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Comments on research for sustaining the nuclear renaissance – and the role of National Labs

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What I will briefly discuss … a personal view of our challenges

- We were here – at the first Summit – to discuss some of the very same questions … and the promised Renaissance within the US has yet to come about …

- But some things have changed, and some things have gotten accomplished since then …
  - The DOE GNEP team – combining both DOE and Lab folks – have largely completed a first-take R&D roadmap for the US nuclear future
    - *NEAMS: Nuclear Energy Advanced Modeling and Simulations program*
    - *New modern codes are under development, with some early results …*
  - Clearer vision of where we want to go …
    - *The importance of staging*
      - Distinguishing what we want to do in the short/intermediate/long term
      - Aiming for transformational technologies as the lofty goal …
    - *The role of national laboratories - and academia*
    - *The importance of integrated assessments and a ‘systems’ approach*
  - Some examples of what we are doing now …

All this has occurred in a context in which much has been promised on the frontiers of other CO2-neutral energy sources, but little has been delivered …

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Where are we today?

- The nuclear proponents have ‘gotten it’ …
  - The nuclear power operators
    - *Operating safety records have become outstanding*
    - *Power plant operations have become highly efficient (>90%)*
      - And some parts of the US are enjoying the fruits of nuclear energy, with no evident regrets among the local population … in IL, we are at ~ 48% nuclear
      - www. eia.doe.gov/cneaf/nuclear/page/at_a_glance/states/statesil.html
  - The DOE, manufacturing industry, academic community and the national labs
    - *Engaged, and raring to go … and betting their own funds in part on a nuclear future!*
    - *Enormous intellectual ferment: The search is on for transformational approaches …*
- But there are obstacles …
  - Antiquated ‘tools’
  - Workforce inadequacies
    - *Training of a new generation of nuclear design engineers, …*
    - *Inexperienced construction workforce: No new plants have been built in decades*
  - Lack of funding
    - *Congressional appropriations have been far off from DOE/NE requests*
  - Remaining concerted opposition among old-time nuclear foes
    - *Insufficient engagement by pro-nuclear folks in ‘neutral’ venues*

What do we need to do? We need to be clear about our goals!!!

- In the **short term** (now!): **Get going!**
  - Build new reactors, based on existing proven designs
  - Where needed, engage Labs and Academia on ‘issues of the day’ for rapid turnaround R&D
  - Deal with the interim storage issue (!!!)

- In the **intermediate term** (5-10 years out): **Get more cost-effective**
  - Complete R&D, design, of next generation reactors: evolutionary, not revolutionary
  - Complete the waste repository …

- In the **long term** (>15 years): **Aim for a sustainable nuclear economy**
  - Work on transformational technologies: Extract maximal fraction of energy
    - *Don’t ‘follow the (present-day) leaders’!*
    - *Make lemonade out of lemons: US has little sunk costs in ‘classic’ reprocessing technologies, … , and is therefore potentially much more agile in going after new ways of maximally extracting energy from nuclear fuel*
      - Closing the fuel cycle via novel reprocessing methods and fast spectrum reactors
      - Novel ways of achieving ‘deep burn’ in once-through technologies

We need to be realistic, not oversell, but have lofty goals …

- Nuclear power is unlikely to play a critical role in limiting CO2 equivalent concentrations in the atmosphere until mid-century at the earliest …
  - No realistic plan foresees a reactor build rate that allows nuclear power to help stay below 550 ppme CO2 within the next ~30-40 years.

- Nuclear power is very likely to play a dominant role in limiting the CO2 equivalent concentration in the latter part of this century
  - Going to a closed fuel cycle, or its equivalent, will allow nuclear power to become sustainable over centuries time scales
  - It is the only non-fossil fuel energy source that does not depend on local climate, weather and insolation conditions, does not impact food production, and does not depend on new (as yet undiscovered) energy storage technologies

- Restoring the lead role of US manufacturers in nuclear energy will critically depend on whether we invest in the transformational strategy …
  - Running after our international competitors, in areas such as variants of traditional acqueous reprocessing, or evolutionary modifications of existing reactor designs, … , is a losing proposition

