Report on Sustainable Design, Design for Maintainability and Total Building Commissioning

For

National Aeronautics and Space Administration
Facilities Engineering Division

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National Aeronautics and Space Administration

1. Executive Summary

A. Tasking

In response to Executive Order (EO) 13123 requiring federal agencies to incorporate sustainable principles into federal facility projects, the National Aeronautics and Space Administration (NASA) Facilities Engineering Division (Code JX) chartered this study to define, research, and recommend implementing strategies for the three practices of Sustainable Design, Design for Maintainability, and Total Building Commissioning (TBC). Other agencies and industries were contacted to identify best practices and lessons learned.

B. Methodology

In addition to a comprehensive literature search, current practices at 10 federal agencies, 7 industry organizations, 4 state or local organizations and several architect and engineering firms were reviewed. This research helped define the three practices, identify organizational best practices, define a framework for implementing the practices, and identified tools and resources needed to develop and implement the practices within NASA.

C. Observations

1. Implementation outside of NASA: Sustainable practices are "emerging concepts" gaining popularity throughout industry. They are being adopted with varying success. Facility owners and federal regulators are driving the increase in sustainability, creating sufficient market demand to cause Architect/Engineer (A/E) firms to develop sustainable design expertise. Some owners incorporate sustainability requirements in their A/E scopes of work, and in construction plans and specifications. Several federal agencies have relatively mature programs, supported by federal initiatives such as the Whole Building Design Guide (WBDG) and the Energy Star program. A number of professional and trade organizations are leading sustainability initiatives, including the U.S. Green Buildings Council (USGBC), the Sustainable Buildings Industry Council (SBIC), the Green Building Information Centre (GBIC), the National Institute of Buildings Sciences (NIBS), the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), the American Institute of Architects (AIA), the American Society of Civil Engineers (ASCE), and the Construction Industry Institute (CII).

The agencies contacted for this study understood the concept of Maintainability and expressed interest in improving their own maintainability practices. Clearly, the NASA initiative (with CII) is the leading edge in this area, and provides the benchmark for other agencies to evaluate their own maintainability practice.

Few agencies have an effective TBC practice. One notable exception is the Department of Defense's Pentagon Renovation Office, which uses TBC extensively in the multi-billion dollar Pentagon renovation. The General Services Administration

(GSA) is developing a TBC policy and has several pilot projects underway. TBC is receiving increasing attention among private sector process manufacturing firms and other public organizations, including universities, correctional institutions, and hospitals.

2. Potential for implementation within NASA

All three practices (sustainable design, design for maintainability and TBC) offer potential return on investment (although specific return on investment has proven difficult to quantify). NASA's facilities engineering program has made progress toward becoming the most imaginative, innovative, effective, and successful within the federal government. Implementing these three practices will further enhance NASA's progressive approach, provide a benchmark for other agencies, and raise the state-of-the-art within federal facilities management.

D. Conclusions

Many elements of sustainable design can be incorporated at no increase in project design or construction cost (first cost). These elements have positive impacts upon project life cycle costs, but some, like impact on employee productivity, are not easily measured. Some sustainable design elements do require an increase in design or construction first costs. Owners must determine a proper balance between design or construction costs to implement sustainable concepts, against their reductions in life cycle operation and maintenance costs. Some sustainable elements may not be economically justified, but may be appropriate when considered from the standpoint of responsible stewardship of taxpayer resources. The extent to which sustainability should be pursued on any given project often depends upon the project's size, mission criticality, location, complexity, and available funding.

E. Recommendations

1) Publish Attachment 1, a NASA Policy Directive mandating sustainability as a fundamental requirement for all facilities projects.
2) Assign a NASA sustainability champion. The sustainability champion would be the central point of contact and would help develop NASA's capability for implementing sustainability on its facilities projects. Attachments 2, 3 and 4 provide recommendations and timelines to assist the sustainability champion in implementing a program throughout NASA and on a specific project.
3) Obtain an engineering services consultant to facilitate implementing sustainability practices on NASA projects. The consultant would conduct an audit to evaluate the current level of sustainability experience at each Center, and work closely with the sustainability champion and Center facilities engineering staffs to develop capability for and implement sustainability concepts on pilot projects. Consultant support would include developing a training course to teach facility project managers how to integrate sustainable practices on significant NASA facility projects. The course should include a sample project as the foundation for

teaching sustainability principals. The consultant could assist in implementing several of the following additional recommendations.

4) Develop a NASA Policy Guideline (NPG) on sustainability.
5) Use the Leadership in Energy and Environmental and Design (LEED) rating system for all new construction projects, and renovation projects that will significantly alter existing facilities. NASA should evaluate the use of the LEED rating system on its pilot projects, and determine the appropriate LEED standard for future NASA projects.
6) The cost of implementing sustainability will vary from project to project. Many sustainability initiatives can be accomplished without any increase in project design or construction costs. NASA should support project specific requirements to achieve the LEED silver rating for facilities projects. In some cases additional resources may be required to provide appropriate maintainability and building commissioning project enhancements. Reductions in operations and maintenance costs should be weighed against increases in first costs, ensuring the overall life cycle cost to NASA is optimized.
7) Implement sustainability on selected pilot projects, expanding the implementation to all projects as NASA Center project management staffs achieve competency.
8) Develop capabilities to implement TBC on simple, moderate, and large projects.
9) Participate with the Environmental Protection Agency in their Laboratories for the 21st Century program, to advance sustainable design concepts in high technology facilities.
10) Incorporate safety and security considerations as integral parts of the overall sustainable facility requirements.

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I. Introduction

The National Aeronautics and Space Administration (NASA) Facilities Engineering Division (Code JX) chartered this study to define, research, and recommend implementing strategies for the concepts of Sustainability, Maintainability, and Building Commissioning. The tasking required:

- Research of other federal agencies, industry, state and local governments, technical and professional societies, and academia to evaluate current state of the art, best practices, and lessons learned.
- Development of a draft policy document for use in implementing the three concepts within NASA, in compliance with Executive Order (EO) 13123.
- Development of an implementing strategy for institutionalizing the three concepts within NASA.

