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The Center for Risk and Reliability

An Outline of MUPSA: Risk Metrics, Safety Goals and Risk Information

Presentation at the

OECD/NEA Committee on the Safety of Nuclear Installations (CSNI)

Working Group on Risk Assessment (WGRISK)

International Workshop on Status of Site Level PSA Developments

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Outline

- Quick Overview of MUPSA: My Perspective
- Site-Level Risk Metrics
- Site-Level Safety Goals
- Final Observations

Disclaimer!

While I'm concerned with practicality and cost of performing MUPSA, as an academic my focus is in the search for truth and associated uncertainties

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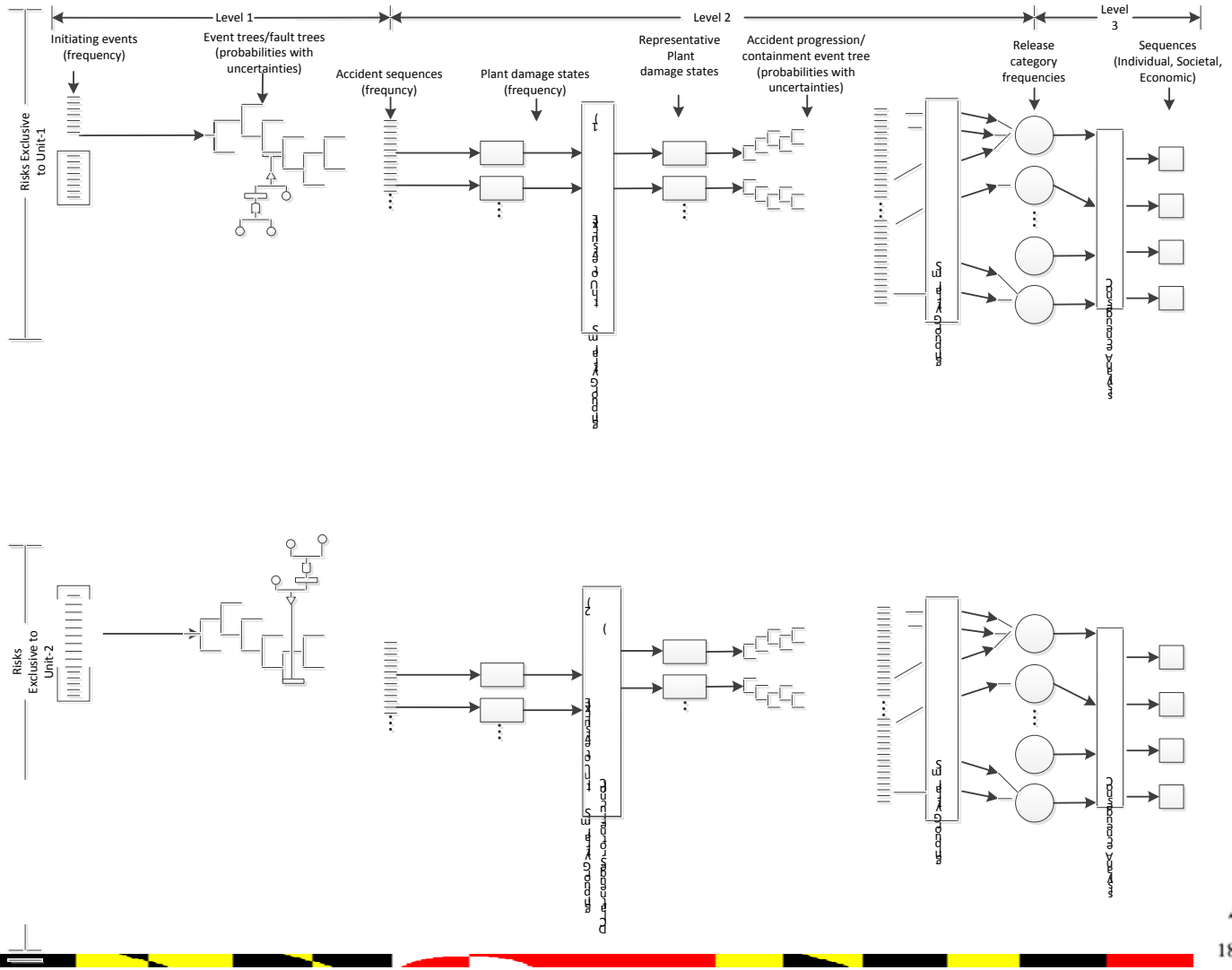
Quick Overview of MUPSA



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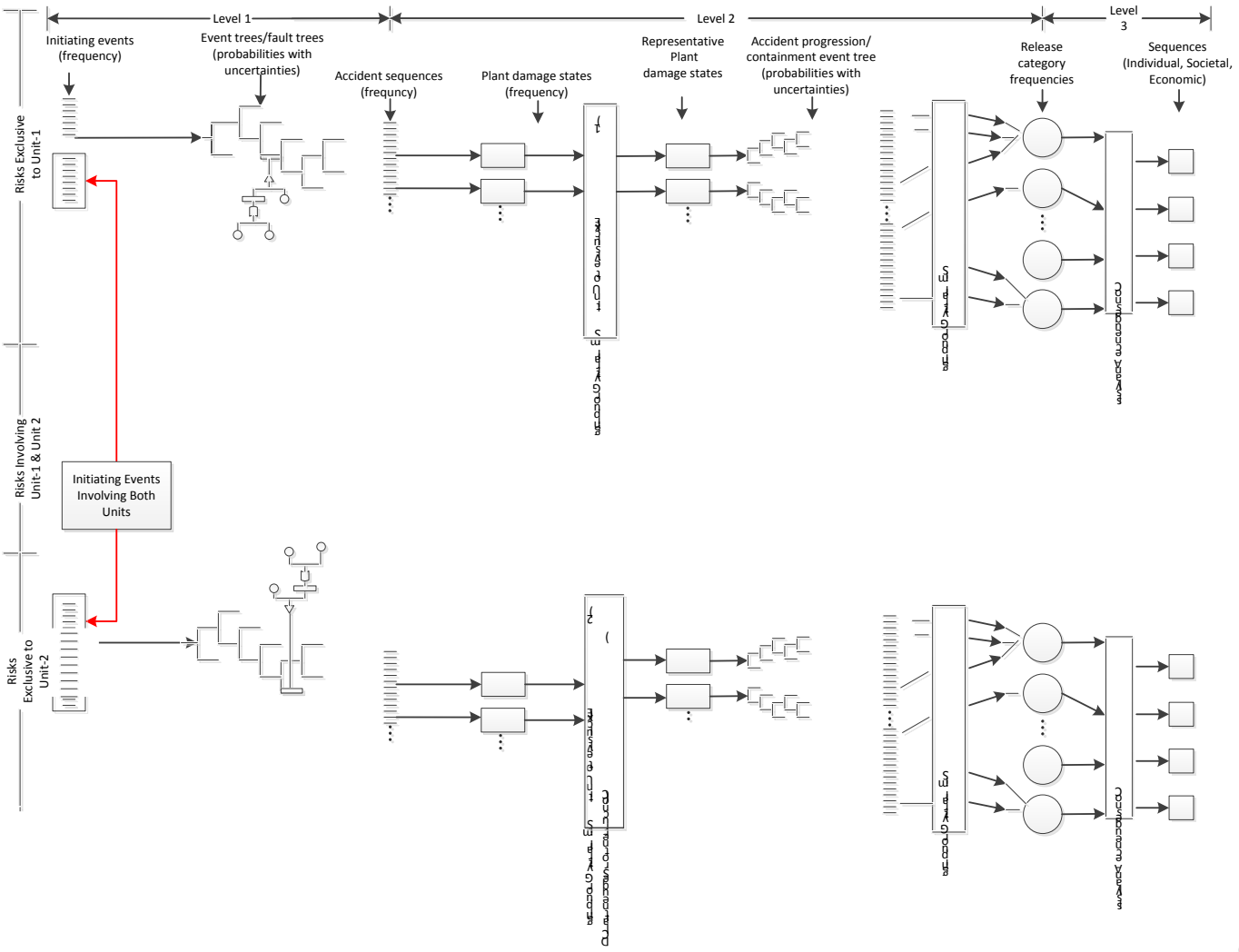

