Proceedings of the 2020 Annual General Donald R. Keith Memorial Capstone Conference
West Point, New York, USA
April 30, 2020
A Regional Conference of the Society for Industrial and Systems Engineering

GPS Tracking System for Military Aircraft in AFRICOM Airspace

Taylor Reim and Christine Krueger

Department of Systems Engineering
United States Military Academy, West Point, NY

Corresponding Author: Taylor.Reim@westpoint.edu

Author Note: The author participated in a year-long senior research project in the Department of Systems Engineering at the United States Military Academy under the advisement of Christine Krueger, a Major in the US Army currently serving as an Assistant Professor in the Department of Systems Engineering.

Abstract: AFRICOM currently lacks a unified method of tracking military aircraft in real-time in a non-radar environment. This research evaluates several GPS candidate solutions through the Systems Decision Process and constructs a simulation model using data collected from AFRICOM representatives for over 30 aircraft in Europe. The first step in this work included defining the scope of the problem and system requirements for the GPS tracking device. Stakeholder interviews provided insight to Africom's flight behavior regarding the number of aircraft, mission frequency, and length, which was then inputted into a simulation model to gauge the number of aircraft away from each base at any given time. This analysis showed promising results, identifying and ranking GPS device elements for military aircraft as well as determining the number of devices required for each airbase. This process holds the potential to help AFRICOM track their aircraft missions on the African continent securely and accurately.

Keywords: AFRICOM, Military Aircraft, GPS Tracking

1. Introduction

United States Africa Command (AFRICOM), one of six US Defense Department's geographic combatant commands, was established in 2007 with its headquarters in Stuttgart, Germany and is currently responsible for US military operations with 53 African nations. Its mission is to counter transnational threats and malign actors, strengthen security forces and respond to crises in order to advance US national interests and promote regional security, stability, and prosperity (United States Africa Command, n.d.). As the newest geographic command, AFRICOM faces many unique challenges with a full range of missions across a large, diverse continent without a major permanent US ground presence or sustainable support from African governments (Dunn, 2016). Today, one of those challenges includes the absence of a standardized method of military aircraft tracking that utilizes modern technology for accurate, precise, and secure reporting.

While the US Army uses Blue Force Tracking, a system of ruggedized laptop computers and communications software that uses satellite links to form a wireless battlefield internet to identify friendly forces on a map in almost real-time, the US Air Force instead uses procedural tracking for its field missions in a non-radar environment (Cahlink, 2008). Procedural tracking for Air Force planes requires pilots to manually file the flight plan, log departure and arrivals, and send position reports with updates throughout the mission. This method relies completely on continuous input from the pilots, which is likely subject to human error and cannot be tracked remotely aside from the occasional position updates. Combined with the poor infrastructural support in Africa for the US military, non-automated tracking methods severely limit AFRICOM's oversight capabilities of its aircraft for operational and security purposes. Therefore, AFRICOM would greatly benefit from gaining a new secure and accurate tracking method found in many commercial aircraft-compatible GPS devices on the market today. This research seeks to understand the scope of AFRICOM's aircraft missions out of Europe concerning the frequency, length, and destination of missions while also assessing several GPS tracking devices and recommending a possible solution.

2. Methodology

The first step to solving AFRICOM's problem focused on determining the appropriate scope and system requirements. Through ongoing correspondence with the client, the scope surrounded two European airbases: Mildenhall, England, and Ramstein, Germany, which possessed a combined total of 31 military aircraft: 14 C-130Js, 15 KC-135s, and 2 C-37s. Next, system requirements from the client formed screening criteria for possible solutions to meet during evaluations, which led to the mission statement that is as follows: AFRICOM needs a unified, real-time tracking system for military aircraft in a non-radar environment to locate and monitor aircraft missions in Africa.

