reacH2

Project ID # SCS011

R&D for Safety Codes and Standards: SCS Project Overview – Risk

Sandia National Laboratories

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and Peer Evaluation Meeting
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Overview

Timeline

- Project Start date: Oct. 2003
- Project End date: Sept. 2015
- Percent complete: 83%

MYRD&D 2012 Barriers

A. Safety Data and Information: Limited Access and Availability

F. Enabling national and international markets requires consistent RCS

G. Insufficient technical data to revise standards

L. Usage and Access Restrictions – parking structures, tunnels and other usage areas

Budget

- Project funding DOE share: $1.2M*
- Funding received in FY12: $0.5M
- Planned funding for FY13: $0.2M

(*Project activities supported by SCS010)

Partners

- **Industry**: FCHEA, Air Products, Nuvera
- **Govt**: NREL, PNNL
- **SDO/CDO**: NFPA, ICC, ISO
- **International**: IEA, IPHE

Project Approach

The Safety, Codes and Standards program coordinates critical stakeholders and research to remove technology deployment barriers

Partnerships with industry, labs, academia

Identify R&D needs → *Perform High-Priority R&D* → *Impact Codes and Standards*

CSA, NFPA, SAE, UL, ISO, ICC International Code Council, ASME Setting the Standard

Harmonize Internationally

Regulations, Codes and Standards (SAE, GTR, IEC)
International Standards (ISO)
International Agreements (IEA, IPHE)

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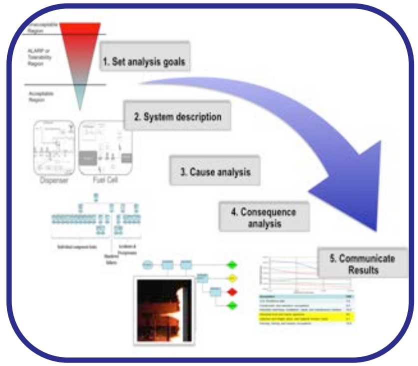
Project Relevance

Objective: Develop & demonstrate methodologies to support the use of Quantitative Risk Assessment (QRA) as a tool for development & revision of RCS and safety best practices.

MYRD&D 2012 Barrier	Project Goal
A. Safety Data and Information: Limited Access and Availability G. Insufficient technical data to revise standards	Develop QRA toolkit to enable sustained use of QRA in line with project objective.
F. Enabling national and international markets requires consistent RCS	Participate as experts for NFPA2, IEA Task 31 and other international programs
L. Usage and Access Restrictions – parking structures, tunnels and other usage areas	Provide QRA results for specific scenarios needed for revision of RCS.

FY2013 Task Approach
Coordinated QRA Process Development

Apply risk assessment techniques to identify risk drivers and associated consequences in step-out hydrogen technologies



Develop integrated algorithms for conducting QRA for GH_2 facilities and vehicles

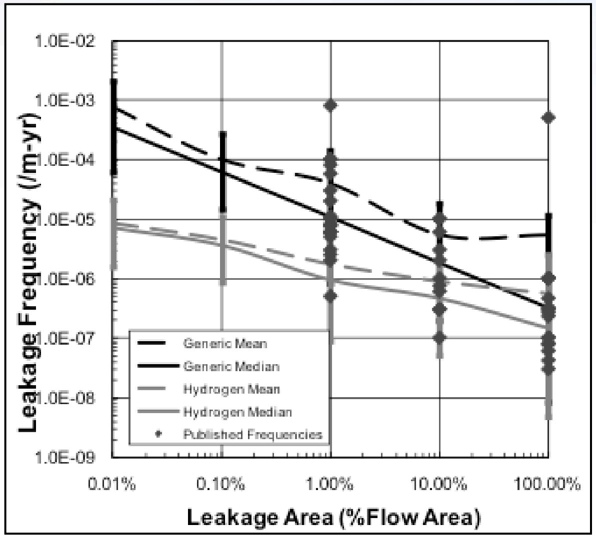
Engage with stakeholders (industry, OEMs, government, SDOs) to build awareness of QRA and related activities to reduce risk

Consequence models (from SCS010 Task) provide reduced order information (ignition, radiation, overpressure) for accurate depiction of physical behavior of unintended releases reacH2

