Sortie Production Optimization Team (SPOT)

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***Abstract*— This study evaluates the operational activities on an Air Force base and how they can be improved through integration of new technologies, organization of infrastructure/installations, and applied process improvement leading to a decrease in operational costs and manpower. This effort, called Sierra Bravo, was tasked to Defense Advanced Research Projects Agency (DARPA) by the United States Air Force, our work has been scoped to evaluating the sortie generation of an Air Mobility Command (AMC) base. Currently the AMC bases are slowly integrating the use of the Air Force Smart Operations for the 21st Century (AFSO-21) to improve some of their processes and organization of their installations. The study uses the AFSO-21 to evaluate ways of improving current processes, but also includes the use of Value Stream Analysis and Lean Methodology to find processes that are wasteful and develop alternatives for how the Air Force will reduce this waste. This study uses Arena software to model design alternatives and analyze/evaluate their effects on sortie generation processes, which include inspection, maintenance, loading of cargo/passengers, and refueling. The data retrieved from the simulation is then aligned with the design costs to achieve the best alternative.**

I. Overview

A. Background

The Secretary of the Air Force has tasked DARPA "to assess the wing/base structure of a CONUS fighter/attack base to provide savings of at least 30% that can be implemented over the Future Year Defense Plan (FYDP)." DARPA contracted Booz Allen Hamilton to develop a modern and efficient design of the ideal Air Force base that could be used as a model for all Air Force bases within CONUS.

To create this ideal model, research must be conducted in several different areas, such as installation support, force protection, IT infrastructure, and operations and sortie production. Technology Focus Groups (TFG) have been created to tackle these areas. SPOT is working in parallel with the sortie production TFG.

The sortie production process includes all aspects of preparing an aircraft or re-generating an aircraft, for its next mission. This process includes inspections, maintenance, passenger loading, cargo loading, and aircraft refueling. Each of these sub processes interacts with external systems and other sub processes. The efficiency of these interactions is an essential consideration of the sortie production process.

B. Stakeholders Description

The United States Air Force's mission "is to deliver sovereign options for the defense of the United States of America and its global interests -- to fly and fight in Air, Space, and Cyberspace." Being able to respond quickly and decisively anywhere needed is key to maintaining rapid global mobility. Rapid deployment and sustainment are essential to successful operations and cannot be separated.

"Air Mobility Command's mission is to provide rapid, global mobility and sustainment for America's armed forces. The command also plays a crucial role in providing humanitarian support at home and around the world." The efficient re-generation of each individual aircraft affects the efficiency of the entire AMC.

Booz Allen Hamilton (BAH) is the primary contractor of this project and the direct stakeholder to SPOTs efforts. SPOT will work in parallel but independently of the (BAH) sortie production team. SPOT and BAH meets regularly to discuss progress and share ideas. SPOT will provide BAH with all information generated from this project.

C. Problem Statement

Inefficiencies exist in the current sortie production process at US Air Force bases. Many Air Force bases are a patchwork of systems which have been developed and integrated over decades. The interaction between the systems was not adequately planed and results in wasted resources. These issues need to be addressed to reduce cost, re-generation time, and the dependence on human labor.

The US Armed Forces is interested in developing a greater level of mobility for all forces. A key component of this effort will rely on the Air Mobility Command and its ability to produce sorties. "The Air Mobility Command is responsible for providing fuel, supplies and aero medical support to troops on the frontline of the Global War on Terrorism, and for providing humanitarian supplies to hurricane, flood, and earthquake victims both at home and abroad." The ability to produce quick and reliable sorties is essential to accomplishing this responsibility.

D. Statement of Need

According to the United States Secretary of the Air Force a new vision needs to be created for the next generation air base. The next generation air base will maintain capabilities while using 30% less manpower than the current air base. Dependence on manpower is an unnecessary constraint driving up costs and reducing performance.

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Many opportunities exist to upgrade these legacy systems by restructuring the sub-system interactions and implementing new technologies. This will alleviate the labor constraint and save the US Air Force resources.

E. *Statement of Work*

To solve the existing inefficiencies of operations in Air Force sortie production and improve performance time between landing and take off, a system engineering team will conduct analysis during a period of eight months, divided into two phase.

- First Phase: To evaluate the wing/base structure of CONUS mobility bases to alleviate 30% in operating costs through the "as is" process/organizational streamlining and system architecture that can be implemented over the FYDP.

- Second Phase: Simulate and evaluate sortie production process improvements implementing innovative technology to improve the effectiveness and efficiency of expeditionary bases and CONUS bases that can be implemented in the 2015 time period.

