Create More Sustainable and Resilient Infrastructure

Gigatech: The largest infrastructures in which humans manipulate matter and energy.

John Crittenden
**Mission:** To create knowledge and technologies that improve the natural environment and the human condition

**Focus on Gigatechnology:** the largest systems in which humans manipulate matter and energy

**Approach:**
- Collaborative and transdisciplinary
- Serves people, planet, and profit
- Produces proposals, publications, and pedagogy
- BBISS facilitates increased research funding to schools and units
China Used More Cement in Three Years than the US did in a Century

4,405 million tonnes

6,615 million tonnes

Source: USGS, International Cement Review

Both are Gigatech: $\sim 10^{14}$ moles of Calcium
By 2025:

- 5 billion square meters of road will be paved.
- 170 mass-transit systems could be built.
- 40 billion square meters of floor space will be built in five million buildings.
- Build between 700 and 900 Gigawatts of new power capacity.
Systems Engineering: Gigatech

Cities: Transport, Building, Water, Energy, and ICT

- 75% global greenhouse gas emissions
- Consume 75% of natural resource
- 54% global population; 82% US Population
- 78% global energy use
- 80% global GDP
- Worldwide, Surface transport is worth $10 trillion per year

Infrastructure

- Infrastructure requires $90 trillion investment by 2030 (UNEP)
- Infrastructure lasts more than 50 years and 80-90% of its impact occurs in use phase
- Global infrastructure needs to double in the next 35 years and it took 5500 years to get to this point
- US infrastructure will increase 40% by 2030
- US housing market is valued at approximately 27 trillion dollars

Adaptation to Climate Change

In 2014, Farmers paid insurance claims resulting from strong storms a year earlier that had overwhelmed sewer systems around Chicago and flooded homes and businesses. Farmers claimed that the municipalities knew about climate change and its increased potential to cause flooding and yet failed to take reasonable preventative actions.
Gigatechnology
Massively Integrated Urban Infrastructure Engineering and Socioeconomic Systems

**BIG SCIENCE:** Gigatechnology is a newly integrative and use-inspired science committed to the study of the interconnections and interdependencies among very large systems, and the properties that emerge from these interactions.

- How can the ecology paradigm be used to understand urban infrastructure systems?
- What new technologies are needed to measure, model, and manage infrastructure systems-of-systems?
- What and how do properties emerge from infrastructure systems interactions with other systems?
- How can the infrastructure ecosystem be made more sustainable, resilient, and productive?

We know much more about the very small (Nanotechnology) than we do the very large (Gigatechnology).
Core Strengths in Sustainable, Resilient and Integrated Infrastructure

• Urban Water Systems (e.g., low impact development, water reclamation, rainwater harvesting, sponge city)

• Green buildings and infrastructure

• Urban Performance Simulation (High Performance Computation, Model Federation, Multiple Design Optimization)

• Urban Big Data Analytics for Urban Monitoring and Control

• Urban Big Data Analytics: Determination Citizen Preferences and Improving the Adoption Rate of Sustainable Infrastructure
Core Strengths in Sustainable, Resilient and Integrate Infrastructure

• Sensors and Sensor Networks
• Urban Ecological System Services and Structure
• Urban Sea and Resource Development
• Urban Air Quality Control and Health Impacts
• Sustainable Energy Production (including Decentralized Energy Production, Grid Design and Control, Combined Cooling Heat and Power)
• Urban Farming, Hydroponics: Food Energy Water Reduction
Why Do We See This?

Why Do We See This?