The interim report was submitted to JX on December 6, 2000, which included:

- A review of practices at 10 federal agencies
- A review of 7 industry and 4 state or local organizations
- A discussion of emerging practices within architect and engineering firms
- A summary of current NASA programs, practices and policy
- A summary of the regulatory and industry drivers creating the impetus for improvements in these practice areas
- Definitions of each practice area and a proposed concept for integrating these three practices under one over-arching concept of sustainability
- A copy of the interim briefing provided on October 4th to NASA's Engineering Continuous Improvement Council (ECIC) and on October 6th to JX

This final draft report includes:

- A draft NASA Policy Directive (Attachment 1)
- Recommendations (Attachment 2) and a timeline (Attachment 3) for implementing sustainability throughout NASA
- A step by step strategy (Attachment 4) to implement sustainability on a typical construction project
- One graphic outlining the implementation of these concepts within the facility life cycle (Attachment 5)
- A listing of web sites referenced within this report (Attachment 6)

The report recommendations considered the March 2000 "Staffing Assessment of the Facilities Engineering Function of NASA Centers", current initiatives at each Center, and ongoing initiatives within NASA's Environmental Management Division (Code JE)

II. Background

Executive Order 13123 requires federal agencies to consider sustainable principles in the acquisition planning, design and construction of federal facilities. This report reviews this order and other laws, regulations, technology improvements and industry trends that are driving the advances in Sustainable Design, Design for Maintainability and Total Building Commissioning (TBC). This report considers the March 2000 study titled "Staffing Assessment of the Facilities Engineering Function of NASA Centers", the current situation at NASA Centers, and ongoing related initiatives within Code JE.

The study reviewed Sustainable Design, Design for Maintainability and TBC practices at 10 federal agencies: General Services Administration (GSA), Department of Energy (DOE), Environmental Protection Agency (EPA), The Department of State (State), The Department of Defense (DOD), The Department of the Navy (Navy), The Department of the Army (Army), The Department of the Air Force (Air Force), The Veterans Administration (VA), and The National Parks Service (NPS). Seven industry organizations were consulted regarding their efforts to advance one or more of these practice areas, including: National Institute of Standards and Technology (NIST), National Institute of Building Standards (NIBS), American Society of Heating, Refrigeration Air Conditioning Engineers (ASHRAE), The Construction Industry Institute (CII), The U.S. Green Buildings Council (USGBC), The Sustainable Buildings Industry Council (SBIC) and the Federal Facilities Council (FFC). The University of Wisconsin, State of Pennsylvania, New York City, the Washington Metropolitan Airport Authority, and several Architect and Engineering firms were also contacted regarding their TBC programs and/or experience.

This report includes sections regarding three practice areas (Sustainability, Maintainability and TBC). Each section includes: the definition of the practice area; the drivers stimulating industry or federal agencies to implement these practices; progress in other federal agencies; progress within industry; and current implementation within NASA. The report includes a review of government and industry strategies to "design in" building safety and building security. The report finishes with conclusions and recommendations for implementing all three practices in an integrated fashion within the NASA facilities organizations.

III. Sustainability

1. Definition. After reviewing many definitions for sustainable design, and considering the practices of Maintainability and Total Building Commissioning, it is recommended that NASA consider Sustainability as a broader concept. A recommended definition for sustainability follows:

Sustainability is an over-arching concept incorporating appropriate sustainable design elements into facilities planning, design, construction, operation and maintenance to

enhance and balance facility life cycle cost, environmental impact, and occupant health, safety, security, and productivity. The essential elements of sustainability include:

- Energy efficiency and water conservation
- Site selection to minimize environmental and transportation impact
- Sustainable materials (i.e., reused, recycled, recyclable, non-toxic, low embodied energy content, renewable)
- Durable and efficient materials and equipment
- A healthy environment, including indoor air quality
- Features in support of enhanced worker productivity
- Design for personnel safety and security
- Design for decommissioning and disposal
- Enhanced building operating and maintenance characteristics (i.e., Design for Maintainability, continued efficiency, and low toxicity)
- A philosophy that defines facility operational objectives, then tests and verifies that all building systems and components have been properly installed and perform to the level intended (i.e., Total Building Commissioning, TBC)

This overarching definition allows NASA facility managers to address all three emerging practices (sustainable design, design for maintainability and building commissioning) in one concept, and promotes integrating the concepts on all NASA facility projects. This definition implies that sustainability transcends facility design to include continuously efficient facility operation and maintenance.

2. Sustainability Drivers

Many laws, regulations and policies drive federal agency actions regarding sustainability. This section addresses the significant sustainability drivers.

The National Environmental Policy Act (NEPA) of 1969 significantly affected the way Federal Agencies conduct business. The NEPA required federal agencies to consider a wide range of impacts before starting any major federal action. Major federal actions were defined to include significant construction projects. The NEPA required federal facility managers to consider sustainability principals for construction projects, even before sustainable design was defined as a practice area.

In 1993 Executive Order 12852 established The Presidents Council of Sustainable Development (PCSD), a presidential advisory committee. The PCSD advises the President on sustainable development, and seeks to stimulate "bold, new approaches to achieve our economic, environmental, and equity goals". The PCSD goals address the full range of sustainability concepts, including clean air, clean water and conservation of natural resources. The PCSD has several broader goals, including economic prosperity, personal and organizational stewardship of our resources, civic involvement, and education. The PCSD sustainable development definition, taken from the World Commission on Environment and Development, Our Common Future, is: "…using

resources today to meet the needs of the present without compromising the ability of future generations to meet their own needs."

Executive Order 13101 (EO 13101), Greening the Government Through Waste Prevention, Recycling, and Federal Acquisitions dated September 14, 1998, requires federal agencies to consider: using recovered materials; recycling; waste prevention and reduction; pollution prevention; and life cycle costing in its daily practices. Additionally, EO 13101 requires federal agencies to consider the following as part of acquisition plans: "…elimination of virgin material requirements; use of bio-based products; use of recovered materials; reuse of product; life cycle cost; recyclability; use of environmentally preferable products; waste prevention (including toxicity reduction and elimination); and ultimate disposal." The order directed EPA to develop a Comprehensive Procurement Guideline to make it easier for federal agencies to identify and use environmentally friendly products. EO 13101 required federal agencies to establish short and long term goals for recycling or solid waste prevention. While not specifically addressing sustainability, EO 13101 does require agencies to implement many sustainable concepts.

Executive Order 13123 (EO 13123) Greening the Government Through Efficient Energy Management dated June 3, 1999, is the primary order driving federal agencies to develop sustainable design capability. EO 13123 superseded EO 12902, originally issued on March 8, 1994. Section 403(d) of EO 13123 requires federal agencies to apply sustainable design principles to the "...siting, design, and construction of new facilities." DOD, GSA, DOE and EPA are tasked with developing the sustainable design principles. EO 13123 further requires agencies to "…optimize life-cycle costs, pollution, and other environmental and energy costs associated with the construction, life-cycle operation, and decommissioning…" of facilities. The order requires agencies to reduce energy consumption compared to 1985 and 1990 usage levels. Agencies are encouraged to meet the Energy Star building criteria for energy performance and indoor environmental quality by 2002.

