Liquid Fueled Reactors

The benefits of a RIPB Approach

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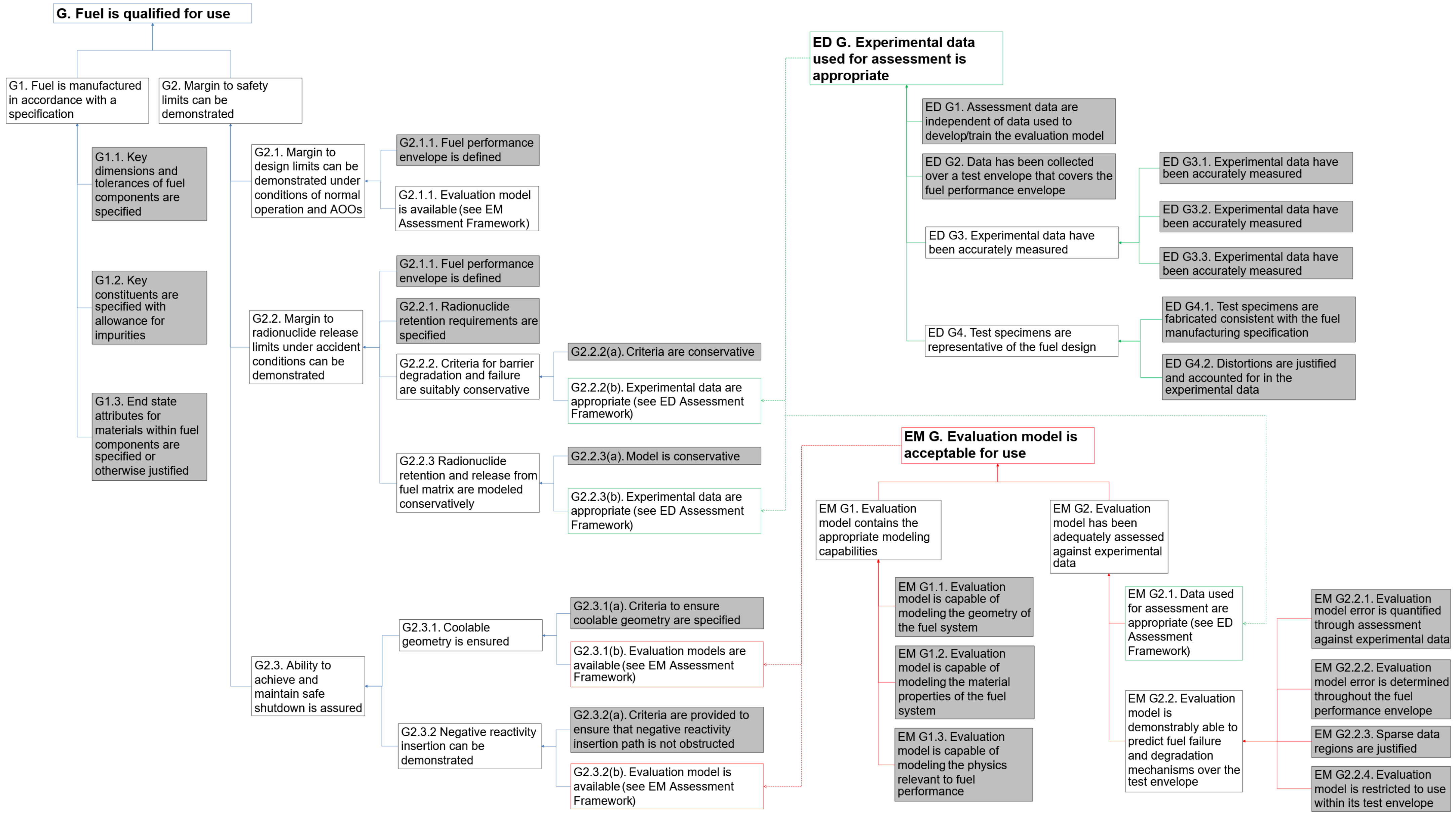
RP3C COP
July 28, 2023