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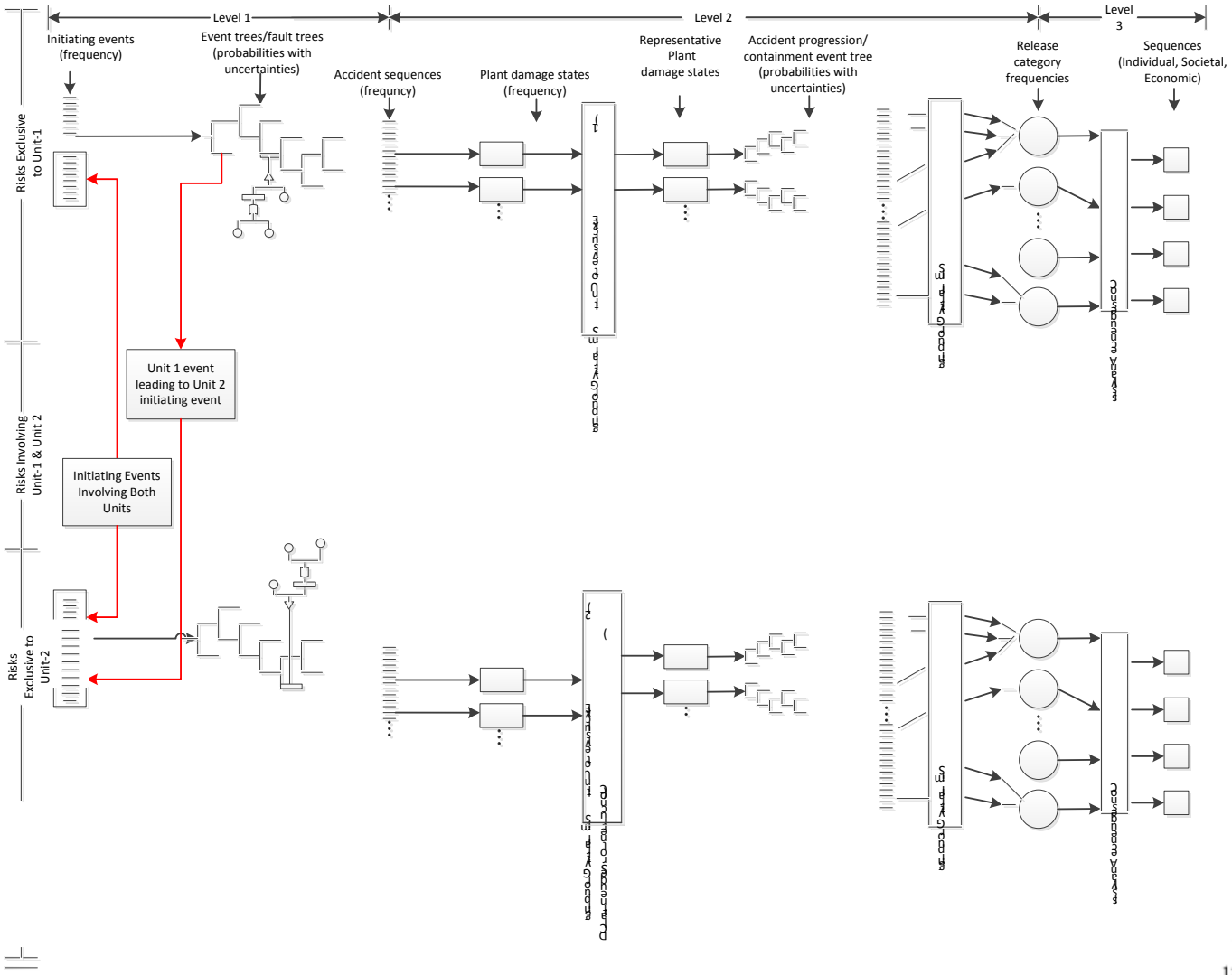

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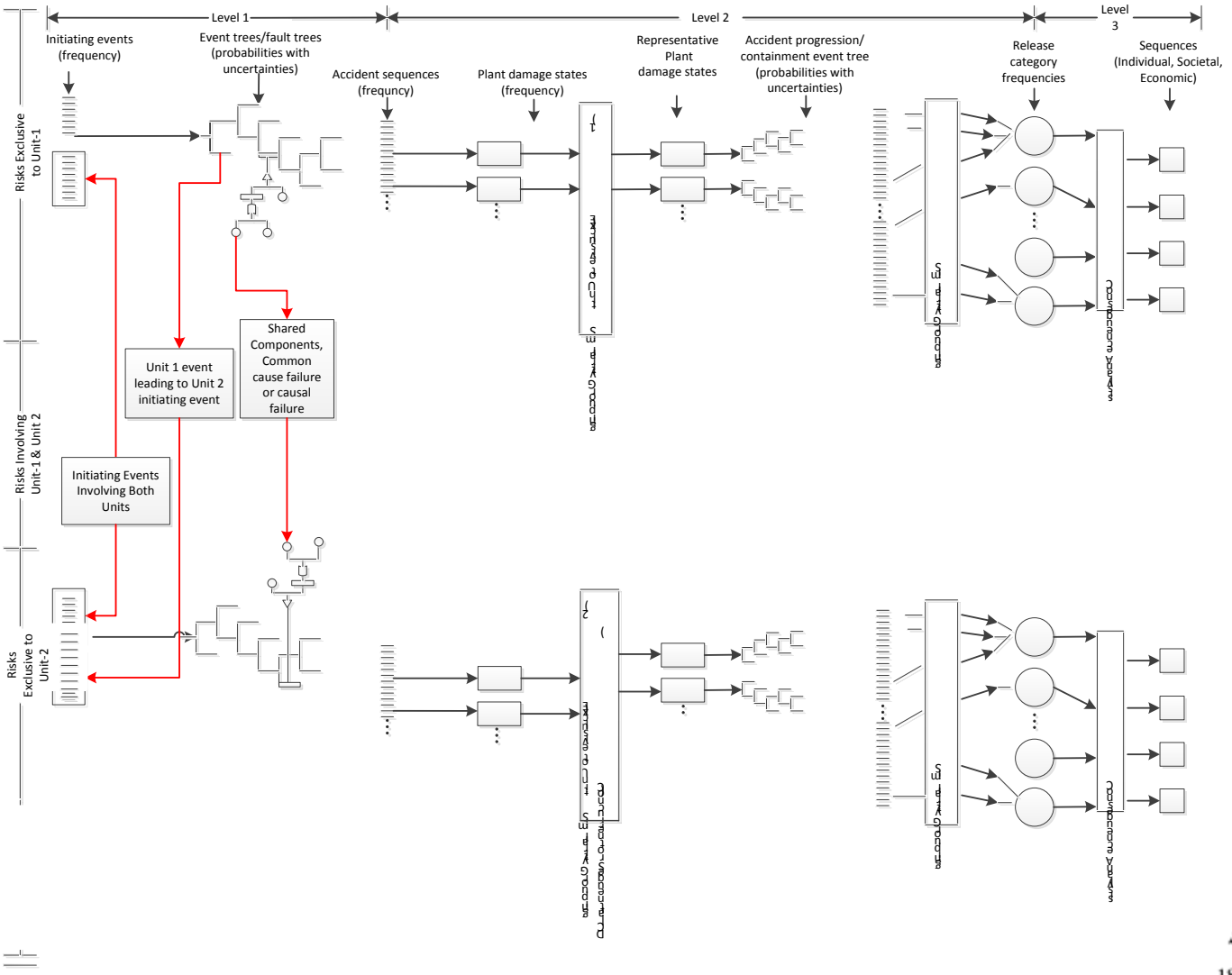

