Babies, Spiders, and Persimmons; Adventures in Post-Fukushima Japan
[*the abridged version*]

RETS-REMP Meeting, Newport RI June 2016

Frazier Bronson CHP
Scientific Director
Canberra Industries
The Nuclear Measurements Business Unit of AREVA

CANBERRA

Babies, Spiders, and Persimmons; Adventures in Post-Fukushima Japan
[*the abridged version*]

REEW Meeting, Newport RI June 2016

Frazier Bronson CHP
?? Scientific Director
?? Canberra Industries
Part [TBD] of The Mirion Group

CANBERRA

Obligatory Caveat

The opinions expressed within this presentation are purely my own; especially those coming after a few margaritas.

My employer, my wife and mother have all been given to opportunity to review this presentation.

None of them have officially done so.

CANBERRA

Preparation for this presentation

- **Previous personal experience at Nuclear accidents like this**
  - **TMI - On-site 36 hours after the accident, for the next ~1mo**
    - **Managed the Radiation Management Corporation team**
      - **Operated a mobile gamma spec lab for ~6mo, then on-site lab during the decon project**
      - **Managed the Environmental lab in Philadelphia; much milk and Chocolate**
      - **Mobile WBC at TMI during the accident and for the next many months**
  - **Chernobyl – several trips to Ukraine**
    - **Many food measurement systems and InSitu [detector on tripod] systems sold**
    - **Supplied 7 mobile WBC in support of Population monitoring + 2 more to the plant**
  - **Fukushima – 33 trips so far to Japan**
    - **Part of AREVA initial response team first 4-5 months**
    - **Since then assisting our Japan office in business development efforts**
- **Published or on-line literature about Fukushima radiation measurements**
  - **Extensive data available about this accident – some of it is correct and useful**
    - **much of it in Japanese; electronic translation software is only marginally understandable**
- **Health Physics Society Professional Development School 2013 - Fukushima**
  - **This is a small part of a lecture I gave as one of the instructors, updated**
- **IAEA 5-volume The Fukushima Daiichi Accident** STI/PUB/1710

My radiation dose as a result of the Fukushima accident

Event	Number	Dose [mRem]	Dose [mSv]
Visits to NPP Site	6	10	0.1
Working in Fukushima region	20	0	0.0
Required medical exam	2	20	0.2

My radiation dose as a result of the Fukushima accident

Event	Number	Dose [mRem]	Dose [mSv]
Visits to NPP Site	6	10	0.1
Working in Fukushima region	20	0	0.0
Required medical exam	2	20	0.2
Days in Japan next to NORM	270	240	2.4
Airplane trips to/from Tokyo	33	567	5.7
	total	**837**	**8.4**

Introduction

- **On March 11, 2011, one of the most powerful earthquakes in history hit just off the Tohoku coast of Japan [magnitude 9.0].**
- **The resulting tsunami caused great damage:**
  - **Nearly 20,000 people dead or still missing**
  - **Over 200,000 people living away from their destroyed homes**
  - **Over 1,000,000 buildings damaged or destroyed**
- **The tsunami seriously damaged 3 of the 10 NPPs in the area**
  - **2 deaths – both from drowning**
  - **0 deaths from radiation**
  - **>300,000 people evacuated from the area, mostly all un-necessary**
    - 600-1600 deaths due to the evacuation
  - **Major radiation releases, but almost all of it toward the [very large] sea**
- **After the first month or so, and for the last 5 years, very little news coverage of the many tsunami victims**
- **Excessive coverage of the unfolding drama at the NPP**
- **Good for our radiation measurement business, bad for Japan.**

Comparison to TMI and Chernobyl

Item of comparison	TMI	Chernobyl	Fukushima
Reactors present, damaged	2, 1	4, 1	6+4, 3
Earthquake damage	-	-	Minimal
Tsunami damage	-	-	Yes
Loss of outside power	-	-	Yes
Explosion with extensive damage	-	Yes	Yes
Loss of many roads to and from the area	-	-	Yes
Large releases to the environment	-	Yes	Yes
Gov't resources focused on NPP accident	Yes	Yes	Rx + Tsu
Population evacuation	140,000 v	350,000 m	150,000 m
Exclusion zone	-	1660 mi^2	~140 mi^2
Deaths	0	56	19,000 [0 Rx]
Evolving event, w/possibility to get worse	Yes	Yes	Yes
Monitored release point, known source term	-	-	-
Money and other resources to respond	Yes	-	Yes
Response decision-making process	Quick	Secretive	Deliberate