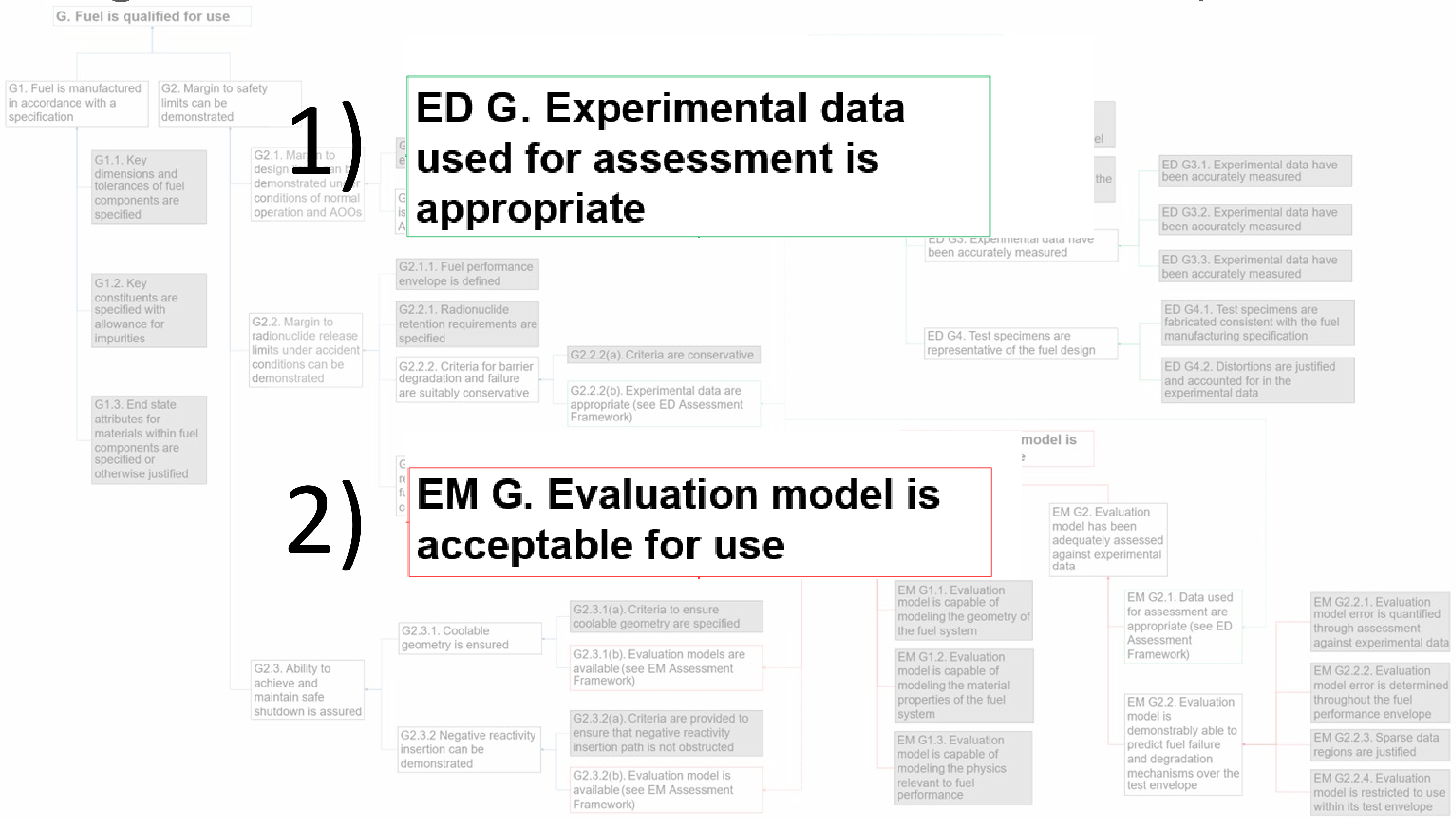
Topics

- Overview of fuel qualification process
  - Assumptions/Inputs
  - Prescriptive vs RIPB
- Fundamental Safety Functions
  - Properties of the system
  - Approach to FSFs

Through the Lens of Fuel Qualification



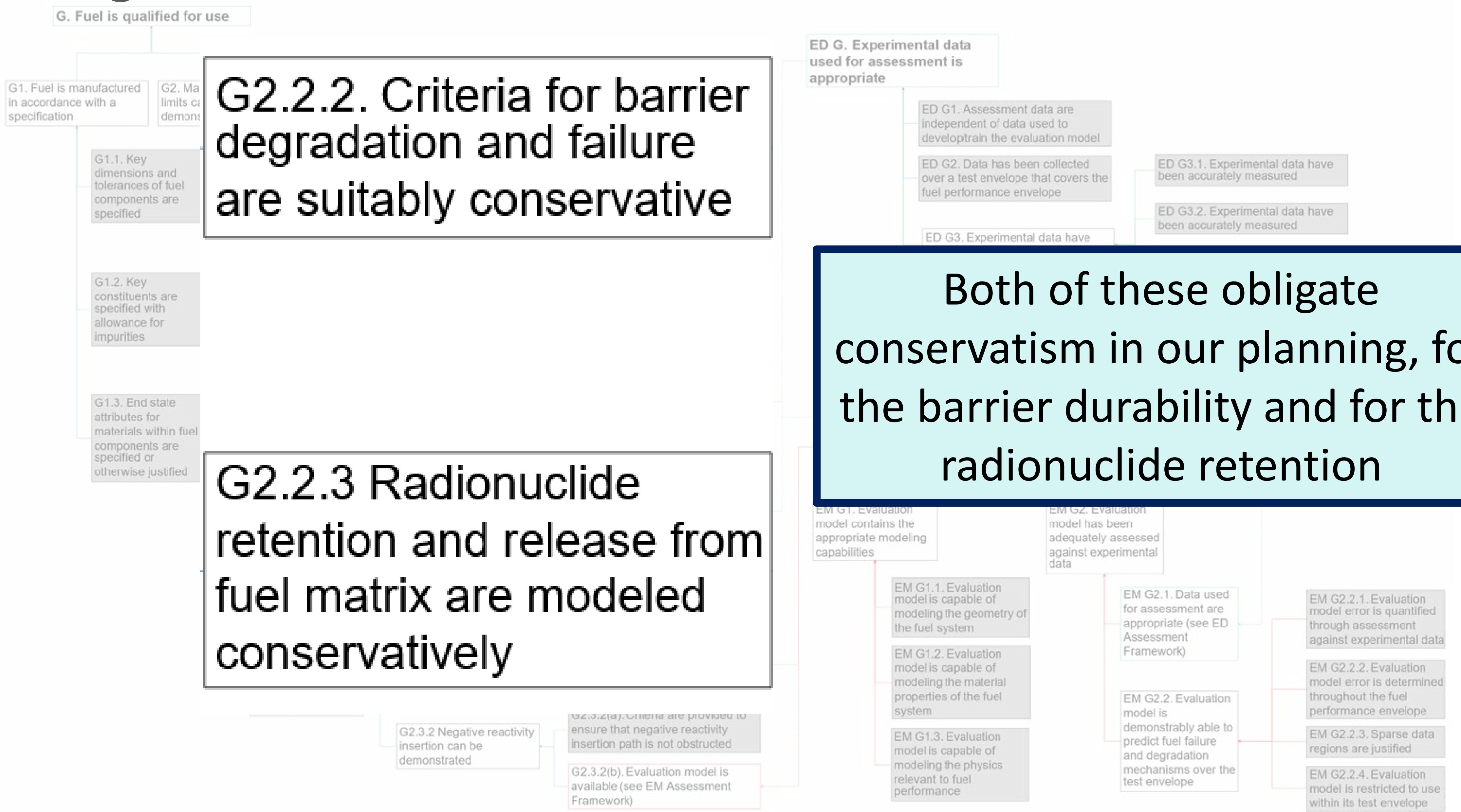
Through the Lens of Fuel Qualification – assumptions



