[redacted]

(99)

3-20-08

Cost Estimation and Monte Carlo Simulation

1. The following two tables show the input parameters and the cost estimate from the Small Satellite Cost Model developed by The Aerospace Corporation.

Table 1: Input Parameter

Parameter	Value	Unit	
Wet Mass	805	kg	✓
Pt. Know.	0.002865	deg	✓
ADCS Mass	33.9	kg	✓
THR Dry Mass	118.2	kg	✓
Beg. Life Power	1880	W	✓
CDH Mass	18.7	kg	✓
STR Mass	~~96.1~~	~~kg~~	102.2 kg ✗
Sol. Arr. Area	8.9304	m^2	✓
THM Mass	11	kg	✓
Design Life	48	months	✓
Bus Dry Mass	429.3	kg	✓
Dev. Time	29	months	✓

Table 2: Subsystem and total satellite cost in 2005 dollars and then adjusted for inflation

Subsystems	Cost Y05	NRe	Re	
ADCS	9158	5312	3846	✓
THR	10929	5465	5465	✓
EPS	10822	5194	5627	✓
COM/CDH	25107	12302	12805	✓
STR	5336	3095	2241	✗ (-1)
THM	1271	699	572	✓
AI&T	8091	2508	5583	✓
PM/SE	9367	5058	4309	✓
LOOS	10027	0	10027	✓
Total	**90108**	39633	50474	✓

Total Y08	**95821**	42146	53674	✓

The assumptions made for the cost estimate to be valid are that the NEAR spacecraft is characterized by "small satellite", which it seems to be. The NEAR spacecraft is a series of small scale, low cost, quick turn-around spacecrafts that seem valid to cost estimate with The Aerospace Corporation's cost model. In addition, it should be noted that for the cost model the spacecraft was considered to be 3-axis stabilized, using a bipropellant one of which is hydrazine, and is a planetary mission. All of which were valid for the spacecraft.

2. The following two figures demonstrate the probability density and the confidence level of the estimated cost about the nominal value when considering the range of variability of the input parameters.

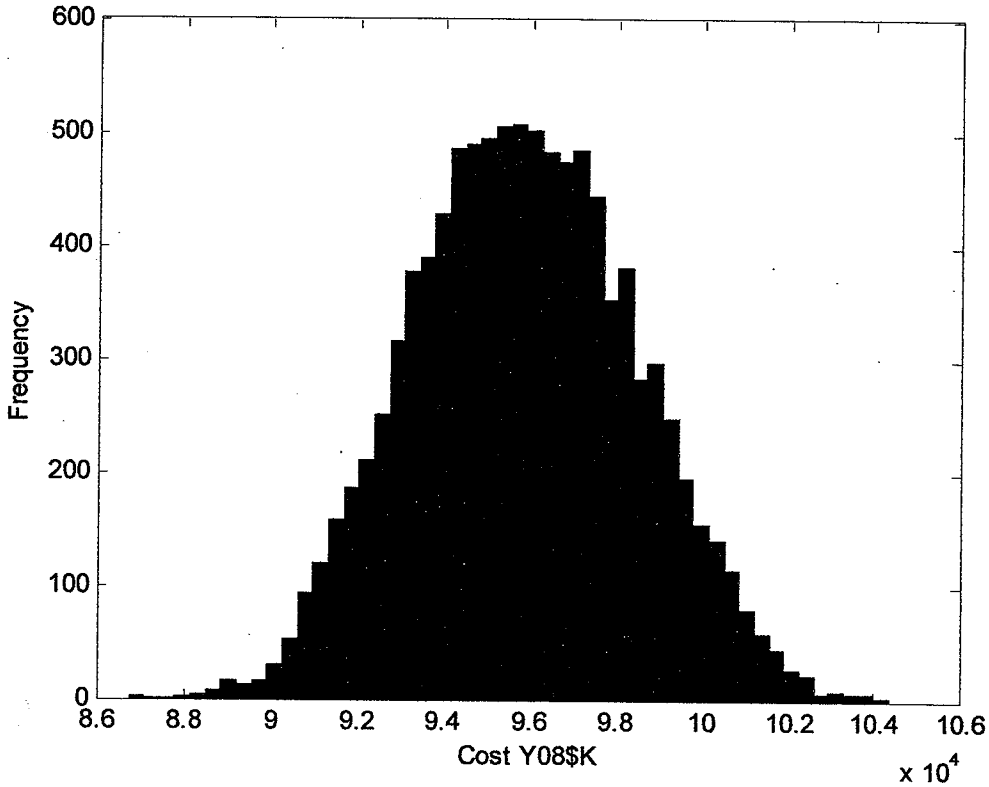

Figure 1: Probability Density Function for the Cost Estimate for the NEAR Spacecraft

