INCREASING AIRLIFT AVAILABILITY THROUGH OPTIMIZATION OF PRESIDENTIAL SUPPORT MISSIONS

Graduate Research Paper

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Abstract

The president of the United States of America's effortless descent down Air Force One's stairs belies a tremendous logistical operation required to ensure the safety, security, and effectiveness of each and every visit. By law, the Department of Defense provides non-reimbursed assistance to the United States Secret Service in support of the Presidential and Vice-Presidential protection missions. This support takes many forms, but doubtlessly, the most expensive is the provision of airlift for the movement of specialized vehicles, equipment, and personnel for all non-local travel by the president. The volume of airlift required and the frequency of travel represent a significant demand for aircraft and aircrew to United States Transportation Command and Air Mobility Command, who operate the strategic airlift fleet for the Department of Defense.

This paper explores a quantitative methodology to answer the question of whether a more cost-efficient alternative exists for the current airlift-only distribution system. Demand point coverage via line-hauling is evaluated using Maximal Covering Location Problem tools.

This analysis indicates that significant quantity of presidential support missions can be achieved via road distribution in lieu of airlift. Expected value costs are determined which can be used in conducting cost-benefit analysis as required by the Department of Defense.

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To my wife and children, for their service, sacrifice, love and support this year – and always.

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Travis C. Harvey

Table of Contents

Page

List of Figures

List of Tables

INCREASING AIRLIFT AVAILABILITY THROUGH OPTIMIZATION OF PRESIDENTIAL SUPPORT MISSIONS

I. Introduction

General Issue

In the performance of his duties, the president of the United States of America travels extensively within the country and around the globe. However, he does not travel lightly, and the logistical tail associated with positioning and de-positioning the specialized security, communications, and transportation equipment places a significant demand on available military strategic airlift. The current distribution system, the volume of airlift required, and the high cost of this mode creates an occasion to seek efficiencies by re-orienting the ecosystem to a ground-based distribution network. The hypothesized net benefit is a reduced opportunity cost to other Combatant Commander validated airlift requirements and increased combat employment training opportunities for the aircrew, while also offering a best value proposition to the taxpayer.

Problem Statement

The current distribution scheme concentrates the presidential support assets for airlift at two distribution points: Joint Base Andrews, Maryland, and Marine Corps Base Quantico, Virginia. This model provides a convenient and responsive network for the users (United States Secret Service, White House Military Office, White House Communications Agency, Marine Corps, White House Medical Office, and the White House Transportation Office). However, strategic airlift aircraft (primarily the C-17 Globemaster III and C-5 Super Galaxy) are not co-located with the distribution points and must be flown from their domiciles to and from the National Capitol Region. These positioning and de-positioning flights are often flown devoid of cargo with no other mission objective than moving the aircraft from one location to another.

The use of airlift is a costly means of transportation and the number of aircraft used is significant. In addition to direct fixed and variable operating costs, other externalities are imposed on the aircraft fleet and aircrew training and seasoning. Higher flight-hour utilization rates require additional maintenance operations and contribute to decreased overall operating lifespan of these low-density combat aircraft. In an attempt to achieve operating efficiency, these support mission assignments are concentrated at the closest air bases to the distribution points of Joint Base Andrews and Marine Corps Base Quantico. This geographic preference spreads costs unevenly across the fleet of strategic aircraft, accelerating the impacts among the most-utilized domiciles. Additionally, these missions take priority over all other missions, resulting in a direct opportunity cost to other essential military operations.

Less tangible costs are borne by the aircrew. From a training perspective, these cargo missions are considered simple in comparison to flying unique or hazardous cargo into combat zones, resulting in a less-seasoned combat aircrew. Further, the high frequency of mission assignment, or tasking, increases the total time pilots and loadmasters are away from their families. This could decrease job satisfaction and impair retention efforts.

Research Focus

This paper focuses on domestic presidential travel within the 48 contiguous states (CONUS). Because domestic travel support requirements represent such a small portion of the overall international White House airlift requirements, this area of focus has been largely overlooked in literature. Investigation into the CONUS problem set, however, provides many advantages, including lower perceived security risk, backup coverage opportunity, and higher frequency of occurrence, particularly in election years. These factors, coupled with the high cost of airlift, make this area ripe for research.

This paper further concentrates on the support provided to the United States Secret Service and the White House Transportation Agency. Other agencies are excluded from analysis for various, sometimes unrelated reasons: infrequency of support; classification; low volume domestic requirements; or an otherwise optimized system, such as the Marine Helicopter Squadron One. This is not to say, however, that there is no room for reorganization or efficiencies in these and other similar areas, as well. Potential avenues for research efficiencies in the organization of support for these agencies are noted in the Recommendations for Future Research section.

Research Questions

1) Can an alternative mode of equipment distribution from Joint Base Andrews, Maryland, effectively meet user requirements?
2) Can establishing an equipment distribution center at a location other than Joint Base Andrews, Maryland, substantially reduce costs to the Department of Defense?

Methodology

A Maximal Covering Location Problem (MCLP) analysis is conducted to identify a global maximal ground transportation solution in lieu of airlift. This analysis is further refined using a Google Maps Maxtrix Distance API. The resulting model is re-evaluated using a deterministic scenario that acknowledges existing infrastructure. This investigation is completed by a cost-benefit analysis comparing the global maximum, deterministic, and *status quo* scenarios.

Assumptions/Limitations

Assumption 1: Future presidential travel conforms to existing patterns for frequency and destinations.

Assumption 2: The payload will be considered on a whole-aircraft basis, as aircraft are provided on this standard for these missions.

Assumption 3: Consecutive local events can share equipment sets and/or airlift.

Limitation 1: Some data pertaining to presidential support operations are classified. Those elements are omitted from discussion in this paper. Additionally, some data will be treated in the aggregate to avoid revealing otherwise sensitive data.

Limitation 2: The archived database of flight records from GDSSII has significant gaps in its records.

Implications

While this research is tailored for the purposes of the White House Military Office and the United States Air Force, its approach to optimizing distribution channels while ensuring high asset availability could be applied to other federal and state agencies for regular and emergency activity support, such as disaster relief. Additional applications could be made in mode determination decisions for the United States Transportation Command when origin and destination pairs are located within the continental United States.

II. Literature Review

Chapter Overview

This chapter explores the United States Air Force's evolving responsibilities in providing airlift for the presidency prior to examining the current situation. Past academic treatments and military staff attempts to address this problem are presented. The chapter concludes with a review of academic literature describing the facility location problem of operations research and supply chain management.

Overview of Presidential Airlift Support

The United States Department of Defense (DoD) has the responsibility and honor of supporting travel by the president of the United States, both domestically and internationally. This support first began in 1936, with dedicated airlift established in 1944 for President Franklin Roosevelt. (Kersey, 2001:2) Since this time, support requirements have increased with the concurrent evolution of aviation technology, domestic and international security threats, and political requirements. The use of aircraft to rapidly and safely transport the commander in chief and head of state has helped define the modern presidency, which is characterized in part by physical omnipresence. This seeming ability to be everywhere can be seen in campaigning, comforting the nation in moments of tragedy, conducting the business of the nation from anywhere in the world, and even simply escaping the pressures of Washington, DC.

The age of jet travel dramatically increased the convenience, and therefore the frequency, with which the president travels. Domestic travel is particularly attractive, with the ability to visit several states in just one day, and still return to the White House in time for dinner. The demand for travel has only increased with the passage of time. Perhaps the most potent symbol of the president's ubiquitous presence is the arrival of the VC-25, known as Air Force One. However, his effortless descent down the air stairs belies a tremendous logistical operation required to ensure the safety, security, and effectiveness of each and every visit.

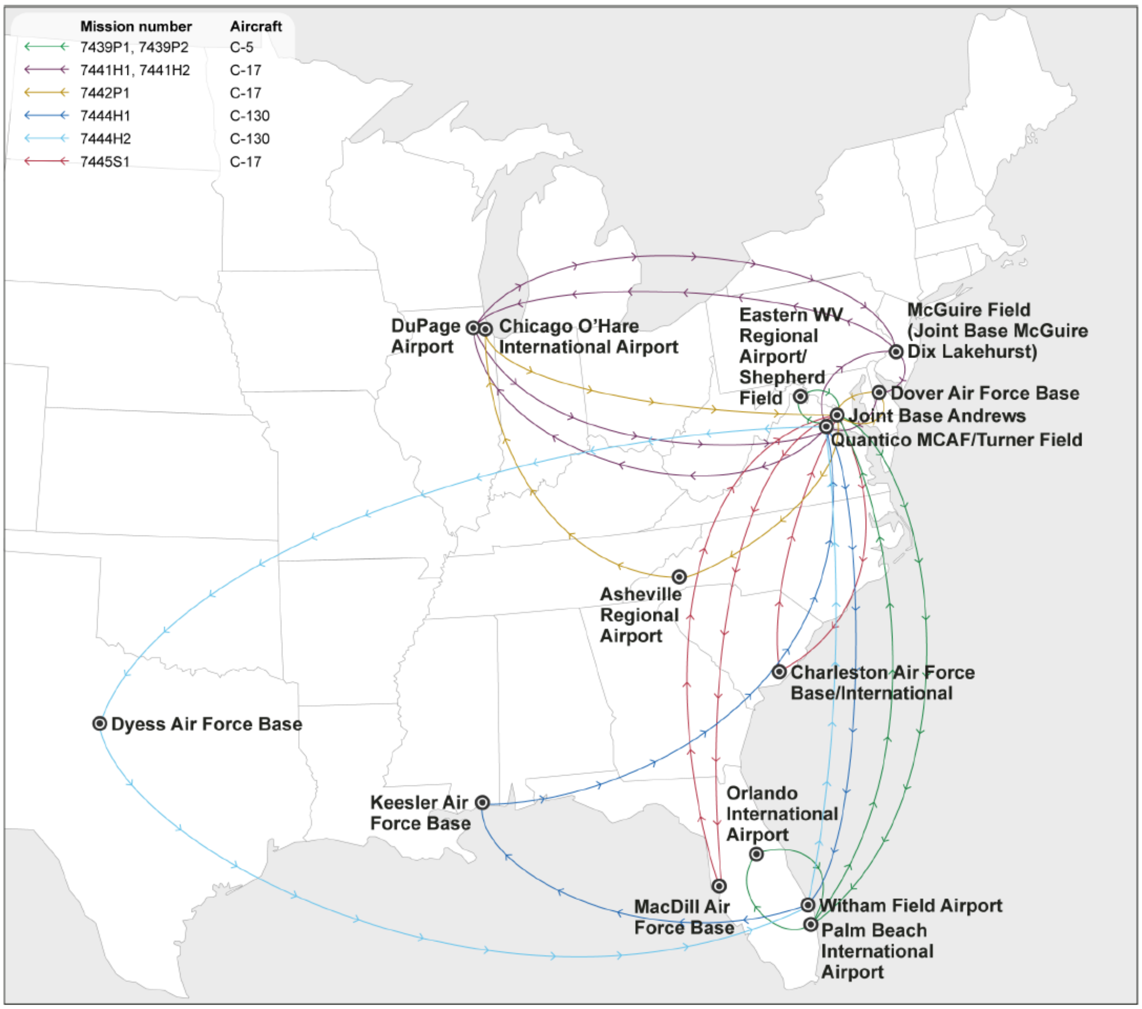
Responsibility and authority for the DoD's support of the United States Secret Service derives from 18 United States Code §3056. This law requires that the DoD provides support for presidential protection without reimbursement. (United States Congress, 1976) The secretary of defense is responsible for detailing DoD compliance with 18 USC §3056, which has taken the form of Directive 3025.13. This directive requires that presidential support requests must "[a]t a minimum . . . be evaluated based on their legality, lethality, risk cost, propriety, and impact on military readiness." (Department of Defense, 2017:2)

Current Situation

Airlift Requirements

Previous studies have identified that White House missions consume 10.72% of annual military airlift missions. (Reese, 2001:45) Figure 1 typifies the airlift requirement for a single presidential trip within the CONUS. Eight aircraft flew twenty-six sorties to deploy supporting equipment and personnel to two locations. This cost of airlift alone for this trip was just under one million dollars and did not reflect the costs of military personnel costs and entitlements or backhauling equipment. (Government Accountability

Office, 2016:8-10) Multiple-destination day trips are not uncommon, and correspondingly increase the amount of airlift required.