1) **ED G. Experimental data used for assessment is appropriate**

2) **EM G. Evaluation model is acceptable for use**

Through the Lens of Fuel Qualification – use of data

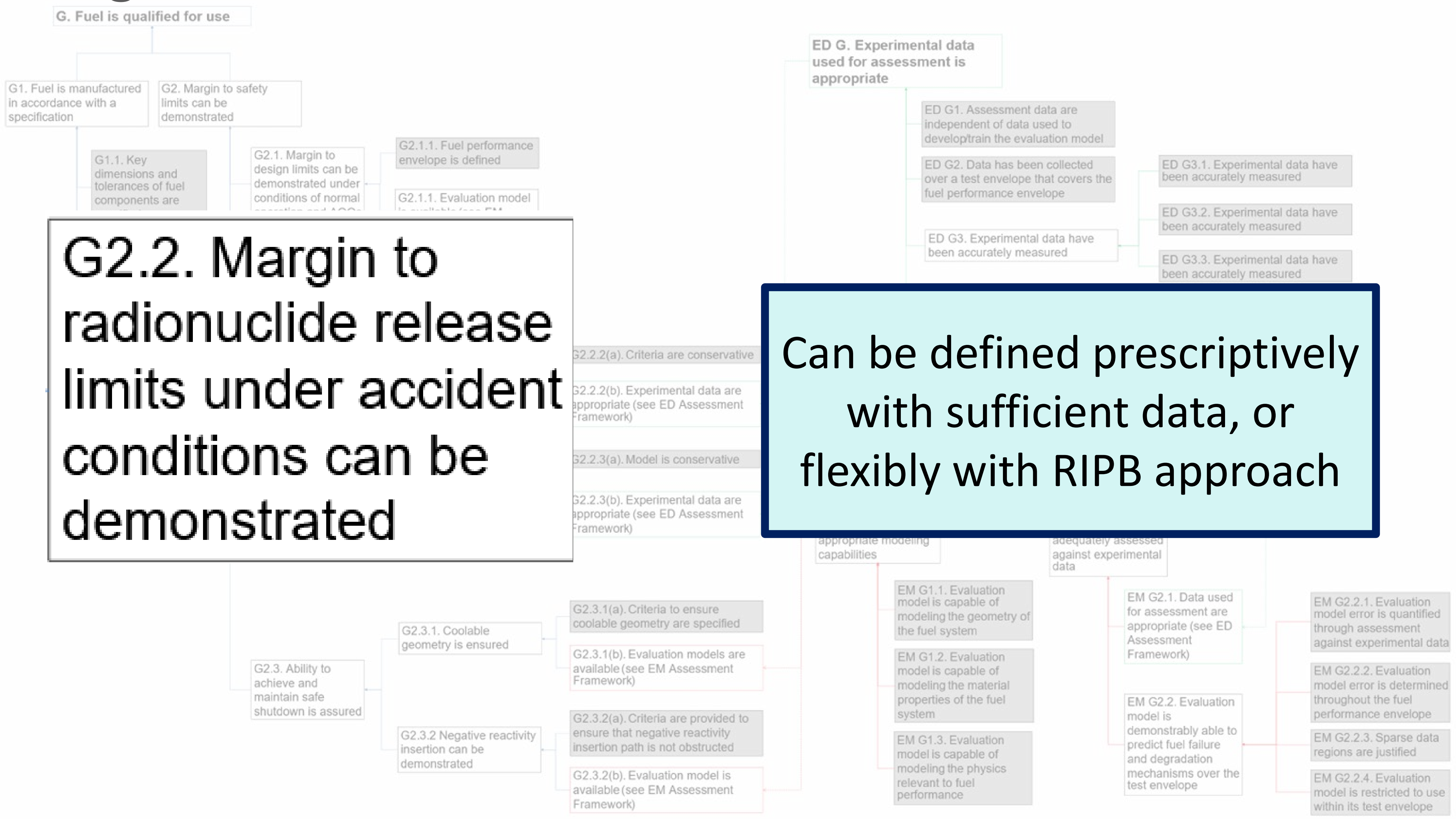


G2.2.2. Criteria for barrier degradation and failure are suitably conservative

G2.2.3 Radionuclide retention and release from fuel matrix are modeled conservatively

