of Aeronautics and Astronautics and Engineering Systems, MIT School of Engineering and Co-Director, Engineering Systems Division, MIT School of Engineering
Dr. Hastings holds a Ph.D. from MIT in Aeronautics and Astronautics, which he received in 1980. He has taught courses and seminars in plasma physics, rocket propulsion, advanced space power and propulsion systems, aerospace policy, and space systems engineering.

Dr. Hastings served as Chief Scientist of the Air Force from 1997 to 1999. In that role, he served as chief scientific adviser to the chief of staff and the secretary and provided assessments on a wide range of scientific and technical issues affecting the Air Force mission. He led several influential studies on where the Air Force should invest in space, global energy projection, and options for a science and technology workforce for the 21st century.

Dr. Hastings’ recent research has concentrated on issues of space systems and space policy, and has also focused on issues related to spacecraft-environmental interactions, space propulsion, space systems engineering, and space policy. He has published many papers and a book in the field of spacecraft-environment interactions and several papers in space propulsion and space systems. He has led several national studies on government investment in space technology.

Dr. Hastings is a Fellow of the AIAA and a member of the International Academy of Astronautics. He is serving as a member of the NASA Advisory Council, the National Academies Government University Industry Research Roundtable and is the chair of the Applied Physics Lab Science and Technology Advisory Panel as well as the Air Force Scientific Advisory Board. He is a member of the MIT Lincoln Laboratory Advisory Committee and is on the Board of Trustees of the Aerospace Corporation. He also served as a member of the National Academy of Engineering's 1996 and 1997 Organizing Committee for Frontiers of Engineering and is a consultant to the Institute for Defense Analysis.

Steven LERMAN, Class of 1922 Professor of Civil and Environmental Engineering, MIT School of Engineering

[See http://web.mit.edu/civenv/html/people/faculty/lerman.html]

Professor Steven R. Lerman holds the Class of 1922 Distinguished Professorship at the Massachusetts Institute of Technology. He served as the Chair of the MIT Faculty from 1998-2001 and as the Associate Chair of the Faculty from 1996-1998.

He is currently the Director of the Center for Educational Computing Initiatives, the research unit of an MIT-wide research center devoted to studying the application of computational and communication technologies on education. He also Chairs the Faculty Advisory Board of the MIT OpenCourseWare initiative and is Deputy Director of the Singapore-MIT Alliance, MIT’s largest distance education program.

From 1983 to 1988, Professor Lerman directed MIT’s Project Athena. This project developed a campus-wide distributed system of advanced computer workstations at MIT. Prof. Lerman has been a Visiting Foreign Professor in the MBA in International Business Program at Gabriela Mistral University in Santiago, Chile since 1993 and was a Professor II (Visiting Adjunct Professor giving periodic guest lectures) at the University of Bergen in Norway for five years.

Dr. Lerman received his B.S. in civil engineering and his M.S. and Ph.D. degrees in Transportation from M.I.T. in 1972, 1973 and 1975 respectively. Prof. Lerman and his wife Lori live on the MIT campus and serve as Faculty Housemasters of one of MIT’s graduate dormitories. They co-chair the Housemaster Council.
Nancy LEVESON, Professor of Aeronautics and Astronautics and Professor of Engineering Systems, MIT School of Engineering
[See http://esd.mit.edu/Faculty_Pages/leveson/leveson.htm]

Dr. Leveson holds a Ph.D. from UCLA. She was a Computer Science professor at the University of California, then became Boeing Professor of Computer Science and Engineering at the University of Washington.

Dr. Leveson started a new area of research, software safety, which is concerned with the problems of building software for real-time systems where failures can result in loss of life or property. She and her students produced a formal requirements specification for TCAS II, a real-time collision-avoidance system required on all commercial aircraft in U.S. airspace. The FAA adopted it as their official specification.

The System and Software Safety Research Project is also working on modeling and analysis of various aerospace and transportation systems. Subtopics in this research area include modeling and analysis of safety, system and software requirements specification, safe software design, software fault tolerance, and verification and validation of safety. Dr. Leveson is also starting to work on Human-Computer Interaction. Recently, she has agreed to participate in some projects to evaluate the safety of proposed enhancements to the U.S. air traffic control system.

Stuart MADNICK, John Norris Maguire Professor of Information Technology, MIT Sloan School of Management and Professor of Engineering Systems, MIT School of Engineering
[See http://esd.mit.edu/Faculty_Pages/madnick/madnick.htm and http://web.mit.edu/smadnick/www/home.html]

Dr. Madnick holds a Ph.D. in Computer Science from MIT and has been an MIT faculty member since 1972. He served as the head of MIT's Information Technologies Group in the Sloan School of Management for more than twenty years. He is the co-head of the PROductivity From Information Technology (PROFIT) and Total Data Quality Management (TDQM) Programs. He has also been an affiliate member of MIT's Laboratory for Computer Science, and a member of the International Financial Services Research Center and the Center for Information Systems Research.

Dr. Madnick is the author or co-author of over 250 books, articles, or reports including the classic textbook on Operating Systems. His current research interests include information integration technologies, semantic connectivity among disparate distributed information systems, database technology, software project management, internet applications, and the strategic use of information technology.

Dr. Madnick has been active in industry, as a key designer and developer of projects such as IBM's VM/370 operating system and Lockheed's DIALOG information retrieval system. He has served as a consultant to major corporations, including IBM, AT&T, and Citicorp. He has also been the founder or co-founder of five high-tech firms, and currently operates a hotel in the 14th century Langley Castle in England.

Fred MOAVENZADEH, James Mason Crafts Professor of Systems Engineering and Civil and Environmental Engineering, , MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering
[See http://esd.mit.edu/Faculty_Pages/moavenzadeh/moavenzadeh.htm]
Fred Moavenzadeh's current interests include technology and development with special focus on formulation of technological policies for socio-economic development. He is particularly interested in institutional structures required to develop a viable science and technology infrastructure that could serve the human resource development strategy of newly industrialized nations.

As director of the Center for Technology, Policy and Industrial Development since October 1998, he is focusing on developing an institutional environment at MIT that fosters development of interdisciplinary research needed for enhancement of industrial productivity and performance. CTPID's primary areas of concentration are Aerospace, Automotive, Telecommunications, Mobility, Materials Systems, Business and Environment, and Technology and Law. CTPID emphasizes interdisciplinary research and encourages collaboration with industry and government on issues of major concern to society at large. Currently he is conducting a collaborative program with the Malaysia University of Science and Technology.

**Joel MOSES**, Institute Professor and Professor of Computer Science and Engineering and Engineering Systems
[See [http://esd.mit.edu/Faculty_Pages/amos/moses.htm](http://esd.mit.edu/Faculty_Pages/amos/moses.htm)]

Dr. Moses holds a Ph.D., which he received from MIT in 1967. He has served as MIT’s Provost, Dean of Engineering, Head of the Department of Electrical Engineering and Computer Science (EECS), Associate Head of EECS, and Associate Director of the Laboratory for Computer Science.

Dr. Moses is a member of the National Academy of Engineering, and a fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Sciences, and of the IEEE. He is a member of the NAE Committee on Engineering Education. He led the development of the Macsyma system for algebraic formula manipulation and is the co-developer of the Knowledge-Based Systems concept in Artificial Intelligence. His current interests include the complexity and flexibility of engineering systems.

Professor Moses is a member of the Board of Directors of the Analog Devices, Inc. He serves on the advisory boards of the Columbia University Fu School of Engineering and Applied Science, and the University of Michigan School of Engineering.

**Richard DE NEUFVILLE**, Professor of Civil and Environmental Engineering, MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering
[See [http://esd.mit.edu/Faculty_Pages/deneufville/deneufville.htm](http://esd.mit.edu/Faculty_Pages/deneufville/deneufville.htm)]

Dr. de Neufville holds a Ph.D. from MIT. His research and teaching interests include dynamic strategic planning; technology policy; airport planning; systems analysis; and real options.