Source: GAO analysis of Air Mobility Command mission data. | GAO-17-24

Figure 1 - Typical Airlift Missions in support of domestic presidential travel (GAO,2016:9)

Demand Patterns of Travel

The demand for travel follows a pattern, with the greatest demand occurring in the "re-election year, followed by the second year of a term—in which presidents frequently campaign and raise money for their co-partisans in the midterm elections—then the third year, and finally the first year in office." Travel is highly correlated to state population, with the states with higher populations receiving more visits. The correlation coefficient between state population and visit-days is 0.94. Additionally, major population centers receive a disporportionate number of visits. (Doherty, 2017:17-19,22)

Since the early 1980s, presidents are utilizing the ease of access to air travel to take more trips, to more places, at a more rapid pace than ever before. Figure 2 demonstrates the growth in domestic and international travel undertaken by recent presidents. From President Reagan's second term, non-local domestic travel days increased by 202%, peaking during President George W. Bush's second term. This dramatic increase in travel days represents not only an increased number of overall trips, but also an increased number of destinations per trip, resulting in shorter time spent at a single location. This figure belies an underlying trend of decreasing time spent at a single location, such that the number of destinations visited has increased concurrently with an increased number of overall trips. (Doherty, 2017:17-19) Given the pace of travel, this effect compounds demand on the military airlift fleet as it must service multiple destinations concurrently. Yet, over the same period as demand more than doubled, the size of the airlift fleet decreased by approximately 40%. (Everstine, 2019)

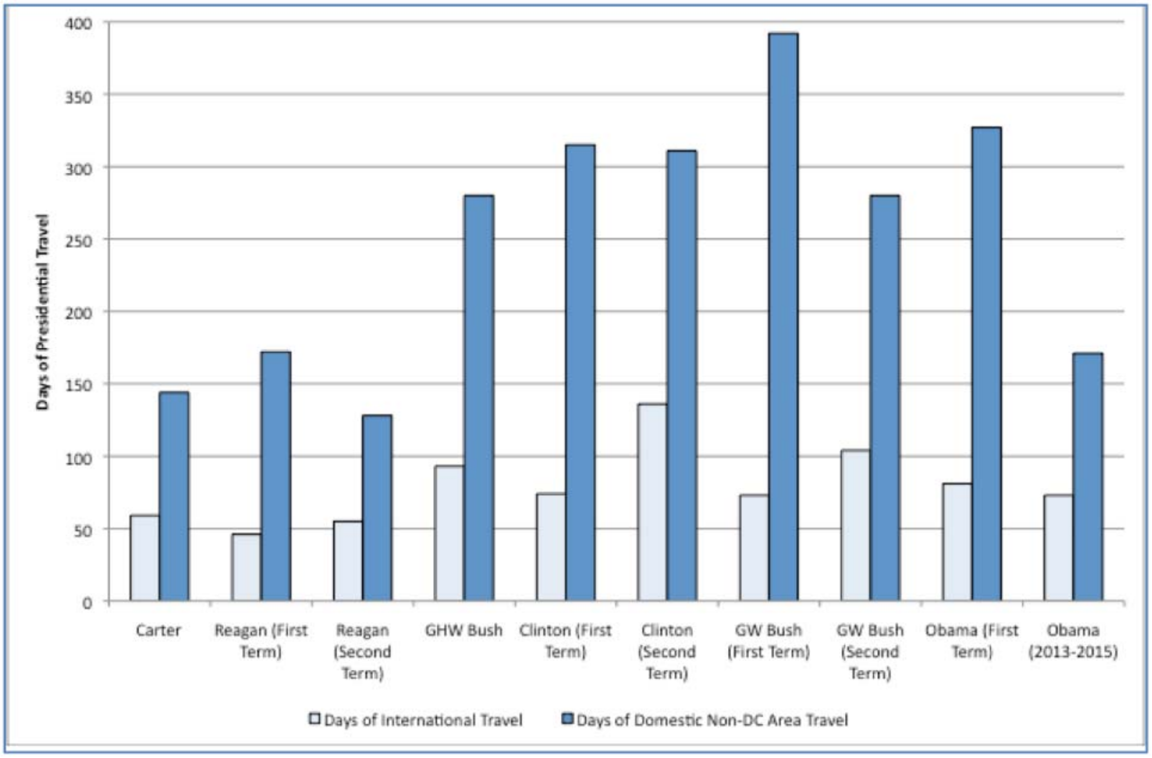


Figure 2 - Days of Presidential International and Domestic Travel, 1977-2015 (Doherty, 2017:4)

Assessing Costs

Determining the true cost of presidential travel presents a myriad of issues. It is difficult to establish the actual cost due to the division in labor between different departments and agencies, different methods of accounting, the political sensitivity of detailing such costs, the classified nature of some support operations, and poor accounting practices within the government. (Kersey, 2001:5,12; General Accounting Office, 2000:6-8) Even within the single entity of Air Mobility Command (AMC), it is difficult to determine a true tabulation of costs.

AMC reports presidential airlift operation costs at the Special Assignment Airlift Mission (SAAM) hourly and Minimum Activity Rate (MAR), as published by the United

States Transportation Command (USTC). AMC publishes a rate manual for SAAMs each Fiscal Year (FY). Organic (military) airlift rates for FY2020 are computed by multiplying the flying hour rate (by type of aircraft) by the number of flying hours for each sortie including position and deposition legs. Any MAR is then added to determine the final tally, to determine total cost. (AMC, 2020:7)

Missions in support of presidential airlift are exempt from delay or "stand-down" fees and are ineligible for scheduling incentives. A MAR of 2 hours billable flight time applies, which "is the charge levied on the user for requests that involve reaction or response that is not otherwise chargeable by reference to other tables." (AMC, 2020:1,3) For presidential airlift, non-DOD U.S. Government movement rates are applied and are depicted in Table 1 below. (AMC, 2020:4,6)

Table 1 - FY20 Non-DoD US Government Charter Hourly Rates and Minimum Activity Rates for Aircraft on TWCF Missions (AMC, 2020:10)

AIRCRAFT	SAAM/JETP/ CONTINGENCY FLYING HOUR RATE	MINIMUM ACTIVITY RATE
C-5	$35,321	$70,502
C-130E/H	$9,252	$18,504
C-130J	$12,657	$25,314
C-17	$17,300	$34,600
KC-10	$24,478	$48,956
KC-135	$15,133	$30,266
KC-46	$20,004	$40,008

Using these SAAM rates, the United States Government Accountability (formerly "Accounting") Office (GAO) has issued several reports on the logistical costs of presidential travel in response to Congressional inquiries. To determine costs, reports from 1999 and 2000 summed published flying hour rates for military aircraft flown in support of a specific international presidential trip, multiplied by the AMC self-reported actual flight hours. These reports did not including MAR in their calculations. (GAO, 2000:9).

Later GAO reports expanded the accounting methodology to include per diem entitlements for lodging, meals, and incidental expenses of government employees across multiple departments and agencies. This number, however, was not reported by Air Mobility Command, and the GAO made no further effort to establish an actual, representative figure. Table 2 demonstrates the expense breakdown of a single day, two-state domestic trip by the president in 2013. This trip incurred an estimated cost of nearly three million dollars, of which airlift of supporting equipment accounted for 34.7%. (GAO, 2016:9).

Table 2 - Estimated Travel-Related Costs of a Presidential Trip, $ Millions (Government Accountability Office, 2016:10)

	Cost of Aircraft Used[a]	Per Diem and other related expenses[b]	Total
Air Mobility Command	$986.7	N/A	**$986.7**
89th Airlift Wing	$1,346.9	$24.2	**$1,371.1**
U.S. Marine Corps	$429.7	$46.9	**$476.6**
Military Working Dog Program	N/A	$4.9	**$4.9**
Total			**$2,839.2**

Source: GAO analysis of DOD data. | GAO-17-24

A review of contributions by military authors indicates that significant non-financial costs exist for both the White House and the Department of Defense. During periods of conflict, the military may be forced to reallocate aircraft for combat or combat support operations, “drastically” diminishing the president’s ability to travel. (Miller, 2003:6) Other authors suggest, but literature does not establish, that the military fulfills its obligations at the expense of force readiness and training for combat operations. (Kersey, 2001:15)

Other Research and Staff Studies

Academics and staff officers within the military community have identified and attempted to address the inefficiencies in the current distribution system. Another researcher proposed establishing a “Super C-17” squadron at Joint Base Andrews, from which most presidential airlift operations begin and terminate. (Miller, 2003:27) As Joint Base Andrews does not possess strategic airlift capability, supporting aircraft must fly empty positioning and de-positioning flights from their own main operating locations. These unproductive sorties decrease aircraft total life cycle, increase maintenance costs by reducing overall mean time to failure (MTTF), increase per mission operating costs due to additional fuel consumption, and increase aircrew temporary duty assignment (TDY) rates.

The Air Force did not adopt this recommendation on a permanent basis, opting in October 2003 to convert the existing 459 Airlift Wing from C-141 cargo aircraft to KC-135 air refuelers and re-designating the unit as the 459 Air Refueling Wing. (United States Air Force, 2016) However, it has continued to create and stage small, temporary strategic airlift units at Andrews to coincide with increased demand in election years (Colella, 2019).

In another effort to reduce the strain, USTC, AMC, and the WHMO tested the ability to outsource airlift to commercial partners in lieu of military airlift in 2019. This effort was judged unsuccessful as the WHTA/USSS's vehicles were found to be incompatible for loading on commercial aircraft. Additionally, the commercial carriers could not provide the flexibility for short-notice mission assignment and changes (cancellations, late arrival of cargo to the aircraft, location changes), burdens which the military must otherwise bear. (Colella, 2019) This study confirmed constraints anticipated by Kersey. (2001:35)

Research thus far has centered on parochial sub-optimization solutions: focusing on finding efficiencies in the Air Force's methods of doing business, either by co-locating aircraft to the customer or commercial airlift substitutes for military aircraft. The implicit assumption in each of these studies is that the Air Force cannot "move the user" or compel any of the supported agencies to redistribute their assets in a more efficient arrangement. (Colella, 2019) In sum, if a time and mone-saving solution is to be found, the onus has been on the Air Force to produce it.

Facility Location Problems

Development

The type of analysis required for this paper's study is a facility location problem. First described in the 1750s by the Weber-Fermat problem, which sought to minimize transportation costs between three points, a mathematical solution was not achieved until the 1970s. Shortly thereafter, the field split into two approaches: the Location Set Covering Problem (LSCP) and the Maximal Covering Location Problem (MCLP). The LSCP, given a set response time or distance, seeks to satisfy *all* demand points while *minimizing* the number of facilities required, as exemplified by fire or emergency services stations. (Toregas, Swain, ReVelle, and Bergmann, 1971; Toregas and ReVelle, 1973) Alternatively, the MCLP, given a set response time or distance, seeks the *maximum number* of demand points to be satisfied by a *constrained minimum* (either defined or calculated) number of facilities. (Church and ReVelle, 1974) This problem is typified by library or hospital location decisions, which gain service advantages through concentration rather than dispersion or are subject to fiscal constraints. This field of study can be classified by twelve principle characteristics: purpose, distance, number of facilities, space, time, parameters, competition, capacity, model type, number of objectives, and different facility types, and solution approach. (Turkoglu and Genevois, 2019:21)

As MCLP matured, real-life applications uncovered a "congestion effect," in which imbalances in demand could lead to a lack of coverage, despite being within the response time parameter. Two broad approaches emerged to resolve this inefficiency. First, a deterministic "backup coverage" model, which maximized redundant coverage utilizing existing model constraints. (Daskin and Stern, 1981; Berlin, 1972) Another approach proposed by ReVelle and Hogan maximized expected coverage by utilizing either uniform or random probabilistic estimation of a "server busy fraction." (1987) The MCLP further matured by recognizing that facilities could not serve an infinite amount of demand concurrently, giving rise to *capacitated* facility problem-solving.

Precedence and Applications in Military Decision Models

Despite its establishment in literature and recognized broad application to defense problems by civilian investigators, a search of literature discloses surprisingly few applications of MCLP in defense problem-solving. Within the Defense Department's research repository, only five studies apply this methodology. These applications include positioning of theater airborne surveillance assets (Fuller, 1997); search and rescue stations (Basemir, 2000); intercontinental ballistic missile (ICBM) defense and maintenance scheduling (Overholts, 2006); alert aircraft posturing with changing threat anticipation (Arslan, 2009); and chemical, biological, radiological, nuclear (CBRN) response network design (Paul, 2015).

