Smithsonian Institution

Office of Facilities Management and Reliability

Study of Facility Management and Operations Best Practices

Research Supporting

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Introduction

This case study is one of several studies conducted on facilities that demonstrate excellence in building operations, maintenance, and management. The study was commissioned by Laney College's Environmental Control Technician Program, as part of its National Science Foundation project *Educating Technicians for Building Automation and Sustainability*.

Best practices, in this context are defined as replicable, proactive strategies and activities that demonstrate excellence in the operations, maintenance, and management of a commercial or institutional facility. Best practices typically meet end-use requirements, improve occupant comfort, reduce energy consumption and meet sustainability goals, improve cost effective operations, and stimulate occupant engagement in energy conscious behavior. Best practices span excellence in technology and design strategies, troubleshooting and problem-solving, proactive organizational management and strategic planning, education and training efforts, and shared leadership. Building technicians play a critical role in each of the best practices highlighted in this study, whether the practices are more technical or more strategic in nature.

The best practices highlighted are not intended as a comprehensive analysis of the operation of each facility. They provide snap-shots of selected areas of excellence that crystallized as particularly significant to the successful operations of each facility. The practices were identified during site visits by a research team from Building Intelligence Group who conducted this research for Laney College.

These case studies demonstrate the critical role building technicians play in all aspects of sustainable building performance. It is our hope that they will inspire educators and practitioners alike in valuing building technicians as key agents of change in facilities and creating education and training opportunities to support technicians in their full professional capacities.

Best practices featured in this case study include:

1. Development and use of a facility management strategic plan
2. Training programs
3. Reliability-centered maintenance
4. Employee and stakeholder outreach
5. Leadership and organizational influence

Facility Overview

The Smithsonian Institution, founded in 1846, is the world's largest museum and research complex, welcoming more than 29 million visitors in 2011.

Mission of the Smithsonian Institution

"The increase and diffusion of knowledge".

Vision of the Smithsonian Institution

"Shaping the future by preserving our heritage, discovering new knowledge and sharing our resources with the world."

Other interesting facts about the Smithsonian Institution include:

- It is made up of nineteen museums and galleries, nine research centers and the National Zoo.
- The Institution's collections include 137 million objects, artworks and specimens.
- 7.4 million digitized objects are available online.
- 95 million people visited the Institution's web site in 2011.

Background

Buildings and Systems

The Smithsonian Institution's facilities include 769 maintained buildings and structures, comprising more than 12 million square feet. These facilities are located in Washington D.C., eight states and Panama. The 19 museums and galleries, National Zoological Park and nine research facilities are operated, managed and maintained by the Smithsonian Office of Facility Management and Reliability, or OFMR.

Facility Staff

The OFMR employs 850 people, including, but not limited:

- 125 full-time building engineers
- 120 full-time supervisors
- 100 full-time crafts and tradesmen
- 50 full-time engineering technicians

Eight zones of in-house staff operate, maintain and manage the facilities with support from some contracted staff. The eight zones provide an opportunity for each team to gain in-depth knowledge about their zone, increasing institutional knowledge, providing a sense of ownership and allowing for quick response times.

The OFMR is directly involved with design reviews for new facilities, system-startup and commissioning, as well as day-to-day support through zone management, systems engineering, business operations, support services, horticulture, safety and organizational performance and development.

Zone management groups perform day-to-day operations and maintenance services. The systems engineering groups provide energy management, electrical and life safety support, building automation and reliability-centered maintenance services. The business operations group is responsible for managing the budget, collecting and analyzing data and personnel management. The support services division provides audio visual, mail, motor vehicle maintenance and transportation services. The organizational performance and development group designs and implements training and develops best practice initiatives to support continuous improvement.

In 2006, the Smithsonian Institution was awarded the APPA Award for Excellence, and was the first non-university organization to win the award. APPA, originally the Association of Physical Plant Administrators of Universities and Colleges, is an organization broadly focused on leadership in educational facilities.

Best Practices

Best Practice #1: Development and Use of a Facility Management Strategic Plan

A strategic plan is a document that describes the business functions of an organization for a specific period of time, such as five years. A strategic plan includes the goals, objectives, strategies and tactics an organization uses to meet its core mission. Within large organizations, several strategic plans may exist.

- There are three strategic plans that influence the work of OFMR:

- Smithsonian Institution strategic plan
- Office of Facilities Engineering and Operations (OFEO) strategic plan
- Office of Facility Management and Reliability (OFMR) strategic plan

The strategic plan for the Smithsonian Institution was developed considering the overall mission and value of the Smithsonian. Facilities management is cited as an essential support service in the Institution's strategic plan:

"Strong, responsive support services – such as collections stewardship, facilities management, Web and new media, audience research, marketing, and financial management – are essential to accomplish the Smithsonian's mission and vision."

