Home of the future

Gordon Roesler is the USC ISI director of energy research. Before coming to ISI, he was a senior physicist in the Ocean Sciences Division of the Science Applications International Corporation (SAIC). Previously, he was a DARPA program manager, a Branch Scientist at Booze Allen Hamilton, and a Research Scientist at the US Department of Energy.

He was affiliated with the Navy between 1975 and 1996, first as an active duty officer (submarines), later in the reserve.

He is a member of the American Institute of Aeronautics and Astronautics and the American Physical Society; and a recipient of the Office of the Secretary of Defense Exceptional Public Service Award and the Hammer Award from former Vice President Al Gore.

Behrokh Khoshnevis is a professor of Industrial & Systems Engineering, Civil & Environmental Engineering, and Aerospace and Mechanical Engineering. He is the Director of the Center for Rapid Automated Fabrication Technologies (CRAFT) and Director of Manufacturing Engineering Graduate Program at USC. He is active in CAD/CAM, robotics and mechatronics related research projects that include the development of novel additive fabrication processes, automated construction of civil structures, development of mechatronics systems for biomedical applications and autonomous mobile and modular robots for fabrication and assembly applications on earth and in space. In the energy field, he has developed technologies for improving production of gas wells, for electric energy generation using a new wind turbine installation paradigm, and for energy storage for renewable energy based grid. His inventions have received extensive worldwide publicity in acclaimed international media. The automated construction invention, Contour Crafting was selected as one of top 25 best inventions from more than 4000 candidate inventions by the National Inventors Hall of Fame and the History Channel's Modern Marvels program. Contour Crafting is the subject of a currently funded NASA project for Lunar construction. He is a NASA NIAC Fellow, a Fellow of the Institute of Industrial engineering and a Fellow of the Society for Computer Simulation.

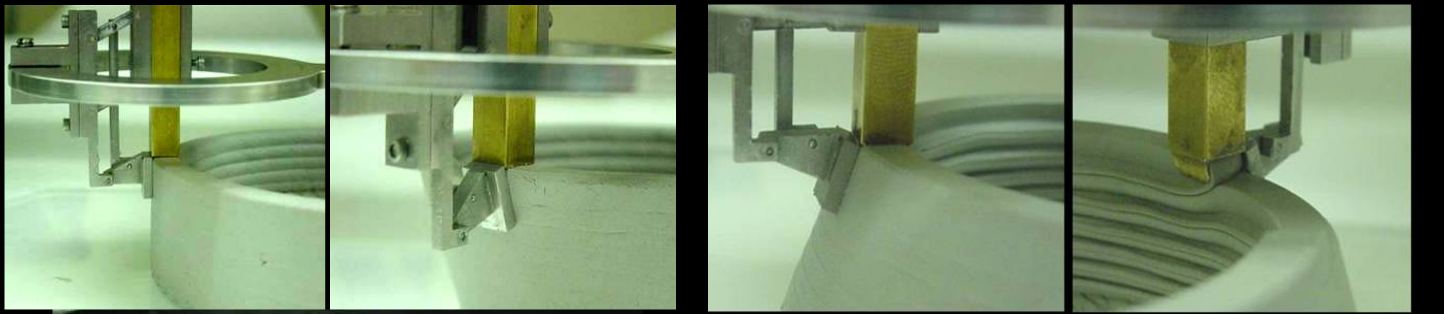
Automated Construction by Contour Crafting – Energy Aspects

On site custom design construction with fully electric CC machine.

Wasteless operation at unprecedented speed: An average home built in one day.

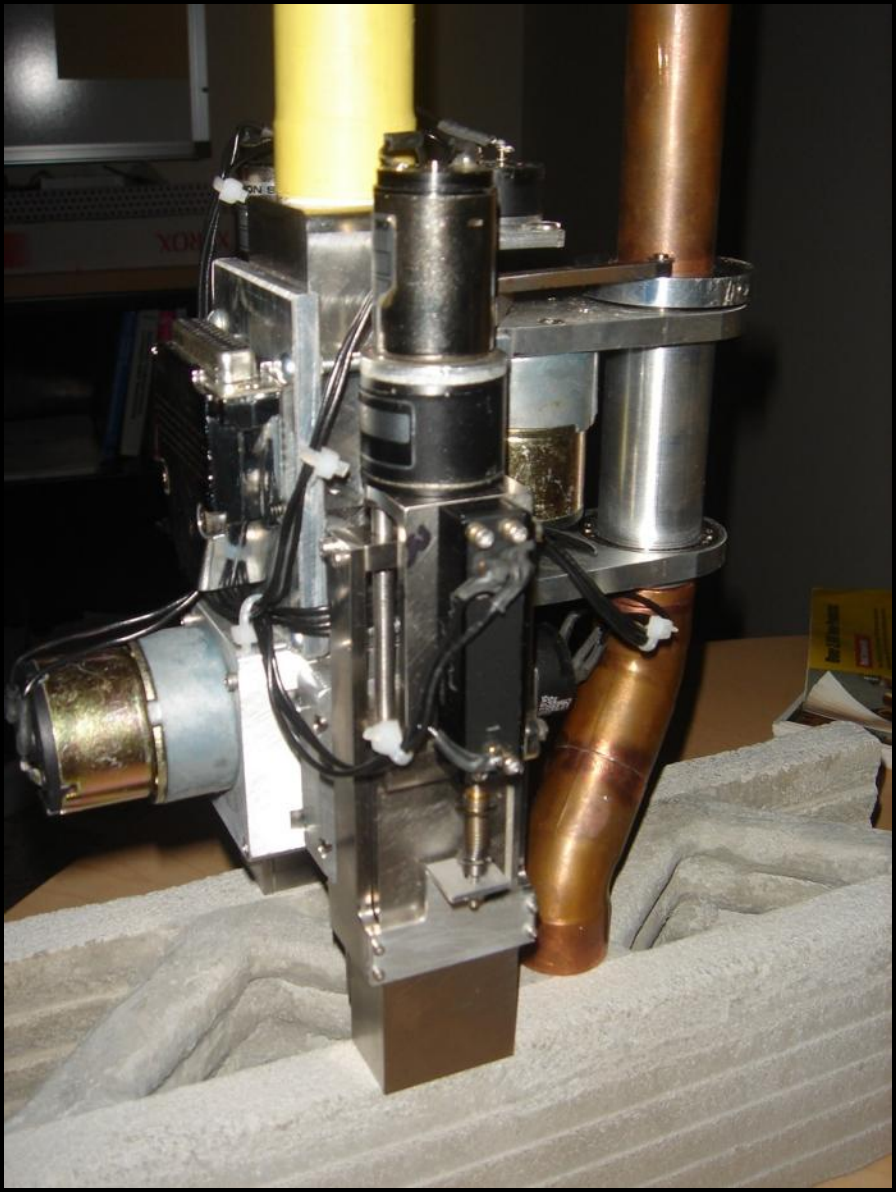
These result in dramatic saving in construction energy. Estimated energy saving is 75% of energy used by conventional construction.

The Contour Crafting Process



CC builds objects by extruding paste material in a layer by layer fashion while smoothing part surface with robotically controlled trowels.

