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The Traveling NET Trainer Problem

Methods for Optimizing New Equipment Training Travel Costs

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Thanks to
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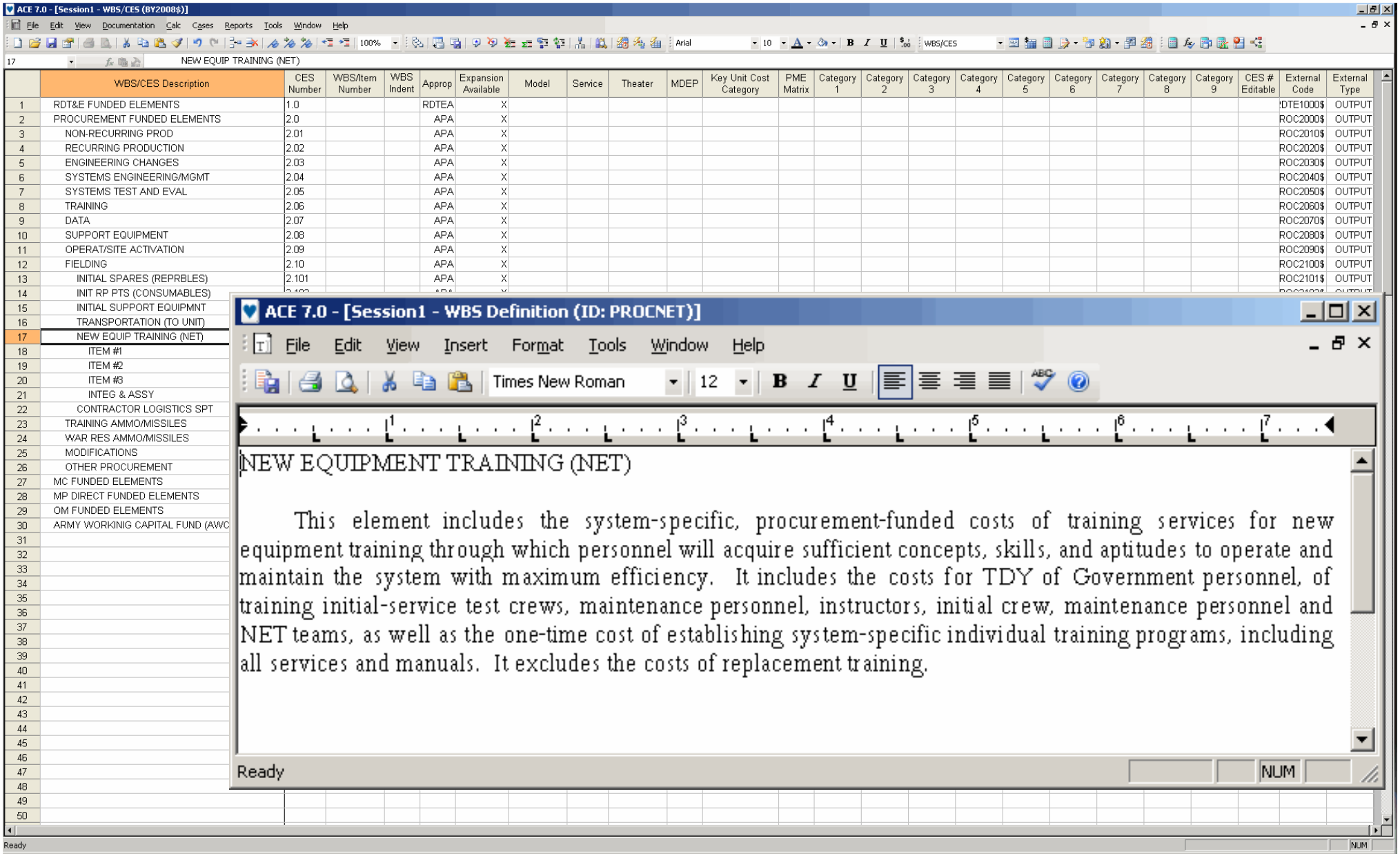
Stephen Cox, UAH

