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

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April 5, 2019
11th European MELCOR/MACCS User Group Meeting, Switzerland

Acknowledgments

- Dr. Bernd Jaeckel and Paul Scherrer Institut
- Dr. Nathan Bixler and Sandia National Labs team
- Patricia Santiago, retired branch chief, Accident Analysis Branch (AAB)
- AAB staff, NRC managers, and NRC partners
- MACCS users and consequence analysis partners worldwide
  - 600+ MACCS users
  - 20+ countries
  - 50+ international organizations

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Part 1:

Consequence Analysis Uses at NRC

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

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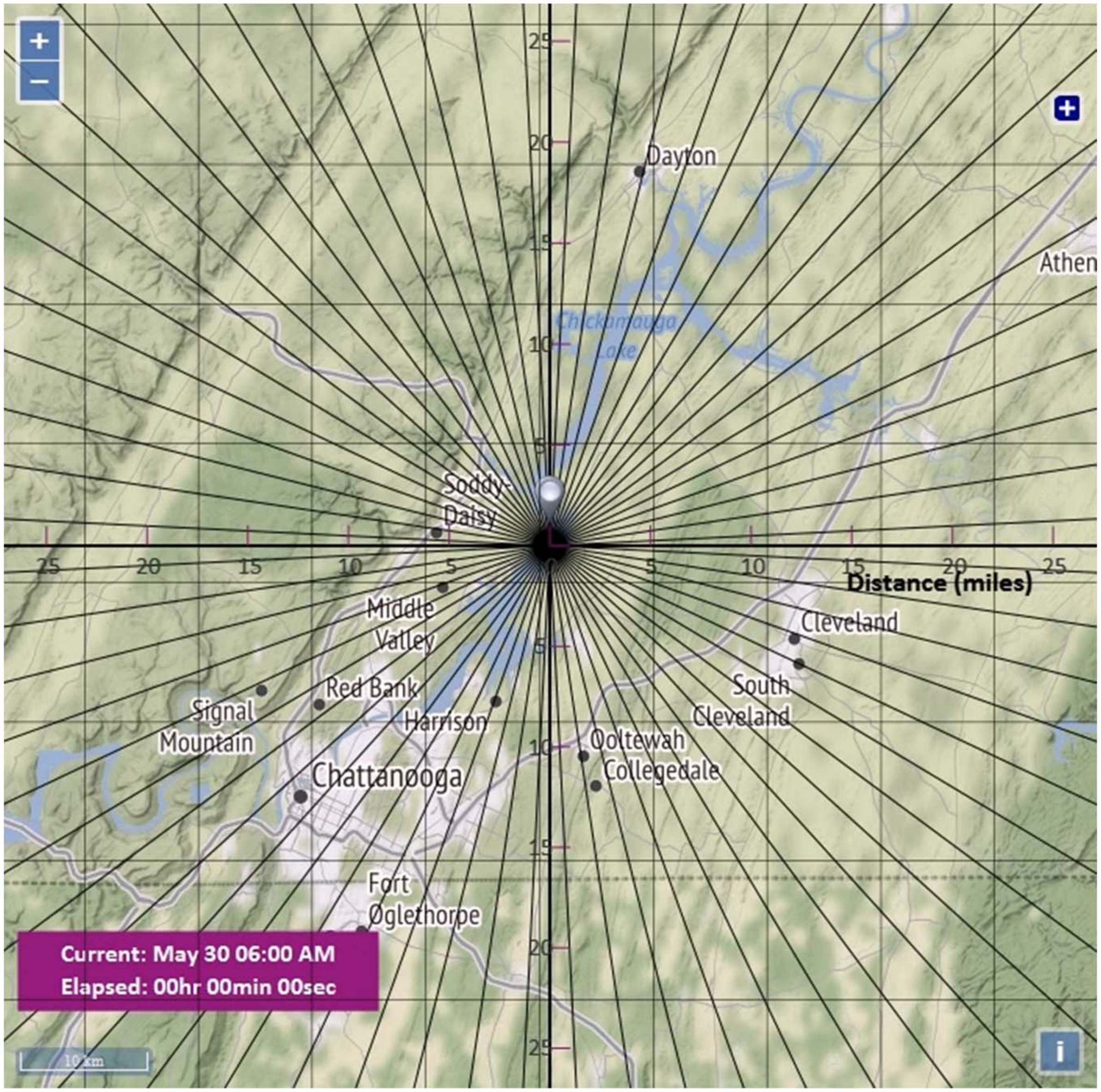
Background on NRC's Accident Analysis Branch: Major Work Activities