CC Nozzle building a hollow wall

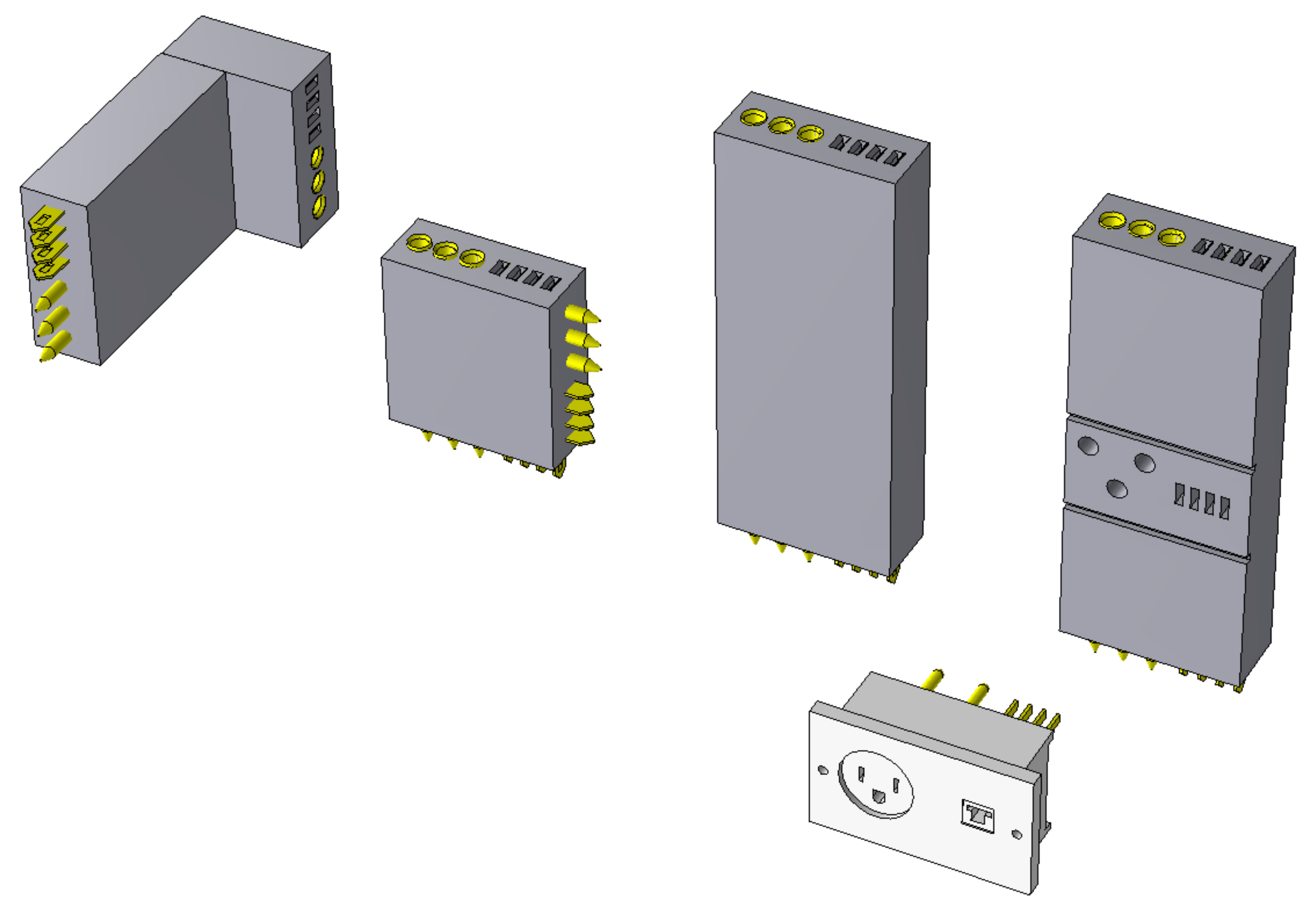


A CC gantry robot

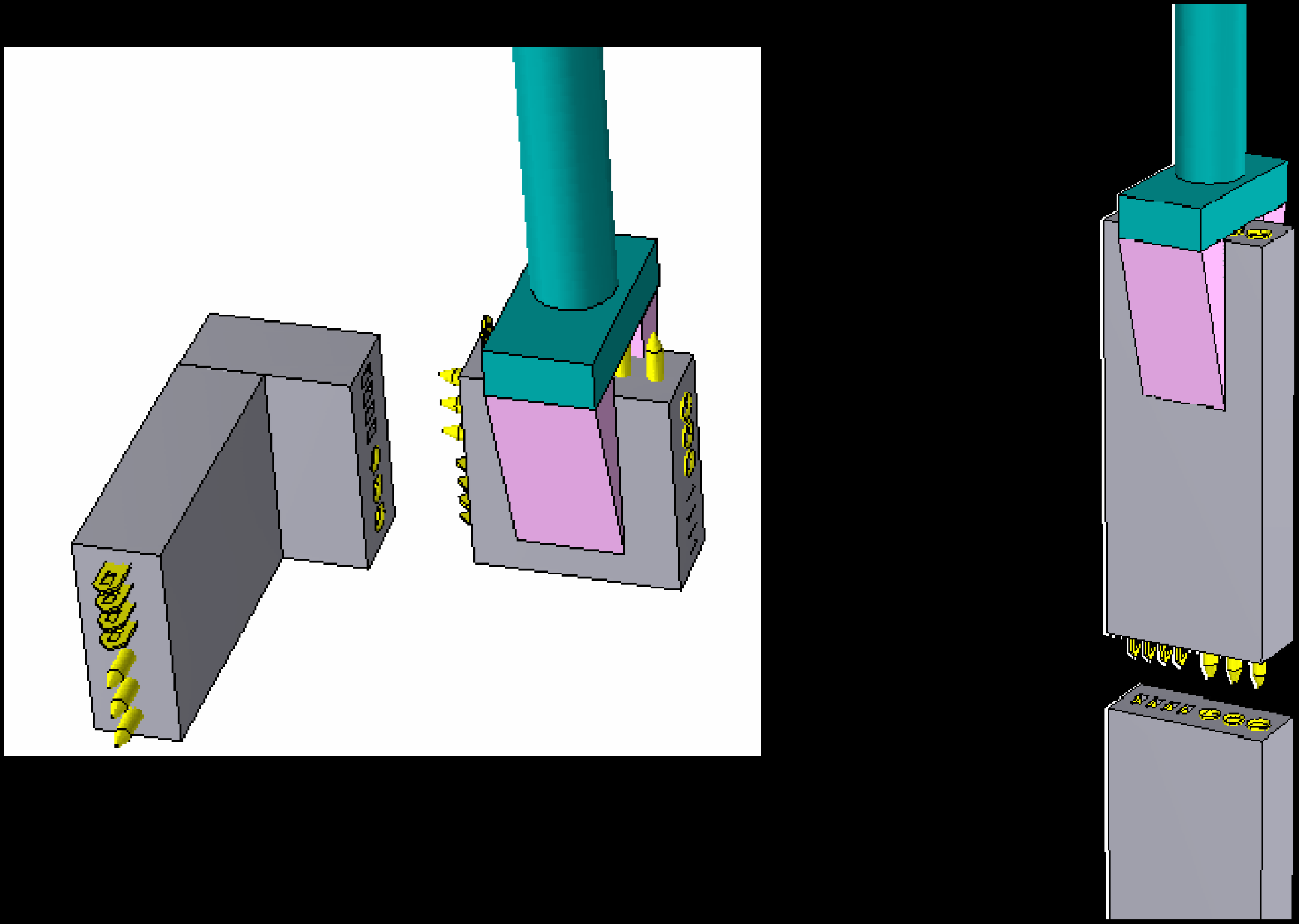
Hollow concerte walls built by CC

Modular electrical & communication lines

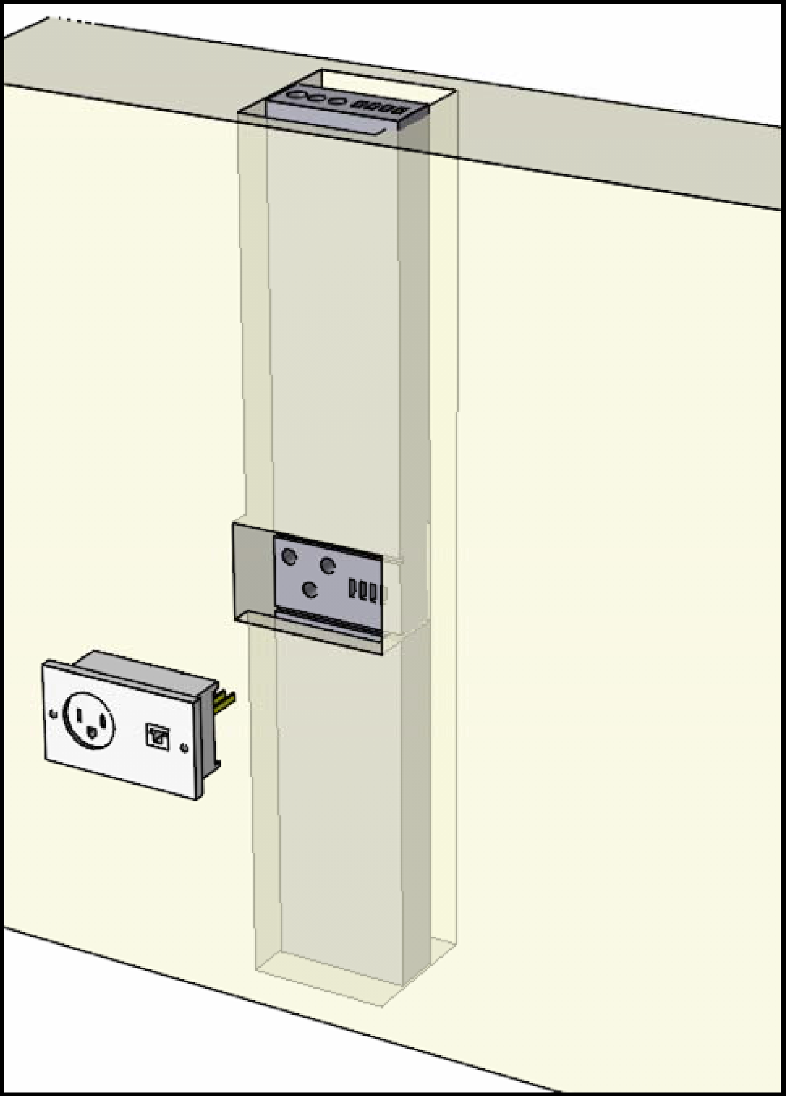
Conductive elements for power and communication lines are imbedded in polymeric blocks and are assembled robotically during construction to form the desired electrical and communication networks.