Summary

Supporting presidential travel is a high honor and a high burden for the DoD, in particular AMC, which operates and maintains a fleet of specialized high-demand military airlift aircraft. Contrary to regulatory directives to conduct cost-benefit analyses, the exclusive use of military airlift is evidence itself that no effective cost analysis is conducted prior to mission assignment. Further, the number of these non-reimbursable missions have doubled over the past thirty years as the size of the airlift inventory has decreased by nearly half, burdening capacity and budgets. Previous attempts in literature to resolve these issues have not been implemented and have failed to consider re-orienting the transportation network to other, more cost-effective modes. Research literature offers a means to empirically describe a cost-effective alternative distribution structure through the use of MCLP.

III. Methodology

Introduction

This paper utilizes MCLP to find global optimal warehouse facility locations that maximize the coverage of public presidential events. The coverage achieved by any location is contingent upon a set proxy estimates that substitute for direct measurement of maximum drive time allowed by law. Nearby federal properties will be identified based on proximity to the calculated optimal locations. These properties will be evaluated using commercial software to derive travel-time tables to estimate actual coverage. This method will then be applied to a facility co-located with the White House to determine coverage from the Washington, DC area.

Definition of Terms

I the set of domestic presidential events (1, … , 2791);

J_n proposed warehouse facility location;

R_J radius of coverage;

t_{ii} distance from event demand point *i* to warehouse *j*

s_{ij} binary condition indicating whether or not the great circle distance between event *i* and proposed warehouse facility location *j* falls within the maximum specified radius of coverage; the variable is one if the demand point is covered and zero otherwise;

a_{ij} binary condition indicating whether or not event *i* is covered by at least one warehouse facility location *j*; the variable is one if the demand point is covered and zero otherwise

x longitudinal value for a given location

y latitudinal value for a given location

Event Demand Points (I)

Event Demand Points *(I)* are defined by the latitude and longitude pair associated with a unique record of a public event attended by the president. This set of 2,791 locations represents public presidential events, where subsequent events are separated by a distance greater than forty miles.

Proposed Warehouse Facility Location (J_n)

The proposed warehouse facility location is the computational variable expressed as a latitude and longitude pair. It was assumed that if the support equipment can be delivered via an over the road mode, then that capability will exist at the origin. While the actual White House Transportation Agency garage location is undisclosed, it can be assumed to be within a reasonable proximity of the presidential residence. The White House is therefore used as a proposed distribution location:

$$J_{WhiteHouse} = (38.8977° \text{ N}, 77.0365° \text{ W}).$$

Radius of Coverage (R_J)

Federal law establishes hours-of-services regulations that govern minimum hours of rest before performing transportation duties; maximum periods while engaged in driving duties; and maximum driving time. For this paper, the eleven-hour maximum driving time within a fourteen-hour duty period for property-hauling commercial trucking is accepted as a constraint. (FMCSA, 2013) This standard does not apply in all circumstances, as the DoD Traffic Safety Program takes precedencefor military personnel, DoD civilians in duty status, and any person operating a Government-owned or leased vehicle. The DoD Instruction (DoDI) 6055.04 limits driving time to ten hours during a duty period, and directs to the maximum extent possible that driving be accomplished during daylight hours only. (United States Department of Defense, 2009:1,23) During the course of research, no similar directive was found for the Department of Homeland Security, which contains the USSS as a subordinate agency.

Accepting a time-defined radius complicates the analysis due to differing units of measure. Literature typically utilizes Euclidian (direct or "as the crow flies") vector distance or a metropolitan rectilinear distance (city-grid) on a two-dimensional plane. Additionally, models are oriented toward population centers (private sector) or average distance traveled by patrons (public sector). (Fitzsimmons, Fitzsimmons and Bordoloi, 2014:224) However, great circle distance must be used when the difference between two points on the surface of a sphere exceeds a few meters. The aforementioned formulas measure distance; however, the constraint in this problem is measured in hours.

An ideal model would calculate the global optimum location by comparing coverage sets through actual driving time between origin-destination pairs. Indeed, several commercial programs offer facility location tools that appear to do this; however, their methodologies and datasets are proprietary. By stepping back from a proprietary solution, R_j is determined for this study through an iterative framework of proxy estimates. These proxies permit rapid computational analysis by reducing the complexity of calculations. In this analysis, a demand point is covered if it falls within the great circle distance R_j of an optimizing origin latitude, longitude pair. By comparison, an ideal model would recursively plot the path and associated drive time to each demand point. A sensitivity analysis is performed at a number of fixed distance intervals to examine the effect of the proxy estimate on the solution. This set of proxy R_j values will be validated against travel-time tables generated by the commercial platform, Maptitude. (Caliper Corporation, 2020)

The upper bounds (R_{Jmax}) is defined by a maximum logical value, calculated by multiplying the maximum legal driving time (11 hours) by a rate. The national maximum speed limit (70 MPH) represents the upper bound of a feasibility region with zero MPH defining the lower bound. Both of these rates would be unlikely to truly represent a coverage radius. An arbitrary value of 85% of the national maximum speed limit, assuming interstate travel from origin to destination, is used to establish a maximum logical value of 654.5 miles, as described by the equation:

$$Driving\ Time\ \times\ Rate = 11\ hours\ \times (\ 0.85\ \times 70\ miles\ per\ hour) = 654.5\ miles \quad (1)$$

The lower bound proxy estimate (R_{Jmin}) is derived from an industry published standard trucking rate of 39.42 miles per hour (MPH). This average rate is derived from all sectors of trucking under a variety of operational conditions, including industry sectors (long-haul vs. inter-city), terrain (mountainous or level), and climate. (Murray and Glidewell, 2019:10) Given these factors, this rate is taken to be a lower-bound due to the nature of this particular problem, including point-to-point delivery (warehouse facility directly to point of demand vs. multi-stop inter-city routes), with the bulk of deliveries arriving at airports, which are further assumed to be directly adjacent to a network of quality roads.

For the sensitivity analysis, the distance between R_{Jmax} and R_{Jmin} is divided into four equal segments of 44.176 miles, which approximate successive one additional hour of travel time over R_{Jmin}, for a set of constraining proxy range estimates of 433.62, 477.80, 521.97, 566.15, 610.32, and 654.50 miles.

Problem Formulation

MAXIMIZE: $$\sum_{i \in I} \sum_{j \in J} a_{ij} \quad (2)$$

SUBJECT TO:

$$s_{ij} = \begin{cases} 1, & t_{ij} \leq R_J \\ 0, & t_{ij} > R_J \end{cases} \quad , \forall i \in I, j \in J \quad (3)$$

$$a_{ij} = \begin{cases} 1, & \sum_{j \in J}^{I} s_{ij} \geq 1 \\ 0, & \sum_{j \in J}^{I} s_{ij} < 1 \end{cases} \quad , \forall i \in I, j \in J \quad (4)$$

Solution must be within the Continental United States, such that $j_{x,y}$:

$$66.95°\text{W} \leq j_x \leq 124.733°\text{W} \quad (5)$$

$$25.1166°\text{N} \leq j_y \leq 49.3833°\text{N} \quad (6)$$

WHERE:

$$t_{ij} = R_{earth} \times \cos^{-1}[\sin j_y \times \sin i_y + \cos j_y \times \cos i_y \times \cos(i_x - i_{xg})] \quad (7)$$

R_{earth} = 3,958 miles

R_J = (433.62, 477.80, 521.97, 566.15, 610.32, 654.50)

Data Preparation

Global Decision Support System II Data

The initial proposal for this research relied upon a database of archived military transport aircraft missions provided by the AMC Analysis, Assessments and Lessons Learned (A9) Directorate. This data included missions flown by Air Mobility Command from 1 January 2011 to 31 December 2019. However, when the presidential support mission data was grouped by quarter-year increments, significant gaps were discovered in the completeness of the database (see Table 3). This problem has been a source of frustration to previous researchers. (Kersey, 2001:5) Given the distribution of missing blocks of data, it is assumed that these gaps in data are the result of improper archiving procedures, rather than due to variation in data. While not useful for creating a weighted-demand travel pattern for presidential travel, the data set was useful for assessing how AMC supported agency requests. This information was used to develop a flight-hour cost model for supported missions.

Table 3 - Completeness of GDSSII archived data

Year	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
2011	X	X	✓	✓
2012	✓	X	X	X
2013	X	X	✓	✓
2014	✓	✓	X	X
2015	X	X	X	X
2016	X	✓	✓	✓
2017	✓	✓	✓	✓
2018	✓	X	X	X
2019	✓	✓	✓	X

✓ Data contained in this period

X No data contained in this period

The available data was filtered to reflect only operational missions flown in support of the president by decoding a twelve-digit mission identification number. The data was filtered further, identifying those missions by supported agency: USSS, WHCA, and HMX-1. This process was accomplished by utilizing the MAF Mission ID Encode/Decode Procedures, with additional assistance of 618 Air Operations Center personnel. (AMC, 2017:19) This process is not detailed in this report, as it could expose sensitive information. The format of the mission number allows the possibility of mission numbers being recycled from one year to the next. To mitigate this possibility, a unique data tag (line number) was assigned to each mission.

These missions had a four-stage format: 1) positioning flight of the aircraft from its home station to the distribution point of Andrews (ICAO: KADW); 2) initial equipment deployment to demand point; 3) redeployment of equipment to KADW; and 4) depositioning flight to return aircraft to its home station. In seventeen instances, a secondary movement occurred, where equipment was moved from one demand point location to another. Another permutation included an "in-system select" when an aircraft, having completed a mission or in the process of completing a lower priority mission, was retasked to KADW prior to returning to home station.

Cost-benefit analysis relied on the four-stage format, and an expected value for positioning and depositioning sorties was developed based on frequency distribution of "owning agency" assignment to presidential support missions. Table 4 depicts the development of this expected value. The "Frequency of Utilization" column shows the relative assignment of the type of airframe from a particular "owning agency" (Wing) associated with the airbase's ICAO code. The roundtrip flight time in the table is based on the time from the aircraft's home station to and from Andrews, calculated using average historical values in the GDSSII database for the Origin, Destination ICAO pairs. This flight time is multiplied by the assessed FY20 SAAM rate to determine a chargeable operating cost for the roundtrip flight. No MAR is included. The products of the frequency of utilization multiplied by the operating cost are summed to provide an expected value for a roundtrip positioning and depositioning flight per demand point mission. This resulted in an expected cost of $75,004.04 just to move an empty aircraft to and from Andrews for every single mission.

Table 4 - Expected Value of Positioning and Depositioning Sorties

	ICAO	Frequency of Utilization	Average Flight Time: To KADW	Average Flight Time: From KADW	Average Flight Time: Roundtrip	Op Cost	Proportional Roundtrip
C-17	KSWF	0.355%	0.835417	0.875	1.710416625	$ 41,867.58	$ 148.47
C-17	PHIK	0.355%	9.457051	10.9814815	20.43853276	$ 500,294.41	$ 1,774.09
C-17	KMRB	0.355%	0.455556	0.36111111	0.816666667	$ 19,990.37	$ 70.89
C-17	KJAN	0.709%	1.869444	2.33055555	4.199999995	$ 102,807.60	$ 729.13
C-17	KWRI	25.177%	0.662845	0.66333332	1.326178316	$ 32,462.19	$ 8,173.11
C-17	KSUU	5.319%	4.757222	5.52941169	10.28663386	$ 251,796.22	$ 13,393.42
C-17	KDOV	26.950%	0.423858	0.39942128	0.823279709	$ 20,152.24	$ 5,431.10
C-17	KCHS	27.660%	1.296951	1.1572254	2.454176602	$ 60,073.33	$ 16,616.03
C-17	KFFO	0.709%	1.068518	1.02037026	2.088888664	$ 51,131.82	$ 362.64
C-17	KTCM	7.092%	4.667347	5.58148148	10.24882842	$ 250,870.82	$ 17,792.26
C-5	KSUU	2.482%	4.698485	5.62333327	10.32181812	$ 364,576.94	$ 9,049.78
C-5	KSKF	0.355%	2.816667	2.81666667	5.63333334	$ 198,974.97	$ 705.58
C-5	KDOV	2.482%	0.458824	0.40520833	0.864031843	$ 30,518.47	$ 757.55
	Total			Expected Value	2.932295908	hrs	$ 75,004.04

The GDSSII data was also used to calculate both the expected chargeable cost per hour of flight and an average velocity in great circle distance miles per hour in Table 5. The frequency of utilization in Table 4 was summed by aircraft fleet to obtain a fleet

Table 5 - Expected Value, Flight Hour Cost and Velocity

	Aircraft Operating Cost Per Hour (FY20 SAAM Rate)	Frequency of Utilization	Expected Value Cost of 1-hr flight	Avg Great Circle Distance/hr
C-5	$35,321	4.26%	$1,503	398.85
C-17	$24,478	94.68%	$23,176	358.37
			$24,679	356.28

frequency of utilization. The products of the fleet frequency of utilization multiplied by the fleet operating cost are summed to provide an expected value of $24,679 for one hour of flight time in support of presidential missions. This same methodology is applied to obtain the average great circle distance MPH rate based on the average fleet velocity as derived from the GDSSII database.