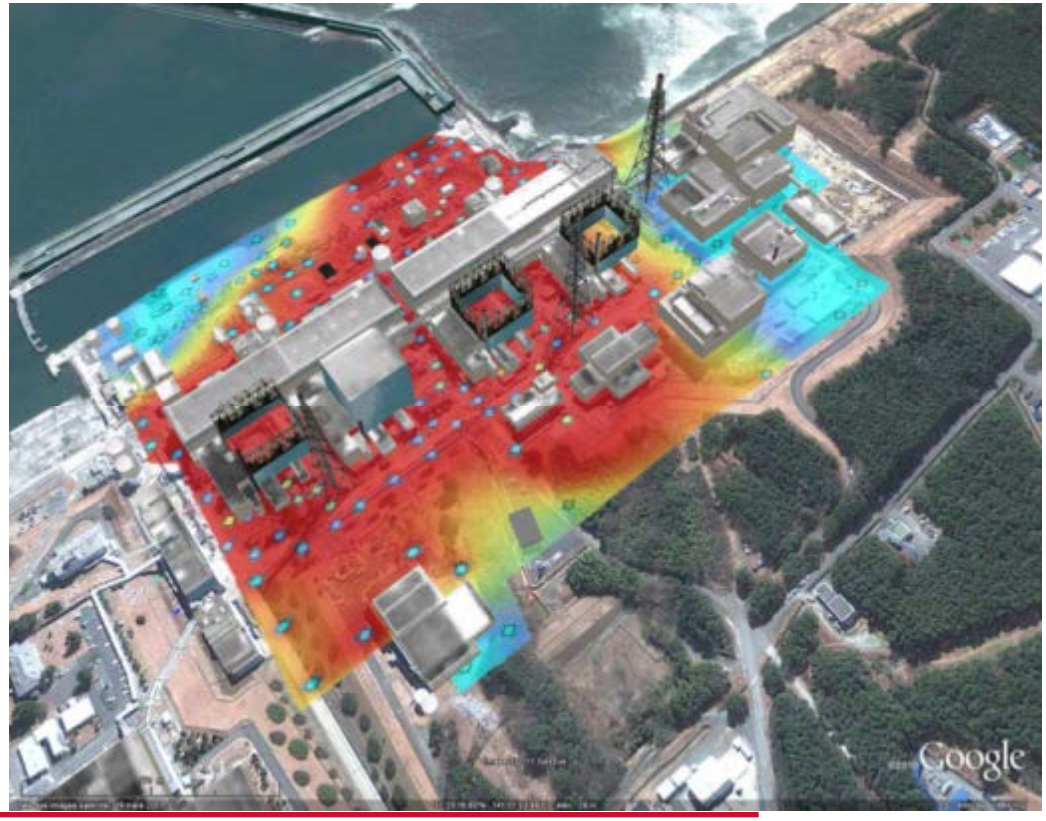
Nuclides and Dose summary

- I-131, Cs-134, and Cs-137 were the important nuclides released
  - Many others but they cause minor dose to the population
- All 3 nuclides easily measured in people and in food
- I-131 is the major contributor to internal dose if the person was nearby the plant at time of release
- Cs-134 and Cs-137 are the major long term internal dose contributors, primarily from the food pathway
- Internal population CEDE very low in Japan, as compared to Chernobyl
  - Ground concentration > dose factor [Bq/m2 > mSv/y] 50-100x lower
    - Milk not big part of diet
    - Plenty of Iodine in the normal diet
    - People and Businesses do as they are advised
    - Alternate source of food easily available and used

CANBERRA

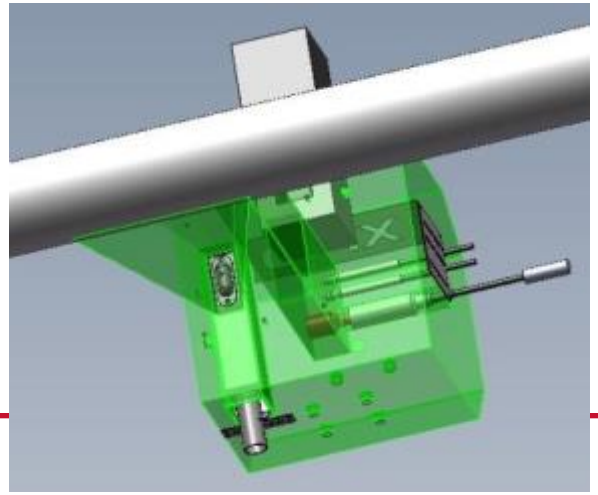
Mapping radiation levels on-site

- A few weeks after the accident, the AREVA team prepared the first map to support the water treatment facility installation and operation
- During the pre-installation inspections workers carried the Colibri doserate meter with them for the first few trips
  - With integral GPS and automatic data logging
- Map created using CEA radiological mapping algorithms licensed by Geovariences
- Used by AREVA team for dose optimization planning
  - Where to locate the water processing equipment
  - What routes for personnel egress



AREVA-Veolia-Canberra water processing system

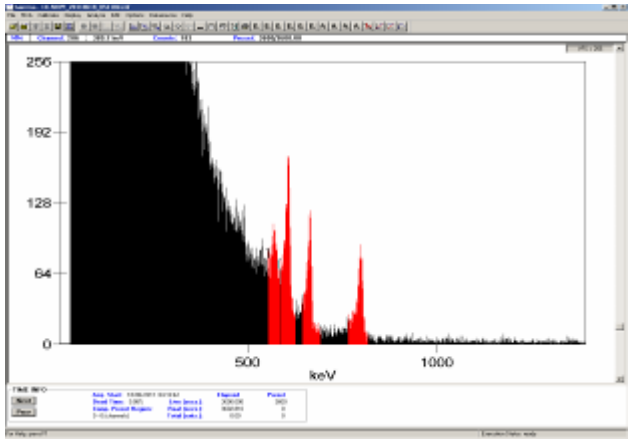
- **75 days from conception to operation !!**
- **Instrumentation [Canberra part]**
  - **5 spectroscopy measuring station, each with dual CZT probes**
  - **MCNP calibration – quantitative results**
    - ISOCS Characterizations now in progress
  - **6 wide dynamic range dose-rate monitoring points**
  - **Shielding for all sensors**
  - **Remote monitoring software for setup, adjustment, viewing results, data archiving**
  - **WAN on site, to TEPCO Tokyo, and to France**



CANBERRA

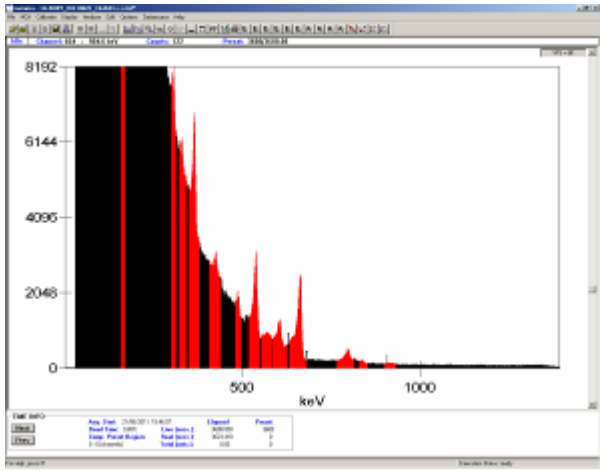
Activity determination via CZT gamma spectrometry measurement channels