- 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

AniMACCS Example

MACCS Gaussian plume segment ATD model animation for a single weather trial



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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, Japan

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

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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

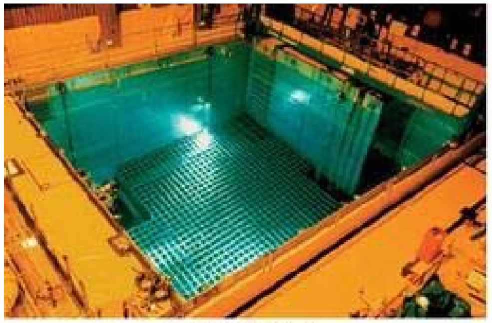
- More information available on NRC's website here

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

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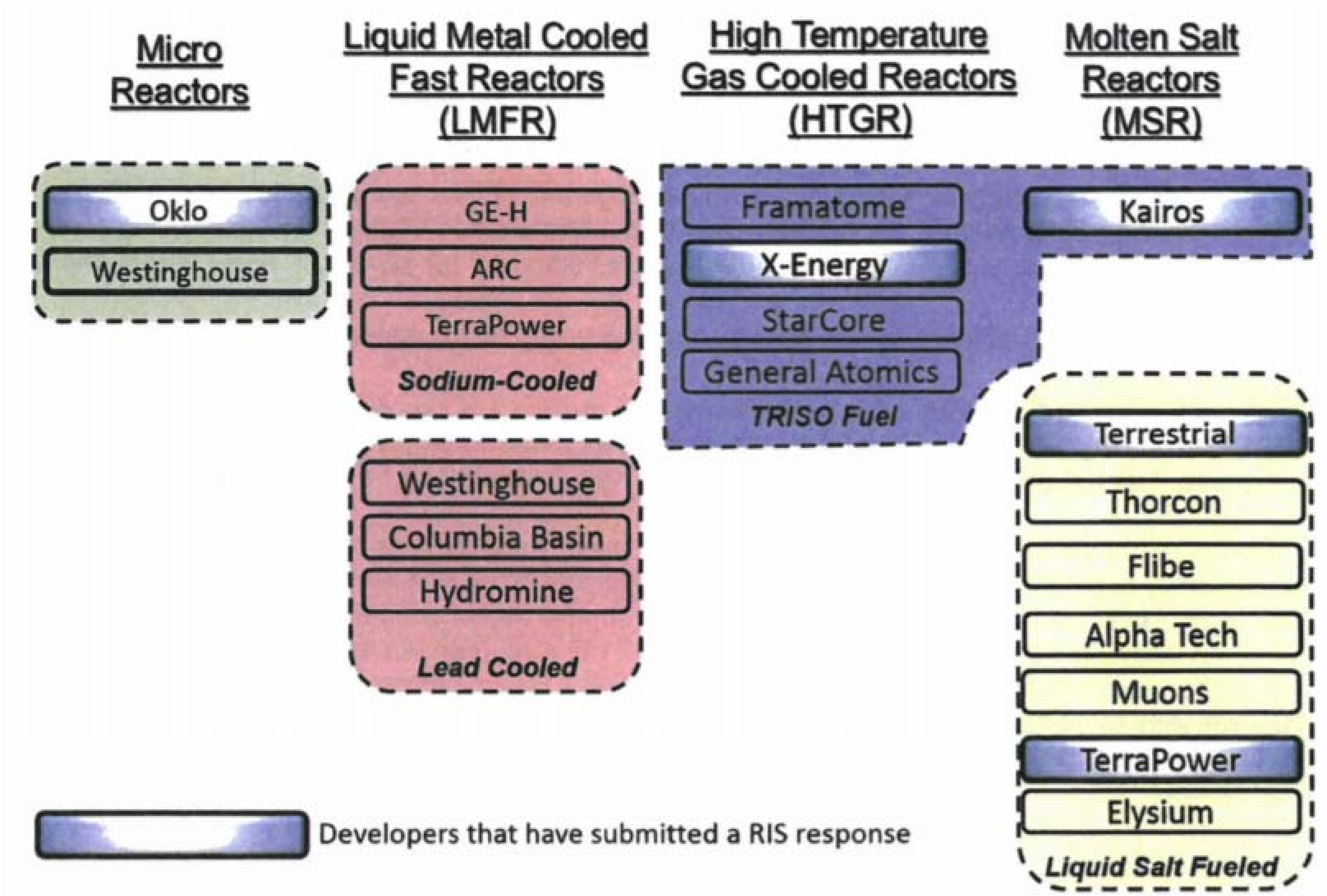
Part 2:

MACCS Code Development Plans for Non-Light Water Reactors

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 vs. Alternatives

- MACCS is a highly flexible code enabling use for different types of sources, accidents, and modeling applications
  - Treats all technical elements of Level 3 PRA Standard
  - Level of specificity for a MACCS analysis can be tailored to the application

- RASCAL – NRC's incident response tool
  - Used in NRC Operations Center to inform protective action recommendations during drills and actual emergencies
  - Very fast-running
  - Can use real-time weather data
  - Computes "fencepost" dose for comparison to US EPA PAGs
  - Does not consider any protective actions
  - Does not calculate full range of consequence measures
  - Does not enable flexibility of MACCS
  - Not designed for probabilistic applications

- RADTRAD – NRC's design basis accident licensing tool
  - Computes site boundary, low population zone, and control room dose for compliance with NRC siting criteria

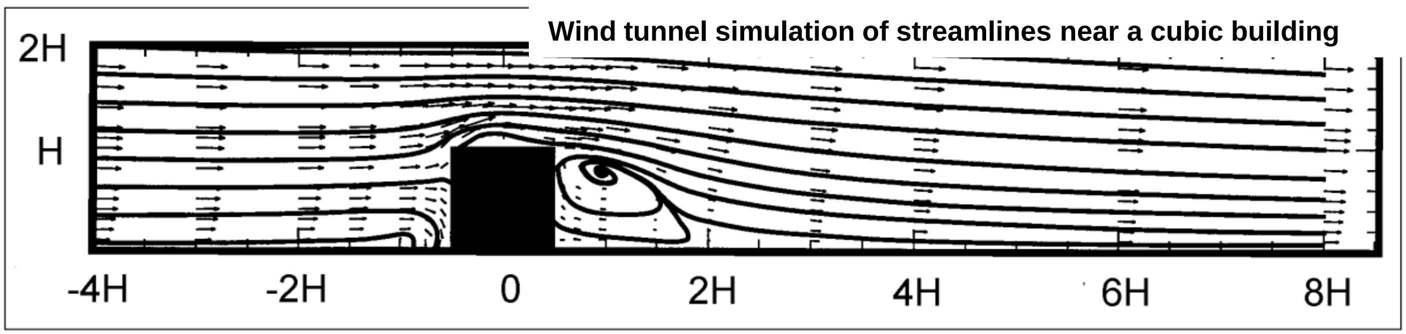
MACCS for Non-LWRs

- Code development plans for design-specific issues
  - Radionuclide screening – which to include?
  - Radionuclide size – significantly smaller size distribution?
  - Radionuclide chemical form – different than for LWRs?
  - Radionuclide shape factor – significantly non-spherical aerosol particles?
  - Tritium – consideration for unique biological behavior?

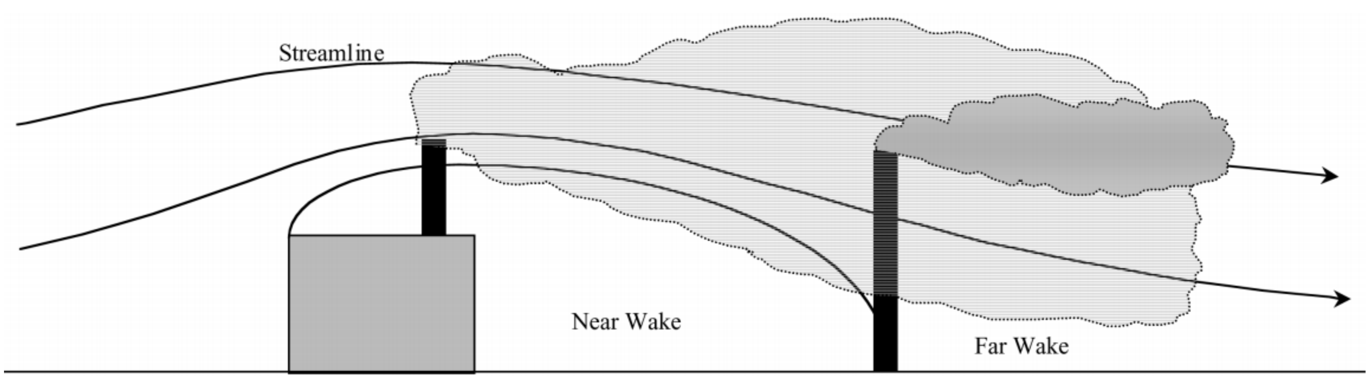
- Code development plans for site-related issues
  - Near-field atmospheric transport
  - Decontamination modeling