We shall model the existing architecture, gaining a better understanding to implement a process design simulation using Rockwell ARENA software to facilitate the evaluation of alternative design. We will model and simulate each alternative design generating performance scores derived from the value hierarchy. These performance scores will be paired with their respective costs and analysis will be conducted.

Throughout this effort project management documentation will be maintained. Earned Value Management (EVM) will be tracked to determine the success of SPOT's efforts. In May 2007, we will present our recommendations to the faculty and our sponsors.

II. SCOPE

SPOT will conduct systems engineering analysis of sortie production for Booz Allen Hamilton, contracted by DARPA for the United States Air Force. SPOT will design, model, and simulate the sortie production process, which includes the period of time between landings and take-off for Air Mobility Command (AMC) aircraft, specifically C-5 Galaxy. SPOT focus on the subsystems of this process will include inspections, maintenance, passenger loading, cargo loading, and aircraft refueling.

III. OBJECTIVE

The objective of SPOT is to provide a design that allows the Air Force to perform their sortie production process at an improved performance level while reducing their operational costs. This will be achieved by conducting an in-depth Value Stream Analysis (VSA) of an "as-is" sortie production process on an Air Mobility Command (AMC) base. By using VSA, SPOT will observe tasks and processes within the sortie production that need improvements and determine what tasks/processes are waste. SPOT developed design alternatives that introduce the insertion of new technologies and improve sub-system interactions using Lean Methodology. The performance scores and cost estimations of each design alternative will be presented to SPOT's stakeholders.

IV. CONCEPT OF OPERATIONS

A. *Vision Statement*

The SPOT will conduct system engineering analysis of sortie production for Booz Allen Hamilton, tasked by the DARPA for the United States Air Force. Sierra Bravo is to "assess the wing/base structure of a CONUS fighter/attack base to provide saving of at least 30% that can be implemented over the FYDP". SPOT will analyze the period of time between landing and take-off for the Air Mobility Command planes, specifically C-5 Galaxy's. Furthermore, the analysis will concentrate on the subsystem of this progress which includes inspections, maintenance, loading passenger, loading cargo, and refueling the aircraft. SPOT's vision is to propose the best design alternative based on performance and cost.

B. *Mission Statement*

SPOT's mission is to conduct a two-semester study and simulation to develop means to enhance the effectiveness and efficiency of the Air Force airbases' sortie production. Therefore, SPOT will dedicate all efforts to the success of the Booz Allen Hamilton Sierra Bravo Sortie Production focus group. SPOT's mission is to provide reliable systems architecture, modeling, and simulation that best describes the "as is" sortie production. Moreover, the SPOT will implement innovative technology within the sortie production to maximize its performance. Performance measurements include usability, reliability, availability, maintainability, and generation time. All of these measurements aspects are critical to the team's success at the end of the second semester.

C. *Operational Scenarios*

Several operational scenarios are defined to model sortie production situations. They are depicted as top level sequence diagrams demonstrating the interactions between SPOT and its external systems.

- Scenario 1 – Sortie production goes according to plan.
- Scenario 2 – Aircraft fails post flight inspection and maintenance is required.
- Scenario 3 – Refueling pump malfunctions and trucks are required to refuel the aircraft.
- Scenario 4 – Aircraft fails pre flight inspection and maintenance is required along with unloading cargo and de-fueling aircraft.

V. ALTERNATIVES

Alternative designs have been developed such that SPOT can develop models and simulate the best alternative for the U.S. Air Force. These alternatives will be used to conduct a trade-off analysis in the second phase once the modeling and simulation is underway. The alternatives will be modeled separately and simulated such that the team can observe the output of each. Once this is done, SPOT will combine the outputs to analyze which alternatives perform most efficiently together gaining the best performance for a minimal cost.

The alternatives are stated and defined as follows:

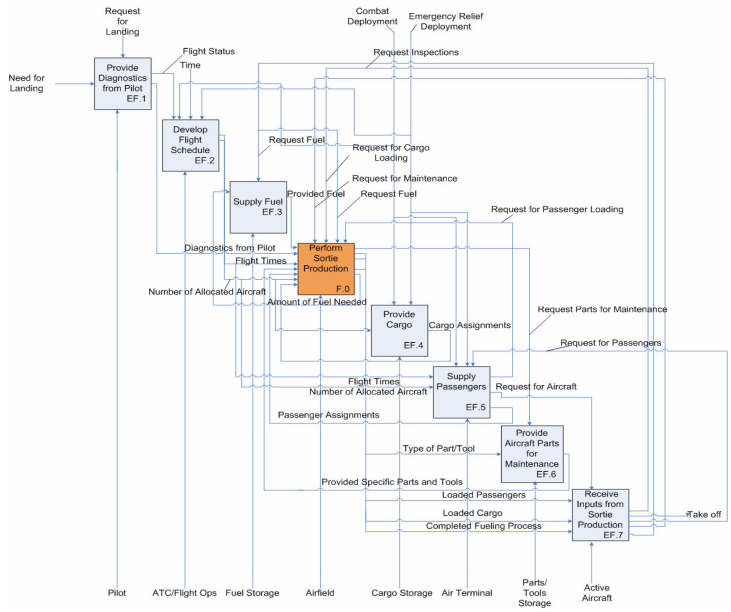
- Alternative 1: This alternative is the integration of a Diagnostic System using Data Link. The diagnostic system is placed on the aircraft and used similar to that of OnStar, often seen on GM vehicles. This system allows the aircraft to perform self-diagnostic test to determine any malfunction occurring on the aircraft as it comes in for landing. Using Data Link, the information from the diagnostic test is transmitted to the maintenance crew who determines the maintenance required. The system is assumed to be accurate to a level such that an post flight inspection process is no longer needed. All other sortie production processes remain the same.

- Alternative 2: This alternative includes the integration of Radio Frequency Identification (RFID) technology. This technology will be used in the cargo loading processes. The RFID technology allows crews to locate parts and cargo within their infrastructures. An aircraft is assigned a specific cargo load for each mission. The RFID is used to locate the load within the warehouse allowing for greater loading accuracy. This is important when trying to develop optimal flight paths.

- Alternative 3: This alternative includes the integration of an underground refueling system that allows fuel to be pipelined out to hydrants for refueling of aircraft. This eliminates the need for trucks, reducing the manpower required.

VI. EXTERNAL SYSTEMS DIAGRAM

SPOT's main function, Perform Sortie Production (F.0), interacts with systems outside the scope. These are called External Systems and are displayed in Figure 9.1.1, an External Systems Diagram (ESD), which models the "as-is" design. Within the ESD, there are mechanisms, which are responsible for the external functions. The ground operations are controlled by the Maintenance Operations Center (MOC), which is built from the Fuel Storage and Cargo Storage, the Airfield, and the Air Terminal. The air operations are controlled by the ATC/Flight Ops, which is represented as an individual mechanism within the diagram.



The systems that provide inputs and outputs to the main function such that the landing and taking off of an aircraft can occur. The systems that have been identified are as follows:

- Provide Diagnostics from Pilot: This external function is responsible for developing the diagnosis of the aircraft and reporting that data to Perform Sortie Production. The pilot gives input on the errors or lack of errors that they have observed to be wrong with the aircraft. This function is activated by the request for landing and receives an input for need to land.

- Develop Flight Schedule: This external function is responsible for providing the flight times and number of allocated aircraft. The outputs are directed to Perform Sortie Production, Provide Cargo, and Supply Passengers. The number of allocated aircraft is sent to cargo storage and air terminal such that the amount of materials and passengers can be assigned properly and efficiently. The number of allocated aircraft is also an important input into the sortie production because it allows the process to prep material for the number of aircraft that will be on the base at a given time. The flight time provided by the ATC/Flight Ops tells the air terminal and the sortie production when aircraft will be provided.

- Supply Fuel: This external function is responsible for providing fuel to the sortie production function. The trigger that activates this function is a request from the active aircraft for fuel. The amount of fuel needed for the sortie production function is reported to this function such that it can provide the accurate amount of fuel to the aircraft.

- Provide Cargo: This external function is responsible for providing cargo to the sortie production based on the operation that is requesting it. These operations range from combat to emergency relief efforts. Based on the operation and the number of allocated aircraft a cargo assignment is provided to the sortie production such that the loading process is performed in an efficient manner.

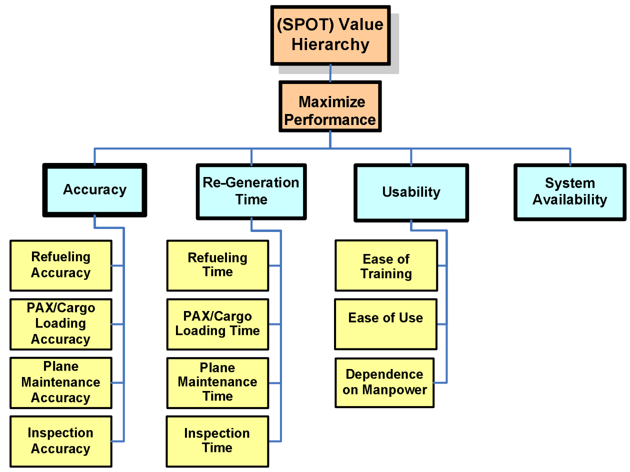
- Supply Passengers: This external function is responsible for providing passengers (PAX) to the aircraft. The type of passengers can differ based on the operational scenario (i.e. the need for soldiers or relief volunteers). The number of allocated aircraft is reported to this function so the appropriate amount of passengers can be assigned to the aircraft.