The mission of the Office of Facilities Engineering and Operations, or OFEO, is to "provide world-class service and stewardship by building, operating, maintaining and ensuring a safe, secure, healthy environment that enhances the Smithsonian experience." The OFEO forms its strategic plan around the mission, vision and values of the Institution with four actionable goals for facilities engineering and operations:

1. One Smithsonian: Facilities and programs partnered for excellence
2. Sparkling facilities: Impassioned stewardship in action
3. Legendary service: Leading the field with best practices
4. An empowered organization: One team driving forward

Paraphrasing, these goals are based on OFEO's values of balance, excellence, service and team work, and are intended to facilitate and deliver:

- Unified facilities and programs partnerships
- Extremely well-maintained facilities
- Excellence in service and leadership through best practices
- Workforce and leadership development and training

Each of the goals includes several strategies to achieve the goal. Within the OFEO, the core mission of the Office of Facility Management and Reliability, or OFMR, is more focused: To "provide world class services through a dedicated and professional workforce committed to providing a safe environment for people and collections by preserving the integrity of our facilities."

The OFMR's vision is to "lead the world in museum facilities management", and this is reflected in the organization's values:

- Integrity: "Continually exceed the expectations of all Smithsonian Institution offices"
- Responsibility: "Deliver high quality service through facilities management excellence"
- Creativity: "Foster an environment that rewards creativity and supports innovative ideas"
- Excellence: "Continuous quality improvement and professional development of team members to sustain our reputation as 'world class'"
- Teamwork: "Partnering with contractors, clients and a diverse workforce to reflect our professionalism"

Vision of OFMR

"Leading the world in museum facilities management"

The OFMR strategic plan pertains to a five year period, specifically from 2009 to 2013. One of the key uses of the plan is to prioritize long-term, short-term, and immediate goals. Every six months, the goals that align with the strategic plan are evaluated. This is important because organizations are often defined by the goals they set and their ability to meet those goals. Without tracking progress, it is not possible to determine if the organization is moving forward. By using

GOAL I	CARE FOR SMITHSONIAN
Objective A	**Operate sites safely, effectively, efficiently, and sustainably**
Strategy 1	Clean surfaces, dispose of waste, and handle materials
Strategy 2	Refine grounds maintenance, plant production, interiorscapes, horticultural collections, and integrated pest management
Strategy 3	Provide vehicle maintenance, shuttle, mail, and audio-visual services
Strategy 4	Ensure sufficient facilities for operations and inventory storage
Strategy 5	Monitor energy and water consumption
Objective B	**Maintain and repair facilities safely, effectively, efficiently, and sustainably**
Strategy 1	Further implement reliability centered maintenance
Strategy 2	Maintain and repair building equipment, systems, and envelopes
Strategy 3	Inspect and assess assets
Objective C	**Manage financial resources and processes**
Strategy 1	Develop dynamic, responsible budgeting and allocation practices
Strategy 2	Maximize acquisition strategies
Strategy 3	Analyze and improve service contract development and management tools

Figure 1: Goal, objective and strategy level excerpt from the strategic plan

GOAL I	CARE FOR SMITHSONIAN
Objective A	**Operate sites safely, effectively, efficiently, and sustainably**
Strategy 1	**Clean surfaces, dispose of waste, and handle materials**
Tactic a	Centralize inventory tracking and contracts for supplies and waste hauling
Tactic b	Select standards for supplies and equipment and validate efficacy of green cleaning products and methods
Tactic c	Appoint a team to conduct appearance metric inspections with real time feedback to supervisors
Tactic d	Emphasize cleaning to reduce presence of microbes
Tactic e	Audit waste stream to prioritize waste reduction and recycling opportunities
Tactic f	Encourage recycling by implementing local collection
Tactic g	Initiate a merit-based program for recycling rebate funds
Tactic h	Compost plant debris, animal waste, and food residuals

Figure 2: Goal, objective, strategy and tactic level from strategic plan

the strategic plan, specific action items can be identified in order to keep a large organization moving forward in the same direction.

The objectives, strategies and tactics within the strategic plan are actionable goals, categorized within four broad categories:

- Care for Smithsonian
- Support OFMR staff
- Commit to customers
- Advance best practices

A portion of the objective and strategy level of the plan is found in Figure 1. An example of the second level of detail, showing objectives, strategies and tactics is found in Figure 2.

The OFMR strategic plan was developed over a period of eight months by an internal task force with members from all levels of the organization. Forming an internal task force provided an opportunity for more OFMR staff members to offer ideas and suggestions than if an external consultant had been hired to write the plan. All the members of the task force volunteered to participate.

"The Smithsonian is totally on board with reliability centered maintenance because of the strategic plan - they preach the technologies."

Tom Batzer, Airborne Ultrasound

As a result of encouraging members at all levels of the organization be involved with the task force, the idea to develop career ladders that provide an opportunity for employees starting at entry level positions to advance to positions higher within the organization became part of the strategic plan. This idea might not have been suggested if the task force had only included staff already in management positions.

The OFMR strategic plan is instrumental in determining how to prioritize what open staffing positions to fill and to determine when employees have gone above and beyond to support the OFMR mission.

The goal of the strategic plan is to implement 80 percent of the strategies. Implementing 100 percent of the items is unrealistic due to the changing nature of organizations and the continuously evolving operations and maintenance requirements of facilities, systems and customers. At the time the case study was completed, great progress towards meeting the goals established in the 2009 to 2013 strategic plan had occurred.