Army LCCE Structure



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

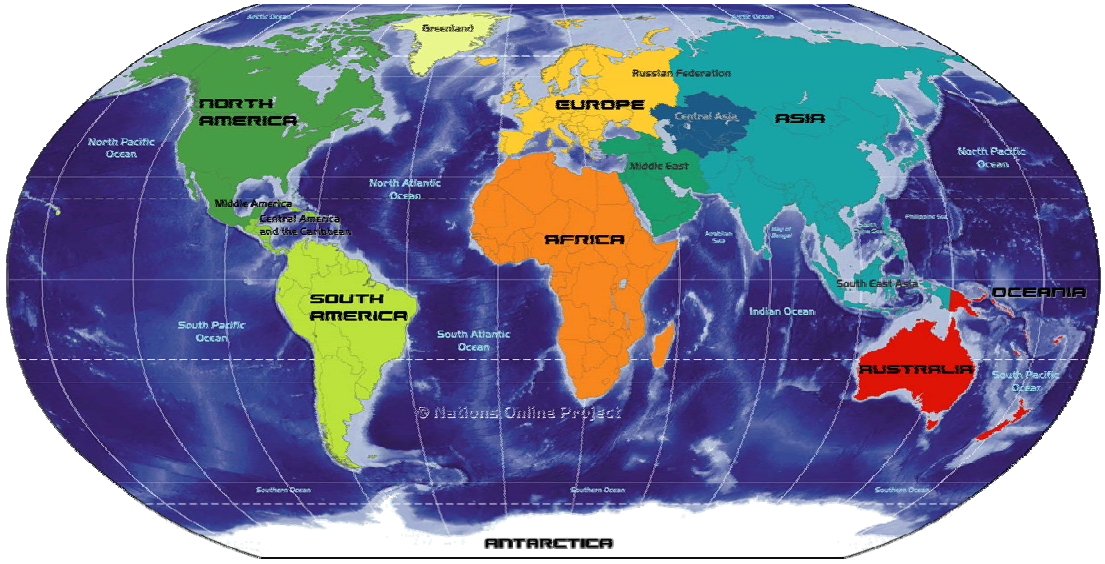
- Status Quo – Use the Mean
  - Estimate cost to travel from Huntsville, AL to each training location
    - NET training is one(1), two(2), or three(3) days
      - We assumed 2 person team, 2 travel days, 2 training days
    - If possible, travel only on week days
    - Always start travel from Huntsville,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

	# Trainers	# Travel Days	# Training Days	Lodging	Full Per Diem	First & Last Day Per Diem	Air Fare to/from LOCATION X	Air fare between training	Airline Fees	Rental Car* - 1 day	Rental Car* - per week	Cost of Fuel	Total
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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