Executive Order 13148, Greening the Government Through Leadership in Environmental Management, strives to minimize the environmental impact of federal facilities. Section 207, Environmentally and Economically Beneficial Landscaping, requires agencies to promote the sustainable management of federal lands through cost-effective, environmentally sound landscaping practices, and other programs to reduce adverse impacts to the natural environment.

As required, DOD and GSA, in consultation with DOE and EPA, have developed sustainable design principles. The principles are contained in the Whole Building Design Guide (WBDG), a web-based resource for all federal agencies. Individual agencies have developed implementing policies and instructions. Progress in defining and implementing sustainable design concepts varies among agencies.

3. Sustainability in other Federal Agencies

a. Whole Building Design Guide (WBDG)

DOD, GSA, DOE, and EPA initially conceived the WBDG through a collaborative effort in response to their mandate to develop sustainable design principles. Since its inception, the Department of Interior, Department of State and National Institutes of Health have also joined the WBDG Advisory Panel under the direction of the National Institute of Building Sciences (NIBS). The WBDG is a web-based resource available to all federal agencies that provides sustainable design principles and concepts. The WBDG also addresses (though not as extensively) building commissioning and design for maintainability. The WBDG has a complete section on security, but does not include a separate section on safety. The sustainable design component of the WBDG is the most advanced, and includes the following sustainable design principles:

- **Energy Efficient**
  To the maximum extent economically feasible, a building should rely on conservation and renewable energy sources rather than fossil fuel for its operation. It should meet and in most instances exceed current **Whole Building Energy Performance Goals**. (Note: this WBDG section currently contains only these two measurable energy performance goals: buildings should be designed to use less than 1 watt/square foot for ambient lighting; and buildings should have meters to measure actual building performance. Opportunities to explore additional measurable building performance criteria should be pursued).

- **Site Responsive**
  Creating sustainable buildings starts with proper site selection. The location of a building affects a wide range of environmental factors such as local ecosystems, transportation energy use, and the reuse or rehabilitation of existing structures. Environmental systems are a form of natural infrastructure with their own cycling processes, which must be integrated during the building design.

- **Water Conserving**
  Water conservation is an increasingly important consideration, especially in areas where fresh water supplies are scarce. A sustainable building should minimize water consumption by reducing, controlling or treating site runoff; specifying water efficient appliances; and, when feasible, recovering gray water for on-site use.

- **Materials Sensitive**
  To the maximum extent economically feasible, a sustainable building should be constructed of durable, low-energy content, non-toxic materials that are manufactured locally using sustained yield methods when appropriate.

Sustainable building assemblies should encourage reuse and recycling, and consider impacts on landfills after disassembly and decommissioning.

- **Healthy**
  The Indoor Environmental Quality (IEQ) of a building has a big impact on occupant health and productivity. Among other attributes, a sustainable building should avoid the use of materials high in pollutants, such as Volatile Organic Compounds (VOCs) or toxins, be well-ventilated, and be operated and maintained in a manner that conforms with sustainability principles.

b. Sustainable Design within DOD.

In 1999, DOD completed a study titled "Sustainable Planning, A Multi-Service Assessment, 1999." The study identified issues and opportunities for incorporating sustainable principles in the planning phase of the acquisition cycle. The study did not mandate sustainable practices, and has not been adopted by the military services. Due to personnel reductions at DOD, the services are developing sustainable design policies and procedures to comply with EO 13123.

c. Sustainable Design within Navy.

The Naval Facilities Engineering Command (NAVFAC), the Navy's facility design and construction agent, established its sustainable design policy in July 1998. The NAVFAC policy promotes sustainable design without increasing the initial project cost, provides guidelines for selecting A/Es based on their sustainable design experience, and references the WBDG. NAVFAC offers a DOD developed training course to employees involved in A/E design. The course addresses a broad range of sustainable design topics, and includes team-based problem solving exercises. The Navy's draft instruction on facility design and construction, scheduled for release in early 2001, includes a comprehensive chapter on sustainable design.

The Navy used sustainable design principles for Building 33 at Washington Navy Yard (a complicated renovation of a 156,000 SF historic building), increasing design cost by $200,000. Navy used sustainable design experts and completed an additional intensive design review with owners and designers early in the project-planning phase. The resultant design included many sustainability features without causing an increase in initial construction cost. The completed facility is operating with 20% lower energy costs compared to a sister building that has not been renovated.

The U.S. Green Buildings Council developed a rating system for evaluating the relative merits of a sustainable design. Its Leadership in Energy and Environmental and Design (LEED) rating system is widely used among federal agencies and the private sector. The LEED system evaluates, among other things, the project site, water efficiency, energy efficiency, air emissions, materials and resources, indoor air quality, and design innovation. Project certification levels vary based upon the number of points scored (Certified level 26-32 points; Silver level 33-38 points; Gold level 39-51 points; Platinum

level 52+ points). Navy's goal is to achieve the LEED Certified Level without increasing the congressionally authorized budget for each project.

NAVFAC uses the design-build acquisition method for the majority of Navy's military construction projects. As part of the technical proposal, NAVFAC requires contractors to demonstrate sustainable design experience, and to self certify the project using the LEED rating system. Having the same firm responsible for both design and construction increases the likelihood of achieving desired facility performance characteristics.

d. Sustainable Design within the Air Force

The Air Force Environmentally Responsible Facilities Guide defines sustainability as:

> Responsible stewardship of our natural, human and financial resources, through a practical and balanced approach. Sustainability requires changes to the facility delivery process to ensure the "best fit" of the built environment to the natural environment. Sustainable practices are an investment in the future. Through conservation, improved maintainability, recycling, reduction, reuse and other actions and innovations, we can meet today's needs without compromising the ability of future generations to meet their own.

The Air Force guide is for all facility programming, planning, design, acquisition and operations personnel. The Air Force Center for Environmental Excellence (AFCEE) is the Agency advocate for sustainable design practices. An ongoing AFCEE case study (Homestead AFB Fire Station) will produce empirical results of the costs and savings associated with the sustainable design. The Air Force has adopted the LEED rating system for its projects, and a specific Air Force policy complying with EO 13123 will be issued in early 2001.