For example, Goal 1 of the strategic plan, seen in Figure 1, has several objectives including "operate sites safely, effectively, efficiently and sustainably" and "maintain and repair facilities safely, effectively, efficiently and sustainably." Meeting these objectives has in a large part been aided by establishment of an organization-wide call center that integrated more than 20 different call centers from each museum and support service office. This consolidation reduced the workload in each OFMR unit, freeing up administrative staff to work on other strategic OFMR initiatives. Staff now uses electronic timecards and tracks all training electronically. Without the electronic call center, it would have been necessary to hire additional staff to track training and timecards.

The OFMR has also addressed the objective to "maintain and repair facilities safely, effectively, efficiently and sustainably" by inventorying all of its critical assets and creating new work tickets for each asset that has planned maintenance requirements. This initiative created a standard framework for all maintenance work on all critical assets Smithsonian-wide. This has resulted in improved OFMR reliability and increased the useful life of equipment.

Skills and Knowledge for Development and Use of a Strategic Plan

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at the Smithsonian Institution's OFMR utilize the following knowledge, skills, and abilities as part of the development and use of a strategic plan:

- Participation in and leadership of prioritization and planning processes.
- Ability and willingness to contribute to organizational initiatives.
- Ability to communicate ideas and concepts to others at all levels in the organization.

- Understanding of the concepts of goals, objectives, strategies and tactics.

Best Practice #2: Training Programs

Training is a very important part of the Office of Facilities Management and Reliability because the core mission of the Smithsonian Institution focuses on learning and knowledge. Judie Cooper, OFMR Facility Management Analyst, finds that "meeting our goals comes naturally because we view training as an important investment in our people, our resources and our stewardship of the Smithsonian facilities." In the OFMR, two percent of the budget is allocated to training.

The objective of training in the OFMR is to educate and equip employees with the skills and knowledge to fully address the challenging operations, maintenance and facilities management requirements for Smithsonian facilities and systems. The main methods of improving organizational performance through training are summarized below.

"Career ladders and training have been an important part of my career. I started out as a mechanics helper, moved up to a building operator, then to controls and then RCM [reliability-centered maintenance]."

Tom Batzer, Airborne Ultrasound

First, the OFMR has established standard training requirements at a variety of levels within each occupation. As each employee's skill set develops, he/she can advance to more challenging positions. Career ladders help to give OFMR a continuous pipe-line of well trained employees. Employees can make training requests based on their career objectives. Career ladders exist for building service workers, facility managers, assistant facility managers, management support assistants, maintenance mechanics and engineering technicians.

OFMR emphasizes the need for cross-trained workers and learning paths. Learning paths are individual career development plans for all levels of employees, considering the competencies identified within the OFMR position descriptions. They can also be used to help identify skills and training needed for each employee to meet his/her career goals. The learning paths include several competency areas: safety, technical skills, mandated training, and personal development. Mandated training is training that anyone working at the Smithsonian Institution is required to take, such as computer security training. Personal development training includes areas of development such as communication, reading, computer skills and many other topics that are determined through discussion between each employee and his/her supervisor. As communication is an important skill, a-one-and-a-half day class is offered to all employees and taught by an external instructor.

Supervisory training is provided to all supervisors. The training focuses on how to supervise a team using collaboration, influence, negotiation, active listening, and effective communication and leadership skills to encourage success. Facilities supervisory training is also offered so that supervisors understand the unique role of supervision in a facilities environment.

To foster the development of cross-trained workers, the OFMR developed a rotational assignment program. The rotational assignment program (RAP) started in 2006, and provides employees the opportunity to work temporarily in other skill areas. Potential participants can select any area from a list of available OFMR opportunities. Thus, individuals in clerical positions can learn a trade, or vice versa. It is a competitive program, so employees that want to participate in the program need to apply. Accepted applicants then work with their supervisors to schedule their RAP assignment work, so they can still meet

the assigned responsibilities of their current positions. All staff who have worked at the OFMR for one year and have a satisfactory employee performance review can apply to participate in the program every two years.

Cross-trained workers are more valuable to their organization and happier overall (Zimmerman 2007). Providing opportunities for employees to be cross-trained ensures employees have a better understanding of the organization in which they work and allows them to see how their work relates to that of others, and to the overall mission. For example, tasks that may seem small, such as repairing one leaky steam trap, can be seen as part of the larger mission of the Smithsonian. Cross-trained employees are also more independent and knowledgeable so that they can respond to situations more efficiently.

The OFMR training program includes both in-house training and training provided by external providers. OFMR works with local colleges and professional associations to provide training and opportunities to earn professional certifications.

OFMR Facility Management Analyst, Judie Cooper, believes that a robust training program must be based on organizational priorities and requirements, and that it should be quantifiable. In order to ensure that the training has an impact on organizational performance, Cooper sees that it is designed and evaluated in the context of the organization, rather than simply measuring how many students attended training. Meaningful training measures are the result of solid planning and integration with financial, maintenance management, budget and project management systems. Now that the OFMR has defined training standards for each occupation, identification of baseline organizational performance is ongoing in order to establish quantitative measures such as pre- and post-test results, project benchmarks and financial target achievements, and the extended life of systems and facilities.

