

Response of Nuclear Materials in Storage and Transport to Malevolent Environments

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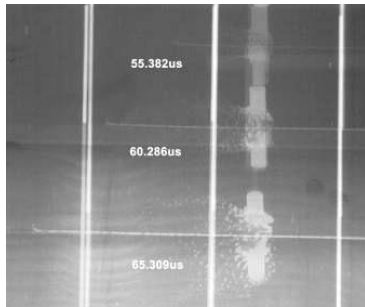
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Flash X-Ray of HEDD jet
and glass pellets



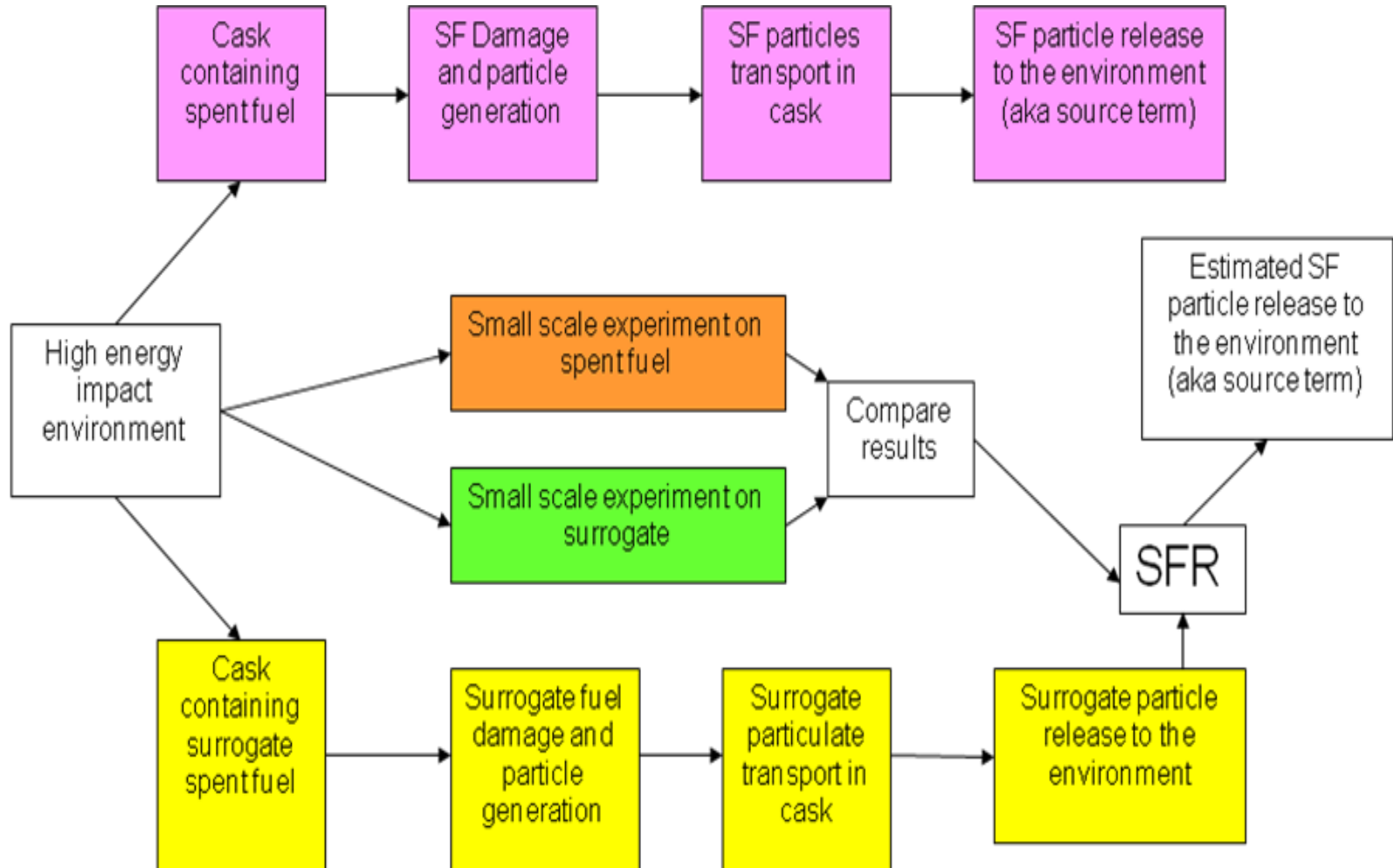
DU spent fuel rodlets:
Pre and post tests

