Consequence Analysis Uses at NRC and MACCS Code Development Plans for Non-LWRs

Jonathan Barr
Acting Branch Chief, Accident Analysis Branch
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission

June 10, 2019
IMUG Meeting, Rockville, MD, USA

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Acknowledgments

- AAB staff
- Dr. Nathan Bixler, Dr. Dan Clayton, and the MACCS team at Sandia National Labs
- Patricia Santiago, retired branch chief, Accident Analysis Branch (AAB)
- AAB partners throughout NRC
- MACCS users and consequence analysis partners worldwide
  - 600+ MACCS users
  - 20+ countries
  - 50+ international organizations

Background on NRC's Accident Analysis Branch

- Support resolution of safety issues concerning offsite consequences of nuclear power-related accidents
  - Operating reactors
  - New reactors
  - Advanced non-LWRs
  - Decommissioning reactors
  - Spent fuel pools
  - Dry cask spent fuel storage

- Maintain and develop codes for consequence analysis for NRC use and by others

- Perform consequence analyses to inform regulatory decisionmaking

- Provide advice to internal and external stakeholders on issues related to consequence analysis

- Supported by several contractors, most notably Sandia National Labs

Background on NRC's Accident Analysis Branch: Major Work Activities

- MACCS code
  - Maintenance
  - Development
  - Verification
  - Documentation
  - User Support
  - Distribution
  - Meetings and Workshops
  - International Collaboration
- MACCS utility, pre-processor, and post-processor codes
  - WinMACCS
  - MelMACCS
  - SecPop
  - COMIDA2
  - AniMACCS
- Applications
  - State-of-the-Art Reactor Consequence Analyses (SOARCA)
  - Level 3 PRA Project
  - Containment Protection and Release Reduction (CPRR) Rulemaking
  - Spent Fuel Pool Consequence Study

