IMPROVED METHODOLOGY FOR DEVELOPING COST UNCERTAINTY MODELS FOR NAVAL VESSELS

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Outline

- Background
- Research Questions
- NAVSEA CGX Model & My Model Analysis
- Conclusions

Background

- **CNO Guidance for 2007-2008**
  - "**We manage risk**. We will identify, analyze, mitigate and then accept risk, appreciating that we must always consider the risks in aggregate across the entire force. Zero risk is not achievable nor affordable. We must manage risk and move forward to accomplish the mission while safeguarding our people and infrastructure."

Background (cont.)

- **The First 100 Days from Vice Admiral McCoy**
  - Common mission: develop, deliver, & maintain ships and systems on time and on cost for the Navy.
  - NAVSEA Strategic Business Plan: Build an Affordable Future Fleet. "…we must take definitive steps to ensure future ships and weapons systems are affordable to **build**, maintain, and upgrade over their service lives."
  - To Build an Affordable Future Fleet, We Will:
  - Focus on reducing acquisition costs, including applying more risk-based decisions to specifications and requirements…

Research Questions

- What is the realism of the cost models currently in use by NAVSEA 05C for the CG(X) class ship?
- How does data elicitation impact the cost prediction?
- How does the choice of distributions in the model affect the predictions of the cost outcome?
- What is the impact of the MAIMS principle on the cost probability distributions?
- How can the current CG(X) model be improved to provide more accurate models to predict cost and risk?

CGX Model From NAVSEA 05C

MAMDJF AoA Lead Ship Production Cost Estimate Risk Analysis

All Costs Reported in Year of award

	X1 (Lead Ship) (TY11$M)						
WBS	NRE	X1 (Rec)	% Low	Low	Most Likely	High	% High
Ordnance	**$ 14.70**	**$107.84**		**$ 86.30**	**$ 93.77**	**$ 165.74**	
VLS	$ 3.20	$70.93	95%	$ 58.60	$ 61.68	$ 101.57	165%
CIGS	$ 11.500	$ 31.97	85%	$ 23.63	$ 27.80	$ 55.60	200%
DLS	$ -	$ 4.93	95%	$ 4.07	$ 4.29	$ 8.58	200%
Electronics	**$ 160.38**	**$ 804.53**		**$ 633.57**	**$ 748.19**	**$ 910.20**	
Radar Suite	**$ 23.15**	**$ 257.49**	**85%**	**$ 190.32**	**$ 223.90**	**$ 257.49**	**115%**
X-band	$ -	$ 65.58	95%	$ 62.30	$ 65.58	$ 75.41	115%
S-band	$ 22.72	$ 154.61	95%	$ 146.88	$ 154.61	$ 177.80	115%
Cooling	$ 0.43	$ 3.71	95%	$ 3.53	$ 3.71	$ 4.27	115%
Power (included in Ship Total)	$ 1.82	$ 55.89	95%	$ 46.17	$ 48.60	$ 55.89	115%
ExComm	$ 30.21	$ 154.44	75%	$ 100.72	$ 134.29	$ 188.01	140%
TSCE	$ 3.45	$ 86.61	75%	$ 56.49	$ 75.32	$ 94.15	125%
IUSW	$ 5.69	$ 30.38	95%	$ 25.09	$ 26.41	$ 27.73	105%
EW-IW	$ 21.02	$ 56.10	75%	$ 36.58	$ 48.78	$ 60.97	125%
EO-IR	$ -	$ 14.15	95%	$ 11.69	$ 12.31	$ 12.92	105%
IFF	$ -	$ 9.65	95%	$ 7.98	$ 8.40	$ 8.82	105%
MS EI&T (SS Only)	$ 60.89	$ 105.19	80%	$ 73.18	$ 91.47	$ 109.77	120%
MS EI&T (CS Only)	$ 15.98	$ 90.52	80%	$ 62.97	$ 78.71	$ 94.45	120%

