Rolling the Dice: Using Risk Tolerance to Define Commissioning Scope

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Synopsis

In the last ten years commissioning has started to gain a foothold. Various guidelines, certifications and services have done an excellent job of defining tasks or deliverables related to the commissioning process. Owners are recognizing there is value in purchasing commissioning services.

Commissioning value is realized through reduced life cycle costs or increased reliability. While these are real dollars, the amount of money saved depends on many variables—variables that require assumptions. What is the business case for a fixed dollar volume of commissioning services?

The answer is that it is up to the owner and their tolerance for risk. As in all risk management services increased commissioning yields a diminishing return. Testing all variables for all circumstances could easily require an investment that exceeds the reward. On the other hand, failing to test everything, declaring a system as commissioned, and then having an untested element fail may be too great a risk.

Nancy Benner used to declare her ambition was to have commissioning become: "business as usual."

Becoming business as usual will involve negotiating for services that make some declaration about risk. This presentation will explore how risk is defined, what measures can be undertaken to mitigate that risk (i.e. different elements of commissioning applied with varying intensity), and how that will translate into a specific scope of services. With this understanding comes doubt—if a commissioned building may still fail, then what is the owner's recourse? That resolution must lie in the contract agreement, insurance underwriting and scope written therein, and this element will be discussed as well.

About the Authors

Wayne A. Dunn, PE is recognized for leadership in project management, systems quality assurance, and commissioning, having participated directly in this specialty for 23 years. This recognition has led to Wayne's direct participation in committees setting guidelines or standards for building systems commissioning. Wayne has acted as the principal in charge of commissioning over 2 million square feet of office space, several laboratory projects, and Space Launch Complex 41 for Lockheed Martin.

Wade H. Berner, PE is an Industrial Engineer employed with Turner Construction Company. He has been involved with facility commissioning for more than nine years. Since graduation, Wade has been involved with all levels of the commissioning process starting as a site engineer on projects like the Canadian Science Center for Human & Animal Health BSL4 Laboratory through to project manager for the Atlas V Rocket Launch Facility. With Turner, Wade is heading up commissioning efforts in the Boston area.

David G. Venters, PE, LEED AP, QCxP is a founding principal with Performance Engineering Group. Starting his career as a mechanical engineer designing HVAC systems he transitioned to specializing in commissioning services in 1995. Seeing a need for improved information management, David has developed software that tracks commissioning data. The success of this software was proven during commissioning of Space Launch Complex 41 for Lockheed Martin. David has pioneered many innovative and cost effective commissioning tools that he has used on a wide variety of commissioning projects—from schools to offices to labs and even several industrial projects.

A. Commissioning and Risk Management

Risk is the possibility of suffering harm or loss. With a building, harm is quantified as damage to equipment, the facility or its occupants. Loss is financially based, productivity based, or both. A building owner avoids risk to the highest extent possible. The ability to avoid risks, through quality assurance, is a factor of time and money. The belief that there is risk is a matter of judgment.

Therefore, it is up to the owner to determine their tolerance for risk. As in all risk management services, increased commissioning yields a diminishing return. Testing all variables for all circumstances could easily require an investment that greatly exceeds the cost of a failure. On the other hand, testing only a sampling of equipment, declaring a system as commissioned then having an untested element fail may prove to be a greater risk than originally anticipated.

This is why risk management is essential to providing a guideline for determining the required level of testing.[3] It allows for a more focused commissioning scope without requiring 100% verification. Figure 1 below shows the direct relationship between risk and cost as a function of project phase tied to potential systems included in the commissioning scope.