Robotic assembly of modules during building construction

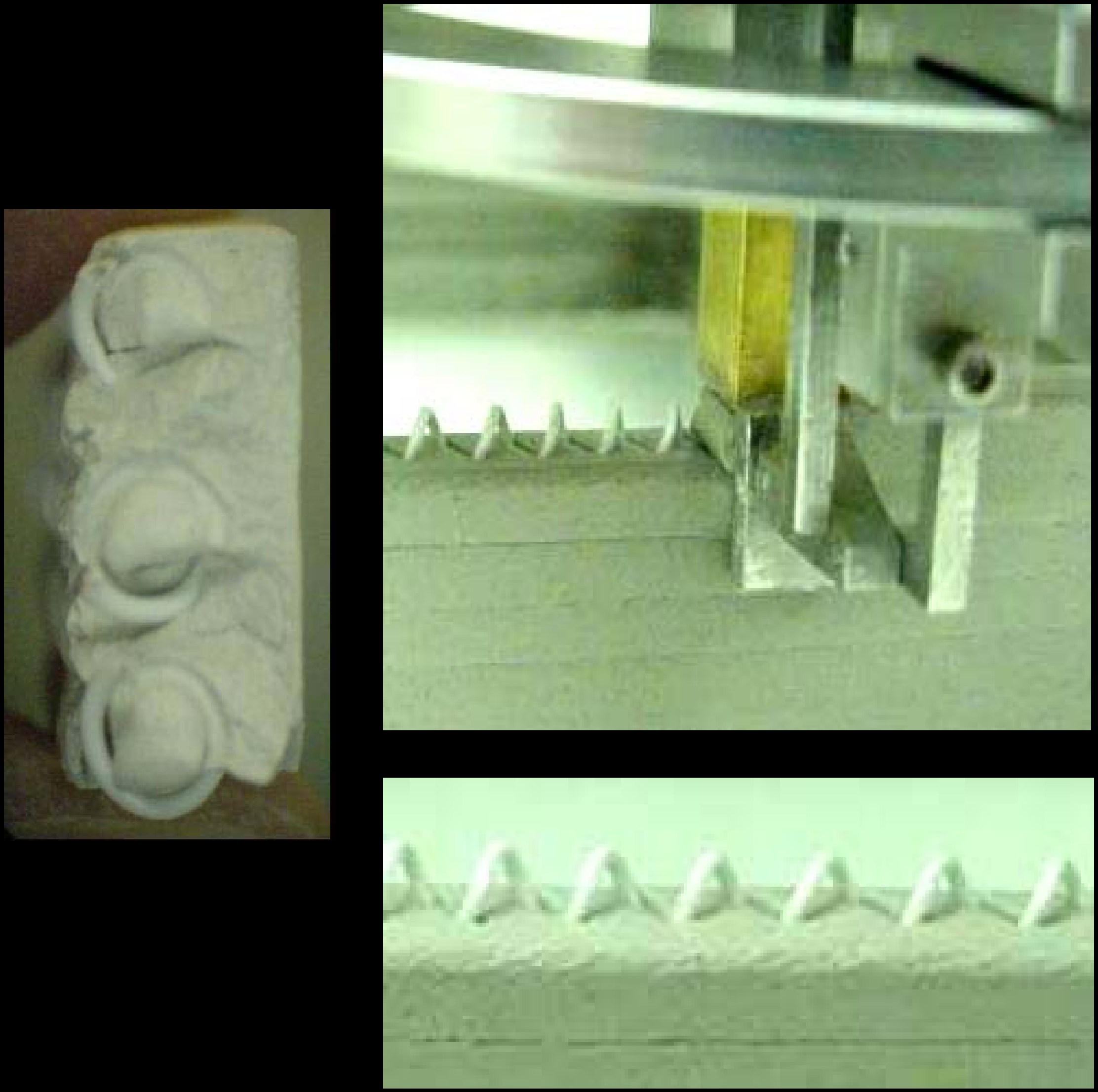


The only manual task is installation of fixtures.



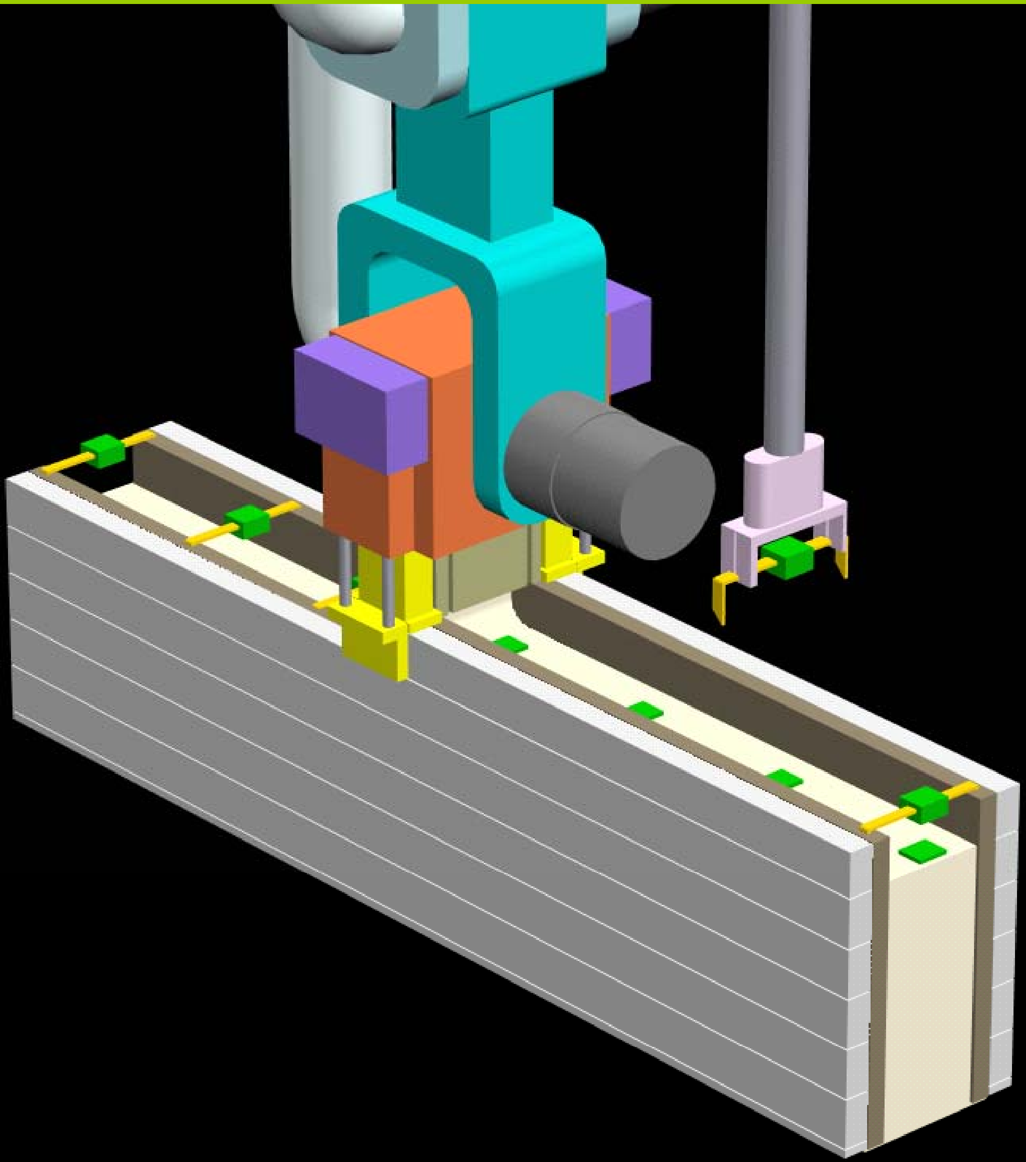
Automatic imbedding of heating / cooling elements

Nichrome wire coil or copper pipe for carrying heating or cooling lfluids may be automatically imbedded upon construction.



Imbedding sensors, actuators and IT components

Conductive concrete (brown layers) may be used to power densely imbedded sensors and actuators.



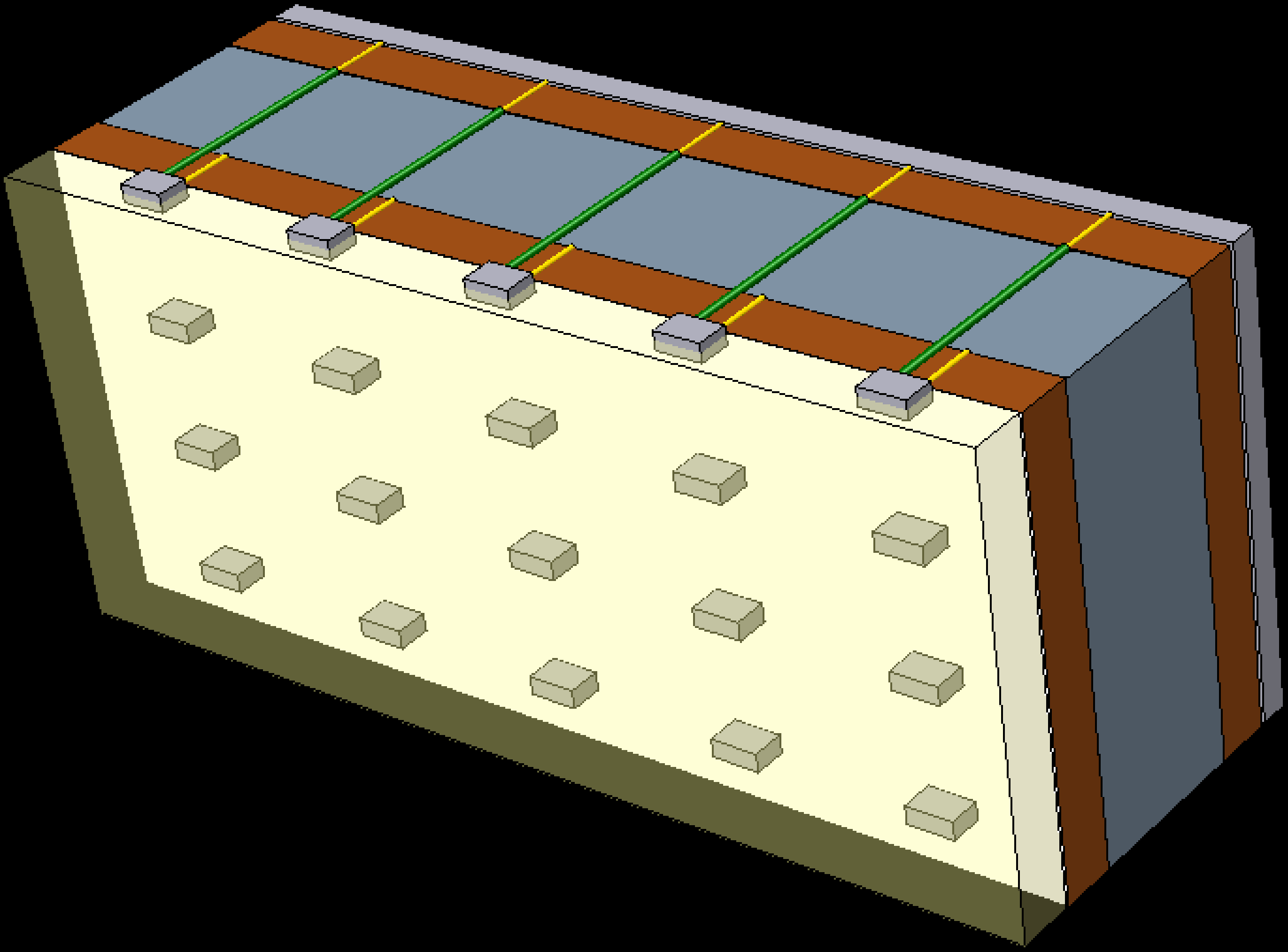
Lighting

Permanently imbedded lighting by automatic placement of LEDs with conductive and translucent concrete to create building structures that provide reliable and low energy illumination.

The translucent concrete shown, Litracon, is already in the market.