Both of these obligate conservatism in our planning, for the barrier durability and for the radionuclide retention

Through the Lens of Fuel Qualification – release limits

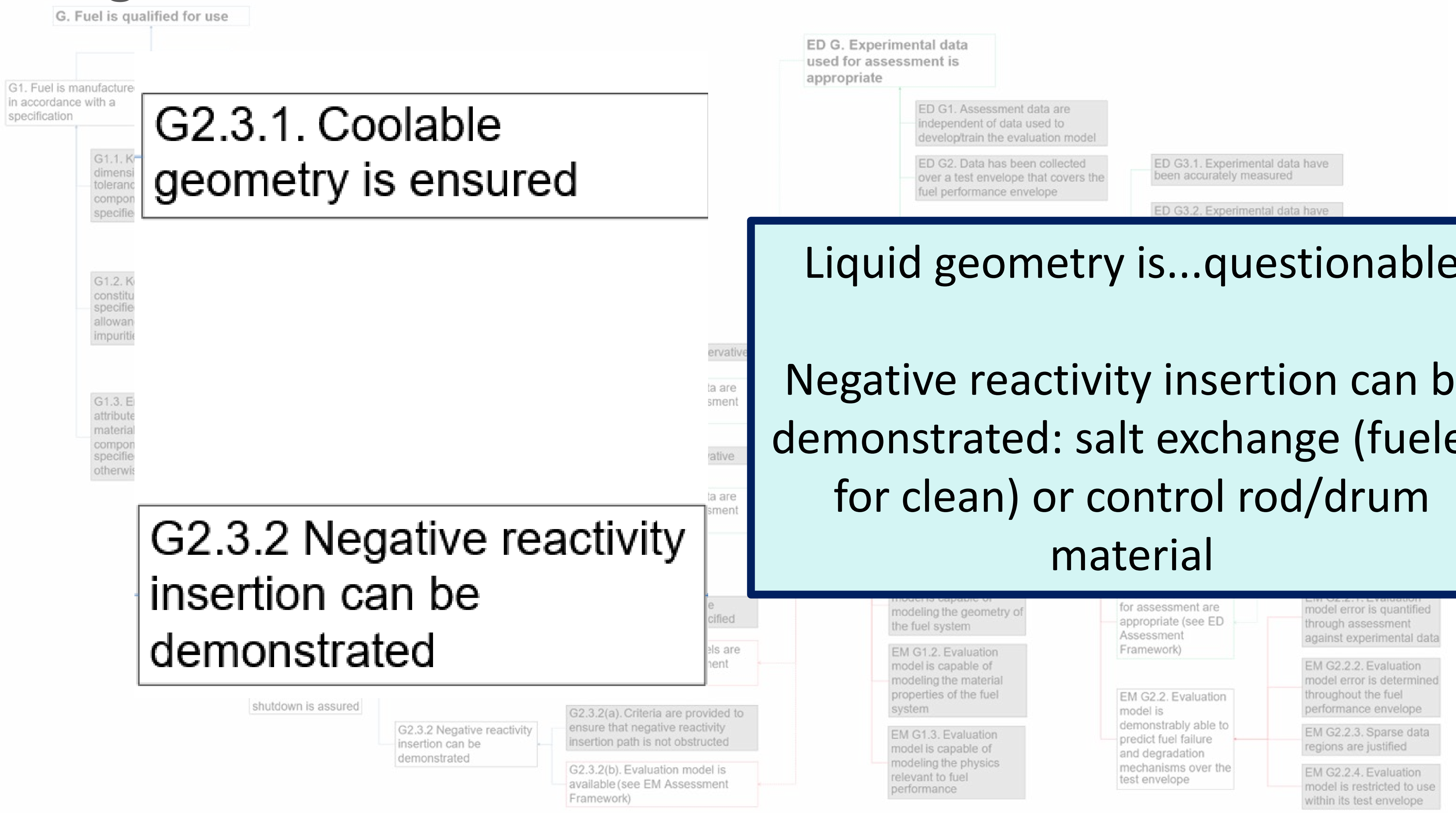


G2.2. Margin to radionuclide release limits under accident conditions can be demonstrated

Can be defined prescriptively with sufficient data, or flexibly with RIPB approach