XI-10 CZT 500

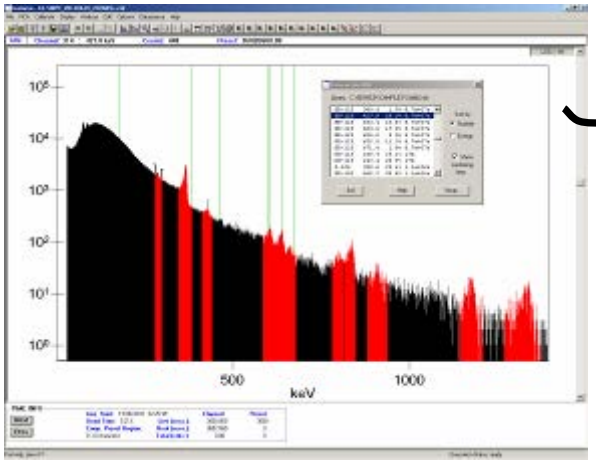


Cs134 and Cs137

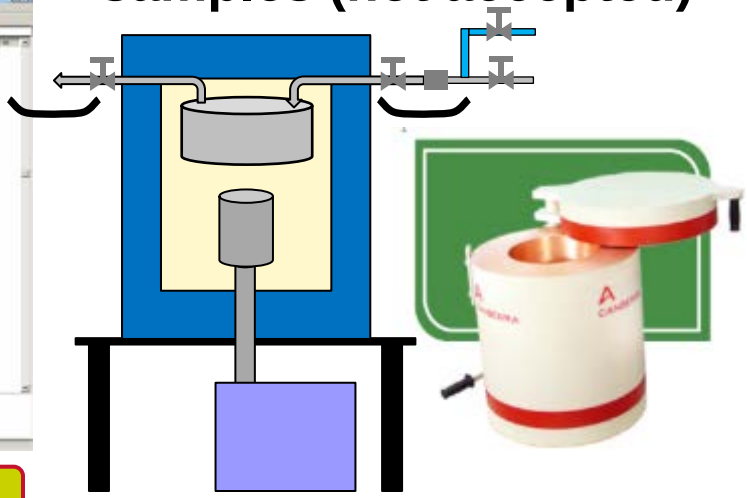
- Unit DF was higher than expected
- Output concentration too low to be measured with CZT
- Proposed more sensitive automatic system instead of grab samples (not accepted)



I131 and Sb125

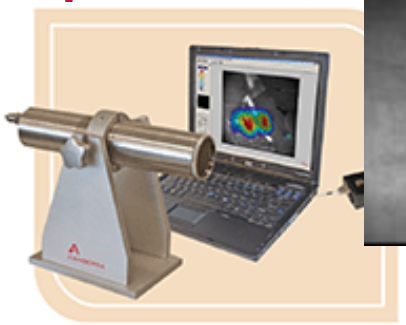


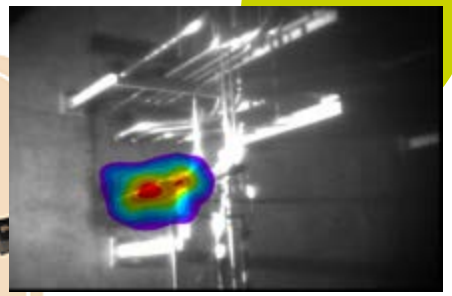
I131 Sb125 and Co60



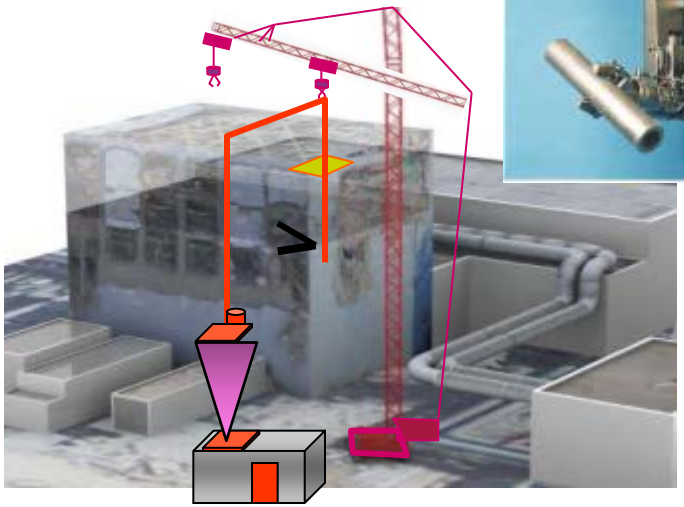
CANBERRA

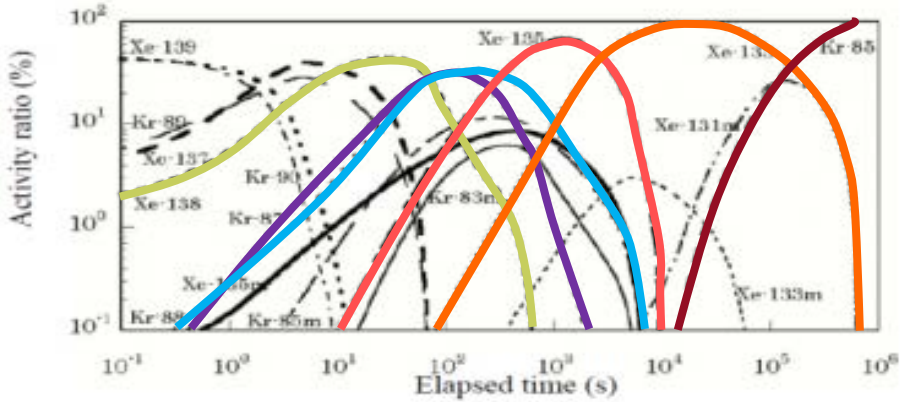
Many other proposals, as part of the AREVA team
technically interesting, but not profitable

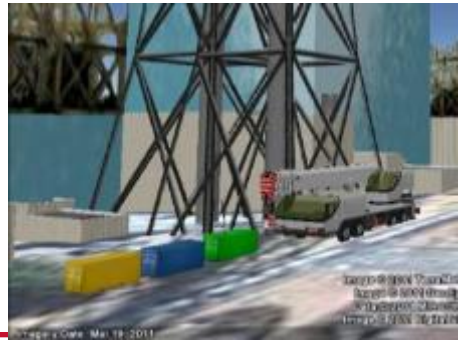


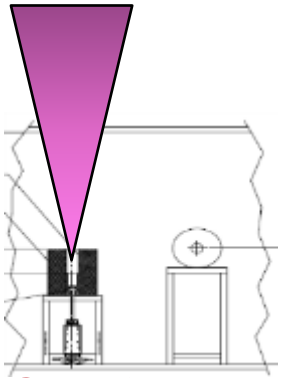


- Gamma imaging
- Debris removal and waste sorting
- Very sensitive stack gas monitoring for "approach to criticality" monitoring
- Exit contamination monitoring of vehicles
- Transportable laboratories
  - Radiochemistry
  - Measurement
  - Gamma in-vivo
  - Alpha in-vivo



