## The Traveling NET Trainer Problem

#### Methods for Optimizing New Equipment Training Travel Costs

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Thanks to Jason Jones, USA AMCOM Stephen Cox, UAH

## Army LCCE Structure

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3	NON-RECURRING PROD	2.01			APA	X																ROC2010\$	OUTPUT
4	RECURRING PRODUCTION	2.02			APA	X																ROC2020\$	OUTPUT
5	ENGINEERING CHANGES	2.03			APA	X																ROC2030\$	OUTPUT
6	SYSTEMS ENGINEERING/MGMT	2.04			APA	X																ROC2040\$	OUTPUT
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	DATA	2.00				^ V																ROC2080#	
10	SUPPORT EQUIPMENT	2.08			APA	X																ROC2080\$	OUTPUT
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#### Representative / Notional Systems



## The Problem

- We need to send a team to a specified number of locations to perform New Equipment Training (NET)
- Locations are both in the Continental United States (CONUS) and Outside the Continental United States (OCONUS)
- How can the travel costs be optimized using common tools such as Microsoft Excel?
  - Travel costs include airfare, per diem, rental car and lodging

## Original Estimating Method

- Status Quo Use the Mean
  - Estimate cost to travel from Huntsville, AL to each training location
    - NET training is one(1), two(2), or three(3) days
      - We assumed 2 person team, 2 travel days, 2 training days
    - If possible, travel only on week days
    - Always start travel from Huntsville, AL
  - Average CONUS travel cost
  - Average OCONUS travel cost



## Travel Zone Method

- Travel zones are based on neighboring training locations
- Travel to two(2) or three(3) locations in one trip, travel back to Huntsville, repeat until all locations have been visited

	A	B	C	D	E	F	G	н	1	J	K	L	M	N
1		# Trainers	≇ Travel Days	# Training Days	Lodging	Full Per Diem	First & Last Day Per Diem	Air Fare toifrom LOCATION X	Air fare between training	Airline Fees	Rental Car' - 1 day	Rental Car* - per week	Cost of Fuel	Total
2	LOCATION A	2	2	2	\$107.00	\$54.00	\$40.50	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$144.00	\$1,164.00
3	LOCATION B	2	2	2	\$107.00	\$54.00	\$40.50	\$0.00	\$583.00	\$0.00	\$0.00	\$0.00	\$144.00	\$1,164.00
4	LOCATION C	2	2	2	\$97.00	\$44.00	\$33.00	\$448.00	\$0.00	\$0.00	\$63.49	\$174.49	\$ 48.00	\$2,983.96
5	LOCATION D	2	2	2	\$70.00	\$39.00	\$29.25	\$222.00	\$497.00	\$0.00	\$66.99	\$180.99	\$ 48.00	\$1,896.96
6	LOCATION E	2	2	2	\$70.00	\$39.00	\$29.25	\$429.60	\$0.00	\$0.00	\$44.49	\$159.49	\$ 48.00	\$2,637.36
7	LOCATION F	2	2	2	\$118.00	\$64.00	\$48.00	\$379.00	\$287.00	\$0.00	\$67.99	\$179.99	\$ 48.00	\$2,991.96
8	LOCATION G	2	2	2	\$177.00	\$112.00	\$84.00	\$1,138.00	\$350.00	\$0.00	\$61.49	\$245.49	\$ 48.00	\$6,691.96
9	LOCATION H	2	2	2	\$108.00	\$59.00	\$44.25	\$458.00	\$0.00	\$0.00	\$75.49	\$285.49	\$ 48.00	\$3,242.96
10	LOCATION J	2	2	2	\$149.00	\$64.00	\$48.00	\$276.00	\$440.00	\$0.00	\$70.49	\$318.49	\$ 48.00	\$2,775.96
11	LOCATION K	2	2	2	\$70.00	\$39.00	\$29.25	\$373.00	\$373.00	\$0.00	\$62.49	\$226.49	\$ 48.00	\$2,482.96
12	LOCATION L	2	2	2	\$159.00	\$64.00	\$48.00	\$385.00	\$385.00	\$0.00	\$66.49	\$259.49	\$ 48.00	\$3,255.96
13	LOCATION M	2	2	2	\$79.00	\$44.00	\$33.00	\$208.00	\$0.00	\$0.00	\$57.49	\$244.49	\$ 48.00	\$1,891.96
14	LOCATION N	2	2	2	\$121.00	\$64.00	\$48.00	\$413.00	\$391.00	\$0.00	\$73.49	\$250.99	\$ 48.00	\$3,167.96
15	LOCATION P	2	2	2	\$70.00	\$39.00	\$29.25	\$320.00	\$0.00	\$0.00	\$66.49	\$146.49	\$ 48.00	\$2,286.96
16	LOCATION Q	2	2	2	\$103.00	\$49.00	\$36.75	\$320.00	\$0.00	\$0.00	\$66.49	\$146.49	\$ 48.00	\$2,554.96
17	LOCATION R	2	2	2	\$97.00	\$54.00	\$40.50	\$171.00	\$0.00	\$0.00	\$72.49	\$174.49	\$ 48.00	\$1,981.96
18	LOCATION S	2	2	2	\$97.00	\$54.00	\$40.50	\$224.00	\$224.00	\$0.00	\$72.49	\$174.49	\$ 48.00	\$2,193.96
19	LOCATION T	2	2	2	\$87.00	\$44.00	\$33.00	\$558.00	\$0.00	\$0.00	\$62.49	\$197.49	\$ 48.00	\$3,359.96
20	LOCATION U	2	3	2	\$265.00	\$150.00	\$112.50	\$401.00	\$0.00	\$0.00	\$93.64	\$491.98	\$ 48.00	\$5,515.20
21	LOCATION W	2	3	2	\$230.00	\$120.00	\$90.00	\$739.00	\$0.00	\$0.00	\$66.09	\$366.14	\$ 48.00	\$6,194.45
22														
23	Region 1	\$ 5,766.88												
24	Region 2	\$ 3,676.34												
25	Region 3	\$ 7,679.76												
26	Region 4	\$ 8,109.32												
27	Region 5	\$ 5,629.34												
28	Region 6	\$ 5,313.92												
29	Region 7	\$ 6,086.32												
30	Region 8	\$ 5,524.40												
31														
32														
33	TOTAL	\$47,786.28												
34	MINIMUM COST Region	\$ 3,676.34												
35	MAXIMUM COST Region	\$ 8,109.32												
36	AVERGE COST Region	\$ 5,973.29												



