[redacted]
Space Systems
HW #7

95

Part 1

1.A.) Produce a cost estimate for the NEAR spacecraft (instruments not included). Show the detailed estimates for each subsystem and wrap factor.

Table 1 – NEAR Cost Estimate

Subsystem	Nominal Value	Units	Cost (2005$K)	
ADCS			9,129.30	✓
Pointing Knowledge	0.0029	deg		
ADCS Subsystem Mass	33.9	kg		
Propulsion			10,929.12	✓
Propulsion Subsystem Dry Mass	118.2	kg		
Power			10,821.67	✓
Beginning of Life Power	1880	W		
TT&C/C&DH			25,107.04	✓
C&DH Subsystem Mass	18.7	kg		
Structure			5,516.41	✓
Structural Subsystem Mass	102.2	kg		
Solar Array Area	2.2326	m^2		
Thermal Control			1,270.94	✓
Thermal Subsystem Mass	11	kg		
Beginning of Life Power	1880	W		
IA&T			8,091.11	✓
Design Life	48	mo		
Bus Dry Mass	429.3	kg		
Program Mgmt/Systems Eng			9,366.93	✓
Development Time	29	mo		
Launch & Orbital Ops Supp			10,026.60	✓
Satellite Wet Mass	805	kg		
Total System Cost			**90,259.12**	✓

1.B.) Populate a table with the cost estimate in (a) including the total cost, non-recurring cost, and recurring cost. This table should include the entire spacecraft, subsystems, and wraps.

Table 2 – System Cost, Non-Recurring Costs, and Recurring Costs

Subsystem	Cost (2005$K)	Non-Recurring Costs (%)	Recurring Costs (%)
ADCS	9,129.30	58	42
Propulsion	10,929.12	50	50
Power	10,821.67	48	52
TT&C/C&DH	25,107.04	49	51
Structure	5,516.41	58	42
Thermal Control	1,270.94	55	45
IA&T	8,091.11	31	69
Program Mgmt/Systems Eng	9,366.93	54	46
Launch & Orbital Ops Supp	10,026.60	0	100
Total Cost (2005$K)	$90,259.12	$39,721.33	$50,537.79

1.C.) Inflate the total spacecraft cost estimate to 2008 dollars using the NASA Inflation Index Table.

Table 3 – Inflated Cost Estimate

Subsystem	Cost (2005$K)	Cost (2008$K)
ADCS	9,129.30	9,704.45
Propulsion	10,929.12	11,617.66
Power	10,821.67	11,503.43
TT&C/C&DH	25,107.04	26,688.78
Structure	5,516.41	5,863.94
Thermal Control	1,270.94	1,351.01
IA&T	8,091.11	8,600.85
Program Mgmt/Systems Eng	9,366.93	9,957.05
Launch & Orbital Ops Supp	10,026.60	10,658.28
Total System Cost	90,259.12	95,945.44

1.D.) Note any ground rules and assumptions for this part of the assignment.

- All Cost Estimating Relationships (CER's) are taken from the Aerospace Corporation's 2005 Small Satellite Cost Model.
- All cost estimates are in fiscal year 2005 thousands of dollars (FY2005$K). Estimates are also inflated to FY2008$K using the NASA Inflation Index Table.

- CER's are to be applied to small satellites as defined by the Aerospace Corporation. Small satellites are defined with a wet mass in the range of 100 to 1,000 kg. The NEAR spacecraft has a wet mass of 805 kg.

- Estimates assume the cost of developing and producing one spacecraft, therefore, no learning curve is applied. Concept development and operations are not included.

- All costs estimated by CER's are contractor costs. ✓

- Instruments are not included in the total system cost.

- The propulsion system cost is estimated by using the overall propulsion system dry mass and assuming one large hydrazine, bipropellant thruster. The actual NEAR spacecraft employs one N_2H_4/NTO, bipropellant, 450 N thruster; four N_2H_4, monopropellant, 21 N thrusters; and seven N_2H_4, monopropellant, 3.5 N thrusters.

- Non-recurring and recurring costs are taken from the Aerospace Corporation's 2005 Small Satellite Cost Model.