Skills and Knowledge for Training Programs

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at the Smithsonian Institution's OFMR utilize the following knowledge, skills, and abilities as part of the training programs:

- Understanding of organizational priorities and requirements.
- Facilitate training, collaboration and sharing.
- Desire and willingness to cross-train.
- Strong communication skills and the ability to communicate with a diverse audience are especially important. As facility managers and technicians are often solving problems, it is important to find effective strategies to communicate what can be perceived as bad news, while still finding an agreeable solution.
- For supervisory training, collaboration, influence, negotiation, active listening, and effective communication and leadership skills.
- For project management, being able to make changes to organizational practices, and proactively adhering to the organizational mission and values.

Best Practice #3: Reliability-Centered Maintenance

Reliability centered maintenance, or RCM, is a proactive approach to maintenance that has been used in manufacturing facilities since late the 1970s (Moubray 1997). The goal of RCM is to only perform maintenance when it is needed, as opposed to completing maintenance at specified time intervals. To apply RCM, equipment and systems are tested and inspected to determine when maintenance is needed. The OFMR uses a streamlined RCM approach, as opposed to a full RCM approach, because it balances the benefits

of manufacturing facility RCM with the OFMR funds available to complete RCM tasks.

The use of RCM helps to increase the life of equipment because the right maintenance is done at the right time. The reliability-centered maintenance techniques used at the OFMR include vibration analysis, laser alignment, infrared cameras, ultrasound analysis and oil analysis. Each technique is further explored in the sections that follow. It is important to note that these techniques are rather advanced, and while they may yield substantial benefits for the Smithsonian's sophisticated museum facilities, they may not be appropriate for many other facilities. What is really important to take away is the reliability-centered maintenance best practice in concept: *Regular practice of methods of observation and data collection provides critical input to maintenance practices and helps to avoid costly preventative and/or emergency maintenance.*

Vibration Analysis

Vibration analysis is a technique that determines the condition of rotating equipment. Vibration analysis can be used to detect equipment problems before a failure occurs to prevent unscheduled downtime by forecasting when to perform scheduled maintenance or repairs. Within OFMR, vibration analysis is used weekly and quarterly to inspect 6,000 critical assets, including chillers, cooling towers and large motors.

The vibration analysis tool used quarterly has red and green indicator lights to show the vibration levels (Figure 3). Technicians check the vibration of pumps and other rotating equipment and record the vibration readings on a form. To record the reading, the technician will count the number of red or green indicator bars that are lit up. A display of only green lights means the vibration levels are acceptable. Red lights mean that further investigation should be performed, as vibration levels may be undesirable.

After collecting many days of data, trends can be created to determine when changes are occurring in relation to operating conditions. A good technician will also listen for different sounds, as well as smells and other differing conditions in the equipment while performing his/her daily rounds. It can take up to five years before becoming an expert in vibration analysis, as it requires a great deal of training.

Figure 3: Vibration analysis tool indicator

Laser Alignment

Laser alignment is used to make sure shafts, pumps and motors are properly aligned. At the Smithsonian, all new or repaired equipment must be laser aligned before going into service. Laser shaft alignment is used to align pumps (Figure 4) and motors. Properly aligned shafts operate more efficiently, resulting in fewer equipment failures and reduced repair costs. Laser sheave alignment is used for belt driven equipment, such as air handlers, exhaust fans and return fans. Properly aligned belts increase belt and sheave life, reduce failures and repair costs, and increase energy efficiency. The use of laser shaft alignment at OFMR has been found to increase equipment efficiency on an average of 2.5 percent per piece of equipment.

Figure 4: Laser alignment of a pump

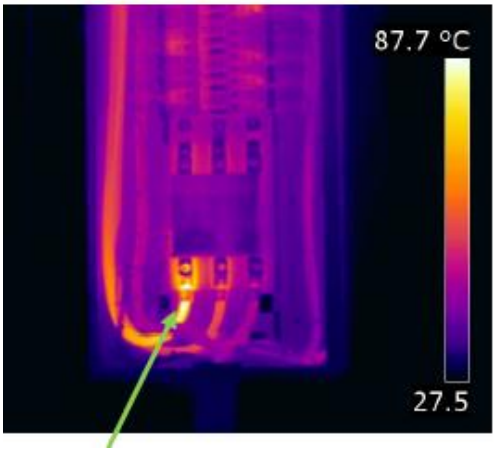

Figure 5: Image seen through an infrared camera of a hot spot on an electrical panel that may have been missed during a visual inspection

Infrared Cameras

Infrared cameras are used to find thermal breaks in window seals, hot spots on electrical panels, (Figure 5) and elevated temperatures on motor starter control breakers (Figure 6). As shown in the infrared images, yellow indicates the hottest temperatures, while purple indicates the lowest temperatures. The benefits of using infrared technology to inspect electrical equipment include reducing electrical costs, improving electrical efficiency, preventing equipment failures, and even preventing fires. Hot spots indicate connection points within the electrical system where heat is escaping. Heat may escape because of loose or improper connections, overloaded or imbalanced circuits or faulty breakers.

Once these hot spots can be identified, the panel can be disengaged and repaired. Even a lower-resolution, less-expensive camera can help to find unwanted heat. If necessary, a higher resolution camera can be used to further understand the source of the heat and how to fix the problem.

