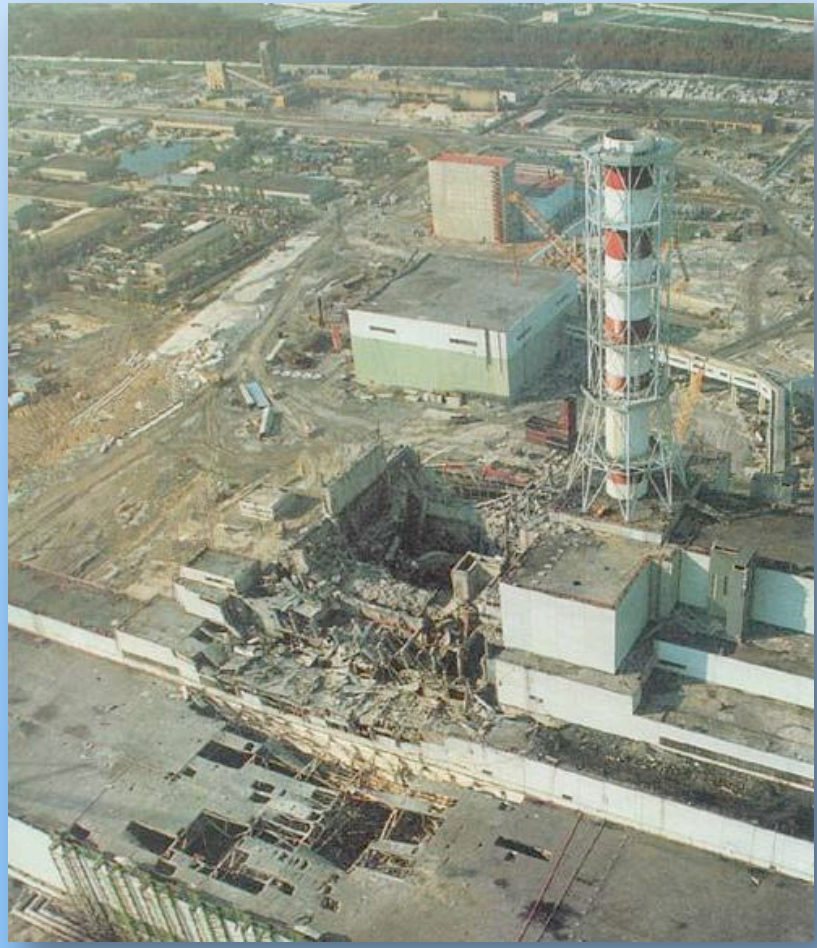
#2: Nuclear Accidents

Presenters: James Hong, Aamoy Gupta

Outline

- Accident classification + Notable incidents
- Japan: Meltdown at Fukushima
- Are we at risk?
- Q/A