Part 2

2.A.) Using the table below, run a Monte Carlo on the NEAR spacecraft cost estimate in 2008 dollars. Use 10,000 for the number of runs. Document the nominal value for your input.

nominal values in Table 1. ✓

```
% Mike Alonzo
% Space Systems
% HW #7 Main Script

clear all
close all
clc

% This program is a monte carlo cost estimation
% model for the NEAR spacecraft.

% Index of variables
% num      = number of experiments
% x1       = Satellite wet mass, 805 +/- 161 kg
% x2       = Pointing knowledge, mean = 0.0029, var = 0.001 deg
% x3       = ADCS subsystem mass, 33.9 +/- 6.78 kg
% x4       = Propulsion subsystem mass, 118.2 +/- 23.64 kg
% x5       = Beginning of life power, 1880 +/- 188 W
% x6       = C&DH subsystem mass, 18.7 +/- 1.87 kg
% x7       = Structural mass, 102.2 +/- 20.44 kg
% x8       = Solar array area, 2.2326 +/- 0.22326 m^2
% x9       = Thermal subsystem mass, 11 +/- 2.2 kg
% x10      = Desing life, mean = 48, var = 24 mo
```

```
% x11     = Bus dry mass, 429.3 +/- 85.86 kg
% x12     = Development time, mean = 29, var = 7 mo
% y_total = output total cost estimation from NEAR model
% y_sort  = sorted array of output values

% Set number of experiments
num = 10000;

for i = 1:num

    % Generate and store random input values
    x1(i)  = 644 + (966 - 644)*rand;
    x2(i)  = 0.0029 + (0.001/3)*randn;
    x3(i)  = 27.12 + (40.68 - 27.12)*rand;
    x4(i)  = 94.56 + (141.84 - 94.56)*rand;
    x5(i)  = 1692 + (2068 - 1692)*rand;
    x6(i)  = 16.83 + (20.57 - 16.83)*rand;
    x7(i)  = 81.76 + (122.64 - 81.76)*rand;
    x8(i)  = 2.00934 + (2.45586 - 2.00934)*rand;
    x9(i)  = 8.8 + (13.2 - 8.8)*rand;
    x10(i) = 48 + (24/3)*randn;
    x11(i) = 343.44 + (515.16 - 343.44)*rand;
    x12(i) = 29 + (7/3)*randn;

    % Call NEAR cost model to get and store cost estimation
    y_total(i) = near_cost(x1(i), x2(i), x3(i), x4(i), x5(i), ...
        x6(i), x7(i), x8(i), x9(i), x10(i), x11(i), x12(i));

end

% Sort values of y_total
y_sort = sort(y_total);

% Plot PDF
figure
hist(y_total, 50)
title('Probability Density Function (PDF)');
xlabel('Cost Estimate (2008$K)');
ylabel('Frequency');

% Plot CDF
figure
plot(y_sort, ([1:num]/num)*100)
title('Cumulative Distribution Function (CDF)');
xlabel('Cost Estimate (2008$K)');
ylabel('Confidence Level (%)');
```

```
% Mike Alonzo
% Space Systems
% HW #7 NEAR Cost Model

function y_total_08 = near_cost(x1, x2, x3, x4, ...
    x5, x6, x7, x8, x9, x10, x11, x12);

% The near_cost function employs the cost estimating relationships for
each
% subsystem of the NEAR spacecraft and totals each CER to find the
total
% system cost in 2008$.

% Subsystem costs
% ADCS
y1 = 1567.03*(x2^-0.26)*(x3^0.069);

% Propulsion (0,1 - cold gas/hydrazine, monoprop/biprop)
y2 = 324.17*(x4^0.446)*(1.781^1)*(2.253^1);

% Power (0,1 - Si, GaAs)
y3 = 281.58*(x5^0.484);

% TT&C/C&DH
y4 = 4061.72*(x6^0.622);

% Structure (0,1 - Al, composite)
y5 = 183.99*(x7^0.54)*(1.742^0)*((x8*4)^0.412);

% Thermal
y6 = 72.37*(x9^0.931)*(x5^0.084);

% IAT
y7 = 141.16*(x10^0.302)*(x11^0.475);

% PM/SE
y8 = 84.56*(x12^1.398);

% LOOS (0,1 - spin, 3-axis)
y9 = 0.136*(x1^1.51)*(3.019^1);

% Total system cost in 2005$K
y_total_05 = y1 + y2 + y3 + y4 ...
    + y5 + y6 + y7 + y8 + y9;

% Inflate total system cost to 2008$K
y_total_08 = y_total_05*1.063;

return
```

2.B.) Plot the Monte Carlo results as a PDF and a CDF.