Dr. de Neufville is Founding Chairman of MIT’s Technology and Policy Program (1976-2000) and the former Chair of MIT’s Technology, Management and Policy Doctoral Program. He also served as Chair, Committee on Industrial Liaison Program, Chair, Committee on Curriculum, Director, Civil Engineering Systems Lab, and Associate Director, Urban Systems Lab.

Dr. de Neufville has received numerous honors and awards. Most recently, he was awarded an Honorary Doctorate (Dr.H.C.), Technical University of Delft. Others include MIT Effective Teaching Award; the Irwin Sizer Award for Most Significant Contribution to MIT Education; US Federal Aviation Award for Excellence in Teaching. He has been a White House Fellow, a Guggenheim Fellow, and a US-Japan Leadership Fellow. He has received NATO Systems Science Prize and been decorated by the French Government as a Chevalier des Palmes Academiques.
Dr. de Neufville has been a visiting professor at University of California, Berkeley, London Graduate School of Business, and Ecole Centrale de Paris. He currently holds adjunct appointments at Harvard University’s Kennedy School of Government, Cambridge University’s Judge Institute of Management, and the French Ecole Nationale des Ponts et Chaussées.

**Dan ROOS**, Japan Steel Industry Professor of Civil and Environmental Engineering, MIT School of Engineering and Associate Dean of Engineering Systems, Director of Engineering Systems Division, MIT School of Engineering
[See http://esd.mit.edu/Faculty_Pages/roos/roos.htm](http://esd.mit.edu/Faculty_Pages/roos/roos.htm)

Dr. Roos serves as Founding Director of the International Motor Vehicle Program and as Director of the Cooperative Mobility Program. He is co-author of *The Machine That Changed The World*, which has been published in 11 languages and has sold over 600,000 copies. Dr. Roos also serves as Special Assistant to the Chancellor and Provost, helping to form large scale industrial and global partnerships. He had a leadership role in partnerships with Ford, Merrill Lynch, and Cambridge University in the U.K.

Previous responsibilities at MIT include Director of the Center for Transportation Studies, and Director of the Center for Technology, Policy and Industrial Development. Dr. Roos received the 1994 Shingo Prize for Excellence in Manufacturing Research. Dr. Roos also received the 1989 Frank M. Masters Transportation Engineering Award from the American Society of Civil Engineers “for his 25 year professional career in directing a series of highly innovative research projects of great relevance in the advancement of urban transportation.”

Dr. Roos has chaired and served on numerous committees of the National Research Council, as National Lecturer with the Association of Computing Machinery; and as an officer with the Transportation Research Board, ITS America, Operations Research Society of America, American Society of Civil Engineers, and Council of University Transportation Centers. He is the author of over 50 professional books and papers and is listed in Who's Who in America.

**Michael SIEGEL**, Principal Research Scientist, Information Technologies Group, MIT Sloan School of Management; co-head MIT PROductivity From Information Technology (PROFIT) Program

Dr. Siegel is a Principal Research Scientist at the MIT Sloan School of Management. He co-directs the Aggregation Research Project and is a co-inventor on several related patents including “Querying Heterogeneous Data Sources over a Network Using Context Interchange” and “Data Extraction from World Wide Web Pages.” He has served as co-director of MIT's International Financial Services Research Center (IFSRC).

Dr. Siegel's research interests include the use of information technology in financial risk management and global financial systems, eBusiness and financial services, financial account aggregation, heterogeneous database systems, managing data semantics, query optimization, intelligent database systems, and learning in database systems. His work in benchmarking Value-at-Risk software systems has been presented to the Federal Reserve Bank, academic, and international audiences. Dr. Siegel obtained an Engineering Degrees from Trinity College and the University of Wisconsin-Madison and a Ph.D. in Computer Science from Boston University.
Richard WANG, Director of the MIT Information Quality (MITIQ) Program at the Center for Technology, Policy, and Industrial Development (CTPID) and Co-Director for the Total Data Quality Management (TDQM) Program at MIT Sloan School of Management. [See http://mitiq.mit.edu, http://web.mit.edu/tdqm, and http://www.IQconference.org]

Dr. Wang has served as a professor at MIT, the University of Arizona, Boston University, and a Visiting Professor at the University of California, Berkeley.

At MITIQ Program, Dr. Wang has developed a well-received information-quality curriculum to certify practitioners for positions as corporate IQ analyst, manager, and trainer positions. His outreach programs such as the MITIQ consortium extend information quality principles and theories to intelligence quality in homeland security, information architecture in both public and private sectors, and intelligent commerce. At TDQM Program, Dr. Wang co-heads the innovative corporate householding research that investigates relationships of business units within the firm and across organizational boundaries such as those in supply chains.

Dr. Wang has put the term Information Quality (IQ) on the intellectual map with myriad journal and conference publications. His books on information quality include Quality Information and Knowledge (Prentice Hall, 1999), Data Quality (Kluwer Academic, 2001) and Journey to Data Quality (MIT Press, forthcoming). In 1996, Prof. Wang organized the premier International Conference on Information Quality, which he has served as the general conference chair, and currently Chairman of the Board. In 1991, he founded the Workshop on Information Technologies and Systems (WITS), which is now the top technical conference in the MIS field.

Dr. Wang received his Ph.D. degree from MIT.

John WILLIAMS, Associate Professor of Civil and Environmental Engineering, MIT School of Engineering and Professor of Engineering Systems, MIT School of Engineering; Director, Intelligent Engineering Systems Laboratory [See http://esd.mit.edu/Faculty_Pages/williams/williams.htm]

Dr. Williams holds a Ph.D. from Swansea University. His areas of specialty include information technology, web based education technology, computer simulation, discrete element analysis of granular and powder systems.

Dr. Williams is internationally recognized in the field of computational algorithms for large-scale particle simulators and has authored two books and over 70 publications. For the past eight years, his research has focused on architecting of large scale distributed simulation systems. He teaches graduate courses on Modern Software Development and on Web System Architecting.

Presently Dr. Williams is Director of MIT’s Intelligent Engineering Systems Laboratory, an IT research laboratory with 5 professors and 50 M.S. and Ph.D. students. He is also project leader of the Agents Simulation Program with the National Infrastructure Simulation and Analysis Center, whose goal is to protect the U.S. critical infrastructure. He is PI on a number of other projects for industry, including the Robot World project for Microsoft, where he leads a software team in developing online educational tools and developing project based teaching software for the Cambridge-MIT Initiative.

Dr. Williams’ software systems are used by Sandia National Laboratories, by MIT, and by several organizations in Japan and Europe. Recent publicity on his collaboration software for the new Tablet PC generated press reports in US News and World Report, CNN, and the Boston Globe.

Dr. Williams is on the editorial advisory board for the International Journal for Computer-Aided Engineering and Software and an active member of ASCE, where he is a member of the Committee
for Granular Materials. Dr. Williams consults to companies in the U.S., U.K., Ireland, and Japan and has spent much time in Japan collaborating with Keio University and the University of Osaka on the use of educational technology.
Angela E.S.GOH, Professor and Vice Dean (Academic), School of Computer Engineering, NTU, Singapore.

[See http://www.ntu.edu.sg/home/asesgoh/]

Dr. Goh was Head of the Division of Software System from 1995 to 2002 and is currently Vice Dean (Academic) of the School of Computer Engineering. She received her PhD from the University of Manchester Institute of Science and Technology (UMIST). Her industrial experience includes an appointment as senior systems manager at Deloitte, Haskins & Sells.

Her current research interests include Active Database Systems, XML databases and XML technology. Collaborators include the eLearning Competency Centre and the Singapore Institute of Manufacturing Technology (SIMTech). In the past few years, she has worked in areas related to database systems in the manufacturing domain including:

- Projects with SIMTech include developing a comprehensive software environment for modelling and schema generation, based on the STEP standard and involved a host of tools to enable users on different CAD/CAM systems to share and exchange product data.
- A major project supported by the then National Science and Technology Board entitled “Advanced Database Technology in Concurrent Engineering” was initiated. This project, worth about US$1million, involved SIMTech together with the School of Electrical and Electronic Engineering and School of Computer Engineering. Dr. Goh’s involvement was in the area of Collaborative Workflow Manager.

