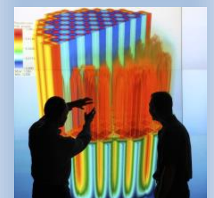

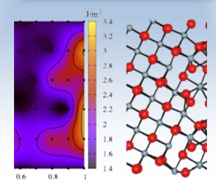

VERA-Input Demonstration

Scott Palmtag
Core Simulator Project Integrator

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Consortium for Advanced Simulation of LWRs

U.S. DEPARTMENT OF ENERGY | Nuclear Energy

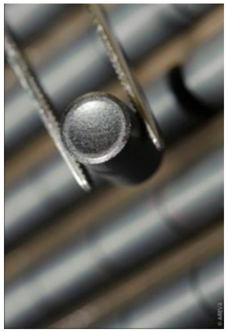
Goals of Demonstration

- Give short overview of PWR core components
- Show how to connect the components to the input
- This demonstration is targeted towards “users”, and not so much toward “developers” (but developers have to know how to use the code)

Agenda

- Introductions
- Short PWR Overview (30 Minutes)
- Detailed Review of Input (1 hour)
  - Geometry Concepts
  - Control Rod Concepts
  - Walk through input file
- Input to XML Demonstration (30 minutes)
- Input to COBRA Demonstration (time permitting)