Let's focus on the lofty goals: Transforming the field of nuclear power

- There are key issues that must be addressed right from the start
  - **Safety** (from fuel fabrication to reactors and reprocessing and waste disposal)
  - (Non)-proliferation **safeguards**
  - **Cost containment**
    - *Design, construction, and operation (including fuels fabrication and waste stream treatment) must be substantially optimized*
    - *Regulatory process must be substantially speeded up*
- This can only be done by adopting a modern science and simulation-based engineering approach
  - **Nuclear engineering must become a modern science and computations-based discipline**
    - *High fidelity (science-based) integrated simulations must form the core of the design efforts, and allow for rapid prototyping*
    - *Science-based, validated modeling at both the detailed (small-scale) and systems-level must be part of the core capabilities*
    - *The field must generate internal technical excitement in order to attract the 'best and the brightest'*

We know how to do this - and have done it before …

- The DOE/NNSA ASC simulation program at the National Labs has accomplished this sort of transition from phenomenology to a science and simulation-based engineering approach … and DOE/SC has more recently led with SciDAC!

- The same program has demonstrated that academia can - and does - contribute substantially: the original ASC Academic Alliance Program
  - *Caltech*
  - *Stanford University*
  - *Univ. of Chicago*
  - *Univ. of Illinois*
  - *Univ. of Utah*

- The Labs know how to compete (w/ each other) and work collaboratively
  - With academia and other labs …
  - With industry …

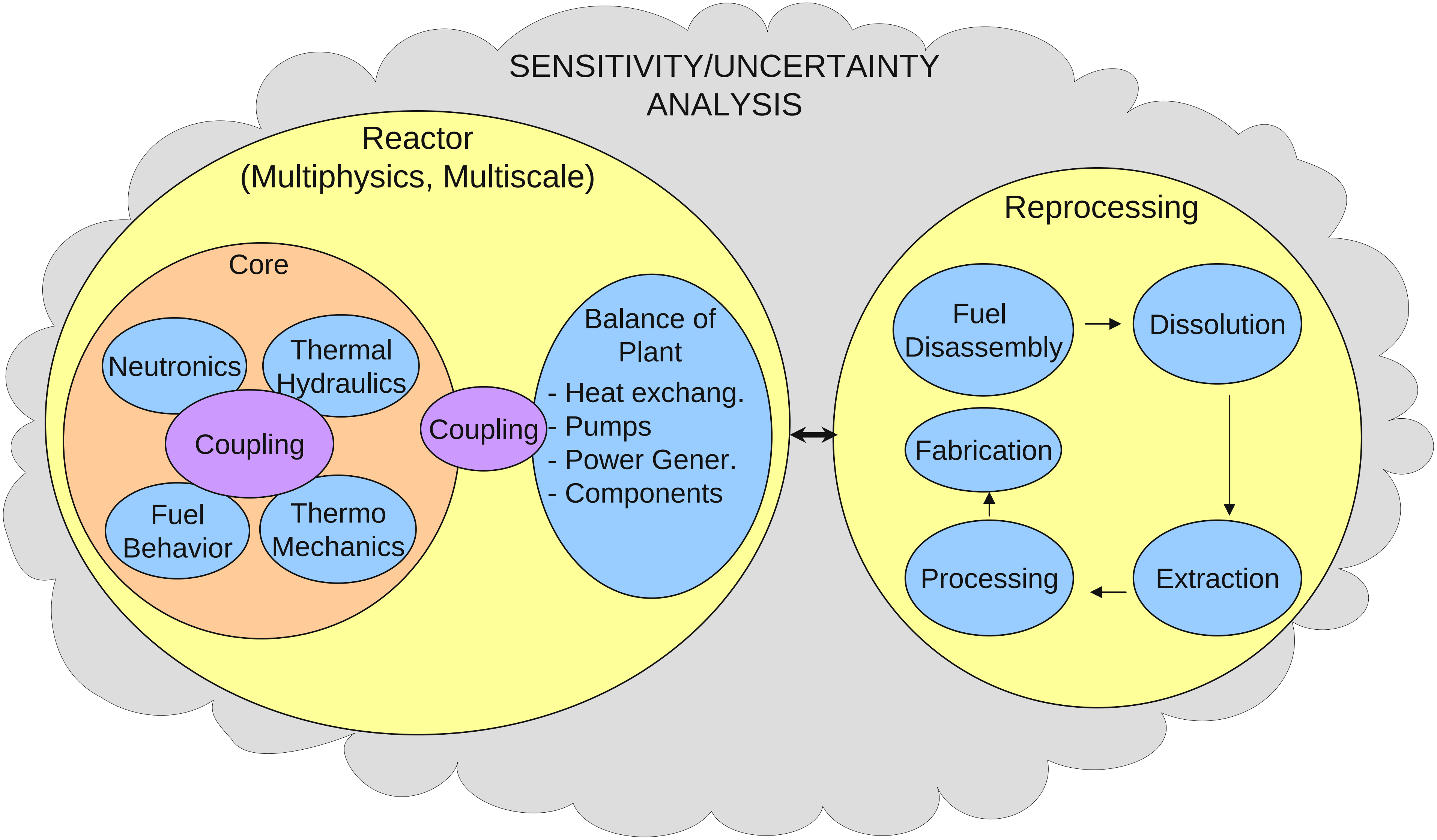
More specifically: The 'Nuclear Energy Advanced Modeling & Simulations' (NEAMS) initiative