**ATLANTA**
- Population: 5.3 million
- Urban area: 7,692 km²
- Transport carbon emissions p.c: 6.9 tonnes

**BARCELONA**
- Population: 5 million
- Urban area: 648 km²
- Transport carbon emissions p.c: 1.16 tonnes

Source: LSE Cities 2014
Engineered Urban Infrastructures

Manage Infrastructures as a Whole for Better Future
We Can Build Infrastructures that:
(1) Are More Sustainable and Resilient
(2) Create More Wealth and Comfort
But How?
State of the Art: Integration has not yet come to infrastructure
Solution: System of Systems Engineering Approach

Communications are information and communications technology (ICT).
Infrastructure Ecology Roadmap to Develop Sustainable and Resilient Urban Infrastructure

Social Decision Making: Managing the Complexity

Predicting the Demand for Urban Infrastructure

Identifying Sustainable and Resilient Alternatives

Evaluating the Sustainability and Resilience Performance

Build the Infrastructure and Assess the Actual Performance; Adapt the lessons learned in new infrastructure projects

Joint Research Center

Data collection

Optimization

Work with Industrial partners
Small Scale Projects
Carbon Neutral Energy Solutions Research Laboratory (CNES)

First LEED Platinum certified building on GT campus
Carbon Neutral Energy Solutions Research Laboratory (CNES)

Building Section

1. 145 kW Crystalline PV Array
2. 10 kW Thin-Film PV Screen Wall
3. Monitor Skylight
4. Light Louver
5. Sola-Tubes
6. Radiant Floor Heating
7. Utility Trench
8. Catwalk
9. Mid-bay Supply Air Shaft / Office UFAD
10. High-bay Supply Air
11. Operable Door
12. Translucent Skin
13. Office Glass Wall
1.4 Million Gallon Cistern

Green Roof Garden

Locally Sourced Materials

Solar Array

Solar Thermal Panels

Rooftop Design Maximizes Water Collection

Smart Lighting Systems

Landscape paving design reduces island heat effect

Radiant Floor Heating Systems

Smart Lighting Systems
Sustainability at Clough Commons

Water Efficiency
Water harvested from a 1.4 million gallon cistern, one of the largest in the U.S., is reused for toilet flushing and water efficient landscaping.

Innovation in Design
An interactive sustainability dashboard displays water and energy usage in real time.

Materials and Resources
Construction materials were transported from a 500-mile radius to minimize fossil fuel consumption. Additionally materials were managed sustainably through on-site recycling, which diverted 75% of construction by-products from a landfill.

Sustainable Sites
The building is oriented to maximize the control of daylight. Open green space is maximized with Tech Green. The green roof minimizes and filters stormwater runoff, as well as reduces the “heat island effect.” A changing room and bike storage are available to staff to reduce automobile usage.

Energy and Atmosphere
Rooftop solar panels provide on-site renewable energy. The mechanical system uses refrigerants with low ozone depleting potential and low global warming potential. A combination of smart lighting techniques is used, including daylight harvesting and motion sensors.

Indoor Environmental Quality
A healthy indoor environment is created through dynamic Carbon Dioxide monitoring and the delivery of outdoor air. Low-emitting materials minimize harmful volatile organic compound exposure from adhesives, sealants, carpets, paints and coatings.
Large Scale Projects
The SMARTRAQ project

- Supports research on land use impact on transportation and air quality
- 1.3 million parcels in the 13 metropolitan Atlanta non-attainment counties
SMARTRAQ DATA AND ATTRIBUTES

- Address
- Road Type
- City
- Zip Code
- Owner Occupied
- Commercial/Residential
- Zoning
- Sale Price
- Sale Date
- Tax Value
- Assessed Value
- Improvement Value
- Land Value
- Year Built
- No. of Stories
- Bedrooms
- Parking
- Acreage

- Land Use Type
- Number of Units
- X,Y Coordinate
- Estimated Sq Feet
- Total Sq Feet
Projected Growth Scenarios for Atlanta

Business As Usual
Year 2030

More Compact Development
Year 2030
Atlanta Water Demand for New Residential and Commercial Buildings in More Compact Growth Scenario (with low flow fixtures + decentralized CCHP system)

Installation of Air Cooled Microturbines save 2.8 times the amount of water used for domestic consumption.
Potential GHG and Cost Reductions in 2030

By 2030, implementation of CCHP in all new and existing residential and commercial buildings could reduce CO₂ emissions by ~ 0.04Gt CO₂, NOx emissions by ~ 25000 Tons, and decrease energy costs by $600 million per year for the Metro Atlanta region.