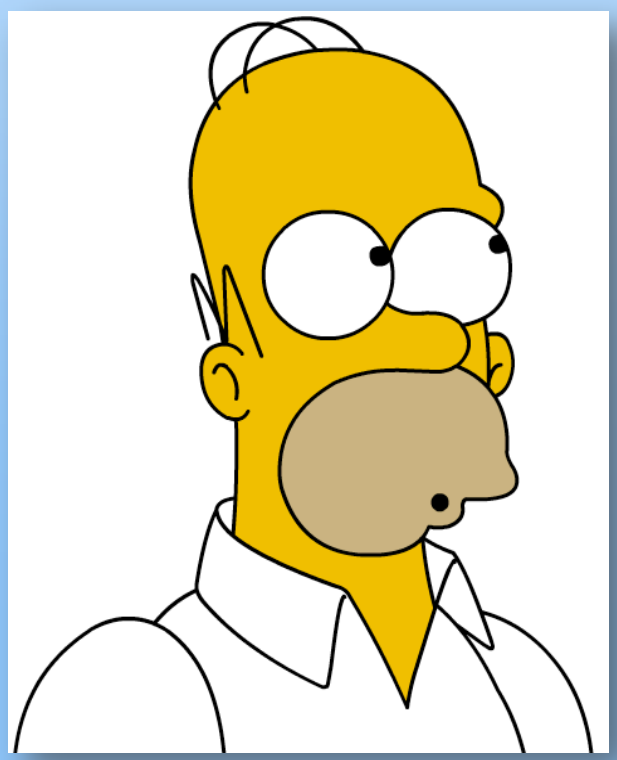


Debunking myths

ACCIDENT CLASSIFICATION

Misconceptions

- meltdown |'melt,doun|
  - melted reactor core

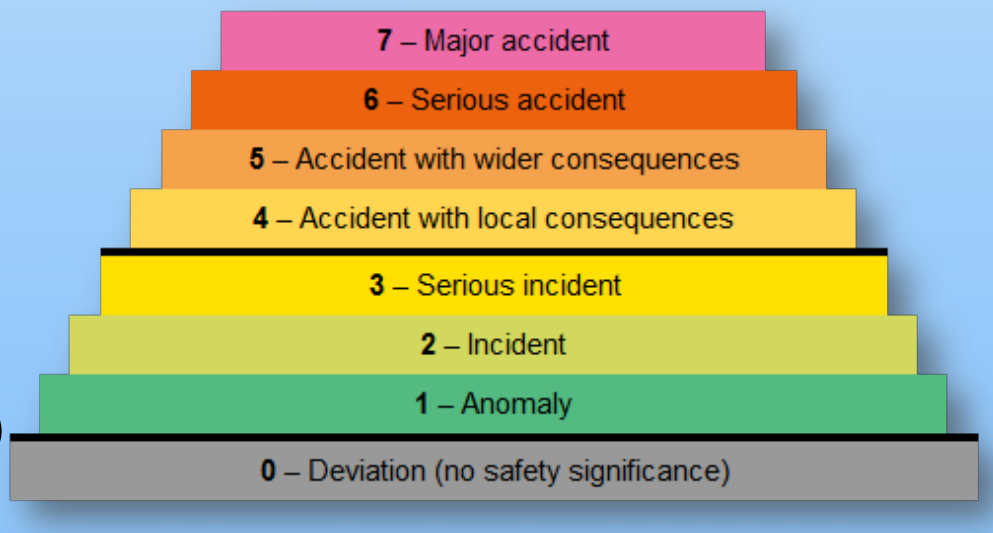


Types of incidents

- Criticality accident (chain reaction)
- Decay heat (overheating)
- Lost fuel source
- Transport
- Equipment failure
- Human error

International Nuclear Event

- IAEA (1957–present)
  - International Atomic Energy Agency
- Rating system
  - 1990–present
- 7 = most serious
  - Chernobyl (1986)
  - Fukushima 1 (2011)