Automatic imbedding of LEDs

Composite wall including concrete, conductive concrete and translucent concrete

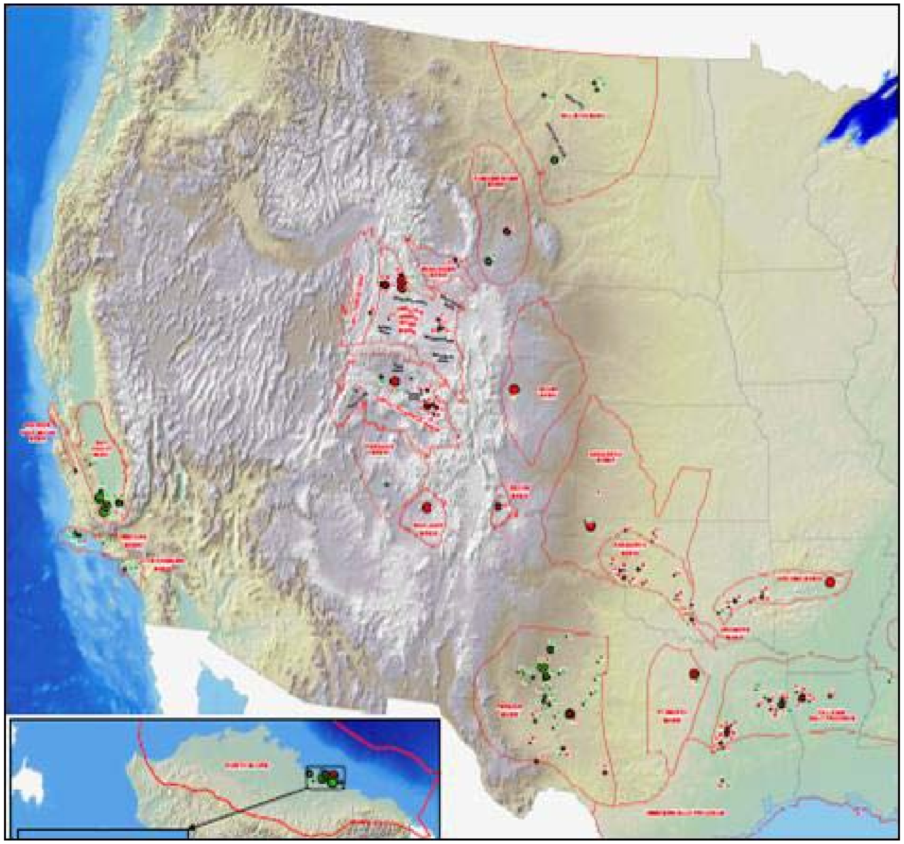


Responsive Energy Storage Through Oil/gas/geothermal-well Reuse (RESTOR)

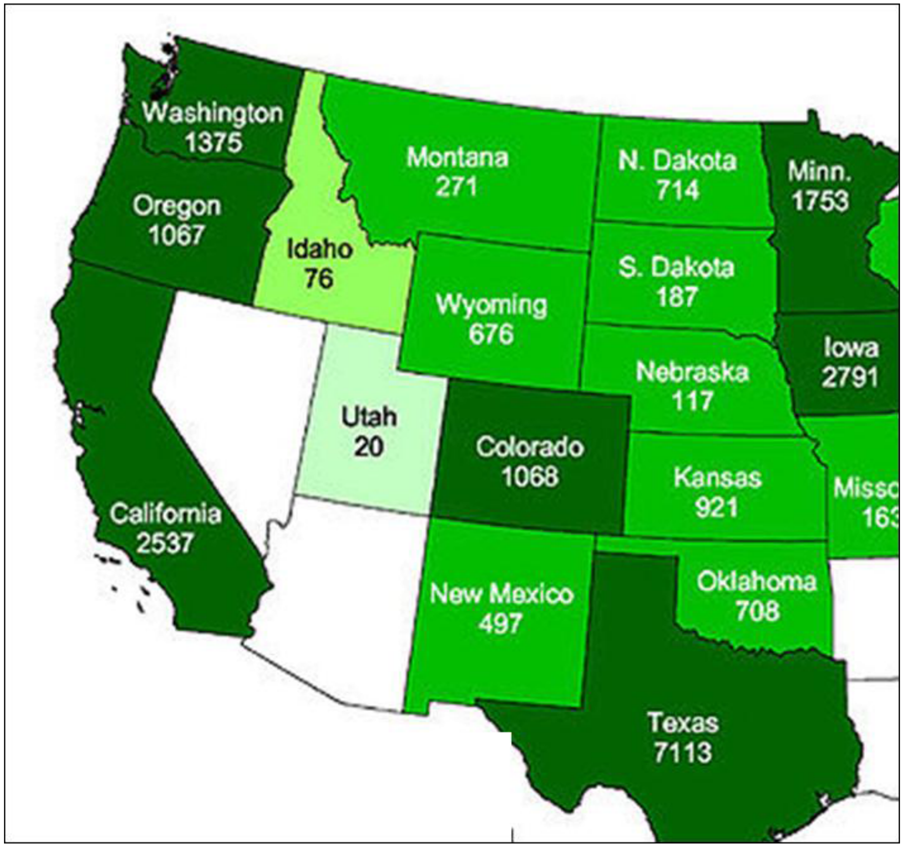
Berok Khoshnevis and

Gordon Roesler

An interesting coincidence

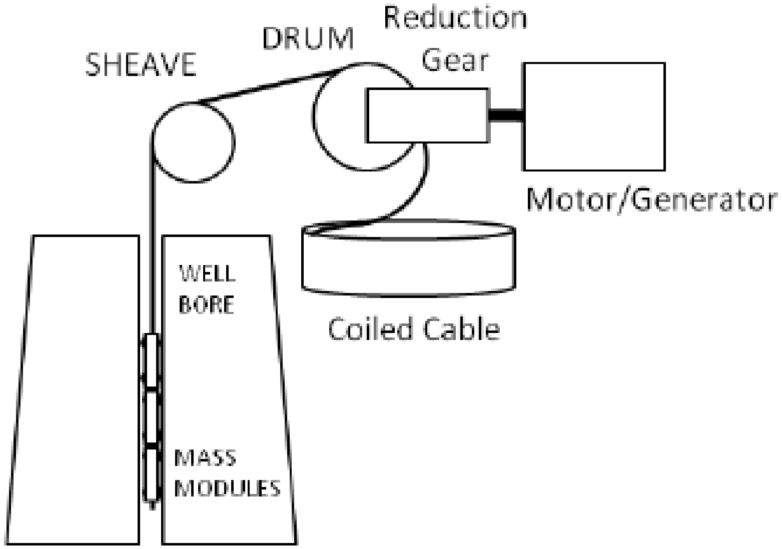


The 100 largest oil and gas fields in the US

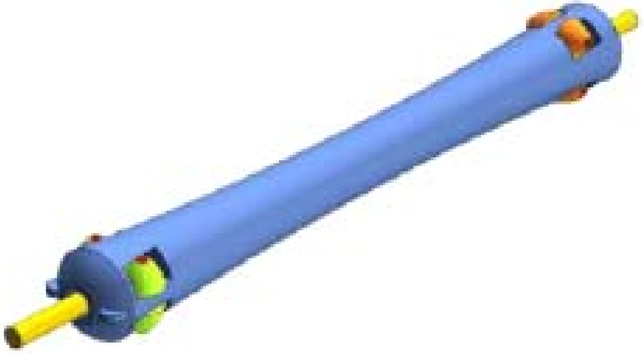


Installed US wind power capacity as of 2008

RESTOR gravitational energy storage system



- all materials readily available from mining industry
- liquid in well has virtually no effect
- oil well owner defers abandonment cost and realizes revenue



Significant energy storage

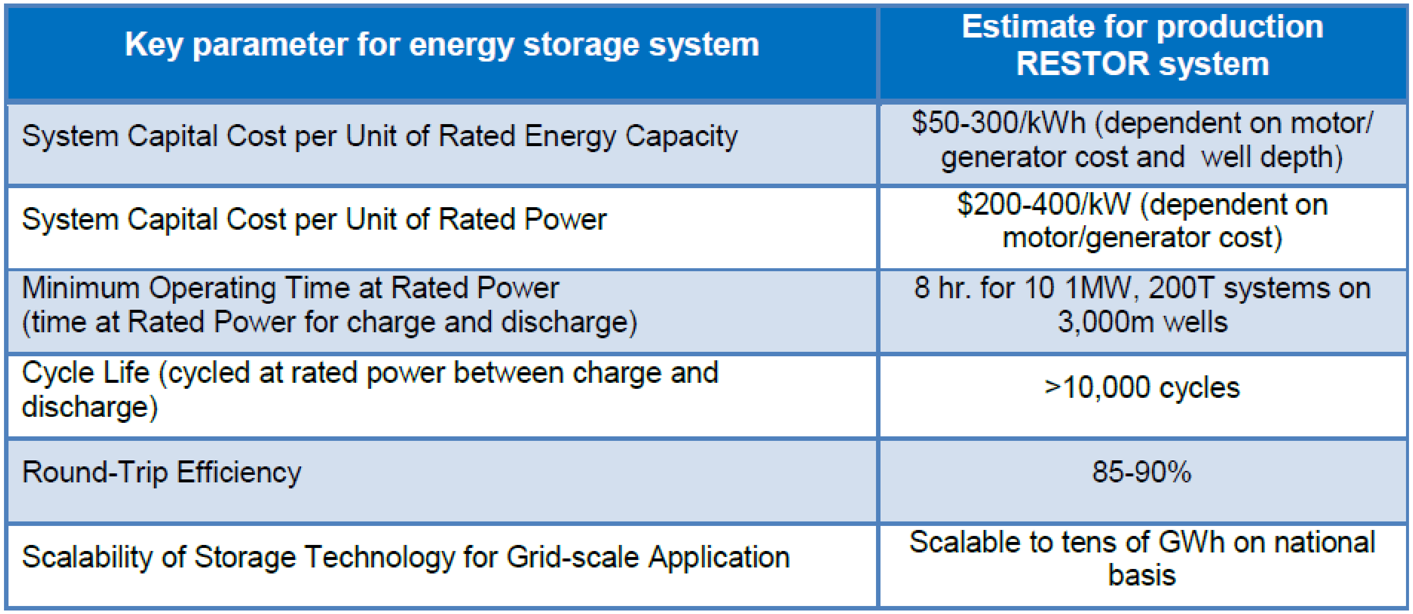
Storage capacity of a well:

$$E = mgh = (140kg/m \cdot \frac{h}{2}) \cdot g \cdot \frac{h}{2}$$ for iron weight of 6” diameter

$$E = 343J \times h^2$$

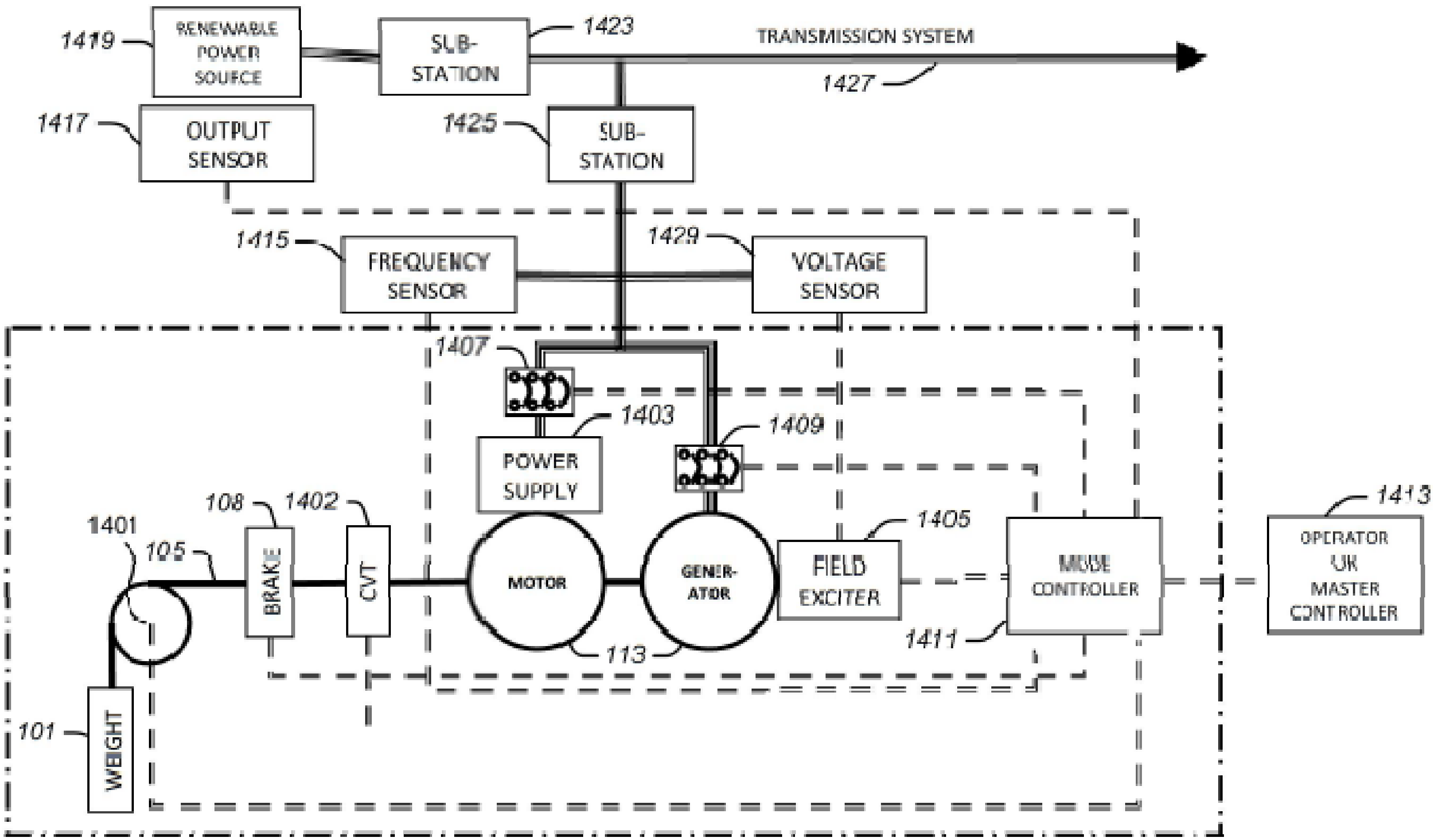
For a 3000m well with 1500kg weight:

$$E = 3.09 \times 10^9\, J = 858\, kWh$$

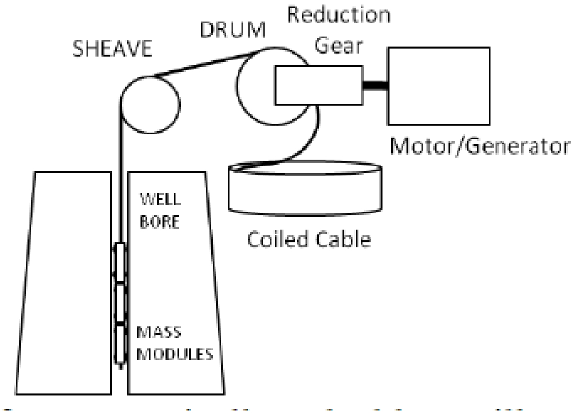


Key parameter for energy storage system	Estimate for production RESTOR system
System Capital Cost per Unit of Rated Energy Capacity	$50-300/kWh (dependent on motor/ generator cost and well depth)
System Capital Cost per Unit of Rated Power	$200-400/kW (dependent on motor/generator cost)
Minimum Operating Time at Rated Power (time at Rated Power for charge and discharge)	8 hr. for 10 1MW, 200T systems on 3,000m wells
Cycle Life (cycled at rated power between charge and discharge)	>10,000 cycles
Round-Trip Efficiency	85-90%
Scalability of Storage Technology for Grid-scale Application	Scalable to tens of GWh on national basis

Power system controls



Microgrid scale



To store

$$E = 3.09 \times 10^{7}\, J = 8.58\, kWh$$

would require a 300-m well of 6” diameter.

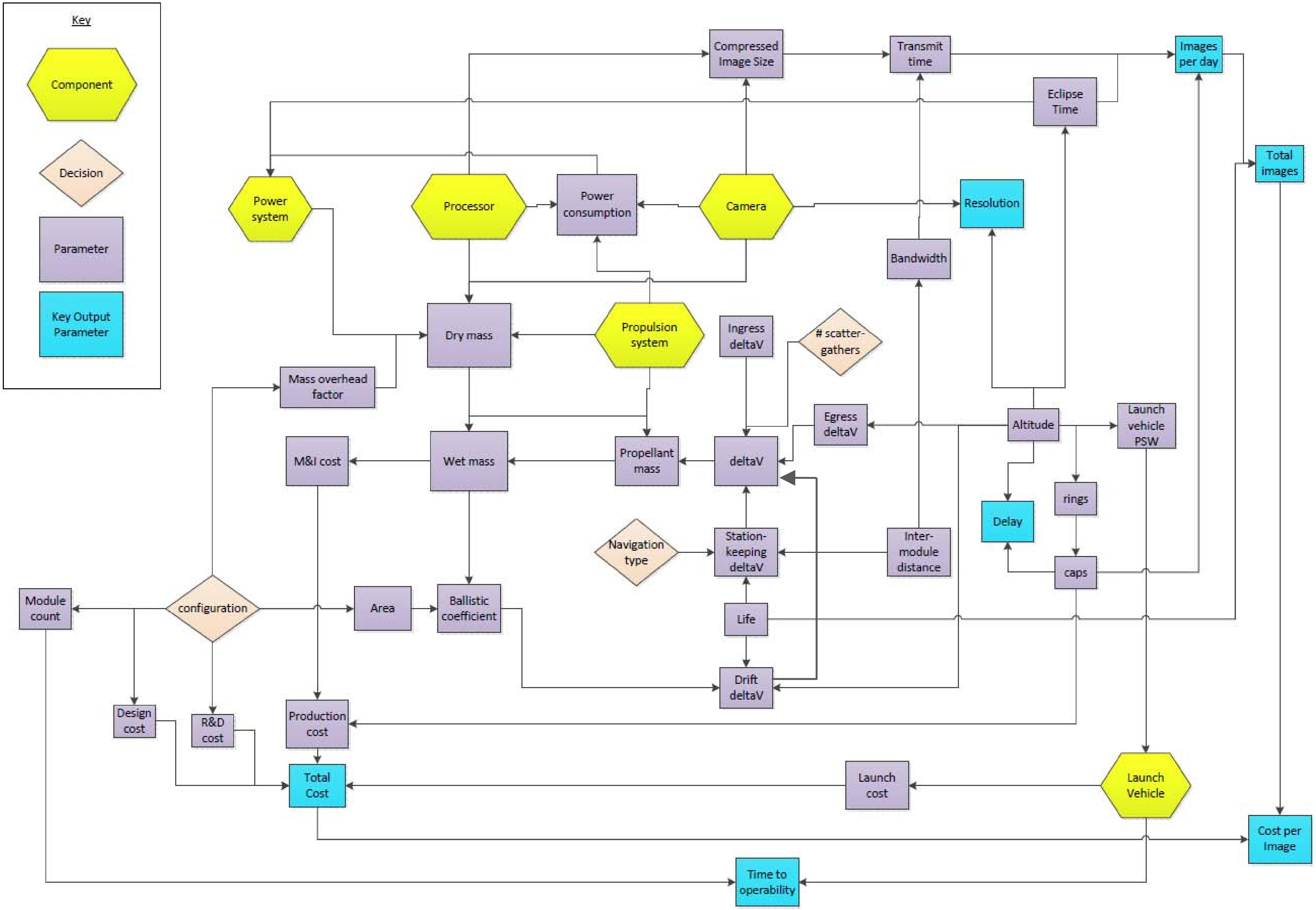
Power-related research at USC Information Sciences Institute