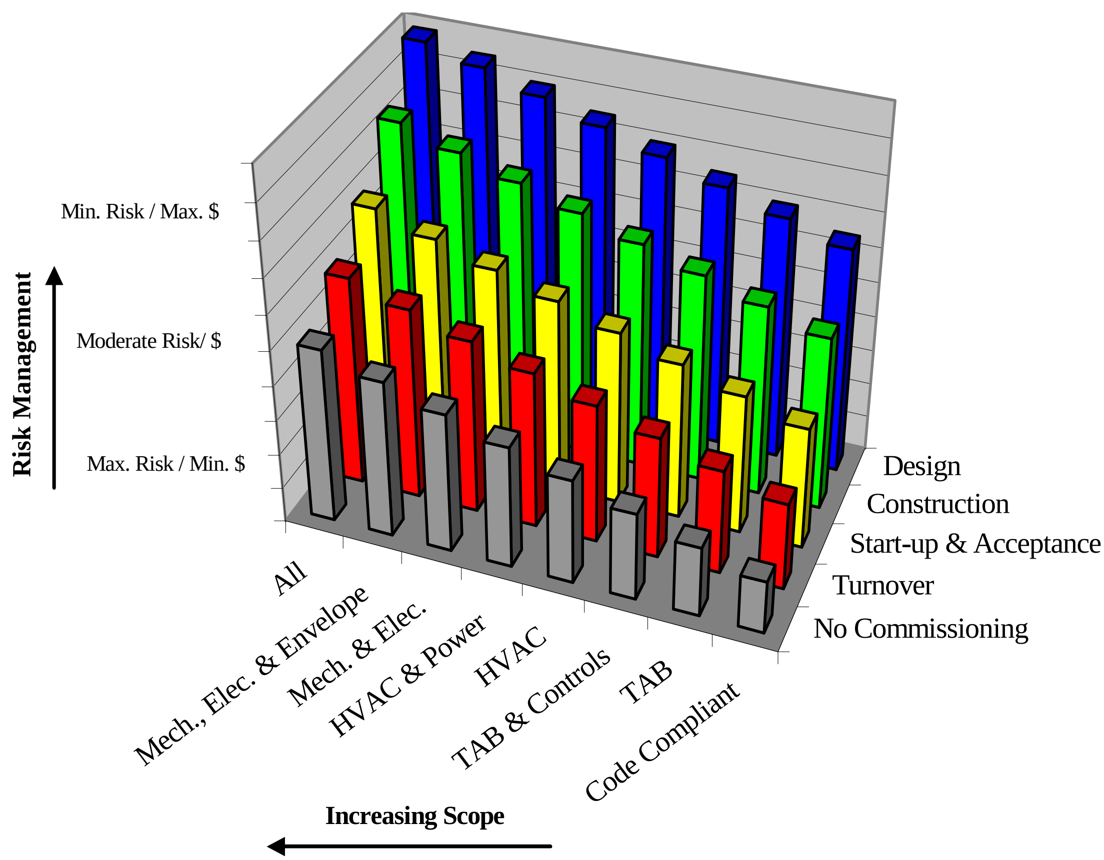

Figure #1: Indicates relationship between phase, scope, project cost and risk management. [2]

By defining the owner's risk tolerance, one can better understand where to focus the commissioning effort to provide the owner with the level of comfort they desire. Focusing the commissioning effort can only be done once we understand the potential failures and the cost of those failures. From this, we can create a strategy for scope development that helps to mitigate those failures.

A.1. Defining System Reliability and Failures

Reliability has been defined as an attribute of any system that consistently produces the same results, preferably meeting or exceeding its specifications. When looking at new building construction, the desired results can be described as the consistent operation of the infrastructure systems to maintain an acceptable facility environment over the life of the building.

Understanding that nothing is perfect or lasts forever, reliability is often represented as probability. Meaning, the reliability of a system is determined by the "probability" that the system will not fail. As the reliable operation of a system becomes more important, the negative consequences related to the failure of that system increase. Also, as the negative consequences increase, the owner's tolerance to the failures decreases. Therefore, as the owner's risk tolerance of failure is reduced so should the potential (or probability) that a failure might occur.

A.2. Definitions of Failure

For building operations, there are two typical failure modes that can occur. They are:

Reliability Failure (Catastrophic) – Major portion of system fails taking it offline or crippling to levels below minimum performance requirements (single point failure such as transfer switch leading to complete loss of power, or system weaknesses such as envelope failures leading to mold).

Efficiency Failure (Partial) – Portion of system fails but system still operational at reduced performance (Loose belt on fan motor, VFD fails leaving system in manual).

