SAN099-1699C

Unattended Monitoring System Design Methodology

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ABSTRACT

A methodology for designing Unattended Monitoring Systems starting at a systems level has been developed at Sandia National Laboratories. This proven methodology provides a template that describes the process for selecting and applying appropriate technologies to meet unattended system requirements, as well as providing a framework for development of both training courses and workshops associated with unattended monitoring.

The design and implementation of unattended monitoring systems is generally intended to respond to some form of policy based requirements resulting from international agreements or domestic regulations. Once the monitoring requirements are established, a review of the associated process and its related facilities enables identification of strategic monitoring locations and development of a conceptual system design. The detailed design effort results in the definition of detection components as well as the supporting communications network and data management scheme. The data analyses then enables a coherent display of the knowledge generated during the monitoring effort. The resultant knowledge is then compared to the original system objectives to ensure that the design adequately addresses the fundamental principles stated in the policy agreements. Implementation of this design methodology will ensure that comprehensive unattended monitoring system designs provide appropriate answers to those critical questions imposed by specific agreements or regulations.

This paper describes the main features of the methodology and discusses how it can be applied in real world situations.

INTRODUCTION

A systems level engineering design methodology is presented that provides a structured approach to development of unattended monitoring systems for safeguards, non-proliferation, and transparency applications. Application of a basic systems engineering discipline towards this design effort should result in an optimized monitoring system that minimizes false signals while ensuring that events of interest are detected and appropriately analyzed for their significance in potential diversion scenarios. This methodology recognizes that an overall system design process is generally initiated by some external stimulus, such as an International Agreement or Treaty. An evaluation of the applicable constraints associated with this external stimulus leads to specification of the system architecture. Completion of sufficient systems level analyses and identification of appropriate strategic monitoring locations enables development of the system design, which then leads to

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component integration and application of a functioning unattended monitoring system. An evaluation of the system performance is then compared to the external stimulus to ensure that the original monitoring objectives have been satisfied. Sandia National Laboratories has developed a training curriculum based upon the methodology described in this paper. The overall design process is depicted in Figure 1 below.