Doherty Database

In lieu of the GDSSII database to identify demand points, Dr. Brendan Doherty of the U.S. Naval Academy generously shared access to his database of location-encoded presidential events covering 20 January 1988 to 30 June 2019. These events represent public engagements by the president, as recorded in the Public Papers of the Presidency, edited by the American Presidency Project. Events in Hawaii, Alaska, and U.S. territories were excluded. According to the Doherty data, the president's daily schedule might include official events in up to seven distinct locations, with the distance between events ranging from zero to 2,732 miles. The assumption was made that nearby consecutive events could utilize the same equipment (and/or airlift). To avoid over-counting these demand points, nearby subsequent events, assessed at a distance of forty miles, were filtered out. This range of forty miles was determined through an analysis of the marginal contribution of ten-mile increments on the number of overall locations.

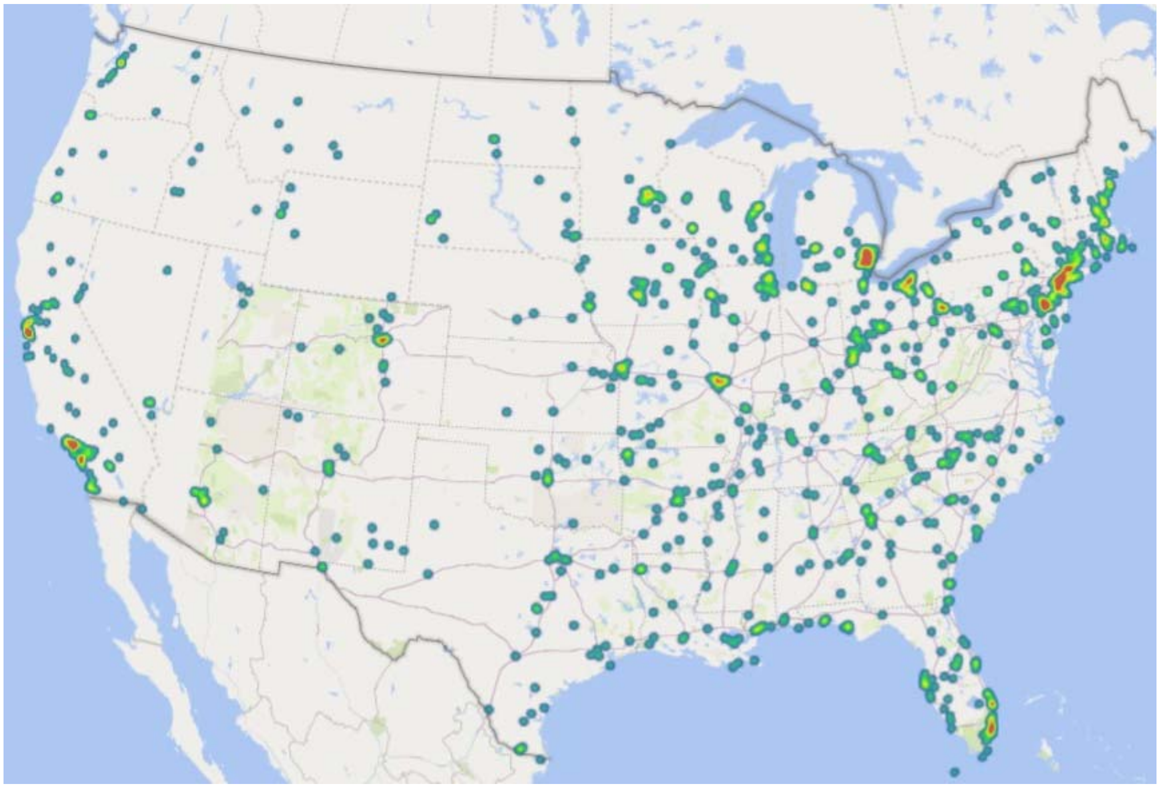


Figure 3 - Heat Map of Filtered Demand Points, 1998-2019

To find nearby events and to perform the MCLP calculations, the location information in the data set, coded by city and state, was converted to latitude and longitude points. This was accomplished by merging the database with a publicly available database of Census-recognized cities and towns. (Pareto Software, LLC, 2019) Location for non-incorporated areas, national parks, military installations, and minor differences in spelling (918 instances) were resolved by manual searches within Google Maps. The result of this is illustrated by a heat map of filtered demand points (Figure 3).

Non-Linear Program using Microsoft Excel's Solver Tool

A non-linear program was developed using Microsoft Excel's Solver tool. The variable cells were set as a latitude, longitude pair which optimized total demand point coverage, given a R_J radius of coverage as constrained and described above. The non-linear program is solved iteratively at each of the six R_J to find an optimal warehouse location which maximizes the number of demand points contained within the given R_J radius of coverage. Coverage is assessed at two locations: the White House and J_n. This is accomplished by an IF statement that returns '1' if the distance between the demand point and the facility is less than the given R_J and '0' if it is not. These values are summed to identify a facility's contribution. Should the warehouse coverage territories overlap, then a demand point could be counted twice. To avoid this, the total coverage is calculated based on a demand point being covered by *at least* one facility through the use of another IF statement. The sum of the total coverage is the objective function maximized by the Solver tool. Additional Solver settings are highlighted in Figure 4.

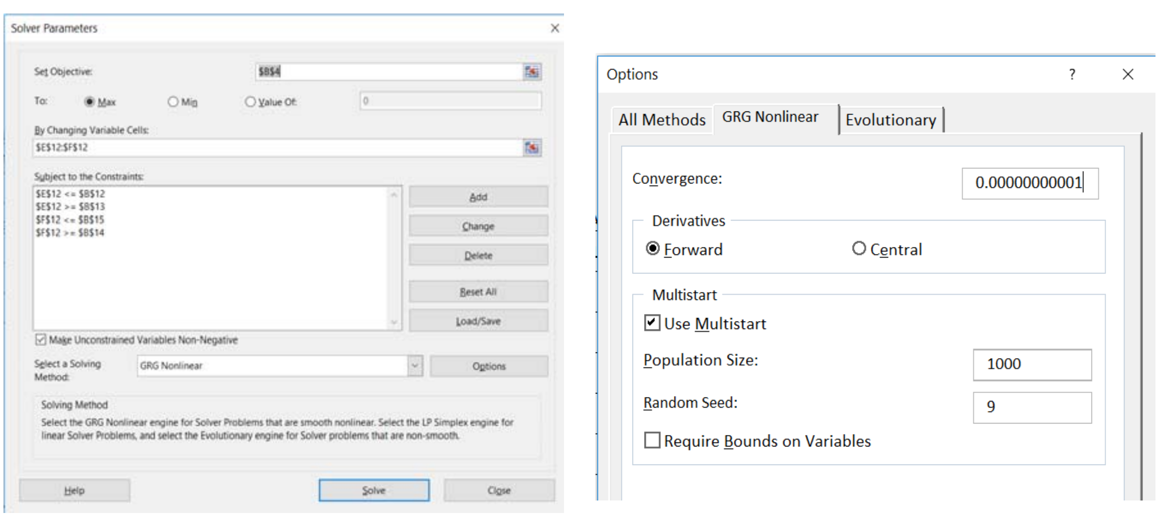


Figure 4 - Solver Parameters

IV. Analysis and Results

Non-Linear Program Results

Global Optimal Facility Locations

The non-linear program (NLP) produced six global optimal facility locations given the associated radius of coverage, of which four were distinct locations. These locations were centered in eastern Kansas, southern Missouri, and northeastern Arkansas. The optimal locations are plotted in black in Figure 6. The duplication of two locations is not an unexpected outcome of a NLP. Given the parameters, the Solver was unable to find a better fitting location in these instances, despite the potential that such an outcome is feasible.

Demand Point Coverage Obtained

Each of the optimal facility locations is associated with a demand point coverage set. These sets can be subdivided into three coverage categories: White House-only coverage, Alternate Facility (J)-only coverage, and the Total Coverage. As noted in Chapter III, the Total Coverage may be less than the sum of the coverage of the independent facilities due to territorial overlap. Total Coverage sets ranged from 58% to 76% of all demand points. Importantly, between 35% and 49% of all demand could have been satisfied by line-hauling from a facility centered at the White House. The additional distribution facility could support between 25% and 38% of all demand at an optimized location. All outcomes are summarized in Figure 5.

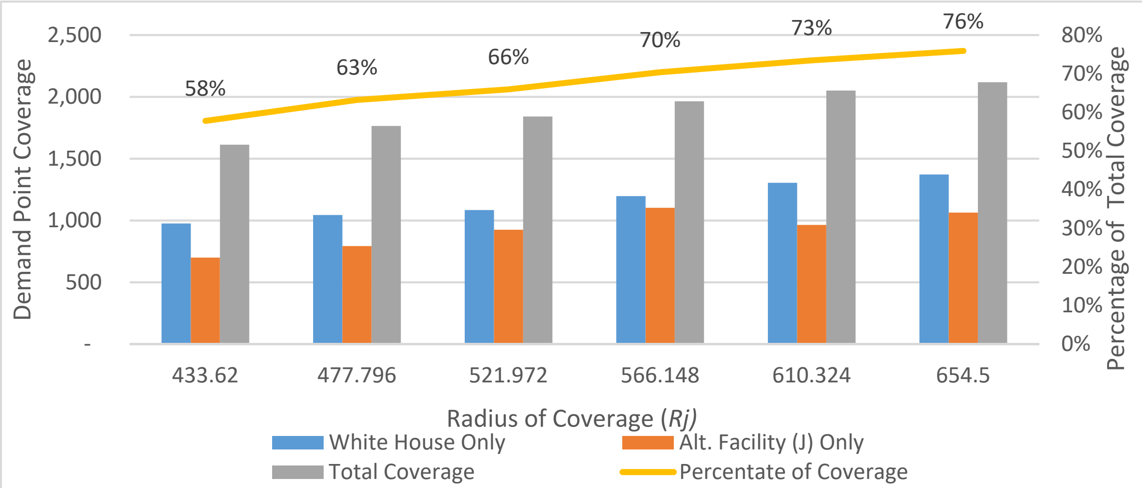


Figure 5 - NLP Demand Point Coverage

A sensitivity analysis was conducted on the coverage achieved by examining how the demand coverage of each presidential term performed relative to the average (Table 6). This reveals travel patterns of each president. The optimal facility locations favored an area of coverage including the East, South, and Midwestern portions of the nation. Generally, coverage for Republican presidents fared better in this solution set, the exception being President Trump. This could be attributable to the fact that southern Florida is not covered by the solution.

Table 6 - Sensitivity Analysis: Covered Demand by Presidential Term

Radius of Coverage *(Rj)*	All Demand	GHW Bush	Clinton - 1st Term	Clinton - 2nd Term	GW Bush - 1st Term	GW Bush - 2nd Term	Obama - 1st Term	Obama - 2nd Term	Trump - 1st Term
433.62	58%	59%	61%	64%	53%	57%	57%	57%	56%
477.80	63%	66%	63%	68%	60%	66%	61%	59%	62%
521.97	66%	68%	64%	67%	67%	68%	65%	62%	63%
566.15	70%	73%	68%	70%	74%	73%	68%	63%	70%
610.32	73%	76%	71%	72%	77%	77%	72%	67%	68%
654.50	76%	79%	73%	75%	80%	81%	74%	68%	70%

Suitability of Existing Department of Defense Real Estate

An analysis of real estate currently owned by the federal government was conducted to determine suitability as a secondary distribution point. Six DoD facilitates near the optimal locations were identified. These included the Milan Army Ammunition Plant in Milan, Kentucky; Naval Support Activity Mid-South in Millington, Tennessee; Fort Campbell, Kentucky; Little Rock Air Force Base, Arkansas; Fort Leonard Wood, Missouri; and Scott Air Force Base, Illinois. Other federal lands were excluded due to the nature of their intended use (primarily preservation of wild lands), lack of existing security provisions, or lack of access to primary road networks. The proximity of these facilities to the set of optimal locations is plotted in Figure 6. A covering set at each *Rj* for these locations was determined according to the procedures outline above. The resulting values were compared to the contribution of the optimal locations to each *Rj* coverage set.

