We've looked a little bit at the transport equation. To venture much farther in thinking about solving the transport equation, it helps to remember what we're applying it to and some other bits of information that we use.

As mentioned, we'll mostly focus on defense applications in this class - shielding, detectors, criticality, etc. However, we will sprinkle in a bit about nuclear reactors because they make great examples and you should know a little bit about them as a nuclear engineer. This also allows us to leverage what you are learning now in NENG681 as opposed to material you will learn next quarter in NENG605 and NENG650.

A nuclear reactor is a three-dimensional structure consisting of complicated geometrical shapes made of variety of materials.

(switch to ppt for image examples)

- A unit cell usually consists of a fuel rod, gap, cladding and corresponding moderator. It is usually surrounded by similar cells. A fuel rod consists of fuel pellets.
- A fuel assembly usually consists of several hundred fuel rods (fuel cells).
- A reactor core consists of several hundred fuel assemblies.
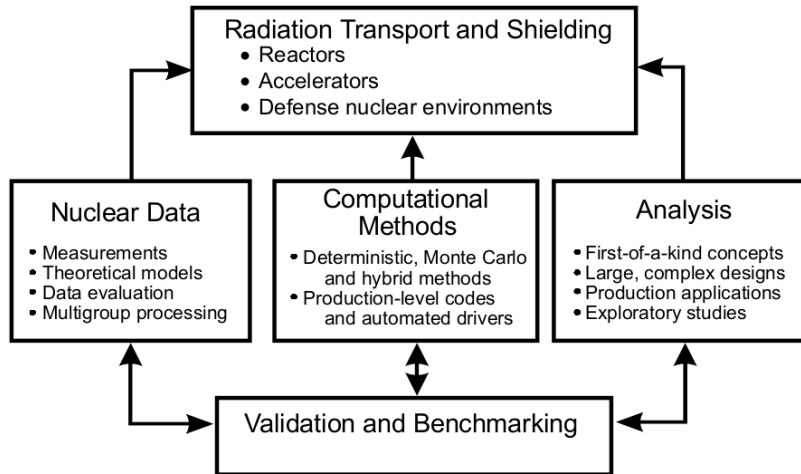- Fuel assemblies and fuel rods are usually arranged in square or hexagonal lattice.

(switch to ppt for image examples)

Solution Context and Data

We have many different types of geometries and physics going on with the systems we're interested in. However, we take the same fundamental approach no matter what. Each component is incredibly important, but let's take a moment to talk about **Nuclear Data**.

We need a description of all of the physical interactions happening inside a nuclear reactor that we can use in our equation. An *evaluated nuclear data file* is a collection of various data enabling to reconstruct, for each isotope, its cross-section's

- general information
- resonance parameters

Radiation Transport and Shielding
- Reactors
- Accelerators
- Defense nuclear environments

Nuclear Data
- Measurements
- Theoretical models
- Data evaluation
- Multigroup processing

Computational Methods
- Deterministic, Monte Carlo and hybrid methods
- Production-level codes and automated drivers

Analysis
- First-of-a-kind concepts
- Large, complex designs
- Production applications
- Exploratory studies

Validation and Benchmarking

- angular distribution for emitted particles
- energy distribution for emitted particles
- energy-angle distribution for emitted particles
- thermal neutron scattering law data
- radioactivity and fission-product yield data
- multiplicities for radioactive nuclide production
- cross-sections for radioactive nuclide production

There are many evaluations coming from various countries such as: USA, Europe, Japan, Russia, China, ... Getting from experimental data (what we have of it) + theory (however accurate that is) to data that can actually be used in a code is no small feat. And, that process is sort of a mess...

We won't go through all of this, but I think it's important to have context about what this is and how confusing it can be. There is a lot of data and many formats, it is quite complicated, and can be quite different depending on the application we're interested in. This will be covered in detail in NENG651 (if not - let me know!). We will also explore aspects of it along the way towards the end of the course.

Physics Impacts

We are often able to use knowledge about the physics to inform method development or, at the very least, choose which methods are more appropriate given our physics.

