Payload safety: Risk and Characteristic-based Control of Engineered Nanomaterials

6th IAASS Conference, 21-23 May 2013

Seraphin Chally Abou\textsuperscript{(1)} & Maarouf Saad\textsuperscript{(2)}

\textsuperscript{(1)} University of Minnesota Duluth  
1305 Ordean Court  
Duluth, MN 55812, USA

\textsuperscript{(2)} Ecole de Technologie Supérieure (ETS)  
1100, rue Notre-Dame Ouest  
Montreal (Québec), H3C 1K3
Presentation outline

1. The STS Payloads and the Ground Support Safety
2. Payload Conceptual Risk Assessment Models
3. Nanopayload Descriptors
4. Conclusion
Payload safety: Risk and Characteristic-based Control of Engineered Nanomaterials

Introduction

- An emerging body of studies reveals the benefit of nanotechnology. However, we are simply uncertain of effects on the environment and the public health.

- This study is by no means to develop epidemiological analysis. We evaluated methods for characterization of Space Transportation System (STS) nanomaterial payloads and the ground support safety from various safety science perspectives and metrics.
Introduction

- Concentrated data of occupational and environmental exposures to nanomaterials is scarce and not fully understood.

- Although recent studies revealed scientific concerns about nanomaterials, it would not be prudent to halt the need to make ground systems and nanomaterial payloads mission processing systems efficient.
Introduction

- This framework provides fundamental understanding of the challenges and variability of nanoparticles characterization, thus, laying the groundwork for the ISS payload safety and policy enforcement for future nanopayload experiment missions.
1. The STS Payloads and the Ground Support Safety

- **Safety policy and requirements**: The International Space Shuttle (ISS) program safety policy assures a safe operation while minimizing Program involvement in the design process of the experiment payloads.

- **Responsibility**: Requirements for assuring experiment payload mission success are the responsibility of the experiment payload organization.
1. The STS Payloads and the Ground Support Safety

- **Nanomaterial payloads:** Nanomaterial payloads must meet the safety policy and requirements for payload using the Space Transportation System (STS).
  - However, at nano-scale, material properties challenge our ability to anticipate, and control potential health and safety issues including our understanding of the risks involved in the ISS realistic exposure conditions.
  - Very little is known of the risks of anthropogenic nanomaterials to occupational safety and health.
1. The STS Payloads and the Ground Support Safety

- **Nanomaterial payloads**: The research questions in this study are:
  - What physico-chemical effects and their quantitative models must be taken into account when defining nano-payload risks and their attributes?
  - What kind of descriptors can be developed for nanomaterial payloads risks assessment?

- Answers to these questions are related to both safety analysis and biologically based risk projection models.
2. Payload Conceptual Risk Assessment Models

- Conventional payloads’ safety compliance assessment is achieved using a preset review process.
- In the review process the payload review safety panel needs to know the payload risk descriptors in order to characterize payloads.
- However, classical risk analysis techniques commonly rely upon empirical models and have difficulties dealing with the effects of multiple concurrent events with interrelated attributes.
2. **Payload Conceptual Risk Assessment Models**

General payload categories are shown as follows:

<table>
<thead>
<tr>
<th>Payload category</th>
<th>Defined hazards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>Hazards identified are “standard” and the appropriate controls are specified on JSC form 1230</td>
</tr>
</tbody>
</table>
| Intermediate     | 1. Payload hazards are not found on the JSC Form 1230 but has controls and verification methods that have been historically accepted by the PSRP  
                    2. Payload has identified “standard hazards” but uses controls and verification methods other than those identified on the JSC Form 1230 |
| Complex          | The payload has unique hazards with hazard controls that are:  
                    1. Active functions, such as electromechanical or pyrotechnic separation systems or actuators/mechanisms providing structural load paths  
                    2. Nonstandard and/or verification methods that depart from historically accepted techniques  
                    3. Operationally complex requiring flight or ground personnel intervention to assist in controlling the hazard |
The classical payload categories depicted in Table 1 and their associated descriptors have been efficient in a number of payload applications but needs to be implemented for nanomaterials.

Note that nanoparticles are distinct from conventional chemicals – they are often too large for standard computational approaches, usually having similar molecular structure within a group, and differ only in size and shape.
3. Nanopayload Descriptors

- Nanomaterial structures are different from conventional molecules, some standard material properties can change at size of 50nm or less.

- Nanoparticle sampling techniques that are available for measuring airborne nanoaerosols vary in complexity for evaluating occupational exposures with respect to:
  - Particle size, number, mass,
  - Concentration, composition
  - Surface area, and surface properties
3. Nanopayload Descriptors

- Figure 1 shows formation of a graphene cap on a spherical catalyst at different higher temperatures [9]: $10^3 K$, $2 \times 10^3 K$, and $3 \times 10^3 K$.

- Figure 2 shows surfactant exchange on carbon nanotube surface [18].
3. Nanopayload Descriptors

- This review framework indicates that:
  - It can be technically difficult to detect some of stray action potentials experimentally.
  - The risk assessment and the safety of shielding nanomaterials challenge our knowledge due to either fluctuations of the applied potential or to the adsorption, desorption, or random motion of adsorbates on nanomaterials surface.
3. Nanopayload Descriptors

- As shown in Figure 3, this study indicates increase of the volume ratio of surface of nanomaterials will have great influence on the overall material properties.
3. Nanopayload Descriptors

Arguably, a simple validated biologically based model, whose parameters have a direct biological interpretation, cannot be a standalone descriptor to extrapolate nanopayload risks to different exposure conditions with high confidence.

Most of the case studies reported in the literature review highlight the fact that structure–toxicity data are potentially multivariate in nature.
Conclusion

- Relevant expressions (descriptors) of relationships between nanostructures and toxicological properties which can be used to code descriptors based on either quantitative nanostructure–toxicity relationship or quantitative nanostructure–activity relationship models require in-depth analysis.

- Moreover, the literature review showed that simple epidemiological descriptors can never capture the whole complexity of global patterns of human genetic diversity and the risk of exposure to nanoparticles.