

**Radiation: More Harmful to Girls and Women**

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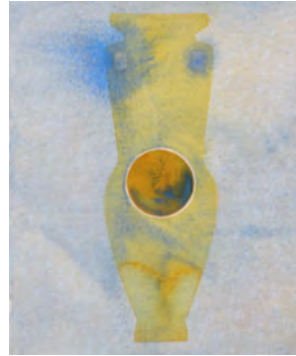
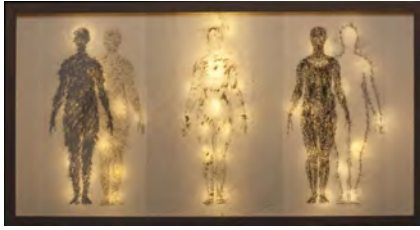


Original Art by **Loren Olson**

Atomic Radiation is more harmful to girls and women compared to boys and men.

A number of independent analysts have found this pattern; I am one of them.

## Radioactivity impacts all life on Earth



This talk will focus on harm to people, however all forms of life are impacted by radiation.

## Gender and Radiation: Why care?

### **Social Choices:**

- **Insurance / health costs**
- **Energy**
- **Security**
- **Climate Mitigation**
- **Occupational Equity**
- **Space / Multi-Planet plans**

### **Personal Choices:**

- Care of daughters v sons
- Location of home
- Choice of occupation
- Rate of high-altitude travel
- Optional medical imaging
- Visits to known contaminated zones

Gender and Radiation: Why care?

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Care of daughters v sons

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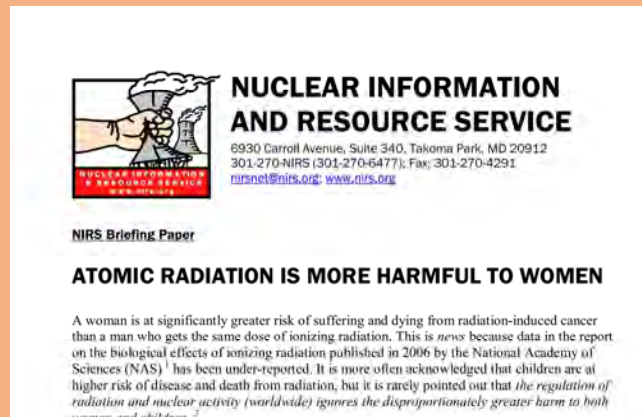
Optional medical imaging

Visits to known contaminated zones

“Is radiation more harmful to me compared to a man?”

~circa 2009

- US National Academy of Science (NAS) Biological Effects of Ionizing Radiation, VII Phase 2 (2006) “BEIR VII”
- Dr Arjun Makhijani, et al (2006) “Science for the Vulnerable” and “Healthy from the Start”
- Multiple nuclear power reactors explode in Japan’s Fukushima Prefecture (2011)



In 2009 a simple question was posed to me during a public lecture. A woman asked “Is radiation more harmful to women?” I spoke to pregnancy and she clarified that she meant her own body.

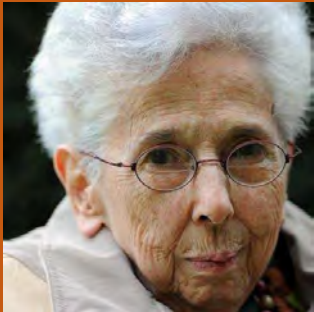

I had never heard anything about gender as a factor in radiation harm.

I had missed two memos, one from the US National Academy of Science and one from a colleague, Dr Arjun Makhijani, both in 2006...

I searched the literature, but I did not find these sources or any other.


When I did my own independent analysis, and wrote the paper “Atomic Radiation is More Harmful to Women” in 2011, my work was an independent confirmation of Makhijani’s findings.

Is Gender a factor in radiation harm (cancer)?



Dr. Rosalie Bertell

Females have 50% more high-risk tissue compared to males



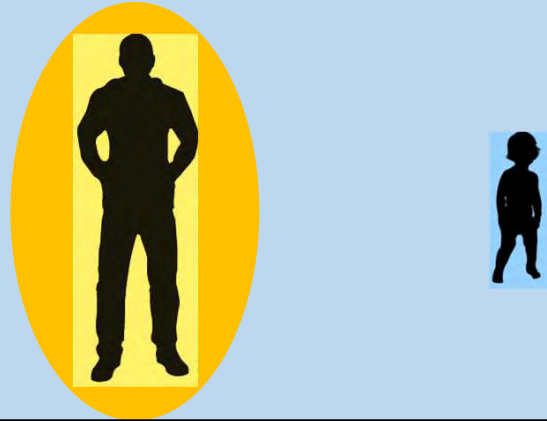
In 2011 reactors were blowing up in Japan adding urgency to the question about gender being a factor in radiation harm?

I contacted my mentor, Dr Rosalie Bertell. She pointed me to only large data-set we have that contains all ages and both genders: the survivors of the A-bomb attacks by the United States on Japan in 1945.

Since I use this data, I must acknowledge that my government chose to use the first nuclear weapons on cities full of people: Hiroshima and Nagasaki Japan, establishing beyond doubt that nuclear weapons are indiscriminate.

Five years later, the US initiated a long-term study of the atomic bomb survivors. Researchers assumed that humanitarian aid might “skew the results” of their study and so they offered no medical treatment. The results of that study is used widely, including by me, here, today. These numbers represent lives of people that endured horrific events. As only one woman, I need to say I am sorry. I regret this history, I wish it had never happened. As I think about new data-sets, we must hope that it is never from another nuclear attack.

Radiation regulation has been based on  
“Reference Man”



My mentor and I were well aware that historically, global radiation regulation assumes that anyone exposed to radiation is an adult male: a “Reference Man”

## Official Definition of “Reference Man”

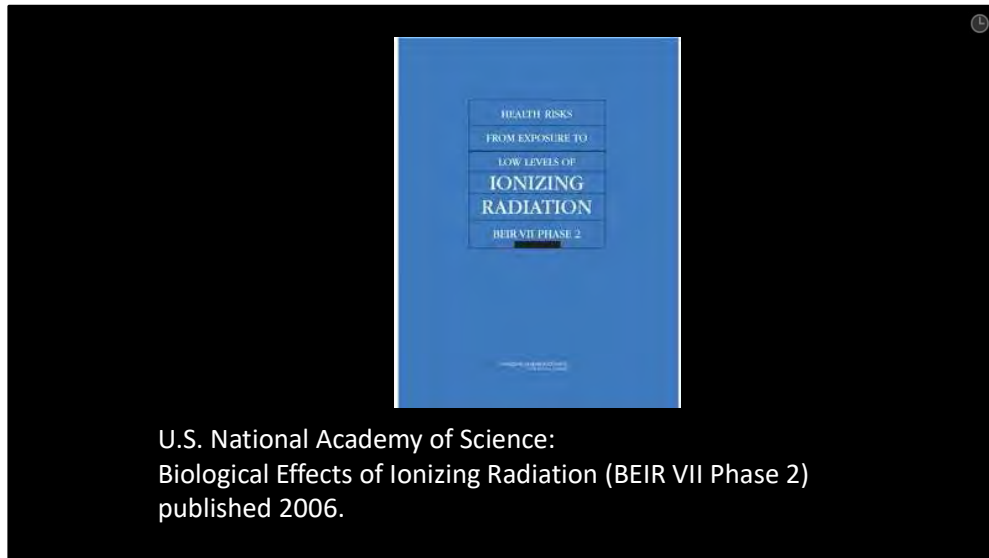
“Reference man is defined as being between 20-30 years of age, weighing 70 kg, is 170 cm in height, and lives in a climate with an average temperature of from 10° to 20°C. He is a Caucasian and is a Western European or North American in habitat and custom.”

Source: International Commission on Radiological Protection. *Report of the Task Group on Reference Man*. [ICRP Publication] No. 23. Oxford: Pergamon Press, 1975, Adopted October 1974. Page 4.

