Introduction to Bowtie Methodology for a Laboratory Setting

Traditionally, safety controls (barriers) have been identified as physical in nature—like a safety shield, glove box, or personal protective equipment—intended to separate and protect people and the environment from specific hazards.[1] However, the success of physical barriers in a laboratory setting depends highly upon specific behaviors by the laboratory workers; these, in turn, are influenced by organizational policies and oversight and an organization's explicit commitment to them. Consequently, to assure their effectiveness, the safety barrier concept has to be extended beyond physical safeguards to consider a variety of organizational and operational barriers. Controlling laboratory hazards requires effective management of a variety of both physical and organizational barriers such as;

- the laboratory environment and equipment must be selected with appropriate capabilities for the experiments being conducted;
- proper maintenance and care of equipment to ensure that it functions as designed as the hazards involved in the work change (i.e. automatic shut-offs, safety shower, eye wash, etc.);
- the laboratory workers' capabilities to identify hazardous situations and mitigate risk;
- organizational procedures and cultural practices that directly influence a laboratory worker's actions; and
- active monitoring of safety management systems (i.e. hazard identification, procedures, incident investigations, inspections, etc.) to ensure their effectiveness.

By expanding the definition of safety barriers, it becomes apparent that individuals responsible for laboratory safety are not just those at the lab bench, nor is "safe" a static endeavor. Instead it requires continual monitoring and response at various levels of an organization to ensure effective barriers to prevent accidents.

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[1] Sklet, S. Safety Barriers: Definitions, Classification, and Performance. *J. Loss Prevent. Proc.* **2006**, 19, 494.

James Reason developed a model to depict accident progression through a series of failed barriers, aptly referred to as the "Swiss cheese model."[2] In the model, holes represent barrier deficiencies that allow for the progression of a threat, as depicted by the red arrow in

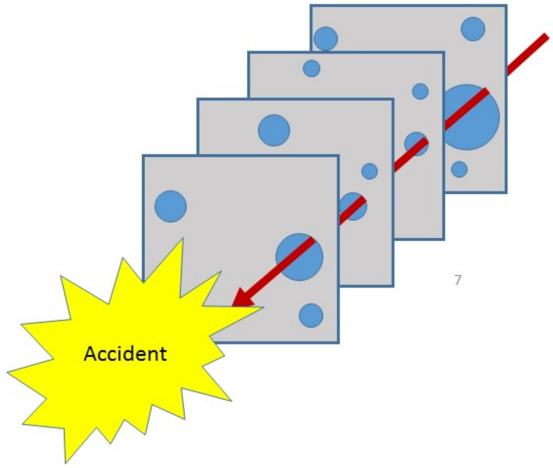

Figure *1*. An increased number of barriers, as well as smaller and fewer holes, leads to a more robust barrier system to prevent accidents.

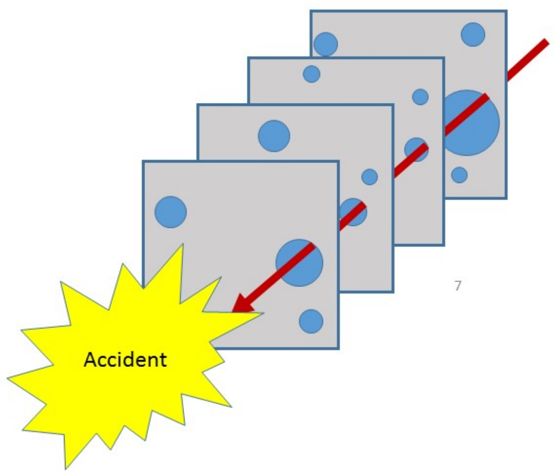

Figure 1. James Reason's Swiss Cheese model of accident causation.

Subsequent to James Reasons' barrier work, a more sophisticated risk assessment tool knows as the Bowtie method was developed. Bowties garner their name from their shape (Figure *2*), and the tool can be used as a hazard identification aid and communication device to depict the evolution of an accident by identifying the preventative and mitigative technical, organizational, and operational barriers (and the management systems meant to support them) that must fail in order for an accident to occur.

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[2] Reason, J. Human error: models and management. *British Medical Journal, 320*, 2000; pp 768-770.

Figure 2. Generic bowtie diagram depicting multiple threats that can lead to the loss of control of a hazard, and intern progress to several negative consequences.[3]

This half day workshop will introduce the development of bowtie diagrams as safety analysis tools for the laboratory setting, and is designed for a diverse audience including undergraduate students, graduate students, and faculty. The workshop will begin with the development of a Bowtie based on a non-laboratory example and then progress to small groups constructing real-world, laboratory based Bowties. Suggestions for developing robust Bowties will be addressed by presenting common pitfalls in the identification of the 'Hazards',[4] 'Top Events,'[5] 'Threats,'[6] 'Barriers,'[7] and 'Consequences'[8] used to generate a Bowtie.

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[3] DNV GL. http://www.dnvba.com/sg/training/Pages/bowtie-technique-workshop.aspx (accessed October 23, 2015).

[4] Anything which is a source of potential loss of damage.

[5] A point in time which describe the release or loss of control over a Hazard.

[6] A possible direct cause that will potentially release a Hazard by producing a Top Event.

[7] Any measure taken which acts against some undesirable force or intention, in order to maintain a desired state.

[8] A potential event resulting from the release of a Hazard, which directly results in loss or damage.