2.1 Systems Decision Process

The Systems Decision Process (SDP) is a multi-step problem-solving process based on systems engineering principles that leverages multiple objective decision analysis, attribute value theory, and value-focused thinking to define the problem, measure stakeholder value, design creative solutions, explore the decision trade-off space in the presence of uncertainty, and structure successful solution implementation. There are four stages of the SDP: problem definition, solution design, decision making, and solution implementation. During the problem definition stage, the systems engineer conducts research and analyzes the client's requirements. In the solution design stage, the systems engineer generates ideas and alternatives, comparing each one based on screening criteria and cost. Decision making involves analyzing each possible solution to compare risk, sensitivity, and value to choose the best candidate solution. Finally, solution implementation includes planning, executing, monitoring, and controlling the solution for the client's use. (Parnell et al., 2010). However, this research only focuses on the first three stages because this is a proposed solution that has yet to be implemented.

2.1.1 Problem Definition

In the beginning stages of this research, the focus was on understanding AFRICOM's needs and the scope of the problem, such as how to best track aircraft in Africa securely and what factors are necessary for a GPS tracking device for the military aircraft. To better understand what comprised a good tracking system, further research and stakeholder analyses with AFRICOM personnel and military pilots were used to gain information and insight. The primary stakeholder for this project was AFRICOM. The lead consultants and points of contact were US Air Force pilots currently partnered with AFRICOM. Interviews with the lead consultants found that AFRICOM needed a GPS tracking system that securely tracks aircraft, while also meeting all the client's requirements. They also wanted to know how many devices should be purchased for their airbases in Mildenhall and Ramstein. Further correspondence with the lead consultants led to the development of a basic system structure for the GPS tracking device as shown in Figure 1. The fundamental objective of our functional decomposition was to find a system to track military aircraft for AFRICOM. Essentially, the model was based on four main functions: real-time location reporting, combatant command (COCOM) compatibility, easy but effective functionality, and securely storing and transmitting data. Real-time location reporting had the two objectives of minimizing delay time and maximizing accuracy which was measured by delay time to report and distance from actual position, respectively. COCOM compatibility had the objective of maximizing compatibility, which was measured by percentage compatible with other systems, meaning if the device could detect friendly aircraft and vice versa. Ease of use had the two objectives of minimizing size and maximizing usability, which was measured by weight and dimensions for size and time required to train the new system for usability. Finally, securely storing and transmitting data had the objective of maximizing security, which was measured by the encryption level of the device. Once the initial problem statement and functional hierarchy were developed, the client reviewed both for accuracy. The problem definition stage concluded with a redefined problem statement, updated functional hierarchy, and initial work on value modeling.

2.1.2 Solution Design

By understanding AFRICOM's system requirements and desires, the solution design phase began with researching multiple portable GPS devices that were capable of tracking aircraft and that did not require installment in the aircraft to decrease the cost and number of devices needed. Several commercial GPS devices were mentioned by the client as a reference point to begin a search for alternatives before ultimately finding Blue Sky Network and Iridium products which met the client's criteria of 256-bit encryption, aircraft compatibility, and communication capabilities (Blue Sky Network, n.d.). Blue Sky Network offered three viable options, HawkEye 7200, HawkEye PT Plus, and RockAir, while Iridium offered the SHOUT nano (Iridium, n.d.). Table 1 shows the cost estimates for each of the candidate solutions for a single device, while the HawkEye PT Plus and HawkEye 7200 have quantity discounts with more devices purchased.