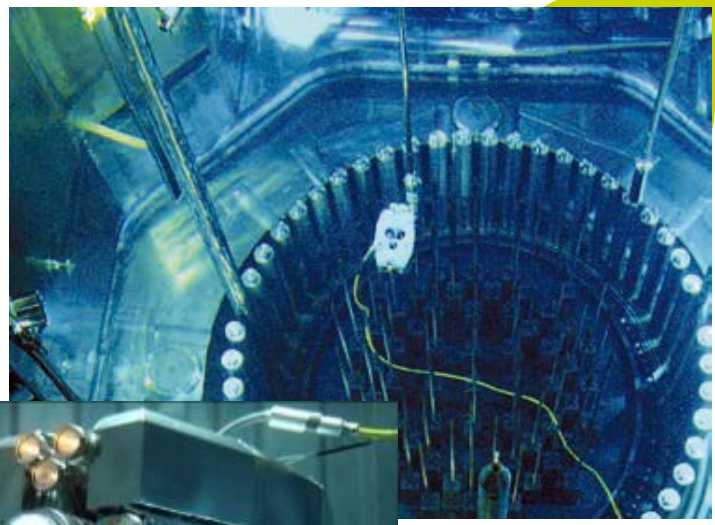


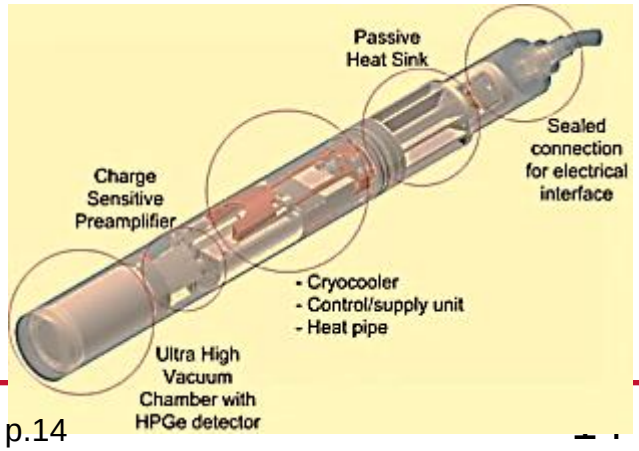




Underwater measurements

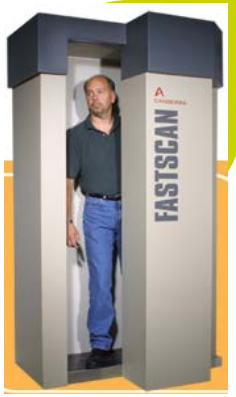
- ROV submarine initially proposed as part of spent fuel removal project
- Later there was need to know the inventory of radioactivity at the bottoms of rivers and lakes and seas [samples difficult and unreliable]
- Proposed several alternatives
  - LN cooled Ge – any size detector
    - Used many times before – Maine Yankee at right
  - Electrically cooled Ge
  - ROV submarine with LaBr scintillator
- Selected the ROV + LaBr option





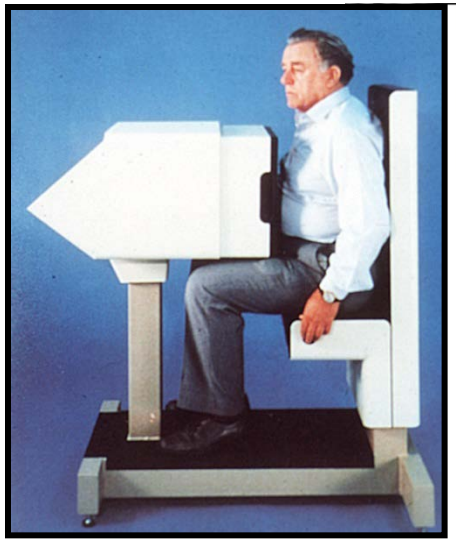
In-Vivo counting other accidents

- **TMI accident and cleanup**
  - **1 mobile Accuscan during accident for workers**
  - **1 mobile Helgeson bed unit for population**
  - **1 FastScan and 1 Accuscan in modular building for cleanup and unit 2 operations**
- **Chernobyl**
  - **1 Accuscan-II, 1 U/Pu Lung counter for cleanup**
  - **7 mobile FastScans [6 part of German population counting project]**



CANBERRA

German-Chernobyl In-Vivo Counters

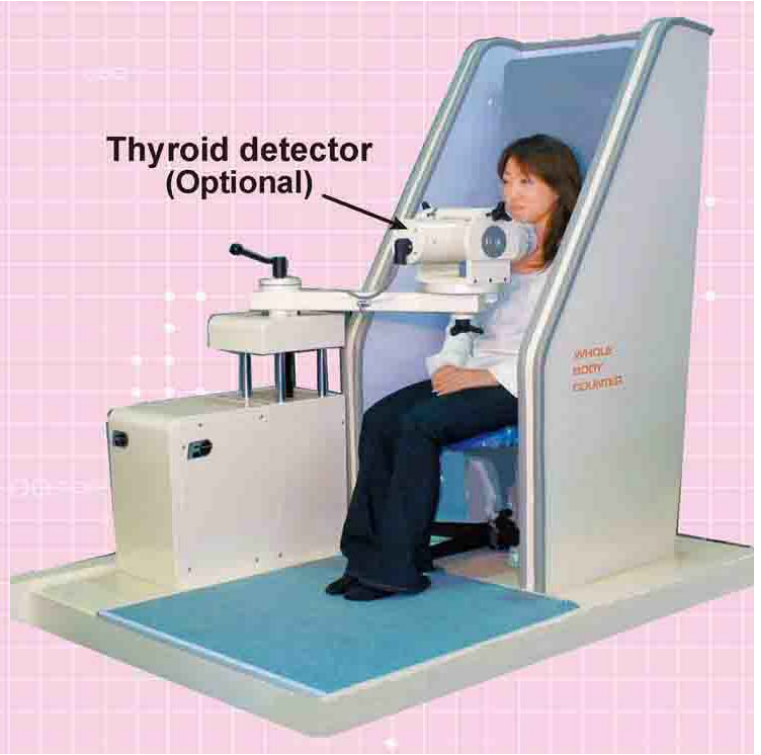


- **Baby counter [lower-left]; Plastic German system [upper-left]**
- **Both had background problems due to Cs in environment**

