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Buildings Finally Get A Brain: Di-BOSS

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Di-BOSS is the world's first Digital Building Operating System that acts as a "Brain" for buildings. All subsystems are integrated into a Systems Integration Facility that archives all past operational data such as energy consumption, occupancy, and space temperatures. Di-BOSS uses computational memory to learn thermodynamic responses of individual buildings under specific weather conditions, so that its Total Property Optimizer (TPO) can combine this with future weather forecasts to optimize all building energy usage (electric, steam, gas), as well as automate other critical building performance operations such as modulating VFD frequencies throughout the workday. Di-BOSS uses this situational awareness to perform continuous commissioning and capture maximum energy efficiency and sustainability gains throughout a portfolio. Cost savings averaged 12% year-over-year in eleven commercial office buildings of the Rudin Management portfolio with Di-BOSS in 2014. That translated to energy savings of more than $5 million for the Rudin commercial portfolio.

About Di-BOSS

Since Nicholas Negroponte theorized about "smart and ready " real estate in his insightful and groundbreaking book BEING DIGITAL in 1995, technologists and real estate executives have been pursuing and researching what this concept actually means and what steps building owners need to take to make their properties more intelligent and efficient. In fact, the question "What makes a building smart?" is still being debated today.

Also in 1995, Rudin Management began the redevelopment of 55 Broad Street in New York City (NYC), considered by many as the grandfather of all smart buildings. For the tenants, fibers were brought to the desktop, multiple choices of broadband carriers were supplied, power cleansed from the vagaries of the electrical grid was provided, and carrier neutral fiber was added to the risers. Also, a "hearth" and a "digital sandbox" was created where people could come together and share ideas. In 2015, the 20th anniversary of 55 Broad's rebirth as a technology center is celebrated, as well as, its incredible impact as the catalyst for the redevelopment and resurgence of lower Manhattan.

Now in 2015, the latest tool is unveiled that allows buildings to become ever smarter while retaining the intelligence they have acquired to date.

Di-BOSS is a new building operating system that uses data analytics and machine learning to remember and learn from past experiences. It then computes prescriptive and predictive pathways that guide our building operators toward optimal performance in real time. Lessons learned were taken from the development of 55 Broad Street, 3 Times Square, and 32 Avenue of the Americas, and introduced learned memory and forecasting into the science of building operations.

The name of this new tool, Di-BOSS, stands for Digital Building Operating System. This new platform performs several unique tasks. First, Di-BOSS integrates all building subsystems into a single database called a System Integration Facility, and displays analytics via a cockpit. Second, Di-BOSS uses machine learning algorithms to empower our buildings so that it remembers, learns, and uses past building performance and weather forecasts to predict and automate daily building operations. Third, Di-BOSS monitors occupancy levels continuously. The results are enhanced energy efficiency, 24/7/365 re-commissioning, reduced hot and cold calls, and a powerful new tenant retention tool contained within Di-BOSS's "Tenant Fractal." In sum, Di-BOSS collects, remembers, learns, expresses and shares the important data that most built environments dump every day. Di-BOSS also allows building subsystems to communicate with each other and to develop new feedback loops and relationships, thus creating new patterns that enable additional operating efficiencies. An example of this is the new relationship that occupancy levels now have with variable frequency fan speeds and space temperatures. Today in 11 Rudin commercial office buildings, Di-BOSS automatically modulates building fan speeds and the amount of chilled air moved based on the actual population of the building at that particular time. Thus, energy consumption is decreased while delivering the required level of comfort using the least amount of energy possible and in the most sustainable way. Di-BOSS also shortens the operating day by telling us the exact times to turn on building systems in the morning, and when to ramp them down in the afternoon since Di-BOSS tracks actual occupancy.

This system allowed the Rudin portfolio to achieve an annual energy savings of 12%, with some buildings saving as much as 17%. This amounts to an estimated $5 million cost savings in 2014 for the buildings that currently have Di-BOSS installed and operational.

The evolution of building analytics, experiences with how big data work in the built environment, and how Di-BOSS fills the void caused by subsystems that are not integrated are important points for the industry. Such subsystems can only deal with problems within their silos. Di-BOSS stores and analyzes data coming from all important subsystems, such as elevators, building management systems (BMS), fire, and security systems made by many high quality suppliers such as Johnson Controls, Honeywell, Schneider, Siemens, Schindler and Otis. Di-BOSS understands the data coming to it from all these subsystems, remembers what happened to each building in the past under like weather conditions, and feeds a continuous prescriptive and predictive glimpse into the future to each building operator using Di-BOSS.