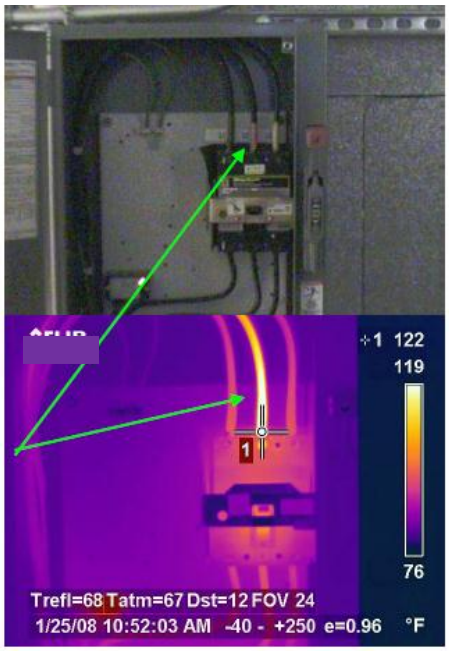

Figure 6: Image seen through an infrared camera of a hot spot on a motor starter control breaker

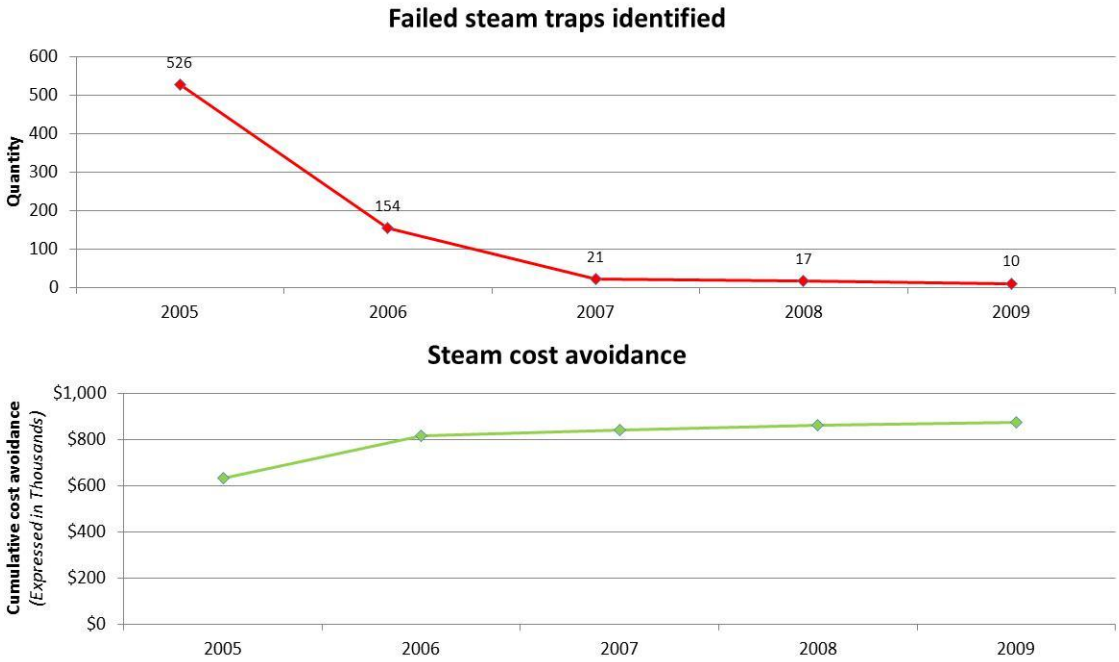

Figure 7: Number of identified failed steam traps and cumulative cost avoidance

Ultrasonic Analysis

Ultrasonic hand-held devices that pick up ultrasonic sound waves (sound waves at the upper reaches of human hearing) and amplify them so they can be heard through earphones (Figure 7) are used to inspect equipment as well. The handheld devices have several different attachments so that different volumes of space can be observed. For example, a cone shaped attachment can be used to find leaks in steam systems, pneumatic tubing and compressors. Ultrasonic hand-held devices can be used by an experienced technician to determine if a steam valve has failed open or closed.

It is estimated that one steam trap which has failed open can cost an average of $15,000 to $20,000 per year. Since 2005, almost $900,000 in accumulative cost avoidance has resulted from the identification and repair of failed steam traps at the Smithsonian (Figure 8).

The ultrasonic handheld can also be used with the probe attachment to determine if the correct amount of grease has been added to the bearings of a pump. When the correct amount of grease is added, the amount of noise heard through the headphones will greatly decrease and the rotation of the bearings within the pump motor will sound smooth.

Within museum environments, ultrasonic analysis can also be used to make sure artifact cases are sealed to prevent air intrusion. A warble tone generator, a device that emits a noise with a specific frequency, can be placed with an enclosure (Figure 9). This technique is especially useful for helping keep air out of cases with one-of-a-kind artifacts, such as the Star Spangled Banner. To find leaks in the case, the cone attachment is moved slowly along the seams of the case. When the noise of the warble tone generator increases, a leak in the case seal is likely present.

The RCM team uses ultrasonic analysis quarterly in all zones and between quarterly inspections on an as-needed basis. An ultrasonic handheld device can be used in a noisy mechanical room and can be a very inexpensive tool to purchase compared to other tools.

Additionally, ultrasonic analysis can be learned fairly quickly as it does not require extensive training.

