Evaluating Design Trade-offs and their effect on cost, schedule and O&S – A Case Study

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Background of the situation

This project came about because NASA needed an independent cost, schedule and risk assessment of a proposed system. This proposed system was an update to an existing system, which was primarily a hardware system with a small amount of software. The proposed configuration used some of the existing hardware, but some of the hardware would be modified while other hardware components would be new.

One of the new components was a tank. This tank was a high risk, high cost, and high interest component. The technology associated with the other components was available so there was less interest. This did not hold true for the tank. This is a high-pressure tank that would likely need composite materials to meet its strength requirements. It was possible that the tank would need to be manufactured with some relatively new techniques to meet the spec. Because of the technology needed for this tank, there were four proposed configurations at the time that we needed to perform the independent assessment. All of the designs were technically viable from an engineering perspective. This tank was not only critical for mission success, but also the cost and schedule impact could decide the future of the project. Since this was really the only high interest component on this project, the cost and schedule impacts were a part of the trade space when the design team was doing their design trades. Since this was for a space system, the

operating and support concept was not as important as the reliability of the hardware. As such,

the reliability (MTBF) of the hardware was also a part of the trade space.

Trade off process

The first step in the trade off process is data collection. When initiating a data collection, it is

important to know what the objective of the analysis is so that the effort can be focussed on

collecting the most relevant data. In this case, since we were planning to compare the cost,

schedule and risk implications of each, our objective was to collect all data that corresponds to

model inputs such that the system will be properly represented in the model. Therefore, to

collect our model inputs we conducted interviews with engineers so that we could correctly

assign knowledge bases and assign risk ranges for the model inputs. This is especially important

for critical model inputs such as the component weight. For this part of the process, it was

helpful to have an input sheet for the engineers to look at while we interviewed them. An

example of part of an input sheet that might be used is shown below.

Selected·Knowledge·Bases					
Application	¤	Acquisition Category	¤		¤
Platform	¤	Development Standard	¤		¤
O&S·Description	¤	Class	¤		¤
Parameter	**Least**	**Likely**	**Most**		**Rationale**
+PRODUCT·DESCRIPTION					
~Weight(lb|kg)	※	※	※	※	
~Volume·(cubic·feet|meters)	※	※	※	※	
+MATERIAL·COMPOSITION					
~Percent Aluminum/Malleable·Metal	※	※	※	※	
~Percent·Steel·Alloy	※	※	※	※	
~Percent·Commrcl·Available·Exotic	※	※	※	※	
~Percent·Other Exotic	※	※	※	※	
~Percent·Composite	※	※	※	※	
~Percent·Polymer	※	※	※	※	
~Percent·Ceramic	※	※	※	※	
~Complexity·of·Form	※	※	※	※	
~Complexity·of·Fit	※	※	※	※	
~Construction·Process	※	※	※	※	
+MISSION·DESCRIPTION					
~Operating·Environment	☐ Ground ☐ Air ☐ Space ☐ Sea ※			※	
~Hardware·Classification	☐ Structural ☐ Mechanical ☐ Hydraulic ※			※	
+PROGRAM·DESCRIPTION					
~New·Design	※	※	※	※	
~Design·Replication	※	※	※	※	
~Certification·Level	※	※	※	※	
~Hardware·Integration·Level	※	※	※	※	

Generate cost estimates

Once we had collected the data from the engineers, we modeled each tank configuration in

SEER-H. SEER-H is a parametric hardware life cycle cost and schedule estimating model with

proven success with these types of projects. We used the knowledge base selections that we had

received from the engineers, and adjusted the parameters as appropriate. In the notes field for

* Diagram shows hypothetical values for demonstration purposes, actuals are protected by NDA

the SEER-H parameters we recorded all decisions and the rationale behind them. SEER-H

knowledge bases are repositories of data that allow users to preset input parameters with ranges that are relevant to the particular type of system being developed.

