CE 400 / CE 500

Process Safety Management

Lecture 37   **Black Swans**

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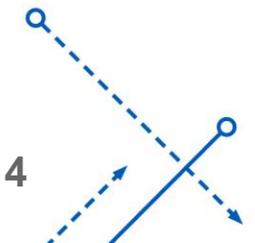School of Engineering and Applied Sciences
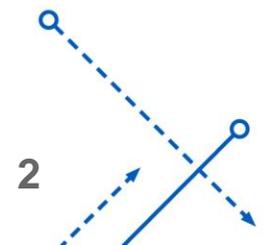
What is a Black Swan?

- All of the swans in Europe had white feathers

- In 16th century London the term "Black Swan" was used to refer to something that is impossible

- At some point when global travel became more prominent it was discovered that in Australia there were swans with black feathers

- The term came to mean something that was thought to be impossible but can actually exist

- It has recently come to refer to a rare and unpredictable catastrophic occurrence

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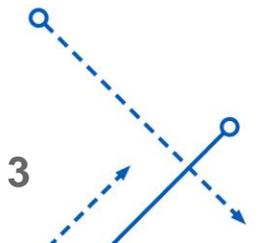
Three Attributes of a Black Swan

- It is an outlier
  - It is outside the realm of regular expectations

- It has an extreme impact

- In spite of being an outlier, explanations are often concocted afterwards to make it explainable and predictable
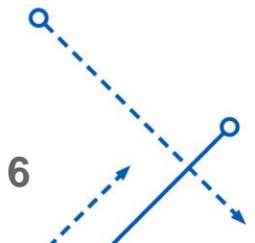
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Fukushima Daiichi Nuclear Disaster

- On March 11, 2011 there was an earthquake and tsunami

- The plant was designed for:
  - Maximum ground acceleration of 5.12 m/s^2
  - Wave heights of 5.2 m

- **These were very conservative designations as earthquake/tsunami conditions such as that had never been observed**

- On March 11, 2011 the conditions were:
  - Maximum ground acceleration of 2.77 m/s^2
  - Wave heights of 13 m

- The waves overflowed the sea walls and flooded the plant

- The cooling water system was disabled by the flood

- This lead to 3 nuclear meltdowns, 3 hydrogen explosions, and the release of radioactive contamination

- Evacuation radius of 20 km was required

- **Would you have designed for the wave heights observed on March 11, 2011?**

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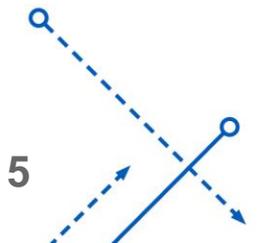
Black Swans and Hazard Analysis

- Black Swan events are ones that are very highly unlikely and also have catastrophic consequence levels

- Normal hazard and risk analysis do not really address these events

- It's not that the actual likelihood of it happening id so small that the frequency/consequence risk fall within acceptable levels

- The frequency is hard to get an estimate on because something like this has never happened before
    - That doesn't mean it can never happen for the first time!

- The other challenge is recognizing this as something to be considered in the first place!

- One must be on guard against assuming that such incidents will occur regardless of one's PSM system

- Sometimes an incident can be labeled a Black Swan as an excuse for poor planning
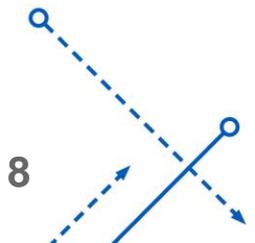
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Why do we miss anticipating Black Swans?

- Confirmation Bias
  - Humans tend to notice and look for things that confirm their own beliefs
  - Don't consider something that they have not ever experienced or observed

- Illusion of Understanding
  - Taking observed events and projecting them in a straight line into the future
  - Assigning patterns to random data to create a narrative

- Inherent Human nature
  - Humans are not good at being vigilant for a dangerous event that is very infrequent

- Ludic Fallacy
  - The problem is not the uncertainty in known variables but in the lack of knowledge of recognized variables
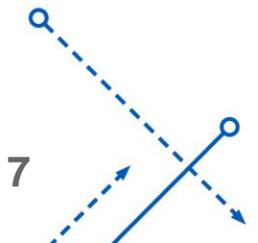
Different Colors of Swans

- **White Swans**
  - Variables are well known and we have experience with them
  - Variables only have a limited range of values
  - Failure of components can be generally anticipated
  - Completely predictable by well-defined procedures

- **Grey Swans**
  - When natural or accidental events lead to parameters varying over a wider range
  - Probabilistic risk-based approach
  - Based on an extrapolation of past events
  - Some low-probability / high-consequence events can be predicted but are sometimes dismissed due to the high cost of adding safeguards versus the likelihood of needing them – **be cautious!**

- **Black Swans**
  - Not foreseen from observed data
  - "You don't know what you don't know"
  - Not predictable by probabilistic means

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Black Swans

So What Can We Do?

- Avoid the Hazard via Site Selection
  - Avoid placing process near hazards like flooding and earthquakes
  - Avoid placing process in close proximity to populated areas

- Avoid the Hazard via Event Detection/Prediction
  - Had the Fukushima site been able to place reactors in safe condition before the flooding occurred, the incident could have been avoided

- **INHERENTLY SAFER DESIGN**
  - Eliminate the hazards in the first place
  - Not always feasible

- Redundant Safeguards
  - The unforeseen event may defeat one safeguard but others may survive
  - The safeguards should work on different principles

- Follow all Industry Standards
  - Many design standards were developed in response to Black Swan events that have since been forgotten!

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References

- Avinash M. Nafday

- https://ascelibrary.org/doi/10.1061/%28ASCE%29LM.1943-5630.0000036

- PrimaTech
  - https://www.primatech.com/technical/pt-notes/164-black-swan-events-and-process-safety

- David Moore
  - https://www.linkedin.com/pulse/process-safety-management-during-black-swan-events-david-moore/

- John Murphy
  - https://www.aiche.org/academy/webinars/black-swans-chemical-processing-industries