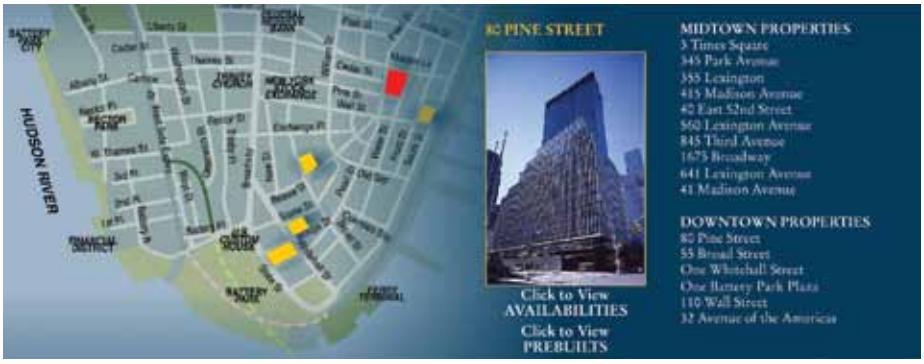
Buildings Need A Brain

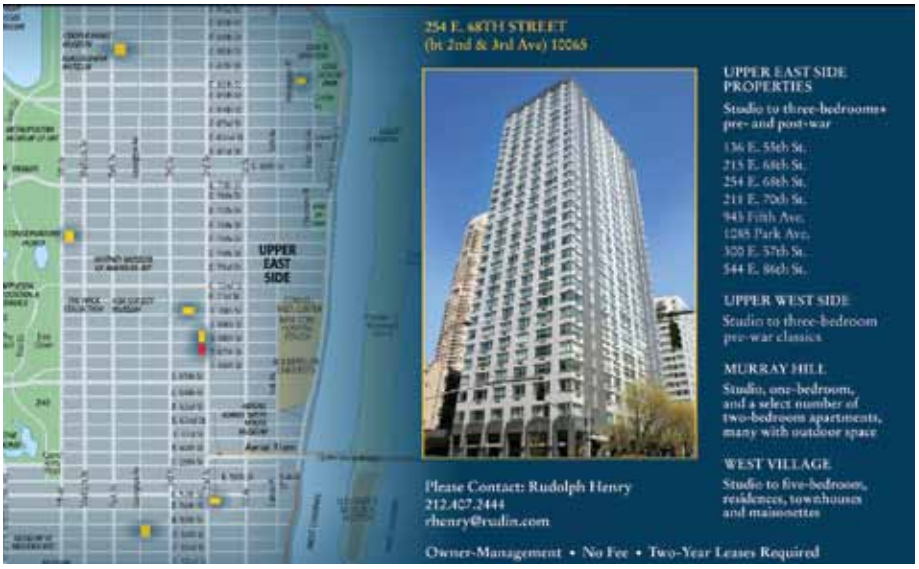
Tall commercial and residential buildings worldwide are designed for tenant comfort

and safety, with engine rooms and support equipment usually managed by a BMS. The BMS primarily integrates the Heating Ventilation and Air Conditioning systems (HVAC) to assist building operators in sustaining comfort of the tenant spaces. The BMS can be used to retrieve energy-related building data, such as readings from electric submeters and space temperature sensors, but the BMS is not an energy optimization tool. Therefore, integrated with other critical subsystems, the BMS could be operated more efficiently to reduce costs of energy consumption. For example, in the case of a commercial building, HVAC systems could be regulated during business hours by changing the speeds of Variable Frequency Drives (VFDs) to reduce energy costs. However, the BMS does not guarantee tenant comfort and reliable building operations because it does not integrate with lighting systems, occupancy sensors, tenant owned supplemental HVAC systems, elevator management systems, power systems, fire safety systems, security systems and the like. In fact, none of these building subsystems communicates with others like a true "nervous system." Instead, they provide supervisory control and data acquisition (SCADA) only within each subsystem. And there is no equivalent to the "brain" that continuously takes in all nervous system data, processes it, remembers it, predicts potential outcomes in the future, and issues orders to the nervous system to cause actions to make the whole operate optimally. All the while, the "brain" is reacting to potential system malfunctions, breakdowns, and changing external conditions. Accordingly, Rudin saw a need for improved computational technologies to integrate the subsystems into a system-of-systems in tall buildings in order to simultaneously optimize comfort, safety, energy efficiency and equipment performance, all the while sustainably controlling building operations.

According to the mayor's Office of Sustainability, forty percent of all the energy usage in NYC is consumed in tall office and

Top: 110 Wall Street is one of several downtown properties that has implemented the Di-BOSS system. Source: Nathaniel Lindsey





residential buildings. It is expected that this energy consumption percentage is similar in other "vertical cities," such as London, Shanghai, Hong Kong, Singapore, Dubai, and Tokyo, to name a few. About sixty percent of this tall building energy use is consumed by tenants. Tall office buildings are obligated to provide comfortable spaces to their tenants from startup in the morning to shutdown at night (some office buildings run till midnight, and others 24/7/365). The optimal operation of these tall buildings is of great importance for the success of the work of tenants, and ultimately, the economies they drive. Tall city buildings also occupy very important workspace other than commercial, including governments, campuses, as well as those of local agencies that provide water, sewage, garbage, etc. As the world moves into the big-data age of the twenty-first century, the opportunity to optimize and build more secure, sustainable, and efficient energy systems is critically important. It is thought only by providing a brain for these tall buildings that such a goal can be achieved. A system-of-systems approach is required that allows each building to be treated as if it were an organism, with the SCADA data sensors providing the innervation throughout all critical components, and a Digital Building Operating System (Di-BOSS) providing the machine learning, memory, and optimization that is the brain. Di-BOSS is needed to provide the identification of problems, evaluation of possible solutions, and prioritization of actions – all in real time. Di-BOSS must oversee all the subsystems of tall buildings, and all their SCADA sensor networks that provide the information that innervates the building. Di-BOSS also must forecast into the future to handle changing conditions. In addition, Di-BOSS should also integrate all of the buildings of each owner in order to optimize energy efficiency and sustainability of the entire portfolio.