She has successfully advised about 7 MEng and PhD students and published in excess of 90 journals/conference publications.

Dr. Goh is a Fellow of the British Computer Society, Senior Member of the Singapore Computer Society, member of the ACM, and member of IFIP Working Group 3.4 (Vocational Education and Training). She is also a council member of the National IT Standards Committee and an advisory board member of various institutions of higher learning. She is on the editorial board of several journals.

Ee-Peng LIM, Associate Professor and Head of Division of Information Systems, Centre for Advanced Information Systems, School of Computer Engineering, NTU, Singapore

[See http://www.cais.ntu.edu.sg/~aseplim]

Ee-Peng LIM obtained his PhD from the University of Minnesota, Minneapolis in 1994. Upon graduation, he started his academic career at the Nanyang Technological University. In 1997, he established the Centre for Advanced Information Systems and was appointed the Centre Director. During the period from December 2001 to June 2003, he was also appointed a visiting professor at the Department of Systems Engineering and Engineering Management of the Chinese University of Hong Kong. He conducts research in web warehousing, digital libraries, mobile data management and database integration. His papers appeared at ACM Transactions on Information Systems (TOIS), IEEE Transactions on Knowledge and Data Engineering (TKDE), Decision Support Systems (DSS), and other major journals. He is currently an Associate Editor of the ACM Transactions on Information Systems (TOIS). He is also a member of the Editorial Review Board of the Journal of Database Management (JDM). He actively participates in conference activities. He was the Workshop Chair of the 17th International Conference on Conceptual Modeling (ER'98), Program Co-Chair of the 3rd and 4th ACM Workshops on Web Information and Data Management (WIDM 2001 and 2002), Program Co-Chair of the 5th International Conference on Asian Digital Libraries (ICADL 2002) and Publicity Chair of the 12th International Workshop on Research Issues on Data Engineering: Engineering E-Commerce/E-Business Systems (RIDE-2EC/2002). At present,
he is the Program Co-Chair of the ACM/IEEE Joint Conference on Digital Libraries (JCDL2003), Workshop Co-Chair of the 5th ACM Workshops on Web Information and Data Management (WIDM 2003), Workshop Co-Chair of the International Workshop on Data Mining for Actionable Knowledge (DMAK2003), and the Tutorial Co-Chair of the 22th International Conference on Conceptual Modeling (ER’2003). He has also served in the program committee of numerous international conferences and also given talks at conferences, and research seminars. Ee-Peng Lim is a senior member of IEEE and a member of ACM.

Francis Bu-Sung LEE, Head and Associate Professor, Division of Computer Communications, School of Computer Engineering, NTU, Singapore.

Bu Sung LEE received his B.Sc. (Hons) and PhD from the Electrical and Electronics Department, Loughborough University of Technology, UK in 1982 and 1987 respectively. He is currently an Associate Professor with the Nanyang Technological University and is the Head of the Division of Computer Communications, School of Computer Engineering.

He is Director of Network Technology of the Asia Pacific Advance Network (APAN) and an Associate of Singapore Research & Education Networks (SingAREN). He has been an active member of several national standards organisations such as the National Infrastructure Initiative (Singapore One) Network working group, the Singapore ATM Testbed. Currently he is also the chairman of the Singapore National Grid Project Network Working group, which is investigating the network infrastructure required to support Grid services. His research interests are in network management, mobile and broadband networks, distributed networks, Network Qos, grid computing. He has published over 40 papers in refereed journals.

Wee-Keong NG, Associate Professor and Director, Centre for Advanced Information Systems, School of Computer Engineering, NTU, Singapore

[See http://www.ntu.edu.sg/home/awkng/]

Wee-Keong NG received the MSc and PhD degrees from the University of Michigan, Ann Arbor in 1994 and 1996 respectively. He is currently Associate Professor at the School of Computer Engineering, the Nanyang Technological University, Singapore. He is also the Director of the Centre for Advanced Information Systems at the School.

He works and publishes widely in the areas of Web warehousing, information extraction, electronic commerce and data mining. He is the principal investigator of various research projects:

1. Native XML database: This project builds a native XML database system as a platform for evaluating ideas for the management of very large XML repositories, which includes storage and indexing, query optimization, concurrency control, user interface, etc.
2. Web Information Extraction: This project builds a set of tools to assist users to build personal views of websites and construct extraction rules for personal views. The views and rules, which are expressed in XML, feed into an information extraction engine and a powerful post-processor to deliver personalized, high quality information to users.
3. Web Warehousing: This project constructs a data warehouse using the Internet as the information source. It investigates issues in the querying, extraction, storage and mining of information from the Internet.
4. Agent-based Electronic Commerce: This project aims to construct a software infrastructure for the large-scale deployment of software agents that engages in e-commerce related activities. Issues in the areas of protocols, security, agent behavior, etc. are investigated.

Dr. Ng has supervised more than 10 Ph.D./Masters students and has published more than 100 journal/conference papers.
Dr. Ng has organized and chaired international workshops, including tutorials, and actively serves in more than 10 program committees of numerous international conferences every year. He serves in the editorial review committee of the Journal of Database Management. Dr. Ng is a member of the ACM and the IEEE Computer Society.

Ah-Hwee TAN, Associate Professor, School of Computer Engineering, NTU, Singapore
[See http://www.ntu.edu.sg/home/asahtan]

Ah-Hwee TAN is an Associate Professor of the School of Computer Engineering at the Nanyang Technological University. He was a Research Manager and Senior Member of Research Staff at the Institute for Infocomm Research (I2R) (formerly known as Laboratories for Information Technology (LIT), Kent Ridge Digital Labs (KRDL), and Institute of Systems Science). His research interests include information mining, machine learning, knowledge discovery, document analysis, and intelligent agents. He received his Ph.D. in Cognitive and Neural Systems from Boston University under the supervision of Gail A. Carpenter and Stephen Grossberg. Prior to that, he obtained a Bachelor of Science (First Class Honors) (1989) and a Master of Science (1991) in Computer and Information Science from the National University of Singapore. He is a recipient of Lim Soo Peng Book Prize, Asia Life Gold Medal, Cambridge Scholarship, Tan Kah Kee Young Inventor Award (Silver), NUS Overseas Postgraduate Fellowship, KRDL High Achiever Award, and Optimal 2003 Gold Award. He is an editorial board member of Applied Intelligence published by Kluwer Academic Publisher. He has recently co-edited a special issue for Applied Intelligence on Text and Web Mining with Philip S. Yu of IBM Research. He has been involving in many international conferences and workshops. This year, he is in the technical program committees of IDEAL’2003, ECML/PKDD’2003, WDA’2003 and WWW/Internet’2003. He is a member of Singapore Computer Society (SCS) and ACM SIGKDD.

Narendra S. CHAUDHARI, Associate Professor, School of Computer Engineering, NTU, Singapore
[See http://www.ntu.edu.sg/home/asnarendra/]

Dr. Narendra S. CHAUDHRUI is with Division of Information Systems, School of Computer Engineering (SCE), Nanyang Technological University, Singapore as an Associate Professor. He has B.Tech. (with distinction), M.Tech, and Ph.D. degrees from I.I.T. Bombay, India. His doctoral work was on algorithms for Graph Isomorphism problem, and he demonstrated that interior point approaches applied to eigen-spaces of strongly regular graphs lead to good set of heuristics for distinguishing them. He is interested in NP-Complete problems since his doctoral work. His subsequent investigations about Interior point methods received funding from Ministry of Science of Technology, Govt. of India, the project during which PC-based algorithms were developed, and an optimal diet design problem was addressed for the region in Central India. Subsequently, he pursued his algorithmic interests in parsing of Context Free Grammars, re-configurable computing, grammatical learning, and neural networks. His current research interests include data mining, neural networks, computational learning, parallel computing. He has more than 80 publications, which includes 33 journal papers to his credit.