Chernobyl & Three Mile Island

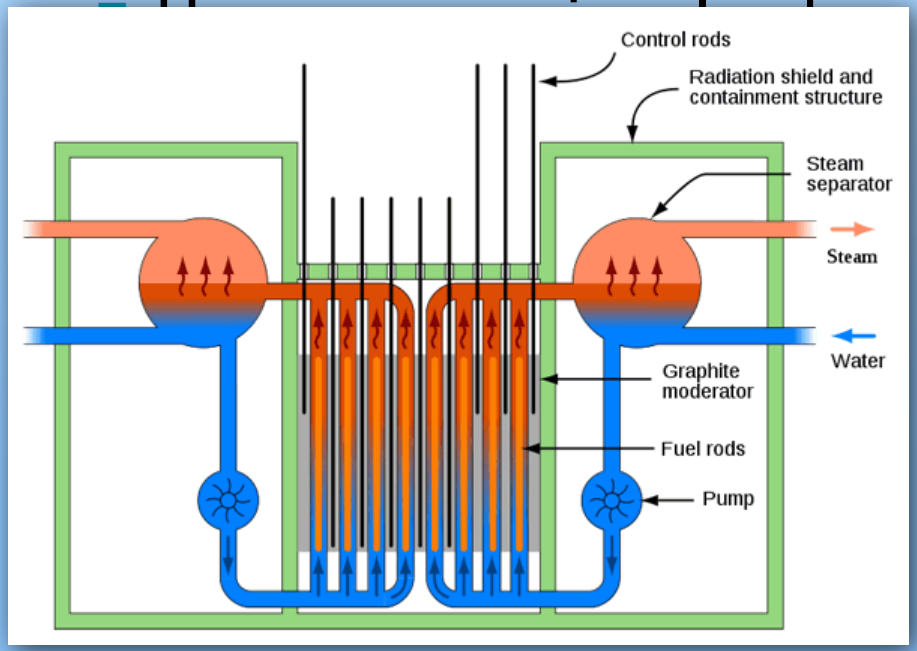
NOTABLE INCIDENTS

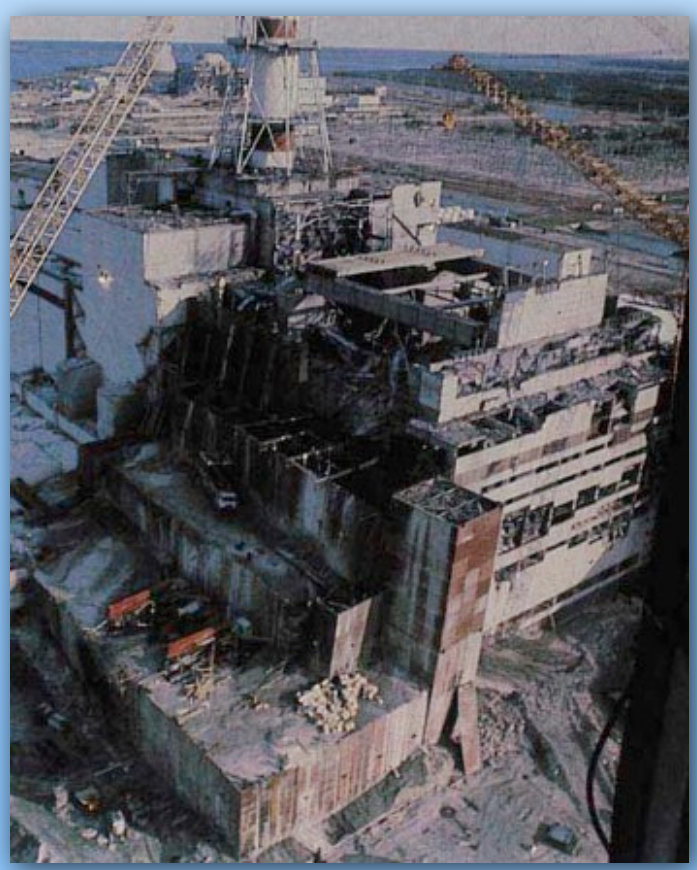
Three Mile Island (1979)

- Level 5 “Loss of coolant”
  - Human error
  - Core meltdown
- Release of radioactiv material
  - 40,000 gallons in to Susquehanna R.
  - Radioactive gases

Chernobyl (1986)

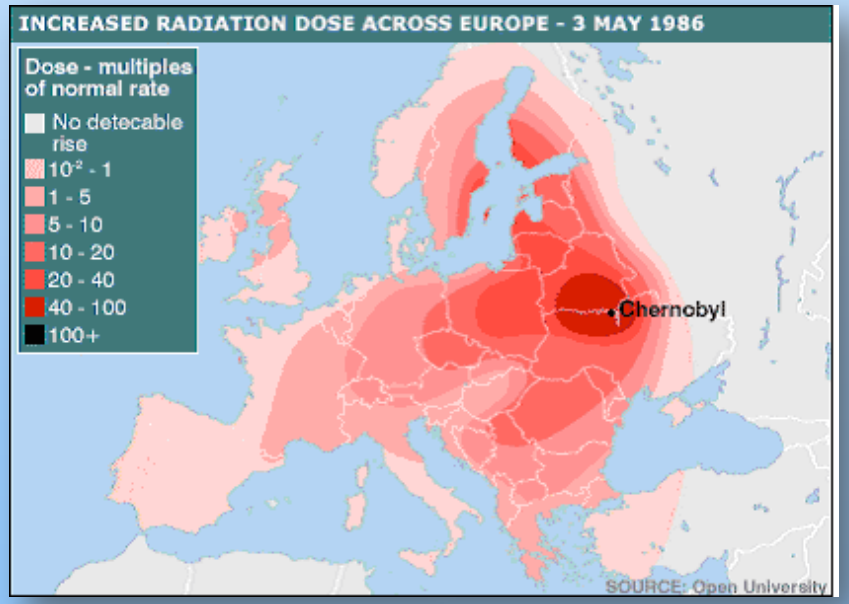
- Level 7 “Criticality accident”





Chernobyl: Consequences

- Casualties
  - 237 emergency workers
  - 270,000 cancers
    - 93,000 fatal
    - Children highly affected
  - Est. 140,000 more deaths
  - Source: Belarus Govt.
- Long-term effects
  - 140,000 evacuated
  - Chernobyl and Pripyat