About the Rudin Portfolio

For over 100 years, Rudin Management has been the leading private owner/ manager of

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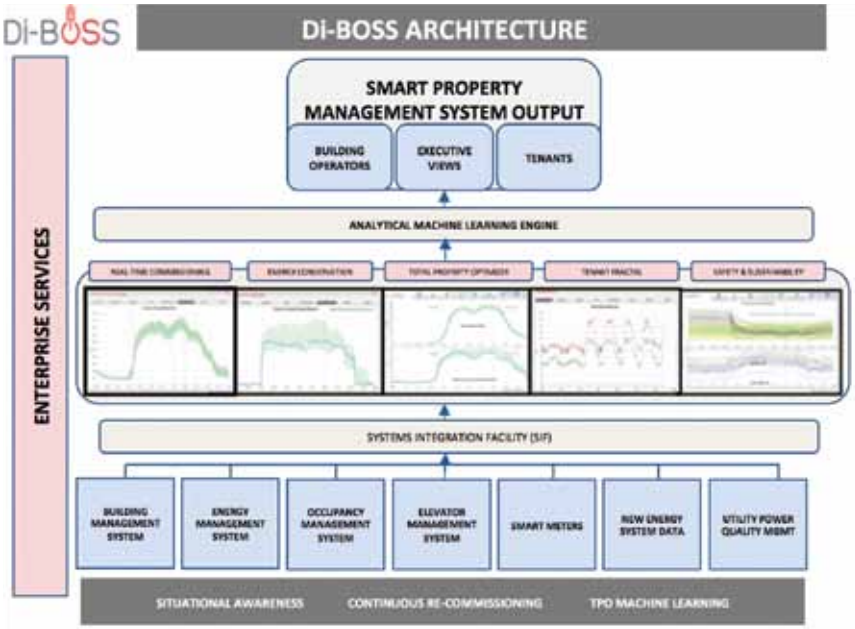


Opposite Top & Middle: Rudin Management Company owns and operates 16 commercial office properties in Manhattan that total 10 million square feet. Eleven buildings have Di-BOSS installed as of October, 2015. Source: Rudin Management Company, Inc.

Opposite Bottom: Rudin Management Company owns and operates 18 residential properties in Manhattan that total 5 million square feet. Two buildings have Di-BOSS installed as of October, 2015. Source: Rudin Management Company, Inc.

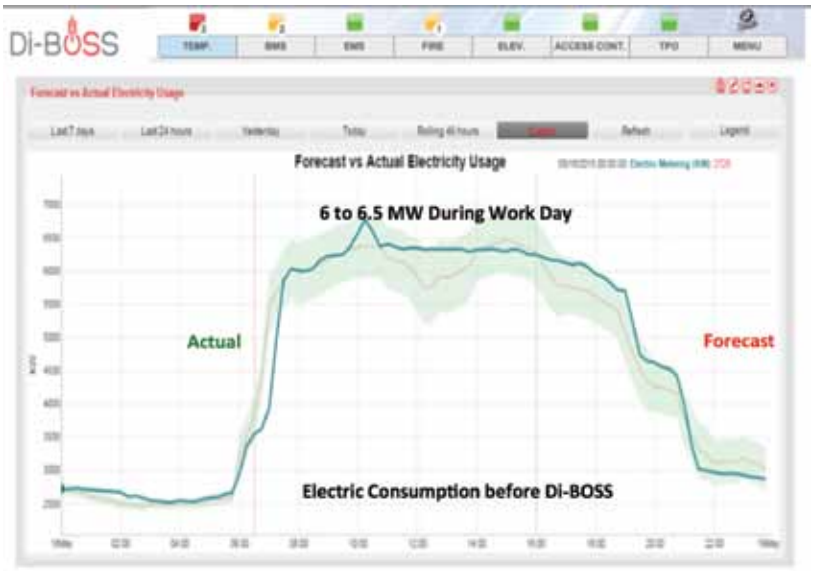
Left: The Di-BOSS architecture delivers data from all critical subsystems in each building to the Systems Integration Facility (SIF), that then distributes the data as required to the analytical apps of Di-BOSS, including the Total Property Optimizer (TPO). Then, results from computations by each app are fed back into the SIF so the system constantly learns. Source: Rudin Management Company, Inc.

office space in NYC. They own and operate more than 10 million square feet in their 16-building commercial portfolio, and an additional 5 million square feet of large residential buildings in Manhattan. Several Rudin buildings are critical to the economic vitality of NYC, including the original AT&T long-lines communications hub for all Trans-Atlantic telephone cables between the U.S. and Europe. That building is now also central to all cell phone, cable TV, and cloud-based Internet traffic between NYC and the rest of the world. Another Rudin building houses the world headquarters of Thompson Reuters news service in Times Square, and our flagship at 345 Park Avenue houses the worlds largest accounting firm, one of the largest international banks, and the National Football League, as well as the global headquarters of the Blackstone Group. First and foremost, Rudin Management has industry leading operational expertise in commercial and residential real estate efficiency, and particularly, in tenant satisfaction. Since 2004, Rudin Management had already improved the energy consumption of our entire portfolio by more than 15% for electricity, and by more than 40% for steam and natural gas (in BTU equivalents), even before the Di-BOSS brain was created.

The Origin of Di-BOSS

Rudin did not set out to build Di-BOSS themselves. They searched globally for a building-wide systems integrator, but found only one, Selex, a subsidiary of Finmeccanica, the Italian defense and aerospace giant, that was interested in helping them build Di-BOSS to their specifications. In fact, they won numerous national awards for both energy savings and environmental sustainability while lowering overall energy costs from over $60 million per year to under $40 million per year. With the addition of the Di-BOSS pilot in the 1.8 million-square-foot flagship on Park Avenue, new savings of an additional estimated $1 million were realized since testing began in the summer of 2012. With such an impressive track record of actual savings, Di-BOSS is now being installed throughout Rudin's entire portfolio of residential and commercial properties.

Di-BOSS was conceived as an operational controller as well as an energy efficiency optimizer. It was designed to lower the



Graph 1: The daily consumption curve of electricity at 345 Park Avenue. Source: Rudin Management Company, Inc.