Although Air Force is promoting sustainable design concepts, it does not have construction authority for its military construction projects. Air Force uses the Navy or Army to administer the design and construction for those projects.

e. Sustainable Design within the Army

The Army has many Engineering Technical Letters (ETLs) recommending Sustainable Design concepts, and is developing a policy on sustainability. U.S. Army Corps of Engineers ETL 1110-3-491 guides the Army Engineering community regarding Sustainable Design. The ETL states:

> Sustainable design is the design, construction, operation, and reuse/removal of the built environment (infrastructure and buildings) in an environmentally and energy efficient manner. The major tenet of sustainable design is to meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainable design includes efficient use of natural resources, better performing, more desirable and more

affordable infrastructure and buildings. Sustainable design incorporates the energy efficiency concerns of the 1970s with the concerns in the 1990s related to damage to the natural environment; emissions of greenhouse gases and ozone depleting chemicals; use of limited material resources; management of water as a limited resource; reductions in construction, demolition and operational waste; indoor environmental quality; and occupant/worker health, productivity and satisfaction.

Current Army guidance recommends using the LEED rating system for new construction and facility renovation. The Army is developing an alternate system to rate the level of sustainability for barracks facilities. The Army is providing sustainable design training for its district engineering staffs.

The Army expanded sustainability to include master planning (sustainable base vs. sustainable facility). Planning for Community Energy, Economic and Environmental Sustainability (PLACE3S) is a program developed to assess the sustainability of entire bases. Army sustainable design policy is viewable at the hyperlink provided.

f. Sustainable Design within GSA

In response to EO 13123, GSA's office of Government Wide Policy published a Real Property Sustainable Development Guide. The guide provides ideas for enhancing the sustainability of federal buildings, and defines Sustainable Design to include strategic planning and programming, site work and site planning, energy, building materials, indoor air quality, water conservation, recycling and waste management, building commissioning, operations and maintenance, and strategic environmental management. The guide provides case studies, sustainable concepts, and other references.

GSA's Federal Building Office studied more than 100 sustainable design elements on one large federal project. Based upon life cycle analysis of those elements, they implemented enough to merit the LEED Silver rating for that project. The 2.5% increases in first costs were paid back through lower life cycle costs from the sustainable initiatives. Lower energy costs, lower operations and maintenance costs and improved employee productivity (from improved indoor air quality and habitability) generate the payback. While not overtly measurable, GSA believes improved employee productivity during a sustainable facilities life generates savings an order of magnitude greater than the facility operation and maintenance savings.

g. Sustainable Design within the Department of State

The State Department policy on sustainable design was issued on December 5, 1997. State department project management staffs should use emerging "best practices"; maintain updated design guidelines; educate Federal Building Office design professionals; select project site, landscape and exterior design appropriate to the climate and function; select sustainable building materials; manage waste during building construction; incorporate building commissioning and operations and maintenance

reducing practices; lower energy usage; improve indoor air quality; reduce use of hazardous materials; conserve water and protect water quality. The policy requires value engineering for all capital projects.

The State Department Architect and Engineer Guidelines emphasize energy efficiency, natural resource conservation and pollution prevention as the three most significant sustainable design concepts. The guidelines also address security, and the need to design facilities for flexible end use. Both the policy and A/E Guidelines are being updated to reflect current executive orders.

While not specifically stated in their guidance, State Department seeks to achieve a LEED Certified rating for all its new facilities and requires its A/Es to have experience with sustainable design practices. Some facility professionals have received training on sustainable design, but only on an ad hoc basis. Currently State Department projects are designed to their targeted budget, and any sustainable design concepts are incorporated without increasing the project cost.

h. Sustainable Design within DOE

DOE will issue sustainable design policy for its internal agency projects in 2001.

DOE has developed sustainable design resources for use by all federal agencies. Through the Federal Energy Management Program (FEMP), they've developed a training course titled Designing Low Energy, Sustainable Buildings; the course provides federal facility managers an overview of sustainable design concepts. The guide, Greening Federal Facilities: An Energy, Environmental, and Economic Resource Guide for Federal Facility Managers, reviews the regulatory drivers for sustainable design, discusses sustainable design principles and practices, and provides federal facility managers help in procuring sustainable facilities. FEMP also publishes Federal guidance for procuring energy efficient products.

In a January 12, 2000 letter, The Secretary of Energy issued implementing guidance for EO 13123, citing the WBDG as the source for sustainable design and development principles for new construction. The letter cites the WBDG as guidance for agencies to ensure costs for design, construction and renovation are life-cycle costs.

i. Sustainable Design within EPA

EPA will issue a sustainable design policy the facilities it manages in 2001.

EPA promotes energy efficiency within federal facilities through its Energy Star program. To qualify for the Energy Star rating, federal facility managers certify that their facility is achieving energy savings. A professional engineer must certify, through measurement of actual energy consumption, that the facility is performing more efficiently than 75% of other buildings in the federal inventory (benchmarking).

EPA developed a catalogue of energy efficient products. As required by EO 13101, they also developed Comprehensive Procurement Guidelines (CPG) providing recommended suppliers of products containing recycled content. The Resource Conservation and Recovery Act (RCRA), Section 6002, requires federal agencies to comply with the CPG.

Under it's Labs for the 21st Century initiative, EPA is developing sustainable design concepts in federal and non-federal laboratory facilities. EPA is seeking co-participants to champion sustainable design concepts within all types and sizes of laboratory facilities.

j. Sustainable Design within NPS

The National Park Service's primary mission is to preserve federal natural resources. The NPS has developed a progressive sustainable design Policy, and has several example sustainable design projects. NPS has detailed guidance and criteria for using sustainable materials in their construction projects. Most of the NPS facilities are located in National Parks, and are not similar in character to NASA's facilities.

k. The Federal Network for Sustainability (FNS).

Representatives from federal agencies (GSA, NPS, Navy, EPA, DOE, DOI, Air Force) and industry (SBIC, Western Area Power Administration, Bonneville Power Administration, Washington State University Energy Program) formed the FNS in 2000. The FNS will "develop and coordinate the network, create and manage an information-sharing clearinghouse, develop and deliver training for network members, communicate ideas through conferences and meetings, seek linkages and partnerships, showcase sustainable programs and projects, and act as a catalyst for change." The FNS held its initial meeting in July 2000, and plans to meet again early 2001. Membership in the FNS is open to other federal or private organizations.

l. Sustainable Design in Industry

Several industry organizations have emerged as champions for sustainable design, including the U.S. Green Buildings Council (USGBC), the Sustainable Buildings Industry Council (SBIC) and the Green Building Information Centre (GBIC). These organizations advance sustainable design concepts, conduct training, and with sponsoring federal or international agencies host conferences advancing sustainable design practice.