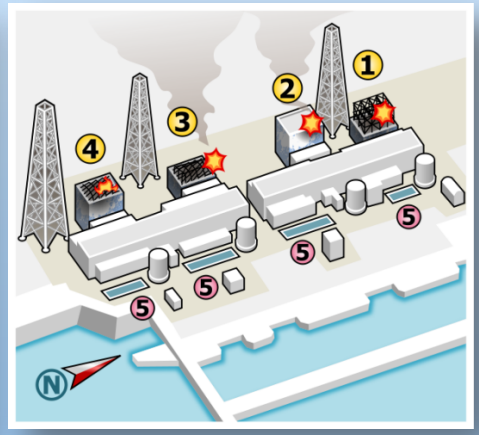


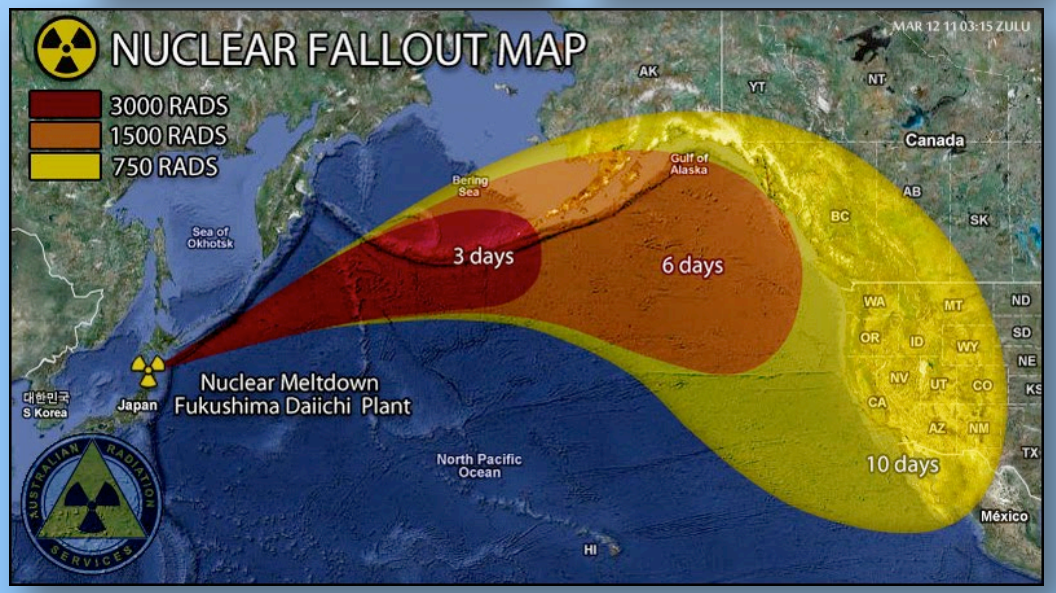
aka. Fukushima no.1

FUKUSHIMA DAIICHI
(MARCH 11, 2011 – PRESENT)

Background

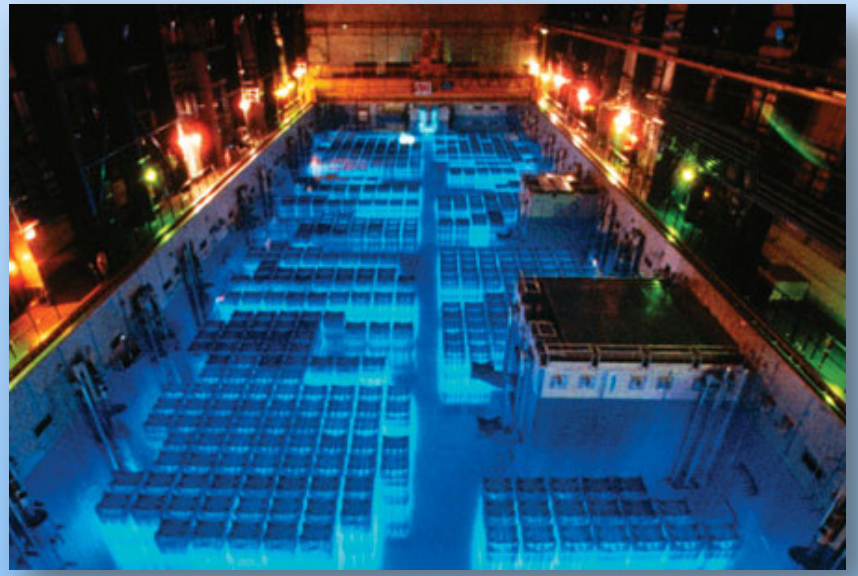
- Fukushima1
- Commissioned: 1971
- Gen 2 design
  - 6 reactors
  - 2 more planned (now cancelled)
- Run by TEPCO
  - Tokyo Electric Power Company





Disaster Overview

- Level 7 – Major Accident
- “Decay heat”
  - Reactors shut down but continued cooling is required for spent fuel rods
- Cooling required emergency generators
  - Generators disabled by tsunami



(above) Example of spent fuel pool. With no cooling, water evaporated and left the radioactive fuel rods exposed.

Disaster Timeline

March 11 – Day 1

- 14:46
  - 9.0 earthquake off Honshu
- 15:27
  - First tsunami hits Fukushima I
- 15:46
  - Backup diesel generators disabled
- 19:03

Day 1 – onwards

- Core temperature climbs
  - All 6 reactors affected
- Explosions
  - March 12 – Reactor 1
  - March 14 – Reactor 3
- Fuel rods exposed
  - Seawater is injected
- March 15
  - Fire breaks out at Reactor 4
- Workers attempt to restore power but cooling pumps are damaged beyond repair

Disaster Timeline

Current situation

- May 18 report
  - No stable cooling at reactors 1–4
  - Continued injection of water
  - “Cold shutdown” not achieved
- Radiation release
  - Seawater
  - Vapor