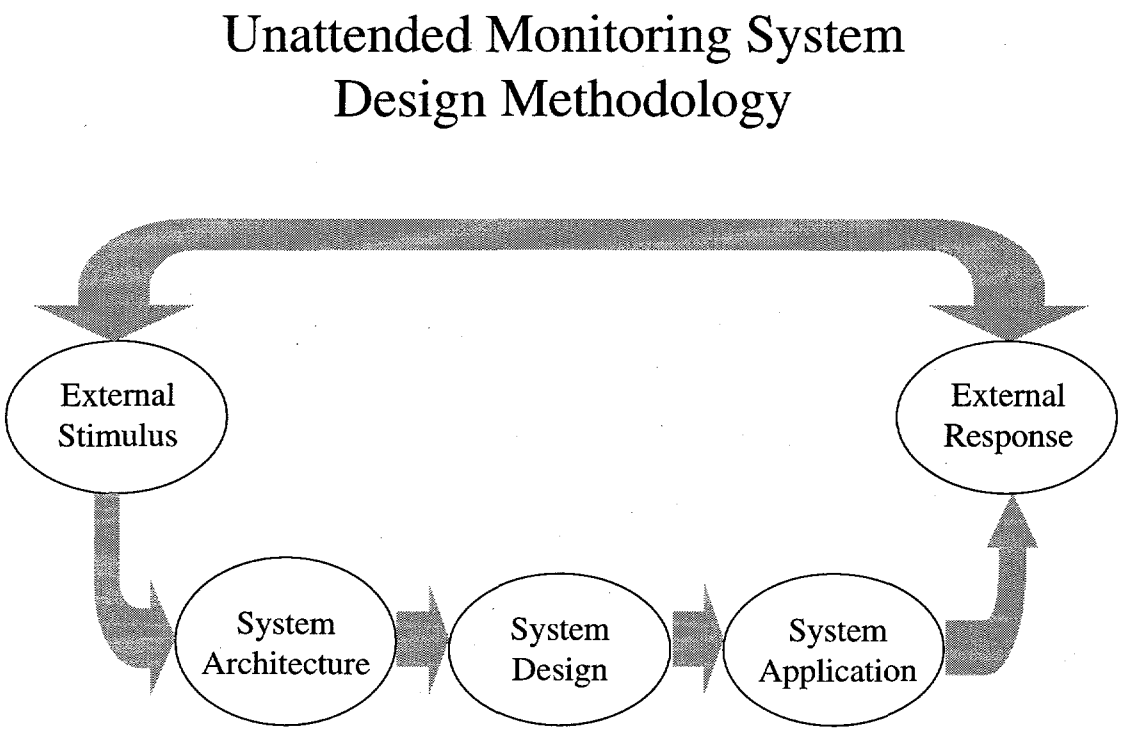

Figure 1. Systems Design Process

Given that the external stimulus has been identified, implementation of this systems level methodology is guided by the three major development phases identified in Figure 1. Within the "System Architecture" and System Design" phases, there are six discrete steps which, in concert with continuous feedback loops, enable a "System Application" that specifically addresses the original monitoring goals and generates an appropriate external response. Each of the individual steps generates an output that provides the necessary input to the following step. An iterative relationship exists between the external elements of the global monitoring system that is outside of the scope of this system design methodology. Implementation of the design methodology is represented in Figure 2.