He had held positions of Senior Software Engineer, in IIT Bombay, as well as Reader and Professor of Computer Science in Devi Ahilya University, Indore, India, where he was involved in the conduct of Master’s level program in Computer Science for training of scientists and engineers in Defense Research and Development Organization (DRDO), Ministry of Defense, Govt. of India, for the duration of 1988 to 1999. He has been Fellow of Institute of Electronics and Telecomm. Engineers (IETE), India, and a member of many other professional organizations. He has also been visiting professor in Freie Universitat, Berlin in 1999, and in Southern Cross University, NSW, Australia in 1998. He joined Nanyang Technological University, Singapore in Dec. 2001. Currently, he has doctoral students working on the topics of Boolean neural networks, Data mining, and Computational Learning.
Sourav Saha BHOWMICK, Assistant Professor, School of Computer Engineering, NTU, Singapore.

[See http://www.ntu.edu.sg/home/assourav/]

Sourav Saha BHOWMICK, received his Ph.D. in computer engineering in 2001. He is currently an Assistant Professor in the School of Computer Engineering, Nanyang Technological University. His current research interests include XML data management, mobile data management, biological data management, web warehousing and web mining. He has published more than 55 papers in major international database conferences and journals such as VLDB, ICDE, CIKM, ICDCS, ER, IEEE TKDE, ACM CS, DKE and DEXA. He is serving as a PC member of various database conferences and workshops and reviewer for various database journals. He is currently the program chair of a workshop on biological data management to be held in Prague along with DEXA 2003. Currently, he is co-authoring a book entitled "Web Data Management: A Warehouse Approach" (Springers Verlag) that is scheduled to be published in August 2003.

Sourav was nominated for the "Teacher of the Year Award" in 2003. He has also won the "Lecturer of the Year Award" for Year 1 course in 2003. His teaching and research efforts in 2002 placed him in the outstanding band (top 5%) among the academic staffs.

Sourav is a member of ACM and an affiliate member of IEEE.

Chunyan MIAO, Assistant Professor, School of Computer Engineering, NTU, Singapore.

[See http://www.ntu.edu.sg/home/ascymiao/]

Dr. Chunyan MIAO is currently an assistant professor at School of Computer Engineering (SCE), Nanyang Technological University, Singapore. She holds a Ph.D from SCE, NTU. Her research interests include software agent, multi-agent system (MAS), agent oriented software engineering (AOSE) and semantic web/grid.

Prior to her current position, she worked as Visiting Researcher/Instructor in Information Agent group, School of Computing, Simon Fraser University. In her early career, she was actively involved in R&D at both research institutes and industry, including Associate Research Fellow at Singapore Institute of Manufacturing Technology (SIM Tech), Software Engineer at Singapore Network Services.

Kevin Kok-Wai WONG, Assistant Professor, School of Computer Engineering, NTU, Singapore

[See http://www.ntu.edu.sg/home/askwwong/]

Dr Wong received the Diploma in Electronics and Communication Engineering from Singapore Polytechnic in 1991, a Bachelor (Hons.) of Engineering (Computer System Engineering) and Ph.D. from Curtin University of Technology in 1994 and 2000 respectively. His doctoral thesis was focusing on intelligent data analysis based on computational intelligence techniques in the areas of petroleum engineering and mineral processing. During his PhD studies, he has won two scholarships in recognizing of his contribution in the area of computational intelligence and formation characterization in petroleum engineering.

Before this appointment, he was a lecturer with the School of Information Technology at Murdoch University in Western Australia, and was also the Assistant to Chair of Information Technology at Murdoch University. In 2001 and 2002, he was the treasurer for the IEEE Western Australia Section, was also the treasurer for the IEEE Computer Society (Western Australia Chapter) in 2002.
His current research interests include intelligent data analysis, intelligent data mining, soft computing, and applications of intelligent techniques. Applications areas include petroleum engineering, bioinformation, business intelligence and information processing. He has received and involved as Principle Investigator or Associate Investigator in numerous research grants at university and national level in Australia. He is the author of over 60 refereed conference and journal publications, and 4 book chapters. He has been involved in the programme committees of several international conferences and workshops, and also the paper reviewer of numerous international conferences and journals.

Xueyan TANG, Assistant Professor, School of Computer Engineering, NTU, Singapore.
[See http://www.ntu.edu.sg/home/asxytang/]

Xueyan TANG is an Assistant Professor in the School of Computer Engineering at Nanyang Technological University, Singapore. He received his BEng degree in computer science and engineering from Shanghai Jiao Tong University, Shanghai, China in 1998, and his PhD degree in computer science from the Hong Kong University of Science and Technology in 2003. His research interests include web and Internet (particularly caching, replication and content delivery), mobile and pervasive computing (especially data management and delivery), streaming multimedia, peer-to-peer networks, and distributed systems.

Yew-Soon ONG, Assistant Professor, Division of Computer Science, School of Computer Engineering, NTU, Singapore
[See http://www.ntu.edu.sg/home/asuryong/]

Yew Soon ONG received his B.Eng. (Hons 1st class) and M.Eng. from the School of Electrical and Electronics Engineering, Nanyang Technological University, Singapore in 1998 and 1999 respectively. During his academic career, he has received awards that include the Philip's Cash Prize for Outstanding Academic Performance, National Science and Technology Board PTI Scheme and the British Aerospace Engineering and Rolls-Royce, United Kingdom scholarship which allows him to pursue his Ph.D. in the area of Computational Engineering, Intelligence and Design. He received his Ph.D. from University of Southampton, UK in 2002. He is currently an Assistant Professor with the Nanyang Technological University, Division of Information Systems, School of Computer Engineering.

His main research interests are in Grid Computing, Optimization, Complex Engineering Design, Computational Intelligence and Information Technology. He has published over 18 papers in refereed journals and conferences during over the last four years in these areas. He worked as an assistant engineer in General Motors, a software engineer in Systems and Computer Organisation, MINDEF and was attached to the Computational Engineering and Design Group, University Technology Partnership for Design in Southampton during the last 3 years, which is a collaboration between Rolls-Royces, British Aerospace Engineering and the Universities of Cambridge, Sheffield and Southampton, working in the research areas of Computational Intelligence, Complex Engineering Design and Grid Computing. He is currently working closely with collaborators from IHPC, Temasek Laboratories, İ²R (A*STAR) as well as the E-Science Southampton Regional Center, at the University of Southampton.

Kuiyu CHANG, Assistant Professor, School of Computer Engineering, NTU, Singapore
[See http://www.ntu.edu.sg/home/askychang]

Kuiyu CHANG is an Assistant Professor in Information Systems (IS) at NTU School of Computer Engineering. He is interested in the efficient organization and reuse of disparate types of knowledge assets faced by people in today’s world, namely computer files/fragments (XML, text, image, video,
audio, proprietary binary), emails, Internet bookmarks, contacts, etc. He is a strong believer in the
ideal that only when the individual person regains control over his/her knowledge assets, can he/she
share his/her knowledge effectively. If and when this fundamental progress is realized, he is also
interested in the sharing/exchange/barter of knowledge in a global peer-to-peer environment.
Knowledge in this context means much more than simple Napster-like file sharing, but meaningful
exchange of expertise or experience.

Kuiyu joined NTU in 2003.06. Prior to that he had served as Senior Risk Management Analyst for
ClearCommerce (Texas), where he helped discover fraudulent online purchase patterns for a number
of Fortune 500 clients, thereby reducing their potential losses by millions of dollars. Prior to that he
co-founded Mosuma (Texas), a data-mining consultancy firm, which provided data/text-mining
services to About.com and Akul group, both based in New York. From 2000.07 to 2002.04 he worked
as a Member of Technical Staff for Interwoven (Texas), where he led the adaptation of the company’s
text classification software product to handle Chinese and Japanese languages. He was also heading
Interwoven’s Austin R&D division, where he supervised a total of 4 graduate interns (3 of whom
were PhD candidates from the University of Texas at Austin) on developing novel data-mining
algorithms, including clustering and ontology-creation. From 2000.03 to 2000.07, he was the principal
architect of the startup Neonyoyo (Texas), where he co-developed a text-recommendation GUI
prototype, which helped secured Neonyoyo’s first customer, and which eventually led to Neonyoyo’s
acquisition by Interwoven in 2000.07 for US$70 million.