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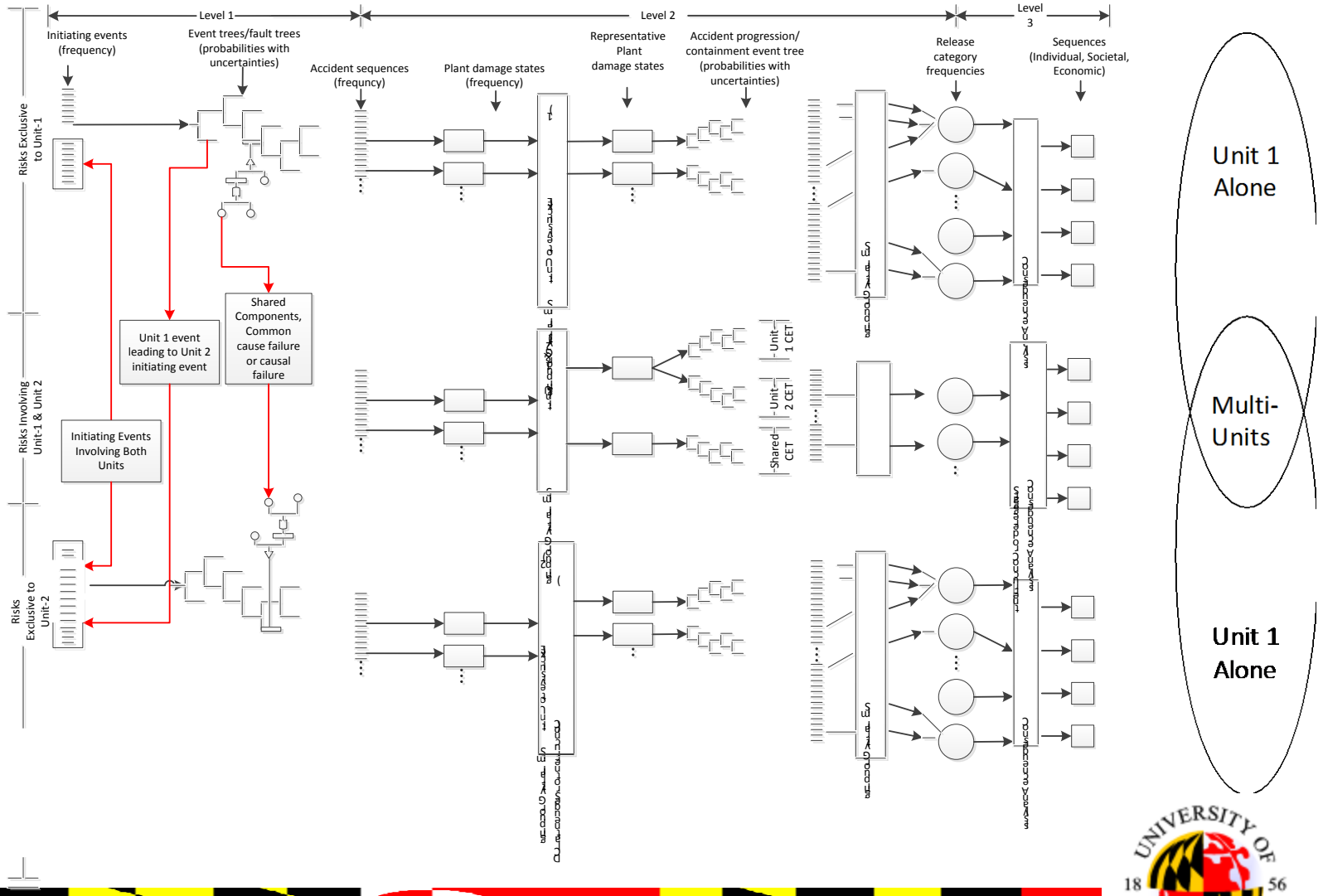

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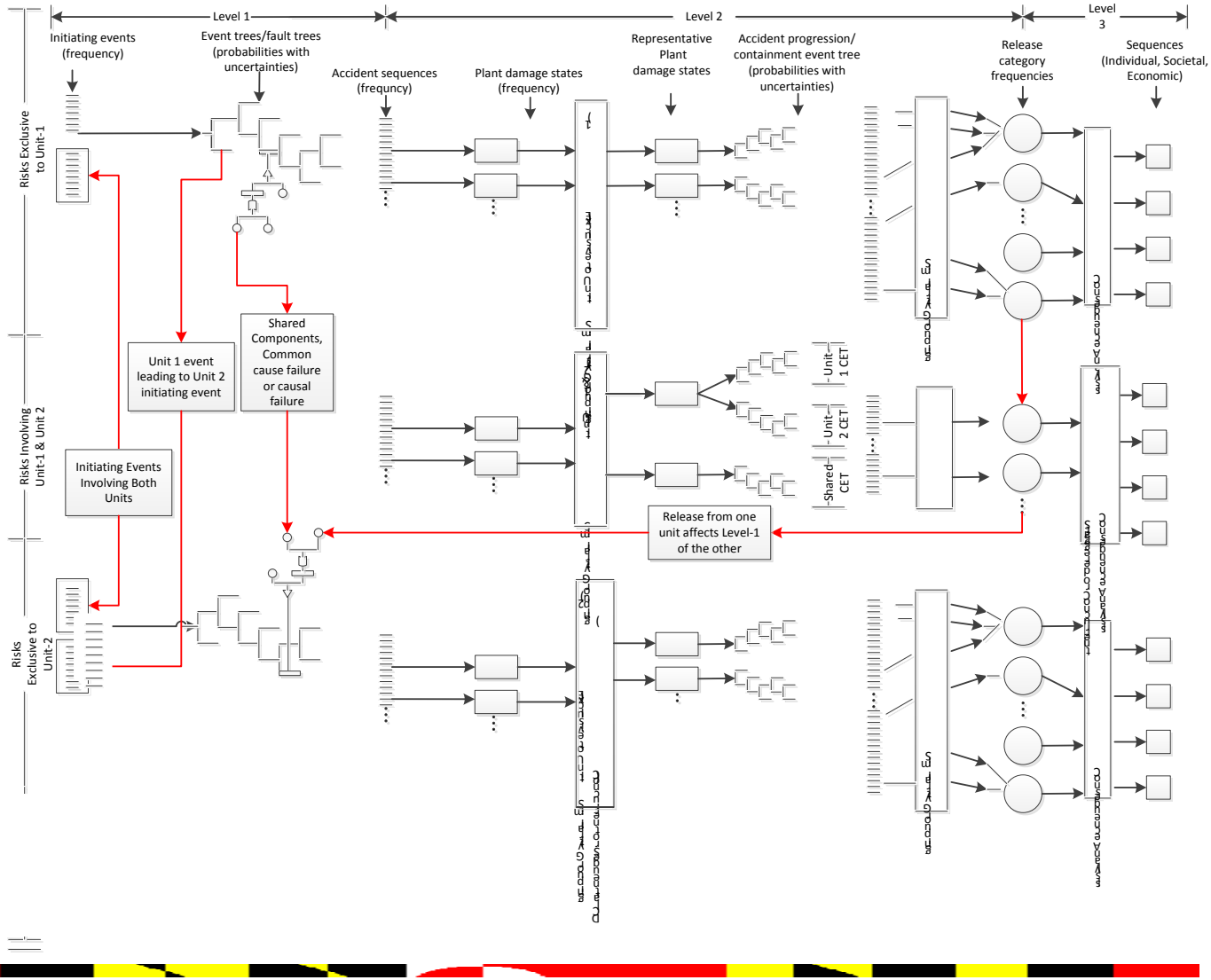