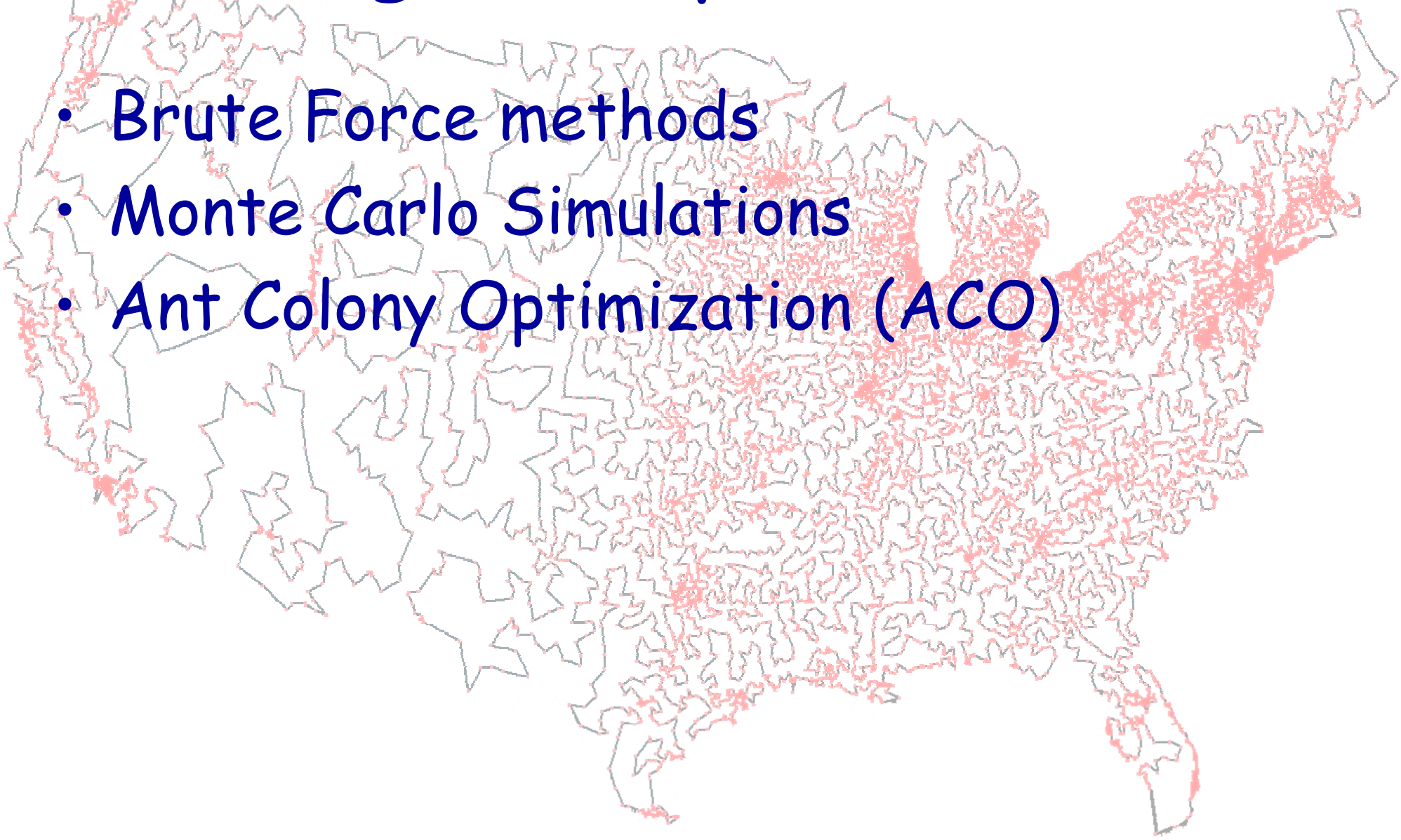
Region 1	$ 5,766.88
Region 2	$ 3,676.34
Region 3	$ 7,679.76
Region 4	$ 8,109.32
Region 5	$ 5,629.34
Region 6	$ 5,313.92
Region 7	$ 6,086.32
Region 8	$ 5,524.40
TOTAL	$ 47,786.28
MINIMUM COST Region	$ 3,676.34
MAXIMUM COST Region	$ 8,109.32
AVERGE COST Region	$ 5,973.29