Kuiyu is a member of IEEE, ACM, and IAPR. He is the author of a dozen of papers, including most
recently one in IEEE Transactions in PAMI. He received his Ph.D. in Electrical & Computer
Engineering from the University of Texas at Austin, his M.S. in Electrical Engineering from the
University of Hawaii at Manoa, and his B.S. in Electrical Engineering from National Taiwan
University. He has more than 12 years experience in neural networks, and has lately been focusing on
statistical pattern recognition techniques, and text-mining. He is also the inventor of Probabilistic
Principal Surfaces, a novel algorithm to visualize and model high-dimensional data on a nonlinear
manifold such as the sphere.

Kiam-Tian SEOW, Assistant Professor, School of Computer Engineering, NTU, Singapore
[See http://www.ntu.edu.sg/home/ASKTSeow/seow_home.htm]

Dr. Seow holds a Ph.D. from Nanyang Technological University, Singapore. His areas of specialty
include intelligent agents and multiagent systems, supervisory control of discrete-event systems and
temporal logic, with emphasis on their applications.

Dr Seow has been involved, as Co-Principal Investigator and Collaborator, in several major SERC
and RG1 (ARC) research grant applications to support R&D in web information retrieval, a key focus
in NTU School of Computer Engineering, and will play an increasingly significant role in leading and
managing the research development.

Dr Seow has held visiting appointments with the Systems Control Group at the University of Toronto,
Toronto, Canada, and the Korea Advanced Institute of Science and Technology (KAIST), Korea. In
December this year, he will be Visiting Scientist with the Cooperative Computing Research Group at
NTT Communication Science Labs (NTT-CSL), Japan, under the auspices of A*STAR’s Overseas
Attachment Programme, Singapore. At NTT-CSL, he will initiate and foster collaborative research
with his host to develop a general foundation for optimization in a distributed agent framework.

Dr. Seow has authored or co-authored about 20 research papers in his areas of specialty, as well as the
textbook Soccer Robotics (New York: Springer Verlag, to be published in late 2003 or early 2004).
His name is included in Marquis Who’s Who in Science and Engineering (7th Edition, 2003). He
serves on the committees of several international conferences, and has been an active paper reviewer
of numerous international conferences and journals.
Dr. Ho graduated in 1978 with a First Class Honours degree in Mechanical Engineering from Imperial College, London. He then qualified as a Chartered Accountant in England and Wales, and later obtained both his Masters and PhD degrees in finance. He is a Fellow of the Institute of Chartered Accountants in England and Wales and a Member of the Institute of Certified Public Accountants in Singapore, the American Finance Association and the International Financial Management Association.

Prior to joining NTU, Dr. Ho had extensive experience in international accounting firms in London and Singapore and was the Group Financial Controller of a publicly listed corporation. At NTU, he is currently the Director of the Centre for Financial Engineering and the MSc (Financial Engineering) Program. He has also served as the Director of the MBA (Banking and Finance) program and a Member of the MBA Advisory Committee.

Dr. Ho’s teaching and research interests are in corporate finance, financial analysis, and valuation. In 2003, he received the Best Teacher Award for the Banking and Finance Division. Dr. Ho’s research has been published in top international journals, such as Journal of Business, Financial Management, and Journal of Banking and Finance, and has been cited by Reuters, Bloomberg, Straits Times, Business Times, Lianhe Zaobao and Today. Dr. Ho is also interested in interdisciplinary research. He was the Principal Investigator of an interdisciplinary research project entitled “IT Framework for the Management of Innovative Financial Instruments and Processes for a Knowledge-Based Economy”.

NANYANG BUSINESS SCHOOL, NANYANG TECHNOLOGICAL UNIVERSITY

Kim Wai HO, Associate Professor of Banking and Finance, Nanyang Business School, and Director, Centre for Financial Engineering and MSc (Financial Engineering) Program, NTU, Singapore
Tok Wang LING, Professor, Department of Computer Science, School of Computing, NUS, Singapore
[See http://www.comp.nus.edu.sg/~lingtw/]

Tok Wang LING is a Professor of Department of Computer Science, School of Computing at the National University of Singapore, Singapore. He was the Head of IT Division, Deputy Head of the Department of Information Systems and Computer Science, and a Vice Dean of the School. He received his Ph.D. and M.Math., both in Computer Science, from Waterloo University, Canada, and B.Sc.(1 Hons) in Mathematics from Nanyang University, Singapore.

His research interests include Data Modeling, Entity-Relationship Approach, Object-Oriented Data Model, Normalization Theory, Logic and Database, Integrity Constraint Checking, semistructured data model, and Data Warehousing. He has published in excess of 90 international journal/conference papers. Most of his publications are listed in http://www.informatik.uni-trier.de/~ley/db/indices/a-tree/l/Ling:Tok_Wang.html. He organized and served as a program committee co-chair of DASFAA'95, DOOD'95, ER'98, WISE'2002 and ER'2003. He organized and served as a workshop co-chair of DOOD'95 Post-Conference Workshops and the 8th International Parallel Computing Workshop. He serves/servert on the program committees of numerous international database conferences as well as was appointed the chair of the steering committee of the International Conference on Database Systems for Advanced Applications and was the Chair and now member of the International Conference on Conceptual Modeling. He was a steering committee member of International Conference on Deductive and Object-Oriented Databases (DOOD).


Beng Chin OOI, Professor of Department of Computer Science and Vice Dean (Academic Affairs and Graduate Studies), School of Computing, NUS, Singapore
[See http://www.comp.nus.edu.sg/~ooibc/]

Beng Chin is Professor of Computer Science and Vice Dean (Academic Affairs and Graduate Studies) at School of Computing, National University of Singapore, and a fellow of Singapore-MIT Alliance Programme. He obtained his BSc (1st Class Honors) and PhD from Monash University, Australia, in 1985 and 1989 respectively. His research interests include database performance issues, indexing techniques, XML, P2P/parallel/distributed computing, and embedded system, internet and genomic applications. He has served as a PC member for SIGMOD'94,03, VLDB'96-97,99-02, ICDE'02, EDBT'98,02,04, DASFAA'93-04, ACM-GIS'98-01, SSD'93-99, and Vice PC Chair for ICDE'00,04, PC Chair for SSD'93, Workshop Chair for FEGIS'93, and Conference Chair for MDM'02. He is an editor of GeoInformatica, Journal of GIS, ACM SIGMOD Disc and VLDB Journal, and guest editor for the special issue(section) of IEEE TKDE on P2P based Data Management. He is a co-founder and director of GeoFoto, a company providing imaging and point-to-point photo management solutions, and BestPeer, a company specializing in P2P computing and IR technology.

Kian-Lee TAN, Associate Professor and Deputy Head of Department of Computer Science, School of Computing, NUS, Singapore
[See http://www.comp.nus.edu.sg/~tankl/]

SCHOOL OF COMPUTING, NATIONAL UNIVERSITY OF SINGAPORE
Kian-Lee TAN, received his Ph.D. in computer science in 1994. He is currently an Associate Professor in the Department of Computer Science, School of Computing, National University of Singapore. His current research interests include multimedia information retrieval, query processing and optimization in multiprocessor and distributed systems, and database performance, database security and genome databases. He has published numerous papers in conferences such as SIGMOD, VLDB, ICDE and EDBT. He has also co-authored a tutorial entitled “Query Processing in Parallel Relational Database Systems” (ISBN 0-8186-5452-X, IEEE CS Press), and two books entitled “Indexing Techniques for Advanced Database Systems” (ISBN 0-7923-9985-4, Kluwer Academic Publishers) and “Data Dissemination in Wireless Computing Environments” (ISBN 0-7923-7866-0, Kluwer Academic Publishers). Kian-Lee was a Visiting Scientist at IBM's Almaden Research Center, California (Jan 92 -- Jul 92), and CSIRO's Canberra Laboratory, Australia (Jun 94 -- Jun 95). He was a Senior Scientist at the Genome Institute of Singapore (Joint appointment (June 01 -- June 03). Kian-Lee is a member of ACM and an affiliate member of IEEE.