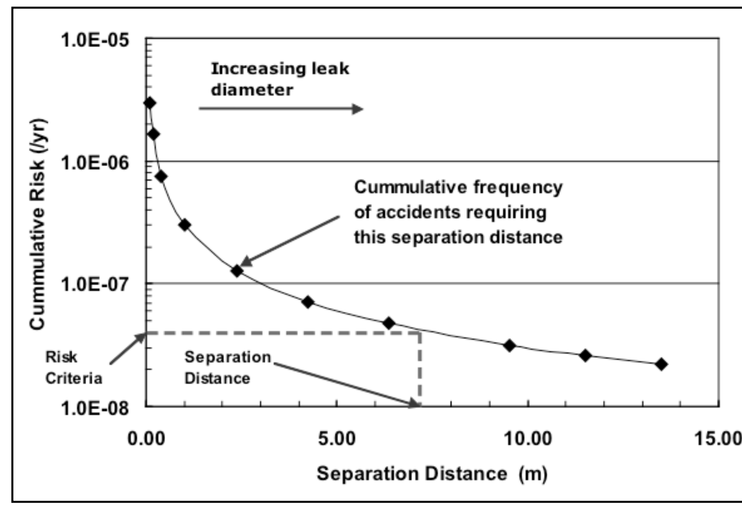
FY2013 Milestones

Aspect	Milestone	Status
Apply QRA	Conduct QRA for indoor fueling of hydrogen powered industrial trucks	Completed Nov 2102 Published SAND2012-10150.
Develop algorithms for QRA	Document new QRA methods & QRA needs for use in development of C&S requirements.	New/refined QRA approach documented in SAND2012-10150
	Create initial version of H2 QRA toolkit	Version 0 used for indoor fueling specific scenario. Version 1.0 in process.
Engage with stake-holders	Host workshop on Hydrogen Specific QRA for stakeholders	Planned for Q3 FY13
	Support IEA Task 31 Activities	IEA Task 31 Workshop (Bethesda, MD, Oct 2012)
	Feedback to NFPA 2 TG 6 (Indoor Fueling)	Proposed code changes to NFPA 2 for 5 task groups (fueling, tunnels, explosion, parking & garages, separation distances) in Dec. 2012 (end of code cycle)

Previous accomplishments: Established data for unintended release frequencies



- Implemented Bayesian approach to develop leak frequency data for H2 systems using frequency data from related industries (FY09-FY08).

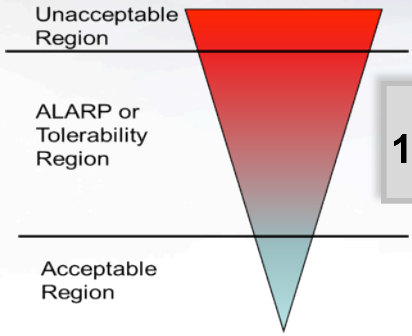


- Documented risk acceptability criteria used in other industries (FY10)
- Documented variety of harm models (FY10)
- Implemented QRA approach to establish separation distances for NFPA 2 (FY10)

Accomplishment: Integrated QRA Algorithm

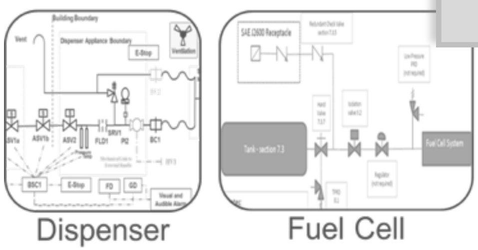
<u>Increase Access to Safety Analysis Tools</u>
Developed integrated QRA algorithm by combining previously disparate process in a single code - Initial "Toolkit Algorithm"

QRA Process

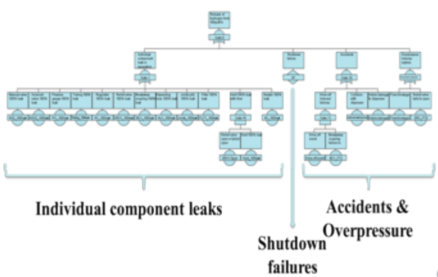


1. Set analysis goals

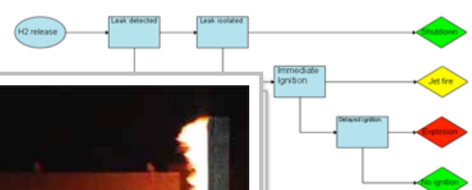
2. System description

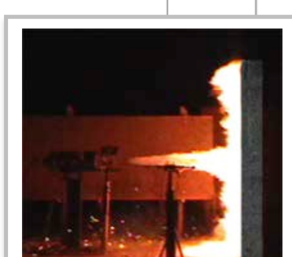


3. Cause analysis

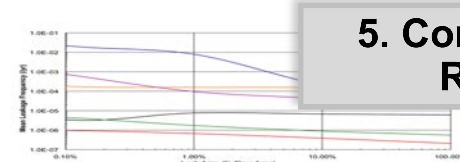


4. Consequence analysis





5. Communicate Results



Occupation	FAR
U.S. Workforce total	1.8
Construction and extraction occupations	5.9
Industrial machinery, installation, repair, and maintenance workers	10.4
Industrial truck and tractor operators	3.0
Laborers and freight, stock, and material movers, hand	3.1
Farming, fishing, and forestry occupations	13.5