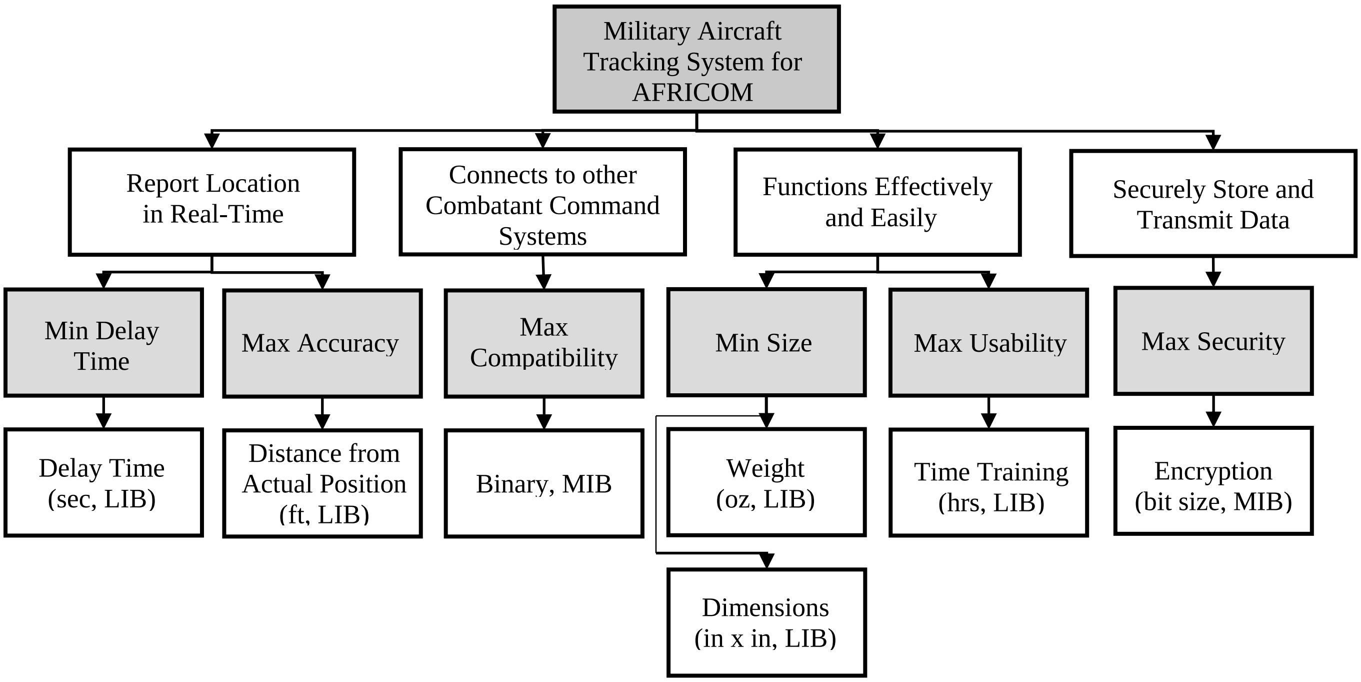

Figure 1. Functional Decomposition

According to the client, the system needed to have a minimum of 256-bit encryption that was also inexpensive and easy to use. To determine what criteria were most important, a survey based on the system objectives from the functional decomposition was taken by Army and Air Force pilots to rank each value measure and gauge the estimated swing weight for it. The results from this survey provided the measured weight for each component and allowed for the construction of a value matrix and comparisons between different candidate solutions.

Table 1. Candidate Solution Cost Analysis

Device	Price for 1
SHOUT nano	$ 746.50
HawkEye PT Plus	$ 1,495.00
HawkEye 7200	$ 1,395.00
RockAIR	$ 1,795.00

2.1.3 Decision Making

The survey data was used to construct a value matrix with global weights for each system component as seen in Table 2. Measure scores were taken from the average of the survey responses based on the ranking of importance as well as the estimated weight range. Discrepancies between rankings and weight ranges can be accounted for by an unfamiliarity with the Systems Decision Process and how weights corresponded to importance ranking.

Table 2. Value Score & Weight of System Components

Value Measure	Delay Time	Encryption	Distance	Compatibility	Time to Train	Size	Weight
Measure Score	90	80	80	60	40	10	10
Measure Weight	0.243	0.216	0.216	0.162	0.108	0.027	0.027

Each of the candidate solutions' value scores was then used to construct a weighted value matrix and a tradeoff analysis, represented by the graph of stacked bar charts in Figure 3 below. Finally, the HawkEye PT Plus system was determined to be the best candidate solution based on having the highest actual value score. The "Best Case" bar chart on the far right of the graph in Figure 3 depicts the best theoretical solution by combining the highest scores in each category together, resulting in the highest value score but not immediately available as a solution for the client since it is only theoretical.