Gordon Roesler

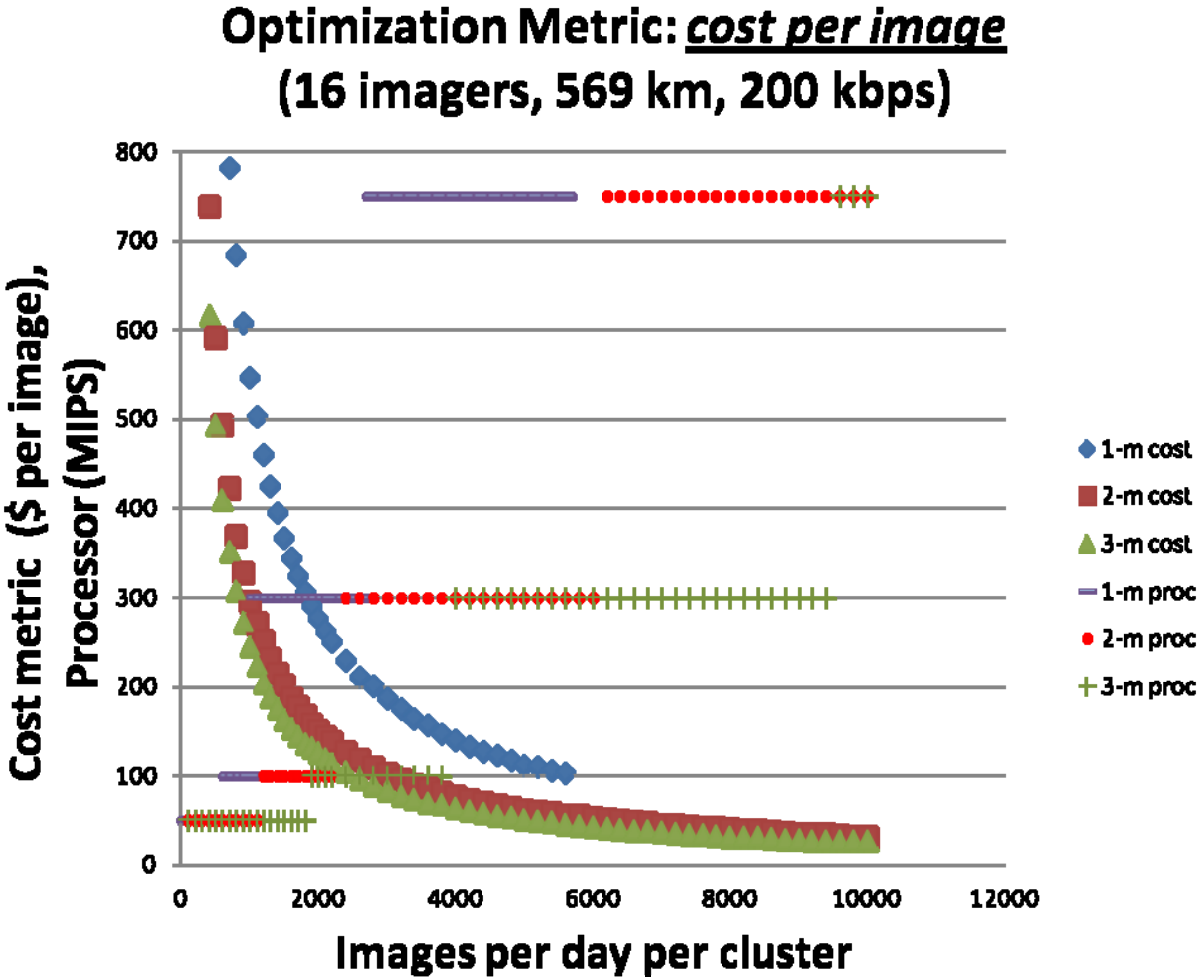
Design optimization and efficient trade space search

- Constraint-based search of deterministic design space
- Proved in three design domains:
  - Nanosatellite design (ISI)
  - Robotic surveillance with energy replenishment (DARPA)
  - Space architecture optimization (DARPA)
- Strong candidate for conceptual design of complex power systems

A small design space



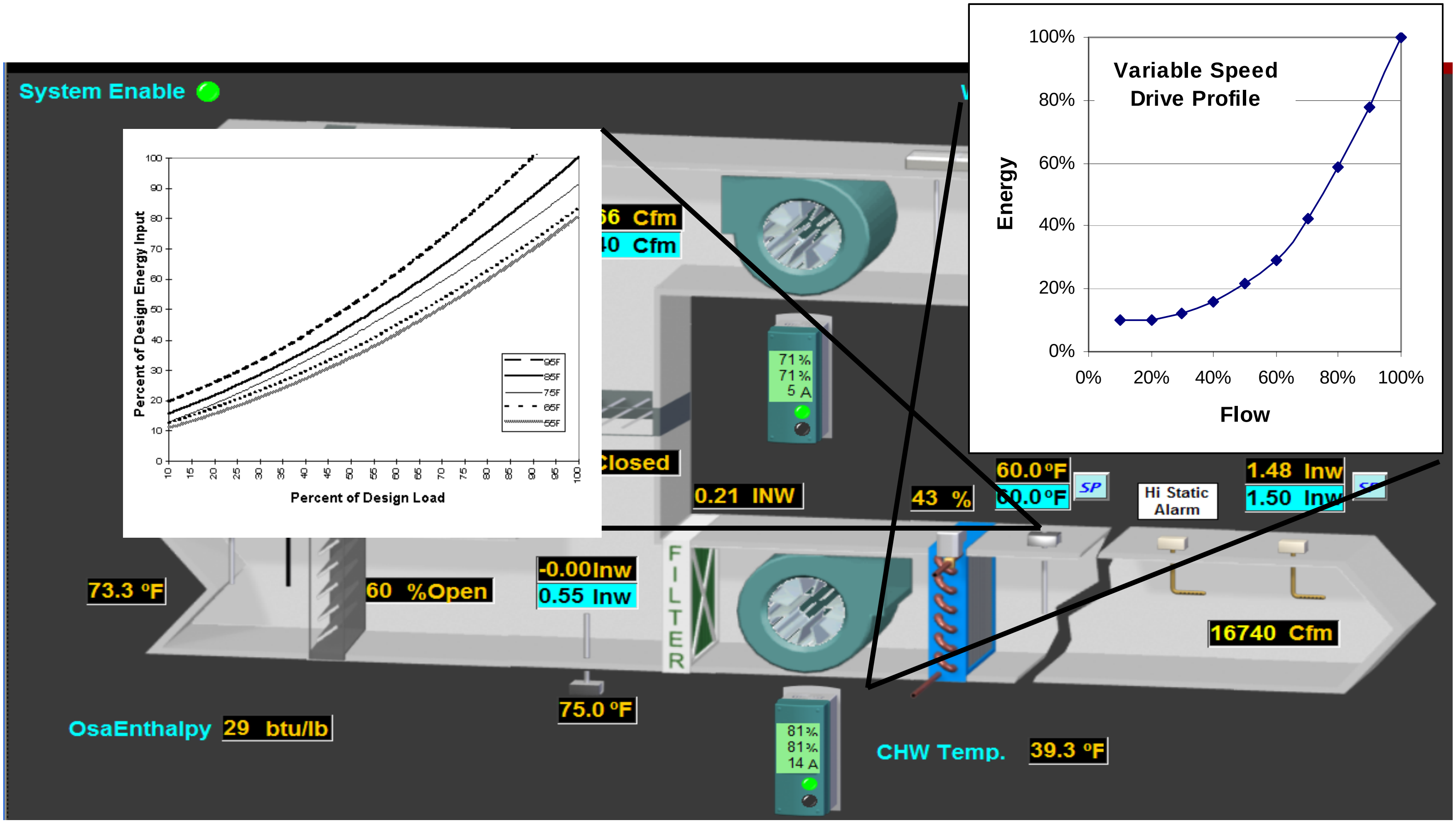
Each data point is an ***optimized*** design



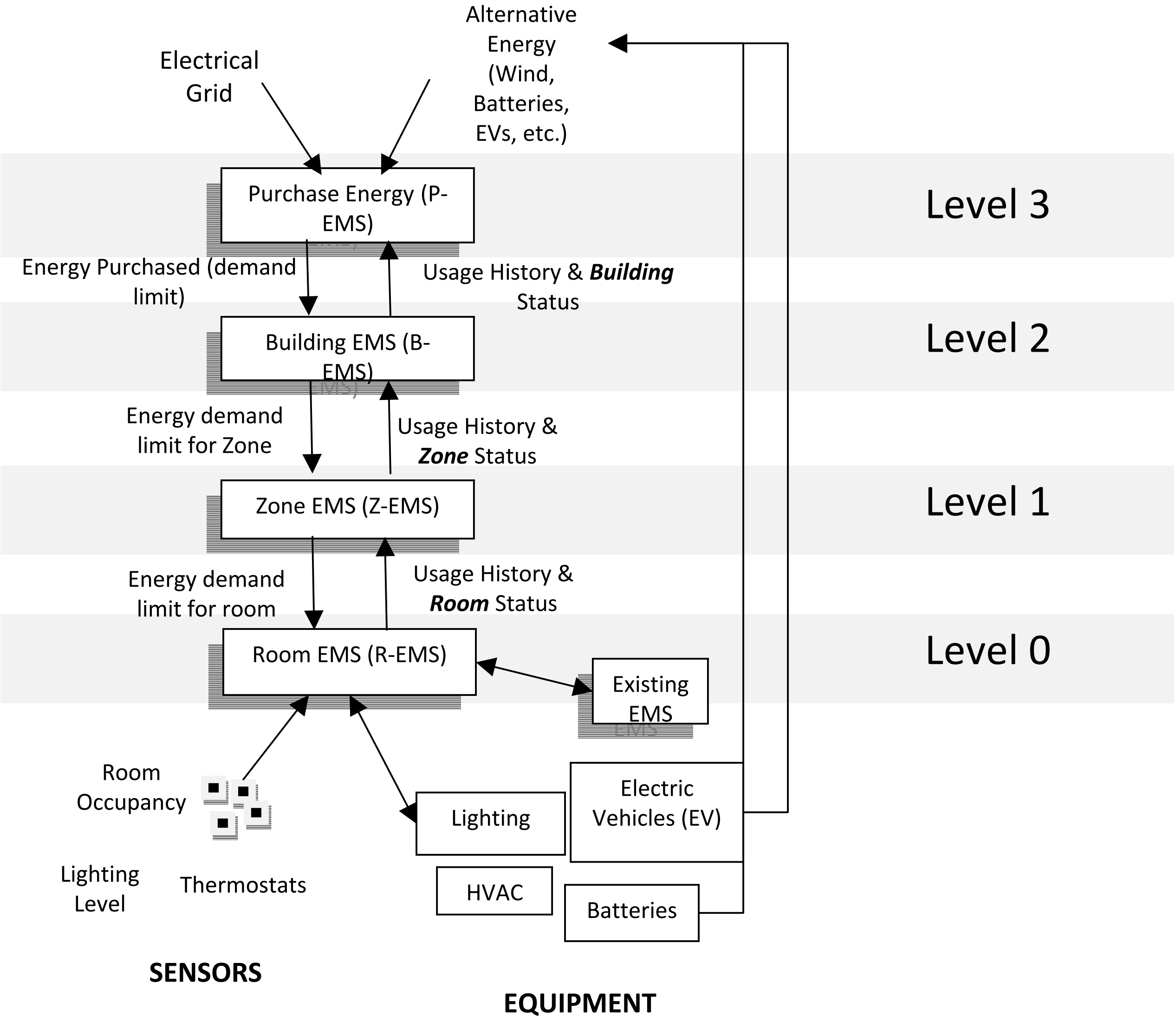
Building Level Energy Management System (BLEMS)