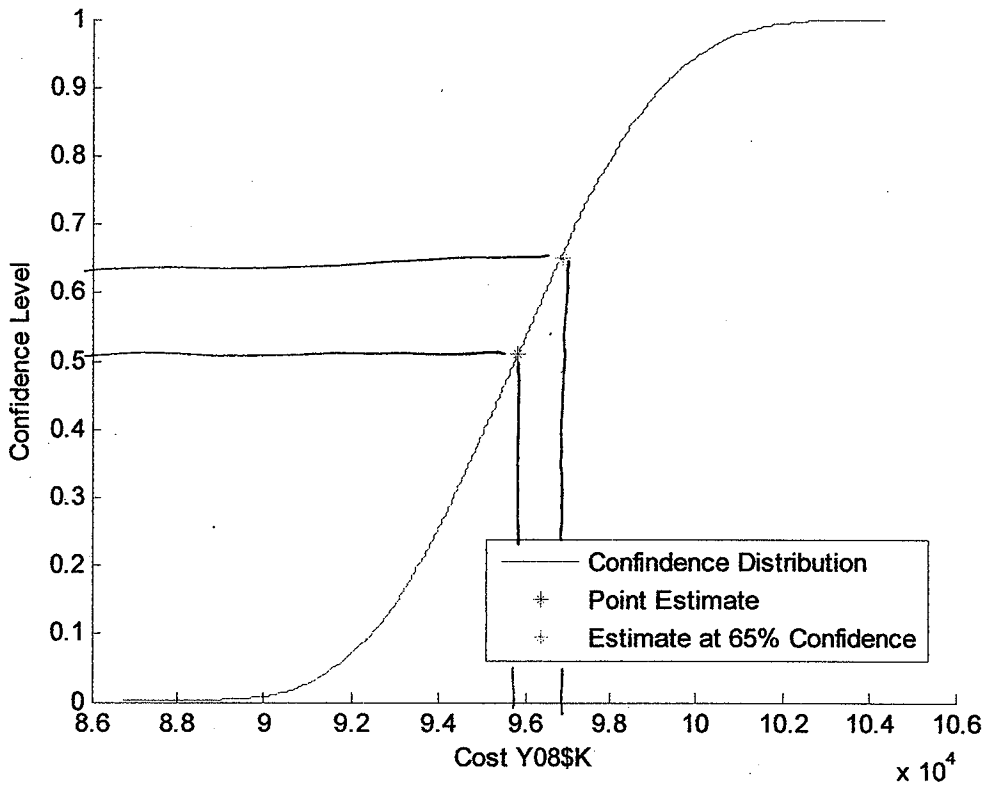

Figure 2: The Confidence Level of the Cost Estimate for NEAR

The point estimate from the Small Satellite Cost Estimate Model is 95821 Y08$K, which is approximately at a confidence level of 51%. To have a 65% confidence level the cost estimate is indicated at approximately 96900 Y08$K. Thus a margin of 1079 Y08$K should be applied to the point estimate to have 65% confidence level that the actual cost will not overrun the estimate.

3. I do not feel there are any major concerns about applying the Small Satellite Cost Model to the NEAR spacecraft. The only concern I have about the cost model was that I first thought that the spacecraft was spin stabilized and applied that cost estimate equation for the attitude determination and control subsystem. The equation gave a ridiculously large cost in comparison to the other subsystems. I quickly thought that it was wrong and revisited the literature only to find that the spacecraft was 3-axis stabilized and the equation gave a much more reasonable answer. Therefore, I am not sure if the spin stabilized cost equation is accurate. In any case, I am concerned about using that equation.

