Water: East Meets West

The Need for Appropriate Technologies and Systems

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The Singaporean government wishes to undertake significant research initiatives with MIT in several areas, one being water systems and water quality. In addition to performing world-class cutting edge research, Singapore wants new products and services to be created from this effort. Markets in Asia are particularly appealing, as there are huge needs for quality water throughout Asia, for drinking, irrigation, fish farming, heating and cooling, wastewater management and industrial processes. One must recognize that Singapore, with its world-class high tech economy, is not representative of Asian economies. The great majority of people in Asia live in emerging countries, with annual per capita incomes far less than that of Singapore. Thus, to the extent that new Asian markets for water-related goods and services are to be served by the fruits of the research, it is necessary to recognize that most of those markets will be in developing countries. Costs of water-related new products and services must be anticipated accordingly. Singapore represents the exemplary model to which many Asian cities and countries aspire. In order to move them in that direction, Singapore needs to develop a full portfolio of research-derived, water-related products and services, those that fit today's and tomorrow's Asian markets.

We have every confidence that Singapore's water-related research will build from its current world-class status to provide new products and services to relatively prosperous urban centers in Asia. But most Asian cities cannot afford huge capital investment in high technology water solutions. Most of Asia is rural, with even fewer investment resources available. Thus, a mechanism must be found for Singapore's expert researchers, working with MIT, also to create water-related products and services 'for the rest of Asia" – urban and rural regions with limited resources. With land area of only 683 sq. km., Singapore requires a large living laboratory for experimentation and to help create – in collaboration with MIT and others – these new research results. We propose the new School of Science and Engineering (SSE) at LUMS, Lahore University of Management Science, in Lahore, Pakistan. LUMS is a private research university. Three MIT faculty members serve on the Advisory Board of LUMS SSE: Professors Robert Jaffe (Physics), John Kassakian (Lab for Electromagnetic and Electronic Systems), and Richard Larson (Civil and Environmental Engineering and Engineering Systems). Several LUMS faculty members, current and prospective, are MIT alumni, as are several benefactors of LUMS. LUMS SSE is modeling itself after MIT, which has had previous success at helping emerging new universities such as the highly respected IIT Kanpur (Indian Institute of Technology at Kanpur). A key theme of LUMS going forward will be research on environment with emphasis on implementable results for developing countries. Pakistan claims to have the largest man-made irrigation system in the world, presenting an excellent Asian test bed for the collaborative research. Plus Pakistan has a spectrum of water-related problems typical of much of the rest of Asia. Thus we propose a three-way collaboration, managed by MIT, supported by Singapore and having collaborative research at MIT, in participating Singaporean universities and at LUMS. LUMS would not only participate in the research, but it would take on the responsibility for identifying cooperating entities within Pakistan for undertaking in-the-field research and experimentation.

East Meets West. That is the theme of the research. Singapore has developed a world-class high technology water collection, purification and distribution system. While much of Singapore's water comes via causeway pipeline from neighboring Johor, Malaysia, approximately 10% is now derived locally from desalination plants. Most of the rest comes from rain collection systems, feeding reservoirs. It is recognized that the collaborative research will involve research on new membranes and processes to make desalination more efficient and cost effective. This high tech research represents "the West". Other "Western style" research will also be undertaken, including research on water systems engineering, design of water systems, placement of dams, real time control of dams, design of rain water collection networks and irrigation networks, design of urban water distribution systems, etc.

But 'the East' has much to offer, also, including many concepts new to 'the West.' Perhaps the oldest continuously operating water distribution system in the world was invented in Iran and is still a major force in Asia. This system is a network of underground tunnels called *Qanats*[1], providing water from higher elevations, often at or near the foothills of mountains, to arid and semi-arid regions. This gravity-directed water, when it nears its destination, leaves the *Qanat* tunnel and provides irrigation to surface crops. While still below the surface, *Qanat* water can be accessed for drinking and cooling. *Qanats* have been found in virtually all of central Asia and China, in northern Africa, southern Europe, and Mexico. The *Qanat* water flows by gravity only, so no electricity or other electro-mechanical intervention is required. The underground design reduces evaporation loss. Even today, the 22,000 *Qanats* of Iran, with 170,000 miles of underground tunnels built by manual labor, deliver 19,500 cubic feet of water per second[2]. We believe that *Qanat* systems would benefit from 21st Century research and should be included in our collaborative work. Our MIT research team has studied the equivalent of *Qanats* in Hawaii and in China.

The East has more to offer in terms of water. Looking to Persia as the source, homes can be architected for maximal compatibility with the environment, resulting in significantly less energy usage than typical Western style homes. This involves orienting the building with respect to the sun, seasons and prevailing winds, using shared walls with adjacent homes, establishing breezeways vertically in the home, and using water (from *Qanats*, wells or underground reservoirs) as a cooling agent in the summer[3]. Such homes allow for creation of middle class or even luxury housing, densely situated to conserve land and to reduce suburban sprawl. We believe that the architectural principals underlying these designs, used successfully in some of the world's hottest places in Asia, are relatively unknown to the West. We also need to learn from other time-tested Asian water usages: 1) sustainable rice farming (4,000+ years cultivation of the same paddies in China and Southeast Asia), 2) use of small on-farm ponds for short-term storage (to provide dependable water supplies over dry spells during the monsoon), 3) "inefficient" irrigation strategies that apply excess water before the crop is planted in order to flush salt out of the soil column, etc.