More information

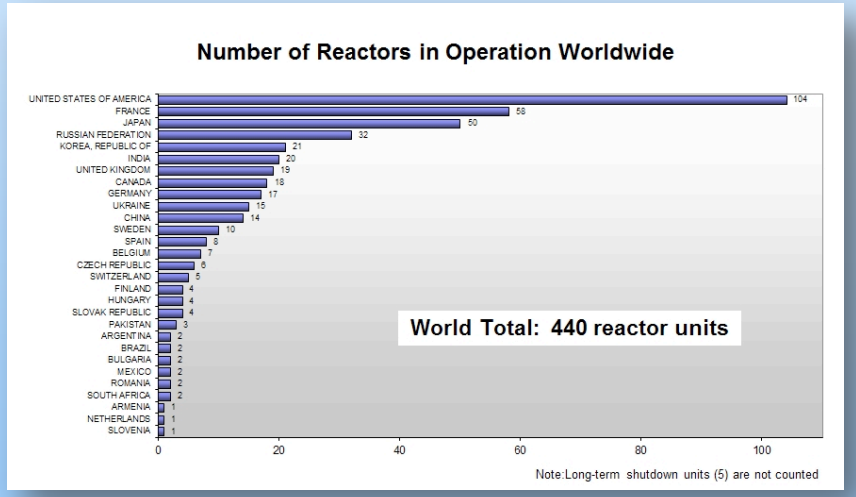
- IAEA homepage
  - Continuous update on Japan
  - Status of reactors 1-4
  - Status of monitoring and restrictions
  - Radiation monitoring data
- http://www.aqmd.gov/
  - Radiation levels in southern california