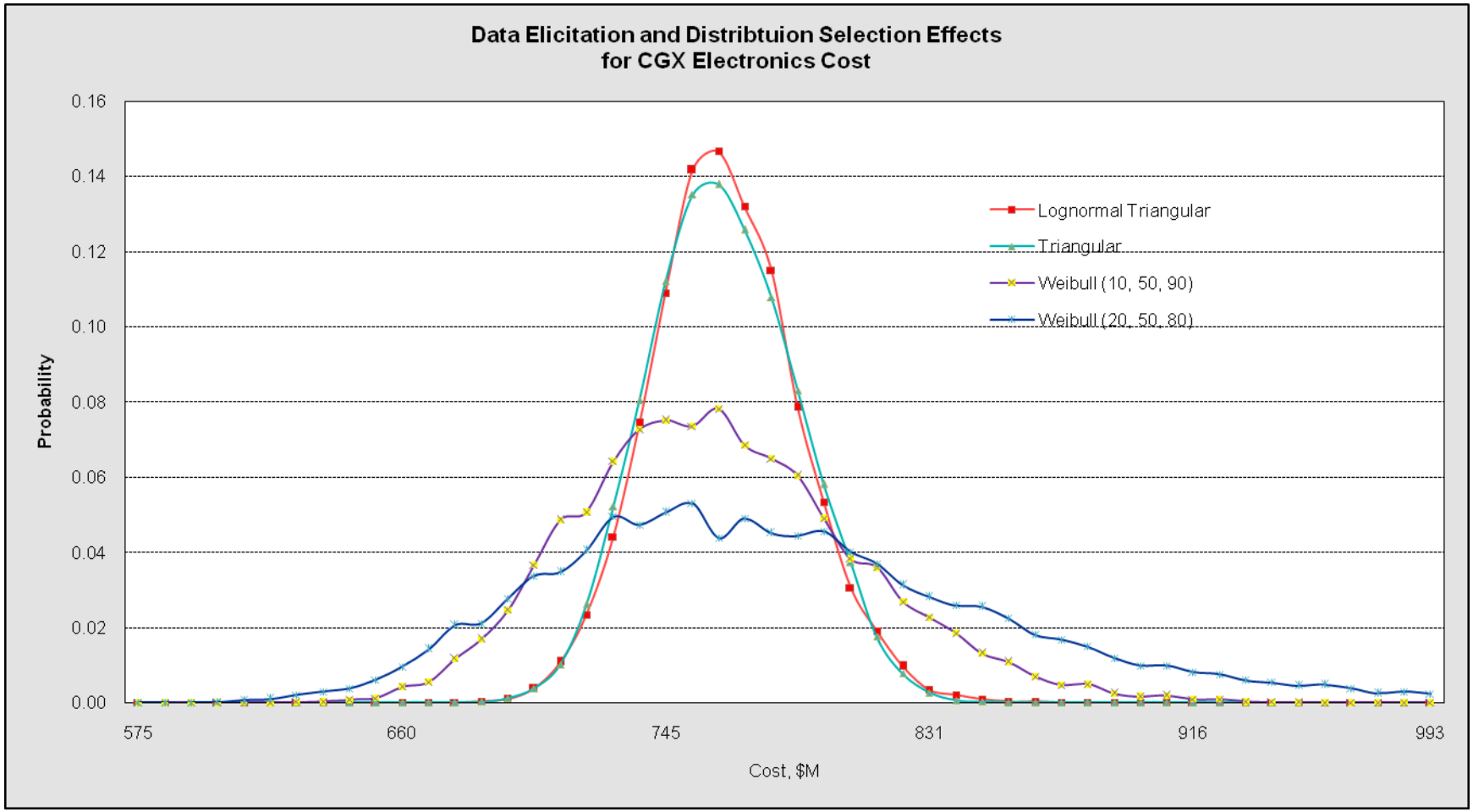
My Analysis

- The Low, Most Likely, and High values were obtained from Subject Matter Experts from Dahlgren.
- Most Likely value corresponds to 50% value based on triangular distribution.
- Conducted individual Monte Carlo simulations of the L/ML/H values, but this ended up giving normalized values very close to the original values.