The USGBC (Council) developed the LEED rating system in cooperation with DOE. The rating system is widely used by federal, state, local and private organizations to benchmark their sustainable design concepts. The USGBC expects empirical results from over 100 case studies at their 2001 conference, with focus on actual cost and benefit data. These case studies may provide significant information regarding metrics, costs, and benefits of sustainable design concepts.

The (SBIC) published a detailed guidebook, Low-Energy Sustainable Building Design for Federal Managers. This sustainable design reference includes excerpts from executive orders, references to sustainable design resources, and discusses the LEED rating system. The guidebook includes key attributes of sustainable designs, operations and maintenance benefits of sustainable design, Energy Savings Performance Contracts, and sources for environmentally friendly products. The SBIC members provide sustainable design training.

The GBIC is an international organization that disseminates information about energy and environmental issues throughout the design and construction industry. The GBIC has links to a broad array of resources and industry leaders on sustainable design concepts. The GBIC hosted an international conference in October 2000 to review case studies from participating countries. The GBIC published a multi-volume Assessment Manual with performance metrics and criteria for several building types. Suggested performance metrics for office buildings include: net annual consumption of primary energy (per square foot, per person or per person-hours of occupancy); net area of land consumed; net annual water consumption; annual greenhouse gas emissions. The assessment manual includes models for measuring building specific performance compared to benchmark performance for typical buildings, and a rating system to compare overall building performance against the benchmark. A second generation of the assessment manual is being developed.

The draft Federal Facilities Council study titled "Sustainable Federal Facilities: A Guide To Integrating Value Engineering, Life Cycle Costing, and Sustainable Development" shows how federal agencies can use value engineering and life cycle costing to support sustainable development and meet the objectives of EO 13101 and EO 13123. The draft study suggests that proper application of life cycle costing and value engineering early in project planning supports using sustainable concepts for federal facility projects.

Many federal agencies require A/Es to have sustainable design experience as a prerequisite to receiving federal contracts. An increasing number of architects and engineers have sustainable design capabilities. Hellmouth, Obata & Kassabaum, Inc. (HOK) is typical of firms demonstrating a sustainable design capability. WorldBuild Technologies, Inc. specializes in green building design. WorldBuild claims to have consulted sustainable designs for more than 10 million square feet of facilities. Rocky Mountain Institute (RMI), a non-profit organization, advances sustainable concepts in facility construction and renovation projects. These private organizations provide a sampling of the industry state-of-the-art for sustainable design.

m. Sustainable Design Within State and Local Governments

Many State and Local governments have sustainable design policies or programs. The Commonwealth of Pennsylvania has a well-developed High Performance Green Buildings program. Pennsylvania's Green Buildings program provides Commonwealth facility managers the tools necessary to:

> … Implement strategies and processes which install products, components, and systems to improve building performance by significantly reducing energy consumption, enhancing facility flexibility through quick, cost-effective space reconfiguration, while improving user comfort and satisfaction through high quality indoor air, visual comfort associated with day-lighting and individual control of temperature and ventilation. Green building includes all aspects of the building delivery process – design, construction, commissioning, operation & maintenance and de-commissioning. The benefits to the Commonwealth are multi-fold: improved worker health, motivation and productivity; improved organizational and facilities flexibility; improved technological adaptability; and reduced costs of operation, energy, maintenance and insurance.

The Commonwealth program prescribes performance criteria for its facilities. For example, the building enclosure shall "…provide for natural ventilation and day-lighting." The infrastructure shall "…be high efficiency" and "…employees shall have individual control of their indoor environmental quality." Further, "…interior systems shall be modular and demountable with high acoustic performance." Energy performance standards include: "…leased space shall consume 40,000 Btu/square foot/year or less of primary energy not including plug loads." Also, "…leased space shall consume 0.9 watts/square foot or less of electrical energy for ambient lighting with a measure of 30 foot candles at the work surface." This mixture of guidance and performance criteria ensures Commonwealth facilities meet sustainable performance parameters. Many other states have sustainable design programs (i.e., California, Florida and Texas).

Austin, San Diego and New York are among a growing number of cities with sustainable design programs. The New York City program is being implemented by the Department of Design and Construction, with assistance from The Design Trust for Public Space. The High Performance Building Guidelines, City of New York, Department of Design and Construction, April 1999, is an excellent compendium of the principles, costs, benefits and rationale for developing sustainable facilities. The Guidelines describe the measurable and non-measurable costs and benefits of producing high performance buildings, and cover the entire facility acquisition cycle from project planning through demolition. They discuss the merits of commissioning and its impact on operations and maintenance.

The New York City Guidelines include: costs and benefits; personnel savings through improved facility performance (reduced absenteeism, increased retention, productivity improvement); reduced municipal costs (waste and hazardous waste management, sewer system impacts, etc.); regional economic benefits (considers impacts on energy industry, air quality, marketing impacts from cleaner environment, impacts on regional competition for industry); and external environmental benefits (cleaner air, soil, air and water pollution prevention). The Guidelines note that annual agency personnel costs vary from $200-$300/square foot for administrative agencies to over $500/square foot for uniform agencies. A 1% increase in productivity is worth $2.00-$5.00 per square foot, or up to $500,000 per year for a 100,000 square foot facility.

n. Sustainability in Academia.

Many universities are advancing the practice of sustainable design. The University of Florida, University of Texas, and University of Virginia are among a growing number of institutions employing sustainable designs for university owned facilities. Many universities are developing sustainable design courses as part of their engineering or architectural curriculum.

4. Sustainability at NASA

NASA's combined funding for significant construction or repair projects is about $300 million per year ($150 million from Construction of Facilities (CoF), and $150 million from program dollars). Projects range in scope from utility repairs to new laboratory facilities.

NASA Policy Guide (NPG) 8820.2C, Facility Project Implementation Handbook (FPIH), requires all NASA facility projects to comply with Title 10, Code of Federal Regulations, Section 435 regarding federal energy efficiency standards. This establishes the minimum requirements for NASA facilities. NASA NPG 8400 requires program managers to consider sustainability during project design review. Implementing the recommendations in this report will establish NASA as a sustainability leader in among federal agencies.

Code JE monitors NASA's compliance with EO 13123. In its recent report to the Office of Management and Budget, Code JE noted improved management and administration in several areas, including: the draft NASA policy guide 8570.X; an Energy Efficiency and Water Conservation course; creation of an Energy Efficiency Board; a NASA 2000 Environmental Conference; energy spot checks at several NASA Centers; and enhancements to the NASA Environmental Tracking System (NETS). The Code JE report also highlighted operations and maintenance improvements through energy savings performance contracts, improvements to the energy monitoring control systems. This study was also highlighted as an ongoing NASA initiative.