Introduction

- Since the '70s, substantial analytical and experimental work has been conducted to assess the adequacy of storage and transportation packaging designs to protect the public and environment from harmful consequences that could result from a radioactive material release stemming from a terrorist event.
- During this time, large uncertainties and limited data sets have been reduced through analysis and experiment in order to develop credible quantifiable estimates of potential consequences resulting from sabotage events.

Introduction

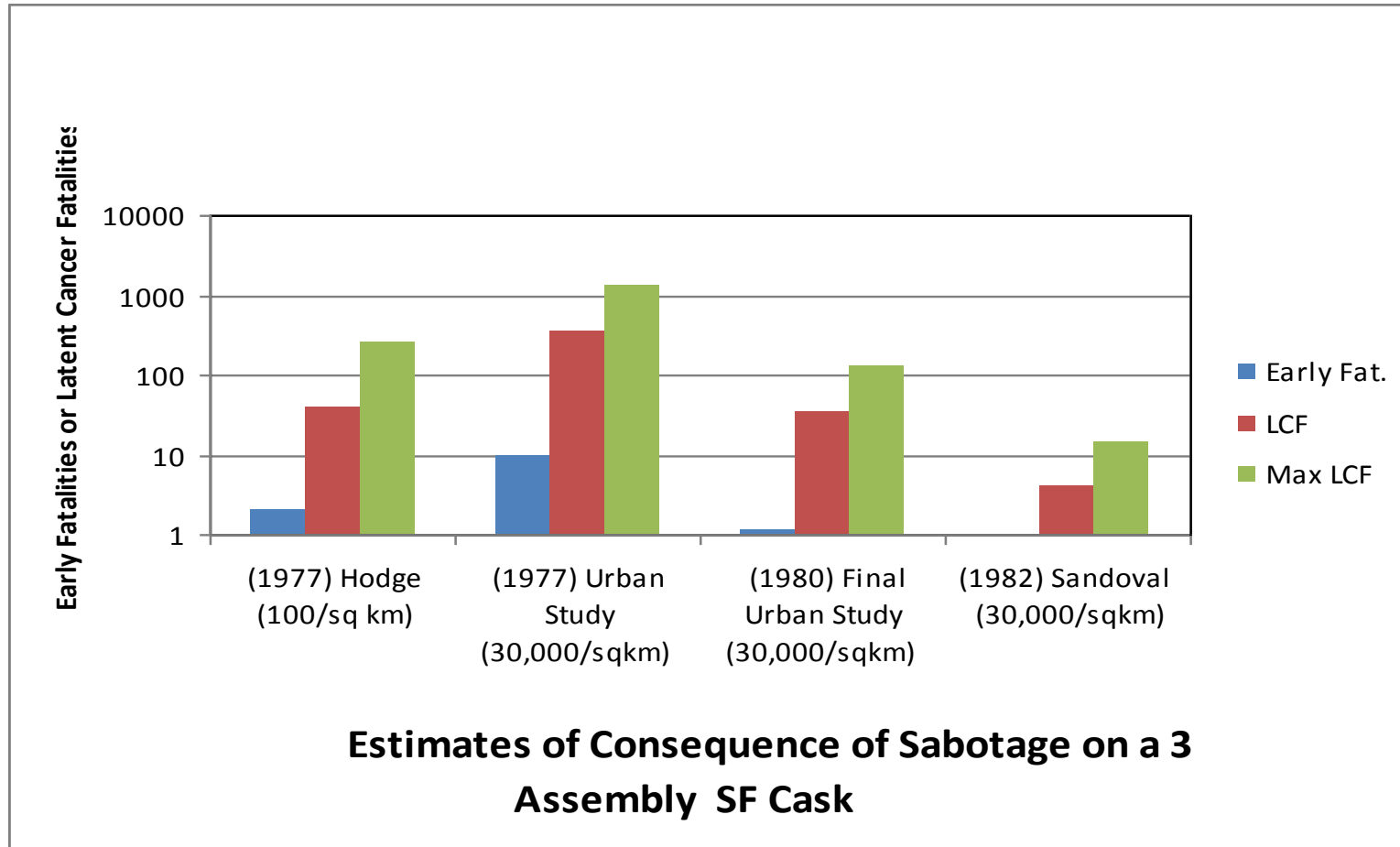
Framework for assessing source term released from a sabotage event