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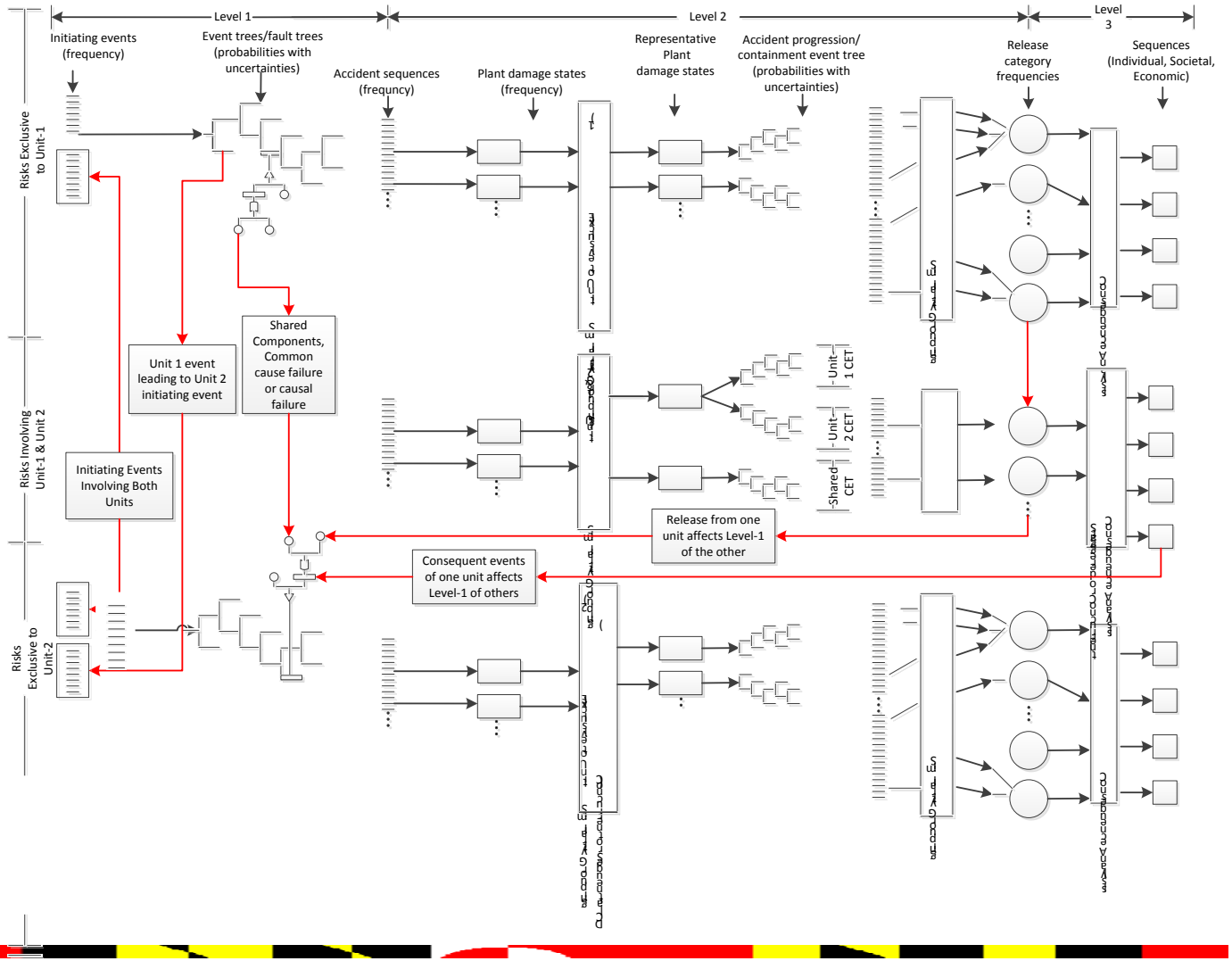

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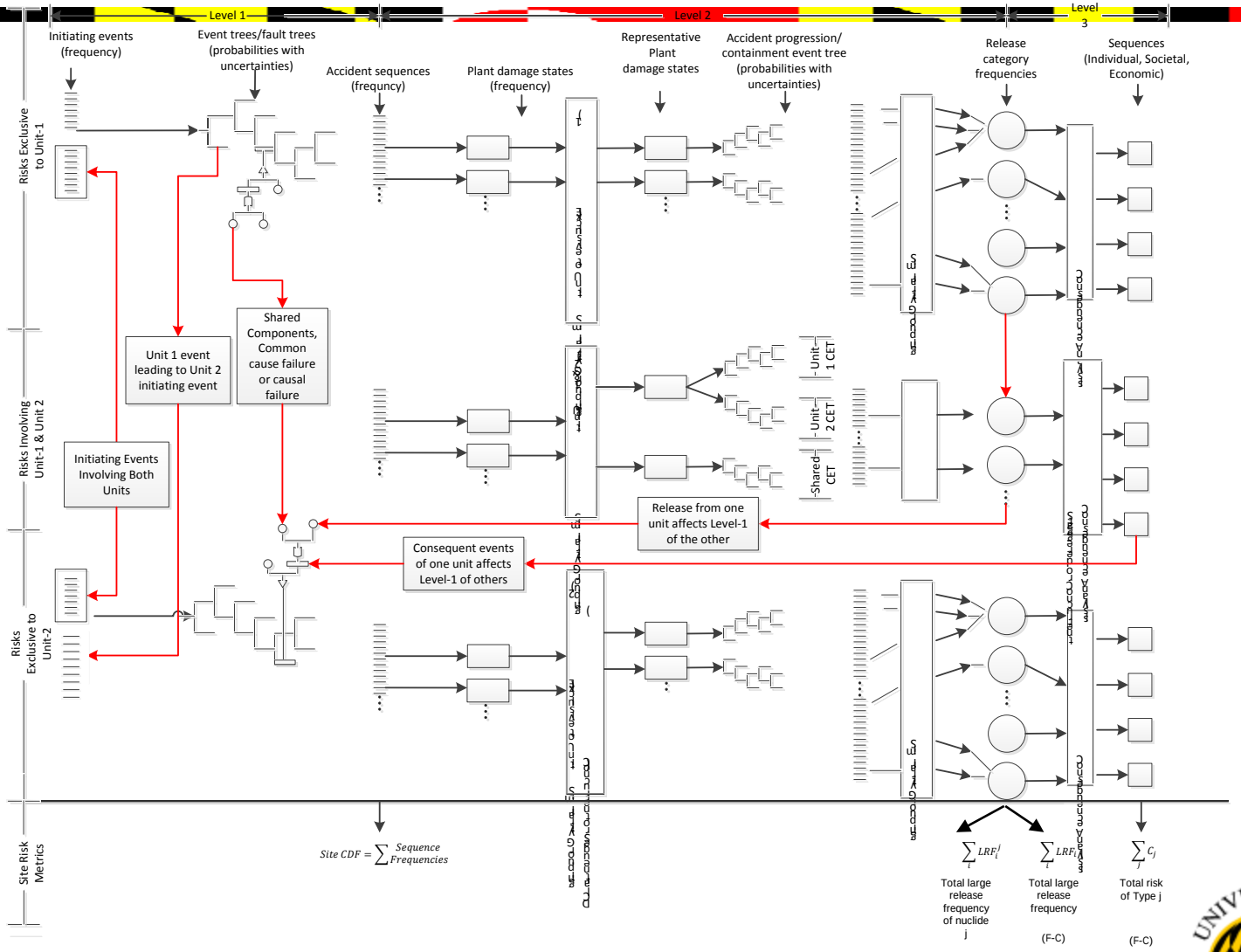