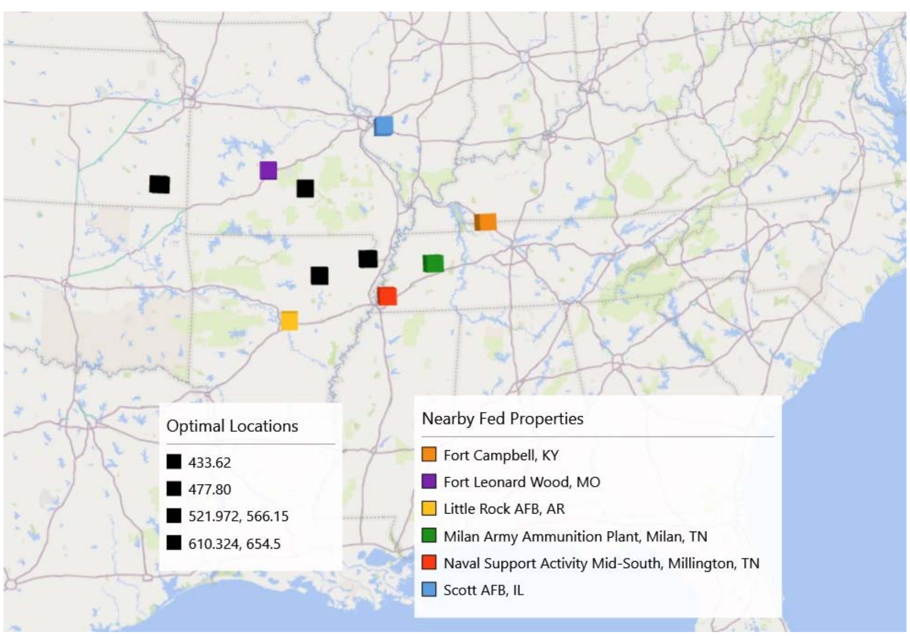


Figure 6 - Federal Real Estate near Optimal Locations

Given the distribution of demand points, facilities located further north and east capture more demand points than locations located to the west and south, as indicated by the sensitivity analysis illustrated by Table 7. Although some facilities perform better than the optimized locations, this would reduce the number of total demand points covered, as the frequency of dual coverage would increase. Additionally, the road networks depicted in **Error! Reference source not found.** are indicative that other variables not captured by the model are worthy of consideration, principally access to the major interstate system with locations near the intersection of multiple interstates (such as Scott AFB or Fort Campbell). Obviously, this ease of highway access would potentially be more effective in a ground distribution scheme. Another positive attribute is multi-modal access, allowing dual coverage by air as well as road. For this reason, Scott AFB, Fort Campbell, NSA Mid-South, and Little Rock AFB might be better candidates by other measures than strictly great circle distance coverage.

Table 7 - Sensitivity Analysis, Contribution of Existing DoD Properties

Radius of Coverage *(Rj)*	Milan Army Ammunition Plant, TN	NSA Mid-South, Millington, TN	Fort Campbell, KY	Little Rock AFB, AR	Fort Leonard Wood, MO	Scott AFB, IL
433.62	1.9%	-16.6%	5.6%	-28.3%	-21.7%	6.0%
477.80	5.8%	-4.8%	31.9%	-19.8%	-15.0%	24.7%
521.97	8.9%	2.8%	26.7%	-21.3%	-13.1%	14.1%
566.15	10.3%	-3.3%	13.1%	-20.3%	-9.2%	7.9%
610.32	40.4%	26.2%	36.6%	-0.1%	21.5%	33.3%
654.50	32.4%	30.5%	31.1%	2.3%	17.5%	27.4%

NLP Cost of Covered Demand Flight Hours

Potential Savings – Total Covered Demand

Using the demand points covered by two locations (the White House and a global optimal location) in each R_J solution set, a cumulative roundtrip great circle distance was tabulated for each set. This distance was multiplied by the expected value operating cost per hour to estimate the operating costs that could have been saved over the period of evaluation by converting the service of these demand points from airlift to over-the-road. The resulting value was added to the expected value operating costs of positioning and depositioning flights multiplied by the number of covered demand points. The results are substantial: potential operating costs savings of between $223 million and $310 million, as portrayed in Table 8.

Table 8 – Two Facility Potential Operating Cost Savings

	Radius of Coverage (Rj), miles					
	433.62	477.80	521.97	566.15	610.32	654.50
Demand Points Served	1613	1764	1841	1964	2050	2118
De-/Position Flights	$ 120,981,520	$ 132,307,130	$ 138,082,442	$ 147,307,939	$ 153,758,286	$ 158,858,561
"A" Mission Flights	$ 102,518,269	$ 120,815,271	$ 119,393,597	$ 125,040,224	$ 148,653,808	$ 151,642,435
Potential Savings	$ 223,499,789	$ 253,122,402	$ 257,476,038	$ 272,348,163	$ 302,412,095	$ 310,500,996

Potential Savings – White House Garage Only

This two facility solution was further scoped to focus only on demand points served by the White House location within the last ten years as determined by the NLP. Switching from airlift to an over-the-road transportation solution for locations within a one-day driving range resulted in an average reduction of between 29 to 39 airlift missions at an operating cost of $3.2 million and $4.8 million (Figure 7). Additionally, this graph shows the surge in demand that accompanies presidential and midterm election cycles.

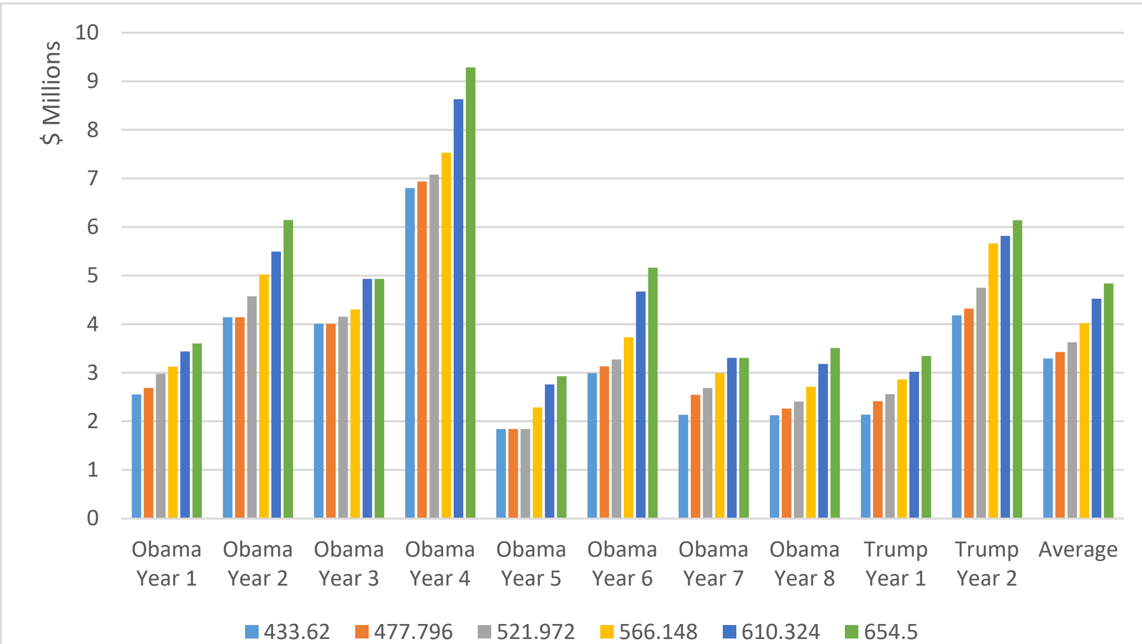


Figure 7 - Annual Operating Hour Cost Savings, Washington, DC Distribution Facility

GDSSII Data Analysis

Missions within one-day's drive time

An analysis of missions flown in support of the USSS reveals that 54 percent of domestic missions originating or terminating at Joint Base Andrews, Maryland, travel a distance of less than one-day's drive time, given an R_J of 654.5 miles, as highlighted in Figure 8. This figure rises to 76 percent of missions when the radius is increased to two days' drive time.

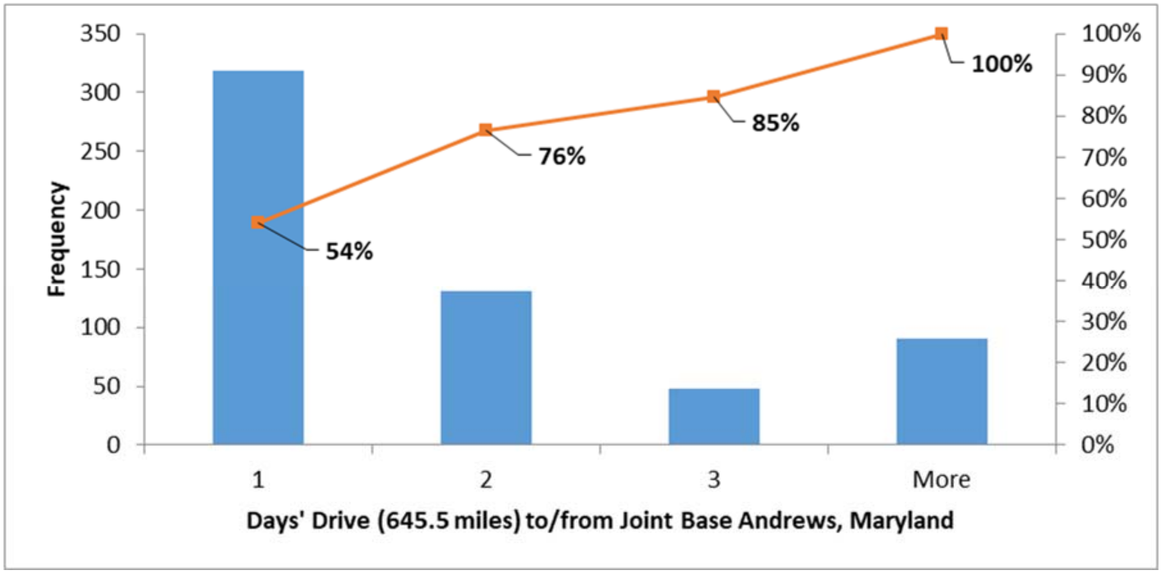


Figure 8 - Miles flown on "Onload to Offload" Missions CONUS to/from Joint Base Andrews

Distribution of Mission Support to White House-affiliated agencies

A discussion of the relative frequency of utilization between supported agencies is warranted at this point. This is best analyzed by examining the total number of missions flown on behalf of a given agency, and how many flight-hours (which directly correlates to cost) that agency has accumulated. This is tabulated on a world-wide basis from the (partial) GDSSII data and excludes certain other classified activities. Figure 9 details the ratio of airlift support provided by the number of missions flown. The USSS receives the bulk of airlift missions, accounting for slightly more than 57 percent. This percentage holds for the number of flight hours accumulated by the USSS, as depicted in Figure 10. The WHCA comprises just 13.1 percent of total missions, but jumps to 19.7 percent of flight hours, suggesting an over-the-road distribution scheme for events near the NCR. Indeed, the average flight time for the WHCA is 4.89 hours compared to the 3.16 hours of the USSS. The HMX-1's reliance on the more cost-efficient C-130 fleet for support allows it to achieve the lowest cost per mission, an average of $46,833, compared to the estimated $58,367 and $85,038 per mission for the USSS and WHCA, respectively, despite logging 24.9% of the total flight time.