Graph 2: Actual occupancy for a typical workday at 345 Park Avenue. Source: Rudin Management Company, Inc.

percentage of energy consumed by each building in a portfolio, using machine learning to inform the actions of Di-BOSS. The intent was to "FutureCast" future conditions and recommend actions to the building nervous system so that these subsystems could react. The result must be to realize energy optimization while maintaining tenant comfort and safety. Di-BOSS was born from a unique partnership among Rudin Management, which has state-of-the-art expertise in owning and operating tall buildings; Columbia University's Center for Computational Learning Systems (CCLS), which adds state-of-the-art expertise in machine learning and optimization; and Selex, which has big data, systems integration, and cyber security expertise. CCLS and Selex have each had experience deploying operational real-time systems in fields other than tall buildings, such as in military, medical, transportation and energy sectors. Beginning in 2011, a joint development team began to flush out the requirements and prototype the development of the data-intensive machine learning software necessary for ingesting big building data sets, defining the innervation of buildings, identifying multi-dimensional clusters of correlation, and marrying them to weather forecasting so that the nascent Di-BOSS could deliver predictions of what actions to take in the future.

These recommended actions to operators and managers were focused on maximizing energy efficiency while minimizing tenant disruptions in comfort and safety. Thus Di-BOSS with a Total Property Optimizer (TPO) was conceived, built and installed in 2 Rudin buildings in 2012 to see if this brain could create added value.

The Di-BOSS Building Operating System

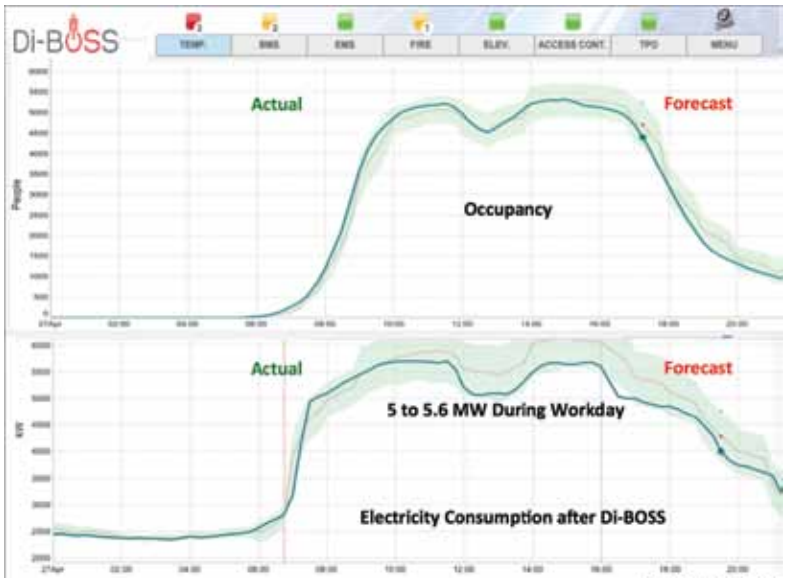
Di-BOSS's practical engineering, ease-of-use, and ability to connect all building subsystems into its brain are the result of its "engine room out" design. Rudin incorporated into the Di-BOSS architecture critical features that appealed specifically to their building managers and engineers, such as real-time commissioning, energy conservation, the TPO working across our portfolio, and tenant fractal that provides safety and sustainability for all occupants. Di-BOSS stands out from the traditional BMS because of its Total Property Optimizer. TPO uses advanced machine learning to learn from the past, and combines that with weather forecasts to each hour predict 24 hours into the future. The feedback loops programmed into Di-BOSS also enable the system to predict adverse conditions such as power quality events that allow building managers to act in advance to clear elevators and put other security measures into place to minimize the impact of power failures on our occupants. Changes in all of the above are monitored and analyzed continuously throughout the day.

During the initial period of prototyping, the Rudin team would pour over each new machine learning and visualization capability created by CCLS and Selex, critiquing and correcting it until Di-BOSS and its TPO were accurately forecasting electricity and steam consumption for each coming day of operations. After that commissioning effort, Di-BOSS now operates with only rare intervention from executives, systems engineers, and tenants. Di-BOSS presents Rudin executives with a view showing "traffic lights" that indicate the status of each subsystem of each building.

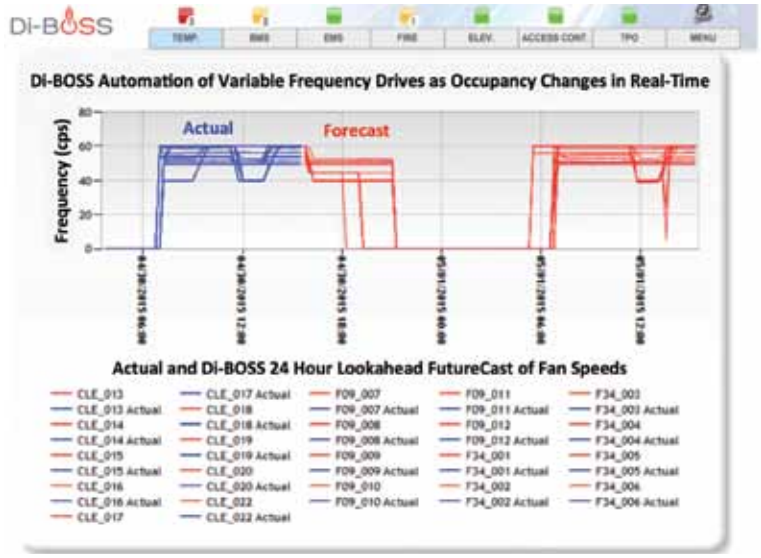
Before Di-BOSS, each building would startup at a fixed time each day, run flat out through the lease obligated time, and then

shut down at the required time each night. Graph 1 displays an electric consumption profile (in blue) like that before Di-BOSS recommendations (in red) changed the profile forever. In Rudin's biggest building up to 6.5 megawatts of electricity were being used every day. Di-BOSS gave us situational awareness of the actual occupancy patterns of our buildings, and the "double humped camel" was recognized, as in Graph 2. In NYC, occupancy reaches maximum at about 10 am in each of Rudin's buildings regardless of size or tenant mix, and people begin going home at about 4:00 pm every day.