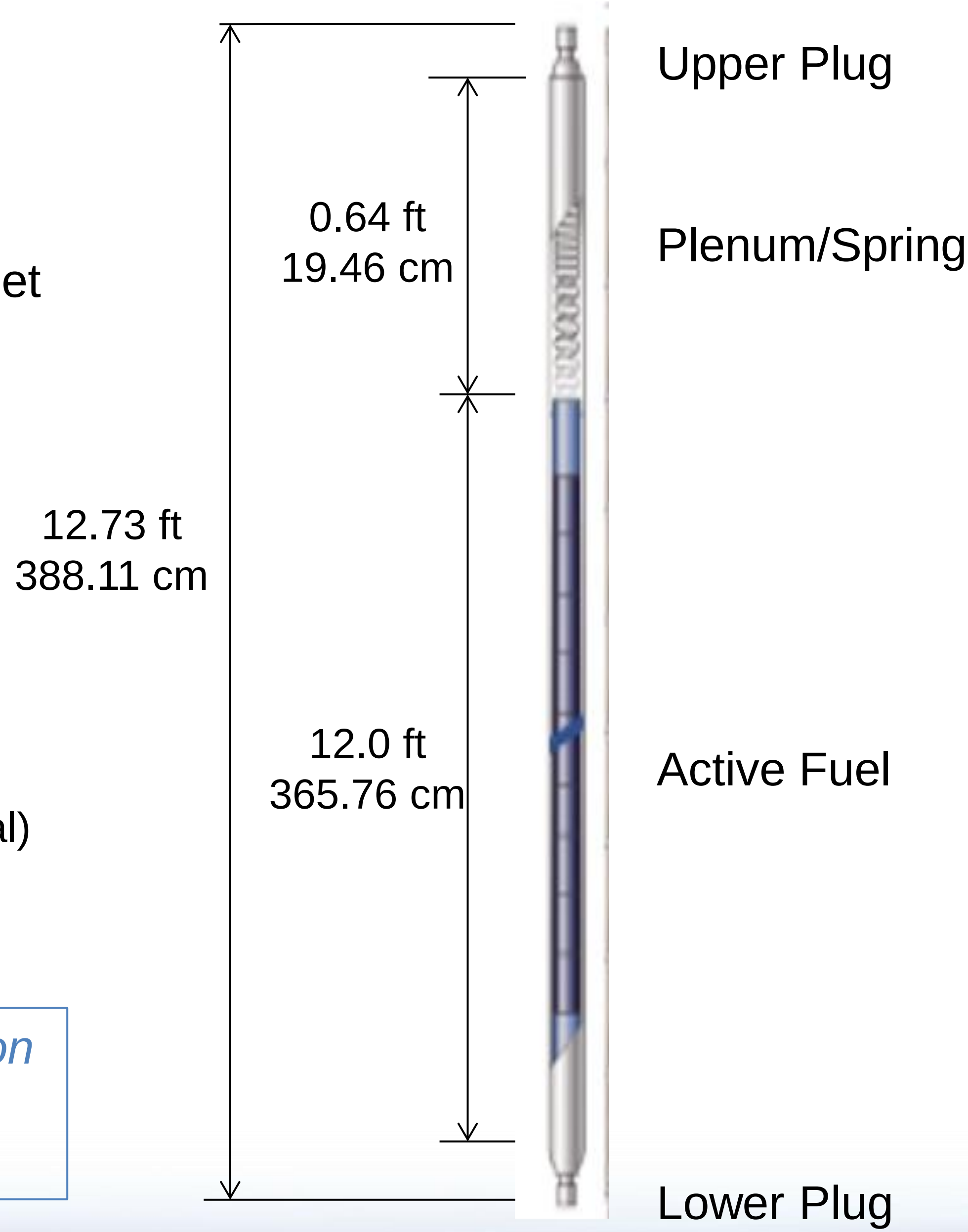
PWR Fuel Rods



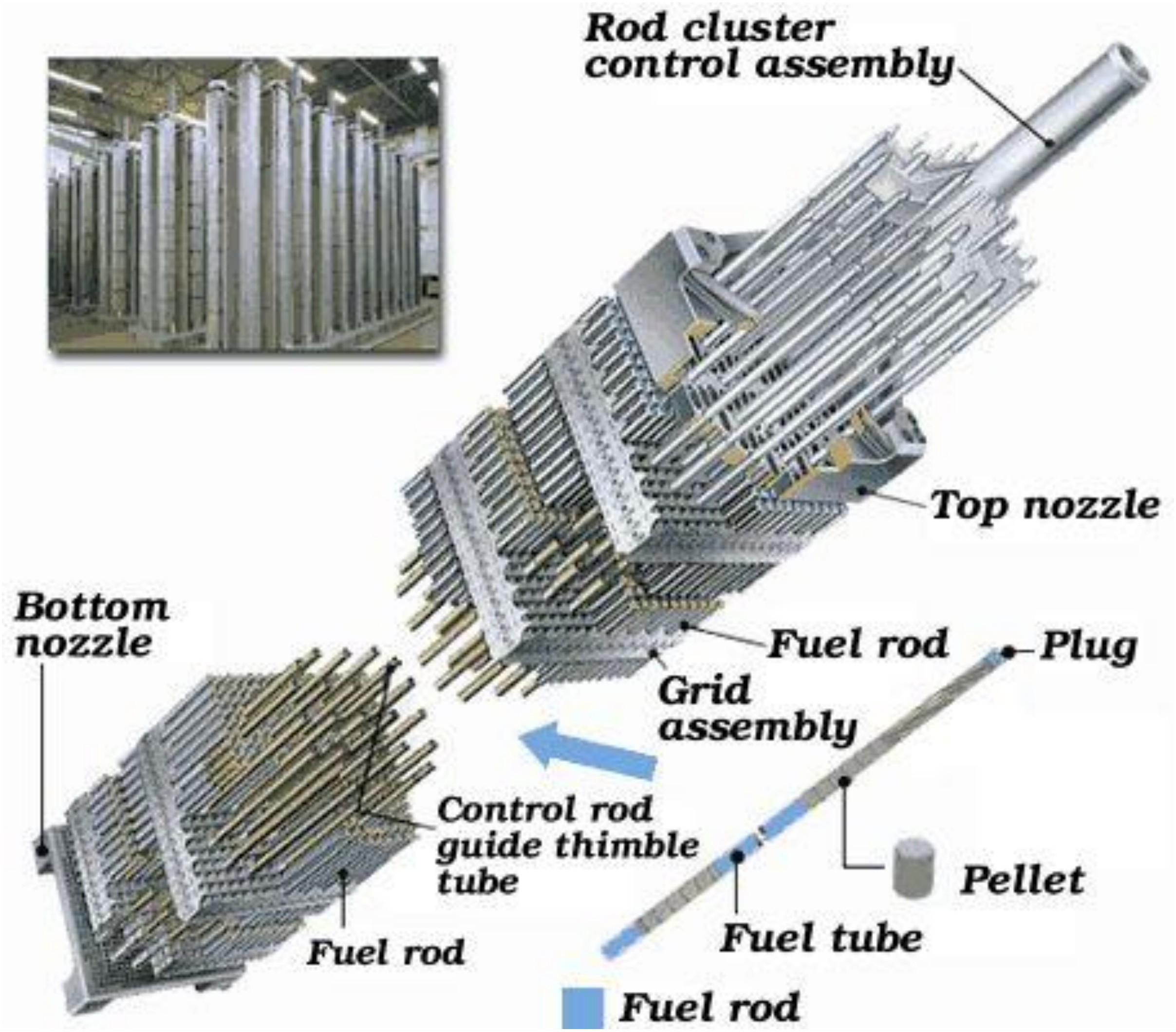
PWR Fuel Pellet
(0.82 cm OD)

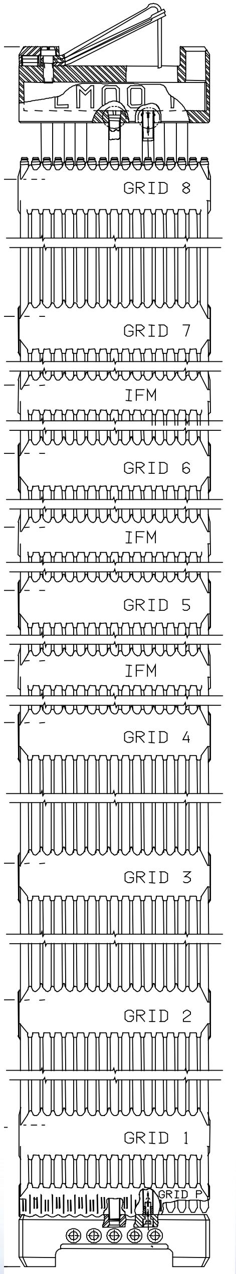
- UO_2 Pellets
- multiple initial U-235 enrichments
  (2.1, 2.6, 3.1 w/o heavy metal)
- Density ~ 10.2 g/cc

All dimensions in presentation are typical of Watts Bar (non-proprietary)