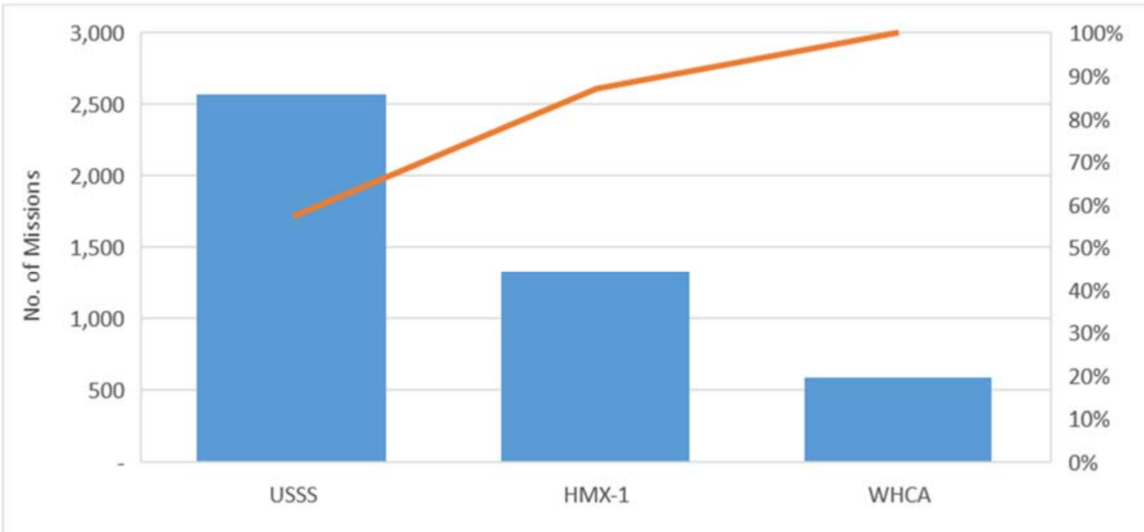


Figure 9- Agency Support, By Number of Missions

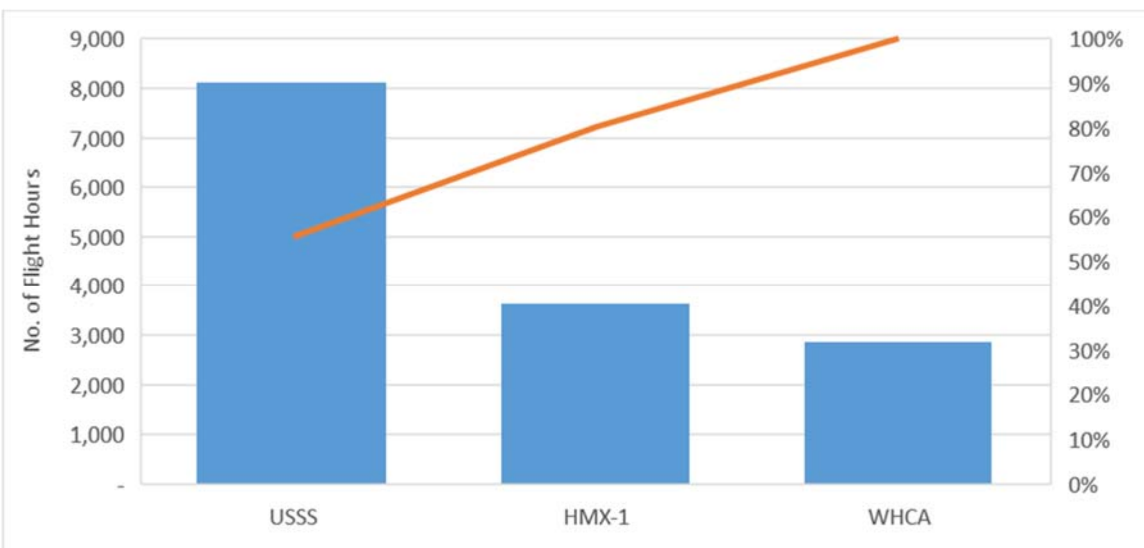


Figure 10 - Agency Support, By Flight Hours

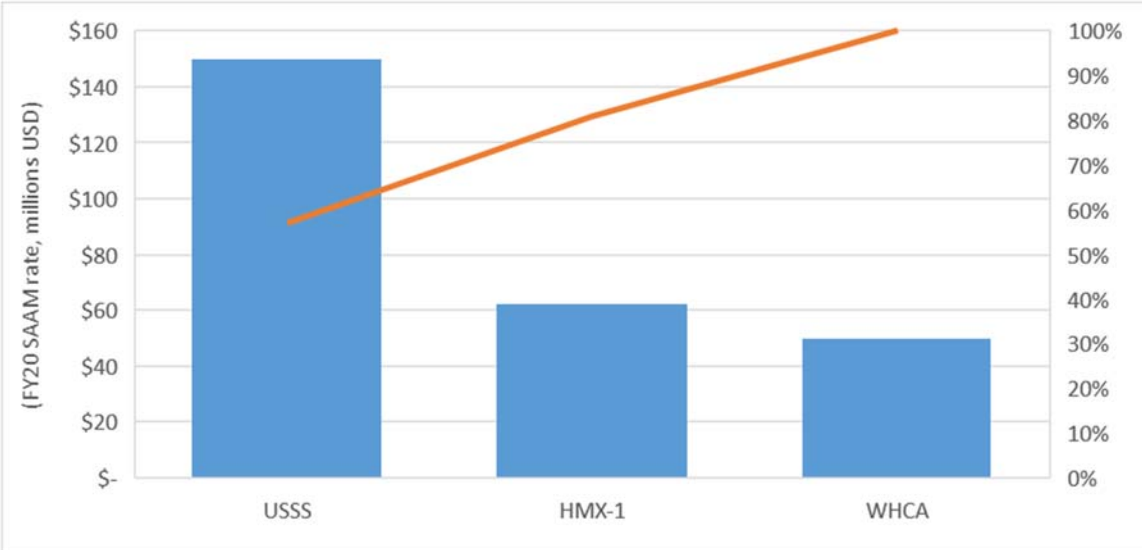


Figure 11 - Agency Support, By Flying Hour Cost

Mission Assignment by Aircraft Fleet and Owning Installation

Although aircraft and unit assignment falls to the 618 AOC at Scott Air Force Base, Illinois, rather than the supported user, the quantity and size of cargo and passengers often dictates the aircraft assigned. In the aggregate, the C-17 aircraft does the heavy lifting for the presidential support mission, accounting for slightly more than 93 percent of all missions. The C-5 and C-130 fleets roughly split the remaining balance, at 3.09 percent and 3.52 percent, respectively. The number of C-17 missions falls disproportionality on just three installations: Joint Base Charleston, South Carolina; Joint Base McGuire-Dix-Lakehurst, New Jersey; and Dover Air Force Base, Delaware. As depicted in *Figure 12* these units combined supported seventy percent of all missions.

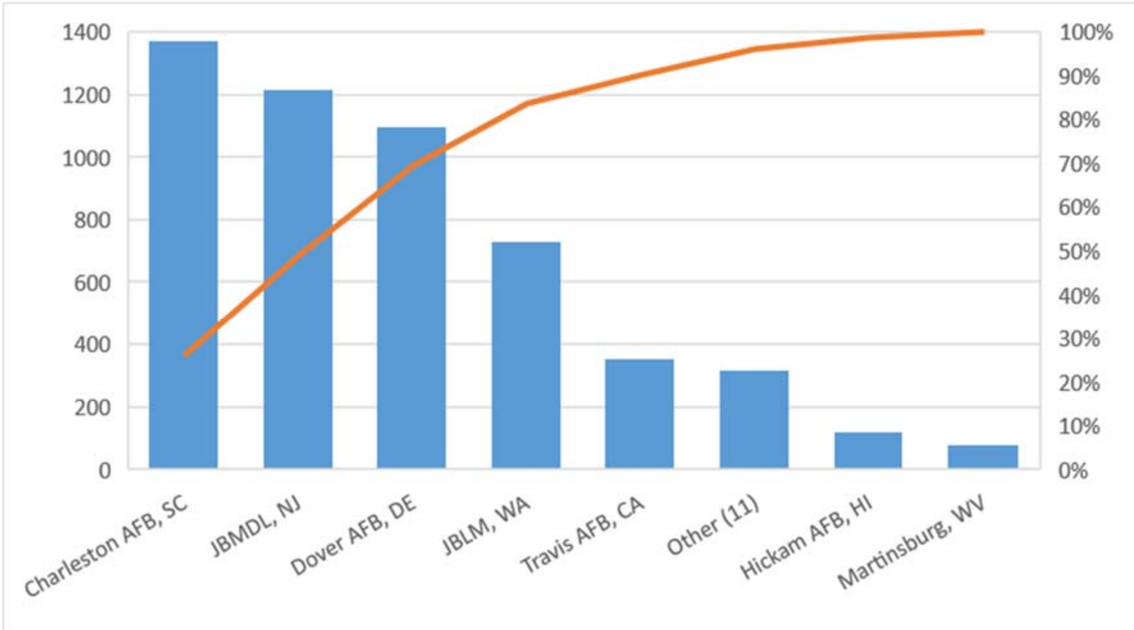


Figure 12- C-17 Mission Distribution, by Installation

Maptitude Software Analysis of Demand Coverage

Validation of Proxy Coverage Radii

The NLP analysis relied on a heuristic set of six proxy coverage radii in lieu of the more computationally demanding driving route and time computation between each demand point and an optimizing location. However, the solution location set derived from the NLP was input into Maptitude, a commercial geographic information system, to produce high-fidelity driving time and driving distance tables. From these charts, an actual coverage set was derived, based on average speeds under normal environmental conditions. The results achieved from this method were matched to the proxy distance results to validate the use of these radii and are displayed in Table 9.

Table 9 - Validation of *Rj* proxies using Maptitude

Radius of Coverage *(Rj)*	Matched Demand Points	Matched Demand Points
433.62	965	80%
477.80	1033	85%
521.97	1079	89%
566.15	1169	96%
610.32	1199	99%
654.50	1213	100%

This comparison validates the usage of R_J of 610.32 and 654.5 miles as effective proxy substitutes in this application. The comparison additionally suggests that for a heuristic, an approximate great circle distance of 600 miles effectively captures all demand. This number may be well-suited for use as planning factor for this and similar problems.

Isochrone Plotting

While utilizing radii of coverage described by a great circle distance proxy substitute readily enables calculation of optimal facility location, limitations of this approach, namely the effects of variations in traffic congestion, speed limits, and terrain on the actual distance achievable within a set time period, reduce the fidelity of the solutions obtained. Isochrones have been plotted to determine performance against the NLP solutions. These isochrones are included in Appendix A.

Mission Distribution from the White House

A histogram was charted using the Maptitude-generated distance and travel time data from the White House to each demand point. This analysis revealed that 43.46% of demand occurred within an eleven hour drive time of the White House. That total rose to

78.25% at the end of two periods of eleven hours and 85.63% at the end of three periods. If through means of effective driver rotation, the movement can be sustained continuously without driver rest periods, all CONUS demand points can be satisfied within 46 hours.

Additional Research on Non-monetary Costs

Background investigation for this paper revealed significant non-financial externalities worth noting and further study. These included negative impacts on combat readiness, aircrew quality of life, and aircrew perceptions of meaningful work. These factors are broadly acknowledged in literature as important antecedents for decreased job satisfaction and affective organizational commitment. Specifically, "satisfaction with the work itself is the single strongest driver of overall job satisfaction." Components of job satisfaction that may be impaired by these externalities include *significance, meaningfulness of work, knowledge and skill, growth need strength,* and *life satisfaction.* (Colquitt, Lepine, and Wesson, 2017:76,100,101-105,114) Literature ties impairment of these attributes, particularly *quality of life* (equitable with *life satisfaction*), a chief criticism and factor tied to increased propensity of aircrew to separate from military service. (Aircrew Task Force, 2019:1; Gultekin, Abdan, and Kilic, 2012:110). See Appendix B for a framework of interrelationships and Strength (2020) for a broader treatment of factors affecting aircrew retention.