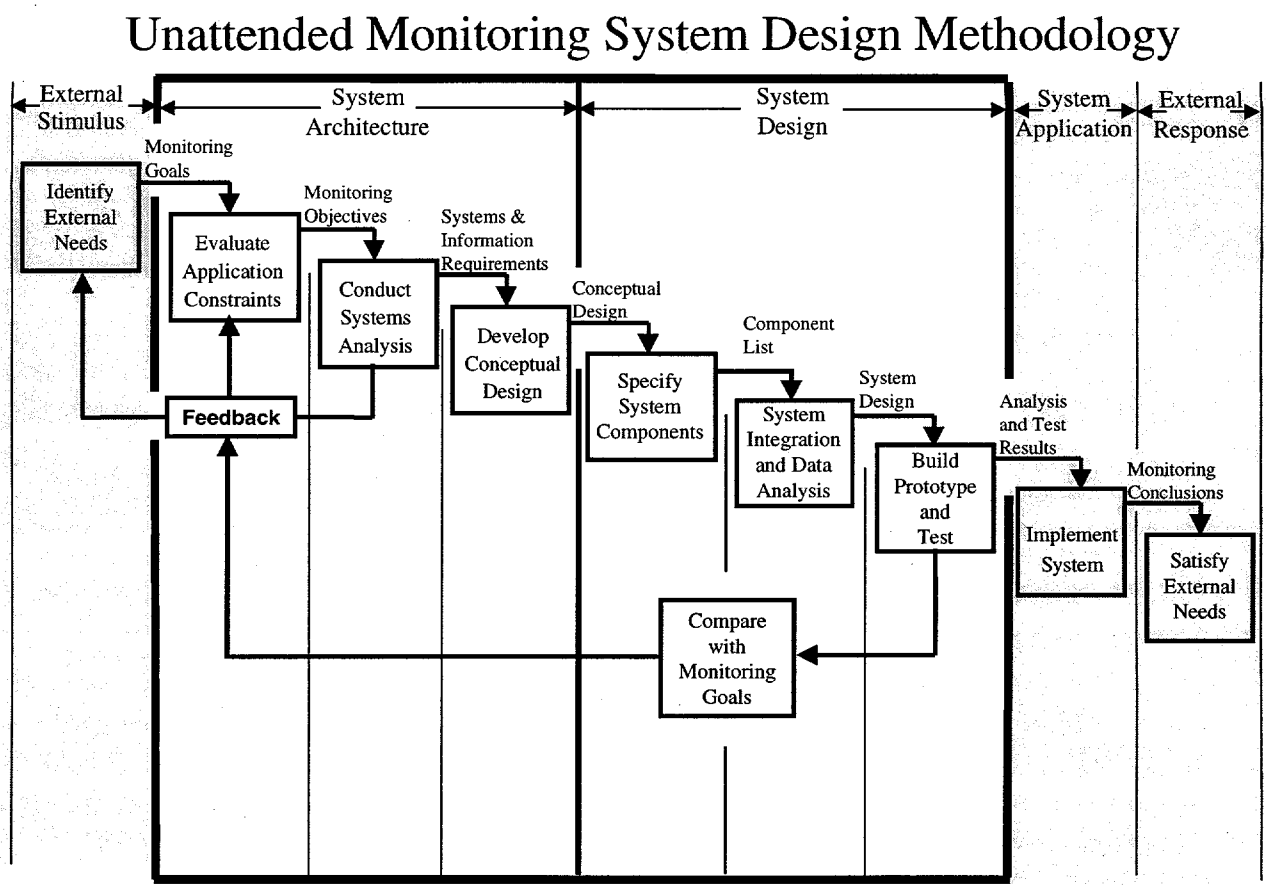

Figure 2. Design Methodology Implementation

UNATTENDED MONITORING SYSEM DESING METHODOLOGY

Development of a "System Architecture" includes three of the six discrete steps: Evaluate Application Constraints, Conduct Systems Analysis, Develop Conceptual Design. The second phase focuses on development of the "System Design" and includes the remaining three steps: Specify System Components, System Integration and Data Analysis, and Build Prototype and Test. Completion of the six steps enables "System Application" and identification of the "External Response" that satisfies the original "External Needs". The External Response could be a report or an alarm that material has potentially been diverted from its intended use or location. While continuous feed back is implied throughout the entire process, it is especially important that development of the system requirements be an iterative process and that the final system output is compared with the original monitoring goals.

The following describes the content of the major steps in this methodology.

Identify External Needs: The overall design process is initiated by identifying the external needs. These design process drivers include international treaties, regional regulations or laws, and/or local

or business needs that dictate the need for unattended monitoring in some form. These external forces may also be referred to as the "System Stimulus" and represent the metric for evaluation of the "External Response" which is the end result from the system design process. The immediate output from identifying the External Needs is a set of Monitoring Goals which initiates the technical design process.

Evaluate Application Constraints: The "Monitoring Goals" resulting from the external stimulus must be filtered with respect to the intended application in order to arrive at specific systems level "Monitoring Objectives" which can be applied within a certain class of industries or processes. This evaluation must include consideration of the types of processes and facilities to which the monitoring system will be applied, as well as the geographical area and climate in which the system will be installed. Additionally, the end user of the system could significantly impact the eventual system requirements. An unattended monitoring system that is designed for safeguards use by the International Atomic Energy Agency (IAEA) may impose many requirements that would not be necessary for a similar system designed for non-proliferation and transparency applications for a different user. This evaluation is intended to be generic at the industry or class-of-facility level rather than facility or process specific and may include considerations of the potential impacts relative to site remoteness, operational schedules, dynamic versus static processes, and existing safeguards and security procedures at similar types of facilities. The specific application issues will be considered during the system analysis section.

Conduct Systems Analysis: A detailed analysis of both the specific facility and actual process to which the unattended monitoring system will be applied is necessary to identify optimum "Strategic Monitoring Locations" where specific sensing components may be installed. The systems analysis process commenced in the previous step; however, it continues here with a more detailed review of the site diagrams, facility blueprints, and process stream flow diagrams. This characterization process is intended to provide the application specific knowledge base, which is necessary to perform the vulnerability analysis and threat assessments. Development of the resultant consequence estimates and fault trees enables identification of a minimum number of scenarios and enables establishment of performance criteria, from which the items to monitor, critical parameters, and strategic monitoring locations lists can be generated. Subsequently, an iterative evaluation process of the preliminary design parameters is performed from which emerge the specific System & Information Requirements that enable initiation of the conceptual design process. An overview of the System Analysis Process is provided in Figure 3.