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This 2006 report by the US National Academy of Sciences, the Biological Effects of Ionizing Radiation, #VII, or BEIR VII, is the source of the data for my findings, and Dr Makhijani's. It is primarily from the A-Bomb Survivors of Hiroshima and Nagasaki Japan.

The report provides the numbers, the graphics I am going to share with you are not in the report.

On-line download of PDF of full report available here:  
[https://www.nap.edu/login.php?record\\_id=11340&page=https%3A%2F%2Fwww.nap.edu%2Fdownload%2F11340](https://www.nap.edu/login.php?record_id=11340&page=https%3A%2F%2Fwww.nap.edu%2Fdownload%2F11340)

Screen capture of report cover



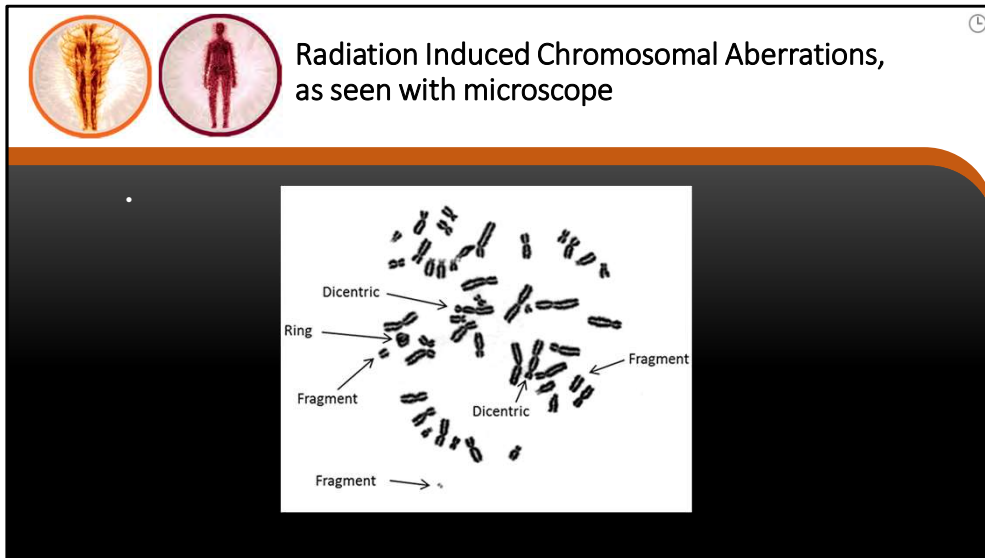


In August, 1945 a single Atomic bomb was dropped on each city. 150,000 people died due to the atomic blasts and fireballs. Over time, many more. Since there were shelters, incredibly, some people survived. There are 100,000 survivors in the Life Span Study.

The Lifespan Study officially began 5 years after the bombs fell. The people were very strong survivors. It therefore does not reflect a “general” population...like us here today.

And yet, this is the only group of all ages and both genders that have been tracked more than 70 years. In their lives and deaths is news.

**Photo Credit:** Nagasaki Atomic Bomb Museum, via Hibakusha Stories Project.



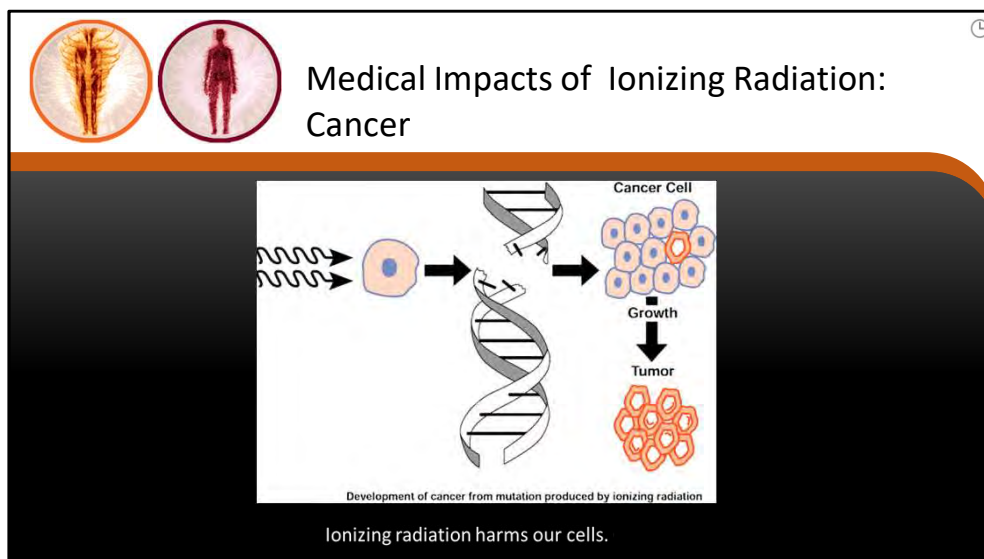
Radiation is invisible but we can see the damage it has done to these chromosomes.

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**Resources:**

Dicentric and other chromosomal aberrations are common in people who have suffered acute radiation exposure. The damaged chromosomes are found in white blood cells and can be assessed as a biological dosimeter. More information here:

[http://www.rerf.jp/radefx/late\\_e/chromoab.html](http://www.rerf.jp/radefx/late_e/chromoab.html)



Cancer is the most studied long-term consequence of non-lethal radiation exposure. It is also the only radiation exposure outcome considered in most regulations.

WHEN genetic material inside a living cell is damaged, sometimes our bodies can repair that damage. Otherwise the abnormal cell may sit quietly in the body for years or even decades before it makes us sick.

There is no way to predict which exposure will result in cancer. In general, more radiation equals more cancer risk. However, even an exposure too small to measure could, sometimes, result in cancer death.

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### Resources

Previous pages have listed some of the classic authors on radiation of the 20<sup>th</sup>

century. The National Institute of Environmental Health in the United States published this broader piece “Cancer and the Environment: What You Need to Know.” posted:

[http://www.niehs.nih.gov/health/materials/cancer\\_and\\_the\\_environment\\_508.pdf](http://www.niehs.nih.gov/health/materials/cancer_and_the_environment_508.pdf)



We have long known that children's bodies are small; so the same amount of radiation delivers a larger dose.

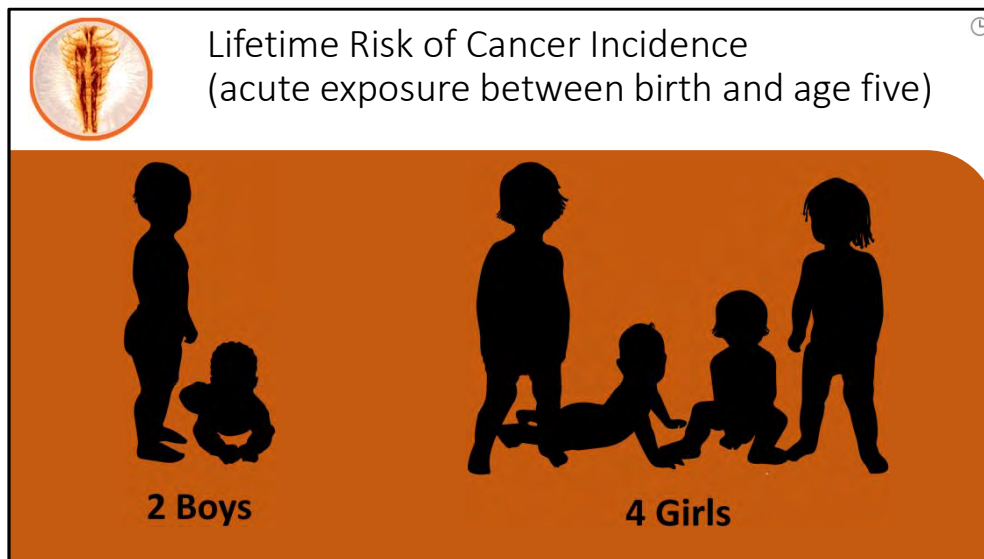
Since children are growing, the cells in their bodies are dividing more rapidly. The DNA in cells is more likely to be damaged when in cell division.

