NARAC Software Quality Assurance: Adapting Formalism to Meet Varying Needs

2nd Joint Emergency Preparedness and Response & Robotics and Remote Systems Topical Meeting
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NARAC-IMAAC Program
Outline

- Overview of NARAC
- Overview of Hotspot
- NARAC Quality Assurance
- SQA Activities
NARAC Provides Predictions for Assessing Atmospheric Hazards

- Explosive dispersal of radiological material
- Nuclear explosions
- Toxic industrial chemical spills
- Fires
- Biological agents
- Chemical agents
- Nuclear power plant accidents

What is the hazard? Where is it going? Who is at risk? How do we respond?
NARAC/IMAAC Provides Operational Services, Tools, Expertise for Preparedness and Response

**Event Information**
- Weather data
- Nuclear, radiological, chemical, and biological source information
- Terrain, land use, and population databases
- Measurement data and observations

**Operational Services and Expertise**
- Suite of stand-alone to advanced WMD modeling tools (multi-scale models)
- 24/7/365 expert scientific staff (< 5 min. reachback)
- Detailed analysis, expert interpretation, quality assurance, and training
- Event reconstruction

**Actionable Information**
- Hazard areas
- Health effects and exposed populations and facilities
- Casualty, fatality, and damage estimates
- Protective action recommendations and response strategies

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# Internal and External Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Source</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotspot</td>
<td>LLNL</td>
<td>Gaussian plume model for radioactive and nuclear material</td>
</tr>
<tr>
<td>EPICODE</td>
<td>LLNL</td>
<td>Gaussian plume model with hazardous chemical databases</td>
</tr>
<tr>
<td>BLAST</td>
<td>SNL</td>
<td>Pressure effects model for high explosives and RDDs</td>
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<tr>
<td>NUKE</td>
<td>SNL</td>
<td>Prompt dose, thermal, and overpressure effects model for nuclear weapons</td>
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<tr>
<td>KDFOC</td>
<td>LLNL</td>
<td>Gross fission products fallout effects model</td>
</tr>
<tr>
<td>COAMPS</td>
<td>NRL/LLNL</td>
<td>Mesoscale forecast model</td>
</tr>
<tr>
<td>WRF</td>
<td>Community</td>
<td>Mesoscale forecast model</td>
</tr>
<tr>
<td>GridGen</td>
<td>LLNL</td>
<td>Grid generation software for ADAPT/LODI using elevation data</td>
</tr>
<tr>
<td>ADAPT</td>
<td>LLNL</td>
<td>Diagnostic meteorological model</td>
</tr>
<tr>
<td>LODI</td>
<td>LLNL</td>
<td>Lagrangian stochastic particle dispersion model</td>
</tr>
<tr>
<td>PUFF*</td>
<td>SNL</td>
<td>Explosive plume-rise</td>
</tr>
<tr>
<td>BIM*</td>
<td>LBNL</td>
<td>Building interior modeling predicts indoor air concentrations</td>
</tr>
<tr>
<td>UDM*</td>
<td>DSTL</td>
<td>Empirical urban model</td>
</tr>
<tr>
<td>FEM3MP/AUDIM*</td>
<td>LLNL</td>
<td>Multiprocessor computational fluid dynamics (CFD) building-resolving model</td>
</tr>
</tbody>
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* Integration in progress

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### Collaborations Provide NARAC With Additional Models & Data

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<tr>
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<tr>
<td>CAMEO/NOAA/ALOHA</td>
<td>NOAA/EPA</td>
<td>Gaussian plume model with toxic industrial chemical databases</td>
</tr>
<tr>
<td>HPAC</td>
<td>DTRA</td>
<td>Plume modeling system with SCIPUFF</td>
</tr>
<tr>
<td>RASCAL</td>
<td>NRC</td>
<td>Radiological source terms and Gaussian plume/puff model for nuclear power plant releases</td>
</tr>
<tr>
<td>Turbo FRMAC</td>
<td>SNL</td>
<td>Radiological dose calculations from air and ground contamination</td>
</tr>
</tbody>
</table>