A.3. Potential Costs of Failure

When talking about facility reliability and the potential for failures, the ramifications of these failures can be assessed as a cost to the owner. When looking at failures from a cost perspective, one first has to determine the extent of the failure and then the risks associated with that failure. From there, a cost can be associated. As mentioned above, there are two categories of failure to consider for calculating costs. They are the following:

<table>
<tr><th colspan="2">Cost Components by Failure Type</th></tr>
<tr><th>Reliability Failure (Catastrophic)</th><th>Efficiency Failure (Partial)</th></tr>
<tr><td>• Repair and replacement costs
  o Materials
  o Equipment
  o Labor
• Possible loss of human health or life (labs, hospitals, health care facilities)</td><td>• Higher Life Cycle Costs
  o Lower efficiency – Increased operation costs (fuel costs)
  o Higher maintenance costs
  o Premature replacement costs
  o Reduced salvage value</td></tr>
<tr><th colspan="2">Either Type of Failure</th></tr>
<tr><td colspan="2">• System clean up costs (Premature filter replacement, clean room cleaning)
• Reduced productivity (processes or human performance)</td></tr>
</table>

System failures typically result from single point faults and depending on the criticality of the facility, should be avoided. Avoiding single point faults may require the additional cost of providing redundancy or more stringent testing during commissioning. However, if an owner is willing to reduce their risk by using redundant systems, it would be an even bigger risk to not commission these systems.

Redundant equipment or systems add complexity. This complexity is magnified if the system is expected to automatically detect failure and transfer to the redundant element. Redundancy only adds resilience if single point failures are examined and relevant systems/ equipment are fully tested.

A.4. Using Risk Tolerance to Develop Commissioning Scope

We understand there is a quantifiable cost to failure and that failure is tied to reliability. This strategy determines commissioning scope based on the owner's definition of reliability. Or put another way, the owner's tolerance to risk of failure. The following steps outline one possible strategy:

Step 1: Identify potential risks or failure modes (previous experience, end-user input, assessment using a Failure Modes, Effects, and Criticality Analysis (FMECA)).

Step 2: Estimate the potential costs of the identified failure modes.

Step 3: Allow owner to select risks with lowest level of tolerance (typically by cost comparison).

Step 4: Develop risk matrix of equipment\systems which apply to risks selected in Step 3. Assign a sampling rate for each type. Typically this will include 100% of equipment associated with reliability failures and only a percentage of the equipment associated with efficiency failures.

Step 5: Calculate estimated cost to commission the equipment and systems based on the risk matrix.

Step 6: Compare commissioning cost to estimated cost of failure and repeat Steps 4 and 5 until owner is satisfied with ratio of commissioning to failure costs.

Step 7: Finalize the scope definition by also documenting the systems and equipment NOT scheduled for commissioning. Establish contingency for retesting or flexibility for discretionary testing.

Initiate or repeat this process at any phase of a project from pre-design to occupancy or even through continuous/ re-commissioning. Changes during the life or the project or the facility affect the severity of various risks and therefore greatly influence an owner's tolerance for those risks.

This process through its iterations can be structured and managed within each update of the commissioning plan. Iterations or repetition of scope evaluation has two benefits:

- Each iteration allows the quality assurance budget to be fine tuned or revisited.
    - For example: concept/ design—general activities; construction—specific scope.
- Risk tolerance is subjective; reexamining risk at regular intervals confirms owner endorsement.

B. Details of the Process

As outlined above, there are specific steps in developing a commissioning scope based on risk tolerance. In this section, we will explain each step and review its impact on the process.

When determining the scope of any commissioning effort, a number of factors must be assessed. These include:

1. What type of facility type? (Laboratory, Hospital, Office Complex, etc.)
2. When is the process implemented? (Planning, Design, Construction, Acceptance, Turnover)
3. Who is performing the commissioning? (Owner, Designer, Contractor, Independent 3rd Party)
4. What systems/ components are included? (HVAC, Electrical, Life Safety, etc.)
5. What are the commissioned equipment\ system sampling rates? (10%, 25%, 100%)

For the purposes of this paper we will assume the first three items have been established:

1. The project in question is a new laboratory facility with 2 separate wings.
    - Wing 1 includes containment labs
    - Wing 2 includes office administration and security with 24/7 operation requirement.