Some Early History

- NUREG-0170 (1977)
*Final Environmental Impact Statement
On the Transportation of Radioactive
Material*
 - Safety risk assessment
 - Recognized sabotage needed to be addressed
 - Did not explicitly address high population density areas
- NUREG-0194 (1977)
*Calculations of Radiological Consequences
From Sabotage of Shipping Casks for Spent fuel
and High Level Waste*
 - Analysis based on initial large assumed conservatisms
 - Attack modes unspecified
- SAND77-1927 (1978)
*Transport of Radionuclides in Urban Environs:
Working Draft Assessment*
 - *Analysis of sabotage consequence based on large conservative assumptions utilizing upper limits on various parameters*
- SAND79-0369 NUREG/CR-0743 (1980)
*Transport of Radionuclides in Urban Environs:
Draft Environmental Assessment*
 - Repeated impact estimates with smaller and more realistic release fractions
- BMI-2095 NUREG/CR-2472 (1982)
*Final Report on Shipping Cask Sabotage
Source Term Investigation*
 - Surrogate and real fuel used
 - Mock up of cask wall
 - Enrichment of volatiles observed in respirable fraction (~2X to 10X)
 - Scaling factors developed to estimate full-scale damage
- SAND82-2365 (1983)
*An Assessment of the Safety of Spent Fuel
Transportation in Urban Environs*
 - One full-scale test and two ¼-scale tests with surrogate fuel
 - Release fractions were estimated
 - Small scale experiments with single pellets of surrogate and spent fuel for SFR determination

Some Early History



- Uncertainties significantly reduced
- Still large range for SFR: $0.5 < \text{SFR} < 6.0$

Recent Efforts

International Working Group for Sabotage Concerns of Transport and Storage Casks (WGSTSC)

- Consortium of French, German, and U.S. technical organizations (support also from the U.K. and Japan)
- Focus on estimation of the spent fuel ratio and aerosol generation phenomena
- Small scale experiments with surrogates at SNL that mirror earlier work with greater accuracy and enough replication to yield reliable results for SFR and aerosol generation phenomena. Four phases:
 - Glass plates and pellets – 6 tests
 - CeO₂ pellets with fission product dopants – 24 tests
 - DuO₂ pellets with fission product dopants – 3 tests, **3 tests delayed**
 - Spent fuel tests – 8 tests, **all delayed**
- An independent review of these tests yielded the following results:
 - CeO₂ respirable release fraction $\sim 6.5 \times 10^{-3}$
 - DuO₂ respirable release fraction $\sim 1.2 \times 10^{-2}$
 - Enrichment of volatile dopants observed ($\sim 2X$ to $40 X$)

Recent Efforts

German Efforts

- German focus on aerosol production, release and deposition phenomenology within cask-like structures.
- Several test programs have provided valuable data related to:
 - Effective disruption of fuel assemblies inside a cask.
 - Estimation of source term generation from VHLW subjected to a shape charge impact.
 - Estimation of particular phenomena and parameters affecting the primary (internal) and secondary (external) source term from a shape charge attack. This program is on-going.

French Efforts

- Multi-year effort estimating the resistance of various casks to various threats.
- Development of methodology to estimate release after perforation.
- Most recent experiments relate to the study of release fractions for powder material.

Conclusions

- **Because of their robust construction and performance based design, spent fuel casks are unlikely to release a significant fraction of their contents in most realistic sabotage scenarios.**
- **Small scale experiments with DUO₂ surrogate materials indicate a respirable fraction from a shaped charge of ~1%, but scale effects may increase the value for realistic scenarios.**
- **Enrichment of volatiles (~20x) in respirable fraction observed in experiments.**
- **Results from 3 independent lab scale experiments indicate a spent fuel ratio ~3.**
- **Further testing is needed on spent fuel to complete the WGSTSC test program to determine spent fuel ratio.**