EPRI

Through the Lens of Fuel Qualification – use of model

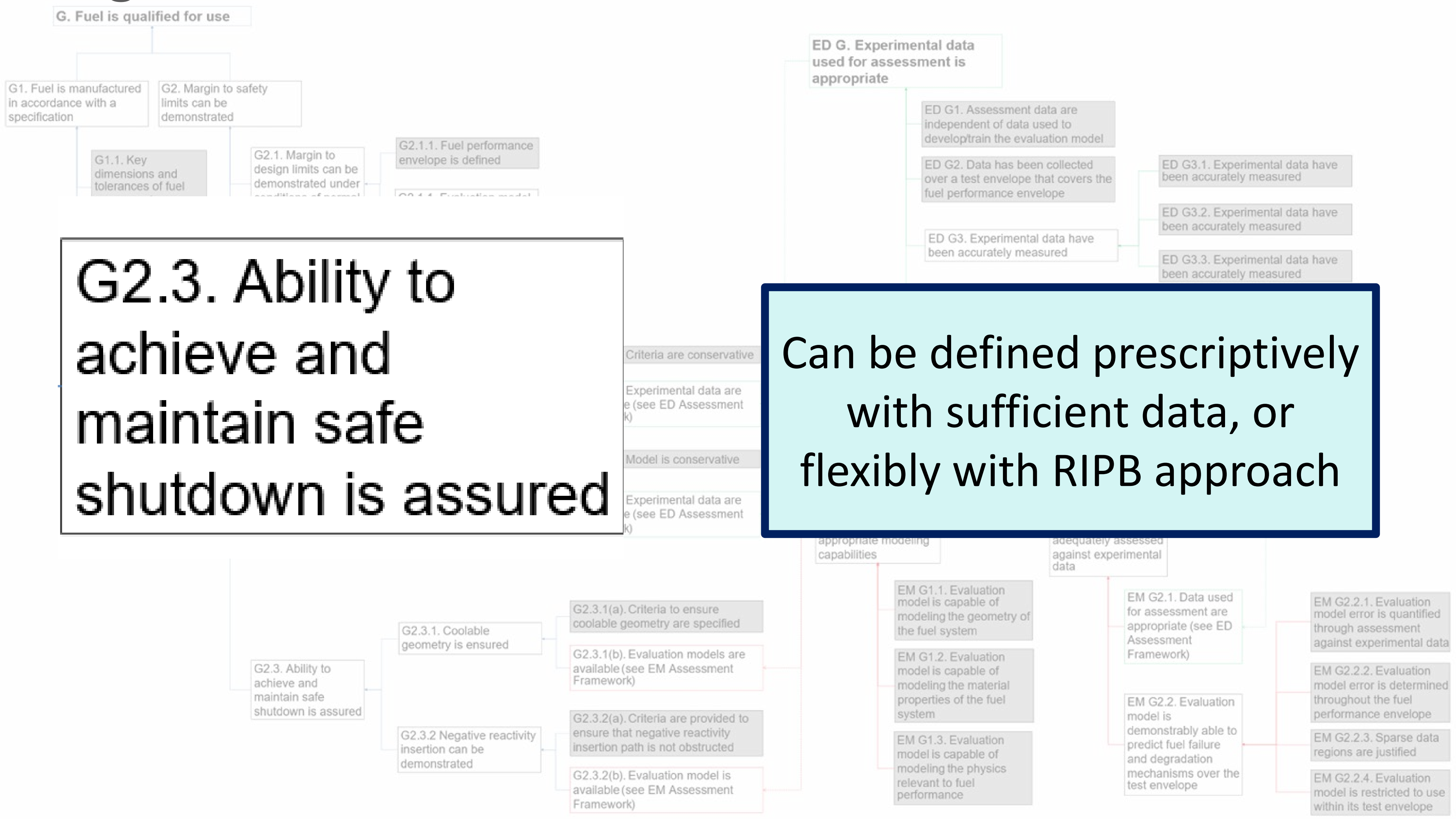


Liquid geometry is...questionable

Negative reactivity insertion can be demonstrated: salt exchange (fueled for clean) or control rod/drum material