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Site-Level Risk Metrics

Level-1 Multi-Unit Risk Metrics

For site-CDF two most cited risk metrics are:

1) Concurrent CDF:

frequency of nearly simultaneous multiple core damage events per year of all or specific permutations (or combinations) of multiple units

2) Site CDF:

frequency of one or more core (or more broadly fuel) damage events per year in a site

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Site-Level Risk Metrics (Cont.)

Level-2 Multi-Unit Metrics

frequency of a specific large release category (or fuel damages) on a site per year

frequency of large release from all site release categories per year

Level-3 Multi-Unit Metrics

1) Site Frequency-Consequence (Complementary Cumulative) Measure:

exceedance frequency of a specific consequence per year for the total aggregated site risk or for a particular release category

2) Site Mean Expected Consequence

total mean frequency of a specific consequence (Expected Consequence) per year due to the total aggregated site risk from all or specific release categories of multi-unit accidents

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Concern For Level 2 Risk Metric

- What release constitutes as "large"?
- Particular concern: How to count multiple discrete releases or nearly concurrent release from the site. Each release separately, sum of discrete releases, something in between?
- What are the site release categories and their frequency per year in terms of the nature, timing, and magnitude of the release?
- If risk aggregation over all site-level initiating events not intended, risk metrics can be expressed for specific initiating events or hazards, (e.g., seismic alone)

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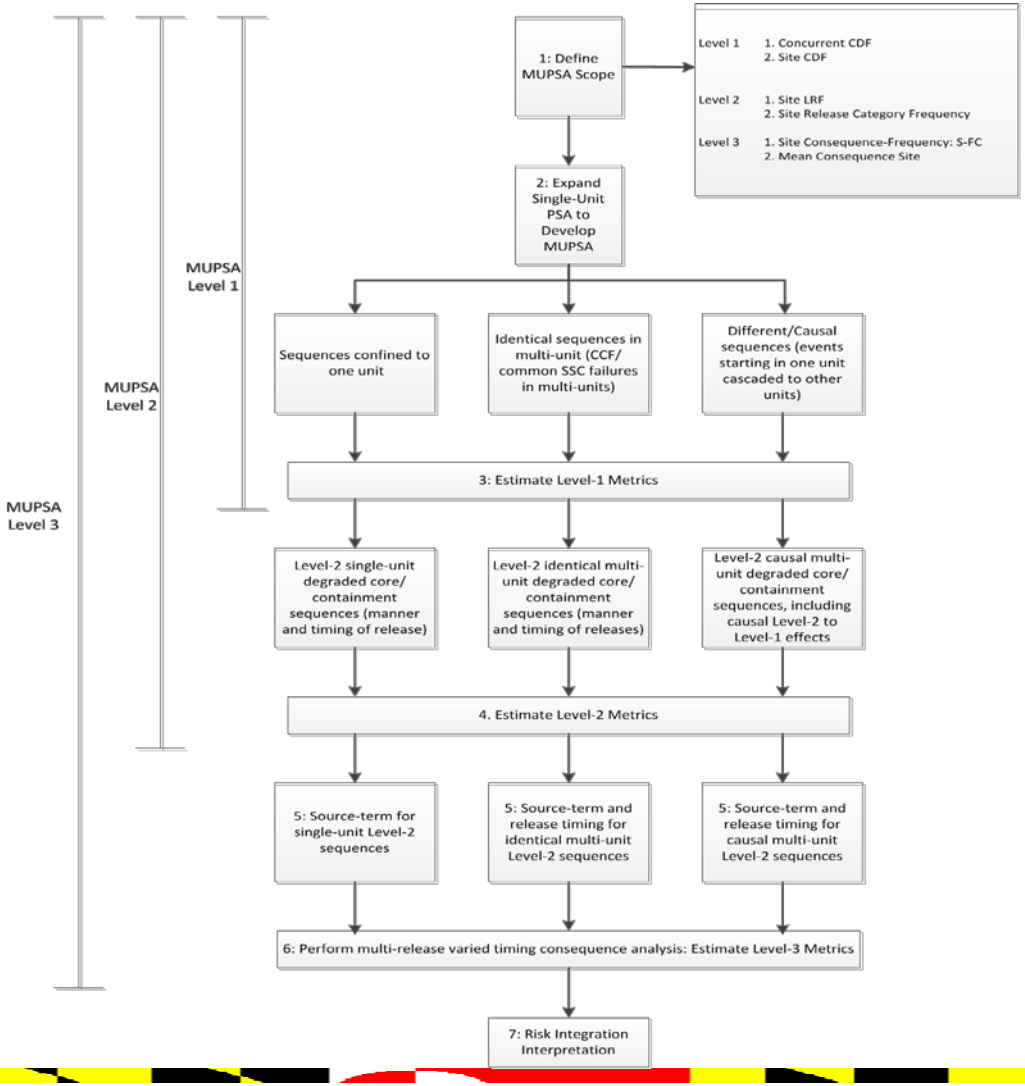
Summary of MUPSA Risk Metrics



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Safety Goals

- Safety goals at the highest-level are qualitative and consistent with legislative and other broad societal needs
- At the lower levels more quantitative objectives, surrogate risk metrics, and sometimes design and operating performance objectives in line with the high-level qualitative safety goals may be defined
- The safety goals could address health and safety objectives
- Less practiced versions of safety goals may be expressed in economic terms, reflecting monetized aversion of any environmental and societal impacts, such as land contamination and population displacement.
- Conformity to safety goals is established through risk acceptance levels (or target levels) in form of quantitative objectives, such as the frequency of prompt fatality or their surrogates such core damage frequency (CDF) or large release frequency (LRF) estimated by performing PSAs