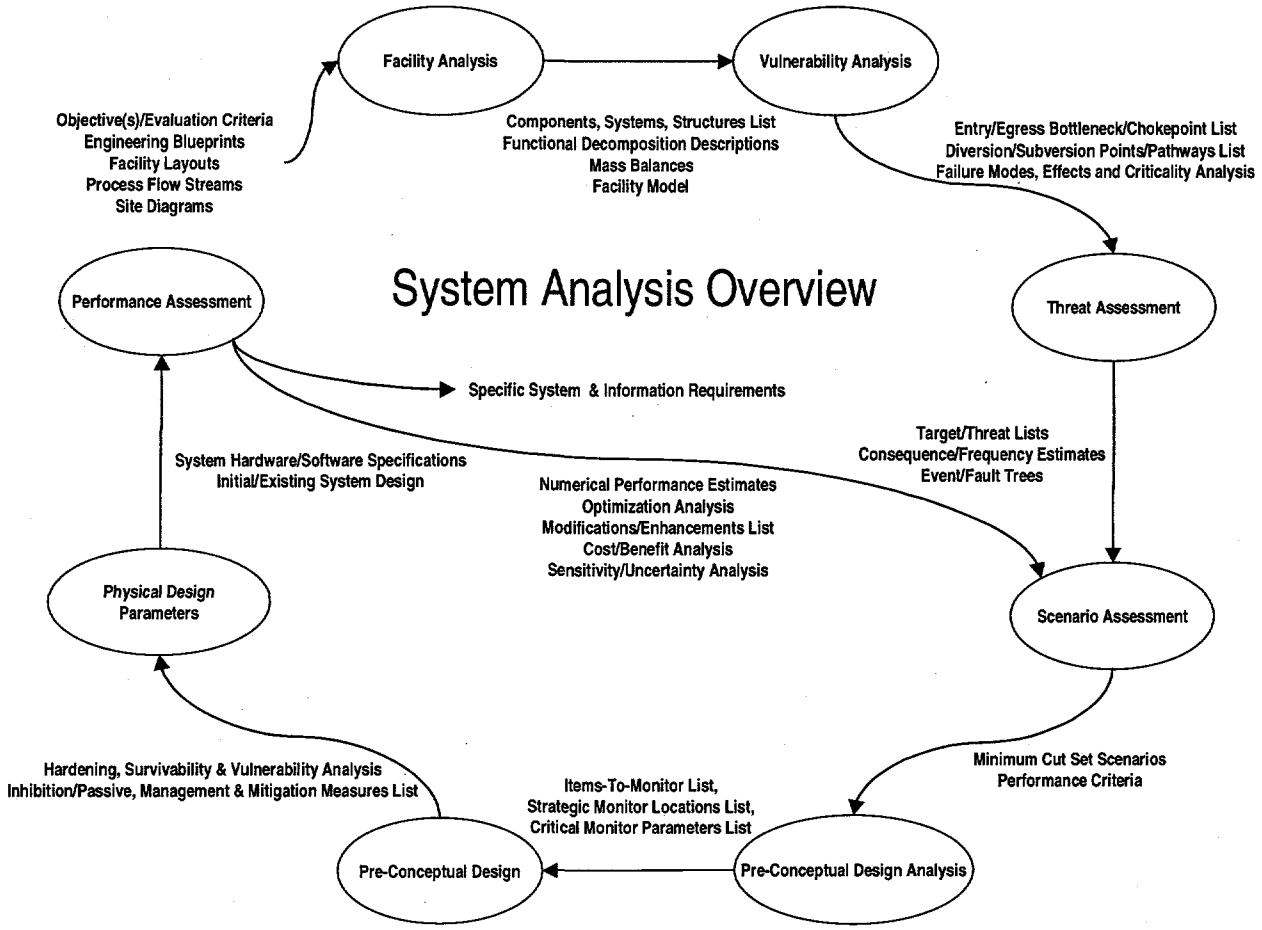

Figure 3. System Analysis Overview

Develop Conceptual Design: Once the system analyses have optimized the lists of strategic monitoring locations, items to monitor and the critical monitoring parameters, it is possible to develop a system level conceptual design. The conceptual design identifies the generic types of monitoring and data management that will be required for the specific system. The conceptual design also provides information to the design engineers relative to the types of sensing components that will be required; a recommended network hierarchy that will ensure efficient communications throughout the system; data management requirements that will result in reliable data collection, storage, and dissemination. The data analysis requirements that will perform logical comparison of the information in the various data bases and provide summary level status to the facility operators is also included in the conceptual design. With the production of the Conceptual Design Report, the "System Architecture" phase of the design methodology is complete and the detailed design effort may commence.