IV. Design for Maintainability (Maintainability)

Task 204 recognizes the importance of Maintainability as a component of sustainability. The task required research and recommendations for incorporating this practice into NASA's future facilities projects. This section addresses Maintainability.

1. Maintainability Defined. Facility Maintainability is the practice of integrating operations and maintenance experience into the project planning, design, and construction processes to achieve ease, accuracy, safety, and economy of maintenance tasks throughout the life of the facility.

2. The NASA/Construction Industry Institute (CII) Initiative

The most significant maintainability initiative is the work currently underway by the CII (with cooperation of and involvement by NASA members), which identifies opportunities for and provides an implementation strategy for maintainability. This initiative produced four publications: Design for Maintainability Research Reports RR142-11 and RR142-12; Design for Maintainability: Improving Project Return on Investment Research Summary 142-1; and Design for Maintainability Guidebook Implementation Resource 142-2.

CII is producing an education module to incorporate maintainability into an organizations facility acquisition practices. The CII initiative recommends the following approach to maintainability:

- Secure corporate commitment
- Assign a corporate champion for implementation and commit the resources required for implementation
- Conduct a self audit to document the current level of maintainability practice
- Prepare and publish a corporate policy
- Prepare implementing procedures (procedural checklists, model specifications, measurable metrics, lessons learned database, etc.)
- Develop and conduct an internal NASA staff training program
- Implement as a pilot project
- Expand implementation to all projects
- Periodically measure results achieved and revise program appropriately

3. Maintainability at Other Federal Agencies

Other federal agencies are embracing maintainability concepts to a limited extent. None have identified goals as comprehensive as those recommended by the CII research discussed above. Agencies in the lead include Navy, State, and GSA. State and GSA initiatives involve inserting sustainability requirements into A/E scopes of work. Navy's initiative is more comprehensive and is tied to development of the Whole Building Design Guide. Navy requires architects and engineers to produce Operations and Maintenance Service Instructions (OMSI) for all significant projects. These OMSI manuals are intended to improve the transition of ownership from construction contractors to operations and maintenance staffs. Navy invests from 0.5-1.0% of the construction cost for the OMSI manuals, and acknowledges the need to develop more comprehensive policy on maintainability.

Army and Air Force also acknowledged a need for policy on maintainability issues. Other agencies contacted are not doing anything formally, nor do they have policies regarding maintainability.

4. Maintainability in Industry

Building Maintainability is not understood as well as sustainability. Although owners recognize the value of designing and constructing facilities to improve operation and maintenance, they lack a formal methodology for doing so. Generally, owners who value maintainability have focused primarily upon the following limited initiatives:

- Timely acquisition of building system and equipment operations and maintenance documentation for building operation and maintenance manuals
- Operation and maintenance staff involvement in the design review process (often during final design review, when opportunity improve the design is minimal)
- Creating lessons-learned files documenting startup, operation and maintenance problems, to avoid repeating mistakes on subsequent projects

Until now, maintainability initiatives occurred during the construction and start up phases, and were reactive. These reactive initiatives missed the opportunity for significant improvements had alternatives been considered prior to facility design completion.

Maintainability proponents advocate applying maintainability concepts at the start of the facility acquisition process, starting with the concept development phase. Maintainability should be a significant project objective. Maintainability experience should factor into A/E selection. Maintainability should influence the design approach and drive material and equipment selection. Maintainability is fundamental to all building commissioning activities. Documents required for maintenance and operation, and appropriate training, should be identified and acquired prior to facility startup.

These recent developments have gained maintainability more visibility:

- Technology advances, including reliability-centered maintenance (RCM) practices such as vibration sensing, thermal imaging, and oil analysis
- Business practices that solicit participation of all project stakeholders, including the operation and maintenance staff
- Material science advances with resultant impact on maintenance requirements.
- Public policy changes, such as greater emphasis upon life cycle costing
- Increased use of metrics to measure facility performance
- Owners who demand higher operating reliability and more effective maintenance practices
- More sophisticated electrical and mechanical building systems that require more intensive maintenance support
- Greater emphasis on sustainability and green building practices that increase the requirements for facility operating efficiencies

5. Maintainability at NASA

NASA Centers have not incorporated maintainability concepts into the planning and design of facilities projects with any consistency. Nonetheless, maintainability techniques, costs, and potential return are better understood within NASA than any other federal agency. This is due to NASAs collaboration with the Construction Industry Institute (CII) in developing maintainability as a business practice. No other federal agency has done as much on maintainability as NASA. A detailed review of NASA/CII material is sufficient to create NASAs benchmark program. A NASA representative chairs the CII committee developing training materials, which will enable member organizations to implement maintainability practices. The training materials are scheduled to be ready later this year. The maintainability concepts can be incorporated into the sustainability initiatives when they are further developed.

V. Total Building Commissioning (TBC) as an Element of Sustainability

Task 204 recognizes TBC as an element of sustainability, and directs Plexus to research it as a possible NASA best practice. The following discussion addresses TBC.

1. TBC Defined. Originally, "commissioning" defined a set of activities associated with checking out equipment (primarily electrical and mechanical) installed during construction. Such activities were performed only at the end of the project construction phase, prior to the owner accepting and occupying the facility. Commissioning was performed by construction contractor representatives and his subcontractors/suppliers who demonstrated to the owner's maintenance and operations staff that the equipment functioned per a vaguely (and often disputed) performance definition.

Building commissioning has recently evolved into a more comprehensive activity addressing more building systems than the traditional electrical/mechanical equipment. Various practitioners have begun to use the terms Total Building Commissioning and Whole Building Commissioning interchangeably to describe this expanded practice. For this report, we have elected to use the term Total Building Commissioning (TBC) that we define as follows:

TBC is a quality process for achieving, validating, and documenting that the building and all its systems and assemblies are planned, designed, installed, tested, and capable of being operated and maintained according to the owner's program and design criteria. The process extends through all phases of a project from pre-design through owner occupancy and operation to disposal, with checks at each stage of the process to ensure validation of decisions to meet the owner's program and design requirements.