Presidential airlift support missions impair training for and experience in combat operations. Significantly, an airlift unit commander noted that these "missions are not representative of our most challenging mission set and detract from crew readiness for combat operations." (Byrum, 2020) A deployed commander assessed his crews' experience and noted that, "[e]ach crew that is sent to us is overall young and inexperienced… We are going to locations that require a level of expertise that we simply don't have." (816 EAS Det1/CC qtd. in Byrum, 2020)

These support missions are largely detailed to 3 east coast airlift wings. This permits servicing user requests within one day. Aircraft are able to "depart home station, onload [their cargo] at Andrews, and offload at the final destination all within the same Zulu day. A west coast crew would likely have to RON [remain over night at] Andrews [Air Force Base], resulting in that tail being allocated" for an additional day. (Amos, 2020) The unit commander noted that this distribution of mission assignment makes it "difficult to get our new copilots and new aircraft commanders the experience they need to successfully employ the C-17 in combat environments," especially in times of "increased [presidential] travel." (Byrum, 2020)

Additionally, these missions may negatively impact aircrew quality of life. Aircrew quality of life is adversely impacted by short-notice mission assignments, and presidential support missions account for as much as 65% of a unit's annual short-notice assignments. (Byrum, 2020) In anticipation of unplanned additional president travel, three airlift units share responsibility to maintain a standing alert aircraft and fully augmented crew, allowing a faster response time to WHMO support requests. This constitutes a standing manpower requirement of 52,200 hours per annum. (Amos, 2020) This requirement strains available resources to the degree that USTC has implemented a standing waiver allowing aircrews to be held on alert status up to 250% of the normally permitted time period for this mission. Organizational incentives encourage the use of this waiver by failing to credit mandatory pre- and post- mission crew rest requirements toward unit manpower utilization rates. (Amos, 2020)

Further, while these missions fulfill a valid military mission, a perceived lack of meaningfulness in some instances may negatively impact aircrew organization commitment and task performance. An airlift unit operations officer identified scenarios where airlift was used to support presidential vacations or to move equipment from Washington, DC, to nearby locations in Atlantic City and Newark, New Jersey, or to Philadelphia, Pennsylvania. (Amos, 2020) Each of those three locations are within four hours driving time from Washington, DC, less time than necessary to fly from the aircraft's home station to Joint Base Andrews, on-load the equipment, fly to the destination, unload the cargo, and return to home station. (Google Maps, n.d.) Commanders and operations officers made multiple inquiries on whether these missions could be more efficiently served by over road transportation. (Amos, 2020; Byrum, 2020)

V. Conclusions and Recommendations

Conclusions of Research

This project was framed to answer two questions. First, can the current airlift-centric distribution model for presidential support equipment be reorganized effectively as a ground distribution channel from Joint Base Andrews, Maryland? Secondly, could establishing an equipment distribution center at a location other Joint Base Andrews, Maryland, substantially reduce costs to the Department of Defense? In both instances, the answer is a resounding yes. Whether from Joint Base Andrews, or from a secondary distribution facility located in the central United States, NLP analysis, supported by available GDSSII data and a high-fidelity commercial geographic information system, confirms that switching to an over-the-road in lieu of airlift mode to the maximum extent possible provides an opportunity for hundreds of millions of dollars of savings to the taxpayers while delivering a faster response time to support requests.

Significance of Research

This research further demonstrates the utility of the Maximal Covering Location Problem methodology in addressing military problem sets, particularly in cost-benefit analysis for transportation mode selection modeling. Additionally, it challenges the maxim that airlift is the most responsive mode of transportation, especially when responding to short-notice demands when cargo is not co-located with the airframe. Further, adopting this research could divert hundreds of days of additional aircraft availability to other operational missions, aircrew training, or additional maintenance downtime. Finally, a review of operational missions found that forty-four percent of all

CONUS to CONUS missions in 2017 traveled a distance of less than 600 miles, suggesting that a broader application of drive-time analysis advanced by this paper has broader applicability to all mission types.

Recommendations for Action

First, collaborative efforts should be undertaken between the Departments of Defense and Homeland Security to examine opportunities for implementing the ground channel as soon as practical. While awaiting budget action for a secondary distribution center, the Departments should immediately implement an over-the-road solution for destinations falling within the 11-hour driving range of Washington, DC, as identified in Chapter IV of this paper.

Secondly, the United States Transportation Command should adopt the cost-benefit analysis as indicated in Chapter IV to effectively weigh modal determination decisions for all missions. Use of this analysis could increase responsiveness to user requests, increase asset availability for the supported user while reducing costs to the Department of Defense.

Thirdly, the Department of Defense should consider reapportioning existing real estate in support of the conversion or construction of a distribution facility that permits the use of a ground distribution channel for presidential support meeting user requirements for security and responsiveness.

Recommendations for Future Research

Operational requirements limit the amount of detail that be included in this unclassified analysis, particularly regarding the quantity, capability, and other attributes of the fleet of presidential support vehicles. A capacitated analysis should be conducted utilizing this information to best develop an executable procurement and implementation plan.

These details, including height, weight, operational limitations, inventory and maintenance space requirements, should be included in a more detailed analysis of factors influencing the location of a secondary distribution facility. This analysis should also include security requirements, proximity to interstate systems, road and bridge capacity.

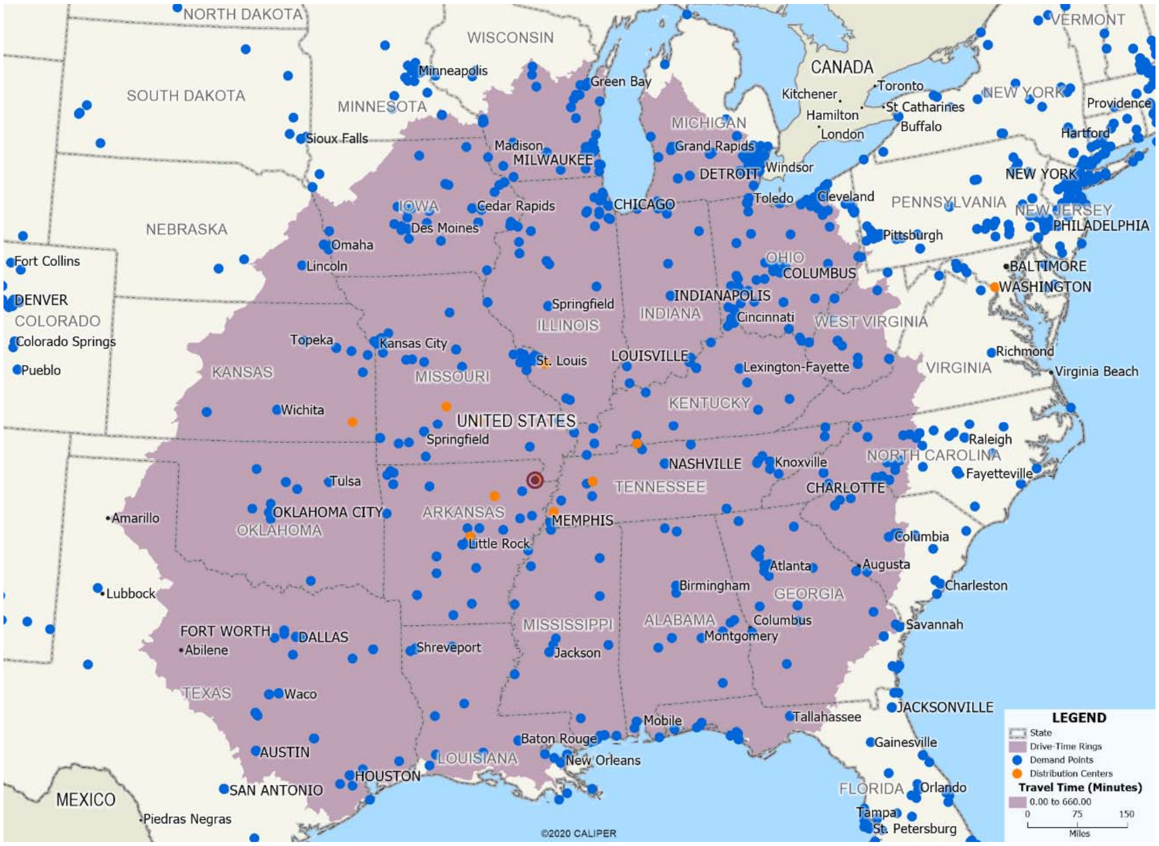
Further, as indicated in the additional research section in Chapter IV, other non-monetary costs exist. While required by DoDD, these costs are currently not included in analyses supporting mode selection. These opportunity costs of lost training and personnel costs of lack of organizational commitment may be significant and certainly warrant further investigation.

Summary

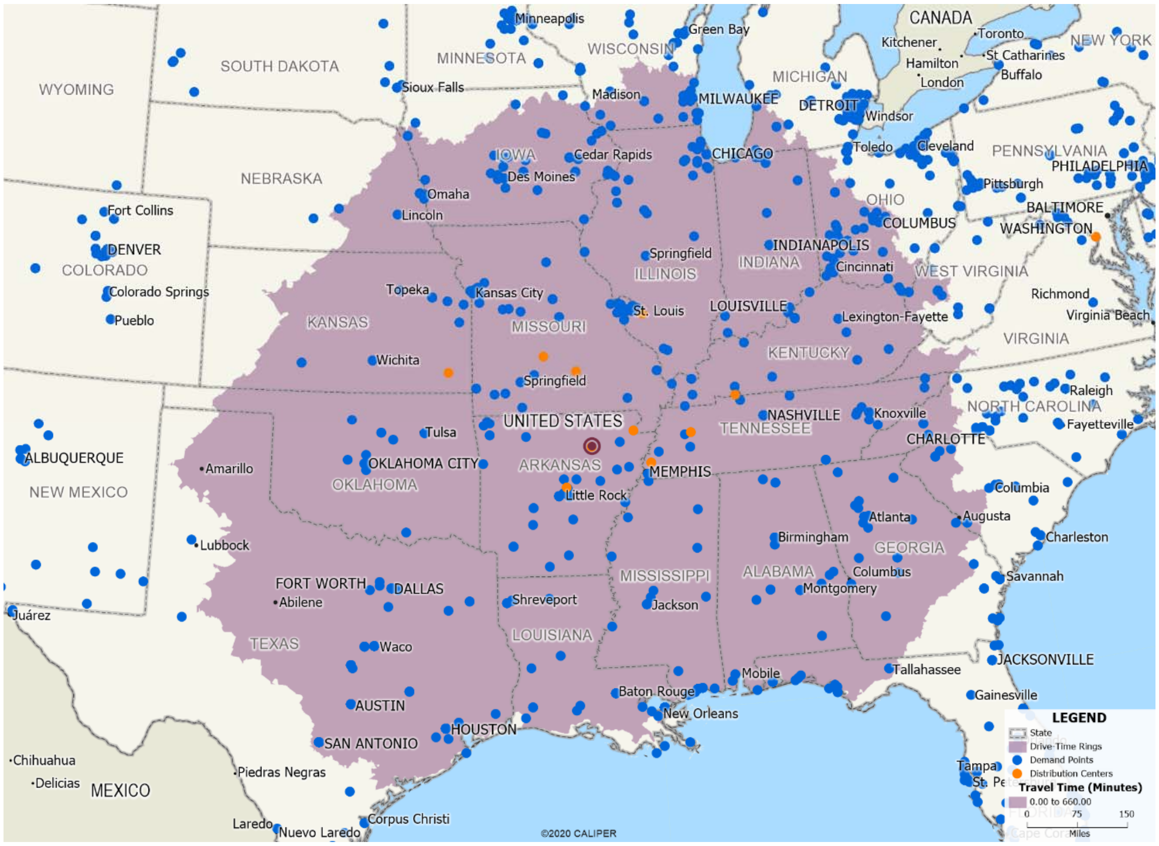
This research project implemented Maximal Covering Location Problem methodologies and successfully identified opportunities to increase airlift availability by shifting demand for support of presidential travel to modes other than airlift.