Specify Components: This is the initial step in the System Design phase of the methodology. Based on the information provided by the Conceptual Design, the system design engineers are now able to identify specific hardware and software that will accomplish the system level monitoring objectives. The selection process is structured for accomplishment in an upward manner (i.e. Sensors, then Network, then Information Management, and then Knowledge Generation. The output from this

selection process will be a list of the components, networks, and software, which will be integrated into a working monitoring system that satisfies the system level requirements.

System Integration and Data Analysis: The systems engineering process takes the list of hardware and software components and develops a complete, functional unattended monitoring system system. Basically this is a component integration process, resulting in system specifications that will allow the procurement and fabrication of the system to commence.

Build Prototype and Test: Having completed procurement and/or fabrication of all specified system components, the engineers may now assemble and evaluate the monitoring system. This system evaluation process includes the development of test plans, data collection sheets, and thorough analyses of the data collected by the monitoring system. Out of this testing process should come hard data on the capability, reliability, and sensitivity of the system and its components, which enable a final vulnerability analysis. This analysis will provide assurance to the system designers that the system does satisfy the system level requirements and meets the original monitoring goals and objectives. Any redesign and reanalysis necessary to ensure compliance with the original goals and objectives must be accomplished prior to system implementation.

Implement System: With the satisfactory completion of the system level evaluations, the prototype system is ready to be removed from the laboratory environment and installed at the facility for field trials and eventual unattended operation. System implementation requires the development of detailed facility drawings and plans for installation; followed by installation, testing, operation, and maintenance. It is only in the final use of the system that the true "Monitoring Conclusions" can be produced. Facility operators will most likely implement the final system; however, the design agency must be available to provide continuous support throughout this process.

Satisfy External Needs: The monitoring system design methodology is completed when the desired response to a monitored parameter is generated by the unattended monitoring system. This response could be in the form of a relatively simple alarm or report or, in some cases, may result in some form of response by the facility operator or the cognizant authority. This whole process was initiated by a "System Stimulus" and the output of this process is the "System Response." Whatever form this "System Response" takes, it represents the ultimate objective of the Unattended Monitoring System Design.

An overview of the design methodology with some representative lower level subjects that might be considered for each of the individual steps is provided in Figure 4. Due to the global nature for potential application of this methodology, these lists are not intended to be compete; however, they hopefully provide some thought provoking subjects that will enable designers for specific system applications to develop an efficient and reliable Unattended Monitoring System.