Lunchtime also produced an opportunity for Di-BOSS to create energy savings. Di-BOSS starts just when occupants actually arrive, automatically cuts the energy usage in each building at lunchtime, and then ramps-down at about 4 pm as occupants begin to leave each building for the day. The electric curve is now automatically matching the occupancy curve, as in Graph 3. Di-BOSS has driven electricity consumption in Rudin's largest building from 6.5 to 5.6 megawatts at peak each day (compare Graphs 1 and 3).



Graph 3: Real-time occupancy (top) to electricity consumption (bottom). Source: Rudin Management Company, Inc.



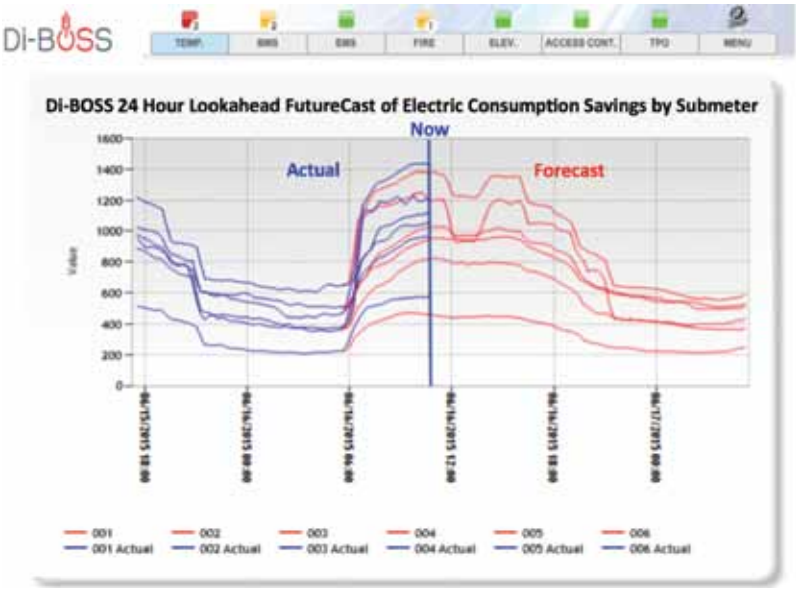
Graph 4: Actual VFD frequencies for the current day (blue) are constantly compared to the 24 hour "FutureCast" of frequencies for tomorrow (red) so that the feedback from any errors can be learned from and corrected by the TPO. Source: Rudin Management Company, Inc.

TPO, the Brain of Di-BOSS

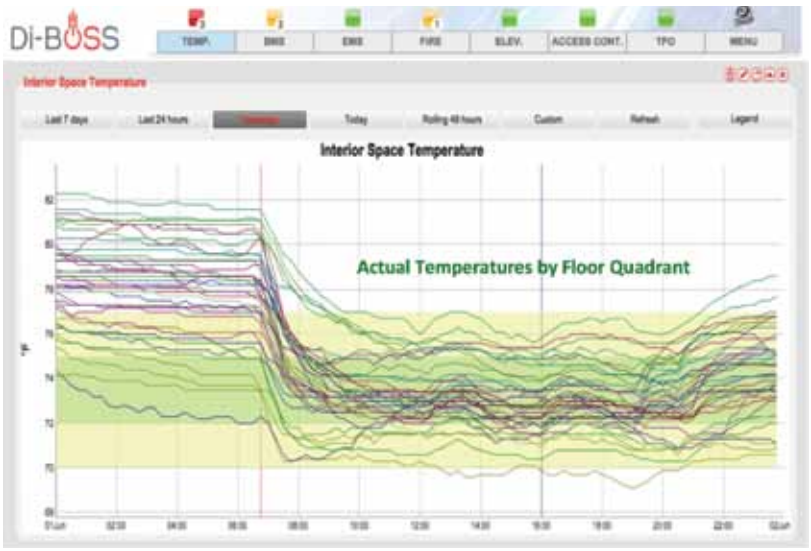
TPO is an integrated machine learning and optimization system that provides the real-time and future forecasting that forms the intelligence of Di-BOSS. The first major breakthrough was the use of machine learning algorithms within TPO. This allows daily predictive and prescriptive forecasts to be created that identify and express the most efficient pathways for the consumption of steam, natural gas, electricity and water. It enables tomorrow's instructions to learn from today's experience, and Di-BOSS continuously remembers what actually took place. For example, TPO tracks occupancy and monitors the past patterns of VFD frequencies so that it can forecast changes tied to expected occupancy. Graph 4 shows how TPO powers down the frequency of VFDs at lunchtime, with blue the actual frequency and red the FutureCast for the next 24 hours. Graph 5 shows the subsequent changes in electricity on each of the 6 submeters in the flagship building (only some of which are connected to VFDs). Sum these 6 submeters and you get the total electricity curve, as in Graph 3. Di-BOSS actions result in far greater energy savings than the smaller frequency cuts made to the VFDs. Savings of 40% in electricity consumption by the fans occur when frequencies are reduced by only 20%.