We cannot know which exposure to radiation will result in cancer. AND we can rarely prove that a particular cancer was caused by radiation. Therefore we have to study large groups called data-sets and look for patterns.

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**Art Credit:**

Saro Lynch-Thomason, Fullsteam Labs who created all the silhouettes used in this presentation



The news, from the atomic ashes of Hiroshima and Nagasaki is that biological sex makes a big difference in the degree of radiation harm to individuals.

The Survivors were grouped by the age they were at the time of the bombing. These groups were tracked over their lifetimes. Cancers and cancer deaths were counted.

Both males and females who were five years or younger when exposed to the A-Bomb radiation in August, 1945 had the most cancer at some point in their lives.

Girls in this group were twice as likely to get cancer at some point than were boys. For every male in the birth-5 cohort that suffered cancer at some point in their lives, **two** females got cancer.

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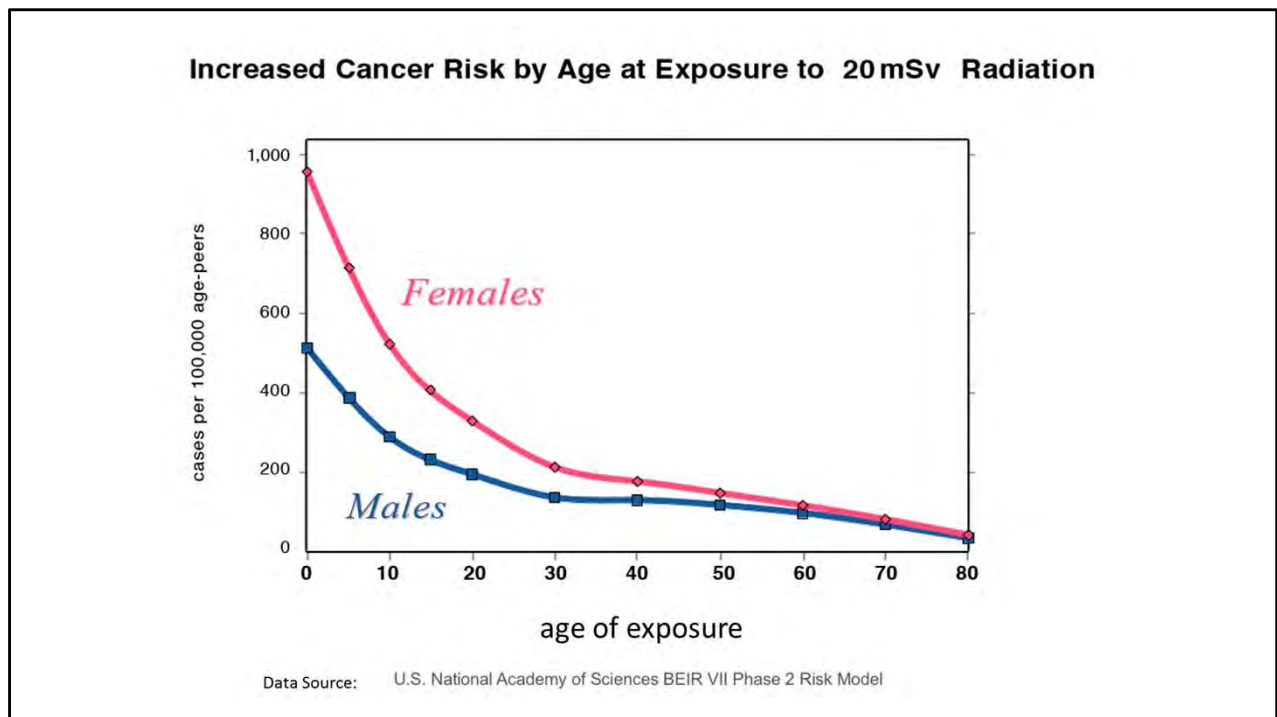
**Source:**

Olson, 2011. NIRS Briefing Paper: "Atomic Radiation is more harmful to women." posted: <http://www.nirs.org/radiation/radhealth/radhealthhome.htm>

Makhijani, 2005 started the Healthy from the Start Campaign to address disproportionate impact of ionizing radiation on young females.

<http://ieer.org/projects/healthy-from-the-start/>

And <http://ieer.org/resource/health-and-safety/open-letter-to-president-bush-on-protecting-the-most-vulnerable/>



Here is the same information in graphic form. The data points are from the NAS publication of 60 years of A-bomb Life Span Study data, but it did not publish the graph.

The pink line is girls, the blue line is boys. We can easily see the gender difference and that it is greatest in the youngest children.

I am going to show you this same graph several times so I will explain it a little.

The level of radiation exposure is fixed and constant. Age-of-exposure, at the time of the bombs in August, 1945 is the bottom axis;

numbers of cancers in each age cohort are the vertical axis.

The age of cancer onset is not shown here. Cancers for all exposure-age cohorts occur across the remaining lifespan, so these are lifetime outcomes from the single event in 1945.

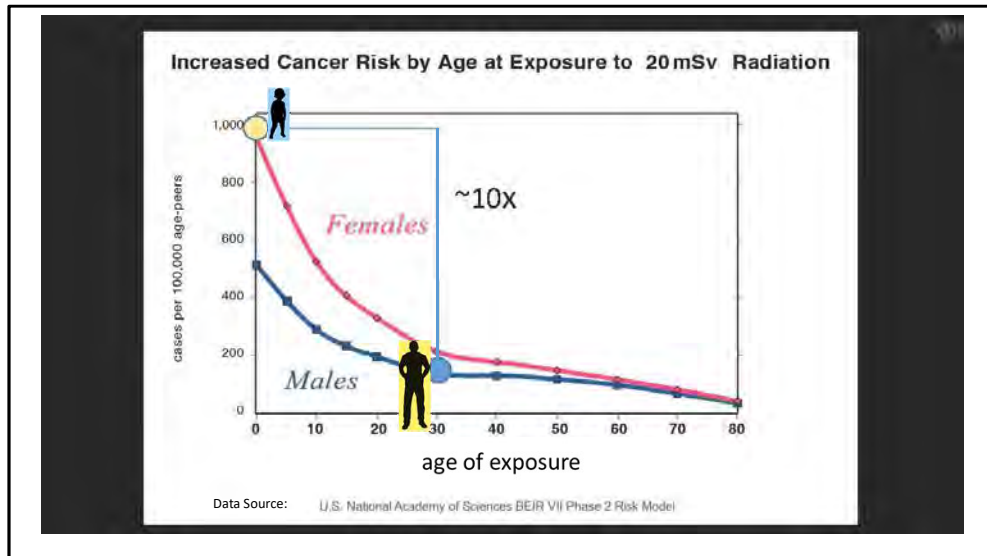
The entire graph is a snapshot of our species cancer-response to a burst of penetrating radiation.



PHOTO REMOVED FOR POSTING

Little girls are not a “subpopulation” as some regulators think.  
We are an inextricable link in the human lifecycle.

Photo credit: by permission of the photographer. Single use only, do not post this slide.



THIS is the same graph, comparing the rate of cancer among the youngest age-female-cohort (pink line upper left) and the adult-male-cohort closest to the definition of Reference Man.

We can see a ten-fold difference. Members of the group exposed in girlhood suffer ten times more cancers than the group used by global regulators.

In Biological research, ten times more is a RED flag.