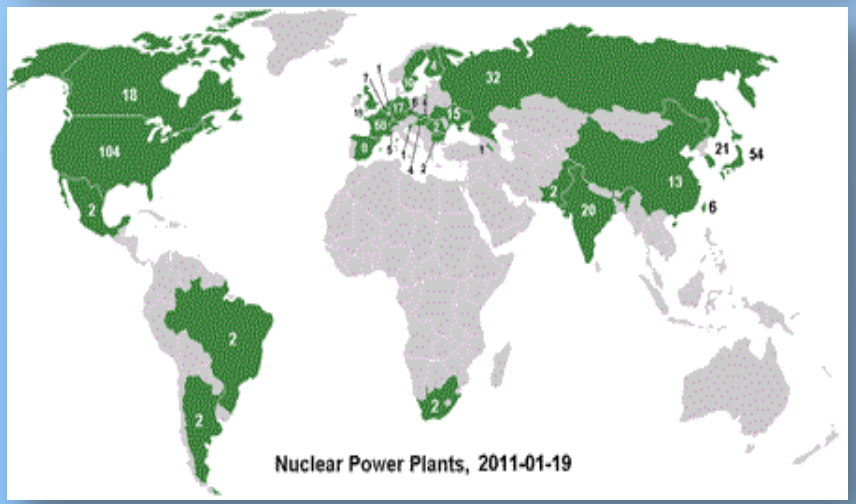
How they apply to us

NUCLEAR DISASTERS

Background

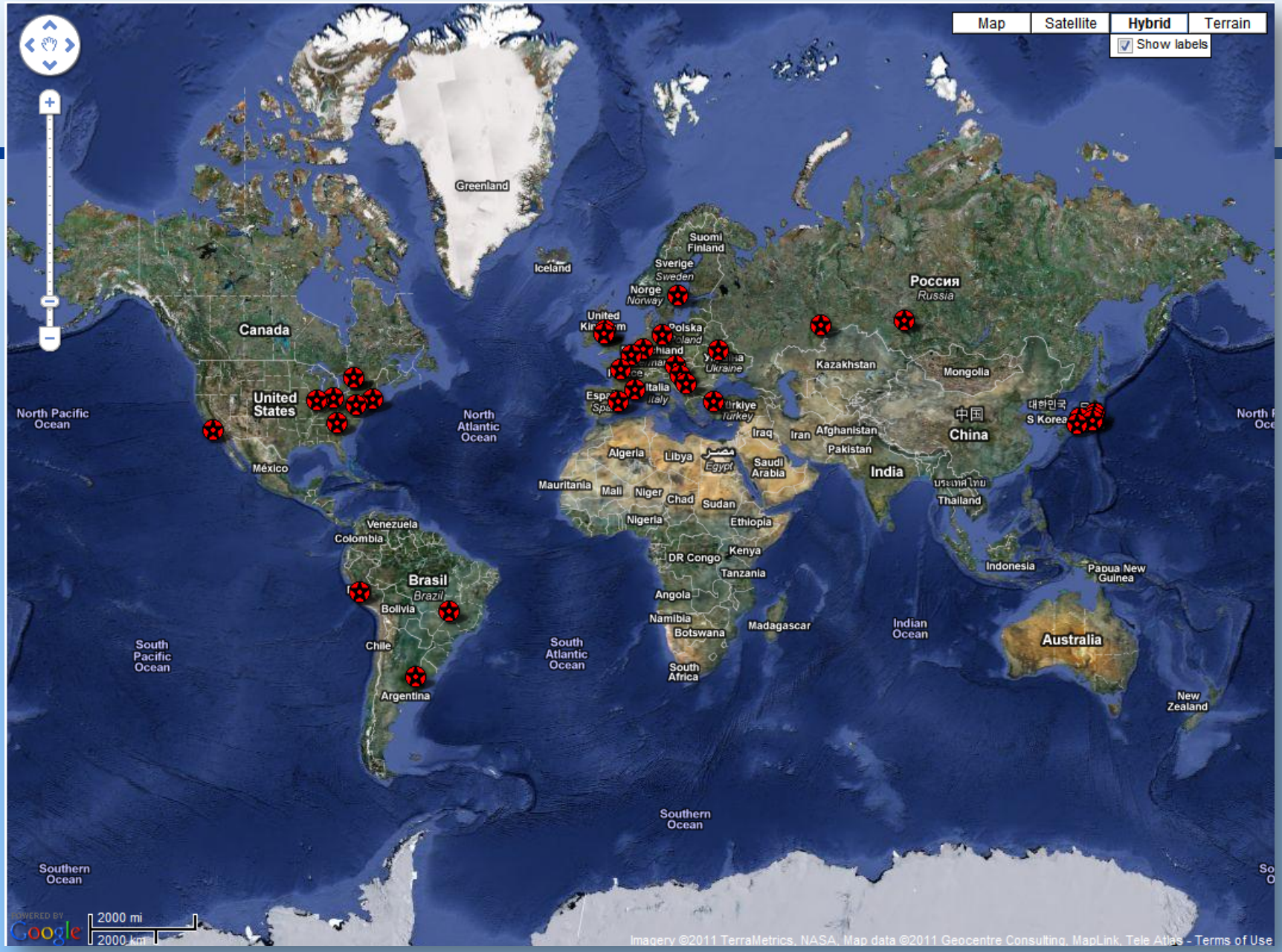
- 440 reactors worldwide (IAEA 2000)
  - 104 in the US
  - 99 serious accidents (1952–2009)
- Current statistics
  - 447 plants, 65 under construction
  - 2 plants in California
    - Diablo Canyon





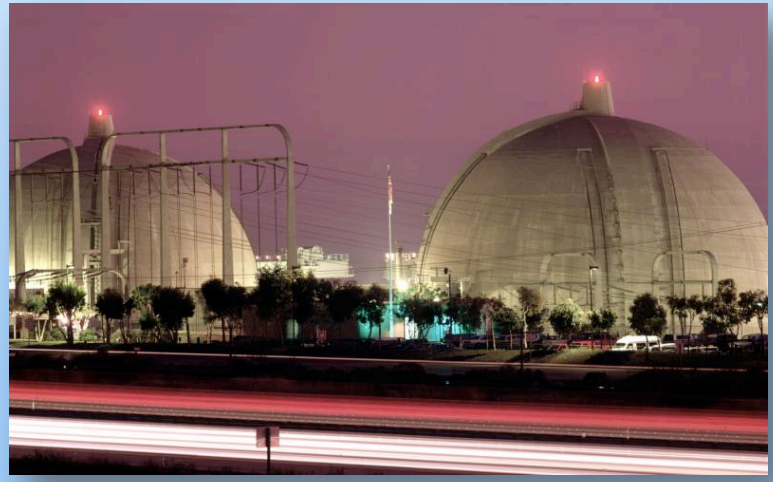
[Notable] Nuclear power plant accidents: listed and ranked since 1952. (Courtesy of Guardian.co.uk)