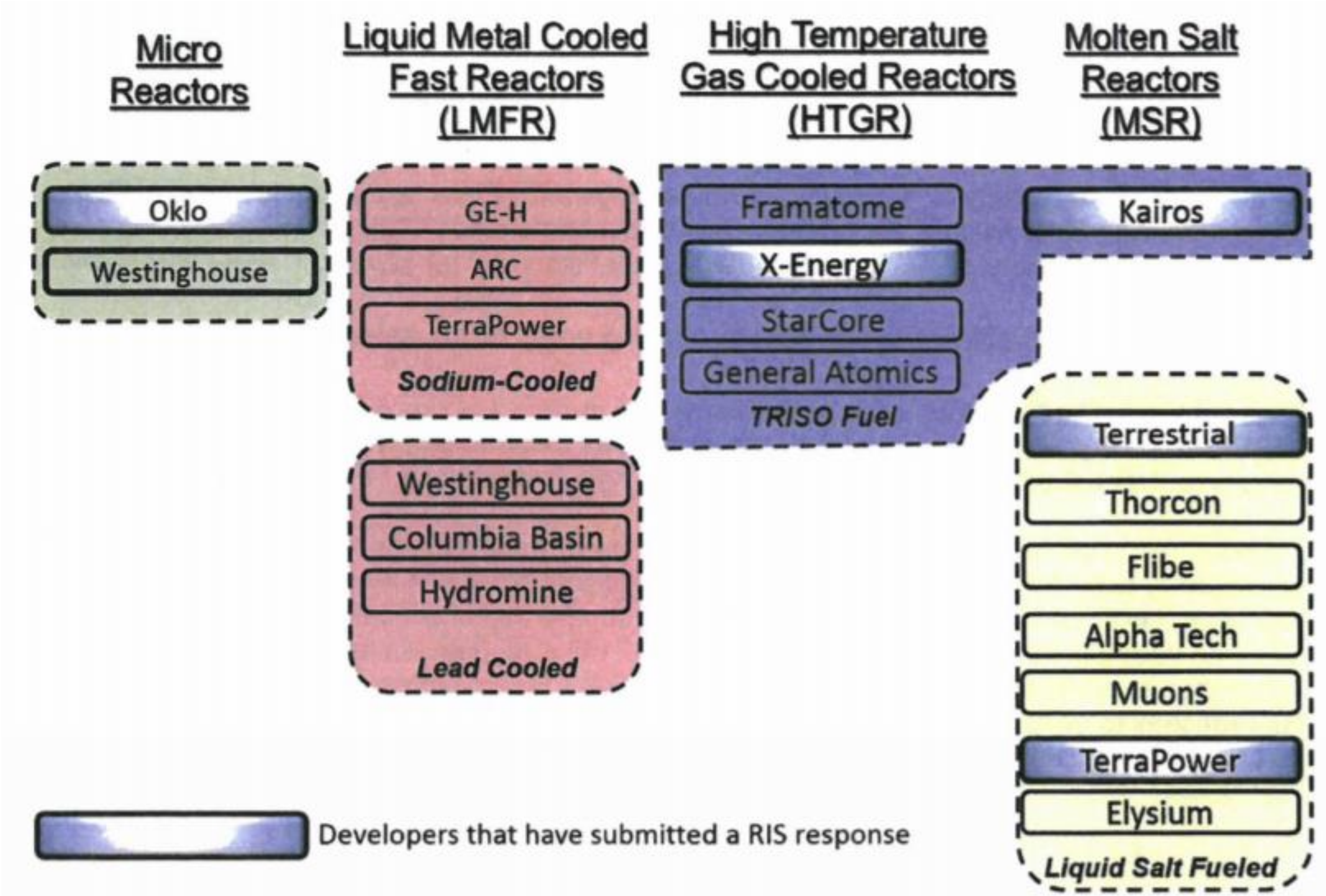
MACCS Meetings and Workshops

- NRC Regulatory Information Conference (RIC) March 2019, Rockville, MD, USA
  - Session TH35, “Atmospheric Transport and Dispersion Modeling for Severe Accident Consequence Analysis”
- EMUG, April 2019, Switzerland
- PSA Conference and MACCS Workshop, May 2019, Charleston, South Carolina, USA
- CSARP, June 3-5, 2019, Albuquerque, New Mexico, USA
- IMUG and MACCS Workshop, June 10-14, 2019, Rockville, MD, USA
- AMUG, November 2019, South Korea

Regulatory Uses of MACCS at NRC

- Backfit and regulatory cost-benefit analysis
- Environmental analyses of Severe Accident Mitigation Alternatives (SAMA) and Design Alternatives (SAMDA)
- Level 3 PRA
- Research studies of accident consequences
- Support for emergency preparedness
- Dose-distance evaluations for emergency planning

Diverse Non-LWR Designs Under Development



- Figure taken from SECY-19-0009
- More information available at: https://www.nrc.gov/reactors/new-reactors/advanced.html

NRC Plan for Non-LWR Readiness

- Six strategies:

(1) Staff development and knowledge management

(2) Analytical tools

(3) Regulatory Framework

(4) Consensus codes and standards

(5) Resolution of policy issues

(6) Communications

MACCS for Non-LWR Consequence Analysis

- MACCS is well-suited for consequence analysis for non-LWRs
  - Highly flexible code enabling use for different types of sources, accidents, and modeling applications
  - Several hundred user-controlled input parameters
  - Generally a technology-neutral code

- Alternative codes with some similarity exist but for different applications
  - **RASCAL** for incident response dose calculations to inform protective action recommendations
  - **RADTRAD** for design basis accident dose calculations for compliance with NRC siting criteria and control room habitability

- MACCS compared to RASCAL and RADTRAD
  - Considers full range of protective actions
  - Calculates full set of consequence measures
  - More flexible for adapting to variations in severe accidents
  - Supports probabilistic application and impact of weather uncertainty