<u>Steps in Preparing a Hardware Estimate</u>

1) Identify Ground Rules and Assumptions

The first step in preparing a hardware estimate is to identify the ground rules and assumptions. These ground rules often include basic information such as what is the scope of the estimate, (what is in the estimate versus what is outside the scope of the estimate). This is also where the estimator would not basic information about the estimate such as the purpose of the estimate, the estimate base year, and any assumptions regarding accounting for inflation. It is vitally important to note any specific assumptions about the program such as any reuse from previous programs as well as the procurement strategy of all the hardware components.

2) Establish requirements and technical baseline

This is the type of system requirements and technical attributes that are usually found in the technical documents associated with the program such as the Cost Analysis Requirements Document (CARD) or other program documents which could include documents such as a Mass Properties or a Mass Equipment List. At this point you are ready to enter the work breakdown structure (WBS) into SEER-H.

3) Describe project characteristics.

Once the WBS has been entered into SEER-H, describe each work element through the use of SEER-H knowledge bases, and then adjust the parameter settings as appropriate to describe the attributes of the work element being estimated. It is important to note work element

characteristics such as weight, number of printed circuit cards, production quantities, and the

operations and support concept.

4) Focus on specific risk drivers

It is important to note which are the controllable risks and which are the uncontrollable risks.

Once the distinction has been made, then trade space can be defined based on the controllable

risks. SEER-H has input ranges for almost all of the parameters, from these ranges the risk
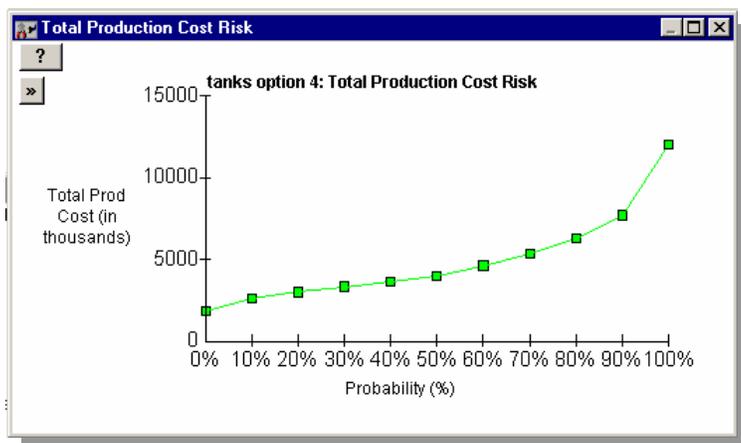
distribution is calculated by SEER-H. Using the risk reports and risk charts the estimator can

quickly identify the overall level of risk associated with the hardware.

5) Examine cost and schedule estimates

Once the SEER-H estimate is complete, it is important to evaluate the outputs and check for

consistency. At this point it is also important to note the confidence level of the estimate. The

default value is 50%, which means that fifty percent of the time the estimated values will not be

exceeded. Depending on the project characteristics it may be necessary to adjust the probability

to reflect higher or lower confidence. A lower confidence estimate may be useful in a bid-to-win

scenario, while a high probability would be used for a scenario when there is a hard schedule

constraint (ex. Hardware must be ready for first flight) or a hard budget cap.

Link outputs to MS Excel and Power Point

Once the estimate was completed, the model outputs were linked to MS Excel and Power Point.

This was a valuable step since this meant that if there was a change to the estimate (due to

	Development Cost	Production Cost
tanks option 1	9,681,895.58	2,840,453.30
tanks option 2	12,380,754.26	3,70
tanks option 3	10,582,103.13	3,12
tanks option 4	13183341.88	40