CANBERRA

In-Vivo counters in Japan

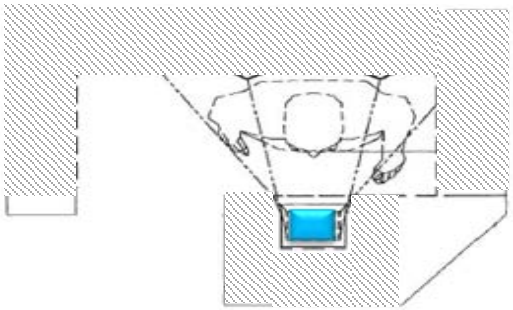
- **4 In-vivo counters at Dai-ichi; 4 more at Dai-ni before accident**
- **WBCs in Japan NPPs all local brands that qualify to local standards**
  - **Most were chair-types**
  - **Incomplete shielding [side, back, not front]**
  - **Most are plastic non-spectroscopic gross counters**
  - **Maybe OK for normal plant operations**
    - Where internal dose is minimal
    - And if located in areas where background is low
    - *And where there are not many lawyers*
  - **Not suitable for these type events**
    - TMI, Chernobyl, Fukushima
- **All WBCs at F1 & F2 unusable**
  - **Initially because of power or water damage**
  - **After power restored, because of high background**



CANBERRA

Worker internal exposures by JAEA

- Most common WBC at NPPs in rest of world is Canberra FastScan
  - Full gamma spectroscopy – nuclide-specific results
  - Total body measurement
  - Full shadow-shield for use in elevated external background



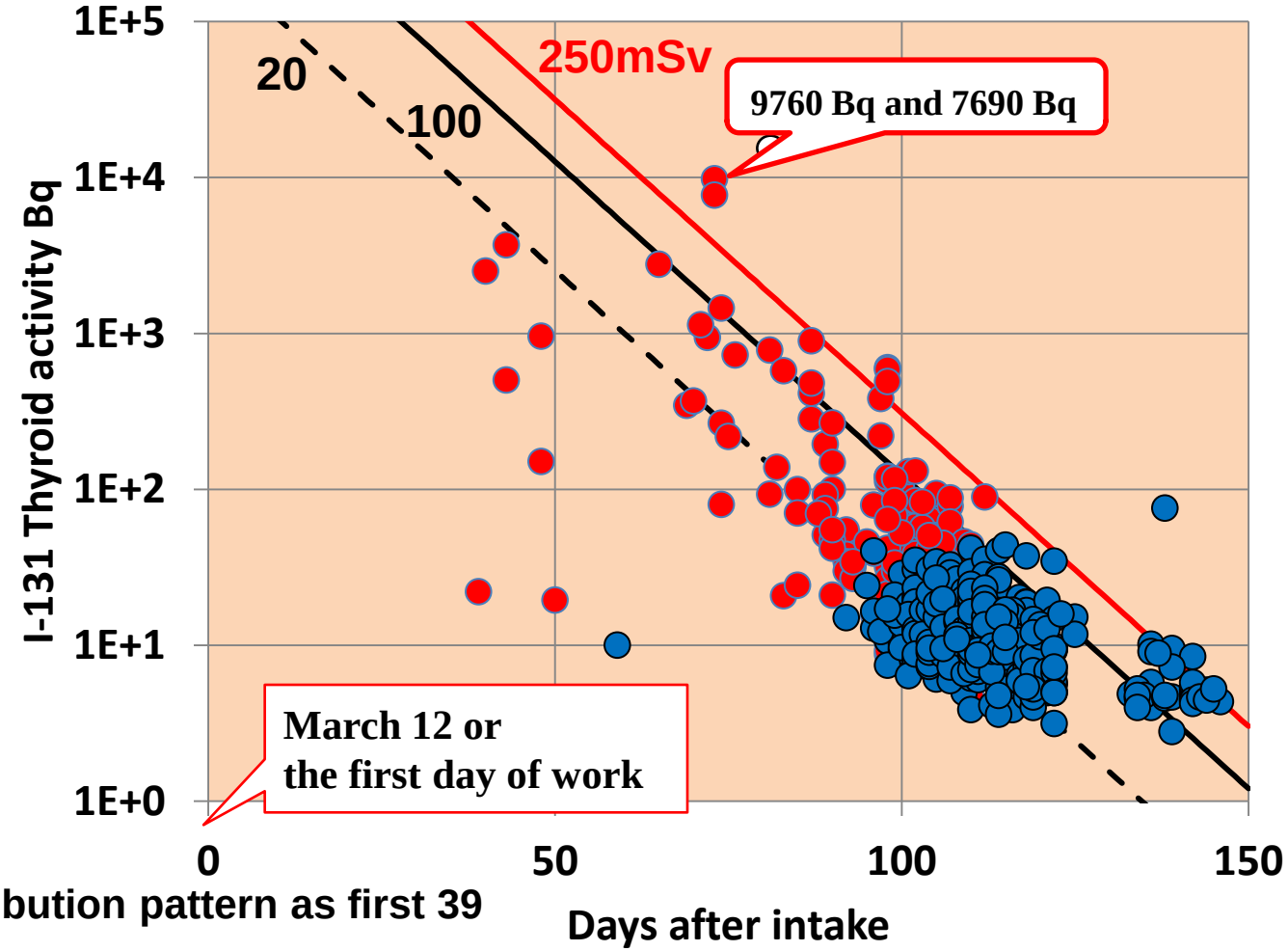
- None in Japan NPPs
- 4 FastScans at JAEA, including 2 mobile units
- JAEA mobile FastScan WBC moved to Onahama plant [55km S] and started counting selected workers on March 23 [+2w].
- Used to select workers for follow-up measurements

Worker internal exposures at JAEA-Tokai

- 23 April [+6weeks] - 5 August 2011
- Workers with preliminary dose estimate >20 mSv went to JAEA Tokai for additional monitoring.
- Whole body monitoring
  - 2x Ge detectors in 4pi shielded room with 20 cm thickness iron
  - 2x Canberra FastScan w/dual NaI detectors
- Earthquake reduced elevation of shield 1m and caused minor damage to mechanicals
- Thyroid monitoring
  - Ge detectors in the shielding room
  - Later NaI detectors on neck
- Number of measured workers
  - 39 in initial wave [those >20mSv]
  - 560 total [6 female]