The cancers from childhood exposure come across the lifetime

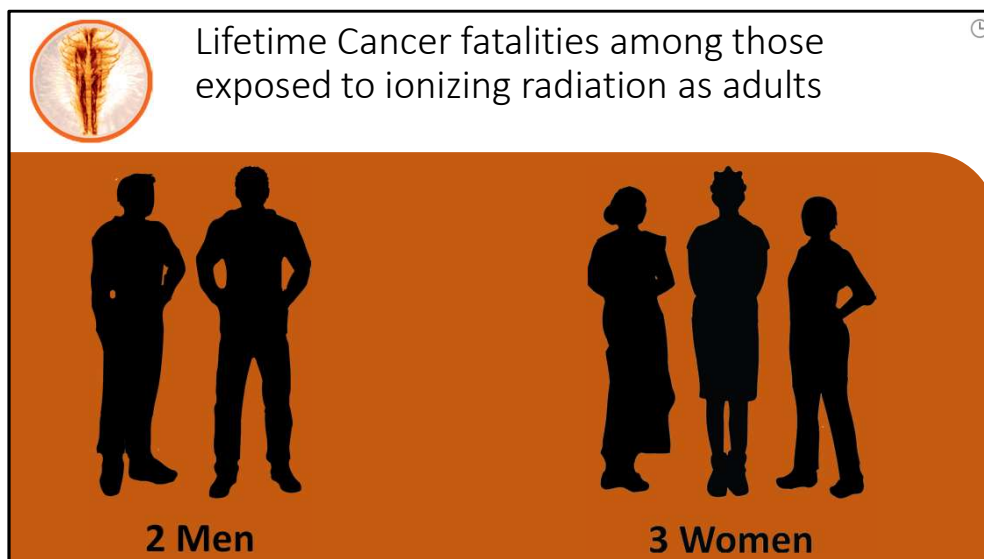


Here is the same information with pictures.

For every ten girls and women who suffered cancer from childhood exposure, there was only one male “reference man” who got cancer.

These cancers do not come only in childhood—they are across the lifetime.

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Gender was also a factor for those who were adults at the time of the bombings.

Over their lifetime women exposed as adults suffered 50% more cancer death than did men in the same age group.

For every 2 men in these cohorts who died of cancer, three women died of cancer.

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Source:  
(see above) Olson, Makhijani, numbers in tables of BEIR VII.

## UN Treaty on the Prohibition of Nuclear Weapons

### Preamble

...*Cognizant* that ...nuclear weapons... pose grave implications for human survival, the environment, socioeconomic development, the global economy, food security

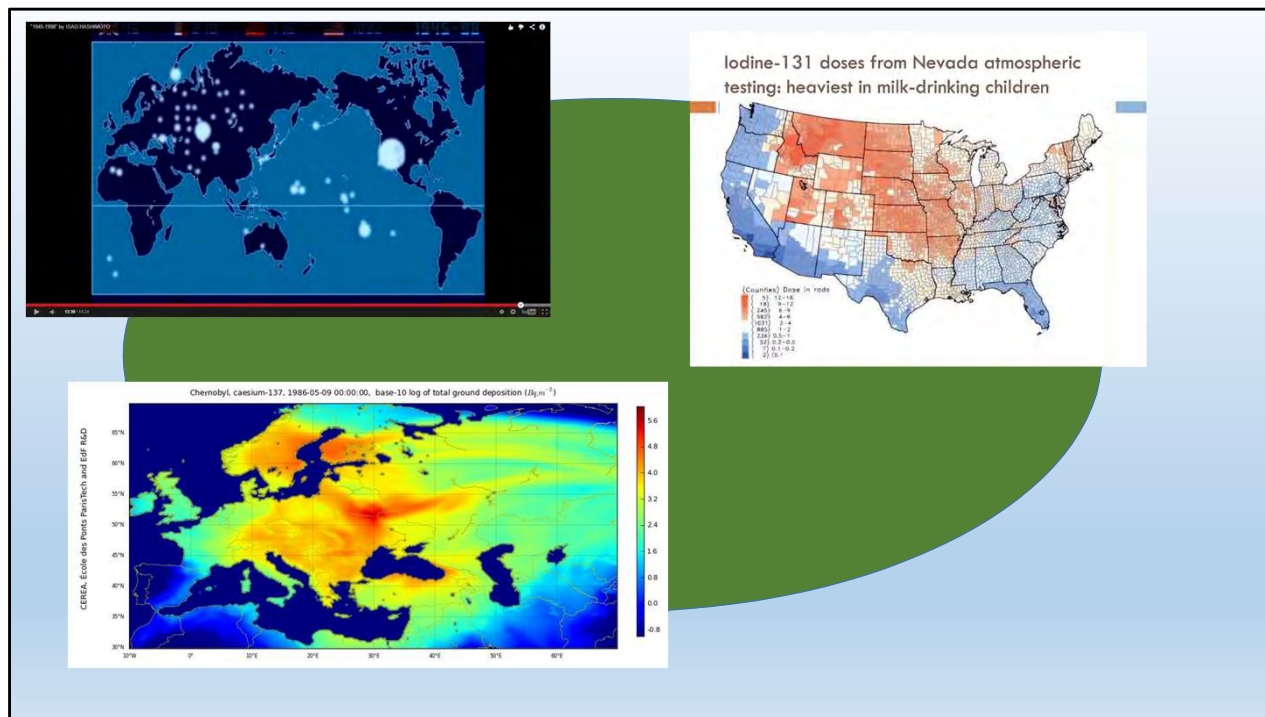
*and the health of current and future generations, and have a disproportionate impact on women and girls, including as a result of ionizing radiation...*



I am very glad that in 2014 I was invited by diplomats at the to the UN to speak to how Humanitarian Law applies to nuclear weapons, and am pleased and proud of this text in the preamble of the 2017 global Convention on the Prohibition of Nuclear Weapons, signed by 59 nations, to date:

...*Cognizant* that ...nuclear weapons... pose grave implications for human survival, the environment, socioeconomic development, the global economy, food security and ***the health of current and future generations, and have a disproportionate impact on women and girls, including as a result of ionizing radiation...*** (emphasis added)

The full text of the treaty is available here: <http://undocs.org/A/CONF.229/2017/8>  
Information on 59 nations that are signatories and the 2017 Nobel Prize is posted by ICANW.org



The use of nuclear weapons is a very limited example of the exposure of human bodies to ionizing radiation.

Here are pictured the sites where more than 2000 nuclear weapons were detonated as “tests” between 1945 and 1998. There have been additional small detonations since.

To the right is a map showing radiation exposures from radioactive iodine released during tests in Nevada. Below is a reconstruction of the measured cesium 137 from the single Soviet reactor, Chernobyl, that exploded and burned in 1986.

Image sources:

Isaio Hashimoto, from film 1945-1998, used by permission

Radiation doses from Iodine released during nuclear tests at the Nevada Test Site, US EPA, posted by Institute for Energy and Environmental Research.

Cesium 137 distribution from Chernobyl, original by CEREA



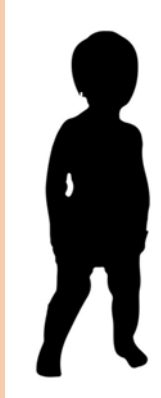
## Sources of daily radiation exposure

- Natural background radiation—causes “natural background cancer and leukemia”
- Radon gas—highly efficient homes increase this hazard
- Air travel—our atmosphere is a radiation shield
  - Divided families—increasing travels / exposure to children
- Medical and dental diagnosis—less per image—now more images!
- Medical treatment (interventional radiation-assisted surgery)
- Living near nuclear industry sites with permitted routine emissions

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It is not her job to stand up to a care provider



A female child, a girl, has double the chance of harm (cancer at some point) compared to a boy the same age. How does this change decisions about the use of CT scans, X-rays and fluoroscopes?

At what point will gender be factored?

## RESEARCH QUESTIONS

- Do we see a gender factor in radiation harm in other species?
- Is there a gender factor when exposure is due to internalized radioactivity?
  - Why is gender a factor in radiation harm?