Estimate vs. budget

tanks option 1   tanks option 2   tanks option 3   tanks option 4
■ Development Cost   ■ Production Cost
— dev budget   — prod budget
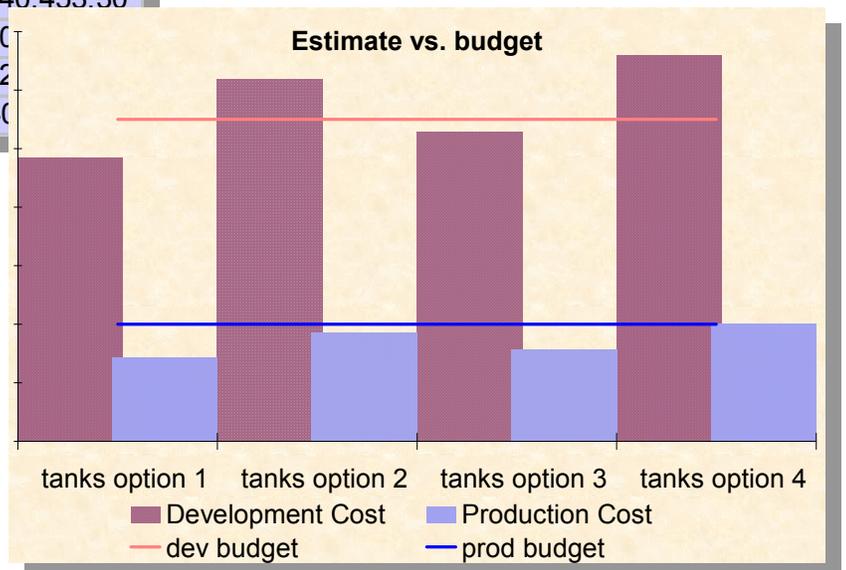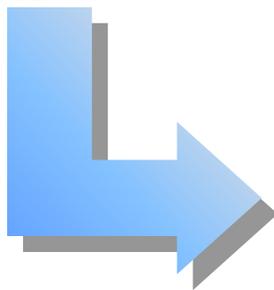
changes in some of the attributes of one of the proposed configurations or a change in the ground

rules and assumptions). From Excel the cost of each option could be compared to external

parameters such as the budget profile. At that point it was linked to the briefing charts. In other

words, if there was a change to the estimate the briefing charts would automatically be updated.

Basis of comparison

In the case of the tank configuration that we were evaluating, cost and schedule were part of the

trade space. With regard to this, the overall funding profile was compared to the budget profile.

It was not just the total cost that was important, but the phasing was important as well.
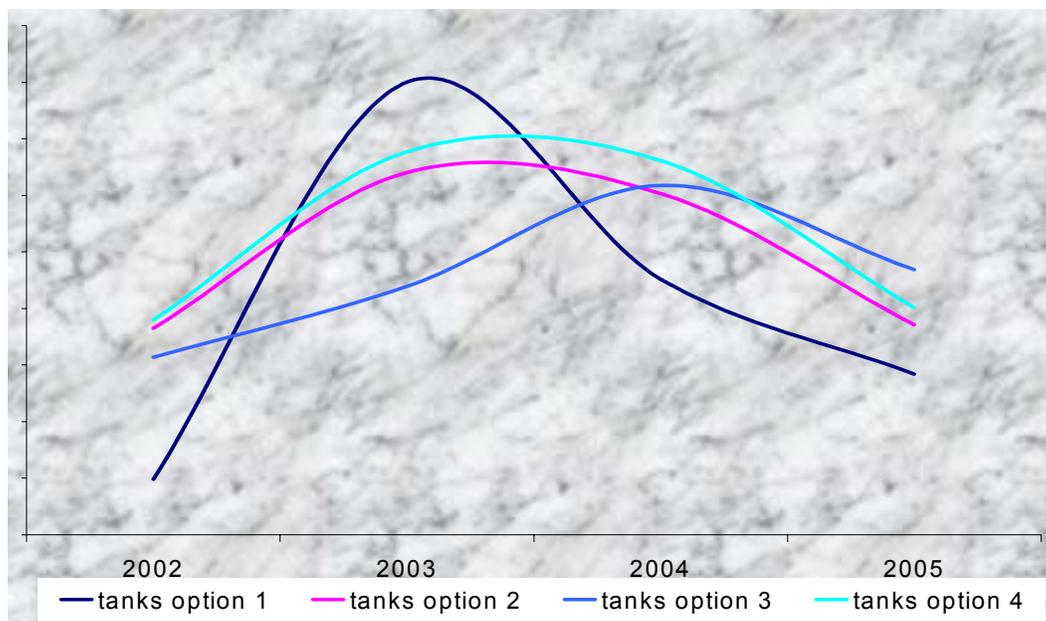
As seen in the chart above, the overall cost of option 1 was less than the other options, but it was

more front loaded than the other options. In contrast, option 3 is more back loaded than the other

options.