Fuel Assembly

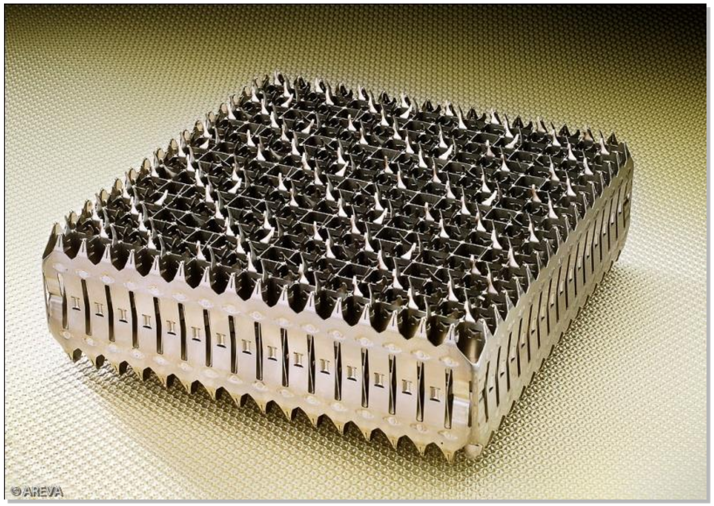


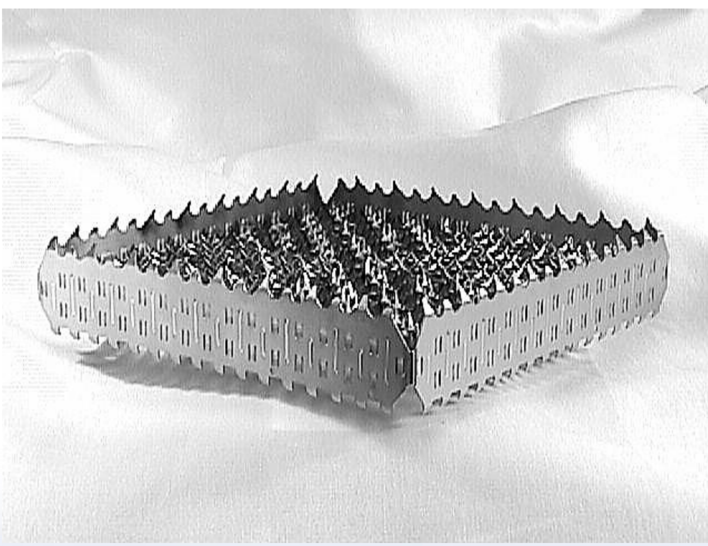


Fuel Assembly

Some idea of relative size!

Spacer Grids





8 (or more) grids per assembly

Grid Materials:

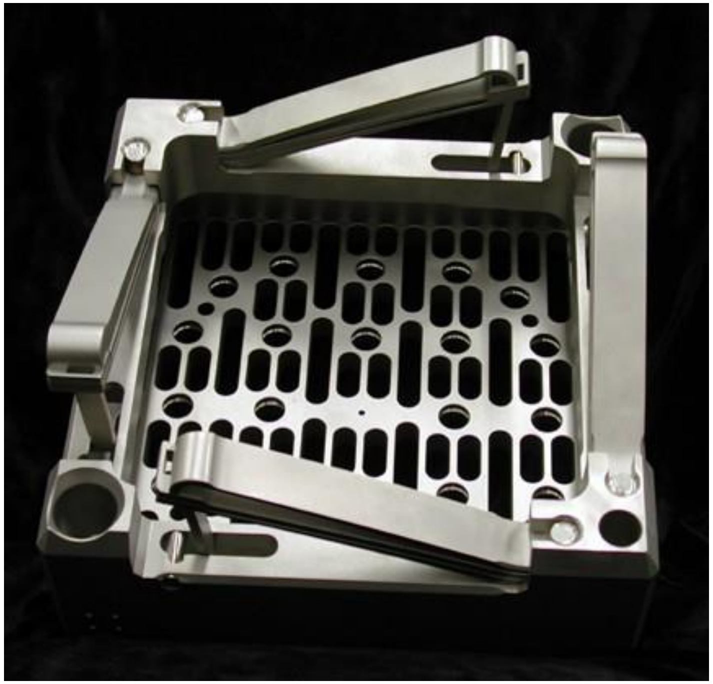
- Inconel (top and bottom)
- Zirconium (middle)
- Combination for structure + springs

Axial Height 3.8 cm
Mass 875-1014 g

Notes on modeling grids:

- Neutron transport usually models as a smeared volume
- Subchannel T/H usually models with loss coefficients and mixing factors
- CFD can model explicitly using CAD drawings (or porous material?)