- CO₂ Emissions: NoCCHP 58, CCHP only 31, CCHP w/ netmet 18 (total CO₂ emissions grid mix reduced by ~47% and ~69%)
- NOx Emissions: NoCCHP 28, CCHP only 10, CCHP w/ netmet 3 (total NOx emissions grid mix reduced by ~64% and ~89%)
- Energy Cost: NoCCHP $10.7 billion, CCHP only $9.9 billion, CCHP w/ netmet $9.0 billion (energy cost reduced by ~8%)

Energy Cost Savings:
- 47% on CO₂ emissions
- 69% on NOx emissions
- 64% on NOx emissions
Synergistic Effects of “Infrastructure Ecology”

More than 50 Technologies

- Grey Water Recycling
- Rainwater Harvesting
- Low Impact Development
- Vehicle to Grid
- Renewable
- Energy Storage
- Autonomous Vehicles
- Transit-Oriented
- Mixed Land Use
- Walkable Community
- Air-cooled Microturbine plus Chiller
- Greywater Sources
- Rainwater
- Surface water
- Groundwater
- Reclaimed water
- Grey Water Recycling Facility
- Transportation System

Gigatech Platform Enabled Multiple Design Optimization (MDO)

Desirable Amenities for a Given Climate, Topology and Location

The Potential Synergistic Effects

- Improve air quality and health
- Livable environment
- Reduced water and energy consumption
- Lower dependence on centralized systems
- Larger share of renewables in the electricity mix
- Reduced vehicle-miles travelled
- An increase in tax revenue
- Enhanced system resilience

System-based Benefits of LID Best Management Practices

- Reduced vehicle-miles travelled
- An increase in tax revenue
- Enhanced system resilience

Footprint Reduction

- CO₂: -23%
- NOx: -65%
- Water: -52%
Advance Planning Group.

We are a specialty group of consultants, thought leaders & integrators providing pre-design and design services. Offices globally across 20 locations.
TSINGHUA FINANCE & SCI-TECH PARK
MASTER PLAN
Changchun, China

Client
Partnership between Jilin People’s Government and Tsinghua University

Completion
2014 (design)

Size
53.1 hectares

Services
Conceptual Master Planning
This new innovation district will be a financial ecosystem creating a diverse, resilient cycle of environment and enterprise, culture and commerce. The Tsinghua Financial District will become one of the first cutting-edge Innovation Districts in China. Surrounding the confluence of activity will be innovative businesses and institutions transitioning to hospitality and mixed-use development. The proposed walkable urbanism intends to mitigate the project’s impact on the local environment and the Yitong River watershed.
Jacobs developed four Transit Station Designs and Urban Master Plans for the city of Xiamen in Southeast China. Created as part of a design competition for select firms, the four station areas are situated in urban areas of the city as well as along existing waterfronts. The combined land area for all four station areas is 100 hectares.

Land use strategies include both mixed densities and mixed types, while inviting diversity in future residents in terms of age and financial capabilities. Service retail, specialty retail, and a variety of design restaurants not only serve community needs but also support arriving tourists throughout each district.
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Research Goals

Small Scale:
• The Sustainable Campus Initiative: To treat the new Shenzhen campus master planning as the first research and practical project on sustainability.
• To give a comprehensive and innovative systems-based approach to creating technological, management solutions for net zero carbon, water and waste campus.

Community Scale
• To uncover the interconnections and interdependencies among civil infrastructure systems and their interactions with social, financial, and natural systems
• To work with industry and government to create the cyber-infrastructure necessary to design, simulate, test, monitor, control, and protect massive, open, and complex infrastructure systems
• To develop and test the laws, rules, standards, and best practices for designing, building, operating, and decommissioning sustainable and resilient infrastructure across its total life cycle
• To develop the pedagogy of engineering massive, open, and complex infrastructure systems
• To recruit and train the first generation of gigatechnologists that is as diverse as the communities in which they reside.
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