High-Consequence, Low-Probability Accidents at SLAC

Joe Kenny
SLAC Safety, Health, and Assurance Department
Views expressed herein are mine, not those of Stanford University, SLAC, or the Department of Energy.
Objective

- Anticipating seemingly far-fetched catastrophes
- Predicting their probabilities & consequences
- Recommending solutions
• **Occurrence**: Accident
• **Consequence**: Result of accident
• **Probability**: Likelihood of accident
• **Risk**: \( \text{probability} \times \text{consequence} \)
  
  (rate: deaths/year, tumors/lifetime)
• **Acceptable Risk**: maximum tolerable estimated rate of specified outcome

Risk is kept low through minimal likelihood...

*meteor w/house collisions per decade*

...or negligible outcome.

*hangnails per 8-hour shift*
• **Acceptable Risk (examples):**
  - **USEPA:** chemical carcinogenicity
    » Consequence: death from cancer
    » Probability: $<10^{-6}$/year
  - **UKMH:** chemical carcinogenicity
    » Consequence: neoplasm dx
    » Probability (varies with factor): $<10^{-3}$/year for dioxin
• **Acceptable Risk** (From DOE O 5481.1B, 1995):
  - Consequence: death of onsite worker
  - Probability: $<10^{-2}$ /year
  - Consequence: injury of offsite person or persons
  - Probability: $<10^{-3}$ /year

• **Medium-consequence**: Resulting in human injury offsite or worker death onsite

• **Low-probability**: Not expected to occur during facility lifetime, or $<10^{-4}$ per year
• Acceptable Risk:
  – Consequence: injury of offsite person (at worst)
  – Probability: $<10^{-6}$ /year

• Why?
  – Public is more likely than a worker to sue, especially a mysterious “radiation laboratory” like SLAC
  – Examination of “worst case” required
  – Onsite death scenarios are extremely numerous
• **High consequence:** *Resulting in human injury offsite*
• **Extremely low probability:** $10^{-4} - 10^{-6}$ per year
• **Incredible:** $<10^{-6}$ per year
Thresholds

No corrective actions are recommended where:

– No offsite persons could be harmed or
– Scenario is incredible
1989: Discovery of ES&H mismanagement at Rocky Flats
- Widespread Pu contamination
- FBI raid, 10 criminal counts, $18.5 million in fines (1992)
- 50,000 residents asked $550 million from Dow and Rockwell International
- Tiger Teams created

1997: Discovery of tritiated groundwater near BNL
- threatened well-being of thousands of local residents
- disrupted lab operations
- 22 local residents filed multi-$M lawsuit
- DOE dismissed BNL prime contractor
What could SLAC expect?

- Injury or death
- Legal action
- Shutdown
- DOE assessments
- Reorganization of plant and management
• Fire from a SLAC-controlled source spreading to offsite structures.
• Significant quantities of hazardous* materials from an onsite source released to offsite areas and affecting general public.

* toxic  explosive  asphyxiating
  reactive  corrosive
- Events caused by any *force majeure* aside from earthquake
- Radiation-control events
- Environmental events with no potential for immediate human symptoms
• Chlorine & hydrogen chloride release after a cooling tower mishap ending in offsite casualties
• Wildland fire ignited by SLAC’s suspended 230kV power lines in the Santa Cruz Mountains
• Cyanide gas release after a Plating Shop mishap ending in an offsite casualty
• An offsite casualty among I-280 traffic during a Klystron Gallery fire
Methods

- Airborne release estimates: CAMEO (Computer-Aided Management of Emergency Operations) software package
- Settlement, damages, and legal-fee estimates based on recent CA precedent
- Forest-fire damage estimates based on recent CA precedent
- Seismic event probabilities & consequences based on projections from USGS & Association of Bay Area Governments
SCENARIO 1
Cooling tower $\text{Cl}_2$ and HCl gas generation and release
Consequence: High
Probability: Extremely low

Recommendations for all cooling tower chemical huts:
• completion of planned seismic bracing upgrade
• division of tertiary containment to separate spills

For chemical huts exposed to motor vehicle traffic:
• installation of vehicle barriers

Recommended response measures: None
Cl₂ & HCl release

- Generated when concentrated sulfuric acid (H₂SO₄) and 12.5% sol. of sodium hypochlorite mix, viz.,

\[
\begin{align*}
2\text{NaClO(aq.)} + \text{H}_2\text{SO}_4(\text{conc.}) & \rightarrow \text{Na}_2\text{SO}_4(\text{aq.}) + 2\text{HClO (aq.)} \\
4\text{HClO(aq.)} & \rightarrow 2\text{H}_2\text{O(l.)} + 2\text{Cl}_2 (\text{g.}) + (\text{O}_2) (\text{aq.}) \\
2\text{HClO(aq.)} & \rightarrow 2\text{HCl(g.)} + \text{O}_2(\text{g.})
\end{align*}
\]