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## RESEARCH QUESTIONS

- Why is gender a factor in radiation harm?
  - Percent reproductive tissue?
    - Percent fatty tissue?
    - Rate of cell division?
  - Other maturation factors?

Read slide



## Rate of Exposure

- **QUESTION:**

Many small radiation exposures over time = same harm as ONE BIG exposure?

- **ANSWER:** YES.

- Source: INWORKS– Atomic workers from Europe and North America: same liner-no-threshold risk model as the Hiroshima and Nagasaki Survivors in the Life Span study.

- Richardson, et al / BMJ 2015;351:h5359

- **QUESTION:** Do many small radiation exposures coming over time cause the same degree of harm as if the radiation comes as ONE BIG exposure?

- **ANSWER:** YES.

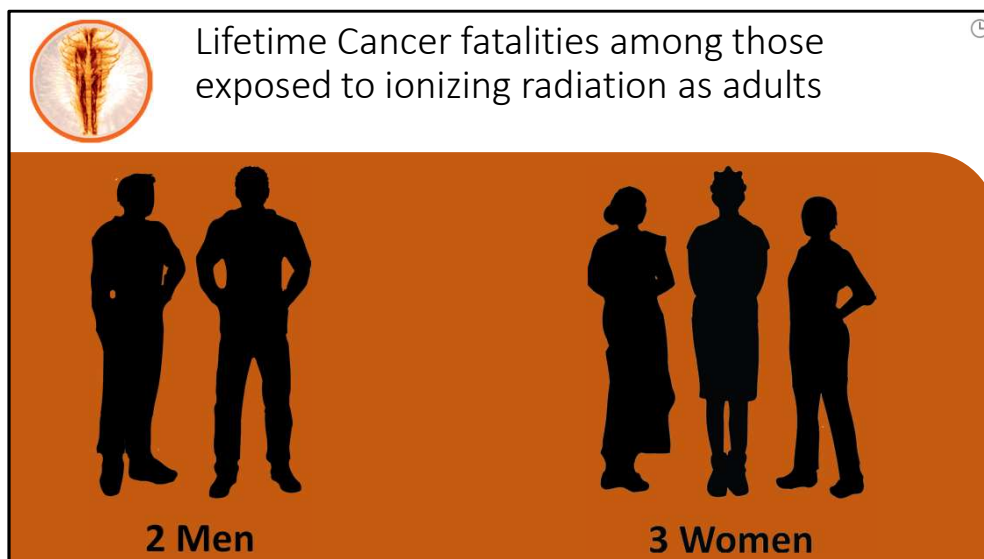
- INWORKS– Atomic workers from Europe and North America getting ongoing, relatively small occupational radiation exposures were tracked for decades. The many exposures add up to the same level the A-Bomb survivors suffered in a single flash. The worker's cancers are described by same liner-no-threshold risk model as the Hiroshima and Nagasaki Survivors in the Life Span study.

- Richardson, et al / BMJ 2015;351:h5359

## What Case-Controlled Data-Sets to we have?

- A-Bomb Survivors—now 80 years of data—soon done
- IN-WORKS: Nuclear Workers, soon will have adult females
- Need to identify any other existing data-sets
- Big Data is often not the same as a data-set

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Returning now to the difference in outcomes when adults are exposed.

Over their lifetime women exposed as adults suffered 50% more cancer death than did men in the same age group.

For every 2 men in these cohorts who died of cancer, three women died of cancer.

\*\*\*

Source:  
(see above) Olson, Makhijani, numbers in tables of BEIR VII.

## Occupational Exposure: Disproportionate Gender-Based Impacts

- Radiation in the workplace is becoming more common
  - Radiation workers—tagged, monitored, regulated
    - Special consideration for “declared pregnancy”
  - Work with / around radiologic sources—not tagged or monitored
- Right-to-know gender (biological sex) is factor in risk of cancer (and possibly other impacts)
- Greater protection to prevent greater harm

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## Occupational Exposure: Disproportionate Gender-Based Impacts

- **Need a body of literature / findings**
- **Policy-makers need**
- **Practitioners also need**

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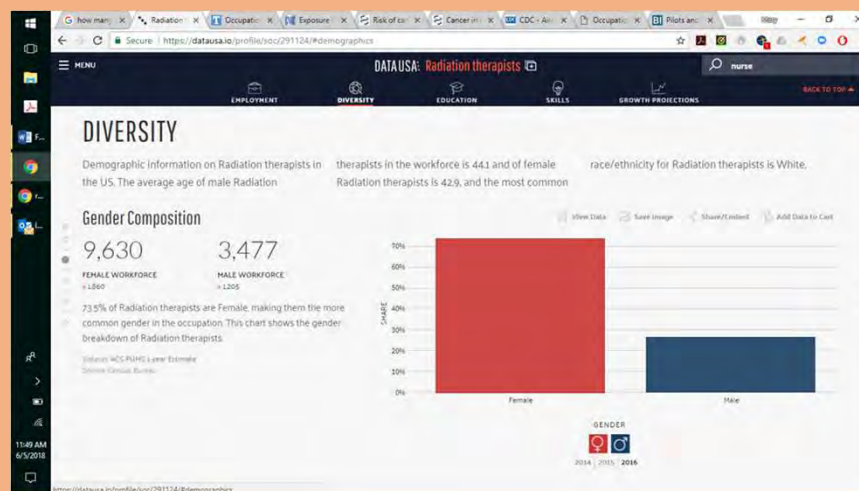


## Example 1: Radiation Therapists (USA data)



I am taking just two groups of workers to illustrate the need to ask and answer many questions.

# 73.5% of US Radiation Therapists are female

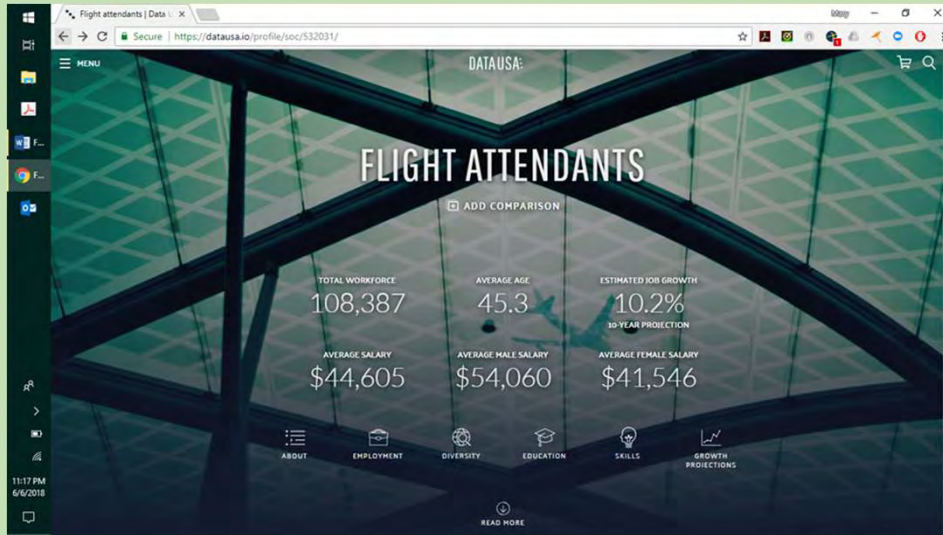


Radiation therapists are tagged radiation workers.

73.5% of the workforce is female.

Exposure will vary widely, but it is a given in the job.