Accomplishment:
Improvements to Previous QRA Process

+ Set Risk Metric: Using FAR (Fatal Accident Rate – the number of expected fatalities per 100 million person-hours)
  - Allows comparison with similar industries

+ Integrated reduced order hydrogen dispersion and flame radiation models
  - Alignment with reduced-order modeling activities (SCS010);
  - State-of-the art approach to risk assessment (flexibility to evaluate a wider range of scenarios in a short time)

+ Developed module to convert hazard (physical effects of accidents) to harm (effects on humans)

Integration of previously disparate process steps required development of modules, this improves the functionality of the project goal a "Toolkit Algorithm"

Accomplishment: Apply "QRA Toolkit" to Indoor Fueling Scenario

- System Description: a "generic" code-compliant fueling system
- Completed screening-level QRA on code-compliant indoor fueling system
- **Predicted FAR of 0.17** is lower than FAR for occupation

Occupation *Data from Bureau of Labor Statistics, 2010*	**FAR**
U.S. Workforce total	1.8
Construction and extraction occupations	5.9
Industrial machinery, installation, repair, and maintenance workers	10.4
Industrial truck and tractor operators	3.0
Laborers and freight, stock, and material movers, hand	3.1
Farming, fishing, and forestry occupations	13.5

Applied early version of toolkit to scenario of interest, validated module results with previous process approach and experimental data, SAND2012-10150

Accomplishment: Stakeholder engagement

- Publications & Presentations:
  - World Hydrogen Energy Conference (Toronto, June 2012)
  - IEA HIA Task 31 Workshop and Expert Meeting (Oct 2012)
  - SAND2012 10150 *"Early-Stage Quantitative Risk Assessment to Support Development of Codes and Standard Requirements for Indoor Fueling of Hydrogen Vehicles"*
    - Includes initial version of toolkit algorithms (written in MATLAB®)
    - Discussed hazard mitigation via gas/flame detection
- Collaboration with international research and commercial partners in "downstream" application of QRA toolkit algorithm (website, app, integration in commercial QRA code base)
- Progress with access to QRA relevant, hydrogen specific data
- QRA workshop in planning (Q3 FY13)
  - Goal – Identify the hydrogen community (the user) priorities for QRA toolkit

Outreach to target users critical to development of effective toolkit

reacH2 Collaborations: Industry & Research Partners

Leadership in NFPA 2 Fueling Task Group

- Task group members in active collaboration:
  - Air Products and Chemicals
  - Nuvera Fuel Cells
  - NREL
  - University of Quebec TR

Leadership role in IEA Task 31 (previously 19) on Hydrogen Safety

- Hydrogen behavior and risk assessment research

Participant role in various codes and standards efforts

- SAE Interface and Safety Working Groups
- NFPA 2 Tunnels, Generation, Separation Distances and Refueling working groups
- CSA standards – HGV 4.3, HPIT2
- FCHEA Transportation and Generation Working Groups
- ISO TC 197 and IEC TC 105

Future Work

FY13

- Enhance methodology:
  - Integrate overpressure model (developed by SCS 010) into QRA code
- Host QRA Workshop
- Improvements to toolkit:
  - Improve graphical abilities
  - Add sensitivity analysis capabilities
- Integrate H_2 data to improve model accuracy

FY14

- Improve ignition probability models based on current behavior research
- Facilitate hydrogen industry adoption of QRA; database, first order tools and published methods
  - Workshop in FY13 and follow on activities
- Engage internationally with partners to promulgate QRA approach