2. The commissioning process will start in the planning phase.

3. The commissioning process will be led by an independent third party.

This paper will speak to the items 4 and 5 (What systems/ components are included in the commissioning scope and what level of sampling will be executed?) as a factor of reliability and life cycle costs as defined above.

B.1. Identify Potential Risks or Failure Modes

B.1.1. Assuming System Risks

Although we are in favor of more analytical methodology, it may be possible to simply assume a level of reliability. One would need to make an educated guess about where the greatest risks lie based on an understanding of how the systems work (which may or may not be accurate) or problems that the owner has encountered in the past.

Although this is the least accurate way to assess reliability, it is likely the most commonly used by owners when developing a commissioning scope. This could be due to two separate reasons. First, the team assessing the scope does not understand how to apply the more structured methods of evaluation or they are unaware that they exist. Second, proper time or budget is unavailable for the analysis.

B.1.2. Failure Modes, Effects and Criticality Analysis (FMECA)

As mentioned above, there are more analytical methods for determining a system's risk of failure, such as a FMECA. A FMECA is a systematic, structured method for identifying system failure modes and assessing the effects or consequences of the identified failure modes. The FMECA also considers the importance of identified failure modes, with respect to safety, successful completion of system mission, or other criteria and assesses a criticality factor to the system. If a FMECA is to be used on a project, it usually begins in the early stages of system conceptualization and design.[3]

FMECA examines failure mode and cause, detection method, effect on system performance, and effects on safety if so required. A sample FMECA (concept only) of our condenser water system is shown in Table #1.

System Name	Function	Time Period/ Time to Effect	Failure Mode	Effect of Failure:	Alternative:	Criticality Level	Criticality Points
Condenser Water System	Provide condenser water for cooling system	Continuous Flow	System Failure	Damage to system and loss of cooling to all areas.	Redundant condenser components start up (If applicable)	3	5
Chilled Water System	Provide chilled water for cooling system	Continuous Flow	System Failure	Damage to system and loss of cooling to all areas	Redundant chiller components start up (If applicable)	3	5
Wing 1 Air Handling Unit	Provide conditioned air & pressurization to lab areas	Continuous Flow	System Failure	Loss of conditioning & containment ability in lab areas	Redundant AHU components start up (If applicable)	3	5
Wing 2 Air Handling Unit	Provide conditioned air to admin & security areas	Scheduled & Continuous Flow	System Failure	Loss of conditioning to admin and security areas	Controlled shut down of equipment	1	1
Lighting Control System	Controls lighting in facility	Scheduled Operation	System Failure	Lighting remains on continuously.	Controlled shut down of equipment	1	1
Control System	Controls infrastructure systems	Continuous Operation	Sensor Failure	Damage to systems and loss of control to area	Controlled shut down of equipment	3	5
			Sensor not calibrated	Inefficient operation of equipment	Controlled shut down of equipment	1	1

Table #1– Representation of FMECA System Level Criticality Assessment Worksheet

A traditional FMECA does not include the last two columns shown here. We have added these columns to allow for a criticality level and criticality point value to be assigned to each system component based on their effects of failure. They are assigned using the following guidelines:

Level 1 – Failure results in loss of service or reduced performance to non-critical areas. (1 point)

Level 2 – Failure results in system damage and loss of service to non-critical areas. (2 points)

Level 3 – Failure results in loss of service to critical areas. (5 points)

One exception to consider when assessing cost of failure is life safety systems. If a failure can cause severe bodily harm or the loss of a life, the system should automatically be given a Level 3 rating.

These criticality points will be used in the final scope creation stage. (NOTE: Equipment in sample FMECA includes associated ancillary equipment.)

B.2. Estimate the Potential Costs of Failure

When estimating the potential cost of failure, first step is to determine the extent of the failure and the owner's risk tolerance to that failure. This is due to the inverse relationship of tolerance to cost. Whatever system the owner feels has the lowest risk tolerance, you will find the cost of a failure for that system is typically the highest.