- Provide Aircraft Parts for Maintenance: This external function is responsible for providing parts/tools to the sortie production such that maintenance can be performed on the aircraft. This function receives inputs about the type of part/tool that is needed in order repair the aircraft.

- Receive Inputs from Sortie Production: This external function represents the active aircraft that interact with Perform Sortie Production. It receives inputs from the function stating that all the requested activities are completed. Some examples of this are loaded cargo, loaded passengers, and completed refueling process. Once it has received these inputs the output is that the aircraft takes off.

VII. VALUE HIERARCHY

The SPOT value hierarchy identifies the values of the stakeholder. The stakeholders are interested in generating the greatest performance at the least cost. This model acts as a metric for measuring how well a performance objective is met. Each alternative design will be measured by this value hierarchy and evaluated to determine its level of performance. Each alternative design will be assigned a performance score. The performance score along with the cost of each alternative design will be presented to the stakeholder for the final consideration.



VIII. UTILITY FUNCTION

A utility function will be used to determine the performance score of each alternative design. The utility function will consist of the sum of the major objective scores multiplied by their weights. The objective scores will be determined by our modeling and simulation.

$$PerformanceScore = \sum (ObjectiveScore * ObjectiveWeight)$$

Above is the utility function that will be used to determine the performance score of each design alternative. Each set of sub-objectives (lower level boxes) will be multiplied by their weights and summed to determine their parent objective (mid-level boxes). Each parent objective will be multiplied by their weight and summed with their respective parent scores to determine the overall alternative design performance score.

IX. MODELING METHODOLOGY

SPOT's modeling methodology will demonstrate the potential outcomes for stakeholders, allowing them to choose the most effective design alternative. The design alternatives will be evaluated once a performance score and the estimated costs of each alternative has been determined. The generation of these critical decision making elements will be explained in this section.

Mathematical models will be used to determine arrival and failure rates along with labor hours. These rates are used as inputs into SPOT's discrete event simulation model. Arena software will be used to combine the various sub functions involved and produce a re-generation time for the entire system.

As determined by the value hierarchy, SPOT will determine scores for the following performance objectives:

- Usability
- Sortie Regeneration Time
- Accuracy

- System Availability

Each of these performance objectives are decomposed into sub-performance objectives. A discrete event-based simulation will be used to determine many of the sub-performance objectives. Other sub-performance objectives will be scored by a direct comparison of the design alternatives.

A. Simulation

SPOT simulation uses the ARENA software package, developed by Rockwell Software. The ARENA simulation is a discrete event-based simulation which captures the re-generation time. Time distributions are assigned for each sub-process. These sub-processes include inspections, cargo loading, maintenance, and fueling. The simulation accommodates all design alternatives and operational scenarios.

The performance parameters measured were used to compare the total time durations for the current model and the future models. The key metrics that were examined are time durations for each sub-process, man power, and failure rate. The performance metrics were defined as follows:

- Re-Generation Time- The length of time required to complete each sub-process and the entire process.
- Man Power Utilization- The number of technicians required to successfully complete one sub-process.
- Failure Statistics- The failure rate within each sub-process. This metrics indicates the number of mistakes committed by aircraft crew during each sub-process.