Di-BOSS is monitoring interior space temperatures all day every day, as in Graph 6, and supply-air and return-air temperatures, the latter shown in Graph 7. In that way, tenant comfort is certainly not sacrificed during these energy efficiency moves. As a consequence, tenant complaint calls have dropped 40% over the whole portfolio since Di-BOSS was first installed in each building. Steam and natural gas usage are optimized, as well, because engineers compete to continuously try to beat the forecast energy consumption for each day, as shown for steam in Graph 8. Di-BOSS is also monitoring air quality on each floor so that more fresh air can be mixed to keep carbon dioxide levels from rising too high for comfort of tenants, as shown in Graph 9.

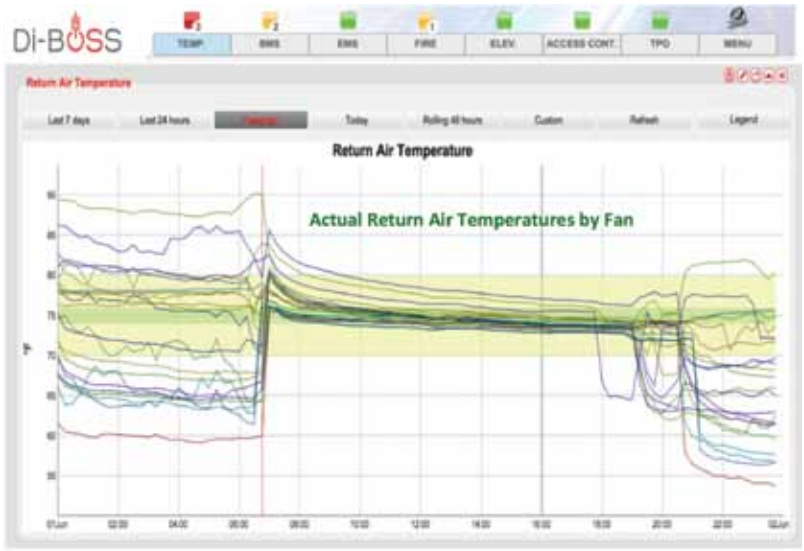
In summary, Di-BOSS saves energy by ostensibly "shortening" the workday, from pre-heating in cold winter pre-dawn hours, to startup each morning, to lunchtime and then to 4:00 pm ramp-down and final shutdown as the last occupants leave the building each night. In the daytime, our



Graph 5: Electricity consumption savings that are constantly monitored on 6 submeters at 345 Park Avenue. Blue is the actual consumption and red is the 24 hour FutureCast. Source: Rudin Management Company, Inc.



Graph 6: Actual floor-by-floor space temperatures at 345 Park Avenue. Source: Rudin Management Company, Inc.



Graph 7: Return air temperatures at 345 Park Avenue that are continuously monitored. Source: Rudin Management Company, Inc.

engineers steer the comfort "Horizon" during prime working hours. A 2-hour lookahead called a "NowCast" is used, generated continuously by TPO to predict tenant temperatures floor-by-floor based on air temperature supplies (Graph 10). Engineers are told not to touch any of the temperature controls for the next 2 hours whenever the NowCast looks to be forecasting comfortable temperatures throughout the building. Their time is better spent doing other maintenance chores. At up to $3,000/hour of operating costs per building, the energy savings from operating optimal buildings have been substantial.

The Di-BOSS Tenant Fractal

Ever since the Internet was born in the mid 1990's, property owners have experimented with bringing intelligence and automation to the built environments . Today, there are finally the necessary tools to allow our properties to express, remember and learn from the data currently collected and to unleash the new powers of the Internet of Things (IoT) as a tenant retention tool. When Di-BOSS was born, buildings finally got a brain. Built environments now have a mobile tool that can monitor, measure, and manage temperature, occupancy, fire safety, energy consumption, security, water and carbon dioxide while also measuring the relationship each of these systems has with each other.

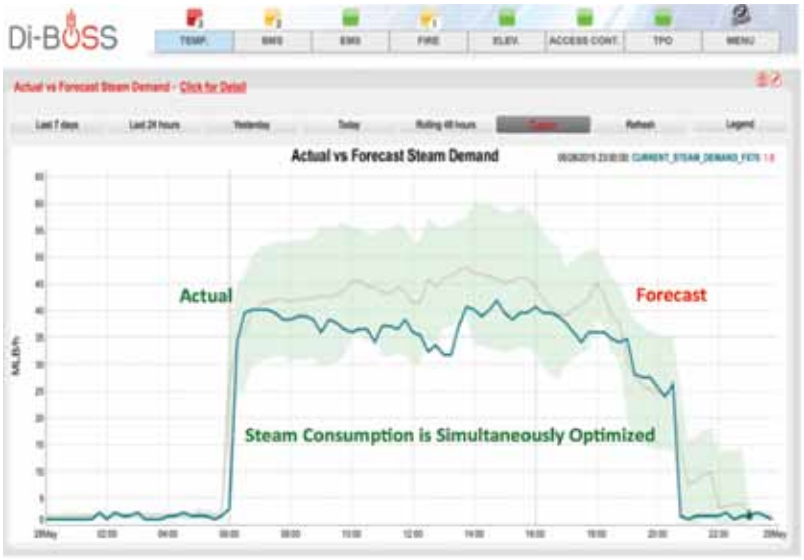
Now that Rudin buildings have a brain and can remember and learn, the next crucial step to carry the IoT into the built environment will be to enhance building central nervous systems. The network of sensors, optical fiber, ethernet and wireless connectivity is what allows IoT machines to communicate with each other. The IoT also collects the data that allows buildings to express their intelligence. Research has shown that the missing link was a device that could act as "the nerve synapse." The synapse is where data are collected, stored and then transmitted back to Di-BOSS so that TPO's analytics can be fully utilized. For

example, tenants have been shown the value of modern LED lighting, and more generally, intelligent lighting systems that are linked to the brain through delivery of added information such as occupancy for each room on each floor in real time. Graph 11 shows the electricity consumption from installation of modern lighting in 2014 (the lower curve in green), overlain onto electric consumption today on a similar floor with the same layout and square footage, but with lighting from 2004 technologies (red curve). The trough of 2004 energy consumption is equal to the peak of 2014 lighting technology. Utilizing such Di-BOSS analytics, it is possible to identify and share base and peak load ratios and create new tools to help tenants establish their own corporate sustainability strategies. The Di-BOSS Tenant Fractal allows customers to track their own consumption patterns floor-by-floor. They are then empowered to eliminate waste at night and decrease consumption during peak hours.