EPRI

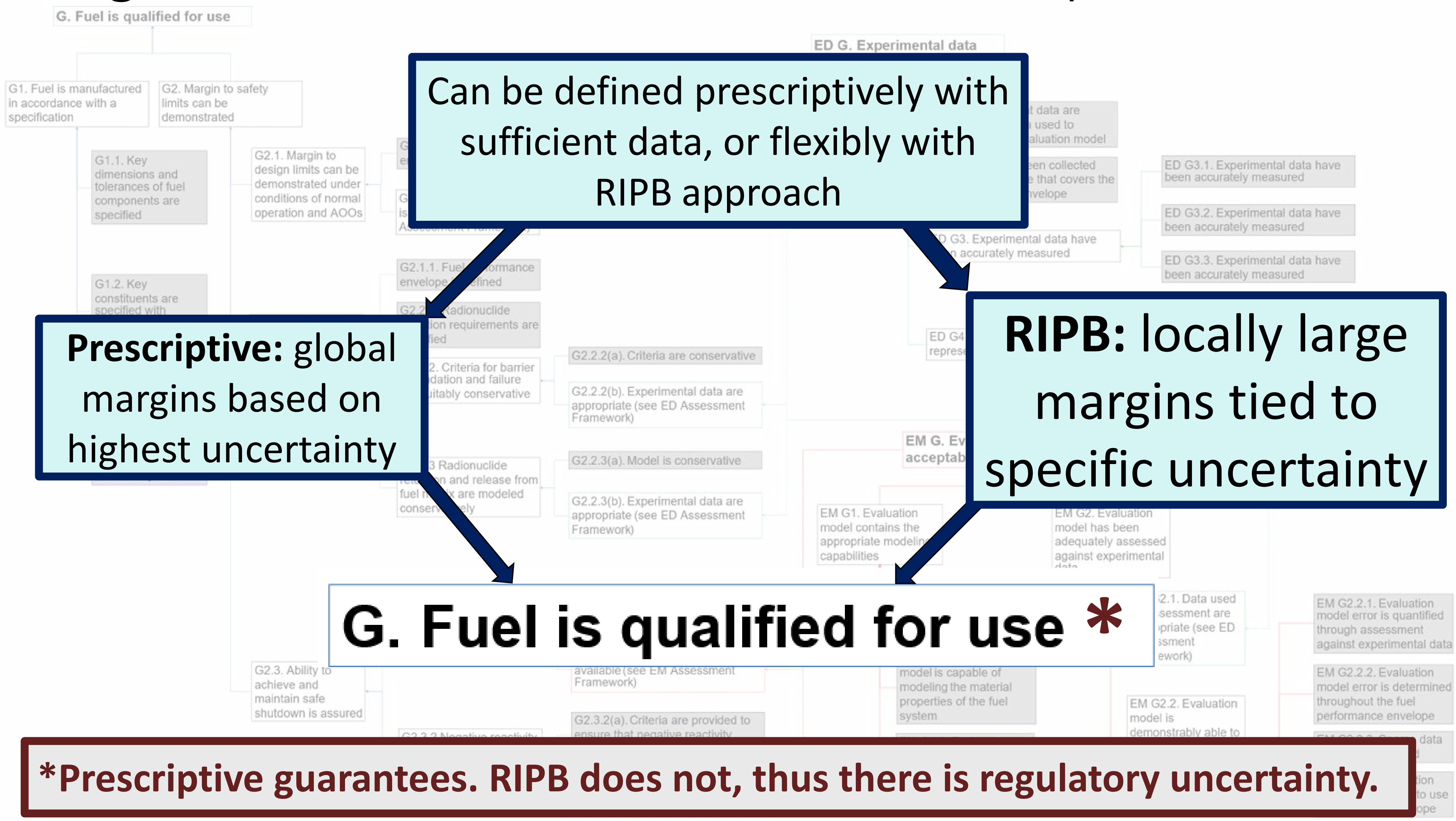
Through the Lens of Fuel Qualification – safe shutdown



G2.3. Ability to achieve and maintain safe shutdown is assured

Can be defined prescriptively with sufficient data, or flexibly with RIPB approach

Through the Lens of Fuel Qualification – options



Can be defined prescriptively with sufficient data, or flexibly with RIPB approach

Prescriptive: global margins based on highest uncertainty

RIPB: locally large margins tied to specific uncertainty

G. Fuel is qualified for use *

***Prescriptive guarantees. RIPB does not, thus there is regulatory uncertainty.**

What is Needed for an RIPB Approach?