Thyroid I-131 results [caused most of internal dose]

- Straight lines correspond to CEDE of 20, 100, and 250 mSv
- Acute intake elemental iodine assumed
- Intake on March 12 or first day of work
- Red is first 39 workers
  - Est >20mSv
- Blue is next group for 560 total workers
  - Most are also >20mSv too
  - Similar dose distribution pattern as first 39 workers
  - Don't know how first 39 were selected

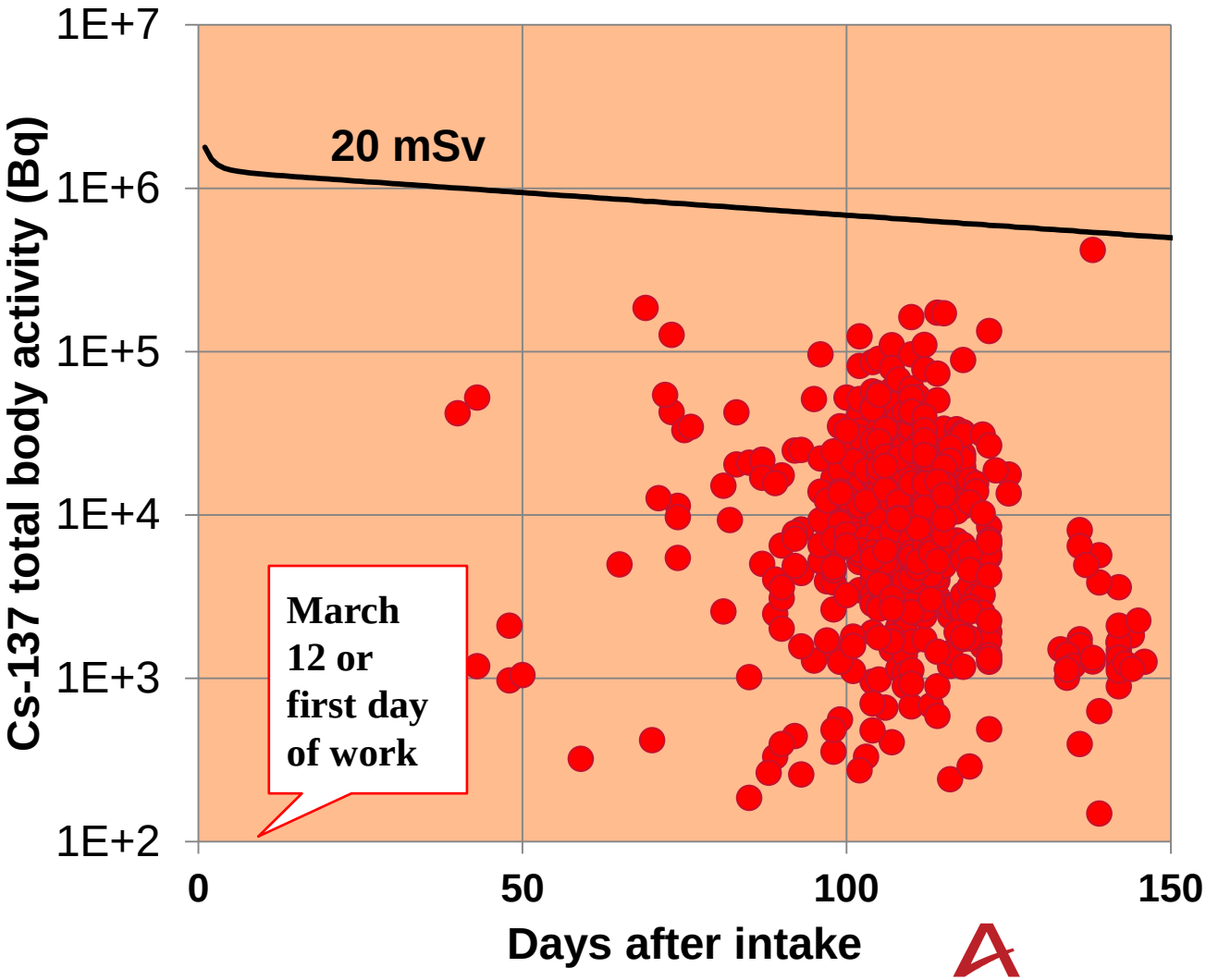


CANBERRA

Cs-137 results

- Straight lines correspond to CEDE of 20 mSv

- Acute intake of type F compounds with 5um AMAD assumed
- Intake on March 12 or first day of work
- All 560 workers; no difference between first 39



CANBERRA

InVivo counting in Japan

- Common WBCs in Japan, esp NPPs, unusable – poorly shielded
- Modern WBCs with good shielding, before the Fukushima accident
  - None at NPPs
  - 1 Accuscan; Scanning NaI Bed
  - 1 Accuscan-II; Scanning Ge
  - 6 FastScans; 2 mobile
  - 3 U/Pu Lung counters