Year	Incident	INES level	Country	IAEA description
2011	**Fukushima**	**7**	**Japan**	**Reactor shutdown after the 2011 Sendai earthquake and tsunami; failure of emergency cooling caused an explosion**
2011	**Onagawa**		**Japan**	**Reactor shutdown after the 2011 Sendai earthquake and tsunami caused a fire**
2006	Fleurus	4	Belgium	Severe health effects for a worker at a commercial irradiation facility as a result of high doses of radiation
2006	Forsmark	2	Sweden	Degraded safety functions for common cause failure in the emergency power supply system at nuclear power plant
2006	Erwin		US	Thirty-five litres of a highly enriched uranium solution leaked during transfer
2005	Sellafield	3	UK	Release of large quantity of radioactive material, contained within the installation
2005	Atucha	2	Argentina	Overexposure of a worker at a power reactor exceeding the annual limit
2005	Braidwood		US	Nuclear material leak
2003	Paks	3	Hungary	Partially spent fuel rods undergoing cleaning in a tank of heavy water ruptured and spilled fuel pellets
1999	Tokaimura	4	Japan	Fatal overexposures of workers following a criticality event at a nuclear facility
1999	Yanangio	3	Peru	Incident with radiography source resulting in severe radiation burns
1999	Ikitelli	3	Turkey	Loss of a highly radioactive Co-60 source
1999	Ishikawa	2	Japan	Control rod malfunction
1993	Tomsk	4	Russia	Pressure buildup led to an explosive mechanical failure
1993	Cadarache	2	France	Spread of contamination to an area not expected by design
1989	Vandellos	3	Spain	Near accident caused by fire resulting in loss of safety systems at the nuclear power station
1989	Greifswald		Germany	Excessive heating which damaged ten fuel rods
1986	Chernobyl	7	Ukraine (USSR)	Widespread health and environmental effects. External release of a significant fraction of reactor core inventory
1986	Hamm-Uentrop		Germany	Spherical fuel pebble became lodged in the pipe used to deliver fuel elements to the reactor
1981	Tsuraga	2	Japan	More than 100 workers were exposed to doses of up to 155 millirem per day radiation
1980	Saint Laurent des Eaux	4	France	Melting of one channel of fuel in the reactor with no release outside the site
1979	Three Mile Island	5	US	Severe damage to the reactor core
1977	Jaslovské Bohunice	4	Czechoslovakia	Damaged fuel integrity, extensive corrosion damage of fuel cladding and release of radioactivity
1969	Lucens		Switzerland	Total loss of coolant led to a power excursion and explosion of experimental reactor
1967	Chapelcross		UK	Graphite debris partially blocked a fuel channel causing a fuel element to melt and catch fire
1966	Monroe		US	Sodium cooling system malfunction
1964	Charlestown		US	Error by a worker at a United Nuclear Corporation fuel facility led to an accidental criticality
1959	Santa Susana Field Lab.		US	Partial core meltdown
1958	Chalk River		Canada	Due to inadequate cooling a damaged uranium fuel rod caught fire and was torn in two
1958	Vinča		Yugoslavia	During a subcritical counting experiment a power buildup went undetected - six scientists received high doses
1957	Kyshtym	6	Russia	Significant release of radioactive material to the environment from explosion of a high activity waste tank.
1957	Windscale Pile	5	UK	Release of radioactive material to the environment following a fire in a reactor core
1952	Chalk River	5	Canada	A reactor shutoff rod failure, combined with several operator errors, led to a major power excursion of more than double the reactor's rated output at AECL's NRX reactor


Map
Satellite
Hybrid
Terrain
Show labels
Greenland
Iceland
Canada
United States
México
North Pacific Ocean
North Atlantic Ocean
South Pacific Ocean
South Atlantic Ocean
Indian Ocean
Southern Ocean
Suomi Finland
Sverige Sweden
Norge Norway
Россия Russia
Kazakhstan
Mongolia
中国 China
대한민국 S Korea
Iraq
Iran
Afghanistan
Pakistan
India
Saudi Arabia
Algeria
Libya
Egypt
Mauritania
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Kenya
DR Congo
Tanzania
Angola
Namibia
Botswana
Madagascar
South Africa
Indonesia
Papua New Guinea
Australia
New Zealand
Thailand
Venezuela
Colombia
Brasil
Brazil
Bolivia
Chile
Argentina
2000 mi
2000 km
Imagery ©2011 TerraMetrics, NASA, Map data ©2011 Geocentre Consulting, MapLink, Tele Atlas - Terms of Use

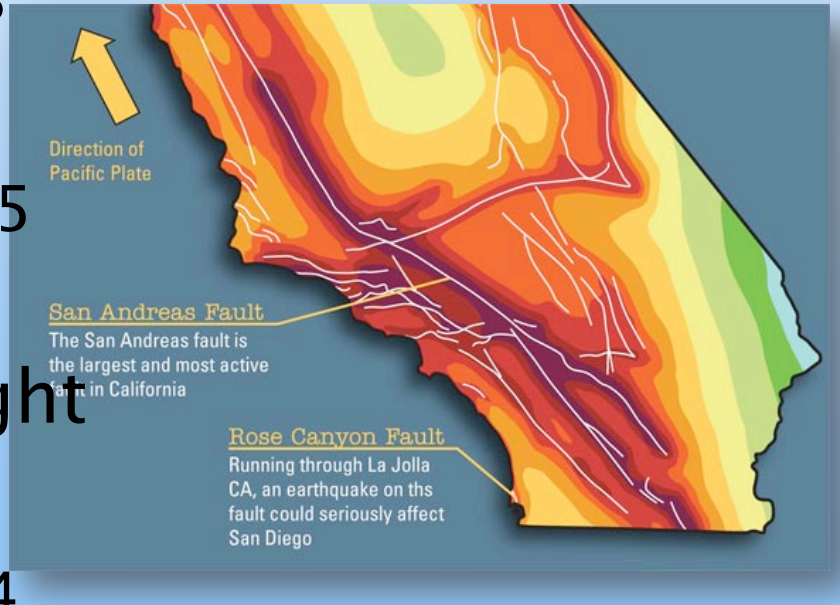
In California

- San Onofre & Diablo Canyon
  - 1968-83 & 1985-6
  - Total of 5 reactors
    - 4 in operation
  - Run by PG&E
    - http://www.pge.com/
    - Current: Diablo Canyon undergoing "seismic study" and pending license renewal
      - 4 faults (2 faults discovered since