The reliability of the hardware was also a consideration for this project. The mean time between

failures (MTBF) and the mean time to repair (MTTR) of the hardware is computed by SEER-H

based on the project attributes as described by the parameter settings. By comparing each option

side by side it was easy to compare each option on its attributes within the trade space.
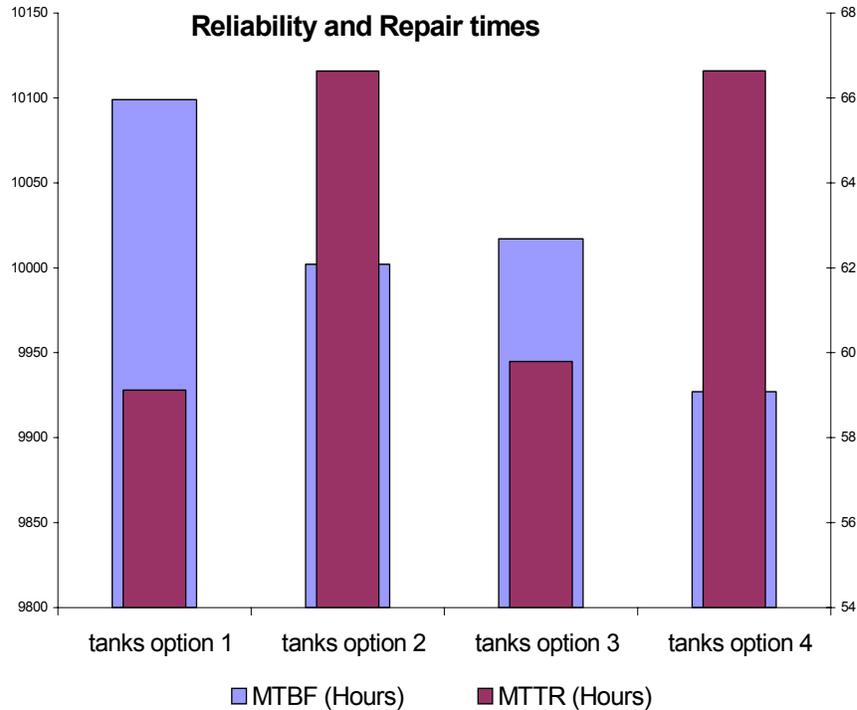
Advantages of this methodology

The advantages of performing the trade off analysis in SEER-H is the ease of performing this

analysis with minimal analyst time, although the model can be modified easily should more

information become available. Because of the SEER-H knowledge bases, there is minimal

impact on analysts and engineers for cost estimating purposes. The other big advantage of this

methodology is its objectiveness. Since it was possible to model all four options in SEER-H, this

eliminated any model bias and each option could be compared on its merits.

Other possible applications of this methodology include very early concept trades. These trades

could include trades such as whether it is more cost efficient to put the processing on the flight

unit or on the ground, or whether it is better from a cost perspective to use several small components versus one large component. Also, this methodology can be used to determine operations and support concepts early on based on the computed MTBF, MTTR, and the calculated number of spares needed.

Conclusions and lessons learned

This type of analysis is especially effective since it allows decision makers to make informed decisions with a small effort investment up front. This is due to the minimal data requirements due to SEER-H knowledge bases, which also minimizes analyst time and the impact on engineers. The powerful linking capability of SEER-H minimizes the amount of analyst time required for updating spreadsheets and briefing charts. Also, if the input ranges are set correctly it can provide insight into the overall level of risk associated with the hardware. Correctly set input ranges can indicate early on whether the project has high cost risk or high schedule risk, as well as indicate the shape of the risk curve. As a result of this type of analysis it is possible to downselect unacceptable options early on, thus increasing the efficiency of the entire process.