MACCS for Non-LWRs

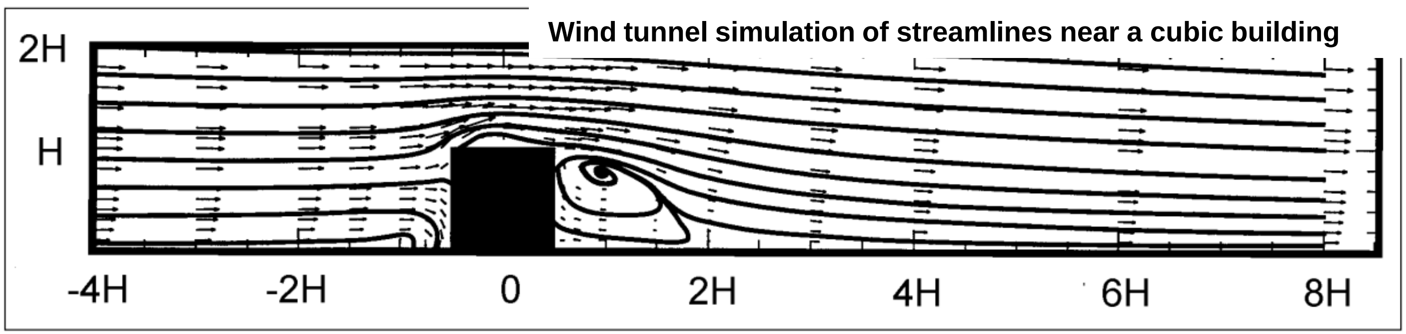
- Code development plans for design-specific issues
  - Radionuclide screening
  - Radionuclide particle size distribution
  - Radionuclide chemical form
  - Radionuclide particle shape factor
  - Tritium

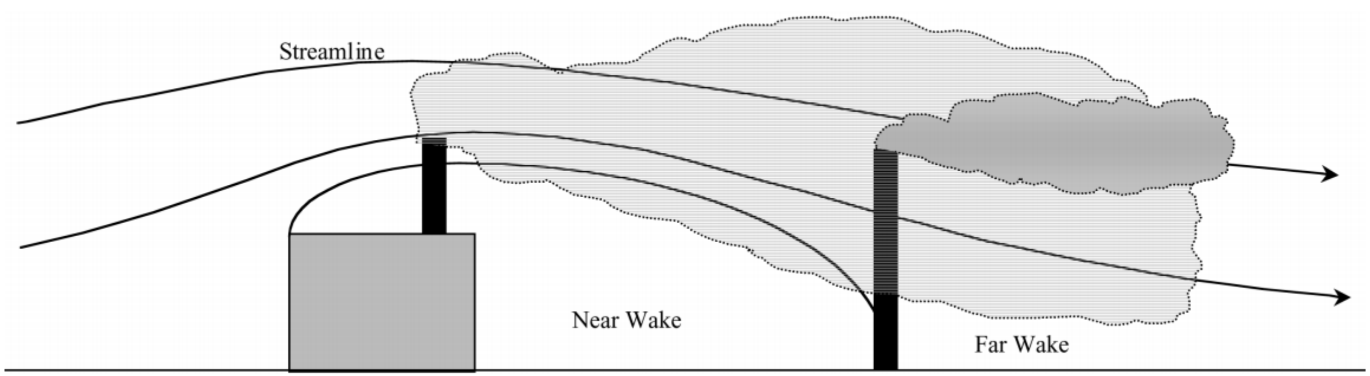
- Code development plans for site-related issues
  - Near-field atmospheric transport

Near-Field Atmospheric Transport

- MACCS currently has a simple model for building wake effects; user guide cautions against use closer than 500m
- Non-LWRs (and SMRs) desire smaller EPZ and site boundary than large LWRs; therefore desire better modeling of near-field phenomena