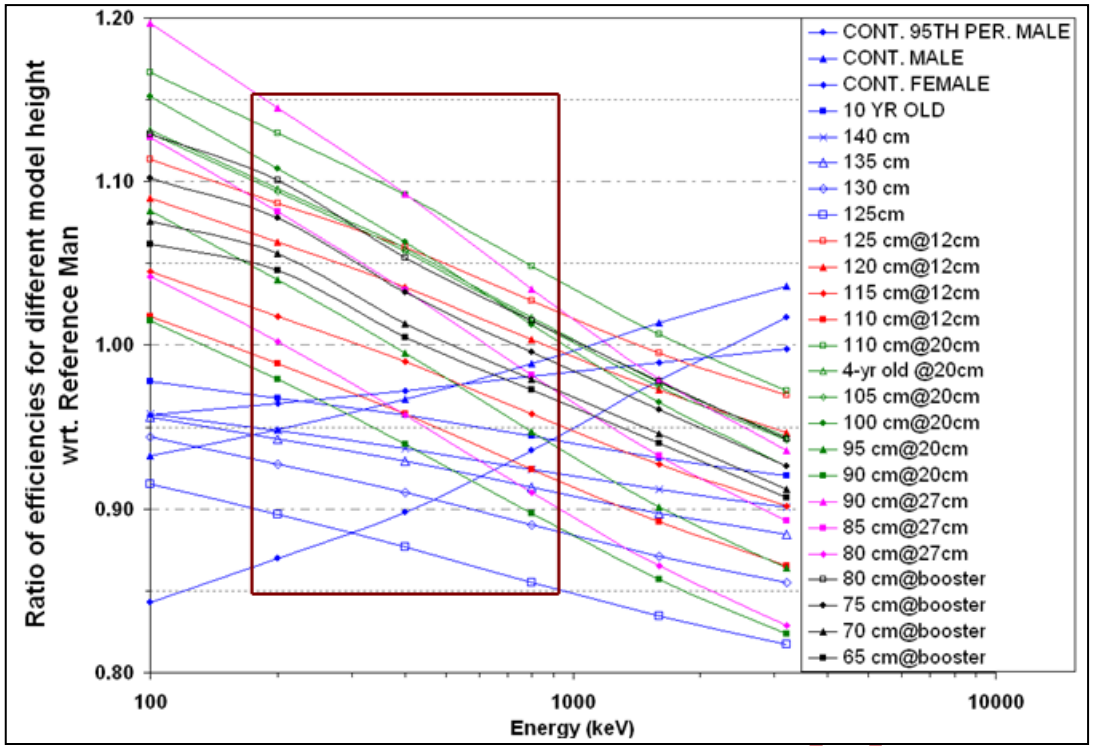
- After accident
  - US Military – ~1-2mo, temporary
    - 3 FastScans and 1 Accuscan-II
  - TEPCO at J Village - ~9mo
    - 1 new FastScan, 1 mobile from JAEA
  - Fukushima Prefecture and other locations – starting ~1y
    - ~60 FastScans; ~20 of them Mobile
    - "defacto" standard for population measurements
    - ~200,000 counts by Prefecture; similar amount private facilities
      - ~99.98% < 1mSv CEDE; only 4 > 3mSv CEDE
      - 1 mSv/y ~ 35 Bq/kg Cs137 continuous in body; ~10x 1m MDA of FastScan

CANBERRA

Population in-vivo counting - children

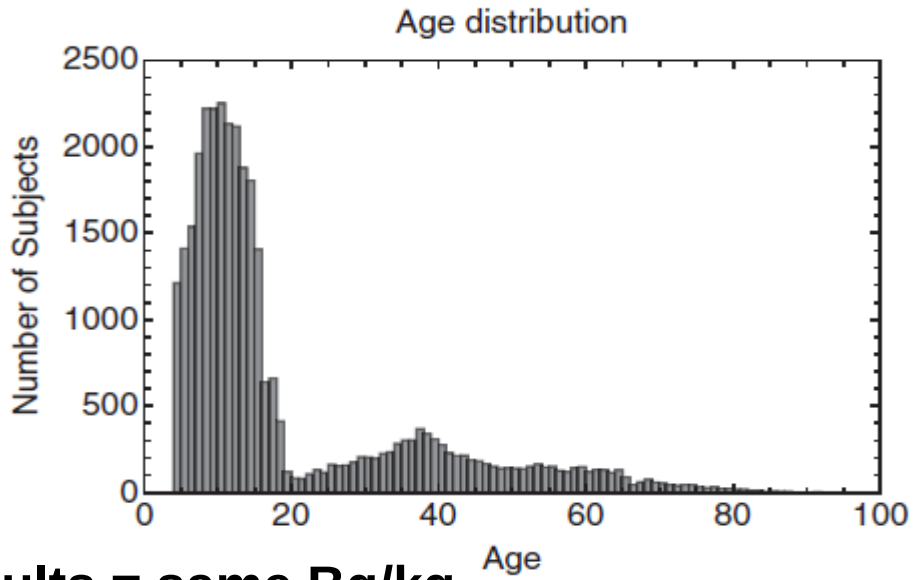
- **WBCs designed for radiation workers – adults**
- **Fastscan has constant efficiency for 99th percentile males [75”] to 1st percentile females [57”]**
- **Used MCNP to simulate child-size BOMAB phantoms.**
- **If short people stand on platform, results within 15% for all subject sizes when using a single adult BOMAB calibration**

Subject Height [cm]	Platform Height [cm]
80-89	27
90-109	20
110-125	12



CANBERRA

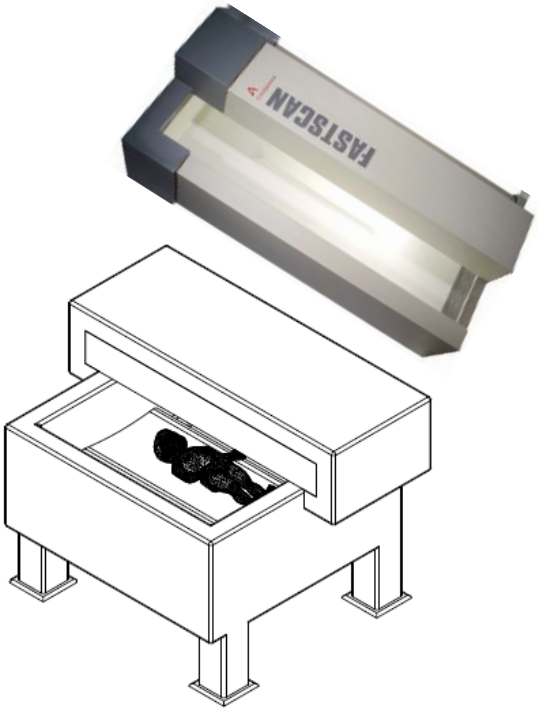
Babies are very important in Japan, but they are different from adults. A different type of WBC was needed.