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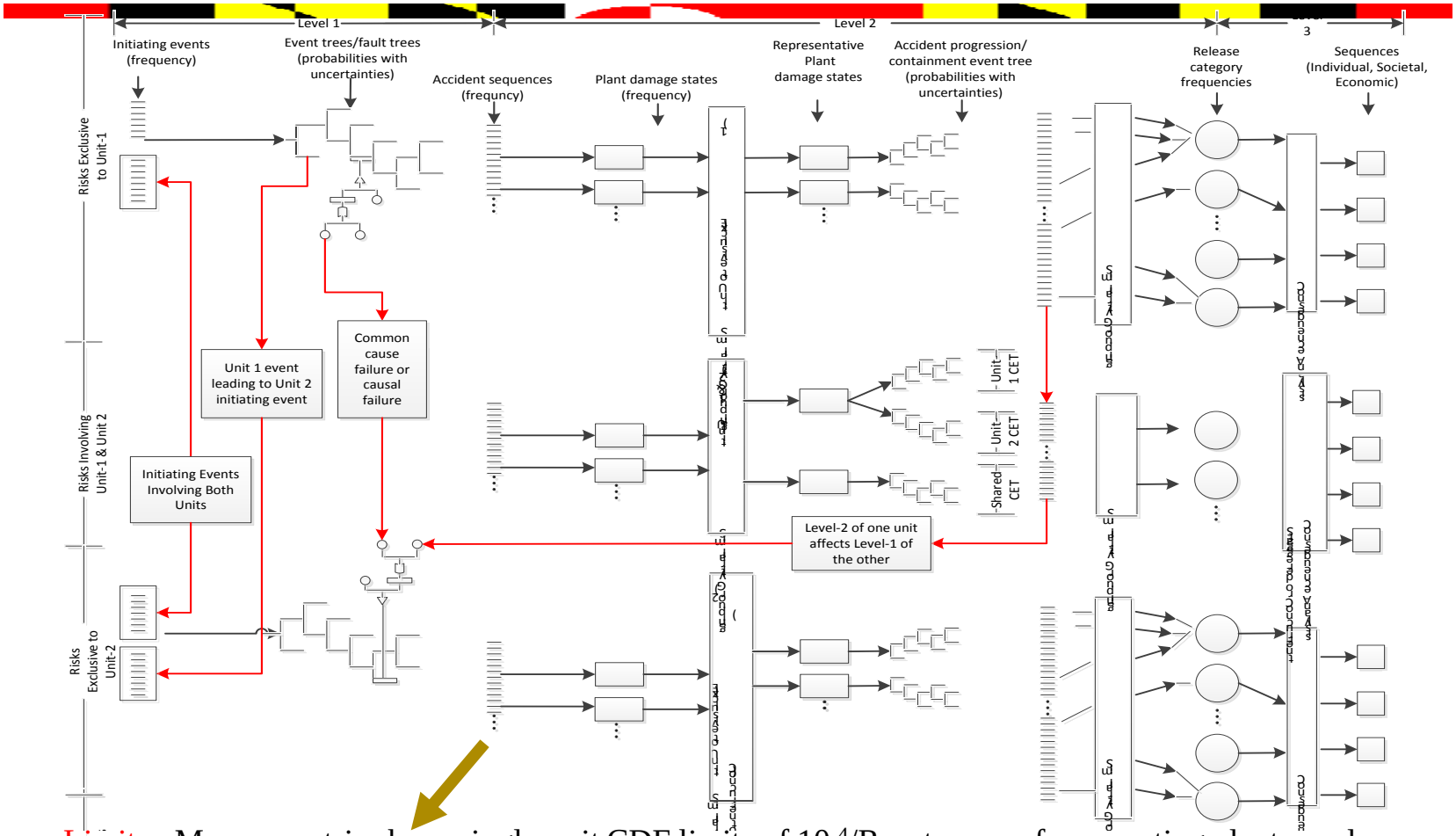
Safety Goals (Cont.)



Frequency Limits: Many countries have single-unit CDF limits of 10^{-4}/Reactor-year for operating plants, and 10^{-5}/Reactor-year for new plants. This includes U.S., Japan, Canada, Czech Republic, Finland, Korea, Russia, and Sweden. New limits for multi-unit sites in terms of site CDF would be needed (e.g., 10^{-5}/Reactor-year for existing sites and 10^{-6}/Reactor-year).

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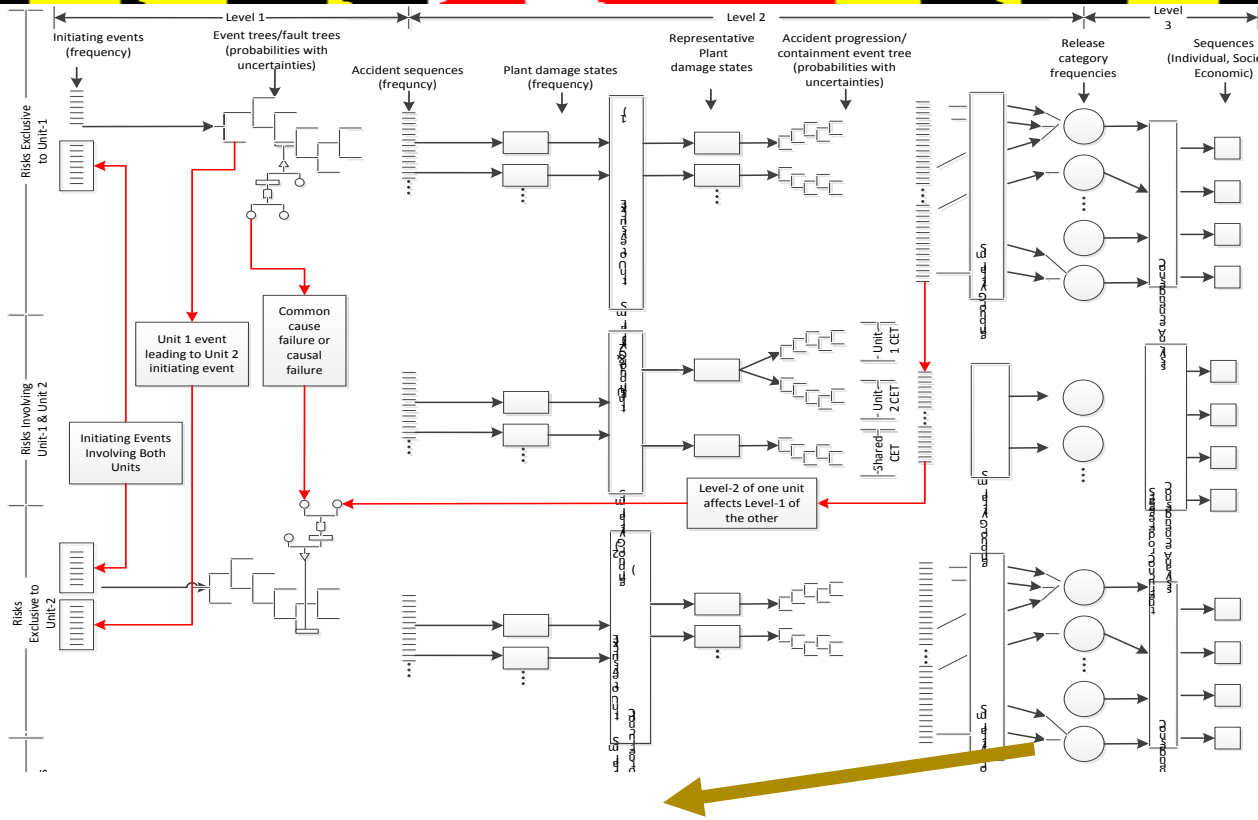
Safety Goals (Cont.)