Overall Advanced Modeling and Simulation Vision

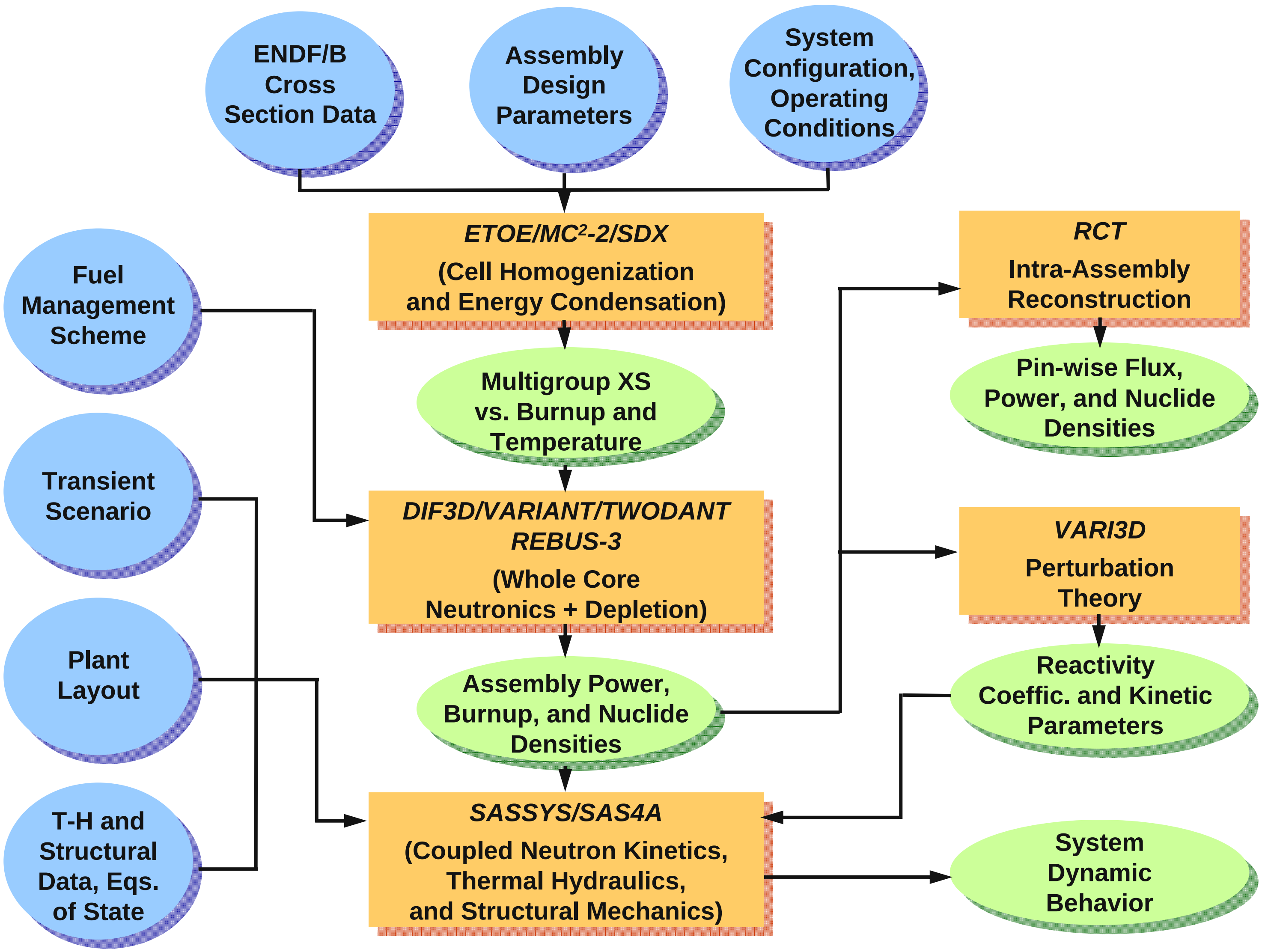
To rapidly create, and deploy next generation, verified and validated nuclear energy modeling and simulation capabilities for the design, implementation, and operation future nuclear energy systems to improve the U.S. energy security future.

