Handout 3: Why Not More TMIs?

Previously, we considered three questions

> **Q1:** How can we avoid error, decrease the number and seriousness of accidents?
> **Q2:** With a fairly high degree of forethought and inquiry, can we anticipate *all* of the *serious* accidents that might result from using technology?
> **Q3:** What is the *primary cause* of accidents?
> **Q4:** What types of benefits do complex, high-risk technologies expose us to?
> **Q5:** Do the benefits of using complex, high-risk technologies outweigh the risks?
> **Q6:** Why haven't there been *more* catastrophic accidents or TMIs?

Last time we considered **Q4** and **Q5**. This time we will consider Q6. Perrow gives two answers:

> Answer #1: The reason there haven't been more TMIs is because we have not given nuclear systems enough time to express themselves, i.e. *more TMIs will happen in the future!*
> Answer #2: The reason there haven't been more TMIs is because our "defense in depth" safety systems have worked.

1. Answer #1: Accidents Take Time but More TMIs are on the Way

Let's look at *why* Perrow thinks that more events like TMI are on the way. Keep in mind that Perrow's book was written in 1984, but the basic lesson can be applied now, and while Perrow is talking about nuclear plants, his argument can be considered with other high-risk technologies.

ARGUMENT FOR MORE TMIS	
P1	We lack operating experience with nuclear reactors.
P2	There are numerous problems with the construction and maintenance of reactors.
P3	Problems in nuclear reactors take time to manifest themselves.
P4	Given our lack of experience with nuclear reactors, problems in the construction and maintenance, and that these technologies are complex and capable of producing catastrophic accidents, it is reasonable to expect that more TMIs will occur in the future.
C	More TMIs will occur in the future.

Let's look at **P1**, that we don't have a lot of "operating experience" with nuclear reactors. First, Perrow claims that nuclear reactors haven't been around that long and that the experience that we do have with reactors cannot always be aggregated for the experience we have with certain reactors doesn't always cleanly transfer to knowledge of other kinds of reactors. His more specific claims are these:[1]

- Just because we have experience with 400 Mw reactors does not mean that this applies to 1000 Mw reactors.

[1] Perrow, p.33

- Just because we have experience with boiling water reactors (BWRs) doesn't mean that it applies to pressurized water reactors (PWRs)

Second, Perrow claims that attempts to reject **P1** are misguided. He says that prominents of nuclear energy say we have 500 "reactor years" of experience with nuclear plants (p.33). This calculation is determined by taking the number of plants and multiplying that by the number of years the plants have been operating, e.g. 100 plants x 5 years = 500 reactor years. In response to this, Perrow argues that this *begs the question* for it simply assumes 500 reactors years of experience is a sufficient amount of experience to prove that reactors are safe. First, 500 reactor years pales in comparison to other technologies for which we have thousands of years. Second, while we have experience with a lot of the different parts of a nuclear reactor, e.g. large turbines, creating steam, large pressurized vessels, there are many ***unique*** components to nuclear reactors that we don't have a lot of experience with, e.g. controlled nuclear fission, condensate polisher systems, specialized emergency cooling systems.

On pp.34-36, Perrow argues that nuclear plants are often extolled as sources of cheap energy, but he argues that the length of time required to building them, the haste in building them, unique rusting issues, and core embrittlement all make nuclear energy *more* expensive than conventionally fueled plants.

Perrow might have also looked at waste disposal, security to guard against terrorism and theft, and the costs of decommission. But this issue gets us into the *economics of nuclear power plants* (which is interesting), but we won't really consider it.

Let's turn to **P2**. **P2** says there are numerous problems with the construction and maintenance of reactors.

- Differences in the *design* of the reactor and the *actual construction* (the company that designs the reactor isn't always the same company that builds it, and they might not have built it in the way that is intended). Example #1: Marble Hill nuclear plant where the builders couldn't pour concrete correctly. Example #2: Difference in design & construction at Diablo Canyon (a reactor built on a fault line).[2]
- Building company intimidates inspectors. Example: Perrow, p.36
- Individuals at regulatory agencies ignored reports that the reactor was not working correctly. Example: Perrow, p.36-7
- See Quote from Nunzio Palladino, pp.37-38

2. Answer #2: Safety Systems are Working, Few, if any, TMIs are on the Way

We have considered the position that more TMIs are on the way. Let's consider a different response:

ARGUMENT FOR TMIs

P1 More TMIs haven't occurred because our "defense in depth" safety systems are working.

P2 Future advances in safety will make technologies even safer and we can build better, safer designs

[2] Perrow, p.37

C More TMIs will **not** occur in the future.

Let's consider **P1**. **P1** says that there haven't been more TMIs because we've employed what is called "defense in depth." The basic idea behind "defense in depth" is that we don't simply use one redundancy or safety system. Instead, we have *multiple safety devices*. We make use of containment systems (if something goes wrong in the core than this mistake is *contained*), emergency coolant systems, and back-up generators in case we can't get coolant to the core, etc.