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

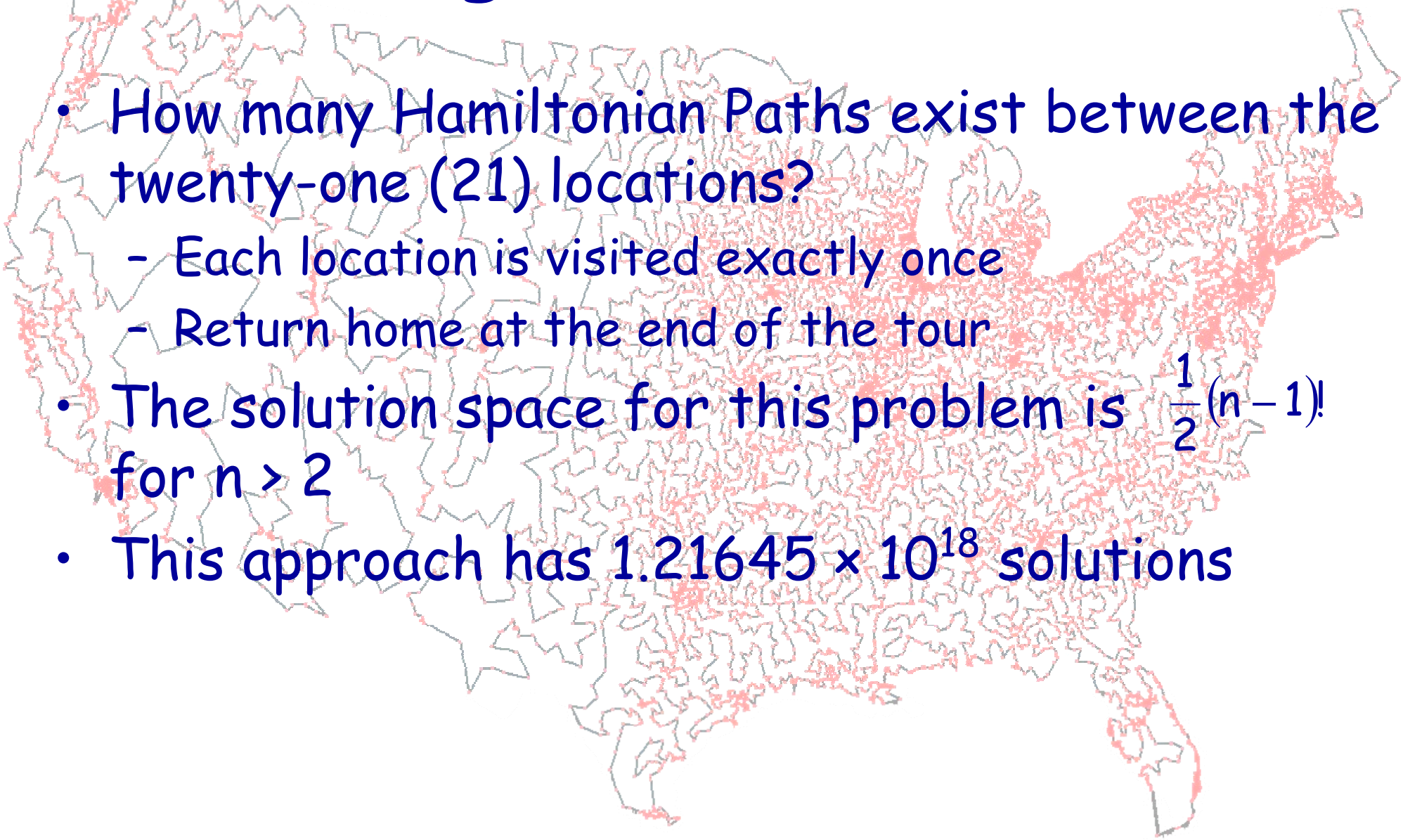
Seeking the Optimal Solution

- 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

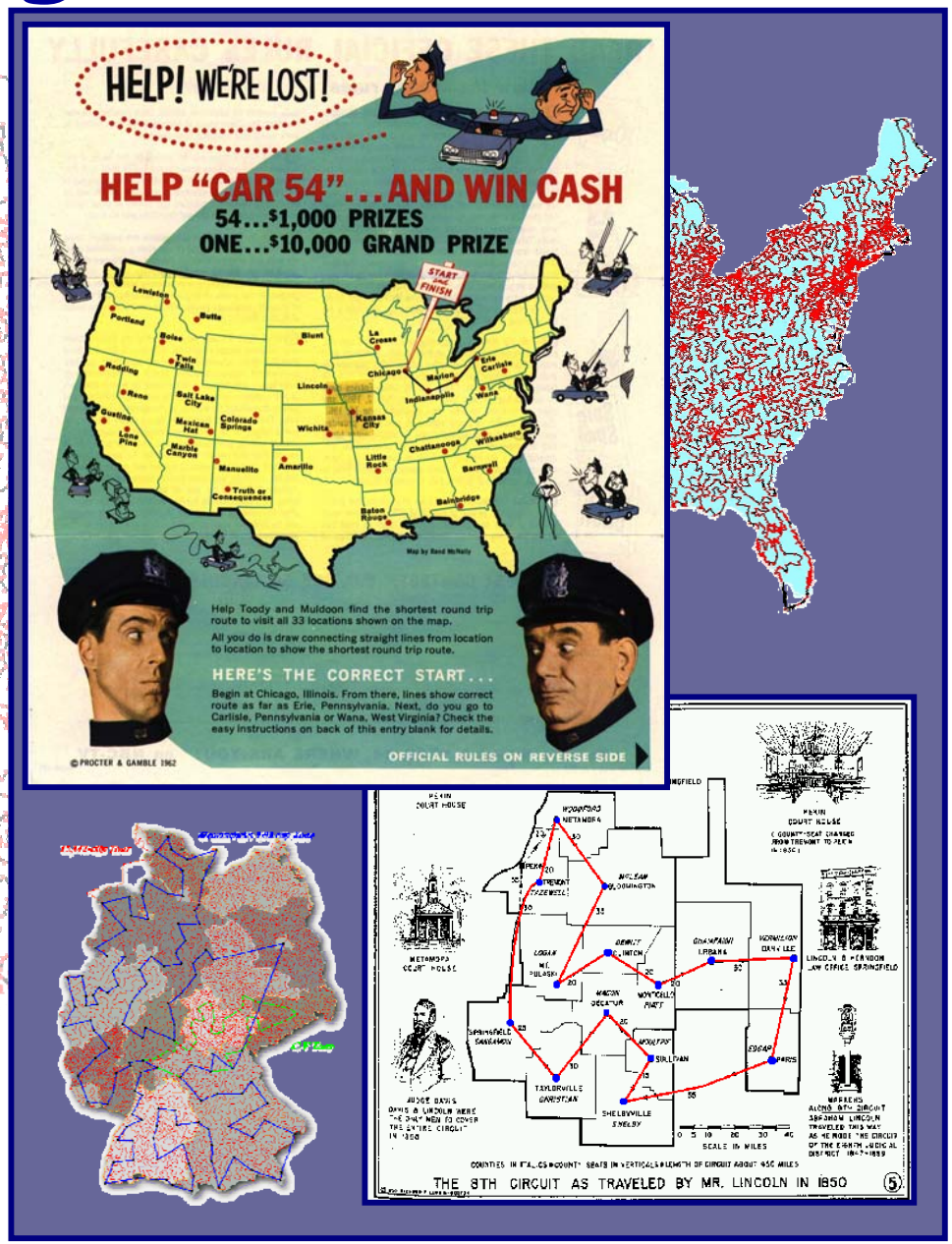


- How many Hamiltonian Paths exist between the twenty-one (21) locations?
  - Each location is visited exactly once
  - Return home at the end of the tour