- **DOE/NE-led initiative**, based on broad involvement by the entire nuclear R&D community
- **Approach**
  - Flexibility: no tuning for particular nuclear energy systems or fuel cycles
  - Continuous (iterative) improvement of modeling/simulation capabilities
  - Competitive development environment
- **Program Elements**
  - Fundamental Methods and Models
  - Integrated Performance and Safety codes: a systems approach
  - Verification & Validation; QMU/PRA capabilities 'built-in'
  - Capability Transfer: To industry, NRC, …
  - Enabling Computational Technologies: Tools, platforms, …

This is what the 'big picture' might look like …

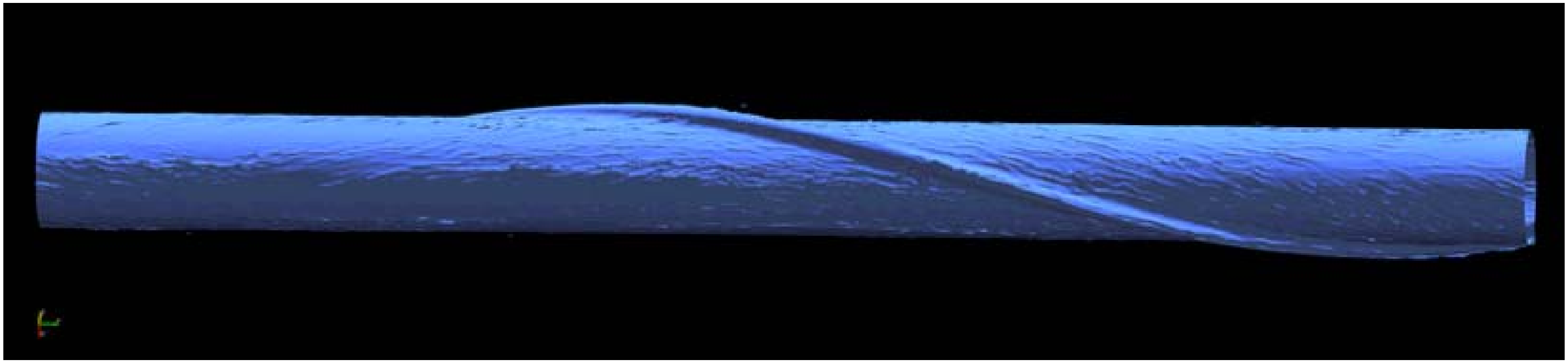


At Argonne, this was our starting point: The Argonne Fast Reactor Code Suite

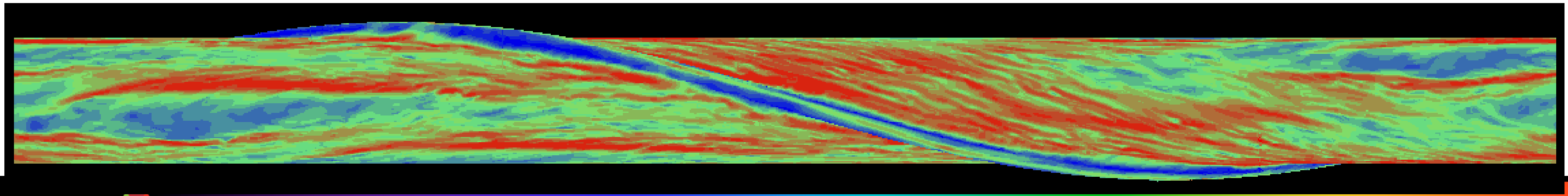


This has evolved to a modern thermal hydraulics code (SHARP), coupled to neutronics …

An early thermal-hydraulics example: subassembly analysis of wire wrap fuel pins

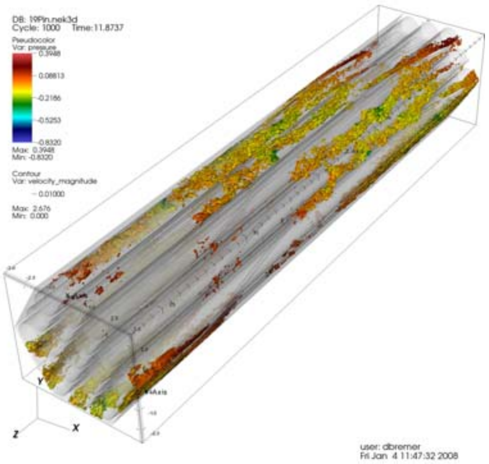


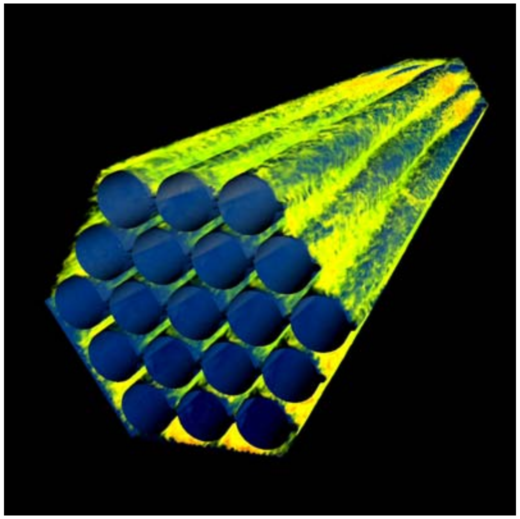
- Single pin in a periodic array:
  - Re=20000, 8.7 M gridpoints, 5 hours on P=2,048 of IBM BG/L
  - *Predicts velocity swirl lagging wire-wrap; 180º out of phase with widely-held assumption that wire pushes flow into neighboring subchannels*