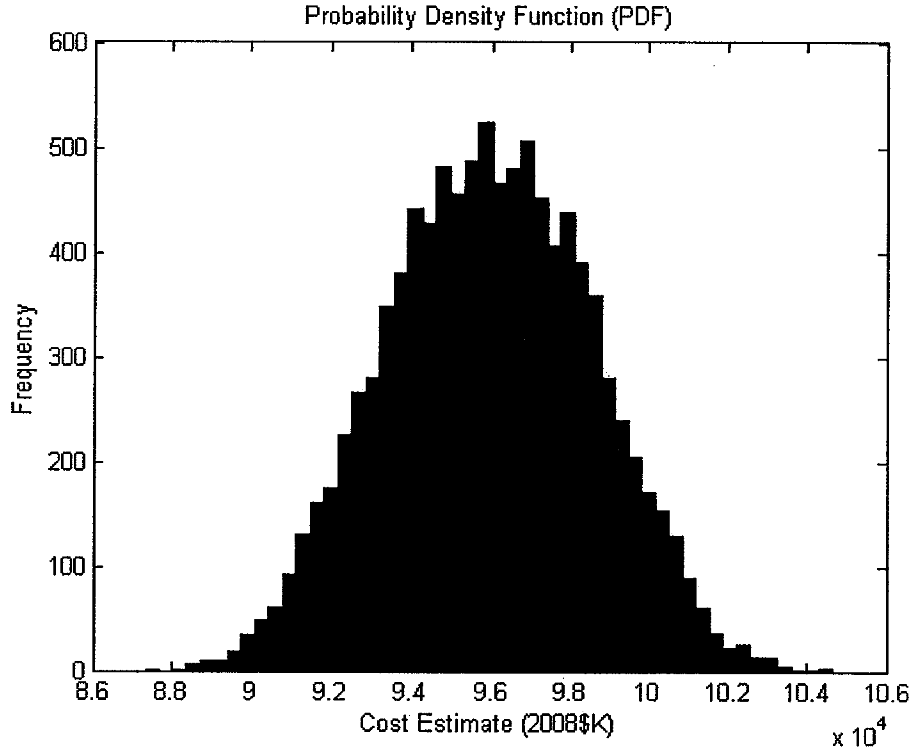

Figure 1 – Frequency vs. Cost Estimate

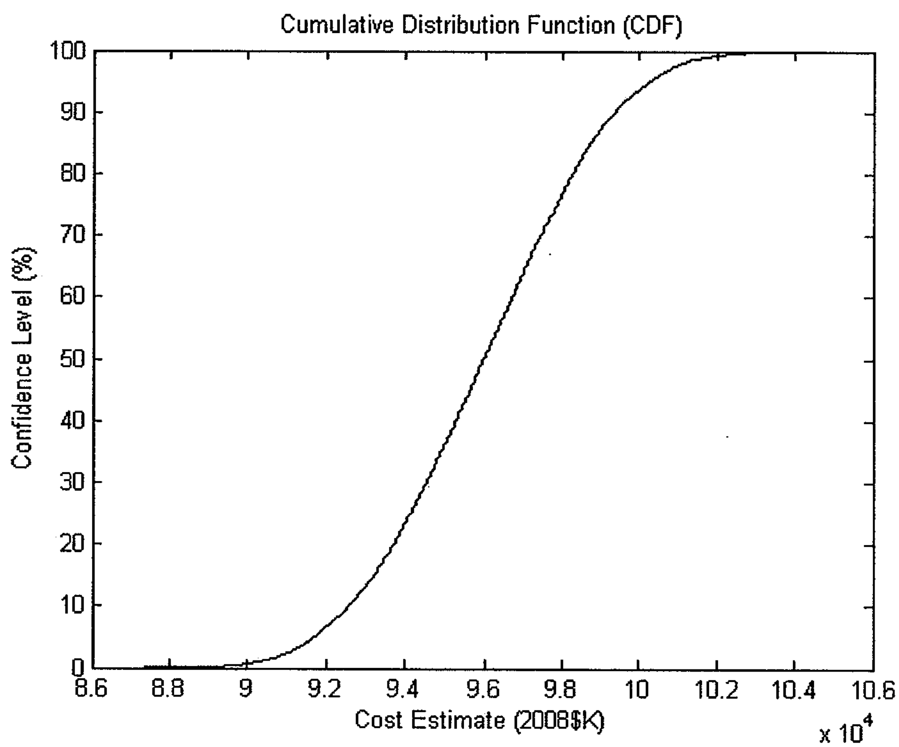

Figure 2 – Confidence Level vs. Cost Estimate

2.C.) Show the point estimate on the CDF and compare to the 65% confidence level.