We are not particularly concerned with the technicalities here. Our concern instead is this:

> High-risk technologies expose us to unpredictable and potentially catastrophic risk. Presumably, we think that people have a **right to security (and to feel secure)** but we balance this right against the benefits of **affordable energy**. However, the right to security and the benefits awarded by high-risk technologies like reactors seem to be at odds. The more we increase the efficiency and productivity of certain technologies, the more we expose ourselves to risk. The more we increase safety devices, we increase costs and decrease the effectiveness with which we can supply cheap energy. How do we decide?

Let's start by looking at some safety considerations.

The **containment system** is a large concrete shell that covers the reactor vessel. The inside of the reactor vessel is at negative pressure so that if there is a leak, outside air will flow in rather than radioactive air flowing outward. Not all reactors have containment systems, e.g. those in the Soviet Union. If what happened at TMI happened in a Soviet reactor, Perrow claims that the operators would have been killed and those in the surrounding area would have been exposed to large amounts of radiation.

Question about Your Reactor	Yes	No
Would you build your reactor with a containment unit?		
Abandon plan to build reactor		

You now have the decision of thinking about how strong to create your containment unit. You could, of course, build it to the recommended design specifications *or* you could build it stronger than specifications?

Question about Your Reactor	Yes	No
Would you build your reactor with a containment unit?		
Would you build your containment unit stronger than recommended by the designers?		
Abandon plan to build reactor		

If you did not build your containment unit stronger than recommended, then you have exposed yourself to at least two additional risks. **First**, at TMI, the containment unit contained a hydrogen bubble that exploded in the containment unit. This explosion had a "pressure surge equal to onehalf that which the building was designed to handle."[3] The only reason it was built this strong was because *the state of Pennsylvania* required that the containment unit be able to withstand an airplane crash. **Second**, if you didn't built your containment unit stronger, than you also risk exposing people to radiation in the case of an airplane crash.

Question about Your Reactor	Yes	No
Would you build your reactor with a containment unit?		
Would you build your containment unit stronger than recommended by the designers?		
Abandon plan to build reactor		

Another question is *how many* containment units. You might consider building a secondary containment unit. One thing that Perrow notes is that overtime the containment unit can become embrittled. If you have ever taken a really hot glass out of the dishwasher and then exposed it to really cold water, the glass will crack if not shatter. A similar process goes in nuclear reactors. The core of the reactor is really hot (550°F). If the core overheats, you can try to cool it by sending thousands of gallons of cold water into it. But this will case the inside of the core to shrink and can cause cracks (see Perrow, p.35-6). One way you might deal with this is by building a secondary containment unit.

Question about Your Reactor	Yes	No
Would you build your reactor with a containment unit?		
Would you build your containment unit stronger than recommended by the designers?		
Would you build a secondary containment unit?		
Abandon plan to build reactor		

Now let's consider location. You have a choice between safety and productivity/efficiency:

Safer	More Efficient
Building your reactor far from a population	Building your reactor in the middle of a populated city
Building your reactor far from environments where contamination would spread and away from earthquake fault lines	Building your reactor on a fault line because it is near coastlines and rivers (you have a PWR / BWR reactor and so you need water to cool the core).

You have to build your reactor near water.

Question about Your Reactor	Yes	No
Would you build your reactor with a containment unit?		
Would you build your containment unit stronger		

[3] Perrow, p.41

than recommended by the designers?		
Would you build a secondary containment unit?		
Would you build your reactor far from a population?		
Would you build your reactor near water?	✓	
Abandon plan to build reactor		

The emergency core cooling system (ECCS) supplies water to the core in order to avoid a core meltdown. The ECCS requires some kind of power-supply. One very efficient way to do this is to simply use power generated by the reactor itself. You are likely creating an excess amount of power anyway! Another option is to buy various back-up generators, e.g. diesel generators.

Question about Your Reactor	Yes	No	#
Would you build your reactor with a containment unit?			
Would you build your containment unit stronger than recommended by the designers?			
Would you build a secondary containment unit?			
Would you build your reactor far from a population?			
Would you build your reactor near water?	✓		
Would you install an ECCS in your reactor? And, if so, how many?			
Would you purchase diesel generators to power your ECCS?			
Abandon plan to build reactor			

The obvious problem with using the reactor to power your ECCS is if the reactor is failing, you might not be able to power the ECCS. In addition, back-up generators catch on fire. So, you might consider adding another back-up source of power, e.g. batteries?