- The solution space for this problem is $\frac{1}{2}(n-1)!$ for $n > 2$
- This approach has 1.21645×10^{18} solutions

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

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/



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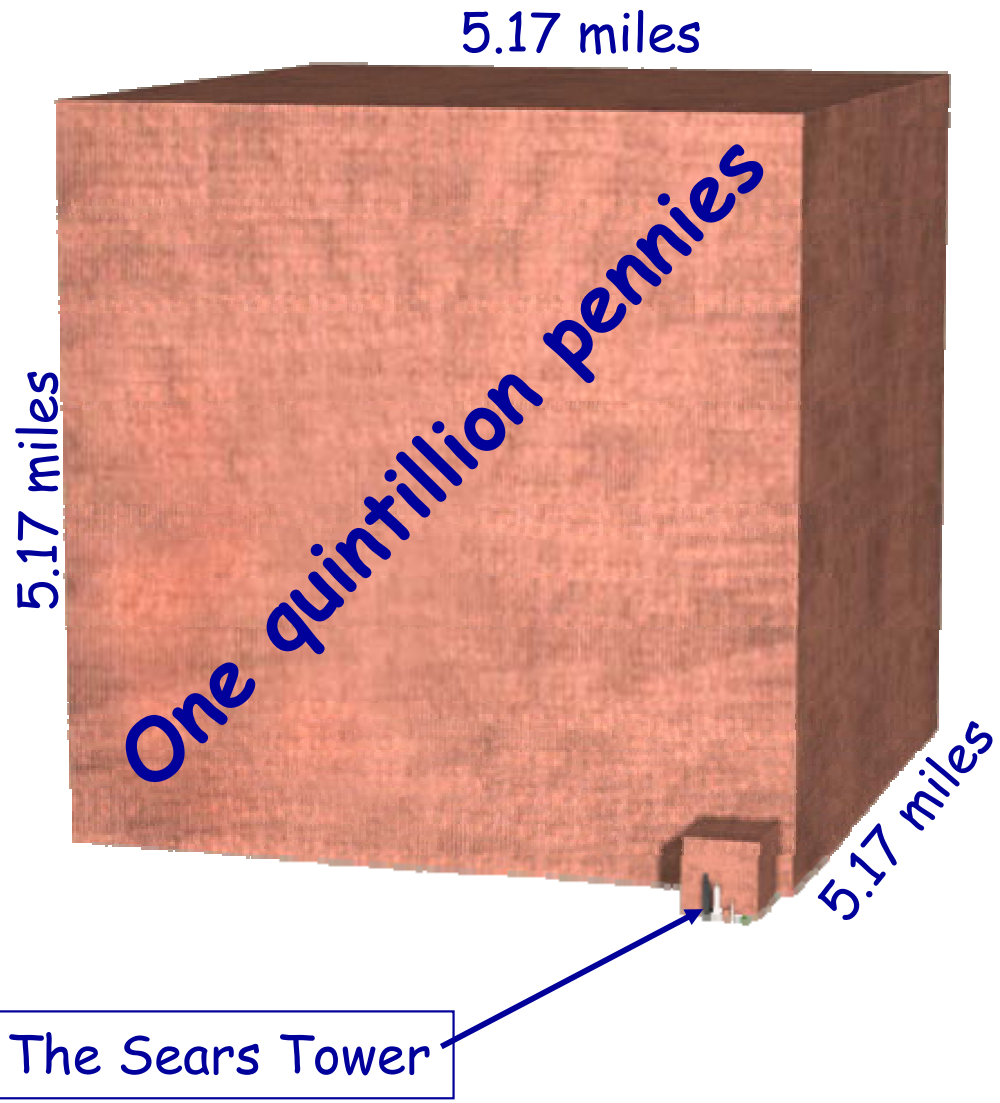
Solution Methods – Brute Force