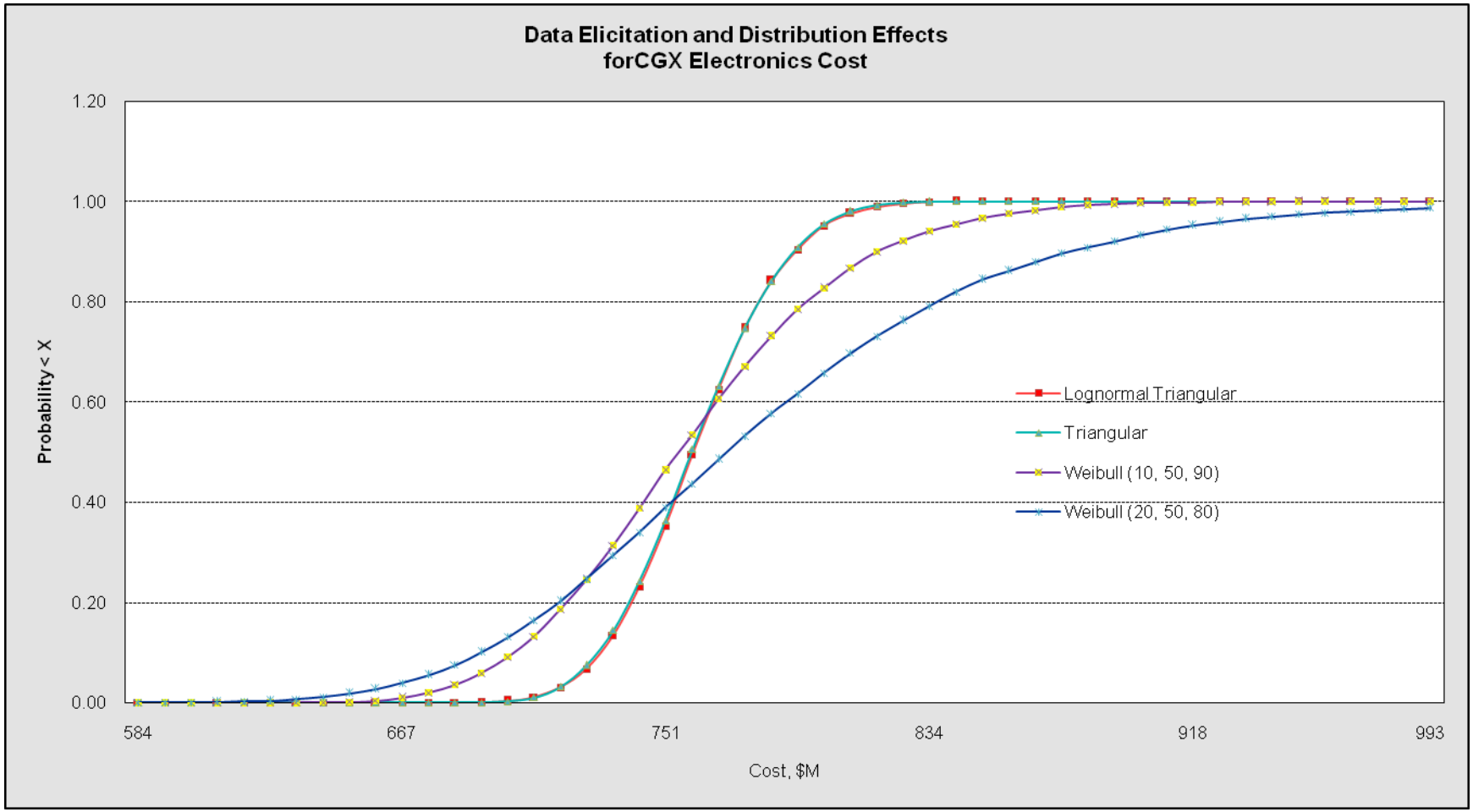
My Analysis (cont.)

- Original L/ML/H values were used in my model.
- Investigated effect of choice of distribution on cost.
- Investigated impact of radar component correlation on cost. Expect only positive or independent correlation.
- Modeled effects of MAIMS principle on cost.