Figure 8: Using an ultrasonic handheld device to look for leaks in pneumatic control lines

Oil Analysis

Oil analysis is a technique that determines the wear metal count and types of contaminants in oil. The wear metal count is used to determine unusual equipment wear patterns. The type of contaminants in the oil helps to determine time intervals between oil changes. OFMR uses oil analysis to determine when the oil used within the hydraulic elevators and emergency generators needs to be replaced and when it can just be filtered. To perform oil analysis, it is necessary to collect the samples and then send them to a testing facility. After the testing is done, a report is sent back from the testing facility stating the condition of each oil sample, allowing the RCM team to decide if the oil can be cleaned or needs to be replaced. Using oil analysis saves money and reduces environmental impacts because the oil does not need to be changed as often.

Implementing and Supporting RCM

Implementing a reliability centered maintenance program often requires a cultural change within an organization. Reactive organizations generally do not rely on data, and instead focus on responding to emergencies and requests from building occupants. By contrast, organizations using RCM seek to find problems before they occur by using data driven procedures. The use of data precludes invasive maintenance procedures, applying the philosophy, "if it is not broken, do not fix it". Unlike RCM, time-based maintenance techniques can require tearing a piece of equipment down after a specified number of run hours. Disassembling equipment when it is not necessary can cause new problems.

To setup the RCM program, the OFMR worked with a consultant, sought support from NASA (National Air and Space Administration) and relied on resources such as the Whole Building Design Guide. The program was implemented from the top down because of the initial investment necessary to purchase the tools and provide proper training for all RCM staff. At the start of the program, it was important to assess the condition of equipment within each facility and to learn which tools and practices work in other organizations. OFMR hired a consultant to help fast track some of the implementation efforts when setting up the program. A pilot team of internal employees was formed to help implement the program. The pilot team was trained so they could start using the RCM technologies. As the pilot activities were rolled out, OFMR began to conduct a full equipment inventory and determine what maintenance tasks were required for each type of equipment. After the pilot program was complete, the program was rolled out to the eight zones where teams were trained in how to use the new technologies. This pilot initiative supported OFMR's efforts to develop and roll out a comprehensive RCM program.

Reliability centered maintenance is about using "the right maintenance on the right equipment at the right time" by prioritizing, identifying and evaluating what, how and when.

(Kennedy and Whittaker 2011)

If an organization has little money to invest in tools and training, selecting just one RCM technology will still help to meet its maintenance goals. If an organization has a larger budget, a full risk assessment examines which equipment is most critical and the corresponding likelihood of failure. This information can help determine what equipment should be maintained using RCM, and which RCM tasks can be economically justified.

One strategy to prioritize equipment is by using a maintenance action code (MAC):

> *Maintenance Action Code (MAC) = Equipment criticality X likelihood of equipment failure*

To use the equation, values from one to ten are assigned to different levels of equipment criticality and types of failures. The number increases as the criticality or likelihood of failure increases. Equipment criticality is determined based on what the equipment serves and facility specific criteria. For example, the equipment criticality for a sump pump in an area adjacent to an artifact storage room would be higher than a similar sump pump in the basement of a building. Likelihood of failure is determined considering equipment characteristics such as age, condition, number of hours of operation, operating environment and frequency of cycling.

After the RCM program was established in the OFMR, each zone was given a toolbox of reliability centered maintenance tools (Figure 10). Providing a set of tools for each zone allowed the budget for the tools to be managed centrally and supported consistent practices across all facilities. To support a uniform data collection strategy, standard forms were developed for individuals collecting data to use. Although most equipment types vary in size and function, the type of data collected is generally the same.

Figure 9: Toolbox of reliability centered maintenance tools

Figure 10: Demonstration table with the warble tone generator at an OFMR open house

In a large organization such as OFMR, a newsletter was developed to support continual use of the new RCM tools. Such a newsletter can be effective to acknowledge successes, share reminders, and document lessons learned. The newsletter within OFMR was started in 2008 and is called Techs Talk RCM Newsletter. It includes articles on completed and upcoming training, safety tips, recent accomplishments, awards and recognition and updates from the RCM branch manager.

To be a reliability-centered maintenance technician requires knowledge of a trade.

Within the RCM team, all team members came up through the trades. Some of the team members were experienced HVAC technicians, electricians or high-voltage electricians. A few members of the team have specialized in more than one discipline, such as both HVAC and electrical. In addition to learning about HVAC and electrical systems; understanding how to record data collected in the field on forms or on handheld computerized devices and knowing how to interpret trend data is very important. Collecting accurate data is essential to create long term trends which can in turn be used to determine when it may be necessary to evaluate a piece of equipment to determine if maintenance is necessary.

"You cannot go wrong learning a maintenance trade – technicians will always be needed"

Kendra Gastright, Associate Director, Systems Engineering Division

In OFMR, the RCM team focuses on collecting and analyzing data. The RCM team relies on the building operators to perform day-to-day monitoring of systems and equipment. Having the RCM team focus on collecting and analyzing the data used to create trends helps to maintain consistent, high quality data.

Without consistent, quality data, it is not possible to have confidence in the data and determine when maintenance should be performed on a piece of equipment. Although it can seem tedious to record detailed data every day, it is important in order for RCM strategies to be used successfully.