The extent of the failure was determined in Step 1. The risk tolerance can be assessed as an aspect of money. Meaning, what risks can the owner afford or not afford. We determine this by using the systems provided in our sample FMECA and assigning costs to each failure mode identified:

System – Failure	Failure Type	Cost Items to Correct Failure	Cost Items Resulting from Failure	Cost	Cost Level	Cost Points
Condenser Water – System Failure	Reliability	New equipment/ materials, labor	Facility down time, ruined lab experiments	>$500,000	3	5
Chilled Water – System Failure	Reliability	New equipment/ materials, labor	Facility down time, ruined lab experiments	>$500,000	3	5
Wing 1 Air Handling Unit – System Failure	Reliability	New equipment/ materials, labor	Wing down time, ruined lab experiments, containment breach	>$1M	3	5
Wing 2 Air Handling Unit – System Failure	Reliability	New equipment/ materials, labor	Wing down time, loss in worker productivity	$10,000	1	1
Lighting Control – System Failure	Efficiency	New equipment/ materials, labor	Increased life cycle costs. (Cost given is over system life)	$100,000	2	2
Control – Sensor Failure	Reliability	New equipment/ materials, labor	Facility down time, ruined lab experiments	>$200,000	3	5
Control – Sensor not calibrated	Efficiency	Possibly new sensor, labor	Increased life cycle costs. (Cost given is over system life)	$20,000	1	1

Table #2– Representation of a Cost of Failure Assessment Worksheet

The cost values provided for each failure in the Cost of Failure Assessment Worksheet above were chosen as samples for this paper only and are subjective based on each particular owner, their facility and their budget. These values have not been calculated using maintenance management or operations software. They exist as a representation of potential costs of failure. Some values, such as the lighting system operating continuously would require life cycle cost analysis to arrive at a true cost value.

As done with the FMECA, columns have been provided to allow for a cost level and point value to be assigned to each system failure based on their cost. They are assigned using the following guidelines:

Level 1 – Failure results in cost to the owner between $0 - $25,000. (1 point)

Level 2 – Failure results in cost to the owner between $25,000 - $200,000. (2 points)

Level 3 – Failure results in cost to the owner over $200,000. (5 points)

As mentioned in Step 1, an exception to the level assessments pertains to life safety systems. If a failure can cause severe bodily harm or the loss of a life, the system should automatically be given a Level 3 rating.

B.3. Prioritize Risks and Select for Commissioning

From Step 1, we have determined the criticality level for each of the risks being evaluated. In Step 2, we have estimated the costs of failure in order to then assign a cost level. These two levels have corresponding weighted points which are components of a calculated risk factor. By summing the two sets of points, the resulting risk factor quantifies an owner's level of aversion to each risk. The greater the risk factor, the greater the aversion and desire to mitigate it through commissioning.

Criticality of risk point value:	1
Cost of failure cost point value:	2
Risk Factor Rating	**3**

This calculation, using weighted values, allows different aspects of the risk to help define the owner's aversion level. For example, a non-critical risk may have low criticality points but the cost of the failure may raise the risk factor such that it should require commissioning. An example includes a building's automatic lighting control system. The criticality of this system is relatively low. However, should this system fail to turn off lights after hours, the resulting excess costs can be substantial.

Each risk factor can be classified into a commissioning category in order to assist the owner in making the final selection of those risks that drive the development of the commissioning scope. For this example, the commissioning categories have been assigned **desirable**, **essential** and **critical**.

- DESIRABLE: Risk Factor (1-2) — Typically these activities relate to components and systems which have a ***limited*** impact on operational program, the life safety and O&M requirements for the defined areas.
  For this example, the level of effort afforded this component is a sampling strategy for both static checkout and dynamic testing.

- ESSENTIAL: Risk Factor (3-5) — Typically these activities relate to components and systems which have a ***moderate*** impact on the operational program, life safety and O&M requirements.
  For this example, the level of effort afforded this component is a combination sampling strategy for static checkout and full verification for dynamic testing.

- CRITICAL: Risk Factor (6-10) — Typically, critical activities relate to components and systems which have a ***significant*** impact on the operational program, life safety and O&M requirements.
  For this example, the level of effort afforded this component is a full verification strategy for static checkout and dynamic testing.

