Breakout-2 High-Level Discussion Topics

- Reactors with minimal human intervention.
  - Sensors
  - Controls
  - Monitoring
  - Design of reactors—what are the design features that are enabling?
  - Materials
- Applications. Not defined, but there are features we want. Namely:
  - Load following
  - ≤ $0.10/kWh
- Optimization with scale /Intrinsic benefits of small reactors. Surface to volume changes for smaller reactors - how does this change/enable (or preclude) particular approaches?

Sensors

- Classify the data types needed– (long-term health vs. transients vs. accidents).
- Priorities, time-scales, etc. must be established.
- Cyber-security is essential.
- Development of radiation-hard sensors, high temperature self-calibrating, low drift, etc. needed.
  - How do we power these devices?
    - Battery? Sealed?
  - Packaging
  - Windows could be enabling (spectroscopy, imaging, etc.)

Priority list for sensors (design agnostic)

- Temperature
- Chemistry
- Pressure
- Flow-rate
- Flux (neutron?)
- Material integrity.
- Others:
  – Level (of coolant?)
  – Inventory (fuel—for material accountability? Coolant?)
- Consider also opportunities to infer quantities.

Elements of Sensors

- Detector
  - Could be imaging, spectrometer, neutron counter etc.
- Transmitter
  - Converts native signal of detector into a signal (e.g. RF, electronic) and this is transmitted to the communications backbone.
- Communications backbone
  - Distributes information to where it needs to go.
  - Could be wired or wireless. Could be gas lines, could be fiber optic., could be mechanical
  - Reliable, long-distance data transfer… usually electronics.
  - Electomagnetic interference can be an issue– fiber optics to avoid interference.
  - Data rate, data reliability, can dictate how big a ‘problem’ noise is.
- Issue of where to do data transmitting– benefits to doing it on site (near the detector), or sending it elsewhere.
- No closed-loop control off site… must be on-site. Need to be done-onsite to enable load following, control/adjustments/operational decisions.

Materials Development

- Superset of materials (and questions) that can be broadly enabling:
  - Material compatibility is essential—both environmental compatibility and "joints"—metallurgy. Manufacturing matters too.
  - Corrosion resistance, creep
  - Manufacturing seamless components (no welds). Can you hot-press a core?
  - How to make joints in, for example, SiC, both with SiC and with other materials is an important question.
  - Creativity on the thermal (design) side can be enabling on the materials side.
- Core:
  - Structural, Moderator, Containment, Fuels
- What development is needed? Or is qualification all that's needed?
  - Probably do not need a test facility? May have everything needed to qualify material up to 20-30 dpa. But this changes if we include fast reactors (new facilities be needed?)
  - Material development is much faster than material qualification– there are some reasons for this (creep, for example, takes a long time).
  - Speeding up material qualification learning cycles may be ARPA-E hard?

Safety vs. Size

- Optimization with scale /Intrinsic benefits of small reactors. Surface to volume changes for smaller reactors - how does this change/enable (or preclude) particular approaches?
  - Flat curve up to 100 MW. Whatever you can fit on a truck is (likely) to be optimum.
  - As big as can fit on the truck?
  - Is there a point where the safety case becomes compelling– the physics may be less efficient, but the ease of getting rid of heat becomes such that safety is stronger.
  - The point where this happens is (?) 100 MW.. But for smaller than 10 MW, scale is an issue.

Breakout 2, March 17th, 2016. Room D

BACKUP SLIDES

Cost of electricity

– ≤ $0.10/kWh
– Real point is cost of the plant– not cost of electricity. Design solution must be cheap!
– Busbar costs.
– Break it down—MMRs—lower costs (factory production, etc.) licensing costs, time (to deployment), cost of operations,
– Peaking reserves– can charge a premium.

- Is wireless needed? Do we need a 600 C RF amplifier?
- Electrical penetration assemblies ar eposisble.
- Detectors vs. sensors–
  - Detector– transmitter-communicaitons backbone.
  - Sensors (e.g. optical imaging) thorugh a window– no access to high T needed.
  - But if you are going to immerse the sensor in a fluid it has to be chemically compatible with the reactor.
  - Windows– optical access…. Opens other

Fast reactors?

- Should we be considering these?
  - Enrichment will be a challenge
  - Criticality would be a challenge with <20%
  - Proliferation would be a issue.

Sensors, continued

- Scarlat: two types of people at reactors– operators and maintenance. May have opportunities to use maintenance to swap out sensors, etc.
- If interesting in extending lifetime (beyond generation I of MMRs), can simply swap out sensors and, if needed, replace sensors to enable continued monitoring.
- Do we have the sensors we need for maintenance crews to collect info every few months?
- Self-calibrating and extended calibration intervals are very important.
- **Sensor summary: Development of rad hard sensors, self-calibrating, etc. needed, BUT should not rule out that we may be able to use modified SoA sensors for first generation of MMRs.**

Breakout-2 High-Level Discussion Topics

- Applications. Not defined, but there are features we want. Namely:
  - Load following/Ramp Rate
    - Equipment may degrade much more quickly under load following– which may increase cost.
    - Frequency following—more common.
    - Usually has little to do with the reactor, just has to do with balance of part… Maybe better
    - Black start capability
    - Reliability– up time on the plant– all will have value associated.
  - ≤ $0.10/kWh