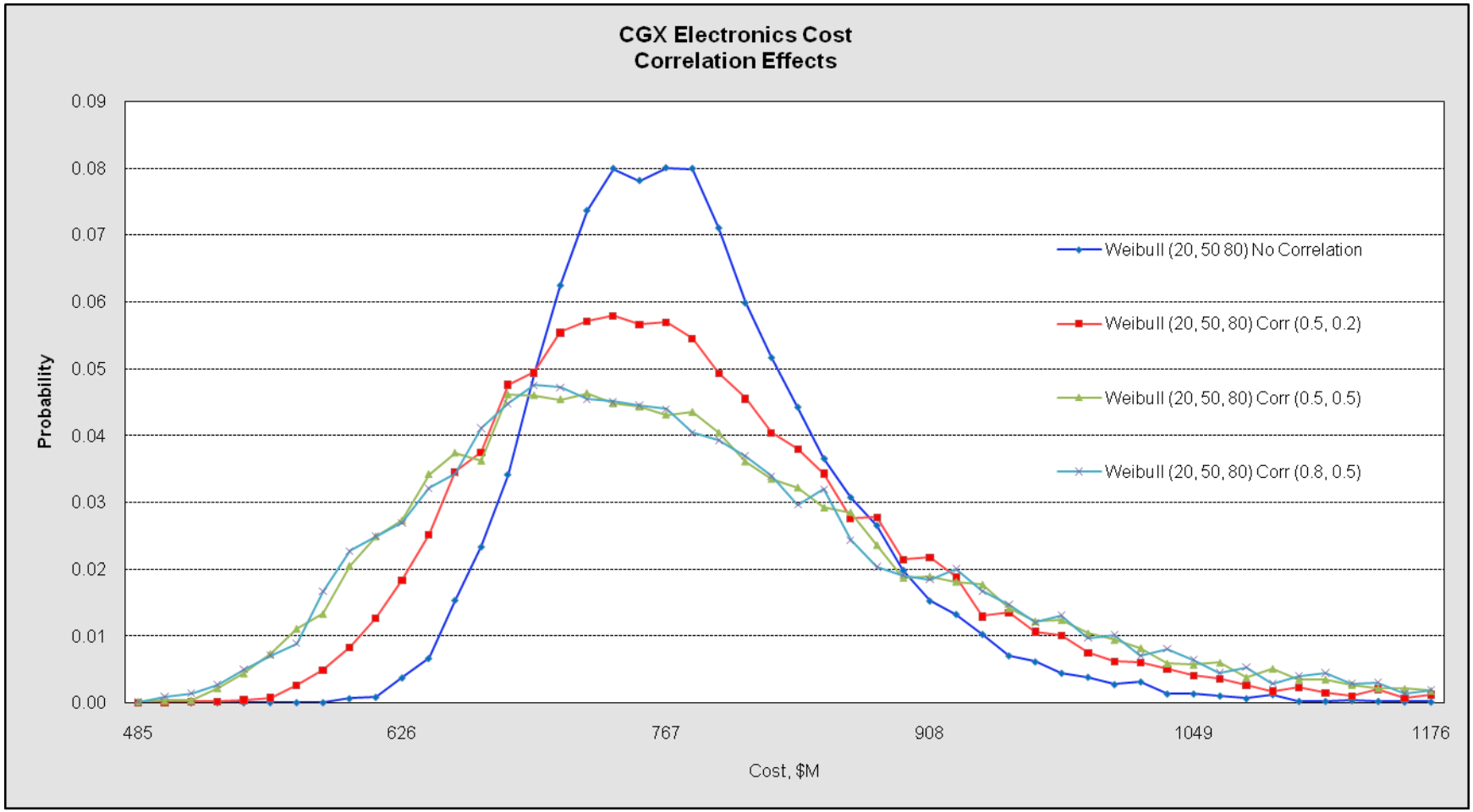
Effects of Distribution Choice on Cost



Effects of Distribution Choice on Cost