Building owners are now realizing that the IoT can exist within their properties, if and only if, they create the platform needed to learn and allow them to flourish. The IoT cannot fully reach its potential without a brain and central nervous system that is part of an integrated platform that can analyze, remember and learn from the data it collects. Di-BOSS fills this vacuum.

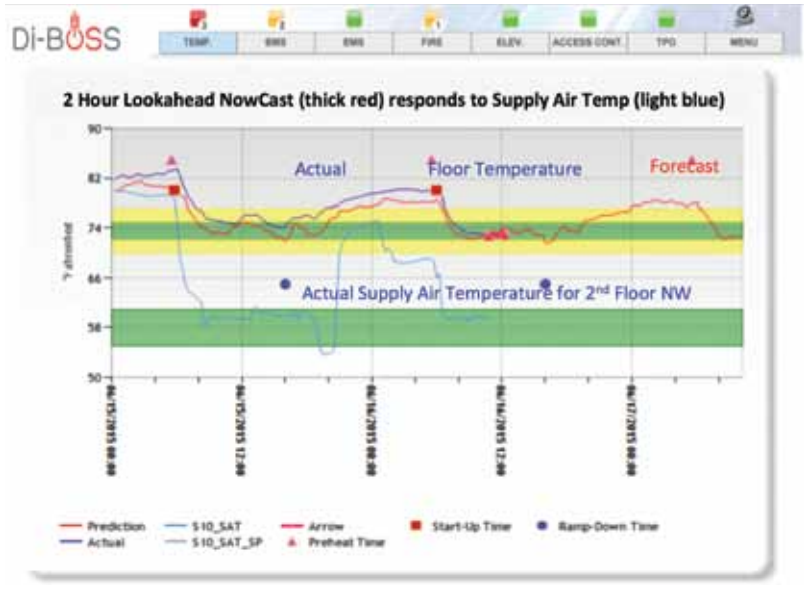
Di-BOSS Return-on-Investment

Energy consumption savings are tracked by Di-BOSS, and Return-on-Investment (ROI) is recorded daily. Table 1 summarizes the savings in energy directly attributable to Di-BOSS command and control. Since installing Di-BOSS in their commercial properties, Rudin Management has realized 2014 energy savings at a portfolio average of about 12%, when compared with a five-year rolling average that accounts for yearly winter and summer temperature variations from 2009 through 2013. Comparisons of 2014 versus 2013, and 2014 versus the 2005 benchmark

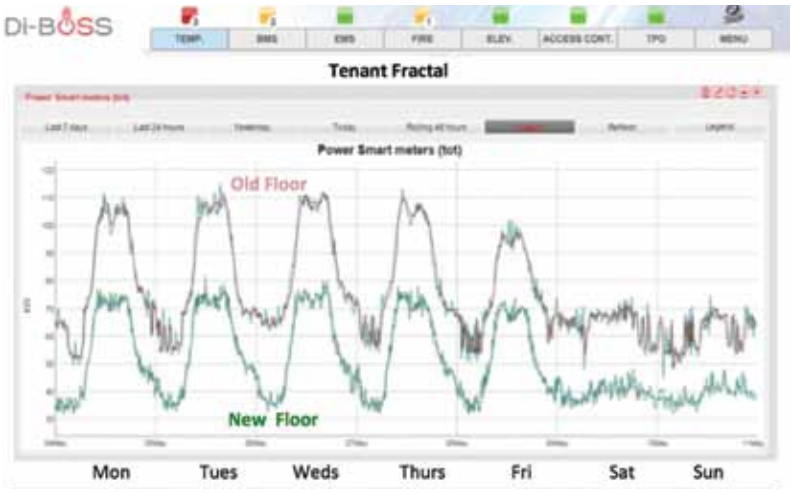


Graph 8: Di-BOSS TPO forecast (red), derived from steam consumption on previous days with similar weather, if operational realities allow. Source: Rudin Management Company, Inc.

Graph 9: Carbon dioxide levels, which are tracked continuously at 345 Park Avenue. Source: Rudin Management Company, Inc.



Graph 10: The Di-BOSS TPO uses a 2-hour lookahead called the "NowCast" (bold red) to forecast space temperatures for tenants based on the current supply air temperature (light blue). Source: Rudin Management Company, Inc.



Graph 11: The "Tenant Fractal" makes available the Di-BOSS capabilities for continuous commissioning to tenants so they can monitor the energy efficiency results from capital improvements . Source: Rudin Management Company, Inc.