- 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 $21! = 51.0909422 \times 10^{18} =$ 51 quintillion elements
  - There are about 100 billion, or 10^{12} stars in the Milky Way Galaxy

http://www.kokogiak.com/megapenny/eighteen.asp . April 10, 2008

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)

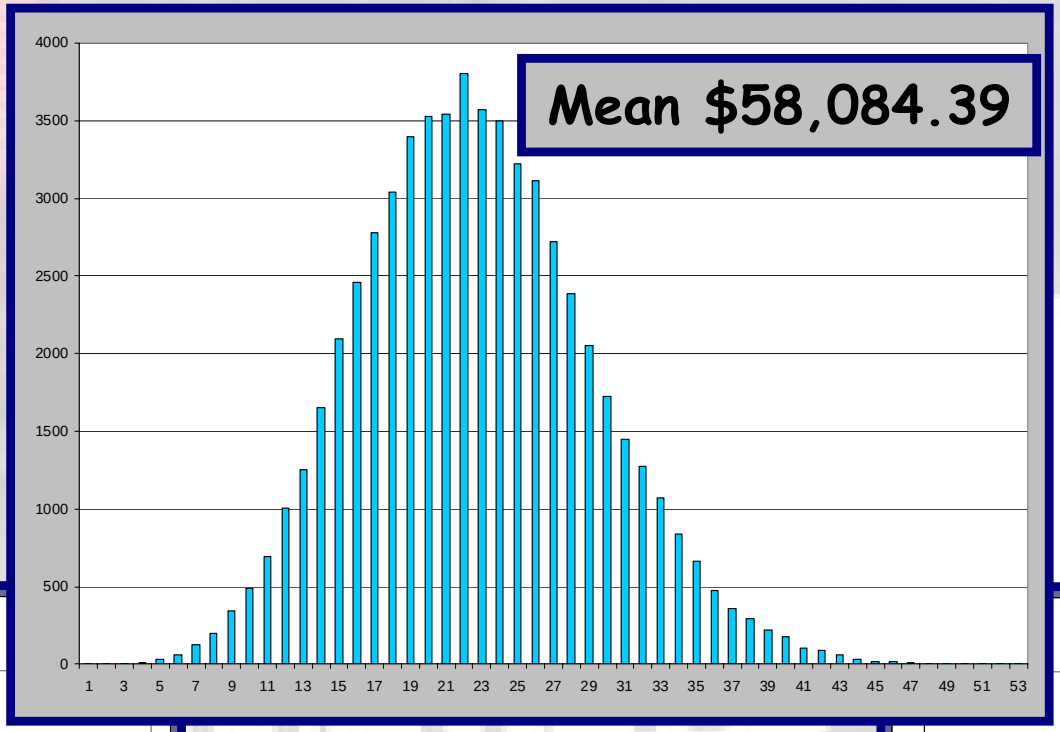
*High Performance Workstation / Still Working……