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

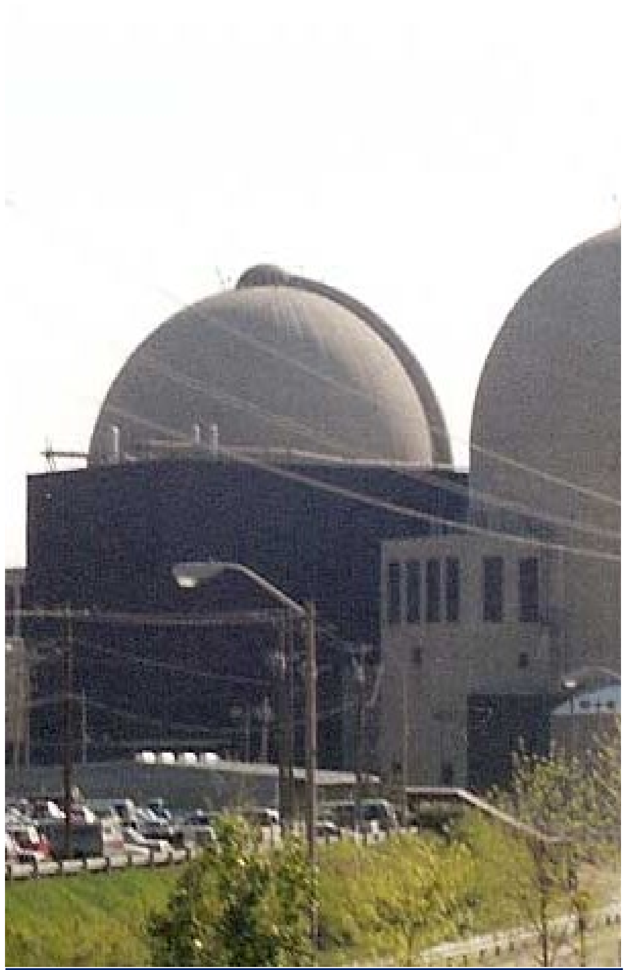
NUREG/CR-7299
ORNL/TM-2022/2754

Fuel Qualification for Molten Salt Reactors

Related Work
ORNL/LTR-2018/1045
ORNL/TM-2020/1576

Primary Source by Holcomb, Poore, and Flanagan

Fundamental Safety Functions

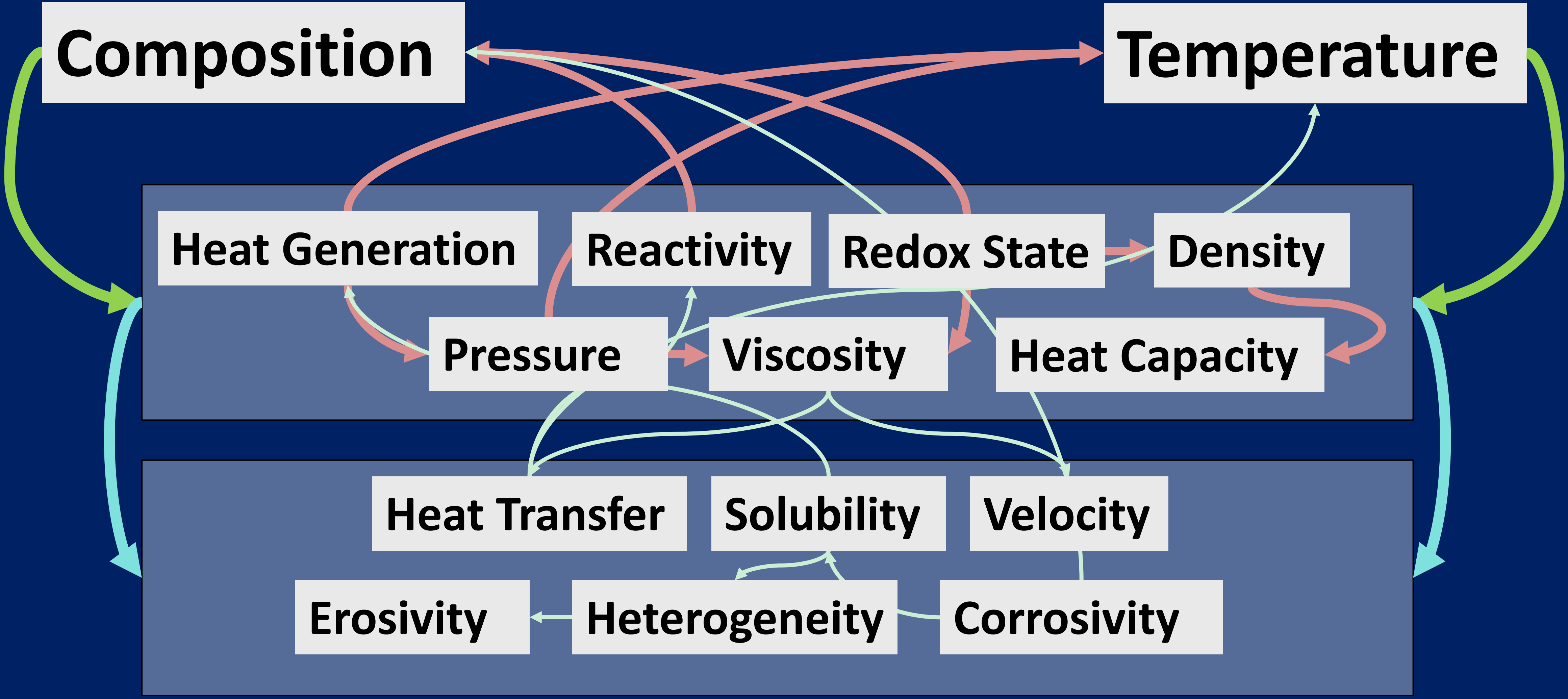


Limit release of radiologic material

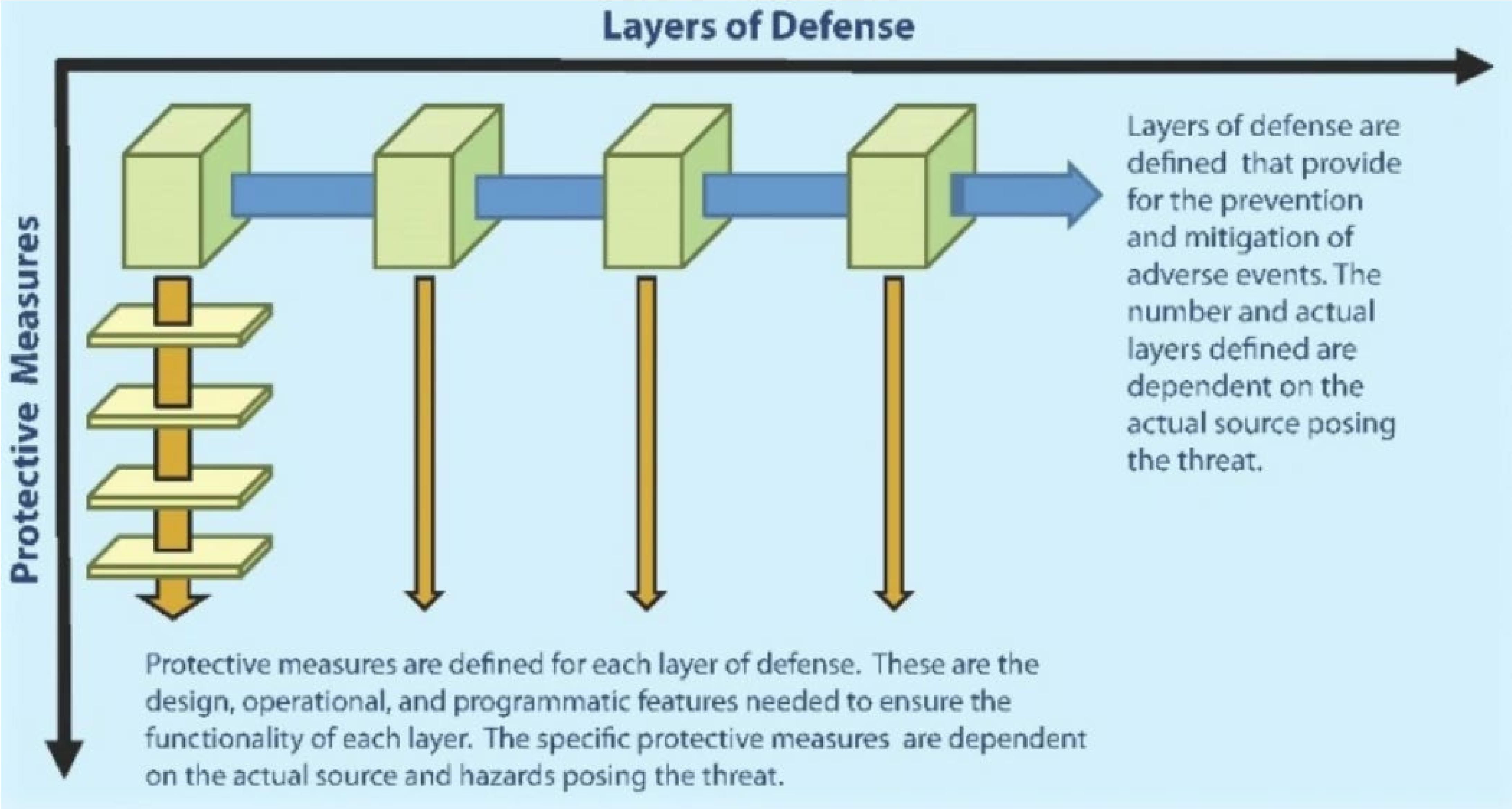
Remove heat from reactor and wastes

Control reactivity

Measurable and Derived Properties



Limit Release of Radiologic Material



Limit Release of Radiologic Material

Element	Core circuit		Fuel salt inlet circuit	
	Equilibrium, kg	Disposal rate, g/day	Equilibrium, kg	Disposal rate, g/day
Se	1.5	4.1	0.07	0.2
Br	0.5	1.4	0.03	0.1
Rb	0.2	0.7	0.005	0.013
Sr	9.1	24.8	0.35	0.9
Y	5.7	15.7	0.19	0.5
Zr	79.6	217.8	2.79	7.7
Nb	1.8	4.9	0.06	0.2
Mo	86.7	237.3	1.86	5.1
Tc	24.8	68.0	0.42	1.2
Ru	102.2	279.7	0.95	2.6
Rh	24.3	66.7	0.13	0.4
Pd	70.8	193.9	0.23	0.6
Ag	8.7	23.9	0.01	0.0
Cd	8.8	24.2	0.04	0.1
In	0.6	1.6	0.003	0.008
Sn	3.9	10.6	0.08	0.2
Sb	1.4	3.9	0.03	0.1

Radiologic Materials

- Fissile elements
  - U, Pu
- Fissionable elements
  - Am, Np, Cm
- Fission product solids
  - Table on left
- Fission product gasses
  - Xe, Kr, I