2. Total Building Commissioning at Other Federal Agencies

Very few federal agencies have implemented an effective TBC program, although several are studying its potential:

- The Pentagon Renovation Office (PRO) has relevant TBC experience. The PRO's Pentagon basement renovation experienced many change orders, extensive cost growth and major schedule delays. The PRO adopted TBC for subsequent renovation phases. The PRO completed one project (remote material receipt facility) with Sebesta, Blomberg & Associates serving as the owners third party Commissioning Authority (CA). The remaining Pentagon work will be renovated in five pie-shaped wedges. The $120 million Wedge 1 project is currently underway using a TBC approach, and TBC will be used on the $500 million design-build Wedge 2-5 project. Results have been impressive: The PRO budget of 2.5% of construction costs funded a rigorous TBC program. Actual cost were closer to 1.5%, with estimated savings on the order of 2 to 3 times the expense. Most important, schedule delays have been significantly reduced, and impact upon Pentagon operations have been controlled.
- GSA is using TBC on selected projects. GSA prefers to add commissioning functions to the A/E contract scope instead of hiring an independent Commissioning Authority.
- State Department has experienced difficulties with facility startups and is studying various commissioning approaches to avoid future project start up problems.
- Veterans Administration said it was conducting a building commissioning to start up its new hospitals. Follow-up discussions indicate that this activity is really a final demonstration of critical systems to secure medical accreditation, and has no impact on the facility planning, design, or construction phases.
- Washington Metropolitan Airport Authority (WMAA) used elements of TBC during the planning, design and construction of the Reagan National Airport Terminal. Although no quantitative cost/return data was recorded, the WMAA noted minimal disruption during initial occupancy where TBC practices had been used. The WMAA is seeking funds to expand TBC for several large-scale projects planned for Ronald Reagan and Dulles Airports.
- Air Force has no TBC policy. Some Air Force commands have independently embarked on TBC efforts, most notably the Air Force Academy. The Air Force barracks project is in design, and will incorporate TBC and Reliability Centered Maintenance. They hired a third party Commissioning Authority. AF does not have construction management authority for their Military Construction (MILCON) program; therefore, their opportunity to use TBC in project management is limited.
- Navy has no formal TBC policy. Through partnering on many of its construction projects Navy has occasionally developed improvements in facility start up, but these improvements occur independent of any formal policy or centralized program. Navy has required contractors to provide Operational Maintenance and Support Information (OMSI) for several years. The OMSI is a package of operating and maintenance procedures for newly constructed facilities. OMSI packages typically cost between 0.5 and 1.0% of the project construction cost.
- Army does not have a TBC policy, but some Army Corps Districts have used some aspects of building commissioning on selected projects.

3. Total Building Commissioning in Industry

During the early 1990s, the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) recognized that significant building start-up problems were associated with heating, ventilating and air conditioning (HVAC) equipment. In response, ASHRAE developed a structured approach to building commissioning for HVAC equipment. This structured approach required development of a "Commissioning Plan" during a project's requirements development phase. Per this plan the owner defined system performance criteria during the project's concept development, and these criteria were refined and incorporated into the project design. During the procurement/construction and equipment installation phases, equipment and system performance criteria were reviewed and validated, equipment maintenance manuals were prepared, and operations/maintenance personnel were trained. Final check of facility and system performance occurred during the project startup phase, and maintenance activities were practiced and refined. The ASHRAE commissioning work was and still is conducted under Technical Committee 9.9, Building Commissioning ASHRAE.

The ASHRAE building commissioning model has been remarkably successful, and many within the construction industry have recommended its expansion to other building systems. The industry calls this expanded model Total Building Commissioning (TBC). The National Institute of Building Sciences (NIBS) is the facilitator for industry development and adoption of the TBC practice. Building upon the ASHRAE model, NIBS is working with other professional and technical organizations, including AIA, ASCE, International Electrical and Electronic Engineers (IEEE), and the National Fire Protection (NFP) Council, to build a nationally acceptable TBC Guideline addressing the total scope of building systems. NIBS estimates it could take up to five years to complete this effort. The following link is to the NIBS Total Building Commissioning website, hosted by the Florida Design Institute NIBS.

Two other organizations have been influenced TBC within the construction industry: The Portland Energy Conservation Institute (PECI) and the Building Commissioning Association (BCA). (PECI) has perhaps the longest involvement and has developed, in conjunction with the Department of Energy, a comprehensive toolkit for any organization to incorporate TBC into projects. Public and private owner organizations, as well as Architect/Engineers, have formed a national professional society, the Building Commissioning Association (BCA), to foster research, networking, and TBC practice recognition. The BCA recently developed and is currently presenting formal TBC training courses. The BCA also publishes a periodic newsletter, The Checklist, which can be accessed through the BCA website.

TBC found early success with hospital, university, and correctional facility projects. Some local governments (such as Montgomery County, MD) and school districts throughout the country have adopted its more structured process. From our research we learned that those most familiar with TBC highlight three issues:

- Depth (the level of detail) and breadth (the variety of building systems involved) of commissioning activities should be determined by the size, sophistication, and mission criticality of the project itself. It is not necessary to commission all systems of all projects with an equally highly structured approach.
- TBC adds approximately 1.0 – 2.5% to total project cost, depending upon the TBC rigor employed. Resultant savings justify the additional expense by reducing project cost growth by two to three times the cost of the TBC activities.
- Many choices exist for managing the TBC process. The owner may perform the commissioning function entirely with in-house personnel. An expert consultant may be hired to provide commissioning functions for multiple projects throughout the owner's physical plant. A project-specific independent consultant can be retained as the Commissioning Agent (CA), overseeing the commissioning activities for each and every phase in a project's acquisition process. The project Architect/Engineer may assume the CA responsibility in a design-bid-build or design/build approach. The Project Construction Manager (CM) may perform as the CA when a CM is involved.

TBC has evolved to the extent that it is now a relatively mature and recognized practice, especially with regard to facility electrical and mechanical systems. The LEED Green Building Rating System recognizes Building Commissioning as a desirable practice. Indeed, "Fundamental Building Systems Commissioning" is required for LEED certification and "Additional Commissioning" can further contribute to LEED certification point scoring. Sustainable concepts are involved in de-commissioning and disposing of facilities at the end of their useful life. Concepts include selecting environmentally friendly products, and assembling facilities in such a way that components can be more easily separated during the demolition process.

4. Total Building Commissioning at NASA

To date, NASA has not used TBC. The NASA Engineering Continuous Improvement Council (ECIC) received a TBC brief from Dr. Charles Dorgan (University of Wisconsin) and debated the degree to which TBC should be implemented on NASA projects, but no consensus was reached. Several Centers are contemplating using some form of building commissioning on one upcoming C of F project.