Top and Bottom Nozzle



Materials: Stainless steel

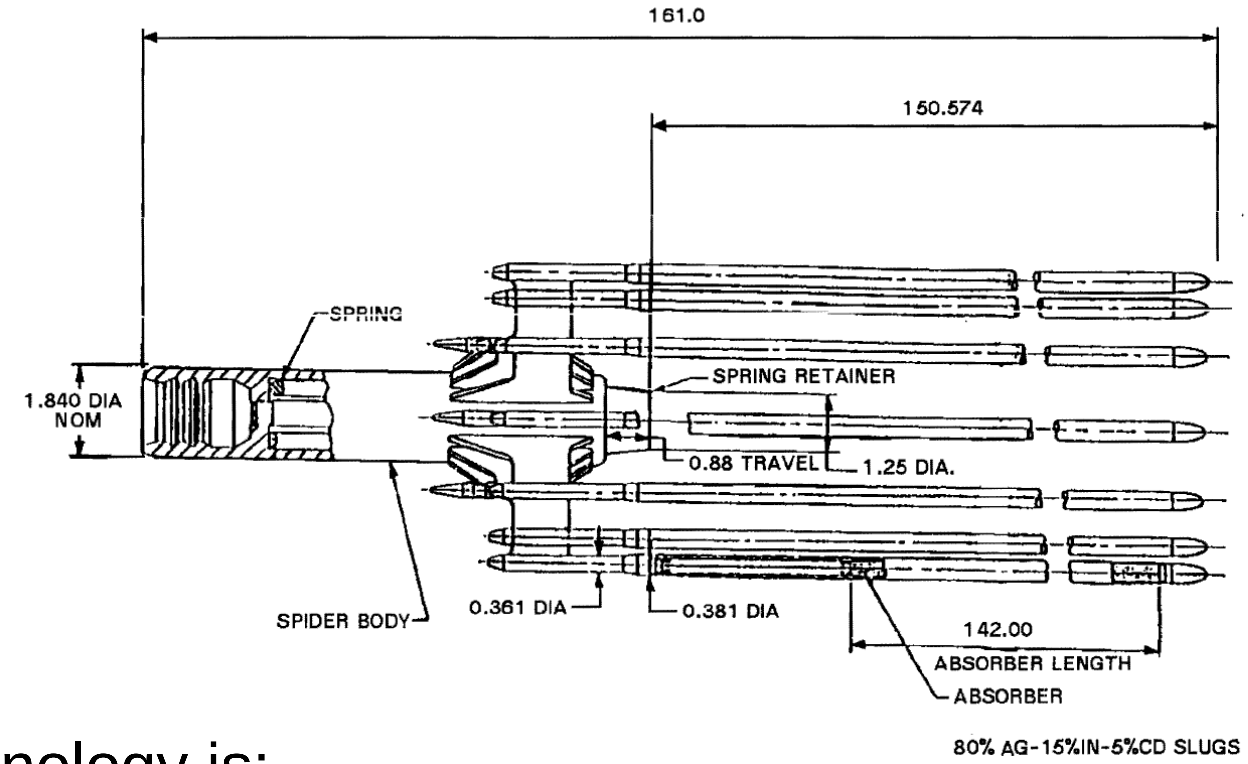
Axial Height 6-9 cm
Mass 6250 g

Modeled similar to spacer grids

Note on Reactivity Control

- As the core is operating, “criticality” must be maintained (neutron source=neutron loss)
- As the core depletes, the source term will decrease.
- To counteract depletion, there must be excess source (reactivity) at the beginning of life (BOL)
- In order to maintain criticality during depletion, the excess reactivity must be balanced with a neutron absorber
  - Soluble boron in coolant
  - Control Rods (RCCA)
  - Integral Burnable Absorbers (IFBA, Gadolinia, Erbia)
  - Discrete Burnable Absorbers (Pyrex, WABA)

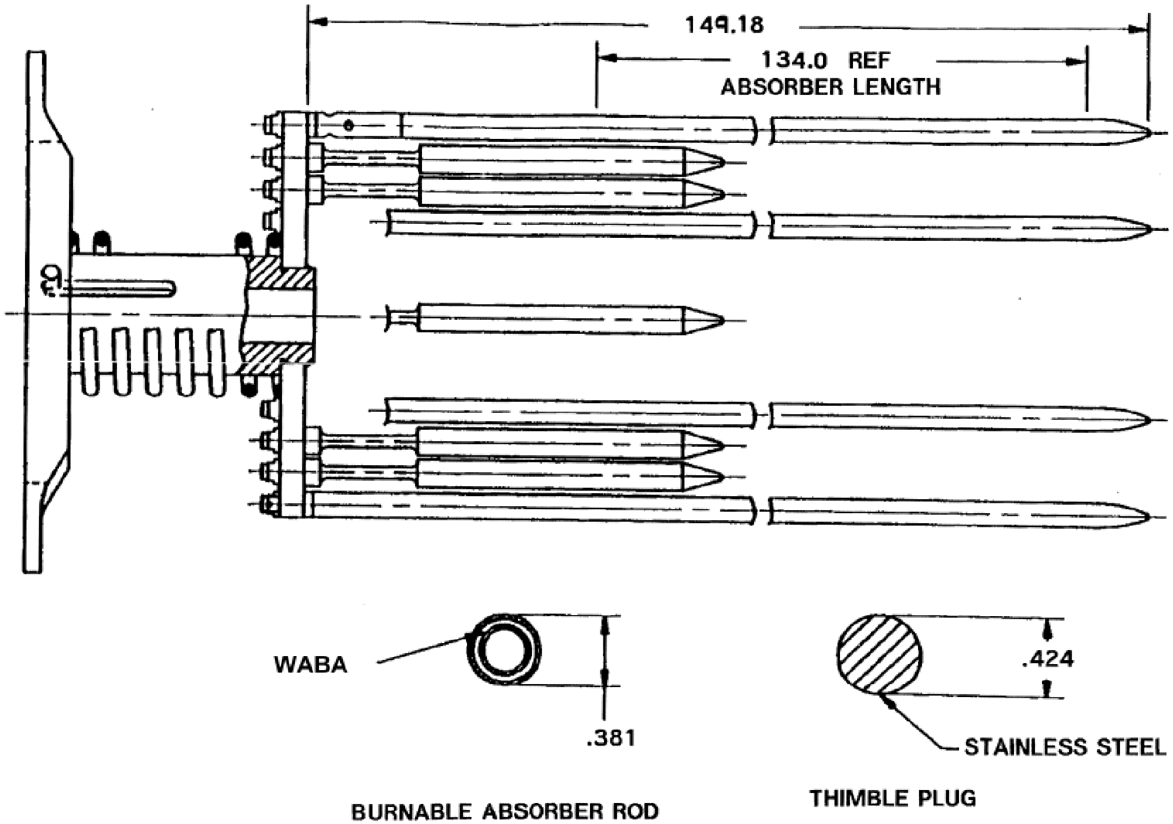
Control Rods



The correct terminology is:
Rod Cluster Control Assemblies (RCCA)

Control Rods move during operations

Discrete Burnable Absorber Assemblies



BA's can have different configurations of absorber rods (8, 12, 16, 20, 24)

BA's are usually Pyrex or WABA

BA's do not move during operation

Fuel Loading Pattern

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1					3	3	3	3	3	3	3				
2			3	3	3	1	3	1	3	1	3	3	3		
3		3	3	2	1	2	1	2	1	2	1	2	3	3	
4		3	2	2	2	1	2	1	2	1	2	2	2	3	
5	3	3	1	2	1	2	1	2	1	2	1	2	1	3	3
6	3	1	2	1	2	1	2	1	2	1	2	1	2	1	3
7	3	3	1	2	1	2	1	2	1	2	1	2	1	3	3
8	3	1	2	1	2	1	2	1	2	1	2	1	2	1	3
9	3	3	1	2	1	2	1	2	1	2	1	2	1	3	3
10	3	1	2	1	2	1	2	1	2	1	2	1	2	1	3
11	3	3	1	2	1	2	1	2	1	2	1	2	1	3	3
12		3	2	2	2	1	2	1	2	1	2	2	2	3	
13		3	3	2	1	2	1	2	1	2	1	2	3	3	
14			3	3	3	1	3	1	3	1	3	3	3		
15					3	3	3	3	3	3	3				