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



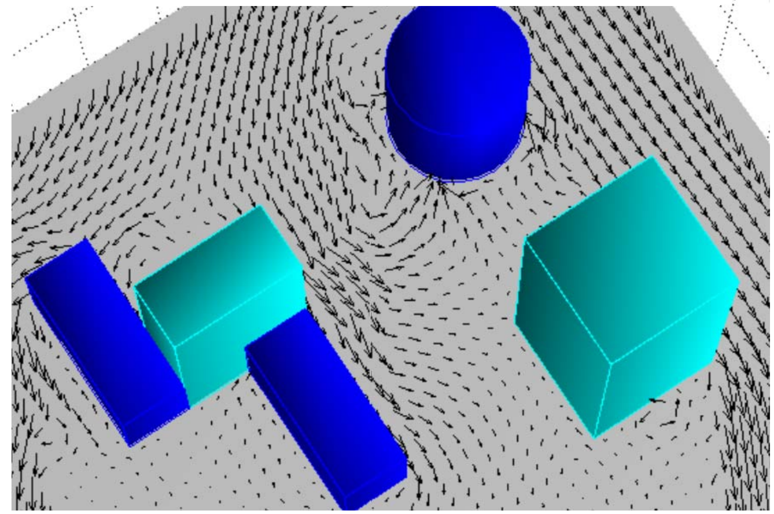
Lloyd L. Schulman , David G. Strimaitis & Joseph S. Scire (2000) Development and Evaluation of the PRIME Plume Rise and Building Downwash Model, Journal of the Air & Waste Management Association, 50:3, 378-390

Near-Field Atmospheric Transport

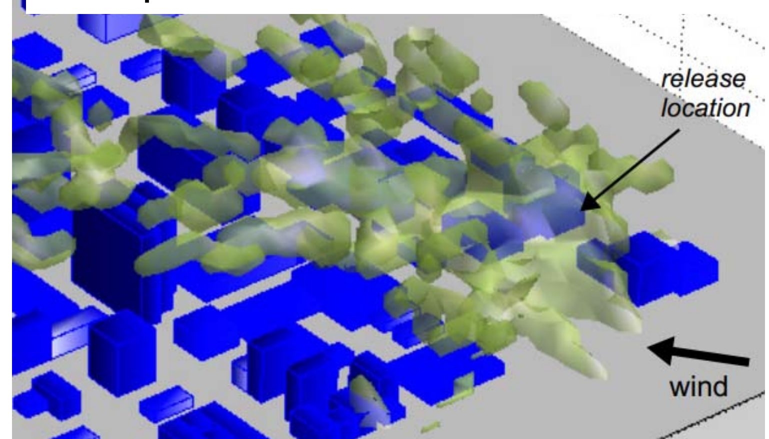
- Various options for addressing near-field ATD
  - Modifications to Gaussian plume segment ATD model
  - CFD modeling of 3-d wind field with Lagrangian particle tracking ATD model
  - Empirical models of 3-d wind fields with Lagrangian particle tracking ATD model

- 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 plan
  - Evaluate the range of applicability of MACCS Gaussian plume segment model
  - While MACCS Gaussian plume segment ATD model may be simple and conservative, an applicant may choose to use it and accept the conservatism
  - Based on study of acceptability of MACCS at close distances, identify an alternative model for integration into MACCS that may be more realistic
  - Seek feedback on plan from NRC's Advisory Committee on Reactor Safeguards
  - Evaluate design-specific issues for non-LWRs prioritized generally based on applicants' plans and technical readiness

Thank you

- Please consider attending IMUG and MACCS workshop! (June 10-14, 2019)

- Please tell your colleagues who might be interested!