Question about Your Reactor	Yes	No	#
Would you build your reactor with a containment unit?			
Would you build your containment unit stronger than recommended by the designers?			
Would you build a secondary containment unit?			
Would you build your reactor far from a population?			
Would you build your reactor near water?	✓		
Would you install an ECCS in your reactor? And, if so, how many?			
Would you purchase diesel generators to power your ECCS?			
Would you purchase batteries as a back-up power supply?			
Abandon plan to build reactor			

You can see where this whole line of questioning is going. Even if we accept that our safety systems are working (i.e. we accept **P1**) and this is the reason that there haven't been more TMIs, and let's assume we don't want to abandon the use of nuclear reactors, we still have the issue that **more TMIs are possible** and so we have to wrestle with the question of **how safe** to make the reactor.

ARGUMENT FOR **ABANDONING** CATASTROPHE-PRODUCING COMPLEX TECHNOLOGIES

P1	If some complex technological systems are likely to produce unpredictable catastrophic events, then we should **abandon these technologies.**
P2	Complex technological systems are likely to produce unpredictable catastrophic events.
C	Therefore we should **abandon these technologies**.

Contrast this argument against the following:

ARGUMENT FOR **SAFER** CATASTROPHE-PRODUCING COMPLEX TECHNOLOGIES

P1	If some complex technological systems are likely to produce unpredictable catastrophic events, then we should **make the existing systems safer.**
P2	Complex technological systems are likely to produce unpredictable catastrophic events.
C	Therefore we should **make the existing systems safer.**

The strength of the abandonment argument is that it isn't as *unstable* as the safety argument. In the safety argument, we have the problem of determining ***how safe is safe is safe enough?*** We think that people have a **right to security (and to feel secure)** but we balance this right against the benefits of **affordable energy**. How do we decide how much risk we can expose people to?

Let's consider **P2**. The idea behind **P2** is that by implementing better, safer technologies we can reduce our risk and avoid catastrophic events. Let's assume that P2 is true. If it is true, the conclusion that more TMIs will not occur only follows if **we actually employ the safer technologies**.

> **O1:** Perrow notes that there are a number of nuclear reactors available and the more efficient, faster, more compact reactors tend to be less safe than the less efficient, slower, more forgiving reactors. For example, he says that CANDU (heavy water reactors) are safer than the reactors used in the United States (PWR and BWR). In addition, perhaps other reactors, e.g. gas-cooled or sodium-cooled reactors, promote even more safety. We can build secondary containment units, or perhaps even a third or fourth containment unit. We can have back-up diesel generators, back-up batteries, back-up etc., etc.

CDQ 1: *How* do you go about making the choice about balancing safety and efficiency? What criteria do you need to consider? What's more important, a person's right to feel safe and secure *or* the benefits of cheap electricity?

CDQ2: Perrow says that accidents seem to be *unique* (p.57), often seem very *trivial* (see p.43-44), and can occur almost anywhere. Being unique, they are hard to learn from them. Since they are *trivial*, they can be easy to ignore. Insofar as they can be almost *anywhere* (builders, design, the materials used, the overseers, the regulators, the operators), they are extremely hard to predict. One thing he suggests is that **we should take even the most trivial problems seriously** and that high-risk technologies need ***more* surveillance then we think is necessary**. Do you agree with this claim?

CDQ3: *Who* should be the one making this choice? Engineers, governmental officials, people living near the community, environmentalists, the designers of the reactors, the operators of the reactor, the owner of the utility company?

3. Have there been more TMIs?

Perrow's book was written in 1984. Since then there have been accidents much worse than TMI, specifically the Chernobyl reactor and the Fukushima reactor. So, in one sense, Perrow was right, there have been more TMIs. But, in another sense he might not be. It may be the case that while there have been some very serious accidents, the total number of accidents has decreased. I don't have the data for this, but it would be interesting to find out if the number of serious accidents has increased since TMI.

LIST OF NUCLEAR REACTOR ACCIDENTS/INCIDENTS AFTER TMI

WHERE	WHEN	LEVEL	WHAT HAPPENED
Middletown, Dauphin County, PA, TMI Unit 2	28 March 1979	5	Partial core meltdown
Orleans, France	13 March 1980	4	
Tsuruga, Japan	March 1981	2	
Buenos Aires, Argentina	23 Sept 1983	4	Radiation exposure
Prypiat, Ukraine (USSR), Chernobyl Reactor	26 April 1986	7	Complete meltdown, explosion, release of radioactive material, 50 dead
Goiania, Brazil	13 Sept 1987	5	Radioactive contamination, 4 deaths
Tomsk, Russia	6 April 1993	4	
Ishikawa Prefecture, Japan	June 1999	2	
Ibaraki Prefecture, Japan	30 Sept 1999	4	
Paks, Hungary	10 April 2003	3	
Sellafield, UK	19 April 2005	3	
Braidwood, IL (USA)	Nov 2005	?	
Erin, TN (USA)	6 March 2006	2	
Fukushima, Japan (two reactors)	11-March 2011	7 & 3	Partial meltdown, release of radioactive gas, explosion, evacuation

*This is a partial list of accidents at nuclear facilities (does not include accidents relating to nuclear-powered ships, aircraft, etc.)