Wind tunnel simulation of streamlines near a cubic building



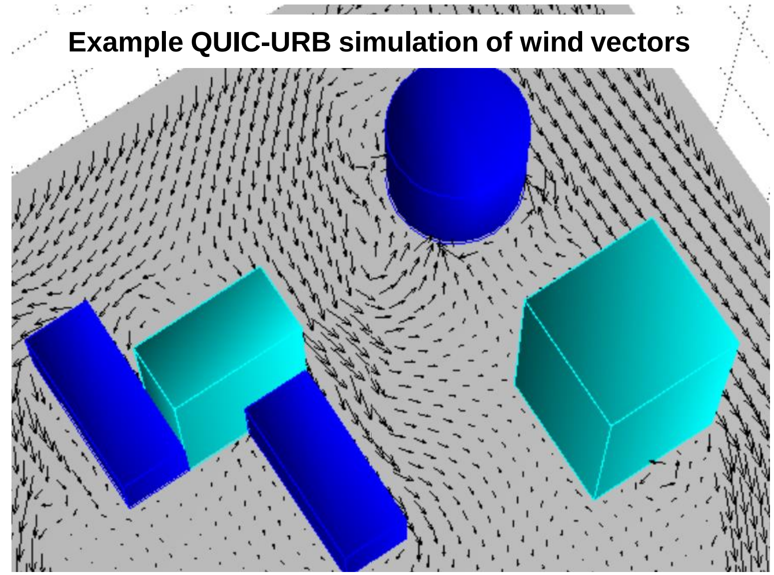


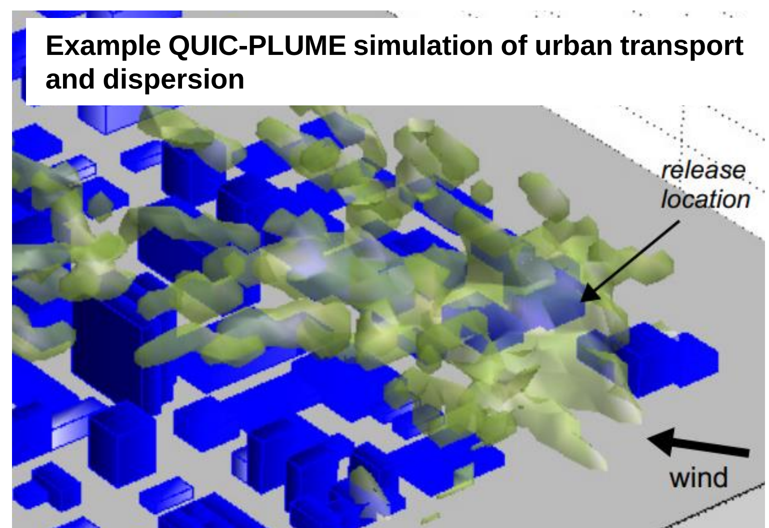
Lloyd L. Schulman , David G. Strimaitis & Joseph S. Scire (2000) Development and Evaluation of the PRIME Plume Rise and Building Downwash Model, Journal of the Air & Waste Management Association, 50:3, 378-390

Near-Field Atmospheric Transport

- Various options for addressing near-field ATD
  - Modifications to Gaussian plume segment ATD model
  - CFD modeling of 3-d wind field with Lagrangian particle tracking ATD model
  - Empirical models of 3-d wind fields with Lagrangian particle tracking ATD model

- Considerations for evaluating options
  - Extent of practical acceptance in the user community
  - Simplicity of use
  - Computational efficiency
  - Cost and time efficiency
  - Accuracy
  - Feasibility for probabilistic application


Example QUIC-URB simulation of wind vectors



Example QUIC-PLUME simulation of urban transport and dispersion

QUIC Factsheet, Los Alamos National Laboratory

Near-Field Atmospheric Transport

- Current status
  - Reviewed several existing ATD models that are relatively simple modifications to a Gaussian for building wake effects
  - Perform a near-field comparison of MACCS to alternatives to identify whether MACCS is conservative and over what distance range, conditions, and input parameters
    - Using existing MACCS with a point source, no buoyancy, and ground level release
  - Based on comparison, then integrate a Gaussian-based alternative into MACCS for better building wake effect treatment