Based on Funding Level



Radar Correlation Effects on Cost



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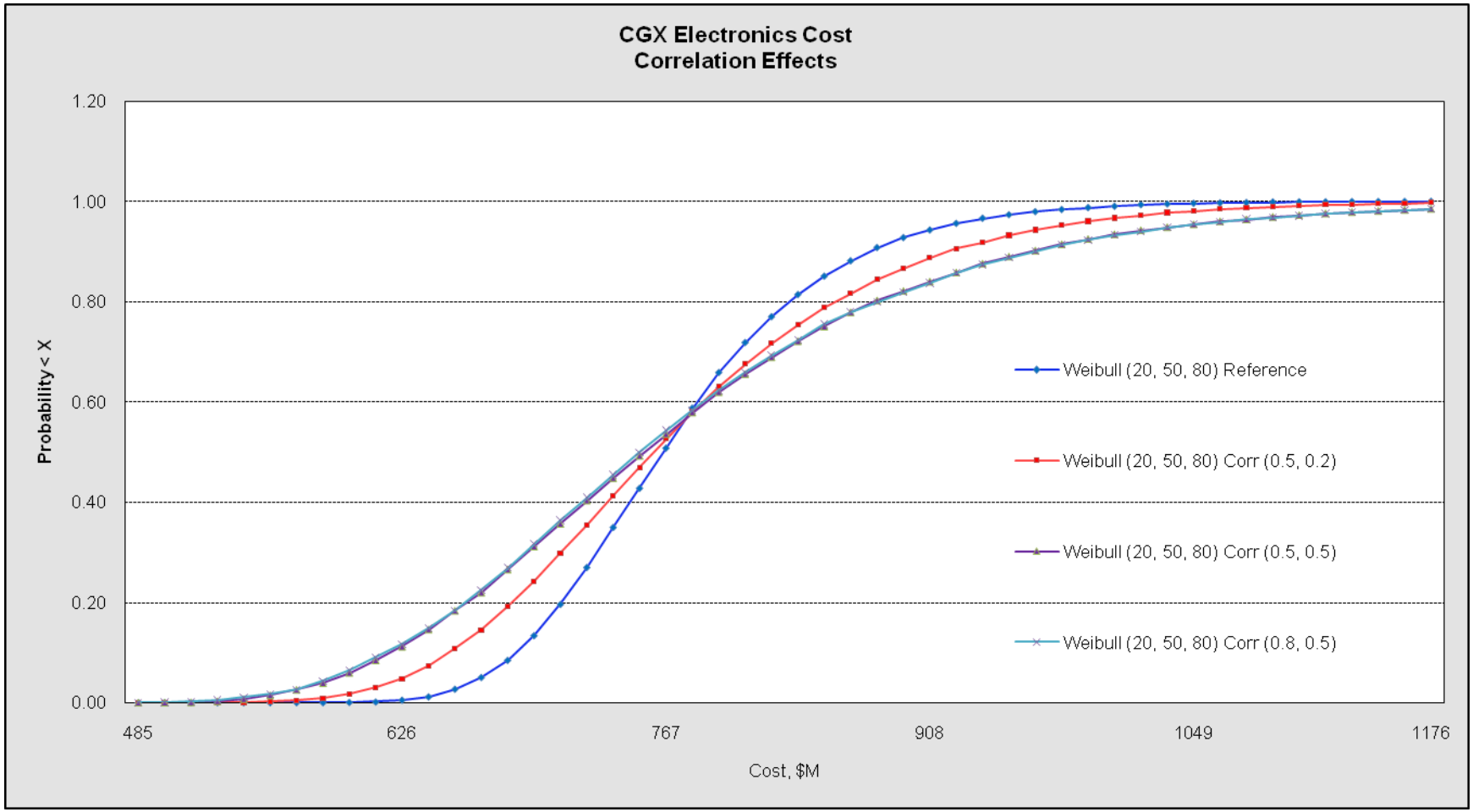
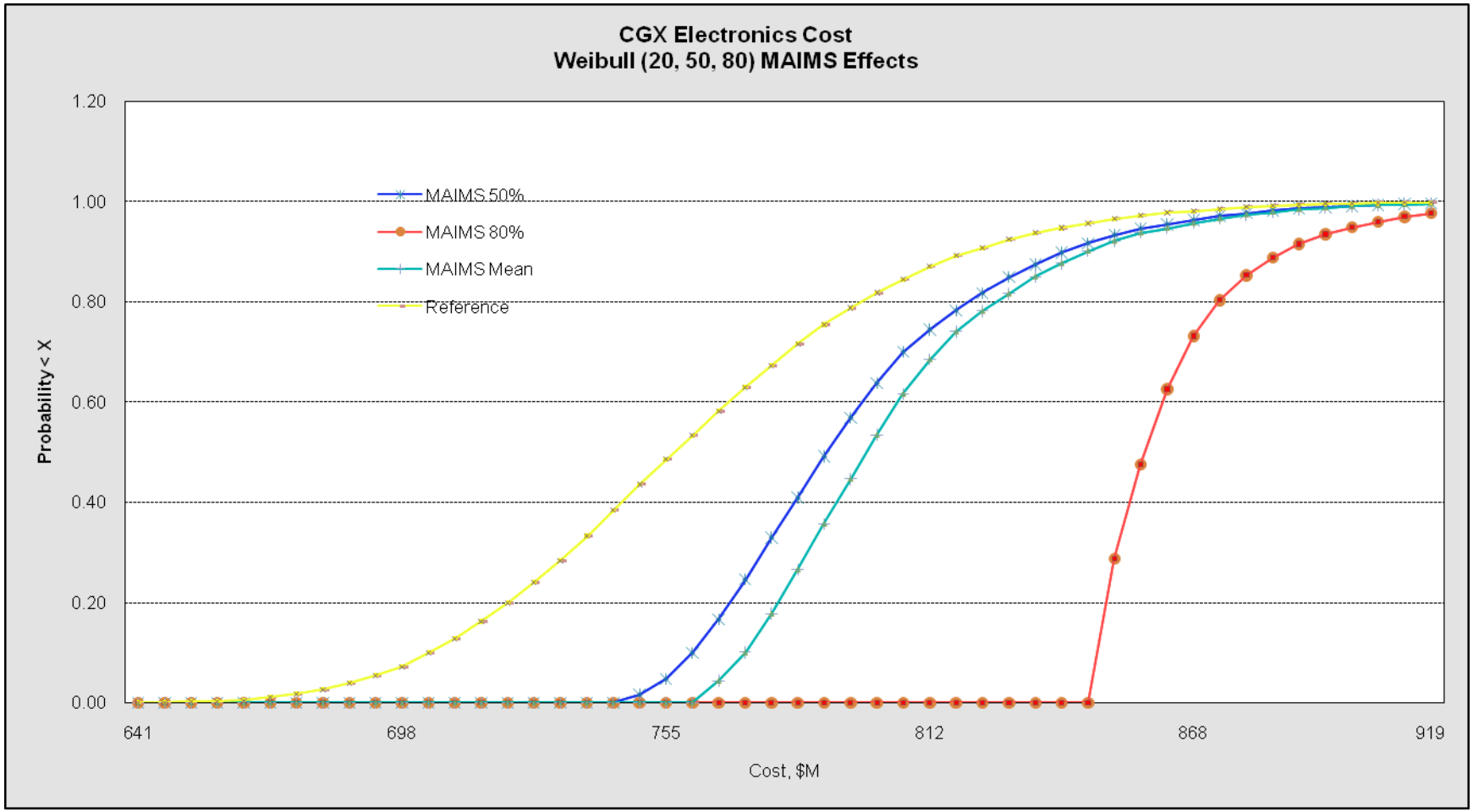
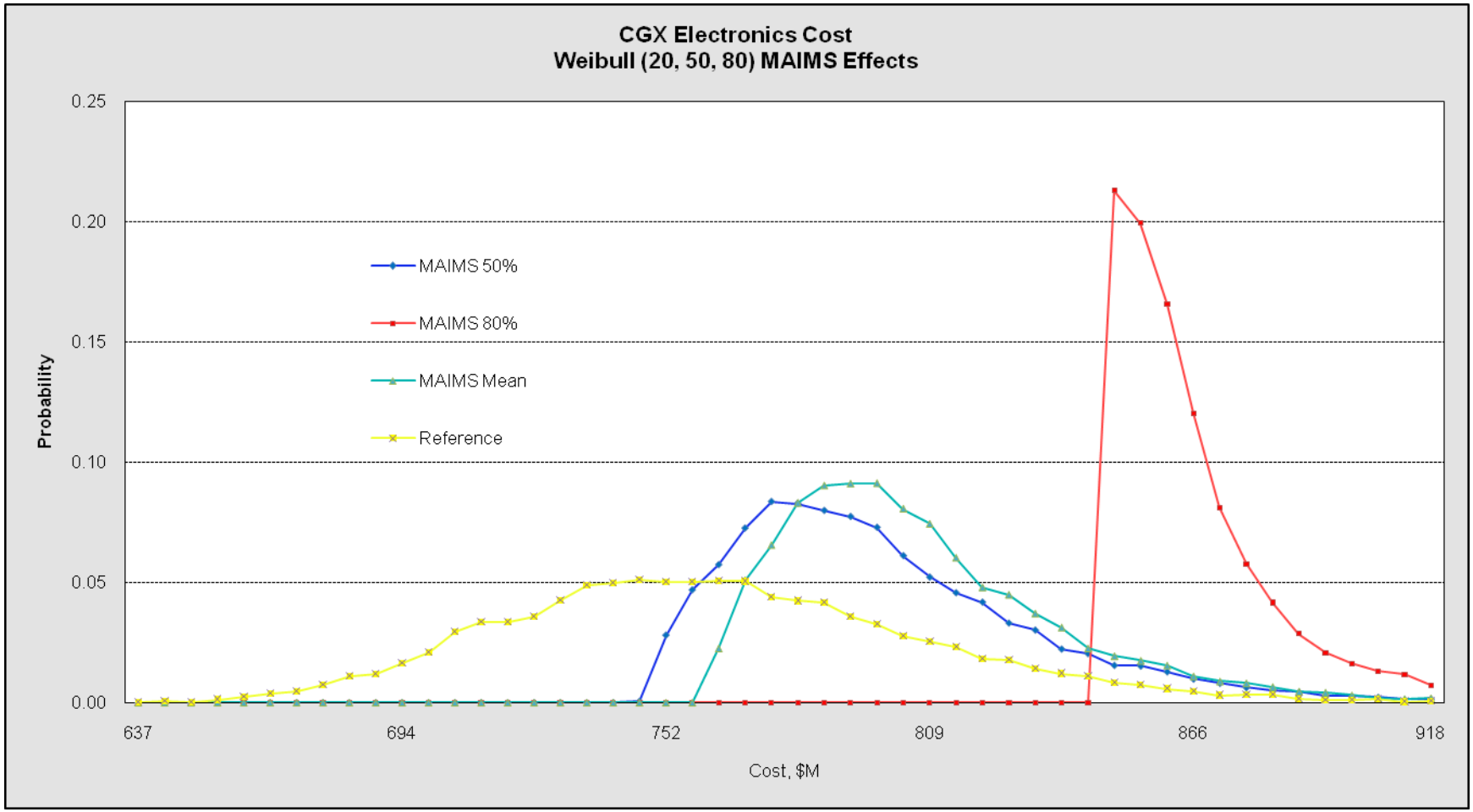