Summary

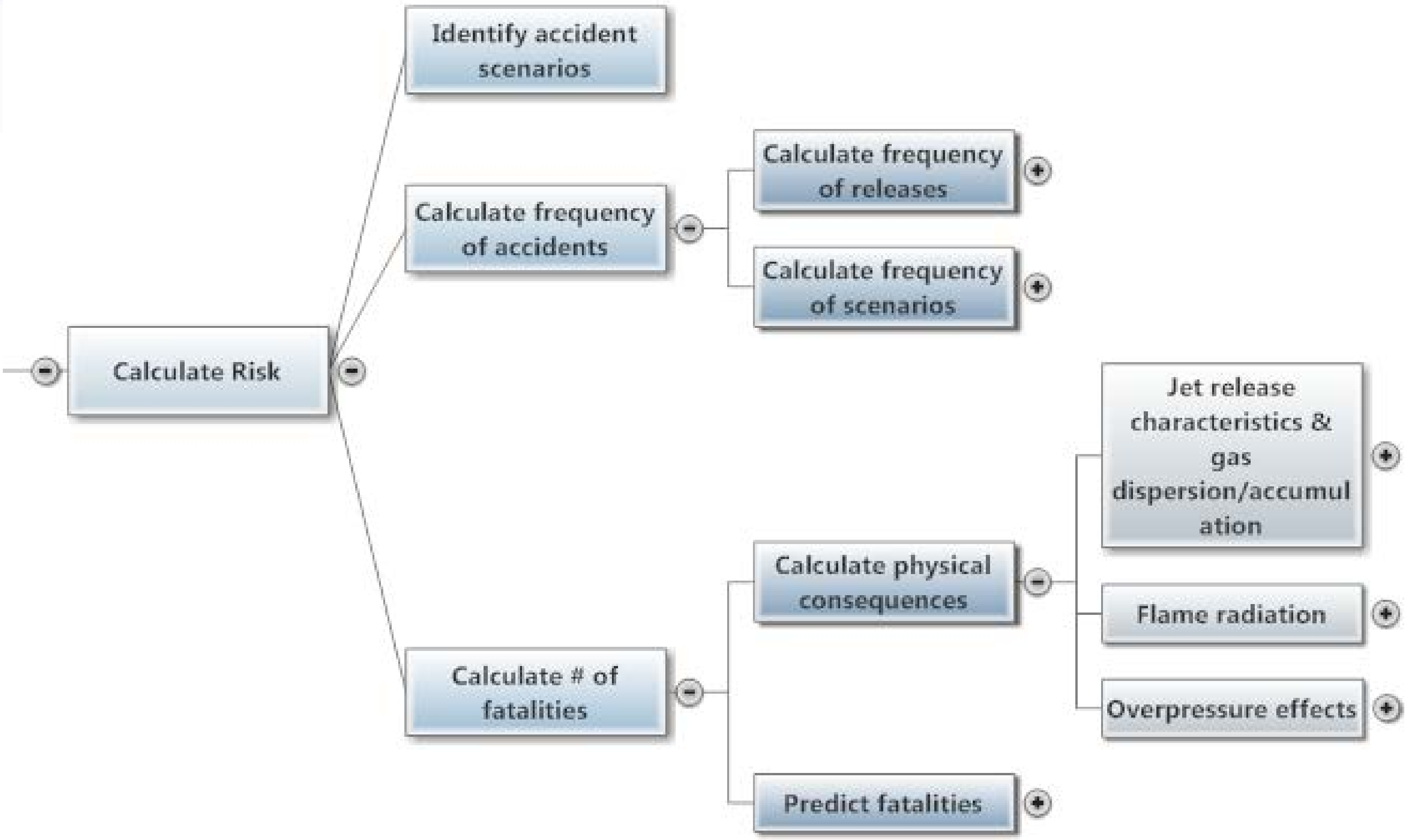
- **Relevance**: Address lack of safety data, technical information relevant to development of Codes & Standards.
- **Approach**: *Develop* and *Apply* QRA techniques; *Engage* with stakeholders
- **Technical Accomplishments**:
  - Screening-level QRA on indoor fueling
  - Apply initial version of QRA tool kit
  - Engagement with IEA, NFPA, NREL, H2CAN.
- **Future research**:
  - Gain user feedback and recruit user participation is toolkit development
  - Improve tool with access to data and improved behavior models