Frequency Limits: Limit LRF for a whole multi-unit site. For example: range of $1x10^{-6}$ to $5x10^{-7}$ /year limit to multi-unit.

Frequency limits for particular class of releases are also possible. For example, limit the frequency of radiological releases from accidents in one unit that compromise the integrity of a shared containment for other units.

Relative measures such as limiting contribution from a single scenario to a fraction (for example 10%) of total risk.

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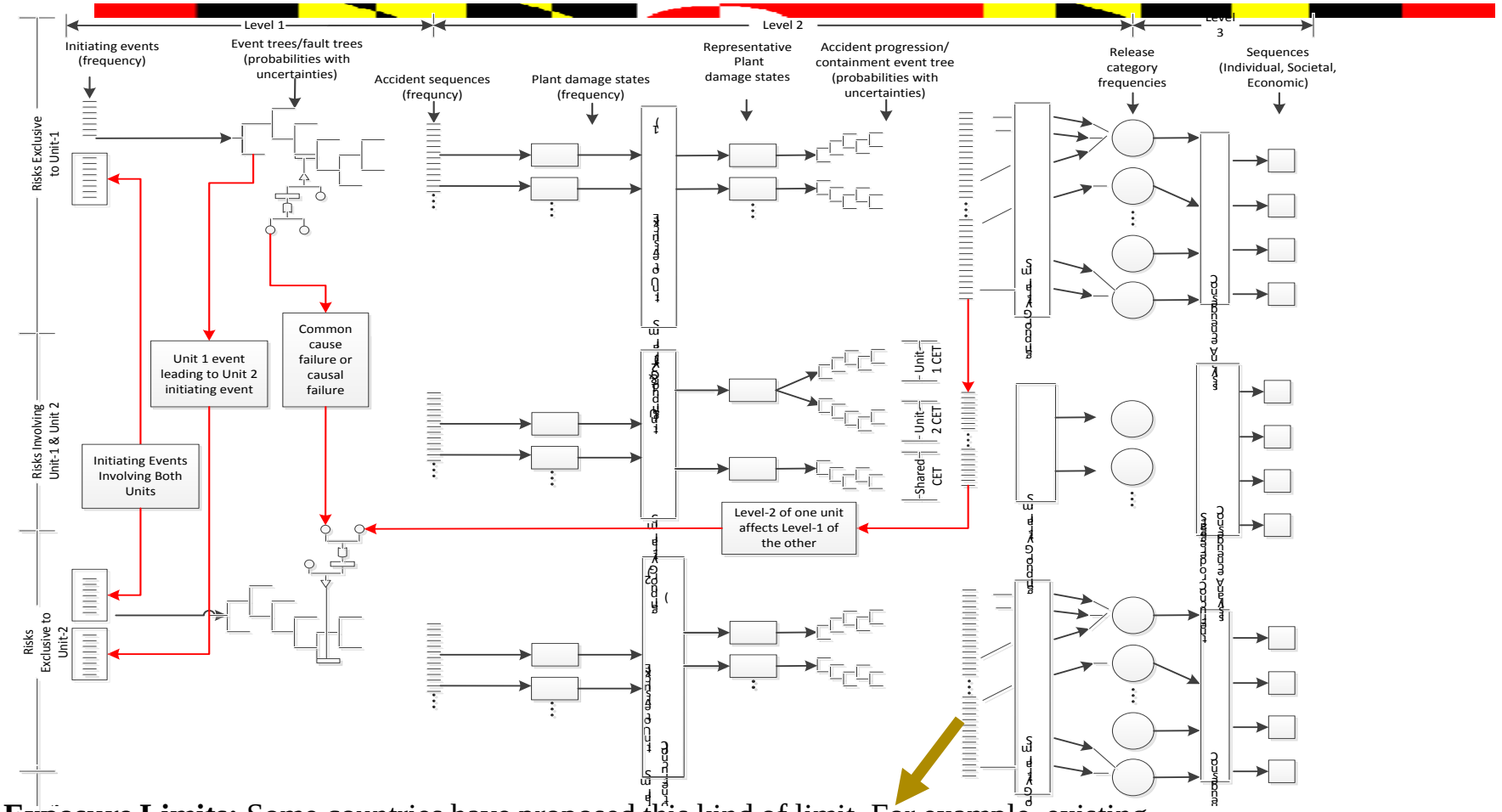
Safety Goals (Cont.)



Exposure Limits: Some countries have proposed this kind of limit. For example, existing Canadian (single-unit basis) limits of Small Release Frequency (SRF) of > 10^{15} Becquerel of ^{131}I < 10^{-4} /Year; and LRF of > 10^{14} Becquerel of ^{137}Cs <10^{-5} /Year. Examples of using relative limits such as 1 % of the core inventory of ^{137}Cs have also been proposed.

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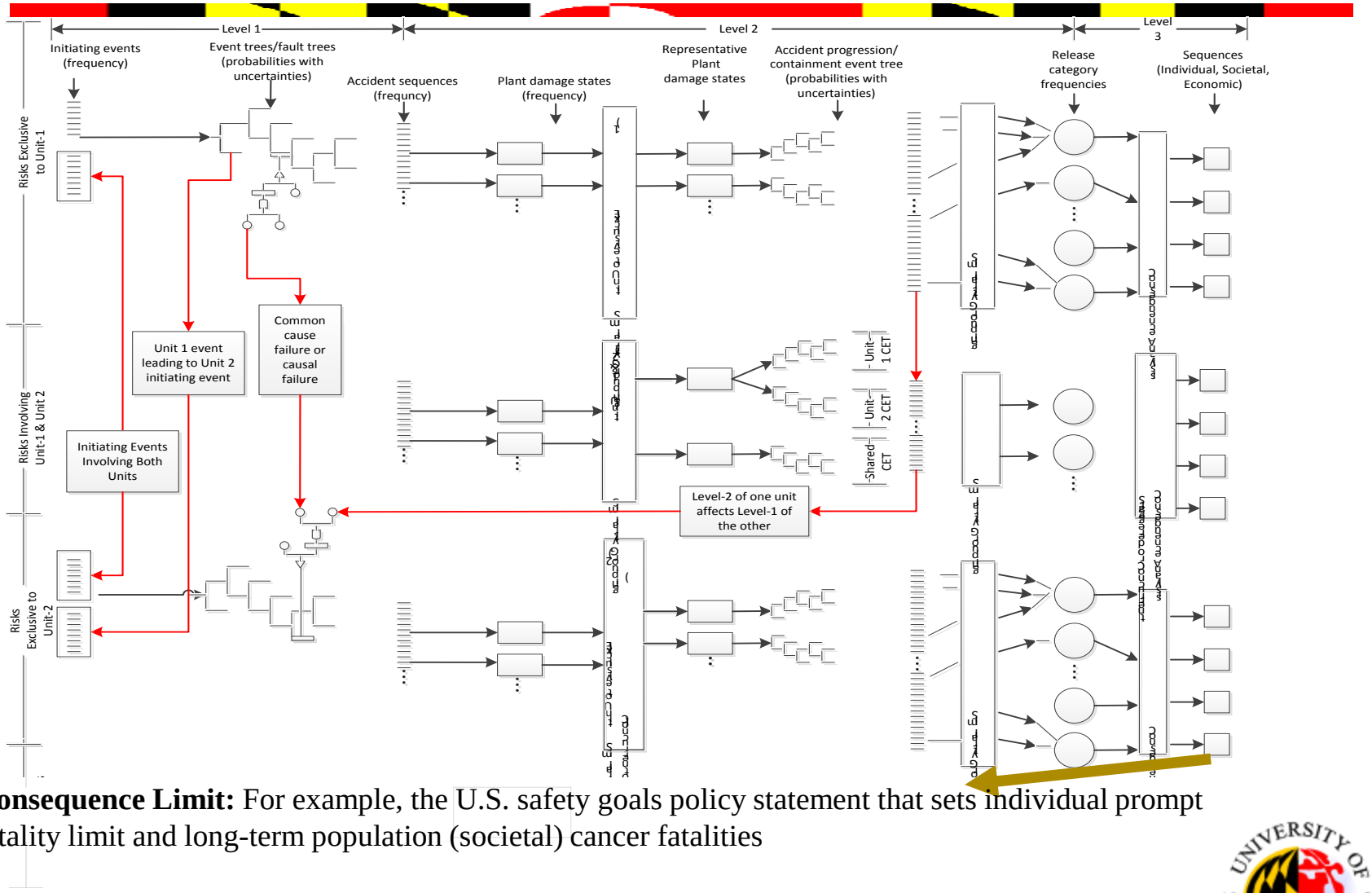
Safety Goals (Cont.)