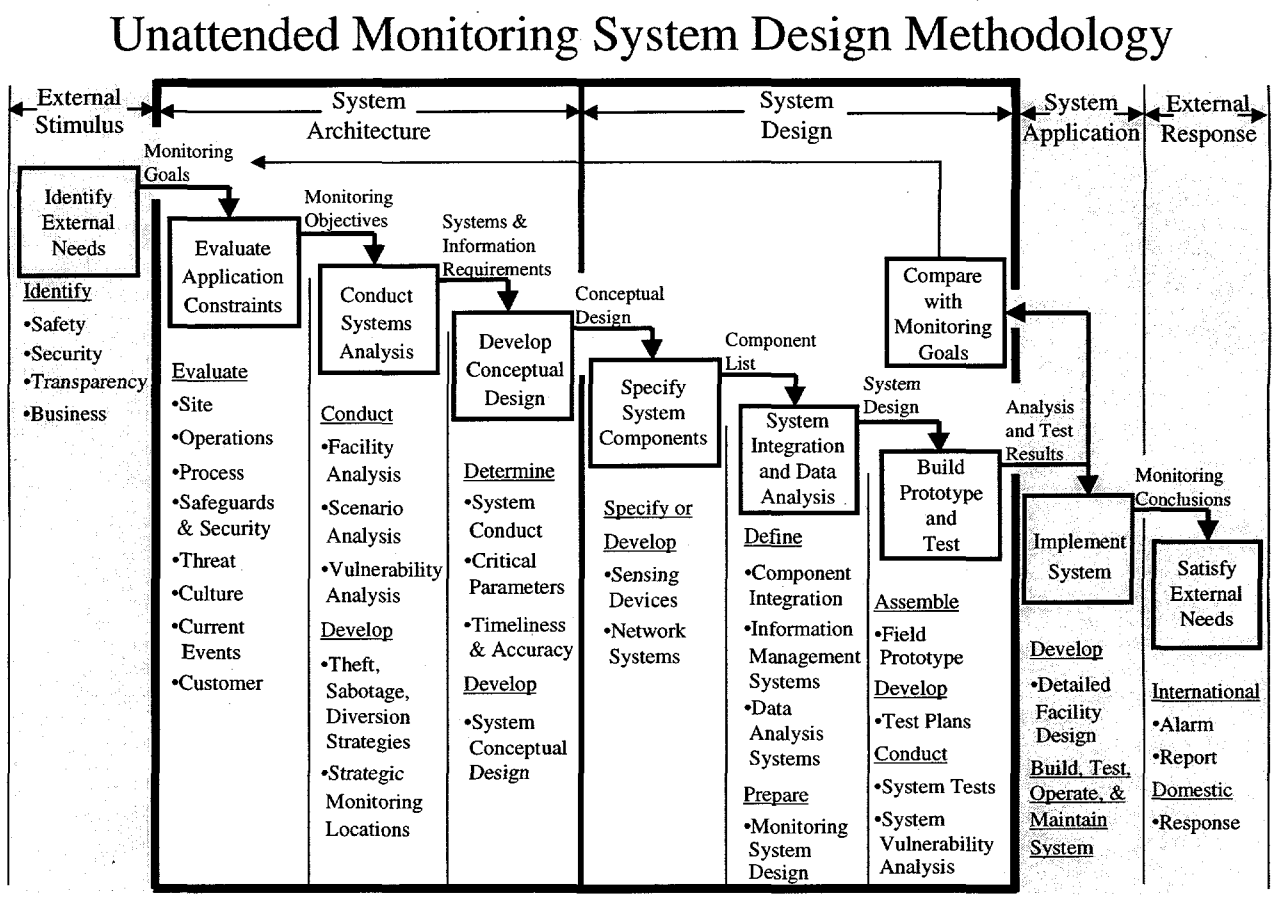

Figure 4. Detailed Design Process Information

APPLICATION EXAMPLE

This system design methodology was successfully utilized to develop an expanded unattended monitoring system for the Experimental Fast Reactor Joyo located at the Oarai Engineering Center in Japan. Development of this system accomplished in accordance with a Bilateral Agreement between the Department of Energy and the Japan Nuclear Cycle Development Institute. The system requirements and resulting strategic monitoring locations were based upon a desire to enhance ongoing transparency and non-proliferation efforts. Based upon a jointly developed system design, Sandia National Laboratories completed the system integration and evaluation at their facilities in Albuquerque. Subsequent to a systems level evaluation, the equipment was shipped to the Joyo facility in Japan for installation and final evaluation. Figure 5 provides an overlay of the design methodology and its application to the Joyo system design process.