### Forecast Model Results from External Sources

<table>
<thead>
<tr>
<th>Agency</th>
<th>Model</th>
<th>Resolution/Coverage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Force Weather Agency (AFWA)</td>
<td>MM5</td>
<td>45 and 15 km resolution, special regional forecasts</td>
</tr>
<tr>
<td>Fleet Numerical Meteorology and Oceanography Center (FNMOC)</td>
<td>NOGAPS 4.0</td>
<td>1° resolution, global</td>
</tr>
<tr>
<td></td>
<td>COAMPS</td>
<td>Special regional forecasts</td>
</tr>
<tr>
<td>National Weather Service (NWS)</td>
<td>WRF</td>
<td>40 km and 12 km resolution, US (NAM)</td>
</tr>
<tr>
<td></td>
<td>GFS (AVN)</td>
<td>0.5° and 1° resolution, global</td>
</tr>
<tr>
<td></td>
<td>RUC</td>
<td>20 km resolution, US</td>
</tr>
</tbody>
</table>
Phased Concept of Operations

1. Initial Local Model
   - Run quickly
   - 1-2 minutes

2. Initial 3-D Model Plots
   - Fully Automated
   - 10–15 minutes

3. Refined 3-D Model Plots—NARAC Staff Quality-Assured
   - 30-60 minutes

4. Refined 3-D model prediction calibrated with field measurements
   - < 2 hours

Additional Refined Plot iterations will be made for new measurements sets.

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System Architecture

User (deployed) -> external systems

Enterprise System
- Web Services
- Web Pages
- Deployed Models
- Mapping

Central System
- Expert User Interface

Model Execution
- Model Run Stream Management

Metadata
- Acquire and Prepare Meteorological Data for Model Input and Visualization

Geodata
- Acquire and Prepare Geographical Data for Model Input, Effects Calculations and Visualization

Meteorological Data Archive

Geographical Data Archive

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NARAC Has a Proven 27-Year Record of Scientific and Operational Excellence

Selected Events

1973 DOE R&D Program
1979 ARAC Operational Center established
Generation-2 system (nuclear/radiological)
DOE site support for toxic industrial chemicals
DOE CBNP program
1996 DOE NARAC facility dedicated
Generation-3 system (CBRN)
2002 LINC program
2003 DHS S&T
2004 DHS interim IMAAC established
2005

1980
1986 Chernobyl reactor accident

1985
1991 Kuwaiti oil field fires
1993 Richmond, CA refinery fire

1990
1997 Cassini satellite launch
1998 Tracy tire dump fire
1999 Tokaimura, Japan, criticality accident

1995
2001 September 11
2003 Staten Island oil barge fire
2003-2004 New Years Orange Alert
2004 Conyers, GA chemical fire
2006 Pluto New Horizons spacecraft launch

Photo of smoke from tire dump fire (Tracy, California, 1998) with plume prediction in red
Hotspot Provides Quick Dose Estimates for Radiological and Nuclear Releases

- Multiple release scenarios (explosive, fire, general plume)
- Fully-integrated FGR11 (ICRP26, 30), and 13 (ICRP 60+) internal and FGR 12 external dose factors
- Straight-line Gaussian plume model
- Standalone version available via Web download: http://www.llnl.gov/nhi/hotspot/
- Also can run in NARAC Web and iClient user interface and maps
Under DHS leadership, IMAAC coordinates dispersion modeling for atmospheric chemical/biological/nuclear hazard predictions among federal agencies.