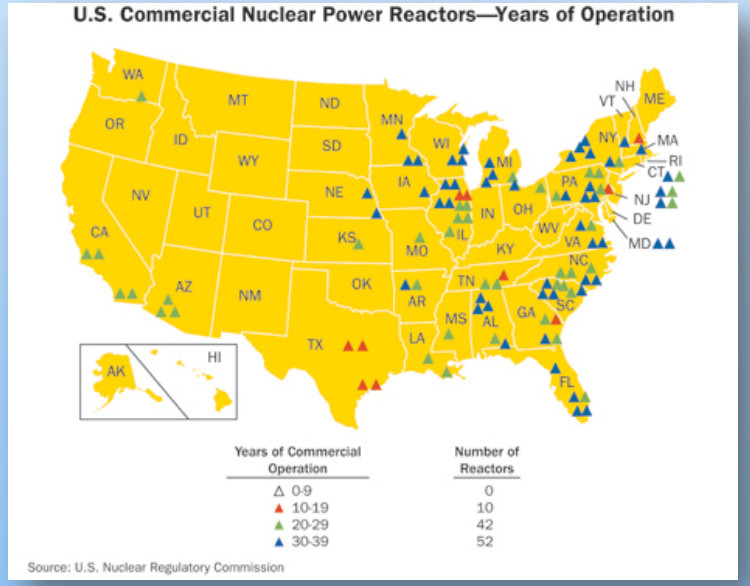
Risks?

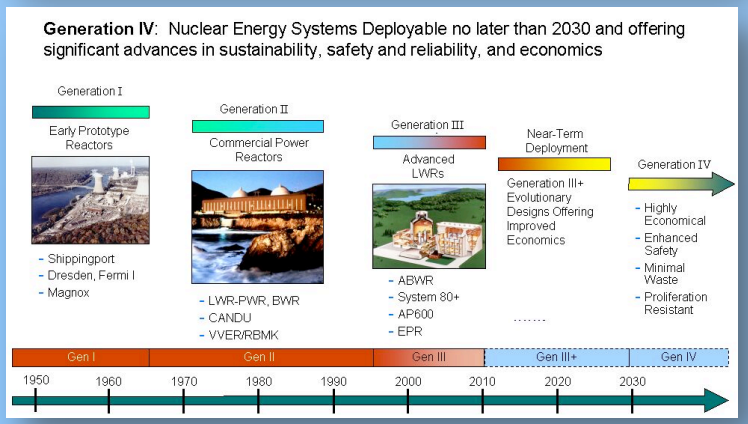
- Earthquake resistance?
  - San Onofre: 7.0
  - Diablo Canyon: 6.75-7.5
  - **Fukushima: 8.6**
- Tsunami? – key oversight
- Risks?
  - NRC (2010): 1 in 58,824 annual chance of core damage caused by earthquake at San Onofre



Future

- DOE
  - http://www.energy.gov/
- Modern reactors
  - Gen II (pre-1990s)
    - most commercial reactors
    - most at risk
    - est. life of 30-40 years, extendable to 80
  - Gen III and beyond (IV)
    - improved safety
      - (IAEA targets $1x10^{-5}$ chance of meltdown)
    - reduced costs





Works Cited

- Department of Energy. US DOE. Web. 22 May 2011. <http://www.energy.gov/>.
- Google Maps. Web. 22 May 2011. <http://maps.google.com/>.
- International Atomic Energy Agency. IAEA. Web. 22 May 2011. <http://www.iaea.org>.
- NRC: Nuclear Regulatory Commission. Web. 22 May 2011. <http://www.nrc.gov>.
- "Nuclear Power Plant Accidents: Listed, Visualised and Ranked since 1952 | World News | Guardian.co.uk." Guardian UK. Web. 22 May 2011. <http://www.guardian.co.uk/news/datablog/2011/mar/14/nuclear-power-plant-accidents-list-rank>.
- Pacific Gas and Electric Company. Web. 22 May 2011. <http://www.pge.com/>.
- University of Illinois at Urbana-Champaign. Web. 22 May 2011. <http://illinois.edu/>.
- World Nuclear Association | Nuclear Power - a Sustainable Energy Resource. Web. 22 May 2011. <http://www.world-nuclear.org>.

QUESTIONS?