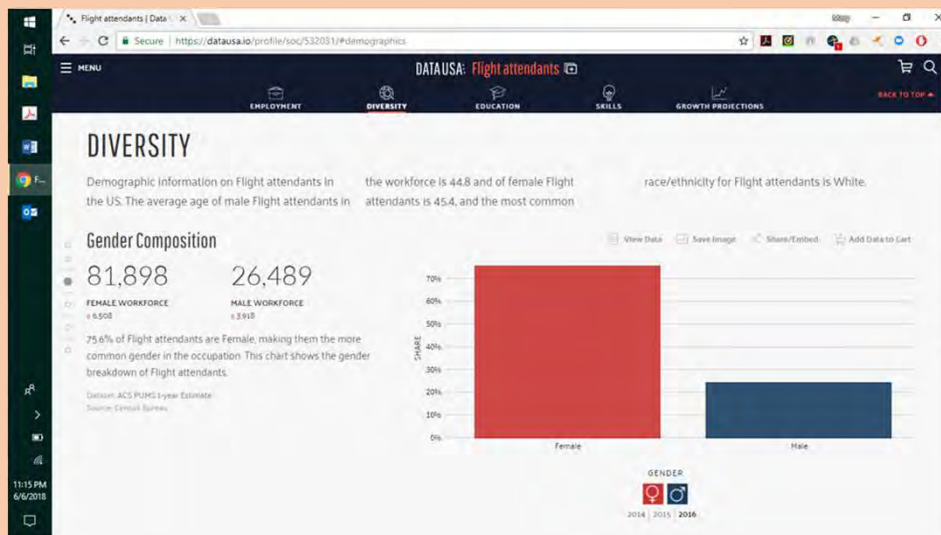
## Example 2: Flight Attendants (USA Data)



Flight attendants, particularly those serving on flights that exceed 6,000 meters, receive elevated radiation. My own anecdotal measurements read 100 times higher than at ground level, at only 4,500 meters.

The aviation workforce is not tagged or monitored.

75.6% of flight attendants are female



Of US-based crews, 75.6% of the flight attendants are female.

## RESEARCH QUESTIONS

- What is the smallest change in practice that changes the level of protection the most in any given occupation?
- If gender as a factor in harm is acknowledged, what is the savings from increased protection?
- What is the impact of disclosure on occupational choice?

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## Gender and Radiation Impact Project



**Working towards greater  
protection of the entire  
human lifecycle**

Founded in 2017,  
US Tax-Exempt Charity

Goal: channel funds via awards to  
support research on gender and  
radiation

Read slide



## Gender and Radiation Impact Project



**Working towards greater  
protection of the entire  
human lifecycle**

1. Development of a peer-reviewed literature on biological sex as a factor in outcomes from radiation exposure
2. Organize symposia and “side sessions” on radiation and human health
3. Sponsor funding for post-doctoral fellows and graduate students to work under outstanding leaders in science, medicine, policy and communications
4. Build a network of leaders ready to carry forward the mission of lifecycle protection

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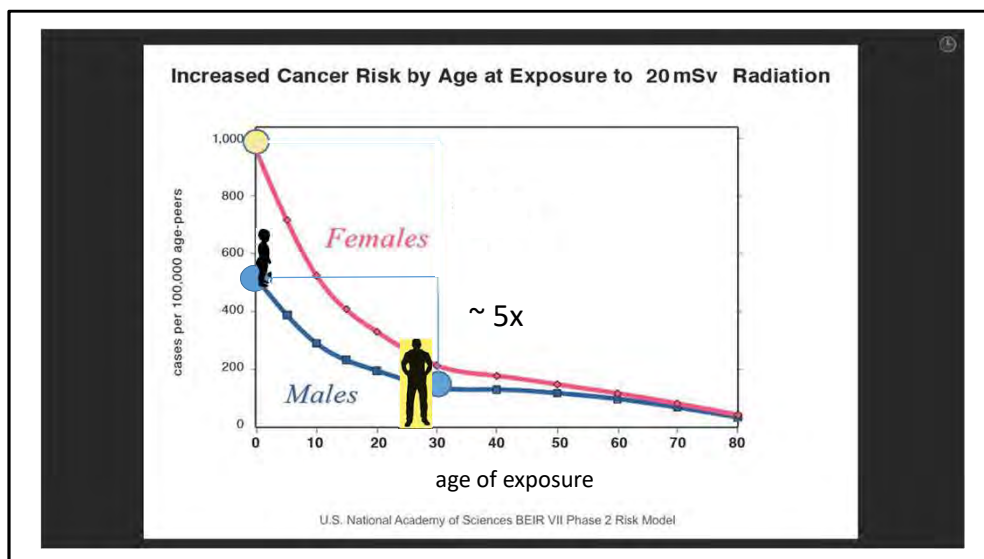
## Radiation regulation has been based on “Reference Man”



- Historical perspective: Early radiation workers were medical or military / para-military males
- No one stopped to evaluate whether Reference Man represents the GENERAL POPULATION

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The use of Reference Man also results in under-estimation of harm to males.

Comparing cancers resulting from exposure of boys to exposure of adult males, those exposed in boyhood suffered about 5 times more cancer across their lifetimes.

Again, these additional cancers are not all in childhood.

This failure to include these additional cancers in the male population results in an effective reduction in the overall evaluation of the harm of ionizing radiation.

Radiation regulation based on Reference Man results in systematic under-reporting of radiation harm for the global population.



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Atomic Age ~ 100 years

“ACCEPTABLE” radiation harm

“ALLOWABLE” radiation harm

Industrial societies “discovered” radioactivity about 120 years ago...and we know it is harmful—

Society speaks of “Acceptable” levels of harm from a governmentally regulated activity or industry. The government then creates regulations with “Allowable levels” of radiation exposure.

“One in a Million....”

It has been said that if there is one death in one million people from an industrial activity, maybe that is ok.

Lifetime exposure to 1 mSv radiation per year  
How many cancers per million people?

ONE?

I am going to look at the simple regulatory limit of 1 mSv since that is a typical annual “allowable” radiation exposure to the general public from nuclear operations.

It is also in the range of the average natural cosmic rays and solar radiation on Earth.

Does the harm associated with 1 mSv a year over a lifetime equate to 1 death in a million?

**U.S. Nuclear Regulatory Commission:**  
70 year annual exposure to 1 mSv radiation  
(70 mSv)

3,500 fatal cancers per  
million Reference Man



REFERENCE MEN

The US Nuclear Regulatory Commission evaluated a 1 mSv annual exposure over a lifetime and has determined that there will be 3,500 fatal cancers in 1 million. In this case, the regulator states that it uses Reference Man for this finding.

So, 3,500 fatal cancers per 1 million Reference Men.

(There are independent researchers who would make that number of cancers higher, even for the adult male Reference Man, but I will use the Regulators' numbers for this illustration).

**U.S. Nuclear Regulatory Commission:**  
70 year annual exposure to 1 mSv radiation  
(70 mSv)

3,500 fatal cancers per  
million Reference Man

REFERENCE MEN

**1 in 286**



Simplifying the 3,500 in 1 million, that is 1 in 286 Reference Men

## Fatal Cancers per Million Adult Women

Lifetime exposure to 1 mSv radiation per year  
(70 mSv)

5,250 fatal cancers (pink line)  
per 1 million females exposed as  
adults

(70 mSv)

**one million women**

[NRC x 1.5]



Using the ratios in the A-bomb survivor data, we recall that for every two fatal cancers in adult males exposed, there will be three in adult females who die of cancer.

There are 5,250 fatal cancers per million women who are exposed to 1 mSv a year.



**Fatal Cancers per Million Adult Women**  
Lifetime exposure to 1 mSv radiation per year  
(70 mSv)

5,250 fatal cancers (pink line)  
per 1 million females exposed as  
adults

(70 mSv)  
**one million women**

[NRC x 1.5]

**one in 190**



And the 5,250 in a million simplifies to one death in 190 exposed women.

## Fatal Cancers per Million Boys

Lifetime exposure to 1 mSv radiation per year  
(70 mSv)

Include BOYS (appropriately)  
17,500 fatal cancers  
per 1 million males exposed in  
childhood



[US NRC x 5]

1 million males

Including boys—it is a little more complex to talk about boys being exposed for 70 years, so instead taking the total exposure of 70 mSv (possible from medical diagnostics alone) we see 17,500 fatal cancers per 1 million exposed boys.