- Learns: Learns & adapts to occupant and building behavior
    - Continuously probing the system to learn about occupant and building demands/tolerances
- Negotiates: Based on overarching goals, BLEMS balances energy consumption with occupant comfort levels via negotiations with neighbors (peer-to-peer communications)
- Hierarchical: Supports the concept of a building composed of one or more zones, each zone with one or more rooms
- Self-contained: BLEMS recognizes existing legacy systems, adapts to new systems and communicates with peers

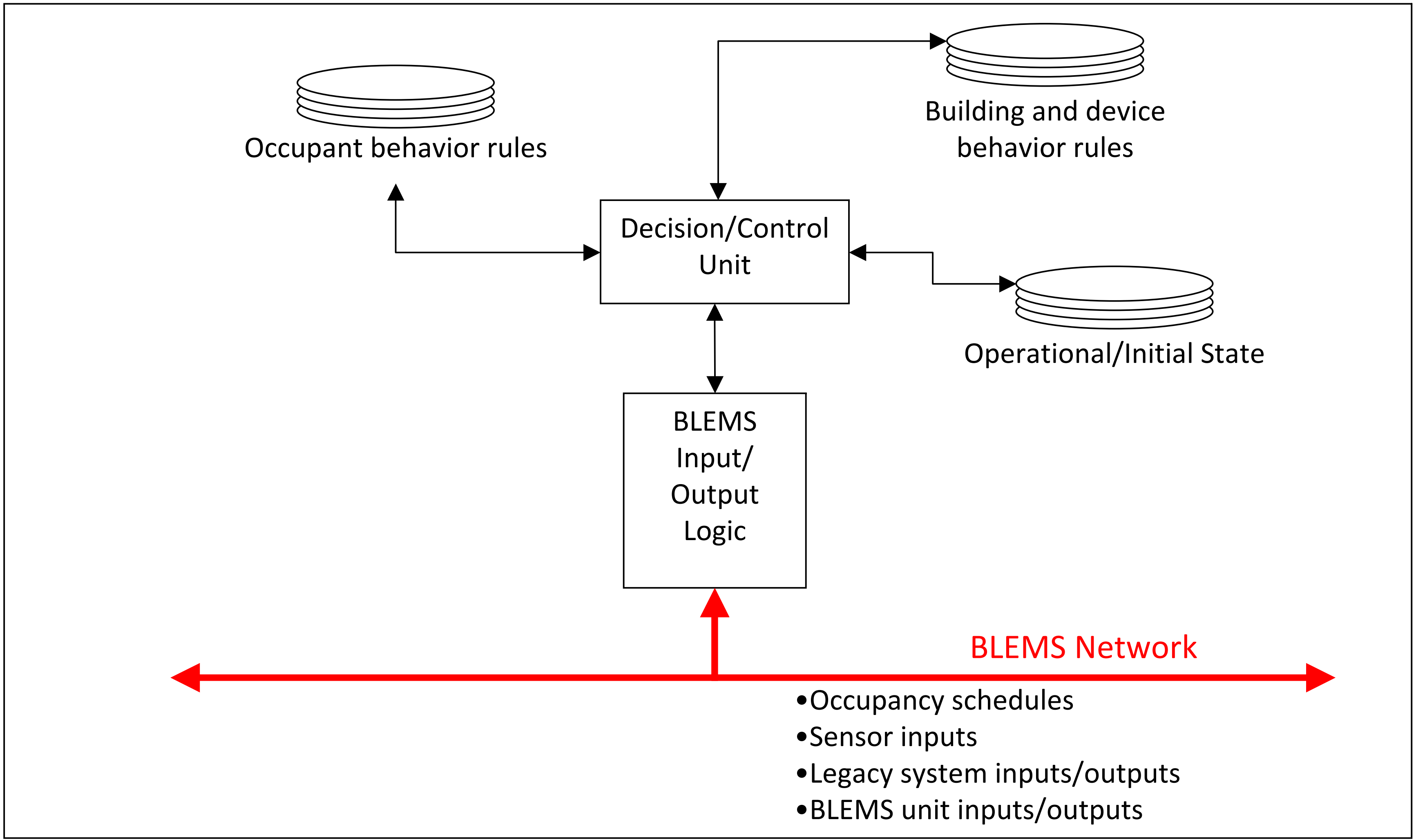
Overall System Optimization



BLEMS Hierarchy



BLEMS High-Level System



Occupant behavior rules

Building and device behavior rules

Decision/Control Unit

Operational/Initial State

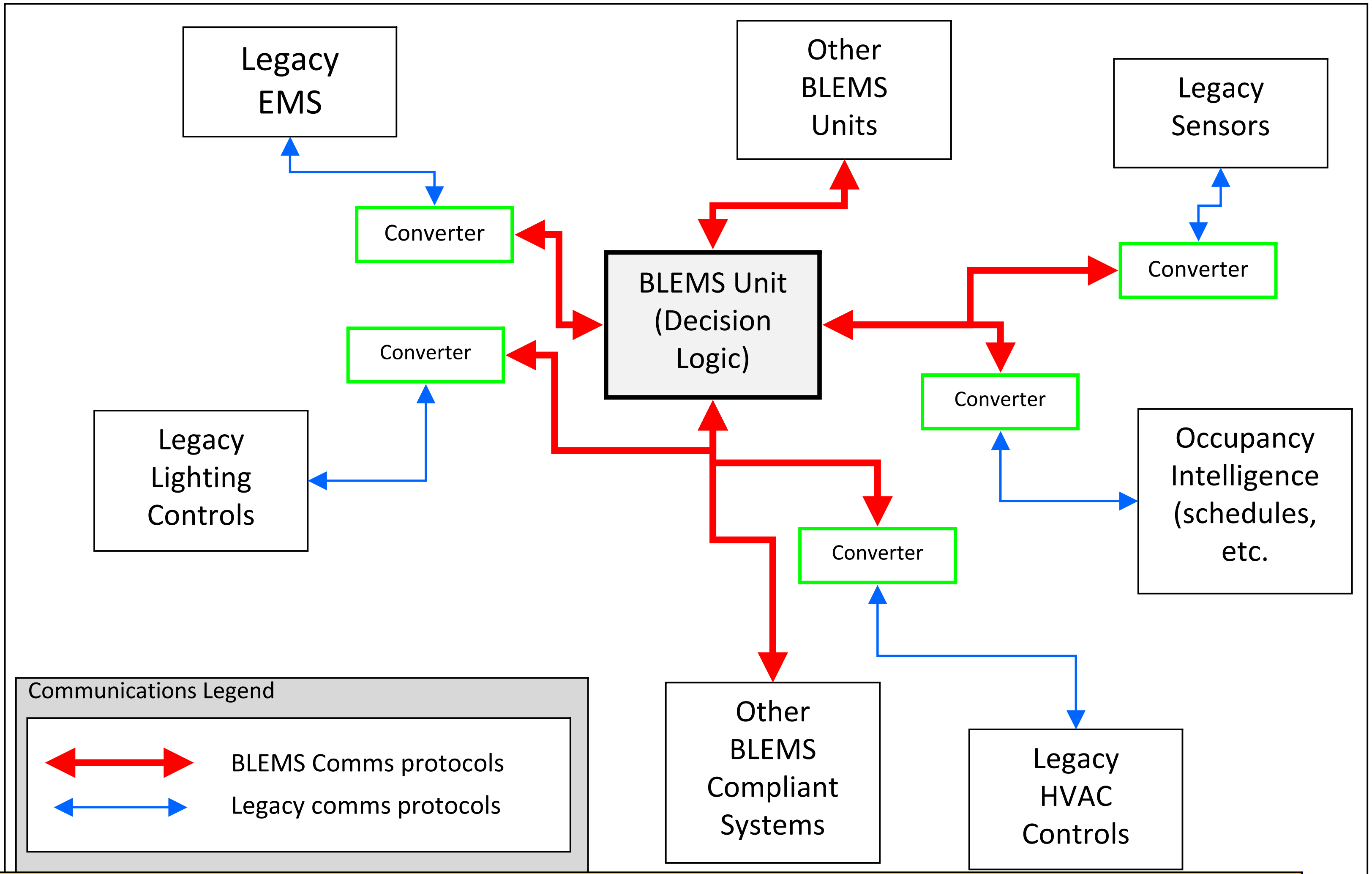
BLEMS Input/ Output Logic

BLEMS Network

- Occupancy schedules
- Sensor inputs
- Legacy system inputs/outputs
- BLEMS unit inputs/outputs