Table from: Fast Molten Salt Reactor–Transmuter for Closing Nuclear Fuel Cycle on Minor Actinides, 2008

Removing Heat from Reactor and Wastes

Heat Sources

- Primary
  - Fission of U and Pu
  - Fission of Am, Np, Cm
- Secondary
  - Gaseous FPs
  - Plated out FPs

Heat Removal

- Primary coolant heat transfer to heat exchanger
  - Pumped and natural circulation
- Radiative heat transfer to structural material
- Cover gas decay heat rejection

Varies with viscosity, density, thermal conductivity, heat capacity

Control Reactivity

Controlling Neutrons

- Fission
  - Fuel in the liquid
- Moderation
  - Graphite or liquid itself
- Absorption
  - Elements in the liquid
  - Added poisons

Reactivity Mechanisms

- Adjust fuel liquid volume
- Adjust heat input or removal
- Control rods or drums

Liquid fuel is one of several reactivity control mechanism

Takeaways

Risk-informed performance-based approaches may provide a near-term pathway to fuel qualification for dissolved fuel reactors

1

Further data is needed to develop right-sized margins for an RIPB approach, or to develop requirements for a prescriptive approach

2

Improvements to modeling to reflect the tight coupling of liquid fuel, and especially molten salt, properties is desired.

3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