- Mixing occurs in tertiary containment after compromise of secondary containment
- Mixing must be quick and complete to present threat
- Concerns: earthquake and motor vehicle collision
assumptions

• Tanks must be severely compromised or inverted
• Secondary containment must be severely compromised or inverted
• Hut must be severely compromised

∴ Requires large earthquake or motor vehicle collision
A note on CAMEO

- **Computer-Aided Management of Emergency Operations** (airborne release simulation software from NOAA)
- Accounts for wind speed, terrain, gas characteristics, and quantity released
- Estimates a worst-case radius for given airborne concentration
- We used most conservative short-term exposure limit for each, *viz.*,
  - $\text{Cl}_2$ : 1 ppm (OSHA ceiling)
  - $\text{HCl}$ : 5 ppm (OSHA ceiling)
CAMEO Cl₂-HCl vulnerability zones after cooling tower release
Cl\textsubscript{2} effects

- Exposure to 1 ppm OSHA ceiling is safe for all exposed
- Eye irritation at 7 ppm (geometric mean)
- Throat irritation at 15 ppm (geometric mean)
- Cough at 30 ppm (geometric mean)
- Death in several breaths at \sim 1000 ppm
Cl\textsubscript{2} effects

- Odor threshold starts at \(~0.2\) ppm
- Throat-irritation threshold starts at \(~0.3\) ppm

So what?
• 7:30 a.m., 26 July 1993, Richmond, CA
• Leaky rail tank car leaks fuming sulfuric acid and sulfur trioxide into a moderate breeze for ~3 hours
• No one killed, but 24,000 nearby seek medical attention for exposure
• 59,000 join class-action lawsuit, ~9,000 of which were passers-by on I-80
• GC’s outlays:
  – Settlement: $140M
  – Legal fees: $40M
Only subjective evidence of injury and proximity to the plant were required to join the suit.
Recommendations

- Installing concrete barriers next to huts 1200, 1201, and 1202
- Completion of planned seismic bracing for all
- Dividing underfloor to prevent mixing in all
SCENARIO 2

Fire ignited by SLAC’s suspended 230kV lines in Santa Cruz Mountains
230kV lines

- Owned and maintained by SLAC
- 5.3 miles long
- Strung from Master Substation to PG&E grid connection 4.9 miles to the WSW
- Strung over woodland (3 miles), pasture (2 miles), and residential/agricultural (0.3 miles)
• Every June & November subcontractors (bonded arborists) clear vegetation
• $5700/mi./yr. for 20 feet around lines & poles
• Includes monitoring, pruning, mowing, herbicide application, and waste removal
• SLAC visually inspects all work
• 89,000 miles of lines on 155,000 poles
• $1700/mi. for 10 feet of clearance around lines, poles, and towers
• Since 1994, line-related fires caused no casualties, prompted 3 lawsuits
• Worst: 1994, 500-hectare “Rough & Ready” blaze. $9M to those who lost houses and livestock
• 9x10^-6 fires per mile per year since 1994
SLAC fires?

- Were we PG&E, expect $4.4 \times 10^{-5}$ fires per year
- We’re better, but still within $10^{-6}$/year of burning down a house or barn

**Recommendations:**
- Keep clearing to 20 feet
- Keep astride of the practices and capabilities of local response organizations.
SCENARIO 3
Offsite casualty from Plating Shop cyanide gas release
CN⁻ and its controls

- B025 Cyanide Plating Room holds up to 270 lbs. of KCN in alkaline solution in several vats
- Each vat vented at 700 cfm
- Room vented at >5000 cfm
- All room exhaust is scrubbed with pH-10 aerosol
- Sensors in room, outside room, and in vents sound at 1 ppm HCN (TLV: 10 ppm)
- All vats have secondary containment
- Acids are prohibited in room
Offsite casualty from HCN release?

If...

- Large quantity (>200 kg) of concentrated acid is stored in room and spilled
- Vats *and* secondary containment are compromised
- Aerosol scrubbers fail (but not the fans) *AND*
- Heavy winds through an open door clear all HCN to the outdoors in 8 minutes or less

...then we’d generate a 10 ppm plume
CAMEO HCN vulnerability zone after Plating Shop release (10-ppm)
Incredible, but...

Worker safety is still a concern, so:
Place cyanide alarm system on UPS
SCENARIO 4
Injury in I-280 traffic during Klystron Gallery fire
Highway 280

- Opened in the mid-70s
- 3 northbound and 3 SB lanes
- Carried ~40,000 cars/day in 1995
Concerns

- Klystron Gallery fire could damage overpass
- Smoke from fire could be implicated in traffic accident
• Tangent, OR, 20 June 1988: smoke from burning restaurant & house causes a 12-car pileup on I-5 overpass with highway 34. No casualties or legal action
• Klystron Gallery and storage under 280 is mostly noncombustible
• PAFD Station 7 can respond to KG fires in <10 minutes
• Probability: incredible
Conclusion