Rules generalize BLEMS – allow multiple implementations

BLEMS Network



BLEMS is agnostic to the communication system used

BLEMS Status

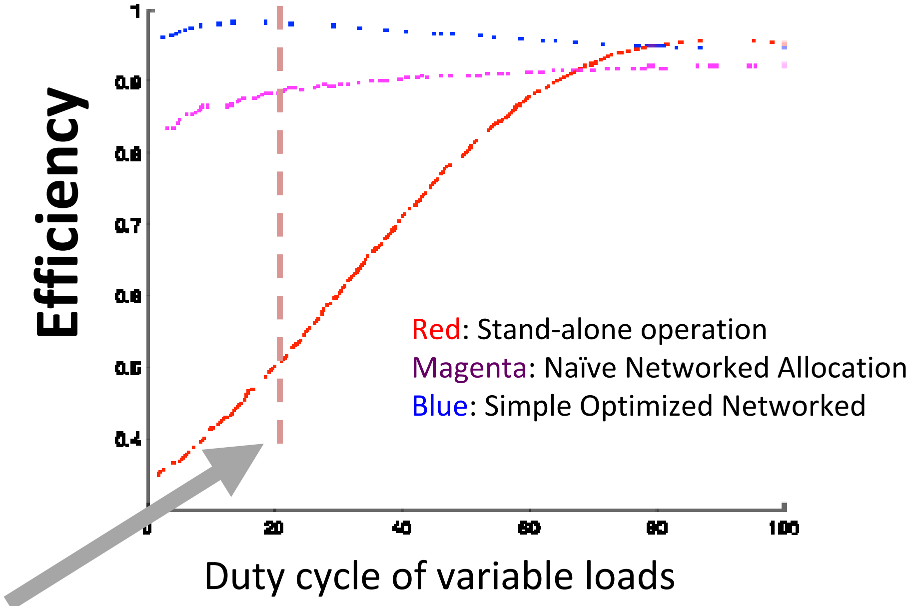
- Prototype 0.4 undergoing evaluation
  - Adjustments are being made to control/decision and behavior modules based on evaluations
  - Sensor boxes designed and tested
- Integration with Lewis Hall in progress
  - Can access RGL scheduling
  - completed development of the parsing software
  - Sensor box installation pending
- Completion August 2012
- Pursuing continuation under LA Smart Grid

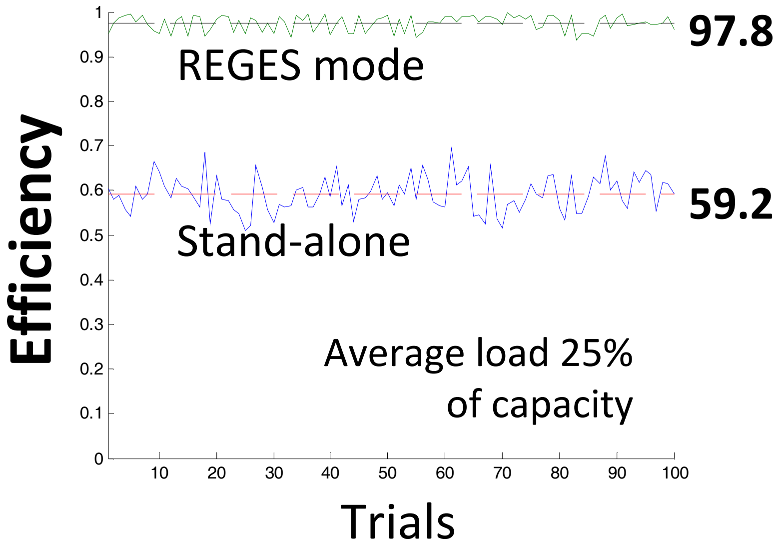
Multi-agent microgrid control

1. Increased Generation Efficiency
    - Operate Generators at Peak Thermal Efficiency
2. Decreased Generation Capacity Requirement
    - Dynamically Defer Lower Priority Loads to Avoid Requirement to Satisfy Peak Load
    - Reduction from Peak to Mean Load is Significant for Low Duty Cycle Applications
3. Reduction in Premature Generator Failure
    - “Wetstacking” Damage Caused by Low Output Operation
4. Enhanced Power Quality
    - Avoid Simultaneous Switching of Highly Reactive Loads
    - Isolate Sensitive Electronics from Busses Powering Rotating and other Reactive Loads
5. Manpower Reduction
    - Autonomous Operation of Power Distribution
    - Automated Fault Detection and Isolation

Key Benefits (1): Efficiency

- Increased generation efficiency
  - Optimized scheduling
  - Automatic load shifting

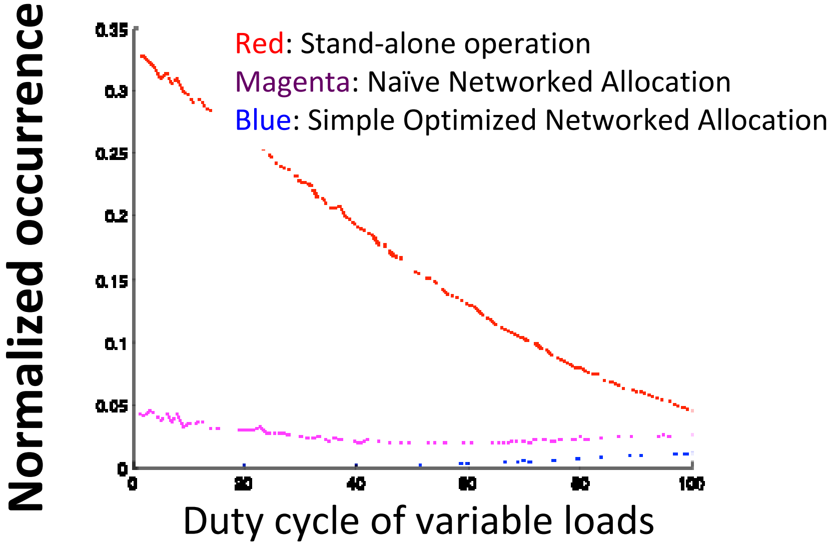


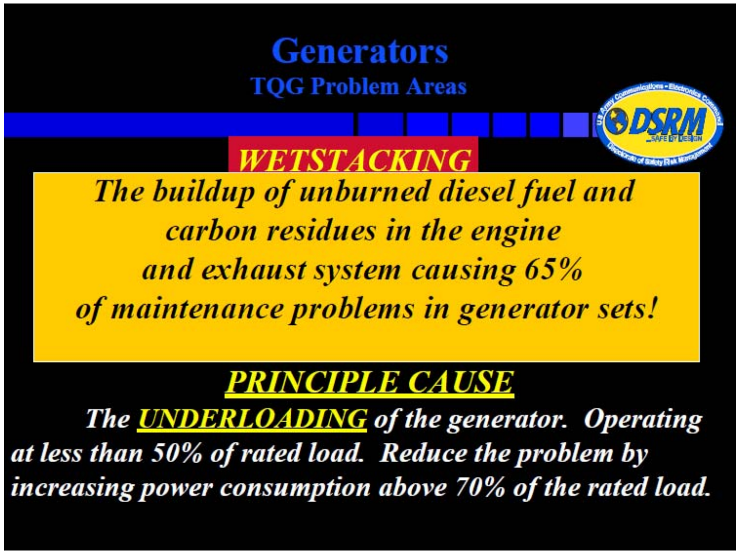


Management of multiple generators in integrated approach provides significant benefits in efficiency

Key Benefits (2): Reliability

- Reduction in generator failure
  - Operate in high reliability output zone





Generators

TQG Problem Areas

WETSTACKING

The buildup of unburned diesel fuel and carbon residues in the engine and exhaust system causing 65% of maintenance problems in generator sets!

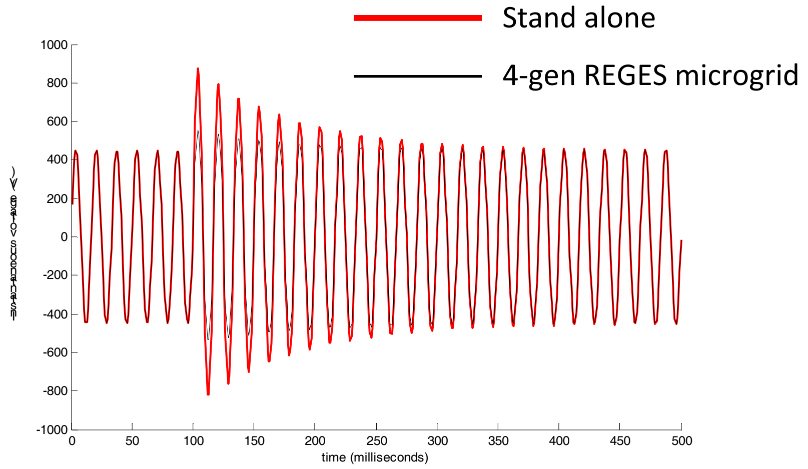
PRINCIPLE CAUSE

The UNDERLOADING of the generator. Operating at less than 50% of rated load. Reduce the problem by increasing power consumption above 70% of the rated load.

Expected Generator Failure Virtually Eliminated with Microgrid Configuration

Key Benefits (3): Power Quality

- Enhanced power quality
  - Effective reduction of impedance reduces transients
  - “Smart starting” algorithm protects vital loads, eliminates generator trips



EVENT	Control Network Action	
Request to start	Load or operator	Transmit REQ START
Verify capacity	REGES	Calculate ΣP(future)
Protect sensitive loads	REGES	Shift plant lineup
Add capacity	REGES	Start additional capacity
Energize load	REGES	Transmit START

Microgrid provides macrogrid-like power quality

Potential power related applications for other ISI technologies

- Wind farm output prediction
  - Probabilistic graph theory approach
  - Derived from CiSOFT oil field optimization
  - Combine with network of low-cost anemometers
- Grid operator decision support
  - Real-time analysis of synchrophasor data
  - Combine graph theory, learning machine, and power system model