**Fatal Cancers per Million Boys**  
Lifetime exposure to 1 mSv radiation per  
year(70 mSv)

17,500 fatal cancers  
per 1 million males exposed in  
childhood

1 million boys



[US NRC x 5]

**one in 57**

These 17,500 fatal cancers per 1 million boys exposed to 70 mSv resolves to one in 57 getting fatal cancer.

## Fatal Cancers per Million Girls

Lifetime exposure to 1 mSv radiation per year  
(70 mSv)

35,000 fatal cancers (pink line)  
per 1 million female exposed in  
childhood

(70 mSv)

one million girls

[NRC x 10]



In the case of girls, taking the total exposure of 70 mSv, reading the graph from the NAS data, there will be 35,000 fatal cancers among 1 million exposed girls.

## Fatal Cancers per Million Girls

Lifetime exposure to 1 mSv radiation per year  
(70 mSv)

35,000 fatal cancers (pink line)  
per 1 million female exposed in  
childhood

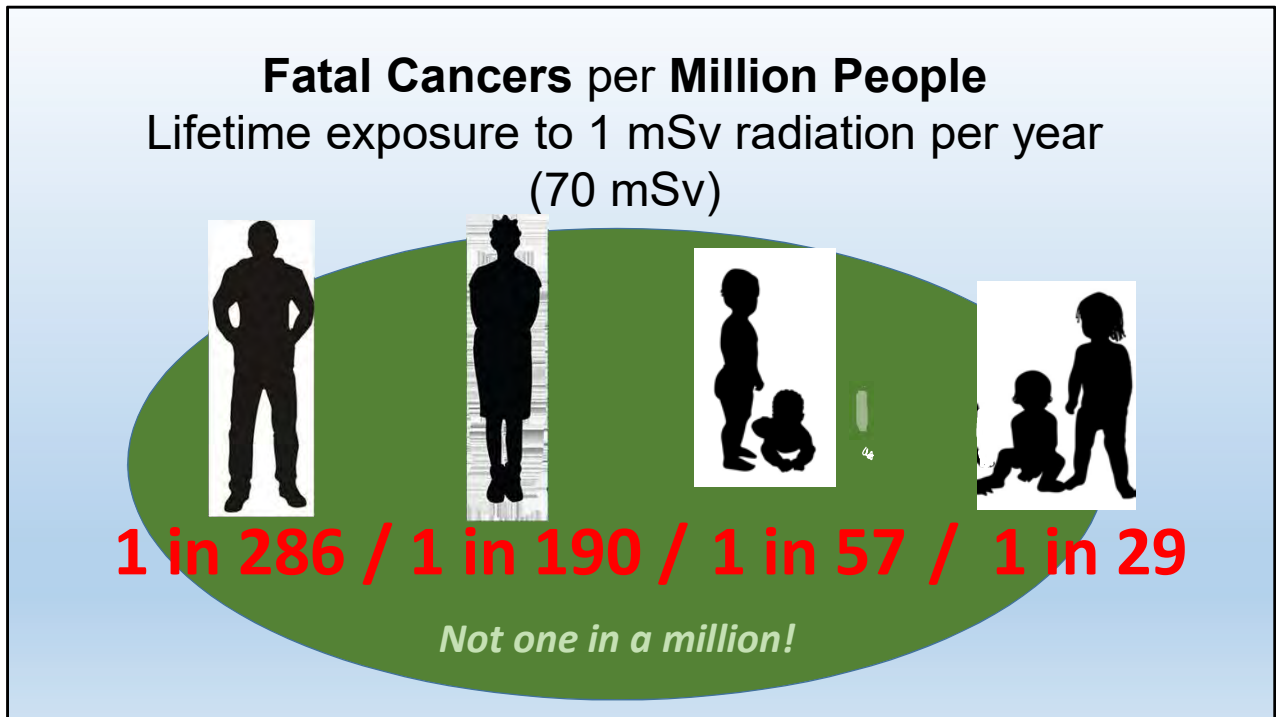
(70 mSv)  
one million girls



[NRC x 10]

**one in 29**

And this resolves to one in 29 suffering fatal cancer from the 70 mSv exposure.



To recap:

Fatal cancer at the rate of

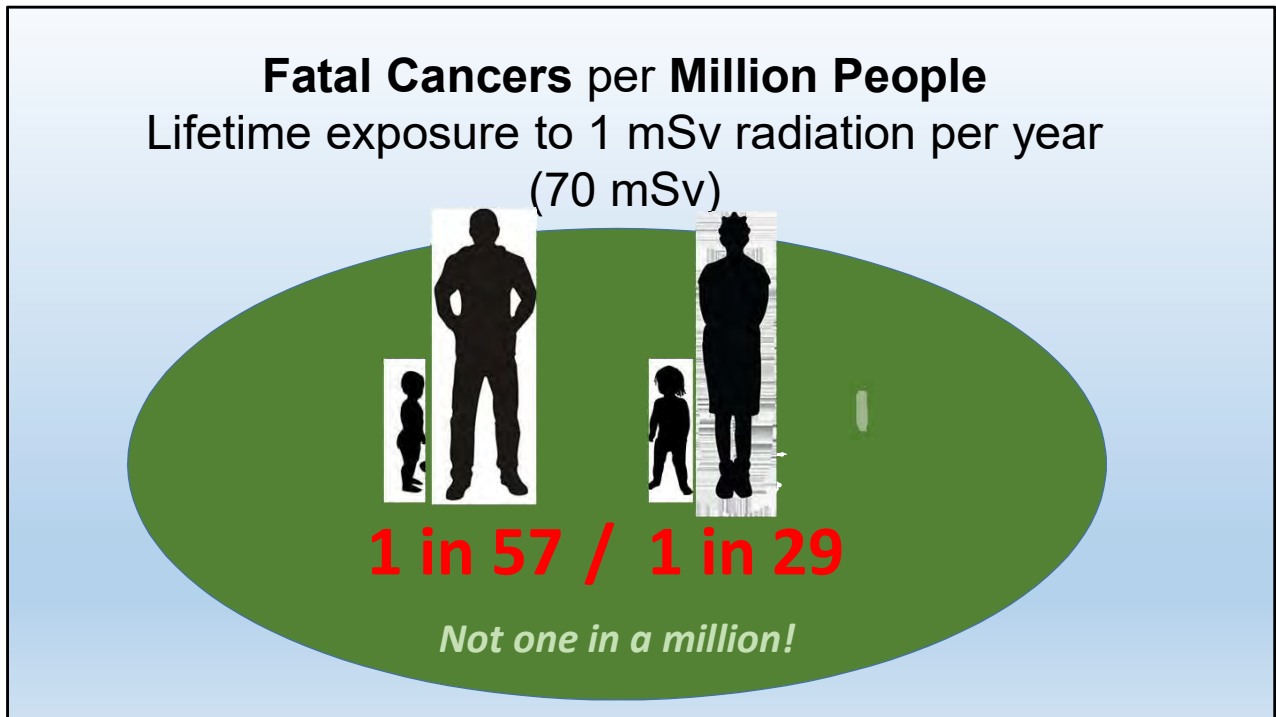
1 in 286 for adult males

1 in 190 for adult females

1 in 57 for boys

1 in 29 for girls.

ALL very much greater than 1 in a million.



We must recall that the age of exposure determines the rate of cancer incidence— but the onset of the cancer itself is across the lifetime.

Our graph is already a LIFETIME RISK TABLE from a single exposure.

Therefore, it is possible to see that when a child is exposed, the cancer incidence will, in most cases be in adulthood.