- MOU signed by 8 federal agencies: DHS, DOC/NOAA, DOD, DOE, EPA, HHS, NASA and NRC
- NARAC has been designated the primary initial provider of IMAAC capabilities
- IMAAC and NARAC roles are codified in National Response Plan (NRP) and National Exercise Program (NEP)
- IMAAC Interagency Working Group (IWG) developing Standard Operating Procedures (SOPs). Agency-specific MOU annexes are being written
- Goal is to integrate the best available scientific capabilities and data from federal, state, and local agencies, and not replace or supplant atmospheric modeling activities that are currently in place to meet agency-specific mission needs
- National training, deployment and exercise program for IMAAC Web use by DHS National Operations Center (NOC), Federal operations centers, EPA/FEMA/NOAA/DOE regional assets
- On-going interagency collaboration: operational coordination, standard plot suite and formats, data sharing

“IMAAC provides a single point for the coordination and dissemination of Federal dispersion modeling and hazard prediction products that represent the Federal position during actual or potential incidents requiring Federal coordination”

*National Response Plan*, May 2006
Model R&D:
- improved internal models
- integrate new models
- peer review
- configuration management
- developer testing
- benchmarking
- verification
- validation
- documentation

Computer & Software Systems:
- robust hardware design
- robust network design
- robust software design
- flexible data integration
- flexible technology integration
- redundancy
- monitoring
- security
- contingency
- Software Quality Assurance

Operations:
- concept of operations
- daily use of system
- user testing
- internal/external training
- on-call readiness
- on-line documentation
- user group feedback
- exercises and real events
- hot washes
- assessments
NARAC/IMAAC Models and Operations are Extensively Tested and Evaluated

- **Analytic solutions** test models versus known, exact results
- **Field experiments** test models in real-world cases
  - Examples: Roller Coaster, Project Prairie Grass, Savannah River Musicale Atmospheric Tracer Studies, Diablo Canyon Tracer Study, ETEX, URBAN

- **Operational testing** evaluates the usability, efficiency, consistency and robustness of models for operational conditions
  - Examples: Chernobyl, Kuwait oil fires, tire fires, industrial accidents, Algeciras Spain Cesium release, Tokaimura criticality accident, Cerro Grande (Los Alamos) fire
HotSpot Becoming a DOE “Toolbox” Code

- DOE has approved (pending 5 “critical” recommendations) inclusion of the HotSpot Health Physics codes into the DOE Safety Software Central Registry

- Five Critical recommendations
  - 95th-percentile dose from historical weather data -- requirement of DOE-STD-3009-94 Change Notice 3 Appendix A, subsection A.3.3 Dose Estimation / Atmospheric Dispersion – Not in version 2.07
  - HotSpot User manual/documentation (.PDF) and online help module
  - Formal internal configuration management plan
  - Formal V&V test process
  - Problem reporting, evaluation and notification plan per DOE G 414.1-4 level B custom software
ASME SQA Work Activities

1. Software project management & quality planning
2. Software risk management
3. Software configuration management
4. Procurement and supplier management
5. Software requirements identification & management
6. Software design and implementation
7. Software safety
8. Verification & validation
9. Problem reporting and corrective action
10. Training
1. Project management

- **Tools**
  - Gantt charts
  - Responsibility matrices
  - Java Café
  - EXCEL
  - Bugzilla
  - Word

- Long-term architectural plan
- Use of Bugzilla for requirements tracking
- Formalism is gradually increasing
- HotSpot management is being integrated with NARAC
2. Risk Management

- Continuous evaluation of processes
  - Identify risks

- Factors mitigating risk
  - Experienced, committed staff
  - Co-located with operations/modeling staff
  - Operations staff use system daily
  - System & software constantly monitored
  - Steadily improving design skills & tools

- Factors increasing risk
  - Growing requirements
  - Complex system

- HotSpot is developed by a single develop
- Integrating HotSpot management and procedures with NARAC should decrease risk

<table>
<thead>
<tr>
<th>Experience (years)</th>
<th>0-5</th>
<th>5-10</th>
<th>10-20</th>
<th>20-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>people</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>
3. Configuration Management

- All system components are in version control
- System domains clearly separate development/production environments
  - Formal procedures for migrating integrated packages to production
- All Production domains are constantly monitored and evaluated
  - Statistics are evaluated regularly
- HotSpot releases maintained in NARAC Enterprise System version control
4. Procurement & Implementation

- Use a variety of systems, packages and tools
  - EXCEL used to track acquisitions & licenses
- Selections are based on:
  - support of required capabilities
  - ease of integration
  - vendor reputation & previous experience
  - cost and deployment constraints
- All components are continuously evaluated
- Maintenance level is tuned to impact
- Current HotSpot procedures in this area are adequate
5. Requirements Management