MAIMS Effects on Cost



MAIMS Effects on Cost



Conclusions

- Using Crystal Ball to develop models to assess cost risk can be a useful tool in risk management of ship acquisition and building projects.
- Factors such as data elicitation, distribution choice, correlation effects, and MAIMS principle all are important in considering risk & cost modeling.
  - Data elicitation and MAIMS have the most significant impact.

Conclusions (continued)

- Data elicitation factors are important. Analyze how data is obtained from SME to account for errors. This paper used Weibull distributions to simulate Direct Fractile Assessment method of elicitation.

Conclusions (continued)

- Weibull distributions are more realistic for modeling cost than lognormal and triangular distributions.
  - Lognormal & triangular have narrower cost ranges.
- Weibull (20, 50, 80) represents a pessimistic distribution to account for SME bias.

Conclusions (continued)

- Correlation modeled with the Correlation Matrix in Crystal Ball ®.
  - More important between elements of the electronic systems than between different components of only one element.
  - Most significant for probability values midpoint between the mean and the extremes, with little value beyond 0.5.

Conclusions (continued)

- MAIMS is modeled with 50th percentile cost value, mean, and 80th percentile cost value.
- MAIMS based on the observation that for a given budget, any money allocated is considered money spent.
- Distributions show how under-funding leads to cost overruns, while over-funding leads to overall higher cost.

Recommendations

- Use the DFA method to obtain data for cost assessment. Elicit data from SMEs at 10^{th}, 50^{th}, and 90^{th} percentiles for optimistic systems and at 20^{th}, 50^{th}, and 80^{th} percentiles for more pessimistic systems.
- Use flexible and realistic probability distribution functions for analysis.

Recommendations (continued)

- Incorporate the use of correlation among cost elements of a system with realistic coefficients. Range of 0.3 – 0.6 is reasonable and can be adjusted for variation.
- Use the “Money Allocated is Money Spent (MAIMS)” principle to model budget management behavior. MAIMS function will not allow system cost to be a lesser amount than the budgeted cost baseline.

Recommendations (continued)

- Continue to utilize the functions of modeling software such as Crystal Ball ® or @Risk.
- Incorporate systems engineering methodologies and thinking into the development of probabilistic cost analysis.

Questions?