We also need to address Asia-specific water problems, such as reducing losses from urban water distribution systems, dealing with arsenic in Bangladesh, preventing salination of agricultural lands in Pakistan and other regions, dealing with predictable and devastating floods, improving inadequate wastewater collection and treatment systems, etc.

The Research. With a world-class team of researchers from MIT, Singapore and LUMS, we plan to embark on a major multi-year research effort that examines water systems in all important aspects, with special emphasis on applications in Asian countries. Our interests are water distribution systems, water origination systems (e.g., desalinization, rain fall collectors), irrigation systems, wastewater treatment systems, water reuse, water systems in poor rural regions without modern support networks, use of water in the design and operations of homes and other buildings, and more. The end product would be new research results in this area, hopefully much of it finding its way to the marketplace seeking solutions to the myriad water-related problems of Asia. To maximize market size, rural Asia is a special focus of this work.

Our work must be contextualized within constraints and traditions of Asian culture. Asian countries have well-developed traditional cultures that are, for various reasons, not always compatible with 21st century Western approaches to decision-making. The institutional issues are tied up with the local culture, and westerners often have relatively little credibility in this area. Naïve application of western 'scientific methods' can backfire, as in Bali[4]. Our team has social science expertise and much practical experience in various countries of Asia, so we plan to be cognizant of cultural issues and utilize centuries-learned knowledge when appropriate.

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[1] *Qanat* is the Persian name, as the *Qanat* was invented in Persia over 3,000 years ago. In Pakistan and Afghanistan, the Qanat is known as a *Karez*. Source: http://www.waterhistory.org/histories/qanats/.

[2] http://www.waterhistory.org/histories/qanats/.

[3] "WIND CATCHERS" The Cooling Systems in Traditional Iranian Architecture" http://www.cais-soas.com/CAIS/Architecture/wind.htm

[4] *Priests and Programmers: Technologies of Power in the Engineered Landscape of Bali*. J. Stephen Lansing, Princeton University Press 1991.

Weather patterns give rise to difficult water system management issues. The monsoon dominates much of South Asia's climate, bringing alternating periods of heavy rain and almost no rain. Countries such as Thailand have ample water on an annual basis but experience a cycle of floods and drought every year. This aspect of the climate is an essential part of any examination of Asian water issues. People in Asia are well aware of the flood/drought cycle and know that large dams are one way to deal with the problem. This raises a host of issues that include better operation of existing facilities, location and design of new facilities, and a search for alternatives to surface impoundments (e.g., underground storage).

Finally, we must place water systems and the people they serve into a larger social/demographic context. Populations in China and Thailand (and probably other countries in the region) could drop by mid-century. Other countries such as Pakistan could experience very large population growth. This difference between countries has significant implications for economic progress and water management. Most of the population in Asian countries (other than Singapore) still lives in the countryside and is still works in the agricultural sector, although the situation is changing rapidly. A transition to more labor-efficient western-style agriculture will inevitably accelerate the rural to urban migration. For this reason some agricultural economists have raised the possibility that technological progress in the agricultural sector could actually be counterproductive on a national scale (especially if populations and food demands level off). Countries such as Thailand are struggling with social implications of a massive change from rural to urban society.

A full inter-disciplinary systems view of water systems should result in important new products and services, ones that can be created in Singapore and marketed from there. Illustrative research topics:

1. Resilience, robustness and reliability of water systems in the presence of weather variability, natural disasters and security threats.
2. Making water distribution systems more earthquake resistant, including retrofitting system components for earthquake effects using new materials and vibration control mechanisms.
3. Design and systems testing of inexpensive sensing technologies and statistical inference algorithms to monitor maintenance needs and leakage[5] in urban water distribution systems, irrigation and rural water supply systems, reservoirs and dams, and wastewater treatment plants.
4. Adopting the MIT-created Decision Aids for Tunneling (DAT) for use in Asian water systems design.
5. Systems requirements for use of water as cooling agent in homes and businesses.
6. Use of remote sensing and autonomous *in situ* sensor networks to monitor hydrologic conditions in real time, for improved understanding of hydrologic variability and for better management of water resources facilities.
7. Optimal operation of surface and underground reservoirs in anticipation of fluctuations in origin supply and end-user demand.
8. Recycling of primary or secondary treatment water for irrigation, cooling, & wastewater flushing.
9. Assessment of options for water trading and flexible water pricing to encourage more efficient use of limited water resources.

The MIT part of the research would be managed from the new Center for Engineering Systems Fundamentals (CESF), part of MIT's Engineering Systems Division (ESD). The research would examine problems in all their multidisciplinary complexity, with emphasis beyond traditional engineering and physics to include system management and issues related to social science. Professor Richard Larson, Director of CESF, would serve as PI for the MIT portion. Singapore would appoint its own Singapore-based PI, as would LUMS in Lahore. The MIT portion of the project would also be affiliated with other MIT programs and activities, including the Department of Civil & Environmental Engineering, the Physics Department, the Ralph M. Parsons Laboratory and the Lab for Electromagnetic and Electronic Systems.

[5] Many places are "losing" 30-40% of water through leakage and illegal extraction. http://news.bbc.co.uk/2/hi/science/nature/4787758.stm#map