"The Continents of the World." http://www.nationsonline.org/oneworld/continents\_map.htm . April 9, 2008.

# Seeking the Optimal Solution

## · Brute Force methods

### Monte Carlo Simulations

#### Ant Colony Optimization (ACO)

TSP tour through 13,509 US cities with population over 500. http://www.tsp.gatech.edu/history/img/usa\_big.html. April 10, 2008.

Traveling Salesman Problem How many Hamiltonian Paths exist between the twenty-one (21) locations? Each location is visited exactly once Return home at the end of the tour The solution space for this problem is  $\frac{1}{2}(n-1)!$ for n > 2This approach has 1.21645 × 10<sup>18</sup> solutions

TSP Background

In 1962, Proctor and Gamble hosted a contest to solve the TSP for 33 cities 54 \$1000 prizes 1 \$10,000 prize · The Traveling Salesman Problem website

- http://www.tsp.gatech.edu/



TSP tour through 13,509 US cities with population over 500. http://www.tsp.gatech.edu/history/img/usa\_big.html. April 10, 2008.

### Solution Methods - Brute Force

# 5.17 miles me quintilion pennies 5.17 miles Triles The Sears Tower

#### Brute Force Method

 Compute permutations throughout all twenty-one (21) locations

 $A \rightarrow B \rightarrow C \rightarrow D \neq D \rightarrow C \rightarrow B \rightarrow A$ 

- Find the least of the solutions
- Solution set is n!
- In this method, the solution set would contain 21! = 51.0909422 × 10<sup>18</sup> = 51 quintillion elements
- There are about 100
  billion, or 10<sup>12</sup> stars in the Milky Way Galaxy

## Brute Force Solution

- An experienced programmer wrote a C program for this method
  - Spent 2 hours to understand problem and write code

Optimal Cost	Time to Optimal Cost	Total Time to Run*
\$43,755.88	1 hr 13 min 13 sec	2 days 20 hours (and counting)

#### Solution Methods - Monte Carlo Simulation

#### There is no single Monte Carlo Method

- Define data set
- Perform repeated random sampling
- Aggregate the results
- Monte Carlo Process for the Traveling Trainer
  - Collect cost data for traveling to all of the 21 locations
  - Carry out repeated random sampling on the data and calculate cost of each complete path
    - The algorithm runs for a specified number of iterations
    - Microsoft Excel and Visual Basic for Applications (VBA) were used to create this solution
  - Save the least cost and highest cost paths until a more optimal path is calculated

#### Monte Carlo Solution

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	0.3845 LOCATION B	50.588 39.406	2 \$ 2,991,96 \$ -	
	0.1164 LOCATION C	42.144 76.2	3 \$ 2,637,36 \$ 1,722,96	
	0.0829 LOCATION D	112 168.379	4 \$ 5515.20 \$ 5.358.56	
	0.5132 LOCATION F	0 0	5 ¢ 6 6 9 1 9 6 ¢ 2 2 9 7 9 6	
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#### Monte Carlo Results - 60K Iterations



#### Monte Carlo Results

	Least	Highest	Time
1 K	\$48,678.17-	\$67,617.20-	19 sec
	\$48,809.43	\$71,371.07	7 sec
10 K	\$47,672.77-	\$70,886.80-	1 min 7 sec
	-\$48,325.17	\$71,249.53	2 min 33 sec
30 K	\$47,217.44-	\$70,560.74-	3 min 2 sec
	\$47,318.30	\$71,837.03	3 min 22 sec
1,000 K	\$45,576.64	\$74,213.40	90 min 34 sec
5,630 K	\$44,740.17	\$76,209.80	~ 23 hrs

🕑 Photo: Wild, Alex. http://www.dphotojournal.com/daily-inspiration-macro-photography/ April 12, 2008.

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