Reg 1	2.10%
Reg 2	2.60%
Reg 3	3.10%

Watts Bar Unit 1 Cycle 1

- 3 enrichment zones
- No IFBA
- WABA

Burnable Absorber Loading Pattern

	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1						8		12		8					
2					16		24		23s		16				
3			12	24		16		20		16		24	12		
4			24		20		20		20		20		24		
5		16		20		20		20		20		20		16	
6	8		16		20		24		24		20		16		8
7		24		20		24		20		24		20		24	
8	12		19s		20		20	+	20		20		19s		12
9		24		20		24		20		24		20		24	
10	8		16		20		24		24		20		16		8
11		16		20		20		20		20		20		16	
12			24		20		20		20		20		24		
13			12	24		16		20		16		24	12		
14					16		24		23s		16				
15						8		12		8					

Watts Bar Unit 1 Cycle 1

- 5 Pyrex Assembly Types
- +4 neutron sources

Note: large number of BA’s because all the fuel is fresh

RCCA Bank Positions

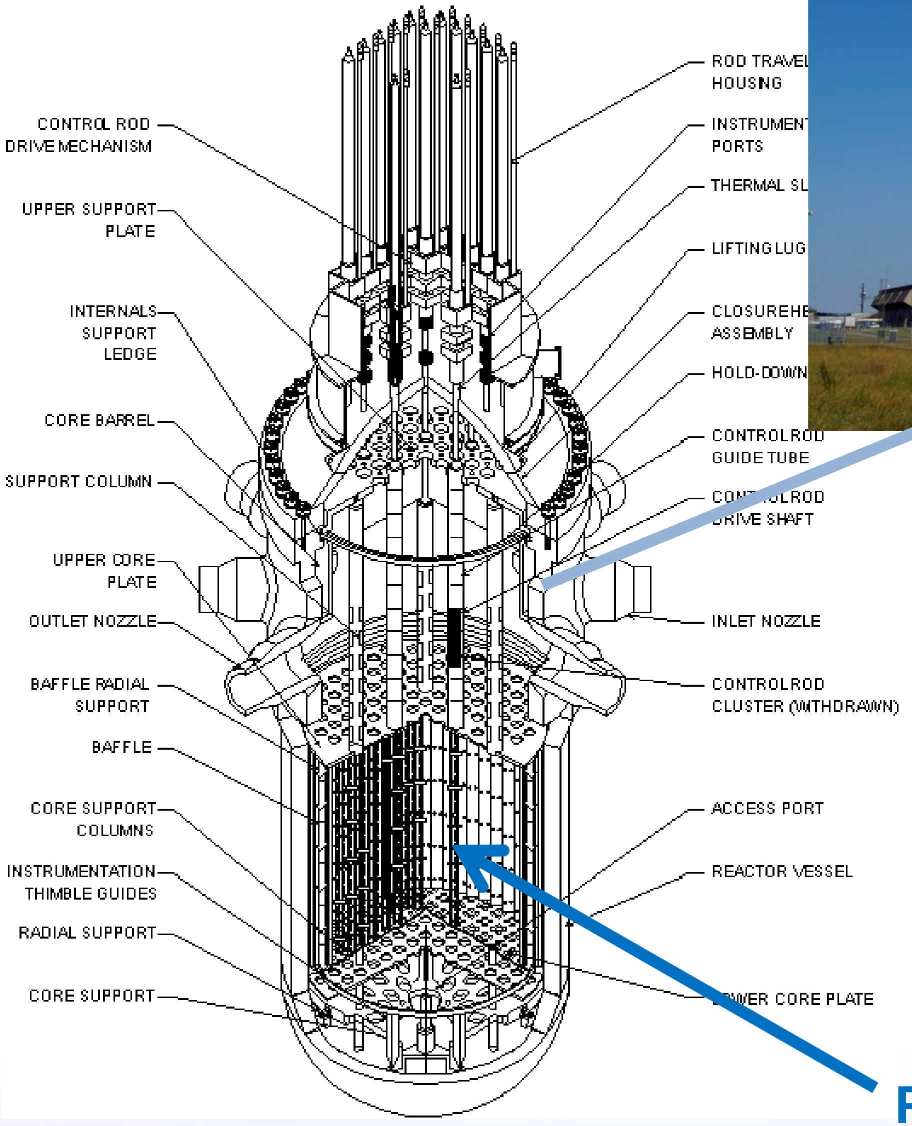
	R	P	N	M	L	K	J	H	G	F	E	D	C	B	A
1															
2				SA		B		C		B		SA			
3					SD		SB		SB		SC				
4		SA		D				D				D		SA	
5			SC		A						A		SD		
6		B				C		A		C				B	
7			SB		SP								SB		
8		C		D		A		D		A		D		C	
9			SB										SB		
10		B				C		A		C				B	
11			SD		A						A		SC		
12		SA		D				D				D		SA	
13					SC		SB		SB		SD				
14				SA		B		C		B		SA			
15															

Watts Bar Unit 1 Cycle 1

- Operational Banks A-D
- Shutdown Banks
- Banks are symmetric

During normal operation, all rods are withdrawn and criticality maintained with soluble boron

PWR Vessel



TVA Watts Bar

Current CASL scope is the inside of the pressure vessel.
This will change as we move to transients