- Software requirements driven from two levels
  - High-level requirements set by sponsors and Program Management
  - Detailed requirements set by internal/external users
- Requirements are evaluated by software staff
- Requirements managed in Bugzilla
- HotSpot requirements management is being integrated with NARAC procedures in Bugzilla
6. Design & Implementation

- Systems have been operational for 3-5 years
- Design & Implementation Approach
  - Formalism is tuned to scope of the work
  - Extensive use of patterns & refactoring
  - Effective use of improving tools
- Software integration is mostly continuous
- Review are tuned to task scope
- HotSpot is largely in maintenance and the design is adequately documented
7. Software Safety

- Software components are continuously evaluated for their effect on operations
  - Critical components are redundant
  - Weak components are improved
- Safety design techniques
  - Extensive use of common design techniques
  - The exception is reduction of complexity
  - NARAC/IMAAC mission implies growing complexity
  - Challenge to manage that growth
- HotSpot has been provisionally accepted for inclusion for inclusion in the DOE Safety Software Toolkit once the 5 issues are addressed
8. Verification & Validation

- Verification is performed throughout the development process
  - Developer testing is the core of this effort
  - Tool-based (e.g., JUnit, WinRunner) & custom tests
- System validation is done by internal users focusing on new capabilities
- Automated tests verify existing functionality
- In-use tests monitor the system
  - Automated system checks run hourly
  - Failures page on-call personnel
- Current HotSpot testing is being supplemented with testing by the NARAC modeling, systems and operations from related but differing perspectives
9. Problem Reporting

- Bugzilla is used for problem reporting
  - Roles are assigned for managing Bugzilla entries.
  - External customers issues are entered into Bugzilla by Customer Support
- The coverage of the changes being tracked is improving
- Corrections are tracked through V&V into production
- HotSpot problem reporting is being migrated from the current informal e-mail approach to the NARAC procedures built on Bugzilla
10. Training

- Training for internal users
  - Presentations are given to the internal users
  - Web-based documentation
  - Internal users maintain a user’s guide
  - Most internal user activities use the system
- Training for external users
  - Documentation on the NARAC Web page
  - Customer Support training
  - Formal classes: remote and at NARAC
- Several NARAC Staff are becoming increasingly familiar with HotSpot and will eventually supplement the current training efforts
Current SQA Activities

- Focusing on LLNL SQAP
  - Graded approach to software risk
  - Gap analysis
  - Updating NARAC SQA, Test & CM Plans
  - Improving suite of automated tests
  - Tracking requirements more precisely
- Working with the NARAC/IMAAC Model VV&A effort
  - Analytic tests/field experiments/operational use
  - Updating model documentation
  - Maintaining benchmark suite
  - Automating model V&V tests
  - Clarifying procedures for VV&A
  - Evaluation strategy for external models
- Completing resolution of HotSpot SQA shortfalls
Overview

- NARAC is more than a model
  - NARAC incorporates multiple models
  - NARAC provides a range of services
  - NARAC services are supported by operational scientists
- All activities in NARAC are Quality Assurance related
  - All model and system development activities address shortfalls in current capabilities
  - All operational activities are focused on providing high quality products
- Formal procedures are balanced with a flexible environment so that new capabilities can be added efficiently
- HotSpot is progressing steadily towards correcting the shortfalls identified by the DOE Safety Software Committee
For more information

Web: http://narac.llnl.gov
Email: narac@llnl.gov
A Comprehensive Approach Ensures Quality, Reliability, and Accuracy

Operational Readiness

System software

- Fate and Transport Models
  - Meteorological Data Assimilation
  - Forecasts
  - Fate and Transport

Consequence and Health Effect Databases

Assessments

Source Generation Models and Databases

Geospatial Databases

Meteorological Databases

Verification

Validation

Testing

SQA

C&A

System Monitoring

Configuration Management

External Use and Peer Review

Operational Documentation

On-Call Readiness

Contingency Planning

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