Yong-Meng TEO, Associate Professor, Department of Computer Science, School of Computing, NUS, Singapore

Yong-Meng TEO is an Associate Professor with the Department of Computer Science at the National University of Singapore (NUS), and a Fellow of the Singapore-MIT Alliance Programme.

Professor Teo graduated with a Bachelor of Technology (1st Class Honours) in computer science from the University of Bradford in 1983. Before turning to academia, Professor Teo worked for two years as a systems engineer in the National Identification Databank project of the National Computer Board (currently Infocomm Development Authority of Singapore (IDA)). His MSc and PhD in computer science were obtained from the University of Manchester in 1987 and 1989 as a result of sponsorship by NUS, the Overseas Research Studentship Award (UK) and the Research Studentship Award (University of Manchester). He is a Chartered Engineer (UK) since 1992. In 1996, he spent his sabbatical leave at Hitachi Central Research Laboratory (Tokyo, Japan) as a Senior Researcher.

Previously the Assistant Dean at the School of Computing, Professor Teo is currently the head of the Computer Systems Research Laboratory. His research interest covers various aspects of parallel and distributed computing including parallel & distributed simulation, grid computing, parallel computer architecture, and performance evaluation.

He has received numerous external research grants from European Commission, Fujitsu Computers (Singapore) Pte Ltd, Fujitsu Laboratories Ltd (Japan), Hitachi Central Research Laboratory (Japan), and PSA Corporation (Singapore) among other institutions. Among the many positions he has held, he is currently an advisory member of the IEEE CS Task Force on Cluster Computing (TFCC), a member of Singapore’s BioMed Grid Technical Committee in Software Engineering and of the NUS Overseas College Steering Committee (previously NUS Technopreneurship Task Force). He was a resource person for the grid computing component of the IDA 2002 Technology Roadmap.

Professor Teo is the founder of Atsuma Technology Pte Ltd, a local start-up company specializing in grid computing. A spin-off from NUS, Atsuma’s ALiCE grid computing technology won the 2002 Start-Up@Singapore National Techno-Venture Business Plan Competition beating ninety other teams.
Hwee Hwa PANG, Director of the Services and Applications Division

Hwee Hwa PANG is the director of the Services and Applications Division at the Institute for Infocomm Research. He is also an adjunct associate professor with the School of Computing, National University of Singapore. He received the BSc - with first class honors - and MS degrees from the National University of Singapore in 1989 and 1991, respectively, and the PhD degree from the University of Wisconsin at Madison in 1994, all in Computer Science. His research interests include database management systems, data security and quality, operating systems, multimedia servers, and real-time systems.

Mun Kew LEONG, Manager of the Media Semantics Department

Mun Kew LEONG is the manager of the Media Semantics Department in the Institute for Infocomm Research in Singapore. He heads a group of researchers in exploring, understanding, and using semantics in text and multimedia. His personal research is in information retrieval, mobile and social information management, digital libraries and distributed multilingual search systems. Mun Kew has a doctorate from Stanford University. He publishes and speaks in many forums, is a member of the IP&M editorial board, is on the steering committee and advisory board of international symposia, and is active in the organisation of conferences and workshops. He was also formerly VP & CTO of BIGontheNet Pte Ltd, a startup IT company, where he remains as Technical Advisor.
Eng Wah LEE, Senior Scientist, Singapore Institute of Manufacturing Technology (SIMTECH)

Dr. Eng Wah LEE is Senior Scientist at Singapore Institute of Manufacturing Technology (SIMTech) and is currently heading the Java Smart Services Lab; an initiative between SIMTech, SUN and IDA. His earlier research is in Computer Integrated Manufacturing focused on geometric data exchange and information interchange and sharing. He co-ordinated and taught in the MSC. CIM course and acted as Internal Examiner for School of MPE, NTU for both MSc. and PhD. Research. His current research has extended from CIM to Manufacturing Enterprise Integration and Web Services, broadly involved in a number of technological areas like XML, interoperability and integration, web services for information exchange. Since 1998, he chaired the Product Information Exchange Technical Committee of Information Technology Standards Committee (ITSC), and promoted actively the use of STEP standards in industry. In October 2001, he set up the new Information Interchange Technical Committee for ITSC looking into XML, Unicode, Electronic Data Interchange (EDI) and Product Information Interchange standards development. He published several papers in feature-based geometric modeling and reasoning and product information exchange and his more recent paper is in information exchange, manufacturing enterprise integration and interoperability.

Yee Hsun U, Principal Scientist and Manager of Production & Logistics Planning Group

Yee Hsun U is a Principal Scientist and the Manager of the Production & Logistics Planning Group at the Singapore Institute of Manufacturing Technology. He received his BSEE degree from Purdue University, PhD from the New Mexico State University and MBA from the Southern Methodist University. His research interests are in the area of manufacturing and industrial applications of IT. He is the Alternate Chairmen of the Manufacturing Technical Committee of the Institute of Engineers, Singapore, and member of the Executive Board for the Centre for Advanced Media Technology at NTU. His industry experience include being a Senior Member of Technical Staff at the Corporate Manufacturing Centre; and engineering manager and general manager at the Process Automation Center, all at Texas Instruments, Inc., in the U.S. He holds 2 U.S. patents from his work at TI.
Hing-Yan LEE, Deputy Director, Singapore National Grid Office

Hing-Yan LEE is currently Deputy Director of the Singapore National Grid Office where he directs, plans and coordinates the national initiative to realize a cyber-infrastructure for sharing and aggregating compute resources for R&D and industry. He is concurrently Project Director of the National Grid Pilot Platform.

He received his BSc(Eng.) with first class honors in Computing and MSc in Management Science from Imperial College London (UK). He also studied at the University of Illinois at Urbana-Champaign (USA) on a National Computer Board scholarship, where he obtained MS and PhD degrees in Computer Science in 1991 and 1992, respectively.

Hing-Yan was previously Director of Knowledge Lab and Deputy Director of Japan-Singapore Artificial Intelligence Center at the Kent Ridge Digital Labs (KRDL). Hing-Yan oversaw and managed industry collaborations and applied R&D in machine translation, spoken language dialogue, expert systems on the Internet, knowledge discovery, and other knowledge-driven efforts. Prior to KRDL, Hing Yan was Deputy Director at the Information Technology Institute, the applied R&D arm of the National Computer Board. He publishes widely and participates in conference activities, which include Program Co-chair of 5th Pacific-Rim International Conference on AI (PRICAI 1998) and General Chair of 1st Pacific-Asia Conference on Knowledge Discovery & Data Mining (PAKDD 1997).

Hing-Yan has founded several start-up companies, including Language Tapestry and eXage, that commercialize the technologies he and his team developed. He serves on the School of ICT Advisory Board at the Singapore Polytechnic and the Singapore National Archives Board. He was a member of the NatSteel Corporate R&D Advisory Panel and the Australia-Singapore Joint Information Communication & Technology Council. Hing Yan is a Senior Member of the Singapore Computer Society and a Certified IT Senior Project Manager.
APPENDIX 5 – BRIEF DESCRIPTIONS OF SOME POSSIBLE INFORMATION
GRID SUB-PROJECTS

It is the LISA program’s intention that the work on each of the Information Grid Services be
conducted by joint teams drawn from researchers from Singapore and MIT. The brief descriptions
below illustrate some of the possible sub-projects. This list is neither complete nor final and the full
membership on these research teams are not yet formed in many cases.