Reactor Core

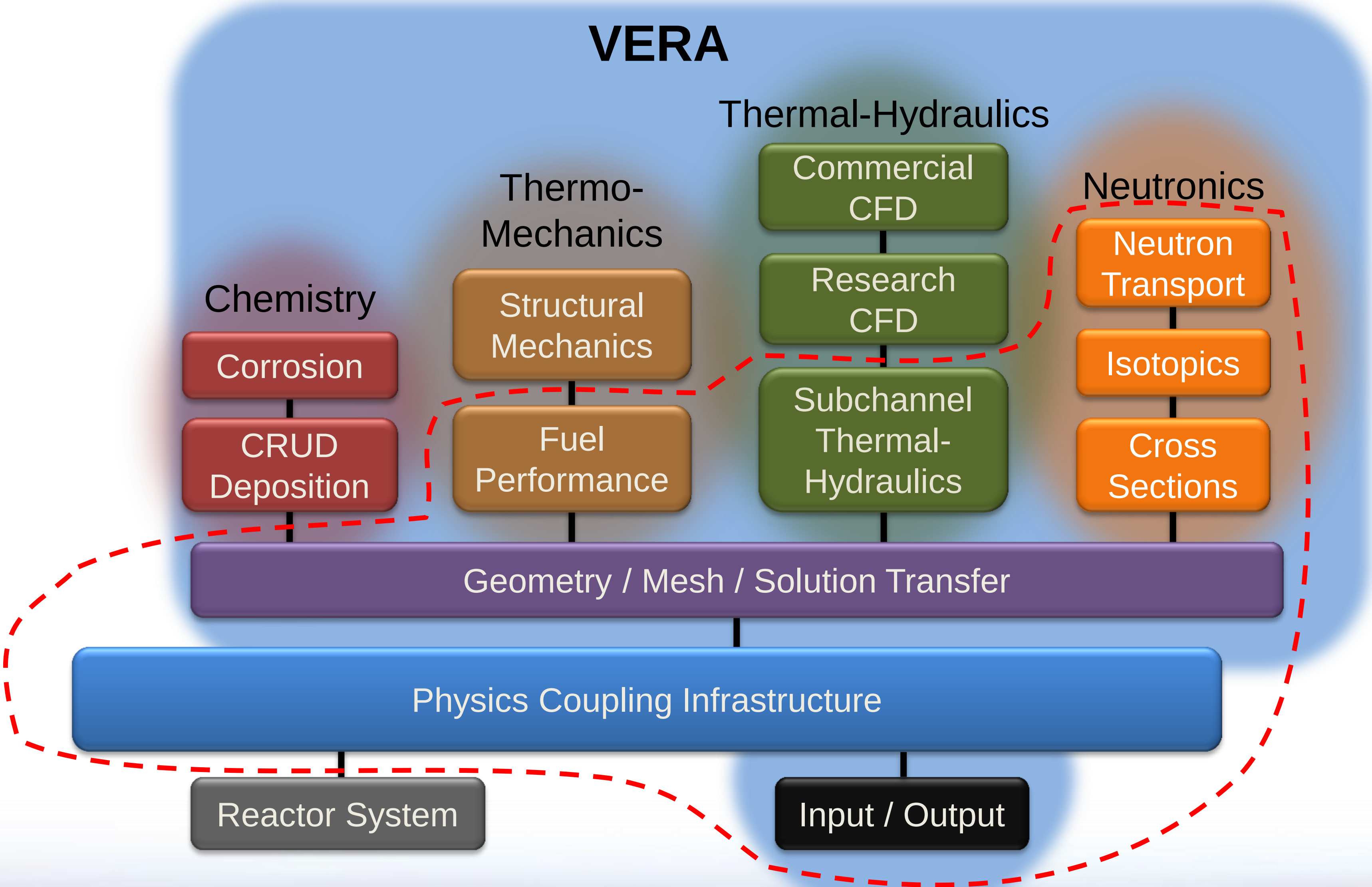
VERA-Input

VERA-Input

Why do we have a common input?

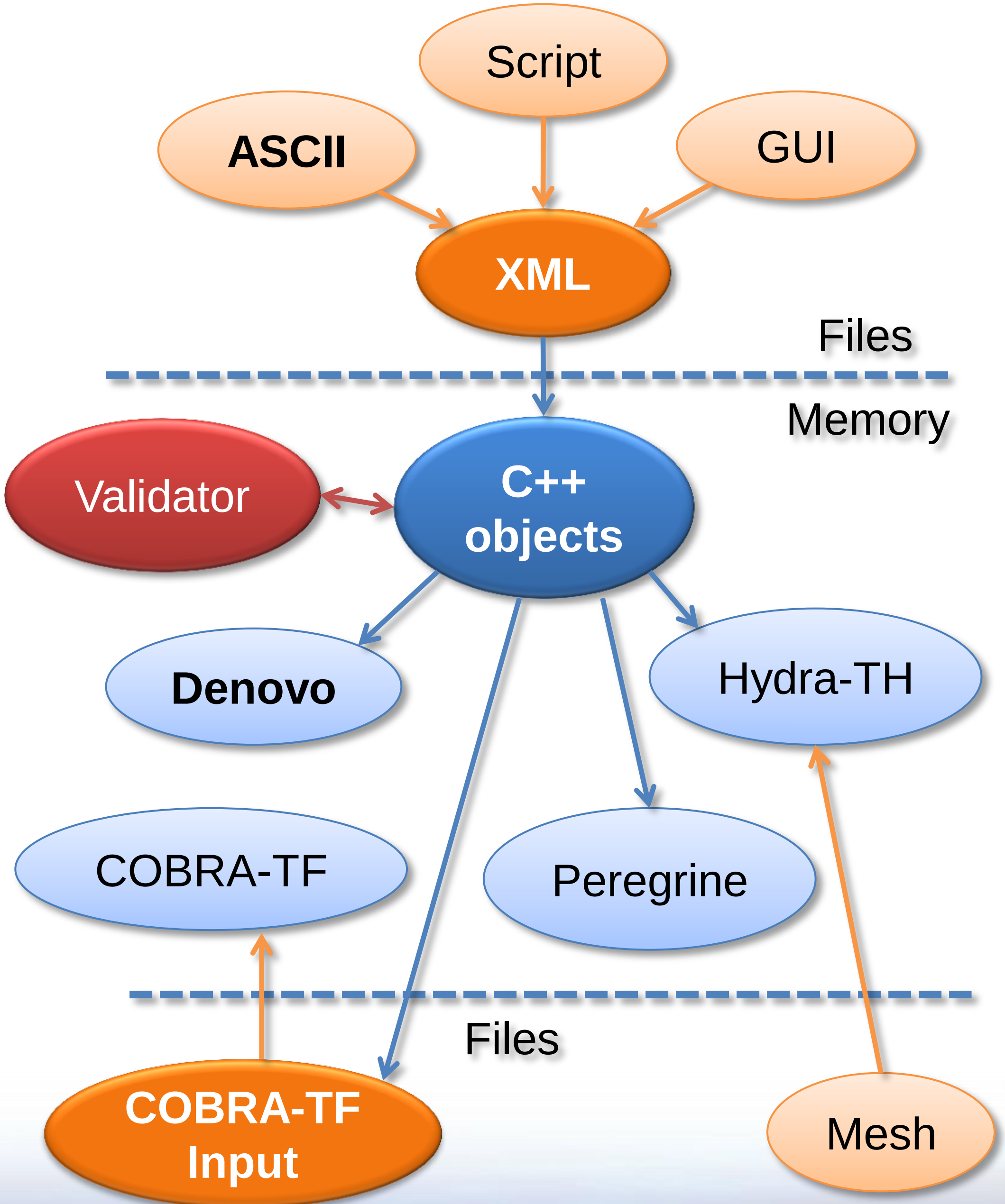
- VERA is a “virtual environment” that is composed of many different computer codes, each with its own input
- It was recognized that users should not have to become familiar with the input of every code
- Another benefit is to reduce errors due to inconsistencies between code inputs