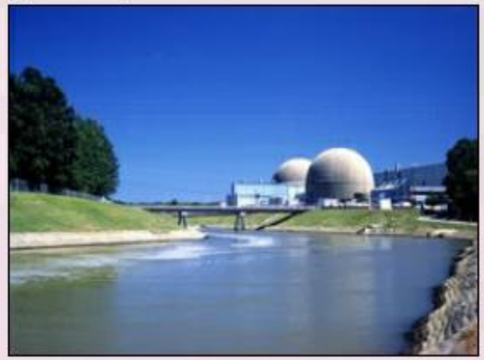
Backup Slides on Recent NRC Consequence Analyses

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

MELCOR/MACCS Applications: (1) SOARCA

- Detailed study of realistic accident progression and offsite consequences for selected important severe accident scenarios
- Three pilot plants studied:

Peach Bottom
(Boiling-Water Reactor
(BWR) Mark I in PA)



Surry
(Pressurized-Water Reactor (PWR)
Large, Dry Containment in VA)

Sequoyah
(PWR Ice Condenser
Containment in TN)

- Includes uncertainty analysis of one scenario at each plant to better understand range of potential outcomes and what drives key phenomena
- Currently developing NUREG report summarizing the insights of the uncertainty analyses in a more useful format for NRC and stakeholders

MELCOR/MACCS Applications:
(2) Site Level 3 PRA Project

- NRC developing contemporary Level 3 PRA for a reference site
- Reflects technical advances since NUREG-1150 (1990)
- Uses SOARCA codes (MELCOR and MACCS), methods, and insights

- Radiological sources
  - Reactor cores
  - Spent fuel pools
  - Dry cask storage

- Project scope
  - All reactor modes of operation (at power, low-power/shutdown)
  - All internal and external hazards (excluding malevolent acts)
  - Level 1, 2, and 3 PRA (full consequence analysis)
  - Integrated site risk

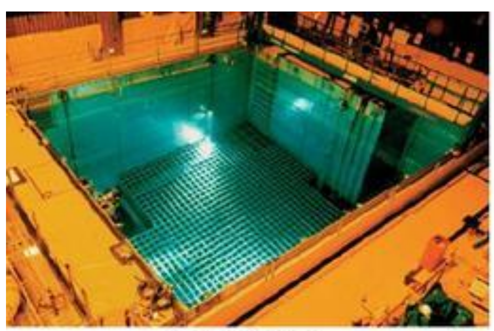
- More information available on NRC's website here

MELCOR/MACCS Applications: (3) CPRR Rulemaking Technical Basis

- Containment Protection and Release Reduction (CPRR) for BWRs with Mark I and Mark II Containments
  - Motivated by Fukushima accident (Tier 1 NTTF 5.1)
  - Evaluated alternatives including severe accident water addition strategies and external filters for CPRR following an extended loss of AC power accident
  - MACCS was used to evaluate fatality risks for comparison to NRC's quantitative health objectives (QHOs) and health and economic benefits for comparison to implementation costs
  - In SECY-15-0085, staff recommended against requiring external filters
  - Technical analysis documented in NUREG-2206

MELCOR/MACCS Applications: (4) Spent Fuel Pool Consequence Study

- Motivated by Fukushima accident (Tier 3 NTTF)
- Evaluated alternatives for moving spent fuel from spent fuel pools to dry cask storage
- Analyzed consequences of radioactive releases from Peach Bottom sent fuel pool assuming earthquake initiator
- MACCS was used to evaluate fatality risks for comparison to QHOs and health and economic benefits for comparison to implementation costs
- In COMSECY-13-0030, staff recommended against requiring expedited transfer
- Technical analysis documented in NUREG-2161


Spent Fuel Pool


Dry Casks