Skills and Knowledge for Reliability-Centered Maintenance

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at the Smithsonian Institution's OFMR utilize the following knowledge, skills, and abilities as part of reliability-centered maintenance:

- Background in and knowledge of one or more trades, such as HVAC or electrical systems.
- Ability to collect detailed data and observations accurately, reliably and consistently.
- Ability to interpret data and feedback from measurements and observations.
- Ability to identify methods and tools for observation and data collection that support RCM.

Best Practice #4: Employee and Stakeholder Outreach

To help Smithsonian researchers, support staff, museum visitors, tax payers and members of the general public understand the value and varied functions of the Office of Facilities Management and Reliability, the OFMR hosts a biannual open house. Each spring and fall, a different Smithsonian facility is selected as the site for the open house. The open house provides an opportunity for OFMR staff to teach stakeholders what the OFMR team does and how they support the daily functions of the buildings. The open houses include demonstrations and informational materials. Demonstrations performed have included how to patch a hole in a wall and how an air conditioning unit works.

Informational materials range widely, from recycling practices to gardening tips. In Figure 11, a member of the OFMR team explains how a filtration system works to individuals attending the open house. Within Figure 12, a building automation system technician displays tools and sensors, such as controllers and flow meters, which he uses or interacts with

daily. In Figure 13, a painter answers questions from a building occupant.

The opportunity to explain these systems, tools and sensors has an impact on the relationship between building occupants and OFMR team members.

Figure 11: OFMR team member uses a drawing to explain how a filtration system works

Figure 12: Building automation system technician displaying control components and tools

For example, Kathleen Flemming, Building Manager of the National Museum of the American Indian, has cited an appreciable difference in communication between building occupants and her facilities team. Flemming finds that "Now, when customers call to request a service, they explain their need much better because the mechanics have had the opportunity to explain building operations and maintenance to them at our open houses." Thus, through the open houses, building occupants are better able to communicate their needs to the facilities team. The OFMR benefits from these events because they provide an opportunity for open discussion and learning.

Figure 13: Painter answers questions about from a building occupant

Skills and Knowledge for Employee and Stakeholder Outreach

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at the Smithsonian Institution's OFMR utilize the following knowledge, skills, and abilities as part of employee and stakeholder outreach:

- Strong verbal communication and presentation skills.
- Ability to demonstrate and explain building systems and tools to non-technical people at all organizational levels.
- Ability to build relationships with customers.

Best Practice #5: Leadership and Organizational Influence

"People are what make or break an organization. Attracting good people doesn't just happen" (Nancy Bechtol, Director, Office of Facilities quoted in Zimmerman 2007). The leadership values within an organization greatly impact the success of the organization as a whole. Three of the leadership values at the Office of Facilities Management and Reliability are employee recognition, fostering a culture of learning and effective communication.

OFMR employees are recognized formally through events such as the Holiday Recognition Event (Figure 14), and by providing cash awards or time off for special acts. Recent special acts that have been rewarded include taking the initiative to develop a better inventory program and going above and beyond in an emergency situation to save a toddler's life at the Smithsonian's National Zoological Park.

"The people factor is everything."

Nancy Bechtol, Director, Office of Facilities Management and Reliability

OFMR's culture of learning is fostered formally through its training program. Informally, a learning culture is fostered when explanations of why things are done a certain way are provided. When the logic behind strategies is explained, employees don't just accept that things are done a certain way because that is how they have been done in the past. Instead, they understand the logic behind each step in the process and are better able to execute each procedure from beginning to end. One instance which a culture of learning is fostered is when best practices are shared across an organization are actively spread and applied throughout other parts of the organization. For example, the OFMR horticulture staff identified that a tree died much sooner than they had anticipated. Knowing the reason the tree died was important to them because there was something peculiar about its death. However, they did not have the technology necessary to determine the case. By working together with the OFMR Systems Engineering Division, they were able to use an infrared camera to determine that the tree had died from a leaking steam pipe. By working together to determine the root cause of the problem, OFMR was able to repair the steam leak, saving money and energy, while also knowing that it was safe to plant a new tree in the same location after the steam leak was repaired.

Communication greatly impacts the success of an organization. Strong communication skills are important and include multiple methods, especially for staff members that work outside the Washington, D.C. metro area, where many of the Smithsonian facilities are located. Effective methods of communication can include face-to-face, phone, e-mail, conference calls and telecast interactions (FEJ 2010). As face-to-face communication is often the most effective means, the director of OFMR travels at least once a month to Smithsonian facilities outside of the Washington, D.C. metro area.

The OFMR also practices:

- Management by walking around, allowing managers to talk with team members, to help solve problems and track the status of activities.
- Accountability by holding supervisors and staff accountable for performing their assigned tasks safely, effectively and appropriately.
- Regular communication through full staff monthly meetings and weekly key leadership meetings.

The willingness of people within an organization to communicate and think outside the box is essential to support innovation across an organization. Willingness of employee engagement is

driven by each person's character, values and personality. Innovation is especially important when seeking to be a world class facility organization, which is part of OFMR's strategic plan.