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

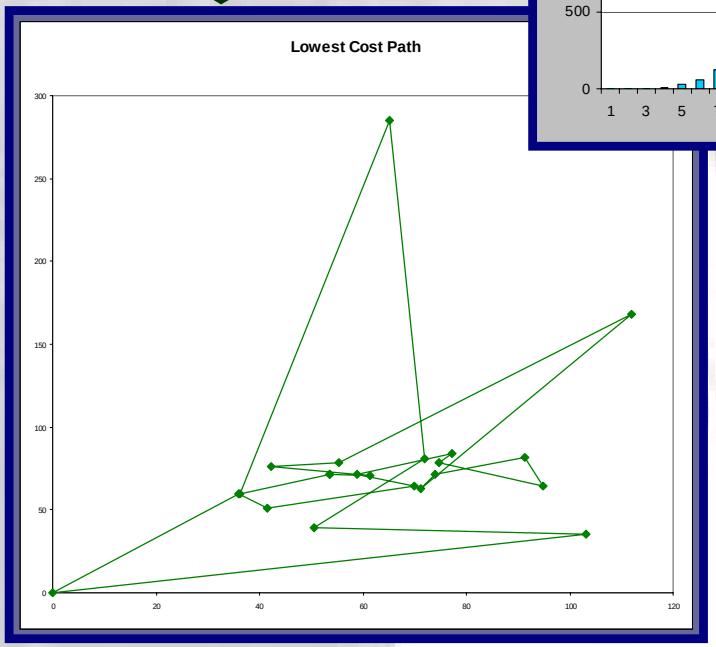
Monte Carlo Solution

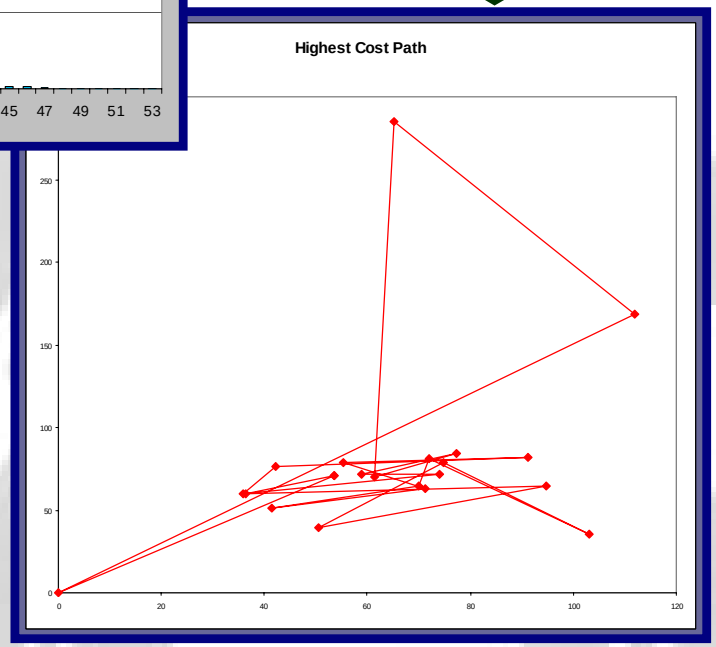
Monte Carlo Results – 60K Iterations



Optimal Cost
$47,058.64

Maximum Cost
$73,293.87





- Path is (X, Y) coordinates to show distance
- Distance is not indicative of cost

Monte Carlo Results

	Least	Highest	Time
1 K	$48,678.17- $48,809.43	$67,617.20- $71,371.07	19 sec 7 sec
10 K	$47,672.77- -$48,325.17	$70,886.80- $71,249.53	1 min 7 sec 2 min 33 sec
30 K	$47,217.44- $47,318.30	$70,560.74- $71,837.03	3 min 2 sec 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.