With a quantified risk factor to guide him, the owner selects only the risks that he feels must be mitigated through commissioning. The remaining risks and failure modes are removed from consideration and evaluation for inclusion in the commissioning scope.

B.4. Develop System/Equipment Risk Matrix

Cross-referencing the selected risks to be mitigated, the commissioning authority assists the owner in determining what systems and components are associated with each risk. In this example, we are including the condenser water system failure and the Air Handling Unit for Wing 2. Typical components include cooling towers, pumps, coils, fans, variable frequency drives and control valves. These components are then entered into a risk matrix as shown in the table below. This matrix will be the basis used to estimate the costs of commissioning in Step 5.

SYSTEM NAME	COMPONENT NAME	TAG NO.	LOCATION	AREA SERVED	CRITICALITY POINTS	COST POINTS	TOTAL POINTS	RISK FACTOR RATING		
								DES.	ESS.	CRIT.
Condenser Water	Pre-Cool Coil	PCC-01	Wing 1	Lab 01	5	5	10			X
Condenser Water	Pre-Cool Coil	PCC-02	Wing 1	Lab 02	5	5	10			X
Condenser Water	Cooling Tower	CT-01	HVAC Building Roof	All Areas	5	5	10			X
Condenser Water	Cooling Tower	CT-02	HVAC Building Roof	All Areas	5	5	10			X
Condenser Water	Cond Wtr Pump	CWP-01	HVAC Building	Chiller - 01	5	5	10			X
Condenser Water	Cond Wtr Pump	CWP-02	HVAC Building	Chiller - 02	5	5	10			X
Condenser Water	Cond Wtr Pump	CWP-03	HVAC Building	Pre-Cool Coil 01 & 02	5	5	10			X
Condenser Water	Cond Wtr Pump	CWP-04	HVAC Building	Pre-Cool Coil 01 & 02	5	5	10			X
Wing 2 AHU	Fan	FAN-02	Wing 2 Roof	Wing 2	1	1	2	X		
Wing 2 AHU	VFD	VFD-02	Wing 2 Roof	Wing 2	1	1	2	X		
Wing 2 AHU	Cooling Coil	CC-02	Wing 2 Roof	Wing 2	1	1	2	X		
Wing 2 AHU	Coil Control Valve	VLV-02	Wing 2 Roof	Wing 2	1	1	2	X		

Table #4 – Sample Risk Factor Matrix for the Condenser Water System

B.5. Calculate Estimated Commissioning Costs

After completion of the risk factor matrix, the commissioning level of effort for each system has been determined and the scope is now ready to be priced. The piece of the commissioning scope covered in this pricing section will pertain to the component and system verification tasks, with the understanding that administration type costs (meetings, coordination, reports, etc.) are more a factor of schedule and can be assessed separately and added on to the total[1]. Also excluded from this pricing structure is the support effort of other team members such as the designers, contractors or manufactures.

Using typical commissioning process steps, such as those outlined in ASHRAE Guideline 0, we can budget time for each of the risk factor matrix ratings to determine the cost to commission each system. For example, looking at the table below, we have selected some sample tasks and with estimated durations given for each task. Using these durations, we have calculated the cost to perform each commissioning task commensurate with the specific level of effort.

This means that if a system is deemed “critical” in the risk factor rating, it will receive 100% of the hours required to completely commission that system and its components. If the system is given an “essential” rating, it will receive 50% of the time required. This can mean that the system components are audited rather than receiving a 100% checkout, or if the system is small, the commissioning focus may only be on certain important aspects of the system rather than all modes of operation. Systems deemed "desirable" obtain a similar scope to "essential only at a lower percentage (25%).

The percentage chosen (25%, 50% & 100%) can be altered depending on the owner, their facility and their budget. As the facility complexity increases, the percentages may as well (E.g. 50%, 75%, 100%). This will help avoid carrying all semi-critical systems as critical and going over budget.