Consequence Limit: For example, the U.S. safety goals policy statement that sets individual prompt fatality limit and long-term population (societal) cancer fatalities

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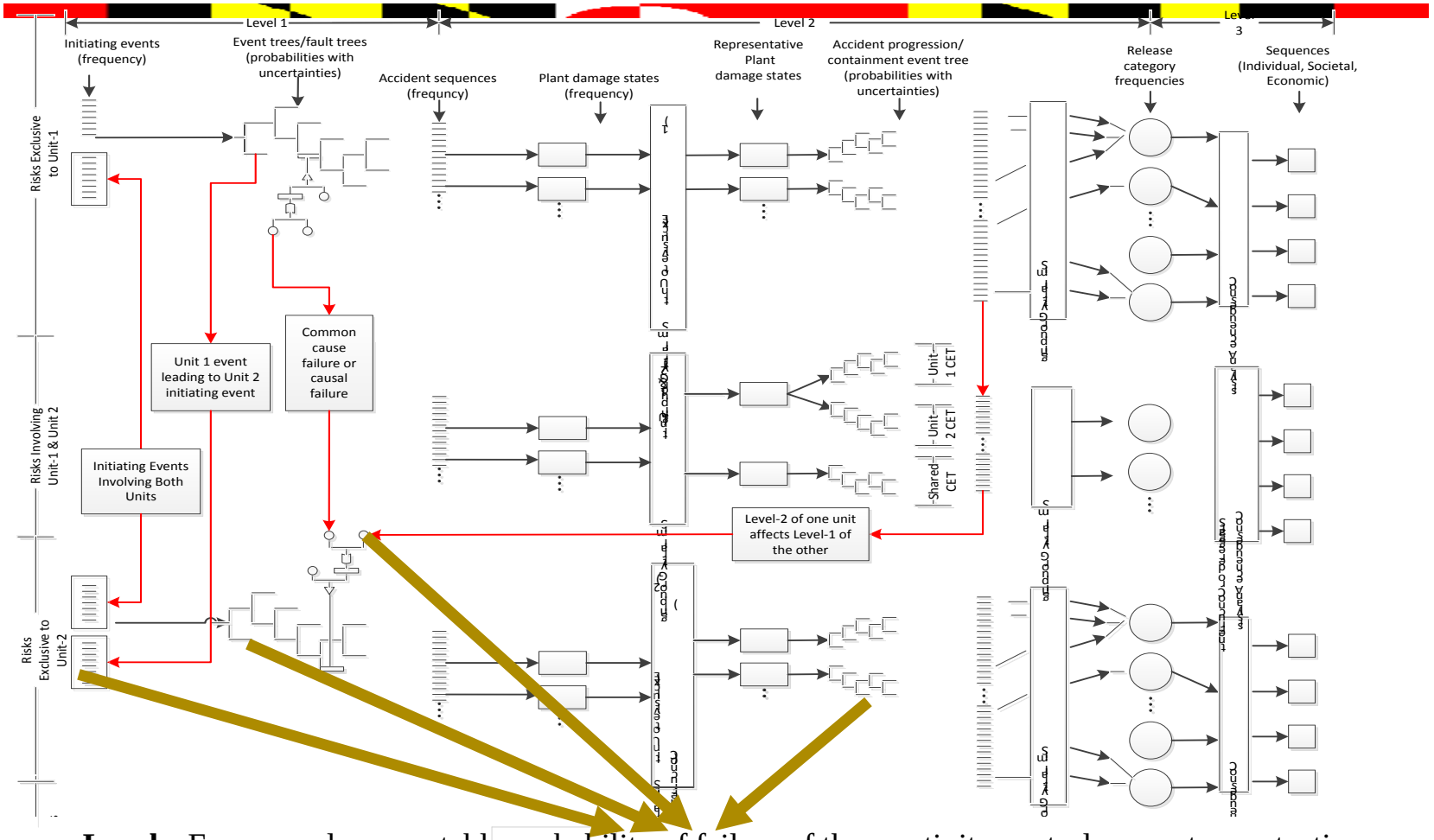
Safety Goals (Cont.)



Performance Levels: For example, acceptable probability of failure of the reactivity control or reactor protection system. Or NRC Severe Accident Policy Statement limits conditional containment failure probability (CCFP) < 0.1. The safety criterion for new or advanced plants by the NRC sets a target for CCFP< 0.1.

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Safety Goals (Cont.)

- France has announced quantitative safety goal for its nuclear power plants that requires the probability of cancer due to all causes for radiological exposure not to exceed 10^{-6} per reactor per year (multiple units?)
- The UK has comparable individual and societal targets that apply to single reactor units as well as the whole site
  - The individual safety goal target limits the frequency of individual early or delayed deaths due to accidental releases from the radioactive sources on a site
  - The societal target limits the frequency of 100 or more immediate or delayed fatalities of people located both on- or off-site
  - The prevailing principle for all the U.K. targets, however, is the concept of as low as reasonably practicable (ALARP)
- Korea is now studying similar goals for application to sites

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Related Observations

- Far more efforts and definitions are needed to implement and use safety goals in the context of multi-unit sites
- Dependency modeling between multi-units: Common cause failures of hardware and human failure events
- Intra- and inter-unit fragility dependencies
- Ground response dependency models
- Role of organizational events
- Better tools to handle very large scale models
- Proper modeling of FLEX equipment
- Models of site accessibility and effects on HRA

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Conclusions

- Diverse and often very different measures and philosophies of risk acceptance are used by various countries
- Site-based risk metrics are getting more mature but are not universally accepted
- In most cases safety goals are not explicit about the scope of their applications
- To develop and demonstrate safety goals, Level 3 MUPSAs should consider all sources, timing and modes of release
- Multi-unit risk should be used for identifying important site risk contributors

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Conclusions, Cont.

- Multi-unit risk insights can be used to enhance the implementation of the Defense-in-Depth principles and to show whether current regulatory requirements are sound enough
- As safety goals are driven by the question of “how safe is safe enough?”, they are understandably expected to differ from one country to another.

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