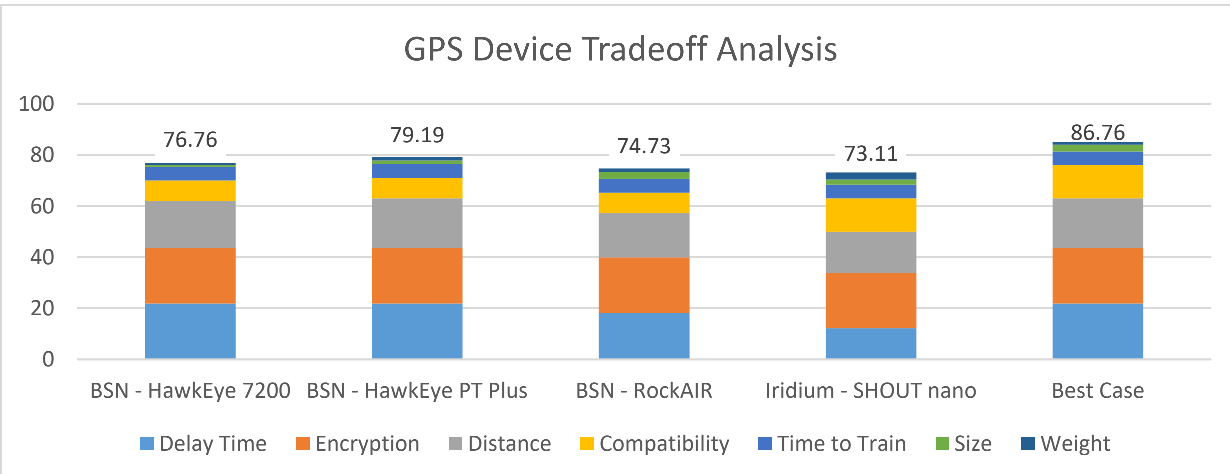

Figure 3. Tradeoff Analysis of Device Alternatives

By comparing these total value scores with their respective cost per device, a cost v. trade analysis shown in Figure 4 was created. This graph shows that while the SHOUT nano is the cheapest option, it also offers the lowest total value. The RockAIR, on the other hand, is the most expensive option while only offering a slightly higher total value than the SHOUT nano. Therefore, the two HawkEye devices are the more viable solutions where the PT Plus offers more total value than the 7200 at only $100 more per device.

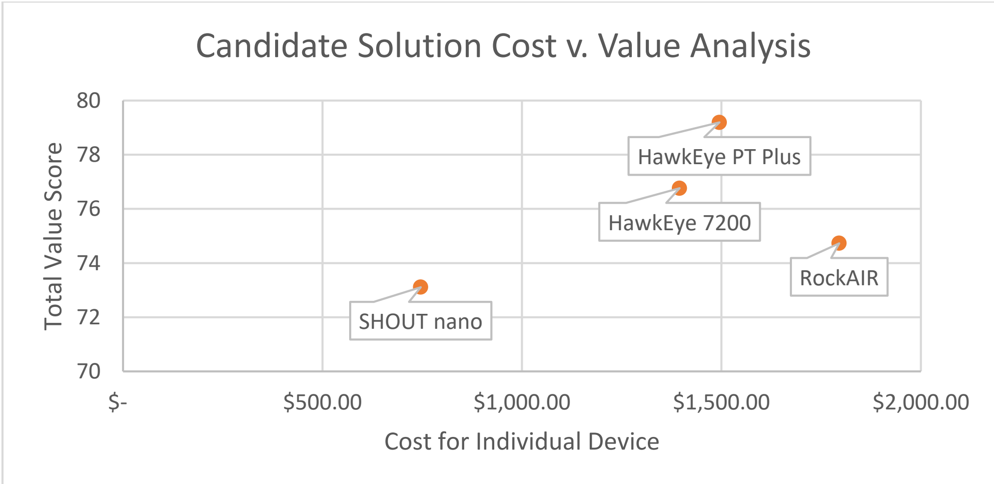

Figure 4. Cost v. Value Analysis

2.2 Model Simulation - ProModel

To determine the number of GPS tracking devices AFRICOM needs for both European airbases, a simulation model was built to find the number of aircraft present at each base at any given time. This model would provide insight into the frequency and duration of aircraft missions to aid in the final recommendation to the client. The data in Table 3 was provided by the lead consultants for the 31 aircraft out of Mildenhall and Ramstein.