For example, Fast and Thermal reactor physics differ. We often need different codes to deal with
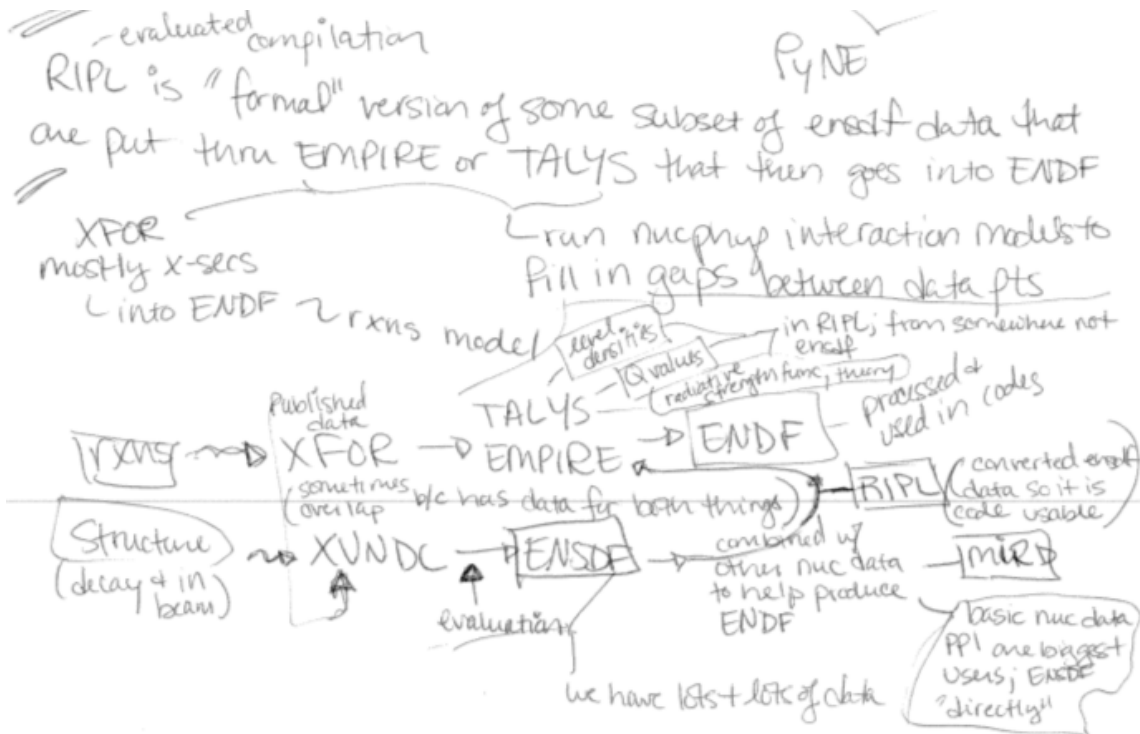
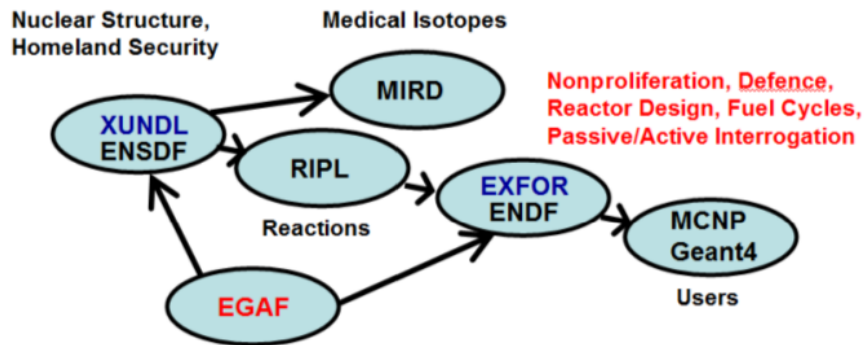Figure 1: Notes from a meeting where someone tried to explain this to me

Figure 2: A more coherent (but less comprehensive) set

LWRs and FRs (note: you can think of nuclear weapons, at a very basic level, as a fast reactor that delivers a lifetime of energy at once...). Many of the assumptions employed in traditional LWR methods do not apply to nuclear weapons (or fast reactors):

- Lack of a 1/E energy spectrum as a basis for the calculation of resonance absorption.
- Upscattering resulting from the thermal motion of the scattering nuclei may be neglected.
- Inelastic, (n, 2n), and anisotropic scattering are quite important.
- Long mean free paths imply global coupling. That is, local reactivity effects impact the entire core.

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- The energy range where neutrons induce fission and the energy range where the fission neutrons appear strongly overlap.

Other physics considerations have high priority in FR methods

- Detailed energy modeling for resonance structure (core/reflector).
- Transport and anisotropy effects are more important at high energy.

In general, a distinct set of physics analysis and core design tools with tailored assumptions are needed for nuclear weapons analysis (or fast reactors).