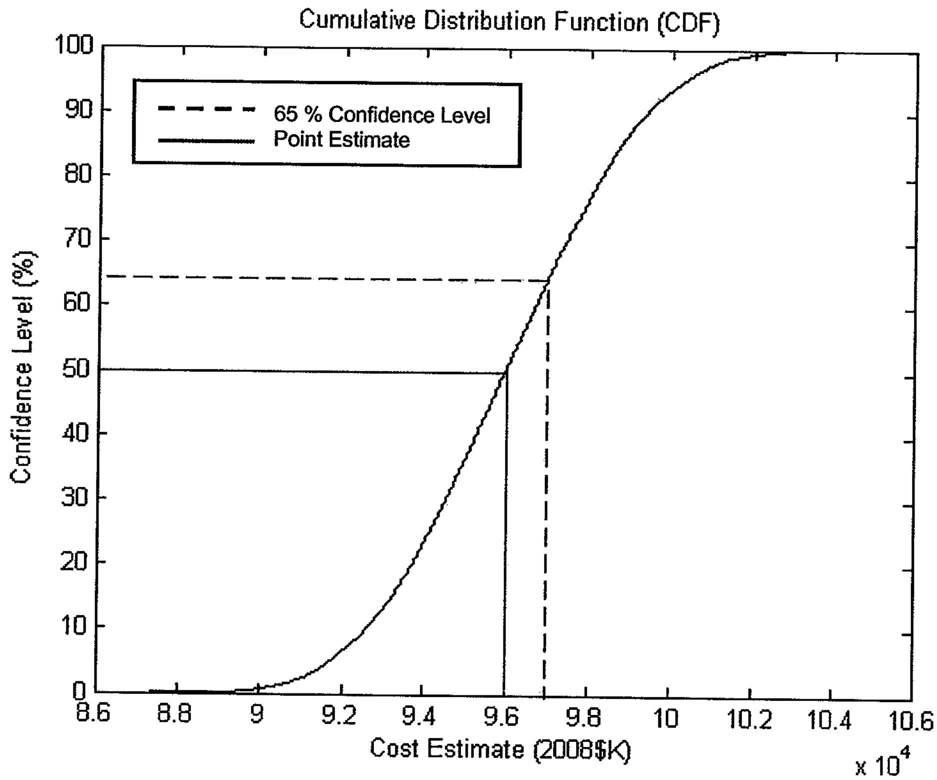

Figure 3 – Confidence Level vs. Cost Estimate

2.D.) How much reserve (also known as margin) should be added to the point estimate to meet a 65% confidence level?

Approximately a ~~15% margin~~ should be added to the point estimate to meet a 65% confidence level.

a 15% change in the confidence level is not the same as a 15% margin!!

-5

Part 3

Discuss the use of the Small Satellite Cost Model.

- **Any concerns applying it to the NEAR spacecraft?**
- **Was the point estimate what you expected? Was its probability of occurrence what you expected?**
- **How would you recommend checking the reasonableness of your point estimate?**

There were no major concerns applying the Small Satellite Cost Model to the NEAR spacecraft. The only major assumption in costs was the propulsion system cost. One large, bipropellant thruster was assumed in the calculation of the propulsion system dry mass instead of several bipropellant and monopropellant thrusters.

Yes, the point estimate was what I expected. Applying the cost estimating relationships in Excel, I found the NEAR spacecraft to cost approximately $96M using nominal inputs for each subsystem. I obtained the same value for the cost estimate using Matlab, with a 50% confidence level. I assumed that the probability for this occurrence would be around this range.

I would compare my point estimate with historical data, similar satellites, and other cost models to check the reasonableness of my point estimate. If my cost estimate is within a certain percentage (around 10%-15%) of these other sources, I would assume my cost estimate to be valid.