SAMPLE TASKS INCLUDED IN COMMISSIONING SCOPE	TIME PER TASK	COST PER HOUR	DESIRED SYSTEM	ESSENTIAL SYSTEM	CRITICAL SYSTEM
	(Hrs)	($125)	(25% of hrs estimate)	(50% of hrs estimate)	(100% of hrs estimate)
Planning Phase					
Include in Design Intent	3	$375	$94	$188	$375
Design Phase					
Include in Design Review	1	$125	$31	$63	$125
Include in Commissioning Specifications	1	$125	$31	$63	$125
Construction Phase					
Include in Contractor Document Review	0.5	$63	$16	$31	$63
Include in Pre-Functional Checklist Development	1	$125	$31	$63	$125
Include in Functional Test Development	4	$500	$125	$250	$500
Include in Site Visit	0.5	$63	$16	$31	$63
Include in Pre-Functional Checkout	1	$125	$31	$63	$125
Acceptance Phase					
Include in Equipment Start-Up Assistance	2	$250	$63	$125	$250
Include in Balancing Review	1	$125	$31	$63	$125
Include in System Performance Testing	8	$1,000	$250	$500	$1,000
Turnover Phase					
Include in Training Coordination	0.5	$63	$16	$31	$63
Include in O&M Manual Review	0.5	$63	$16	$31	$63
Include in Systems Manual	4	$500	$125	$250	$500
Include in Warranty Visit	1	$125	$31	$63	$125
TOTAL COST PER SYSTEM			$906	$1,813	$3,625

Table #5– Sample Commissioning Cost Estimation Worksheet

B.6. Compare Commissioning Cost to Cost of Failure Modes

Insurance companies bond or underwrite projects using actuarial (history) data to establish risk. Until actuarial data is developed for commissioning—judgment is involved when budgets are set for all forms of quality assurance or risk management. Commissioning scope decisions are based on analysis (as described herein), experience or mandated by code (i.e. concrete cores, fire alarm verification).

To determine commissioning value the owner or their representative would compare commissioning cost to both failure risk and performance gain. Lacking actuarial data and, therefore, insurance alternatives an owner is left with establishing a financial ratio between commissioning scope and contingency, where the contingency is used to focus on weak areas or systems that are not performing.

Contingency funds are the best way to accommodate retesting or—alternatively—reward success.

B.7. Finalize Commissioning Scope (set contingency)

It has been the purpose of this paper to provide a detailed methodology to evaluate a project and focus the commissioning effort in the most efficient manner possible. Therefore, the final step to developing the commissioning scope is to itemize what systems and components are to be included. It is also a good idea to include in the final scope document a clear understanding as to what will not receive commissioning. This clarification allows for the owner to fully understand what they are getting for their money and allows for the commissioning authority to eliminate the potential for scope creep.

Commissioning scope creep typically occurs either when tested elements of the project fail to perform or it evolves from misunderstood expectations. Scope is inadvertently increased by the owner or sometimes the commissioning authority themselves when the delineation between accepted risk and mitigated risk remains subjective. The risk factor matrix helps structure expectations.

Contingency allows the project to survive failures without compromising testing or performance. The owner maintains discretionary funds to repeat tests or optimize system performance. While one may argue or even specify repeat testing as a contractor responsibility, the desire or need to maintain the project schedule interferes with decisive action on repeat testing. The best way to preserve control is to repeat tests with contingency funds until satisfactory performance is achieved then, when justified, resolve those expenses against the project retainage.

C. Conclusion

This paper shows the relationship between risk tolerance and risk management. Commissioning scope can be structured, with contingency, in a manner that is tied to specific areas of concern—risks.

Scope development, using this seven step value specific process, can be engaged or repeated at any phase of a project or for any form of commissioning. By structuring one's investment along these lines an owner will realize two things:

- Benefits: A commissioning scope that yields value according to the owner's priorities.
- Limitations: While commissioning mitigates risk—it does not eliminate risk.

Ultimately actuarial data will be developed for this industry such that financial tools can be offered with risk management services. Commissioning will share responsibility either for performance or for evidencing performance. This responsibility will be represented in some form of bond or insurance.

In this way both the commissioning scope and the owner's risk will be well defined in financial terms.

D. References

1. Dunn & Berner. "Evaluating Commissioning Scope and Investment," 1999

2. Juran, Joseph M. Juran's Quality Handbook. Fifth Edition. McGraw-Hill, 1999.

3. Dunn & Berner. "Industrial Applications: Commissioning Critical Systems," 2002.