1 INFORMATION ACCESS and DELIVERY SERVICES
- Ee Peng LIM, Wee Keong NG, Sourav Saha BHOWMICK, Hwee Hwa PANG, Mun
Kew LEONG, Kian Lee TAN, Beng Chin OOI, Stuart MADNICK, Michael SIEGEL

1.1 Semantic query evaluation
   Since the sources are maintained autonomously, there could be inconsistency and incomplete
   information among them. As a result, conventional syntactic query rewriting techniques are no
   longer guaranteed to produce equivalent query evaluation plans. Instead, we need to develop a
   methodology to capture semantics about the sources and apply them in generating "correct" query
   plans.

1.2 XML change management
   Since online information changes frequently, being able to quickly detect the changes in XML
documents is important to many applications. Previous works in change detection on XML focused
on detecting changes to text file using ordered and unordered tree model. These approaches are not
suitable for detecting changes to large XML document as it requires a lot of memory to keep the two
versions of XML documents in the memory. In this research, we take a more conservative yet novel
approach of using traditional relational database engines for detecting changes to XML data. To this
end, we have developed preliminary algorithms and implemented a preliminary prototype system
called XChange that converts XML documents to relational tuples, detects changes to these
documents by executing a set of SQL queries, and represents the changes using table and tree views.

1.3 Web Wrapping Technologies
   With the proliferation of information sources on the World Wide Web, it is increasingly
important that we have the capability to effectively and efficiently tap this vast information resource
of diverse formats (HTML, XML, etc). Although the current COIN Web Wrapping technologies
have been adequate to facilitate the convenient extraction of information from many sites, they are
not optimal for all sites. This effort will extend the current capabilities as well as develop methods
and tools to enable convenient and rapid "wrapping" of new sources.

1.4 Adaptive Distributed Query Processing
   Traditionally, queries are optimized at compile time to produce an optimal query execution
plans. However, in a distributed environment, the system has no control over unpredictable factors
such fluctuations in server workload, selectivities or operations (if statistics is lacking), data arrival
rates, and so on. As such, it is important to design a query processor that is adaptive and robust to
the changing environment. We will design an adaptive query processor that evaluates queries in a
distributed environment, as well as in the middleware.

2 INFORMATION INTEGRATION AND EXCHANGE SERVICES
- Hwee Hwa PANG, Kuiyu CHANG, EePeng LIM, Tok Wang LING, Stuart MADNICK,
Michael SIEGEL

2.1 Data mining and integration of heterogeneous sources
   In this research, data mining and integration are performed to facilitate the discovery and
visualization of trends and correlations.
2.2 P2P Knowledge Exchange using Knowledge File System

Once the Knowledge File System (KFS) is deployed, we will develop a peer-to-peer token-based knowledge exchange/barter environment, where each user can selectively allow part of his KFS to be queried for a price. The quality of returned results can be regulated by an advanced rating system (like Ebay). We will also research into meaningful ways of labeling a piece of knowledge. One potential technique involves using stripped and simplified questions (Jeopardy) to label each fragment.

2.3 Information Integration and Aggregation Services

Not only must information be accessible via the Information Grid, many applications require that the information be correctly and efficiently integrated and aggregated. This raises many research challenges.

2.4 Advanced Mediation Reasoning and Services

The COIN abductive framework [BGLSS2000, GBMS1999] can be extended to problem areas such as integrity management, view updates and intentional updates for databases. Because of the clear separation between the declarative definition of the logic of mediation into the COINL program from the generic abductive procedure for query mediation, we are able to adapt our mediation procedure to new situations such as mediated consistency management across disparate sources, mediated update management of one or more database using heterogeneous external auxiliary information or mediated monitoring of changes. The COIN approach holds the knowledge of the semantics of data in each context and across contexts in declarative logical statements separate from the mediation procedure. An update asserts that certain data objects must be made to have certain values in the updater’s context. By combining the update assertions with the COIN logical formulation of context semantics, we can determine whether the update is unambiguous and feasible, and if so, what source data updates must be made to achieve the intended results. If ambiguous or otherwise infeasible, the logical representation may be able to indicate what additional constraints would clarify the updater’s intention sufficiently for the update to proceed. We will build upon the formal system underlying our current framework, F-Logic and abductive reasoning, and extend the expressiveness and the reasoning capabilities leveraging ideas developed in different yet similar frameworks such as Description Logic and classification.

2.5 Intra-source information integration

While much of the previous information integration research assumes that there is no data heterogeneity problem within an information source, this assumption does not always hold. For example, web pages from the same web site are usually created by different people and the logical structure of the web site is usually loosely defined. It is therefore necessary to address the information integration even for web information coming from the same web source, merging them into semantically richer information units. The construction of semantic information units requires a combination of knowledge about the information source and the ability to construct information units. As part of the process, we need to assign semantic labels to the information units.

3 SEMANTICS AND ONTOLOGY SERVICES

- Stuart MADNICK, Michael SIEGEL, Benjamin GROSOF, John WILLIAMS, Ee Peng LIM, Kevin WONG, Angela GOH

3.1 Extensions to COIN Domain Model Structure

The COIN Domain Model and Ontology (as depicted in Figure 3) is intended to support the capture and processing of "context knowledge" for any application domain (e.g., financial services, manufacturing, transportation). Although it has been used in several areas already, in particular, in limited financial services and logistics applications, the full scope of its capabilities have not tested. Certain limitations have been identified requiring research to define extensions to the Domain Model structure. In addition, tools will be developed to facilitate the convenient and rapid acquisition of new context knowledge.
3.2 Temporal Context

In addition to the types of domain and context knowledge currently handled by the COIN framework, we need to perform research to add capabilities for both the representation and reasoning to provide support for temporal context. Temporal context refers to the fact that context not only varies across sources but also across time. Thus, the implied currency context for France’s GDP prior to 2002 might be French Francs but after 2002 it is in Euros. If one were performing a longitudinal study over multiple years from multiple sources, it is important that this variation in context over time be understood and processed appropriately.

3.3 XML, RDF, DAML-S, OWL and other pre-Semantic Web tagging

An important area of research is the tagging of data for knowledge management. At MIT we are developing test bed in the Instructor-to-Instructor site of ESD (see http://i2i.mit.edu).

3.4 Translation and Inferencing Services

It is necessary to provide translations between heterogeneous forms of ontologies and rules. As well as provide inferencing services (both query-answering/backward and data-driven/forward) for ontologies and rules.

4 QUALITY/RELIABILITY/PERFORMANCE SERVICE
- Richard WANG, Stuart MADNICK, John WILLIAMS, Nancy LEVESON, Hwee Hwa PANG, Mun Kew LEONG, Wee Keong NG, Xueyan TANG

4.1 Improvement of Information Quality

Although the number of information sources available has been increasing rapidly, the quality of information sources remains a serious concern. In fact, this has been expressed as "we now have more and more information sources about which we know less and less." This issue becomes even more critical when information from multiple sources is merged or integrated. In this part of the effort, attributes of information quality will be defined, metrics established, and methods for incorporating this "quality knowledge" into the query processing determined. Since one source of "data errors" is caused by misinterpretation of the information, we also plan to provide explication services so that users will be able to more fully understand the information that they are using.

4.2 Effective Use of Grid Computing Technologies

Another area of interest is the effective use of Grid Computing, especially with respect to Infrastructure Protection (we have done some work on OGSA GT3) and are developing our own Grid Environment based on .NET (it will also run on Linux using Mono). Trying to implement some of Ian Fosters ideas in GT3 have helped us understand some of the shortcomings of OGSA and Web Services in general. One area of weakness is the lack of any programming model for distributed computing. Most "power users" of parallel/distributed computing presently use MPI and OGSA does not explicitly provide this kind of messenger model. Another weakness of Web Services (WSDL), especially when used for information access, is the lack of an appropriate UI. Finally there is presently a disconnect between Grid Computing (predominantly university driven) and Web Services (predominantly industry driven).

4.3 Data quality, Authority, and Attribution

As the sources are backed by different authorities and may differ in the quality of their data, we will investigate how, as the raw data are transformed by database operations (e.g. relational algebra), the associated authority, attribution, and quality can be combined to reflect the authority, attribution, and quality of the query result.
4.4 Information Grid Software Safety

Although we have assumed that the underlying Grid and Network services provide a certain level of reliability and safety of operation, we must also address these issues at the Information Grid level as well.