Today, SHARP has become far more capable, and now runs effectively on the world's largest unclassified computer, IBM's BG/P at Argonne …

- ***A more recent 19-pin fuel assembly fast reactor simulation***





Reference: Petascale Algorithms for Reactor Hydrodynamics, Paul Fischer, James Lottes, David Pointer, and Andrew Siegel J. Phys. Conf. Series (2008).

As I pointed out in 2006, there might be some concerns …

- **“We can’t trust simulations …”**
  - *Perhaps in days of yore, but today we fly Boeing 777s, which were designed via computer, no prototype was ever built, …*
  - *Unlike climate/astrophysics/…, nuclear engineering is a data-rich environment; engineering V&V is a very well-developed, mature field*
- **“Let’s not rush into things, there’s plenty of time …”**
  - *Perhaps, but waiting (or insufficiently funding R&D) is a sure-fire way of*
    - *Guaranteeing mediocrity in the US nuclear engineering community*
    - *Making sure US is technically disadvantaged vis-à-vis foreign technology leaders, and ensuring that there is no US industry to compete for the ongoing world-wide nuclear revival*
- **“It’s all too expensive …”**
  - *Compared to what?*
  - *Do we know enough to predict costs reliably out to 2050, especially given the likely transformational effects of computing, technological advances, … ?*

Which brings us to ... Discussion