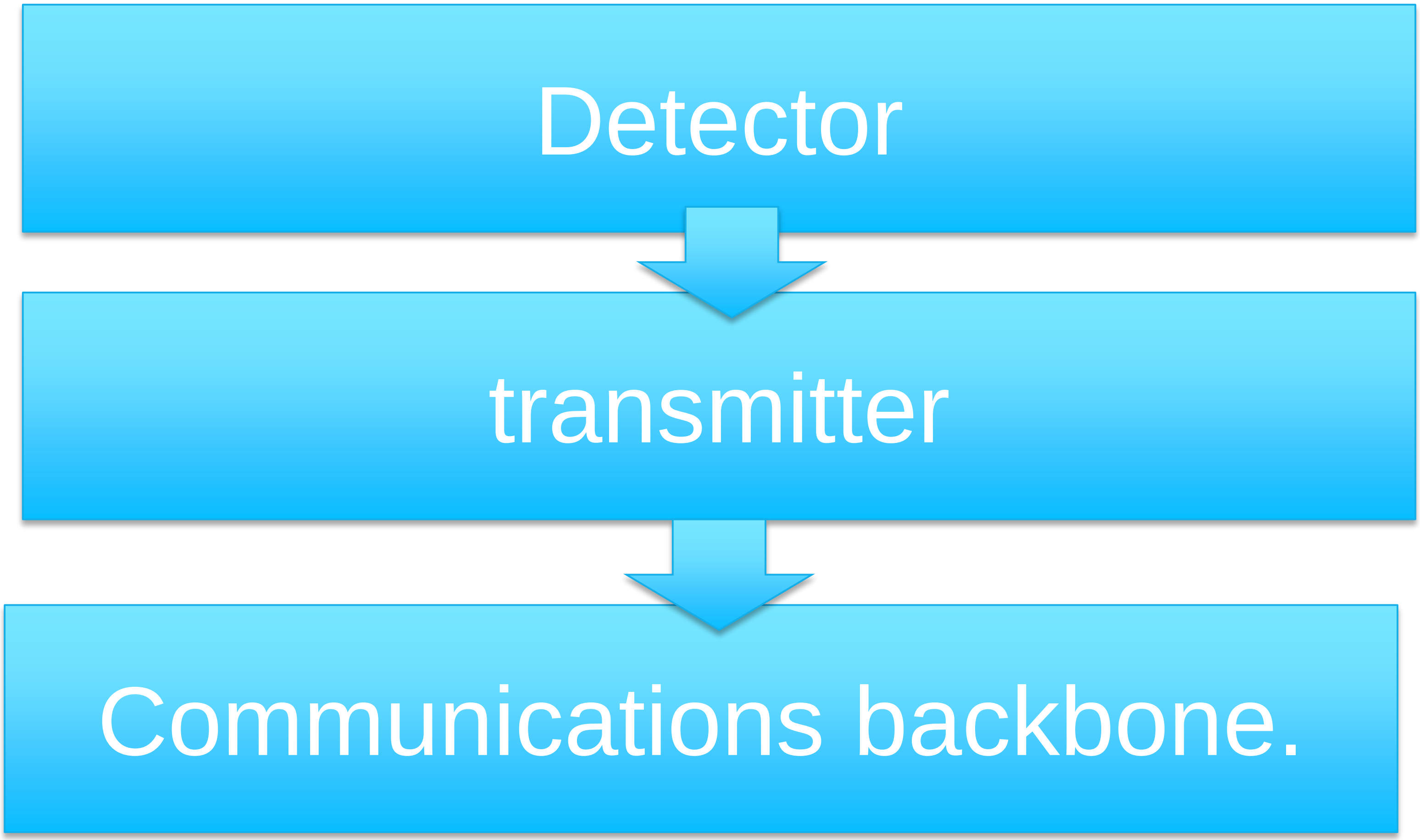
Breakout-2 High-Level Discussion Topics

- Reactors with minimal human intervention.
  - Sensors: **NEED RAD HARD SENSORS WITH LONG LIFETIME.**
    - Mohar: existing sensors, control systems.. Can be modified to meet needs.
    - Snead: yes– secondary system sensors exist. But development needed for primary… for example, reactor evolution over 10 years (structural, pressure, etc.) But sensors are not rad hard (yet?) Can tell you about turbine and coolant conditions, but not everything you need about the core.
    - Core: need to know fracture toughness, thermal conductivity (more, topics too). Developing rad hard sensors is a huge challenge—very useful for any reactor, anywhere to have these sensors.
    - Need for sensors is whether you have operators or not. NE is working on this (but more to do?)
    - Can we go outside the box? Neutrino monitoring (also cool).

  - Controls
    - Control vs. walk-away safe. Back to cost….
    - Material accountability (nonprolif) comes into this somewhat
  - Monitoring
  - Design of reactors—what are the design features that are enabling?
  - Materials

Final Thoughts

- Self-driving car– needs some data on site, but will still be sending data to the ‘mothership,’ so longer term decisions can be made.
- “Loop control” must be local.
- Data model– which types of data for which purpose.
  - Long-term health monitoring
  - Transients
  - Accidents
  - .. If we can create a map of the diffetent types of dat needs and how it’s used.
  - All agr


Detector
transmitter
Communications backbone.

Breakout 2: Poll

- Poll question: How can a potential $30M and 3-year ARPA-E program make a difference in the previously discussed areas?