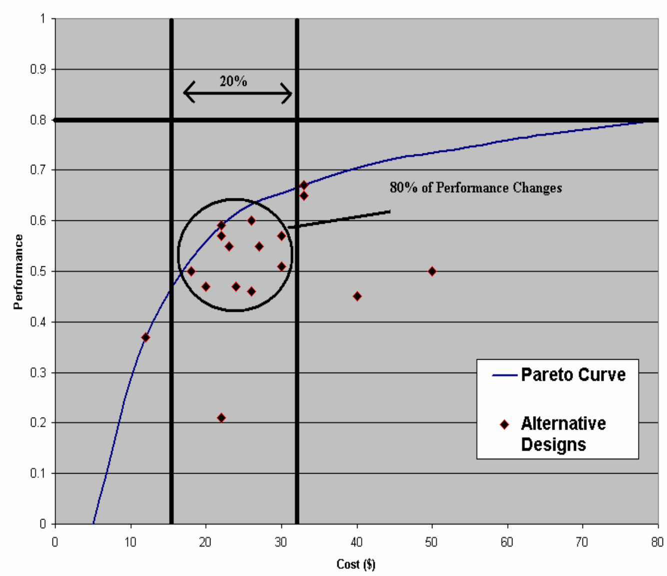
X. Cost Estimations

Cost estimations will be conducted on all design alternatives that are integrated into the sortie generation process. The cost estimations include procurement and lifecycle costs. These will be performed for Self Diagnostic System, Automates C-5 Refueling System, and Cargo RFID Placement. The cost analysis for each technology are described as follows:

- Self Diagnostic System
  The cost analysis of the C-5 Self Diagnostic System and Data Link System was calculated primarily comparing similar existing systems and mapping attributes of those existing systems to those of the C-5. Specifically, the most notable system is OnStar, developed by General Motors, which was used to develop most of the cost analysis for the Diagnostic System. The OnStar system is a vehicle self diagnostic system which monitors various aspects of the vehicle; engines, tires, fluid levels, etc. The OnStar system also provides a satellite uplink to monitor the vehicle from a central location.
- Automates C-5 Refueling Systems
  The cost analysis of the Automated C-5 Refueling System was calculated on a piece by piece basis, following the Automated Robotic Fueling System (ARFS) developed by Albert Lőrincz of the University of Louisville. Lőrincz's system, uses sensors and a robotic arm to view a vehicle, and without any human interaction, fuels the vehicle on its own.
- Cargo RFID Placement
  The cost analysis of the Cargo RFID Placement system was modeled after similar implementation used in libraries, specifically the Vancouver Public Library. Data was collected from a case study from the University of British Columbia School of Library, Archival and Information Studies regarding the implementation of a RFID system in public libraries. Radio-frequency identification (RFID) is a technology that uses radio waves to identify objects based on a unique radio frequency that requires no power source, also known as passive RFID.

XI. Analysis

The analysis will be conducted to determine the best design alternative. A current model will be run multiple times to obtain averages for each activity within the model (i.e. average for post flight inspection, pre-flight inspection, operational maintenance). These averages will be used to develop distributions and compared to activities within the TO-BE models. SPOT will use the distributions to determine if the processes are being improved or maintained for duration times. To observe how parallel processes are effected by the integration of new technologies, SPOT will use MS Project to create a GANTT chart and determine a critical path for the overall sortie generation process.
The analysis will also be conducted on cost and performance of the alternative designs.



In the chart above, the line itself is the optimal line of cost versus performance, where performance is at its peak with the least amount of cost. The Pareto Curve follows the 80/20 principle, where in this case, 80% of the performance changes fall within a 20% cost range. The alternative designs that fall on the curve are considered optimal values. The cost-performance analysis will be conducted using simulation data and performance scores. Using the Pareto Curve, SPOT will be able to determine the best alternative.

Biographies

Mr. Jean Pierre Goncalves is in his senior year in the Systems Engineering Department with a minor in Computer Science. He has work experience with Electronic Data Systems (EDS) in Herndon, Virginia; where he won EDS intern competition. He plans to fulfill a full-time position with ManTech, supporting the simulation and software development team. His interests include soccer and computer programming languages.

Mr. Kari Saade is a senior systems engineer at GMU. Kari maintains a 3.6 in major GPA and a 3.3 cumulative GPA. Kari is an active member of the International Council on Systems Engineering (INCOSE) and the President of the Systems Engineering Society (SES) at GMU. Kari will begin work in Boston, MA with Raytheon's Integrated Defense Systems (IDS) in June. He can be contacted at ksaade@gmu.edu.

Ms. Katherine Stevenson is a graduating senior from the Systems Engineering department receiving her concentration in Software Intensive Systems at George Mason University. She has had much success in gaining opportunities to work with Systems Engineering teams in several different settings. She interned with The Boeing Co. in the summer of 2005 developing requirement and qualification documentation for CH-47F Chinook Helicopters. She is currently co-oping on an architecture team at Booz Allen Hamilton where she is assisting in the development of DoD Architecture Framework for the Navy.

Mr. Tony Sukhwani is currently pursuing his B.S. in Systems Engineering at George Mason University. His concentration is in Software Intensive Systems (SIS), and he has also completed a minor in Computer Science. After graduating, Tony plans to obtain a M.S. in Software Engineering, while pursuing a career in a similar field. He can be contacted at tsukhwan@gmu.edu.

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