Appendix A

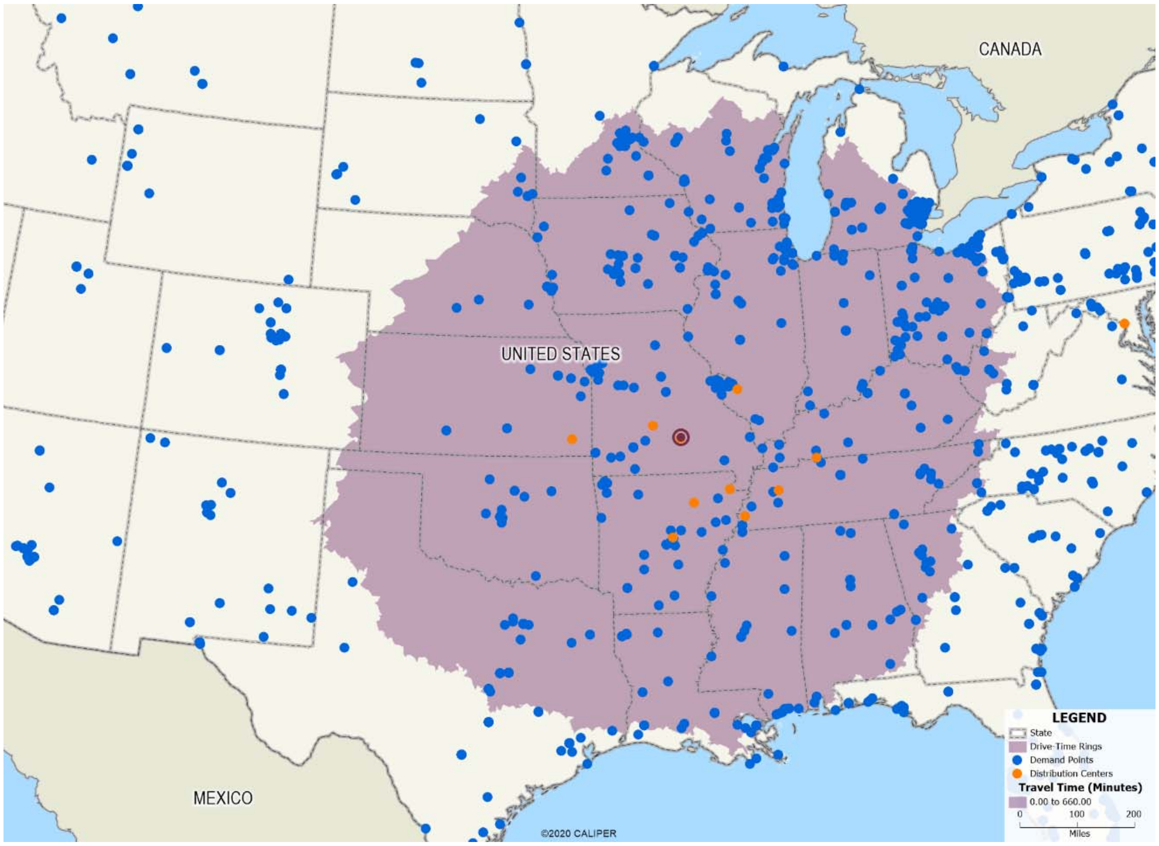
Maptitude Isochrones for NLP Optimal Locations



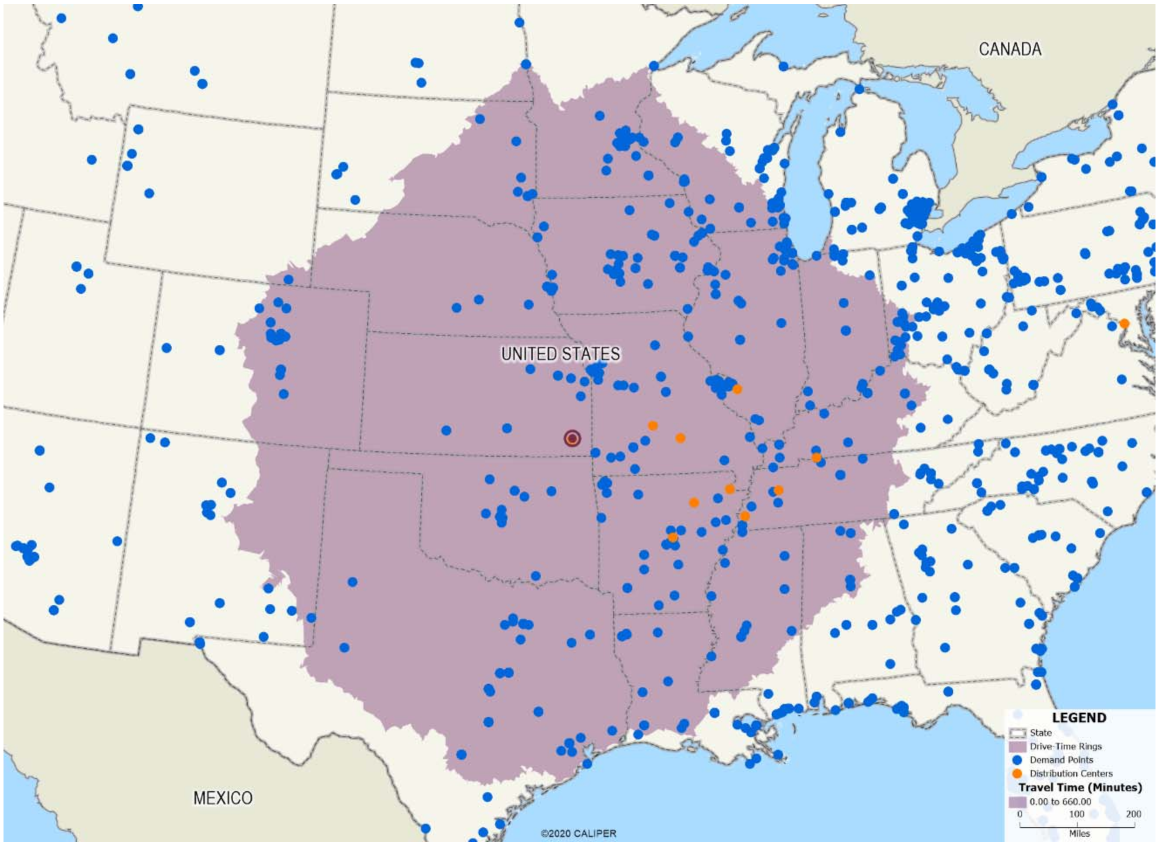
11 Hour Coverage Range from 36.047° N, 90.299° W



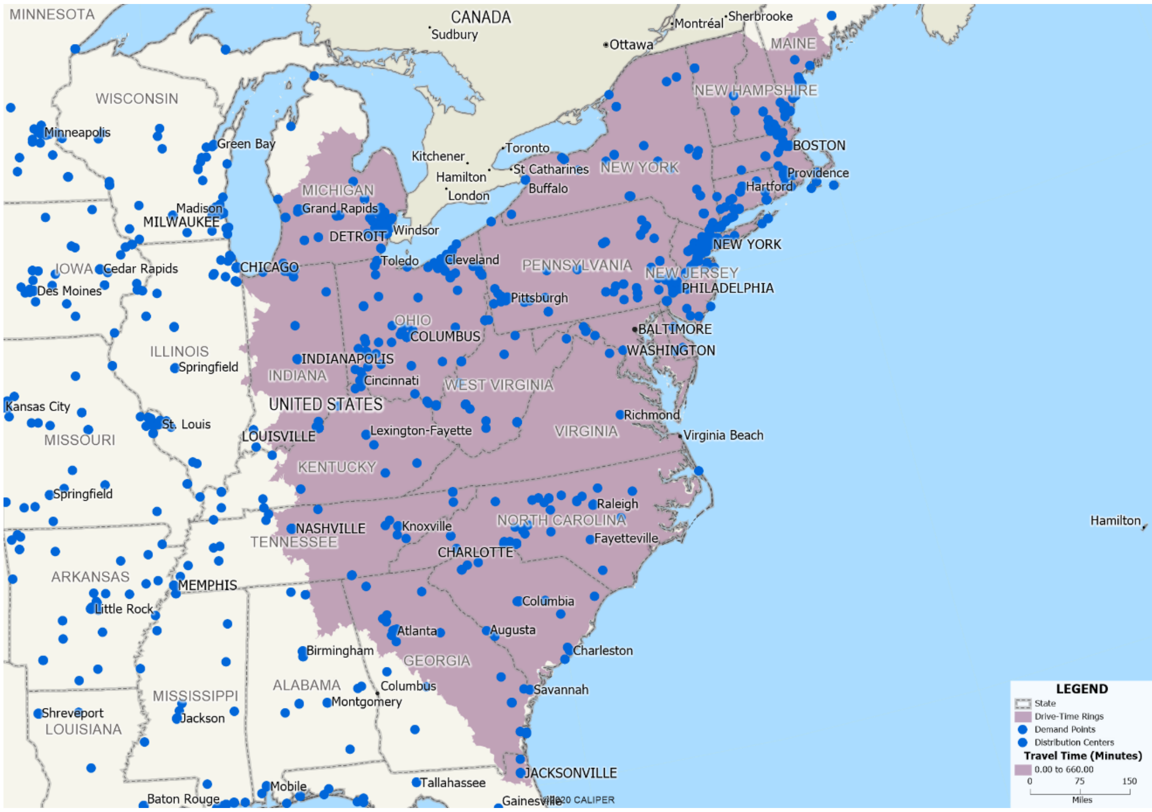
11 Hour Coverage Range from 35.743° N, 91.442° W



11 Hour Coverage Range from 37.385° N, 91.767° W

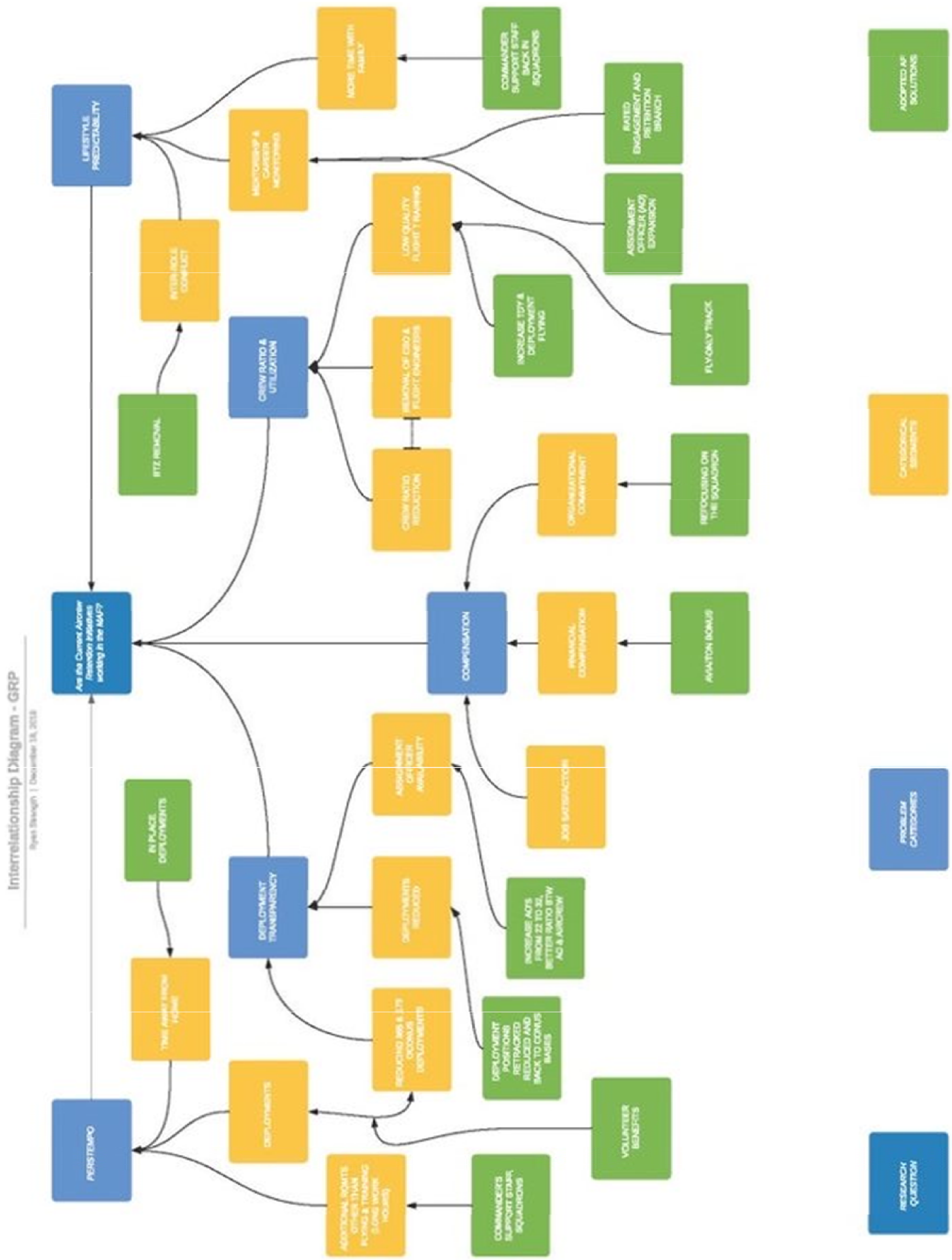


11 Hour Coverage Range from 37.426° N, 95.254° W



11 Hour Coverage Range from The White House, Washington, DC

Appendix B



US Air Force Aircrew Task Force Solutions Diagram (Strength, 2020)

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14. ABSTRACT

The president's effortless descent down Air Force One's stairs belies a tremendous logistical operation required for every visit. These logistics take many forms, but the most expensive is airlift for the movement of specialized vehicles, equipment, and personnel for all non-local travel by the president. The volume of airlift required and the frequency of travel is a significant demand for the Air Force. This paper explores a quantitative methodology (Maximal Covering Location Problem) to find whether a more cost-efficient alternative exists for the current airlift-only distribution system.

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