Technical Back-Up Slides

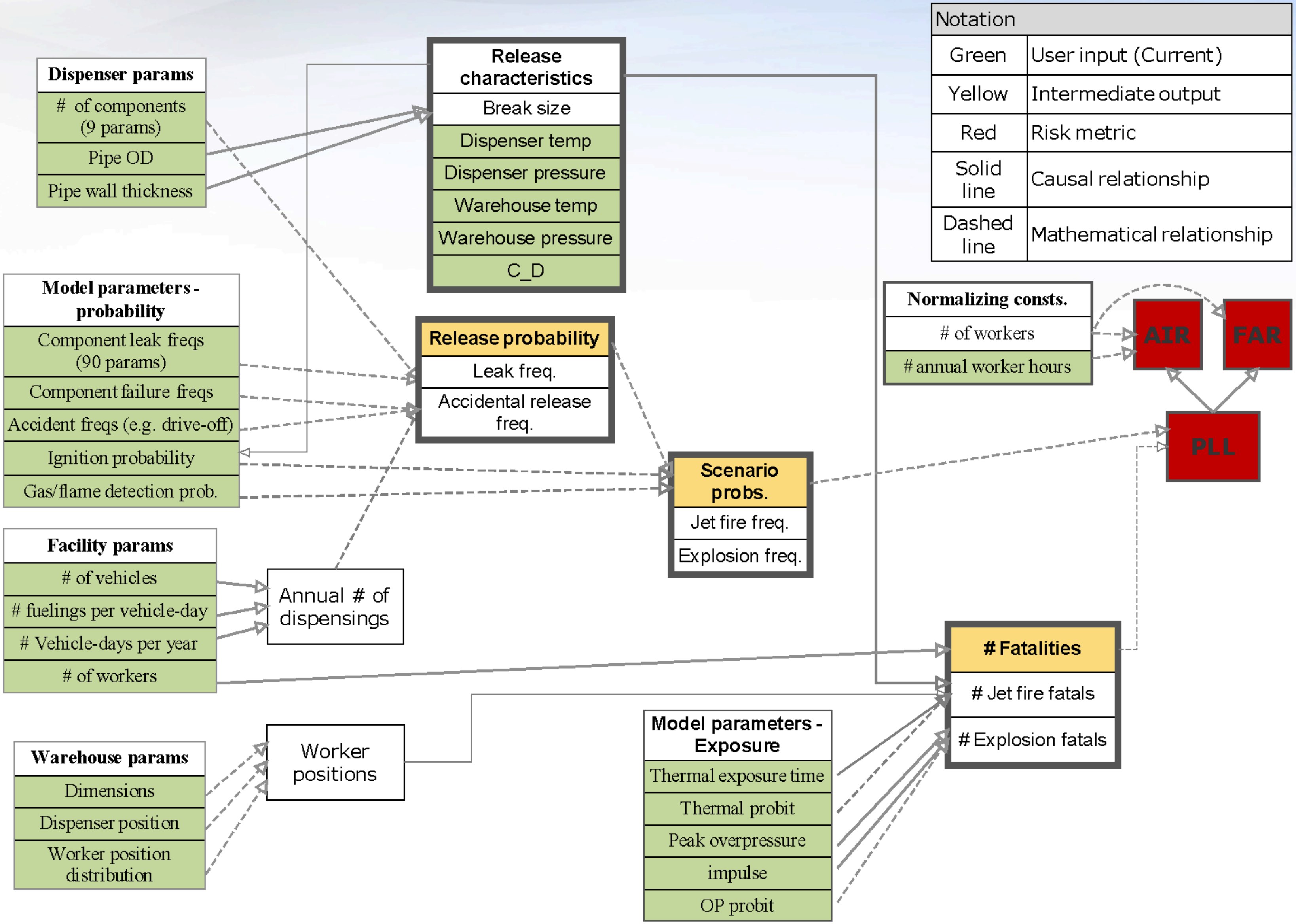
QRA – Basic Steps

1. Assume that hydrogen release is the only change in hazard vs. current use scenario (e.g., forklift operation, automotive refueling, etc.)
2. Describe scenarios that occur after a H2 release (Event Sequence Diagram)
   - Use events records (from H2, CNG, and gasoline fueling) to build an Event Sequence Diagram to describe the scenarios that can occur after an H2 release
3. Describe the events that can lead to H2 releases (Fault Tree)
   - Use accident records from H2, CNG, and gasoline fueling. Also use component failure mechanisms.
4. Use frequency data to quantify the Fault Tree
   - H2 component leakage rates from LaChance work (presented at 2011 AMR)
   - Component failure rates from offshore oil and nuclear industry
5. Use existing probability models to quantify the probability of ignition, given a leak
6. Use best estimate to determine the consequences (number of fatalities) from each accident scenario (release behavior models, ignition probability, etc.)
7. Calculate predicted Fatal Accident Rate (FAR). Compare fatality rates with other industries
8. Communicate results - Participate in code development committee interpretation of QRA results

Modules in current version of QRA Algorithm



Sensitivity Analysis of QRA Algorithm



Notation	
Green	User input (Current)
Yellow	Intermediate output
Red	Risk metric
Solid line	Causal relationship
Dashed line	Mathematical relationship

QRA Tool modules