I was not at all sure of how much the NEAR spacecraft was going to cost, but the confidence level was expected. A confidence level of 51% was expected because the Monte Carlo simulation varied the input parameters about the nominal values. Thus the cost estimate was expected to be approximately 50%, the nominal, and all other estimates would vary in occurrence about the nominal value.

I would say to compare the estimate to past missions, but if the Small Satellite Cost Model is based on many of the past missions, then such a comparison should only confirm your point estimate. Depending on the time table allotted to checking the reasonableness of the point estimate, one could begin the very detailed cost estimate which is done by actually adding up costs for components and labor expected on the project. I believe such a cost estimate has to be done eventually anyway.

```
function NEARCostEst

clear all, close all, clc

%Initialize Nominal Values
swmN = 805;
ptkN = 0.002865;
adcsmN = 33.9;
thrmN = 118.2;
bolpN = 1880;
cdhmN = 18.7;
strmN = 96.1;
solAN = 8.9304;
thmmN = 11;
dlN = 48;
bdmN = 429.3;
dvltN = 29;
%Obtain Nominal Projected Cost
costN = NEAR(swmN,ptkN,adcsmN,thrmN,bolpN,cdhmN,strmN,solAN,thmmN,dlN,bdmN,dvltN)

n = 10000;
for ii = 1:n
   %Randomizing Parameters
   swm = (swmN-swmN*0.2) + swmN*0.4*rand();
   ptk = ptkN + 0.001/3*randn();
   adcsm = (adcsmN-adcsmN*0.2) + adcsmN*0.4*rand();
   thrm = (thrmN-thrmN*0.2) + thrmN*0.4*rand();
   bolp = (bolpN-bolpN*0.1) + bolpN*0.2*rand();
   cdhm = (cdhmN-cdhmN*0.1) + cdhmN*0.2*rand();
   strm = (strmN-strmN*0.2) + strmN*0.4*rand();
   solA = (solAN-solAN*0.1) + solAN*0.2*rand();
   thmm = (thmmN-thmmN*0.2) + thmmN*0.4*rand();
   dl = dlN + 24/3*randn();
   bdm = (bdmN-bdmN*0.2) + bdmN*0.4*rand();
   dvlt = dvltN + 7/3*randn();


   %Run Cost Model
   cost = NEAR(swm,ptk,adcsm,thrm,bolp,cdhm,strm,solA,thmm,dl,bdm,dvlt);

   %Store Parameters
   swmT(ii) = swm;
   ptkT(ii) = ptk;
   adcsmT(ii) = adcsm;
   thrmT(ii) = thrm;
   bolpT(ii) = bolp;
   cdhmT(ii) = cdhm;
   strmT(ii) = strm;
   solAT(ii) = solA;
   thmmT(ii) = thmm;
   dlT(ii) = dl;
   bdmT(ii) = bdm;
   dvltT(ii) = dvlt;
   costT(ii) = cost;
end

costSort = sort(costT);

figure(1), hist(costT,50)
xlabel('Cost Y08$K');
ylabel('Frequency');
figure(2)
hold on
```

```
plot(costSort,[1:n]/n)
plot(costN, 0.51, 'r*')
plot(96900, 0.65, 'g*')
legend('Confindence Distribution', 'Point Estimate', 'Estimate at 65% Confidence');
xlabel('Cost Y08$K');
ylabel('Confidence Level');
hold off
```

```
function cost = NEAR(swm,ptk,adcsm,thrm,bolp,cdhm,strm,solA,thmm,dl,bdm,dvlt)

ADCS = 1567.03*ptk^-0.26 * adcsm^0.069; %0.613*swm^1.584 * ptk^-1.316;
THR = 324.17*thrm^0.446 * 1.781^1 * 2.253^1;
EPS = 281.58*bolp^0.484;
CDH = 4061.72*cdhm^0.622;
STR = 183.99*strm^0.54 * 1.742^0 * solA^0.412;
THM = 72.37*thmm^0.931 * bolp^0.084;
AIT = 141.16*dl^0.302 * bdm^0.475;
PMSE = 84.56*dvlt^1.398;
LOOS = 0.136*swm^1.51 * 3.019^1; %Note value depends on ACDS

cost05 = ADCS + THR + EPS + CDH + STR + THM + AIT + PMSE + LOOS;
cost = cost05*(1 + .0634);
```