Virtual Environment for Reactor Analysis (VERA)



VERA-Input Internals (a peak under the hood)

- provide ability to create, archive, compare, and modify input similar to current industry workflows
- provide common reactor problem setup for physics components
  - VERA-CS: assemblies, poisons, control rods, non-fuel structures, baffle, power, flow, depletion, etc.
- reduce inconsistencies between coupled physics codes through the use of a common geometry description
- **Users only interact with ASCII input!** (or GUI in the future)



Geometry Concepts

We build up the core geometry from smallest → largest

1. Define material
2. Define cell
3. Define 2D lattice/segment
4. Define 3D assembly
5. Add grids and nozzle
6. Place assemblies in core

1. Define Materials

Structural Material

mat [user-name] [density] {[libname$_i$] [fraction$_i$], i=1, N}

```
mat he      0.000176  ! Default libname
mat inc     8.19
mat gmat     8.0  zirc 0.5  ss 0.5
mat zirc4   6.56  zirc 1.0
mat aic    10.20
mat pyrex  2.23
mat b4c     6.56
```

Fuel Material

fuel [user-name] [density] [th-den] / [U-235 enrichment]

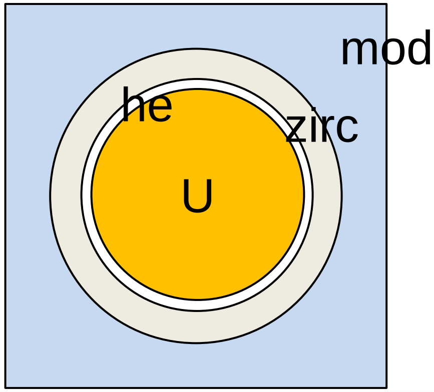
```
fuel  U21 10.257 95.0 / 2.11
fuel  U26 10.257 95.0 / 2.60
fuel  U31 10.257 95.0 / 3.10
```

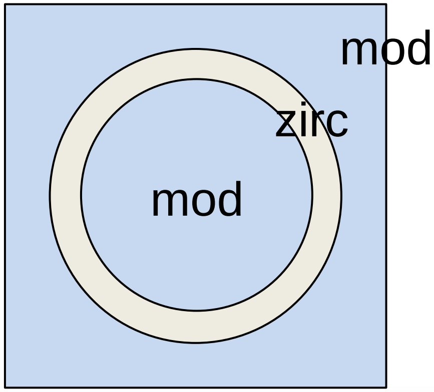
2. Define Cells

```
cell 1   0.4096 0.418 0.475 / U21 he   zirc    ! low enriched pin cell
cell 2   0.4096 0.418 0.475 / U26 he   zirc    ! med enriched pin cell
cell 3   0.4096 0.418 0.475 / U31 he   zirc    ! hi  enriched pin cell

cell 4          0.561 0.602 / mod  zirc        ! guide tube
cell 6          0.559 0.605 / mod  zirc        ! instrument tube

cell 8          0.418 0.475 / he   zirc        ! plenum pin
cell 9          0.418 0.475 / zirc zirc        ! end plug
```