Table 3. AFRICOM Aircraft Mission Data

Aircraft	# of Aircrafts	Freq	Mission Duration	Base
C130J	14	1.7 per wk	5 hrs	Ramstein
KC135	15	3-4 per wk	8-9 hrs	Mildenhall
C37	2	1 per qtr	8 hrs	Ramstein

The ProModel simulation used the type and number of aircraft, frequency and duration of missions, and the bases from which the flights originate. However, this model does not account for any other aircrafts conducting AFRICOM missions out of different bases. One assumption for this model was that the aircraft missions followed the frequency and duration given in Table 2 above with only a small amount of variation. Another assumption was that the arrival frequency of each aircraft mission followed a Poisson distribution while wait time used a normal distribution based on mission duration. The model then moved each of the aircraft from their home base to one of the African countries, waited until mission completion, and returned each aircraft to their respective home base. The goal of this simulation is to determine the average number of aircraft present at Mildenhall and Ramstein at any given time to recommend the number of GPS tracking devices to order.

3. Results

3.1 Model Output

The data output from the simulation found that Ramstein requires more devices than Mildenhall since more C-130s are in use than KC-135s. Further deduction could be made to conclude that Mildenhall only needs two devices, one primary and one backup, while Ramstein needs around four devices, two for C-130s switching out on missions, one for the C-37 missions, and one backup device. However, the model is mainly deterministic due to the frequencies of flight missions only using the normal distribution to trigger when the next aircraft will take off. To create a more realistic picture of the number of aircraft over the African continent at any given time, more probabilities will be incorporated into the current model's processing and a Poisson distribution will be used for arrival frequency.

3.2 Recommended Candidate Solution

After conducting this research, the Blue Sky Network's HawkEye PT Plus was determined to be the best candidate solution based on its total value score. It meets AFRICOM's requirements of 256-bit encryption, ease of use, system compatibility, and communication capabilities. This device is also small and portable, making it ideal for moving devices between aircraft. If six devices are required, 2 for Mildenhall and 4 for Ramstein, then the cost would amount to $8,970 at $1,495 per device. However, if AFRICOM wanted a slightly cheaper option with similar capabilities, then the HawkEye 7200 would be the best next solution.

4. Conclusion

At the end of this research, further work must be conducted on the model to increase its complexity to more accurately simulate reality. While all the candidate solutions met AFRICOM's needs, the HawkEye PT Plus proved to be the best alternative based on its capabilities and the pilots' input from the survey. This project model currently stands to offer what device that AFRICOM should purchase, but further work will be able to determine exactly how many devices should be purchased for Mildenhall and Ramstein. AFRICOM could also consider more permanent forms of a tracking system for their aircraft, which would require installation into each aircraft and therefore increase the final cost but potentially improve long-term tracking capabilities. However, as of now, the short-term solution for AFRICOM requires a portable, secure, and cost-effective GPS tracking device.

5. References

Blue Sky Network. (n.d.). *Tracking Devices: Satellite, Cellular, & GPS Trackers*. Blue Sky Network. Retrieved from https://blueskynetwork.com/shop/tracking-devices/?filter_product-application=aviation

Cahlink, G. A. (2008). Better "Blue Force" Tracking. Retrieved from https://www.airforcemag.com/article/0604blue/

Dunn, B. J. (2016). The AFRICOM Queen. Retrieved from https://www.armyupress.army.mil/Portals/7/military-review/Archives/English/MilitaryReview_20160630_art011. pdf

Iridium. (n.d.). SHOUT nano Personnel Tracker. Retrieved from https://www.iridium.com/products/nal-research-shout-nano-personnel-tracker/

Parnell, G.S., Driscoll, P.J., & Henderson, D.L. (2010, November). *Decision Making in Systems Engineering and Management Second Edition*. Retrieved from ISBN: 978-0-470-92696-3.

United States Africa Command. (n.d.). About the Command. Retrieved from https://www.africom.mil/about-the-command

Williams, K. B. (2019, February 20). AFRICOM Adds Logistics Hub in West Africa, Hinting at an Enduring US Presence. Retrieved from https://www.defenseone.com/politics/2019/02/africom-adds-logistics-hub-west-africa-hinting-enduring-us-presence/155015/