5 DIRECTORY/ DISCOVERY SERVICES
- Xueyan TANG, Kuiyu CHANG, EePeng Lim, Sourav Saha BHOWMICK, Narendra S CHAUDHARI, Stuart MADNICK, Michael SIEGEL

5.1 Distributed Indexing for Fast Information Access

In this research, we explore the use of distributed hash table (DHT) like index to locate information and services. DHT is a fully distributed index. It was originally proposed for peer-to-peer networks, but has the potential to be used in many other applications. We can investigate whether DHTs can be used for indexing in an information grid, how DHTs can be applied to index data replicas, whether DHTs can be adapted to user access patterns to improve performance, where DHTs should be placed, whether DHTs can be replicated to improve reliability etc.

5.2 Knowledge File System (KFS)

Information explosion is a term often used to characterize the amount of data that each person is facing today. We manage the myriad types of information with disparate tools, e.g. email/contact and Internet bookmarks are managed by different software. Consequently, only the file system of an OS allows cross-application access. However, using the file system for organizing data comes with severe limitations.

We propose the creation of a database-driven and XML-based Knowledge File System (KFS). The KFS will be modular and extensible, so that intelligent modules such as a hierarchical text classifier or rule-based classifier can be easily added later. Other types of modules such as cross-language recommendation engines can also be added. Although Microsoft is moving away from the file system metaphor to that of a database query access approach in the next version of Windows codenamed ‘Longhorn’, we strongly believe that humans organize information best within a hierarchical context. Further, our approach is unique in that it offers a superior and fundamental framework for information management/exchange.

5.3 XML data mining

Over the last few years, data mining especially web mining has attracted a great deal of attention in both the information research community and the information industry. As the amount of information available online increases in a daunting rate, web mining, which aims to extract useful and hidden knowledge from information available online, is becoming an issue of great importance. At the same time, we found that data on the web is dynamic. On the one hand, it can change autonomously without informing; on the other hand, it can change at any time in any way. However, we observed that none of the current state-of-the-arts has considered both the dynamic property of web data and the time dimension. In this research, we proposed a web delta mining research to extract useful and hidden knowledge from web data by incorporating both the dynamic property of web data and the changes over time dimension.

5.4 Applications of Computational learning for Data Mining

Identification of structural aspects in data is one of the important problems in data mining. Use of well-known results in computational learning theory for this purpose has remained a relatively less investigated area, and one of the reasons is due to complexity of many algorithms in computational learning theory. In this project, we plan to investigate these aspects. The work involves evolving somewhat easier grammar models, and machine models, like classification grammars, and classification automaton, which are “somewhat easier” to learn. Applications of these models to data mining will be investigated.
5.5 Novel Approaches to Automatic Source Selection and Attribution

As the number of sources of information grows, it becomes increasingly unrealistic to expect the user to know of all of the sources. Thus, techniques for automatic source identification and selection have to be developed. We first propose to incorporate such source selection capabilities into the current COIN prototype. Then we plan to explore some novel approaches that take advantage of more comprehensive source scope information (especially sizing knowledge, such as "contains at least 10 companies from each European country") to develop more intelligent source selection. Finally, we want to be able to reverse the process so that a user can essentially ask "where and how did the system get this information", we call this source attribution. Source attribution can also be an important tool for improving data quality.

6 POLICY AND AUTHORITY SERVICES
- Sourav Saha BHOWMICK, Wee Keong NG, Hwee Hwa PANG, Stuart MADNICK

6.1 Access control in XML

XML Access Control aims at providing XML documents with a sophisticated access control model and access control specification language. With this access control technology, the access control policies control how an XML document appears. The policies also insure the document is securely updated as specified by the security programmer. Suppose there is an online catalog document written in XML that lists available goods sold on the Internet. Consider an access control policy such that only premium members can view the special discount price information in the document. When a regular member views the catalog, any information provided for the premium members should be hidden. XML access control is capable of specifying such fine-grained access control policies for XML documents. In this research we are exploring issues for fine-grained control and conflict resolutions.

6.2 Legal and Regulatory Policy Issues Impacting Information Re-Use and Re-Purposing

Different approaches and views towards information re-use and re-purposing are emerging around the world. Sometimes extreme positions have emerged with a movement toward strict regulation coming from the European Union Data Base Directive while the United States has taken a much more benign approach. But in “cyberspace” such geographic boundaries have less meaning. A global view and recommendations for policies and regulations, incorporating perspectives from Asia, needs to be studied.

7 AGENT SERVICES
- Chunyan MIAO, Angela GOH, Ah Hwee TAN, Kevin WONG, Kiam Tian SEOW, Benjamin GROSOF, Stuart MADNICK

7.1 Agent for Grid Intelligence

Grid intelligence refers to a newly emerging research field focusing on how the data and information available on different levels of Grid services (e.g., HTML/XML/documents, Web usage, service response time, service quality etc.) can be carefully acquired, preprocessed, represented and eventually converted into intelligences (knowledge) to improve the overall Grid services. Intelligent agents presents some promising characteristics such as the autonomy, scalability, adaptability and goal-driven. In this research, we explore how intelligent agents can help grid intelligence in the dynamically changing Grid environment.

7.2 Domain Oriented Semantic Web Agents

The Grid Computing has evolved from the earlier days of merely sharing distributed resources for solving big computational tasks to the latest trend of developing the semantic Grid. There has being an increasing demand for semantically modeling and querying the web for a specific domain in the grid environment. This research project aims to propose an agent based model for re-engineering the web structure in the format of XML, and presents a semantic extension to an XML...
query language within a specific domain. The proposed approach will lead to reduced human effort and high reusability for providing domain oriented semantic-web services.

7.3 Cooperation in Multi-agent Systems

Central to the research focus is the search for new ideas of collaboration and coordination among computer agents - the two mutually dependent mechanisms of cooperation. No universally accepted definition of cooperation, collaboration and coordination exists, so as a conceptual guide, we say that an agent cooperates by collaborating and/or coordinating; it collaborates with other agents to meet some joint or common quantitative goal, such as to maximize a total benefit function; it coordinates with others to meet some qualitative goal (i.e., a proper temporal behaviour that describes the permitted order of events or activities to guarantee some form of safety and progress). A multiagent system is said to be cooperative if all its agents cooperate with one another. The ability to collaborate and coordinate is critical in enabling distributed agents as helpful assistants, and not merely tools, in providing a wide variety of knowledge-based and information services.

7.4 Adaptive Hierarchical Architecture for Personalized Software Agents

In recent years, Customer Relationship Management (CRM) initiatives have gained much attention. The idea of a personalized software agent is identified as a key initiative to improving CRM. Central to this research idea is the search for a new personalized agent model capable of personalizing interactive activities and product filtering based a customer’s preferences, acquired via learning of the customer’s behavior. The ability to learn and respond to a human customer’s needs is crucial in a computer agent serving as a helpful assistant, and motivates the organization of an agent model as an adaptive hierarchical architecture to more tractably handle the humans.

7.5 Theory of Trusted Agent

An important use of the Information Grid technology can be to support the development of automated "trusted agents" that can act as information brokers, such as matching up customers with appropriate suppliers without revealing unnecessary proprietary information from either the potential customers or suppliers. We believe that an extremely important and fundamental theory for such "trusted agents" can be developed.

8 SYSTEM ARCHITECTURE - Angela GOH, Ee Peng LIM, Joel MOSES, Stuart MADNICK, Michael SIEGEL, Hing Yan LEE

8.1 Architectural Design of the Information Grid

One of the most important tasks for this research is the precise definition of the Information Grid services, including their functionality and interfaces, to ensure effective interoperability.

8.2 Challenging Applications in Financial Services

The true value of this research effort can best be determined by demonstrating its capability to solve the needs of real and challenging applications. As noted in the Flagship description, the initial application area to be addressed will involve financial information. The specific financial applications will be determined as part of this effort, possibilities include: international financial payment mechanisms, global risk management, intelligent trader assistant, and integrated financial analysis.