Task forces are an effective method for leaders to use to solve large challenges. In 2006, a task force was formed by OFMR Director Nancy Bechtol to determine how to reduce energy consumption and costs. A task force of more than 70 members was assembled to meet once a week between April and October. During this time, the task force figured out how to implement about 300 energy conservation measures, saving about $2.7 million (Zimmerman 2007). To be an effective member of a task force, it is important to be dedicated to the team and to be willing to gather feedback and ideas from others within your trade or division within the organization.

Networking is a very important skill for all members of a task force. Networking to support the efforts of a task force includes asking others within your trade or department what their needs and opinions are, and then reporting these findings to the task force. As a task force member, it is also important to be willing to take on responsibility, be outgoing, think of and embrace ideas that are larger than yourself, be a good listener and be willing to learn new things.

Through her experience, Nancy Bechtol, Director, Office of Facilities Management and Reliability, finds that a good leader is able to work in an environment of managed chaos. As Bechtol moved through the ranks within OFMR, she found that good managers need to be able to let their team try new things, understand that things may occasionally go wrong and that mistakes may happen. It is important to be engaged with the team enough so that if the team is starting to veer off in an undesired direction the leader can help to refocus the team. As nobody is perfect, it is important for leaders to acknowledge and support occasional mistakes, but to encourage the team to learn from their mistakes. A good leader must be comfortable with failure, be able to encourage others, be willing to ask their team what they need and support cooperation across the team. Asking for feedback from the team also requires the leader to be willing to accept feedback.

Jeff Ridgeway, Deputy Director, Office of Facilities Management and Reliability, finds that becoming a leader requires practice and experience. He advises that to build leadership skills, one must seek opportunities to practice. Since leadership skills are transferable, leading a team on a student project, volunteer activity or in a non-facilities related work experience are all valuable. To start developing leadership skills, one only has to find something they are passionate about and take on a small leadership opportunity. During such an experience, mistakes may happen, but there will undoubtedly be opportunities to learn. And, when mistakes do happen, one must be willing to accept criticism, learn from the mistakes and move on.

Skills and Knowledge for Leadership and Organizational Influence

Based on the site visits and interviews conducted, building technicians and other members of the facilities team at the Smithsonian Institution's OFMR utilize the following knowledge, skills, and abilities as part of leadership and organizational influence:

- Strong communication and networking skills, especially listening.
- Desire and willingness to learn.
- Team work and team building.
- For team leaders, the ability to encourage and support team members, and to accept their feedback.

Conclusion

The Smithsonian Institution Office of Facilities Management and Reliability is a large organization with over 850 employees and 10,000 critical assets. As the OFMR strives to be world class facility management organization, the five best practices identified within this case study are a key part of achieving and maintaining this status. Each member's willingness to embrace the OFMR vision, values and goals will contribute towards the organization's success.

As the eyes, ears, and hands of the OFMR team, technicians play a critical role in the application of and ongoing improvement of such best practices. The practices featured in this case study are summarized by the table below that concludes this document, where the skills and knowledge attributes associated with each best practice are listed. It is the intent and hope of this work that other facilities management and operations teams will benefit from the OFMR's experience, that educational institutions will incorporate the seeds of these skills and knowledge attributes in their programs, and that the technicians themselves will strive to develop the skills and knowledge as they work towards a future of sustainable and high performance buildings.

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Resources

Smithsonian Institution Strategic Plan

http://www.si.edu/Content/Pdf/About/SI_Strategic_Plan_2010-2015.pdf

Smithsonian Institution OFEO Strategic Plan

http://www.ofeo.si.edu/pdfs/OFEO_StrategicPlan.pdf

Whole Building Design Guide

http://www.wbdg.org/

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Smithsonian Institution OFMR: Summary of Best Practices

Best Practice		Skills and Knowledge Attributes Identified in this Study that Apply to Technicians and other Key Facilities Personnel
1	**Development and Use of a Facility Management Strategic Plan**	Participation in and leadership of prioritization and planning processes.
		Ability and willingness to contribute to organizational initiatives.
		Ability to communicate ideas and concepts to others at all levels in the organization.
		Understanding of the concepts of goals, objectives, strategies and tactics.
2	**Training Programs**	Understanding of organizational priorities and requirements.
		Facilitate training, collaboration and sharing.
		Desire and willingness to cross-train.
		Strong communication skills and the ability to communicate with a diverse audience are especially important. As facility managers and technicians are often solving problems, it is important to find effective strategies to communicate what can be perceived as bad news, while still finding an agreeable solution.
		For supervisory training, collaboration, influence, negotiation, active listening, and effective communication and leadership skills.
		For project management, being able to make changes to organizational practices, and proactively adhering to the organizational mission and values.
3	**Reliability-Centered Maintenance**	Background in and knowledge of one or more trades, such as HVAC or electrical systems.
		Ability to collect detailed data and observations accurately, reliably and consistently.
		Ability to interpret data and feedback from measurements and observations.
		Ability to identify methods and tools for observation and data collection that support RCM.
4	**Employee and Stakeholder Outreach**	Strong verbal communication and presentation skills.
		Ability to demonstrate and explain building systems and tools to non-technical people at all organizational levels.
		Ability to build relationships with customers.
5	**Leadership and Organizational Influence**	Strong communication and networking skills, especially listening.
		Desire and willingness to learn.
		Team work and team building.
		For team leaders, the ability to encourage and support team members, and to accept their feedback.