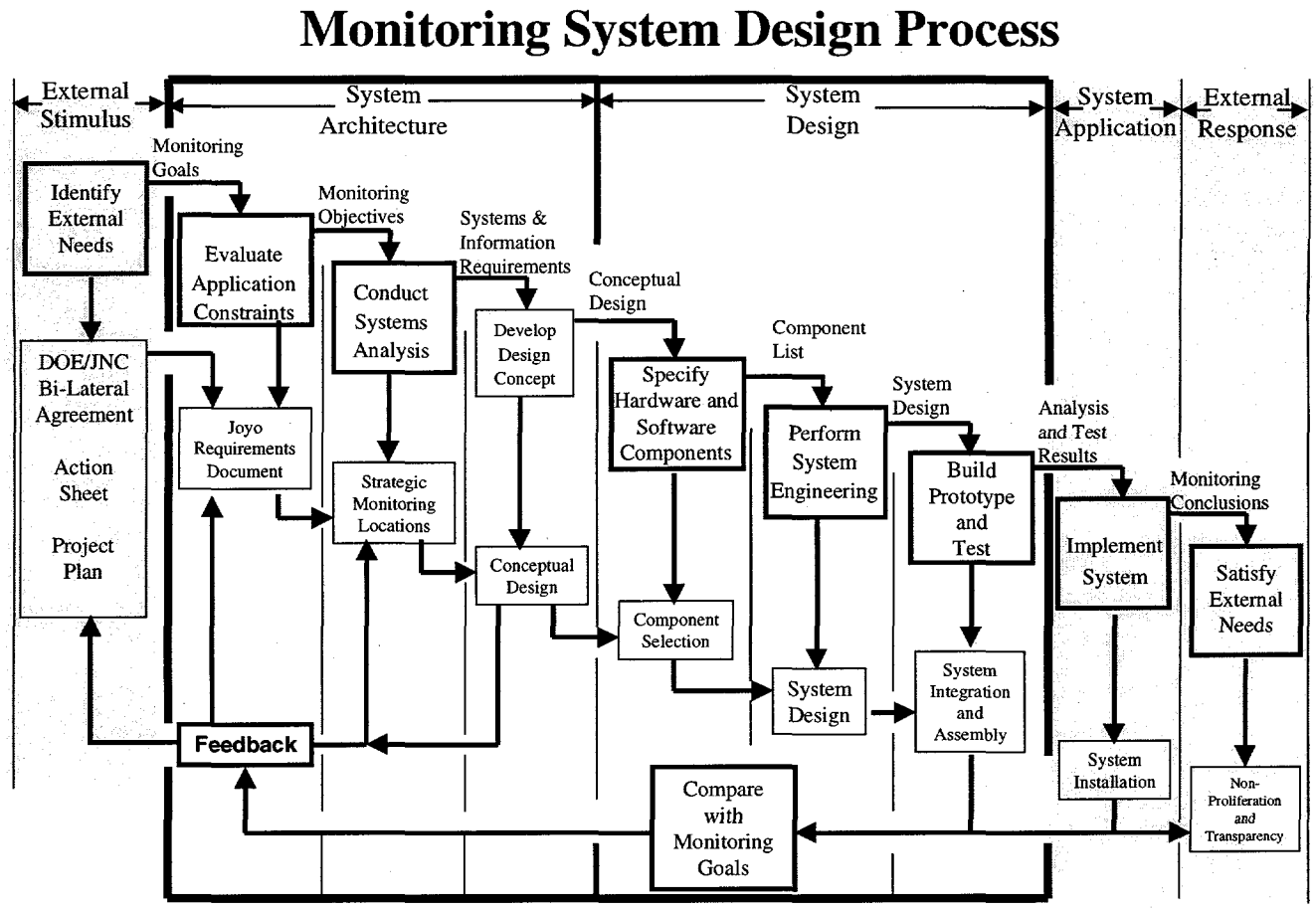

Figure 5. Monitoring System Methodology Application

CONCLUSION

Sandia National Laboratories has been an important element in the Department of Energy's effort to assist facilities throughout the world in conceptualizing, designing, and implementing unattended monitoring systems. Sandia has formalized their successful design methodology process into nine discrete steps, each of which has a specific output that leads into the following activity. Responding to requests for training, Sandia has developed a one-week, interactive training program based on this proven design methodology. This paper has described the formalized Unattended Monitoring System Design Methodology and presented the individual design process steps which also comprise the major topics of the associated training curriculum.

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under contract DE-AC04-94AL85000.