Many large-scale and sophisticated facilities support NASA's critical missions. TBC will positively impact NASA's ability to produce high performing critical facilities projects. TBC's discipline in defining facilities performance requirements, and in ensuring project planning, design and construction produces facilities that meet those requirements, will improve facilities support to critical missions. NASA Centers will have to decide among several different TBC approaches, with the goal of tailoring the approach to match the projects scale, complexity, risk level and mission criticality. For example, a large scale project with sophisticated electrical and mechanical systems, a full TBC application using a third party commissioning authority will likely produce the best results. For smaller, less complex projects, TBC concepts can be incorporated using in-house or consulting

services on a smaller scale. Applying TBC in varying ways on several pilot projects may be the best way for NASA to gain practical experience and generate lessons learned for future applications. Attachment 4 provides a structured implementing strategy for sustainability that incorporates a flexible project specific approach to TBC.

VI. Facility Safety and Security

In addition to sustainable design, design for maintainability, and building commissioning, the statement of work required an investigation of government and industry strategies to "design in" building safety and building security. This section provides the results of that investigation.

1. Facility Safety and Security Defined.

For this study, Facility Safety and Security includes the features required to protect the health and welfare of facility visitors, occupants and equipment against internal hazards or external dangers (due to facility siting or terrorist activities).

2. Facility Safety and Security at other Federal Agencies

a. The Department of Defense (DOD) and the military services accommodate safety and security considerations in all their significant facilities projects. Project justification documents and designs are required to address safety and security very explicitly. Safety considerations are addressed through specific Hazards Analysis during the facility planning phase. Evidence of the Hazards Analysis must be presented on the DD Form 1391, Project Data Sheet, prior to project approval. In response to recent terrorist activities DOD also requires all projects to be designed in accordance with strict anti-terrorism and force protection criteria. The criteria include consideration for construction materials and blast protection, boundary clear zones, personnel access, and other force protection measures. Criteria for safety and security are considered in addition to sustainability concerns on all DOD military construction projects.

b. Due to the locations of its facilities, The State Department places additional emphasis on facility security. A separate construction security management group provides Architects and Engineers specific guidance on security related items, including access control, surveillance equipment, locks, uninterrupted power supplies, and other issues. State Department projects also undergo a safety review as part of the project planning process.

c. The Whole Building Design Guide includes a comprehensive section on facility security. The section addresses seven attributes of a secure facility, including deterrence, demarcation, prohibition, delay, detection, communication and denial. The section includes criteria, trade journals and web sites with additional information and resources useful for designing secure facilities.

3. Facility Safety and Security in Industry

a. The National Institutes of Buildings Sciences efforts to develop commissioning specifications include safety and security and important elements of the overall facility design intent. The proposed specification includes a section on protective systems commissioning, and considers the security requirements from the design intent. This collaborative effort is evidence that safety and security considerations can and should be considered along with sustainability principles in a federal facility project.
b. The Construction Industry Institute study on Design for Maintainability: Improving Project Return on Investment states "…maintainability is considered as inherent to the system design, regarding the ease, accuracy, **safety**, and economy of maintenance tasks." The CII study includes safety as an important element of its design practice.

4. Facility Safety and Security on NASA Projects

Chapter 2, Requirements, of NASA Procedures and Guidelines (NPG) 8820.2C requires NASA project managers to consider fire protection and life safety when defining facility requirements in the facility concept study. The facilities requirements document further requires consideration of security requirements. NASA Facilities Engineering Handbook (NHB) 7320.1 requires project managers to consider safety, fire protection and security while completing a project design. The guide specifications used on NASA projects also incorporate many of the routine safety and security requirements for many project items. Including safety and security as elements of sustainable designs on NASA facilities will provide added emphasis to these important design elements.

VII. Conclusions

The following conclusions are based upon a detailed review of sustainability (including design for maintainability and TBC), safety, and security practices among other federal agencies and industry.

1. Executive Order 13123 requires NASA to incorporate sustainability concepts as a fundamental objective of facility project planning, design, construction and operation. Many elements of sustainable design can be incorporated at no increase in project design and construction cost (first cost). Other elements will increase first cost, but may reduce project life cycle costs. Some elements, like impact on employee productivity, are not easily measured. The proper balance between additional design or construction cost for sustainability and reduced life cycle O&M or productivity costs is not always obvious. Some sustainable elements may not be economically justified, but may be appropriate when considered from the standpoint of responsible stewardship of taxpayer resources. The extent to which sustainability should be pursued on any given project is thus highly variable and depends upon the individual project's size, mission criticality, location, complexity, and available funding.

2. Facility safety and security concerns can be incorporated as part of an integrated sustainable facilities project. Facility safety and security criteria can be developed along with sustainable criteria, and made a part of the final facility performance criteria.

VIII. Recommendations

The following recommendations are intended to move NASA toward a proper balance of sustainability (including Maintainability, TBC, safety and security) on its facility projects.

1. Publish Attachment 1, a NASA Policy Directive mandating sustainability as a fundamental requirement for all facilities projects.
2. Assign a NASA sustainability champion. The sustainability champion would be the central point of contact and would help develop NASA's capability for implementing sustainability on its facilities projects. Attachments 2, 3 and 4 provide recommendations and timelines to assist the sustainability champion in implementing a program throughout NASA and on a specific project.
3. Obtain an engineering services consultant to facilitate implementing sustainability practices on NASA projects. The consultant would conduct an audit of sustainability capability at each Center, and work closely with the sustainability champion and Center facilities engineering staffs to develop capability for and implement sustainability concepts on pilot projects. Consultant support would include developing a training course to teach facility project managers how to integrate sustainable practices on significant NASA facility projects. The course should include a sample project as the foundation for teaching sustainability principals. The consultant could assist in implementing several of the following recommendations.
4. Develop a NASA Policy Guideline on sustainability similar to existing NASA manuals for partnering and pre-project planning, based on the NASA/CII maintainability initiative.
5. Use the Leadership in Energy and Environmental and Design (LEED) rating system for all new construction projects, and renovation projects that will significantly alter existing facilities. NASA should evaluate the use of the LEED rating system on its pilot projects, and determine the appropriate LEED standard for future NASA projects.
6. The cost of implementing sustainability will vary from project to project. Many sustainability initiatives can be accomplished without any increase in project design or construction costs. NASA should support project specific requirements to achieve the LEED silver rating for facilities projects. In some cases additional resources may be required to provide appropriate maintainability and building commissioning project enhancements. Reductions in operations and maintenance costs should be weighed against increases in first costs, ensuring the overall life cycle cost to NASA is optimized.
7. Implement sustainability on selected pilot projects, expanding the implementation to all projects as NASA Center project management staffs achieve competency.

8. Develop capabilities to implement TBC on simple, moderate, and large projects.
9. Participate with the Environmental Protection Agency in the Laboratories for the 21st Century program to advance sustainable design concepts in high technology facilities.
10. Incorporate safety and security considerations as integral parts of the overall sustainable facility requirements.