## **OCCUPATIONAL:**

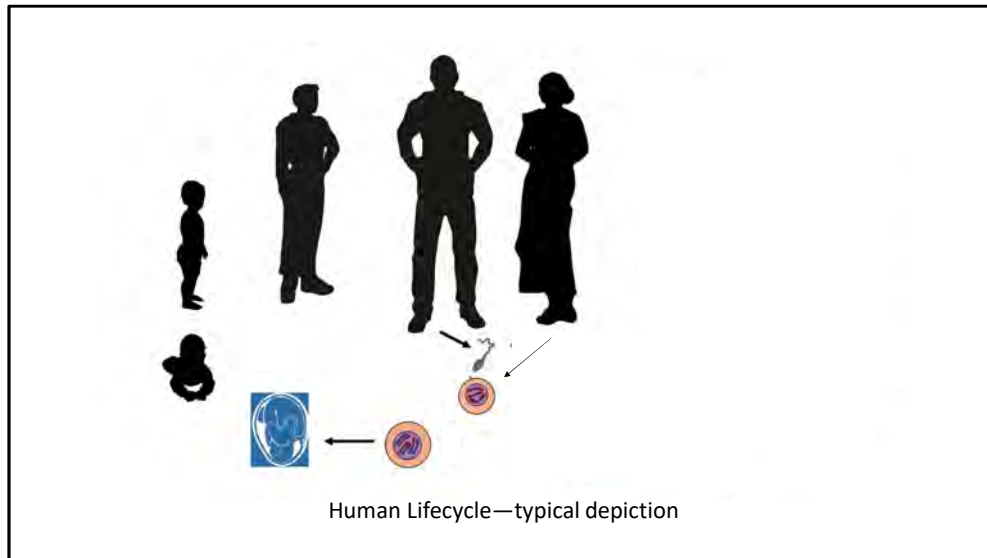
Exposure to 10 mSv radiation per year for 10  
years per 100,000 workers (adult)  
(100 mSv)



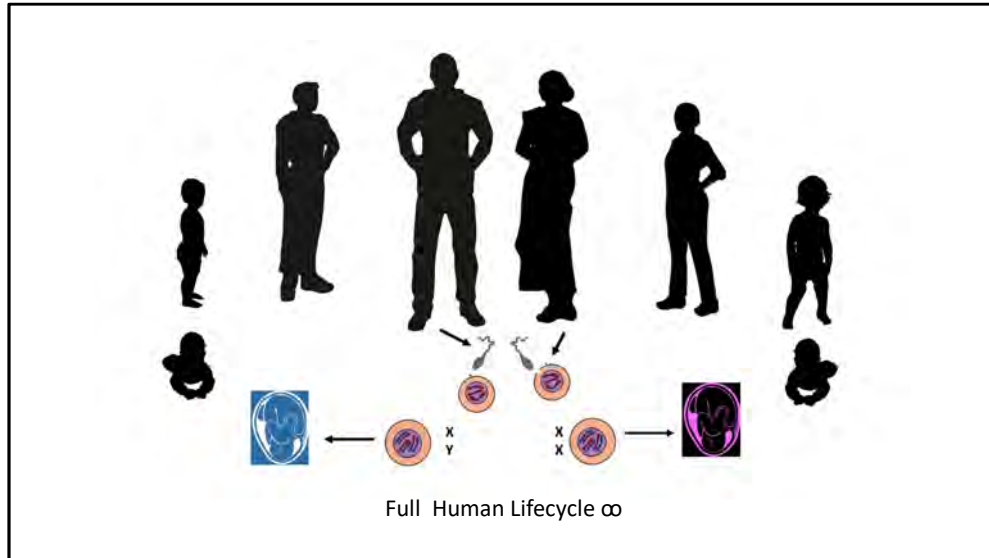
This calculated evaluation of radiation harm must be taken as a guess. We need research to show gender in occupational exposure.

The NAS data from the A-Bomb survivors suggests that we have a problem here.

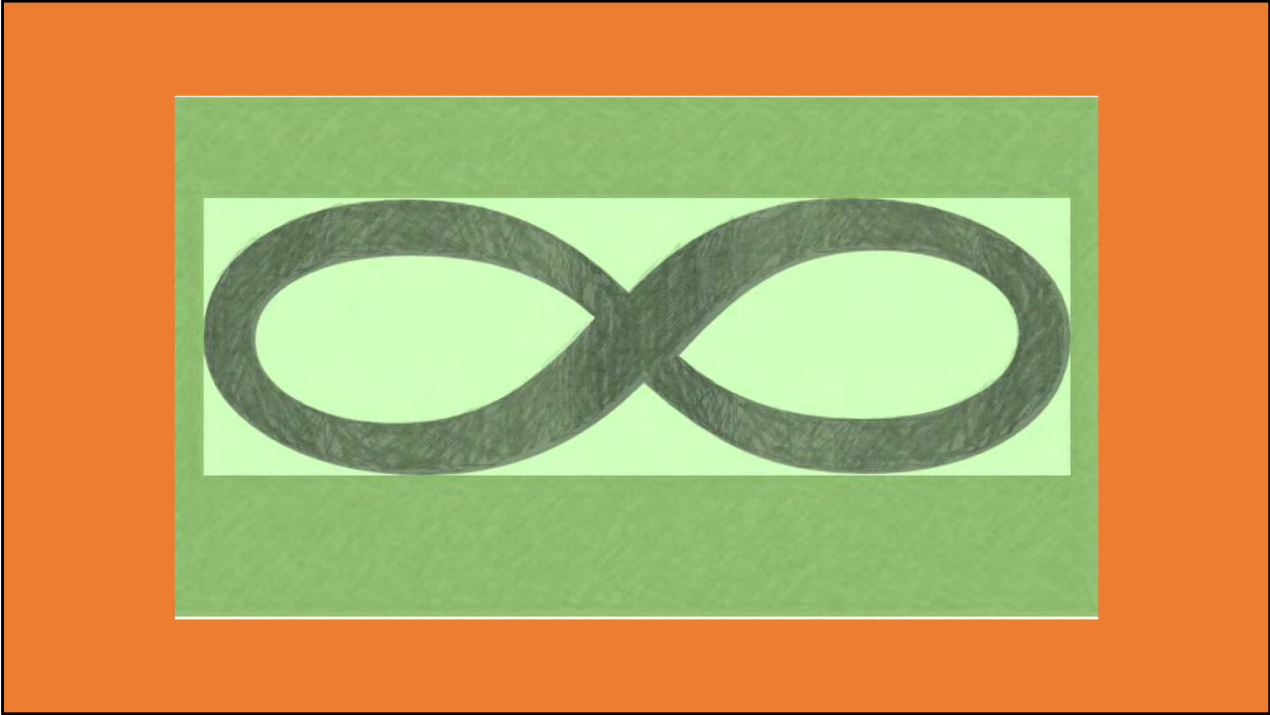




The lifecycle of our species cannot be accurately described by a single loop, such as the previous slide.



We need two loops: the male soma and the female soma. This is now a figure 8. An infinity symbol ∞.



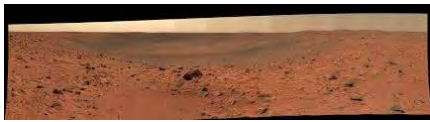
Radiation regulation based on Reference Man results in systematic under-reporting of radiation harm for the global population.



Read slide



All of this pertains to our planet, to terrestrial life.



## 100--200 times more radiation exposure per year on Mars than Earth

Photo: NASA, open use

FIGURE REMOVED FOR POSTING—SEE CHART  
OF EXPOSURE IN ARTICLE

Source of figure:

<https://physicsworld.com/a/the-long-road-to-mars/>

[single-use permission only, do not post slide]

As leaders and industries move towards taking our species into space, and to Mars or other locations, all of these factors will be multiplied by 100—200 in unshielded locations.

At least some Star Men will be looking for Star Women. We need to understand so much more before we go there.

#end#