Outer material defaults to “mod”, which is determined by T/H

3. Define 2D Lattice/Segment

```
lattice FUEL1
      6
      1  1
      1  1  1
      4  1  1  4
      1  1  1  1  1
      1  1  1  1  1  4
      4  1  1  4  1  1  1
      1  1  1  1  1  1  1  1
      1  1  1  1  1  1  1  1  1

! Numbers/labels in map
! refer to cell labels
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1																	
2																	
3						GT			GT			GT					
4				GT										GT			
5																	
6			GT			GT			GT			GT			GT		
7																	
8																	
9			GT			GT			IT			GT			GT		
10																	
11																	
12			GT			GT			GT			GT			GT		
13																	
14				GT										GT			
15						GT			GT			GT					
16																	
17																	

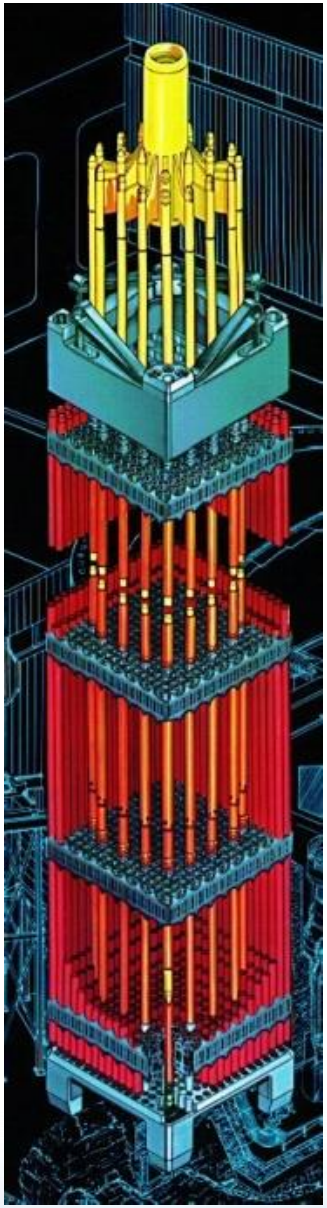
Only need to define octant (1/8) maps due to symmetry

Define multiple lattices for each unique 2D slice

4. Define 3D Assembly

```
axial A1                 ! Assembly label
              6.050  ! Bottom elevation
      LGAP1  10.281  ! Lattice label, elevation
      PCAP1  11.951  ! etc.
      FUEL1 377.711
      PLEN1 393.711
      PCAP1 395.381
      LGAP1 397.501

! Lattice labels are defined on lattice maps
```



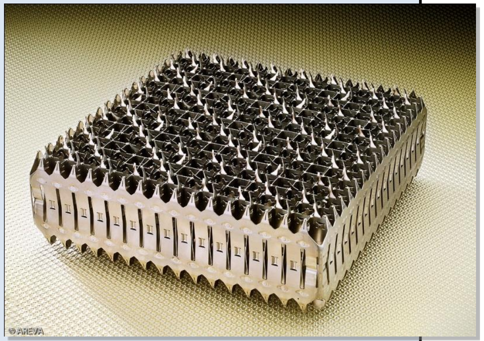
Stack up 2D lattices to form a 3D assembly

5. Add Grids and Nozzles

```
grid END inc  1017 3.866   ! Name, material, mass (g), height (cm)
grid MID zirc 875  3.810

grid_axial                 ! Axial grid locations
    END  13.884
    MID  75.2
    MID 127.4
    MID 179.6
    MID 231.8
    MID 284.0
    MID 336.2
    END 388.2

lower_nozzle  ss 6.05  6250.0  ! material, height, mass (g)
upper_nozzle  ss 8.827 6250.0  ! material, height, mass (g)
```



6. Place Assemblies in Core

```
  assm_map
                   A3 A3 A3 A3 A3 A3 A3
             A3 A3 A3 A1 A3 A1 A3 A1 A3 A3 A3
          A3 A3 A2 A1 A2 A1 A2 A1 A2 A1 A2 A3 A3
          A3 A2 A2 A2 A1 A2 A1 A2 A1 A2 A2 A2 A3
       A3 A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3 A3
       A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3
       A3 A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3 A3
       A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3
       A3 A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3 A3
       A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3
       A3 A3 A1 A2 A1 A2 A1 A2 A1 A2 A1 A2 A1 A3 A3
          A3 A2 A2 A2 A1 A2 A1 A2 A1 A2 A2 A2 A3
          A3 A3 A2 A1 A2 A1 A2 A1 A2 A1 A2 A3 A3
             A3 A3 A3 A1 A3 A1 A3 A1 A3 A3 A3
                   A3 A3 A3 A3 A3 A3 A3
```

Additional Core maps for RCCA's, RCCA Banks, Inserts, and Detectors

Control Rod Concepts

- Define RCCS geometry as “fully inserted”
- RCCS geometry is analogous to assembly geometry
  cells → 2D segments → 3D axial description → core map
- Define total “stroke” as distance from “fully inserted” to “fully withdrawn”
- Define total number of notches from fully inserted to withdrawn

Example: Stroke 360 cm, 228 total notches

- 228 notches is fully withdrawn
- 114 notches is inserted half-way
- 0 notches is fully inserted

Inserts and Detectors Concepts

- Insert and Detector geometry is analogous to assembly geometry
  cells → 2D segments → 3D axial description → core map

- The only difference is that Inserts and Detectors do not move during operation

Input File Structure - “blocks”

```
[CORE]
   core information, including maps of assembly layouts
[STATE]
   statepoint data, including core power, flow, rod position, etc.
[ASSEMBLY]
   assembly descriptions
[CONTROL]
   control rod descriptions
[COBRATF/MPACT]
    code specific options
```

Look at Example Input

Link to Full Core Input file

User References

VERA-Input documentation is on WIKI page:

https://github.com/CASL/VERAin/tree/master/verain/docs

Watts Bar Reference: (if you are curious)

- Watts Bar Unit 2 Final Safety Analysis Report (FSAR), Amendment 93, Section 4, ML091400651, April 30, 2009. http://adamswebsearch2.nrc.gov/idmws/ViewDocByAccession.asp?AccessionNumber=ML091400651

Demonstration

Demonstration

- VERA Input parser is in VERA GIT directory under:
  …/verain/scripts/verain/scripts/react2xml.pl
- Run with command line:
  react2xml.pl [file.inp] [file.xml]
- You can view the resulting xml file with a web browser as long as you have associated “PL9.xsl” file in the same directory

COBRA Demonstration

- Run ASCII parser
- Run COBRA-TF pre-pre-processor to convert XML to input for COBRA-TF pre-processor
- Run COBRA-TF pre-processor to create COBRA-TF input deck
- Run COBRA-TF

Questions?