Property			Consumption				Total Cost			
Type		Square Footage	2014 Consumption	2014 vs. 2013 % Change	2014 vs. 5 Yr Avg (2009-2013) % Change	2014 vs. 2005 % Change	2014 Cost	2014 vs. 2013 % Change	2014 vs. 5 Yr Avg (2009-2013) % Change	2014 vs. 2005 % Change
C	1 Battery Park Plaza	859,807								
	ELECTRIC - (Kwh)		15,247,200	-10%	-12%	-17%	$2,507,103	-9%	-24%	-25%
	STEAM - (Mlbs)		55,611	-3%	7%	-46%	$1,467,278	-10%	5%	-36%
	TOTAL MMBTU's		118	-6%	-3%	-36%	N/A			
C	1 Whitehall Street	329,991								
	ELECTRIC - (Kwh)		4,286,400	-10%	-14%	-12%	$767,625	-9%	-23%	-20%
	STEAM - (Mlbs)		16,151	12%	3%	-33%	$556,816	-4%	0%	-4%
	TOTAL MMBTU's		34	1%	-5%	-25%	N/A			
C	345 Park Ave	1,859,875								
	ELECTRIC - (Kwh)		36,034,400	-6%	-7%	-17%	$5,903,062	-6%	-19%	-21%
	STEAM - (Mlbs)		130,665	5%	11%	-37%	$3,037,515	-7%	4%	-33%
	TOTAL MMBTU's		279	0%	2%	-29%	N/A			
C	355 Lexington Avenue	256,272								
	ELECTRIC - (Kwh)		2,919,216	-5%	-8%	-16%	$617,681	-2%	-14%	-20%
	STEAM - (Mlbs)		3,796	19%	15%	-41%	$197,454	13%	22%	3%
	TOTAL MMBTU's		14	2%	-2%	-26%	N/A			
C	40 East 52nd Street	363,967								
	ELECTRIC - (Kwh)		2,319,120	-6%	-17%	-35%	$420,381	-6%	-28%	-30%
	STEAM - (Mlbs)		4,562	9%	3%	-29%	$211,266	-1%	2%	9%
	TOTAL MMBTU's		13	0%	-10%	-32%	N/A			
C	41 Madison Ave	563,080								
	ELECTRIC - (Kwh)		7,018,824	-5%	-10%	-27%	$1,351,249	-4%	-18%	-28%
	STEAM - (Mlbs)		31,906	-3%	-13%	-33%	$1,017,098	-10%	-11%	-12%
	TOTAL MMBTU's		62	-4%	-12%	-31%	N/A			
C	560 Lexington Avenue	357,764								
	ELECTRIC - (Kwh)		4,721,600	-8%	-17%	-36%	$858,107	-5%	-26%	-40%
	STEAM - (Mlbs)		3,912	26%	31%	-10%	$195,199	10%	26%	41%
	TOTAL MMBTU's		21	-2%	-10%	-31%	N/A			

Table 1: Electricity and steam costs and consumption during 2014 in seven Rudin Management commercial office buildings that had Di-BOSS operational for the full year . Source: Rudin Management Company, Inc.

"Utilizing such Di-BOSS analytics, it is possible to identify and share base and peak load ratios and create new tools to help tenants establish their own corporate sustainability strategies. The Di-BOSS Tenant Fractal allows customers to track their own consumption patterns floor-by-floor. They are then empowered to eliminate waste at night and decrease consumption during peak hours."

Property	345 Park Avenue	560 Lexington
Square Footage	1,859,875	357,764
Electricity Saved in 2014 (kWh)	7,500,000	2,500,000
Electricity Saved in 2014 (verses 2009-2013 5 year Running Average)	7%	9%
Total Energy Cost Saved in 2014 (verses 2009-2013 5 year Running Average)	$1,412,000	$308,000
Emissions Saved (MT CO2e)	2,100	708
All Costs to Implement Di-BOSS	$500,000	$290,000
Simple Payback (ROI)	5 months	11 months

Table 2: Sustainability analysis for the biggest (345 Park Avenue) versus smaller (560 Lexington) Rudin commercial office buildings. Source: Rudin Management Company, Inc.

year identified for sustainability improvement by PlaNYC, are also detailed in Table 1. The winter of 2014 was dominated by the famous "Polar Vortex's," so steam usage was higher in most buildings than in the winter of 2013. That winter was far colder than any since weather was officially recorded in the 1860's. In spite of that, some buildings are saving as much as 17% in year-over-year electricity consumption. The comparison of electricity consumption between 2014 and the 2005 baseline set by NYC for its PlaNYC ranged from 15% to 35% savings per building, as shown in Table 1. Overall, cost savings range from 20% to 40% across the Rudin Di-BOSS portfolio.

The annual savings equates to an estimate of $0.75 per square foot at 345 Park Avenue, a 1.8 million square foot property, and an estimate of $0.90 per square foot at 560 Lexington, a 360,000-square-foot property, as shown in Table 2. These energy savings are converted into 2,100 MT and 708 MT of carbon dioxide equivalent emission savings in these two buildings. Table 2 also shows the Di-BOSS software and hardware costs and simple payback ROI of 5 months for the larger building and 11 months for the smaller one.

The Future of Di-BOSS

As we peek into the future and attempt to predict the evolution of building analytics and how they are integrated into the invisible architecture of smart buildings, two facts are clear. Society cannot have smart cities without smart buildings, and we cannot expect to have smart buildings without an operating system that acts like a brain. It is believed that all future operating systems designed for the built environment will utilize machine learning and big data analytics like those in Di-BOSS and its TPO. It is also believed that all such system-of-systems will need to provide predictive and prescriptive pathways to guide building operators in real time. Once collected and expressed, this data needs to be shared as soon as possible with customers. This last step enables the true consumers of energy to measure and manage their own load profiles. Without this step the solution will never be fully addressed. Further, it is believed that each real estate vertical, including commercial, multi-family residential, hotels, hospitals, college campuses, data center facilities, as well as manufacturing and industrial complexes need a centralized brain such as the Di-BOSS system. In addition, Di-BOSS should inform future base-build and fit-out designs and influence architectural decisions to specifically direct the built environment toward more efficient energy technologies and new methods of occupation. In addition, Di-BOSS provides owners and operators with the ability to drive their buildings using performance-based evidence, another major benefit.