- **Large fraction of population voluntarily going for WBCs are young people**
- **Children are different**
  - **Shorter Biological Half-life for Cesium**
    - 1y = 13d; 5y = 30d; adult = 110d
  - **More radiosensitive than adults**
- **Desire same dose sensitivity as adults = same Bq/kg**
- **FastScan MDA**
  - **200-300 Bq Cs-137 = 3-5 Bq/kg for 70kg Adults [we all should have ~70 Bq/kg K40]**
  - **But only = 20-30 Bq/kg for 10kg Child**
- **Goal = 3-5 Bq/kg = 30-50 Bq for 10kg baby**
- **Important Requirement – make it look pleasing for the mothers**

CANBERRA

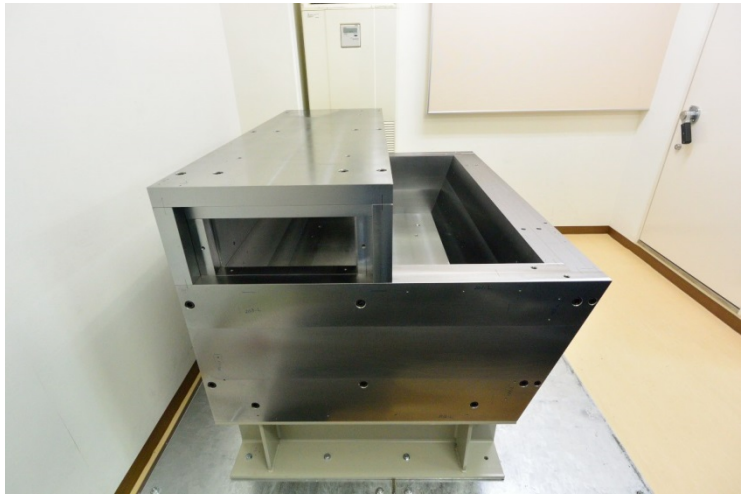
Evolution from FastScan to BabyScan

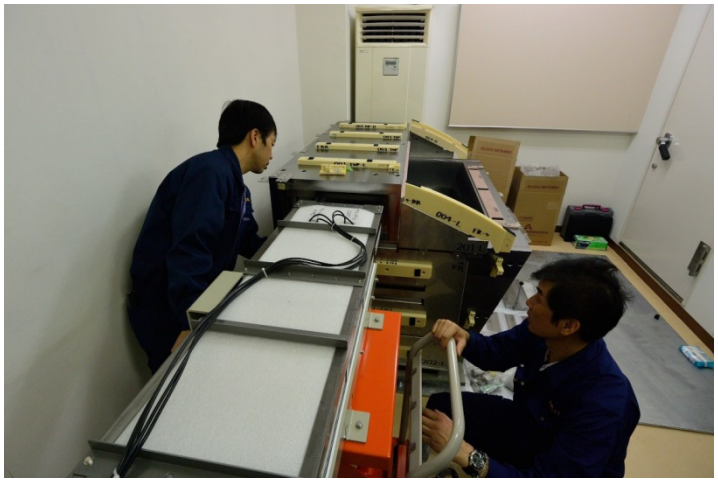


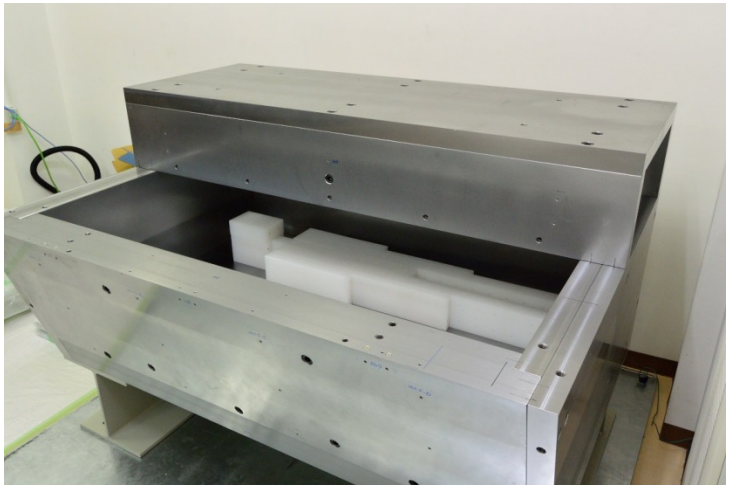
- **Retained shadow shield concept to avoid "Chernobyl" and Japan elevated background issues**
- **Increased shielding in important areas from 10 to 15cm Fe**
  - **Used selected or measured low background components**
- **Increased efficiency**
  - **More detectors from 2 > 4**
    - 5" x 16" x 3" thick [25% better than 4x4x16"]
  - **Detectors in tight packed array; no gaps**
  - **Detectors closer to subject**
    - 15, 20, 25, and 30cm detector-bed distance geometries; vs. 41cm FastScan
- **University of Tokyo industrial designers made it much more pleasing to look at**

CANBERRA

Installation sequence for 1st of 3 units







Background testing with St. Petersburg phantom inside shield

CANBERRA

Making it look pretty and “soft”

- **Fiber glass shell on outside**
- **Carbon-fiber shell on inside [fiberglass too radioactive]**

CANBERRA

Taking the BabyScan for the first test ride

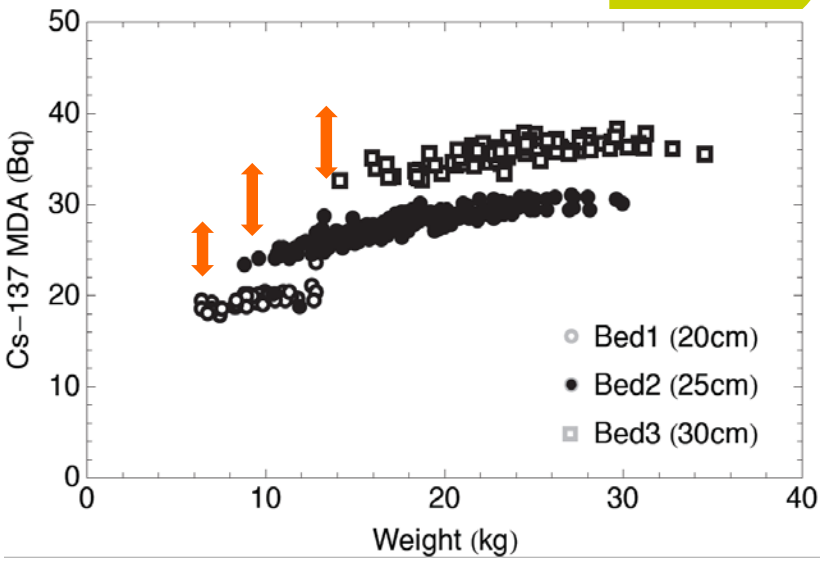
CANBERRA

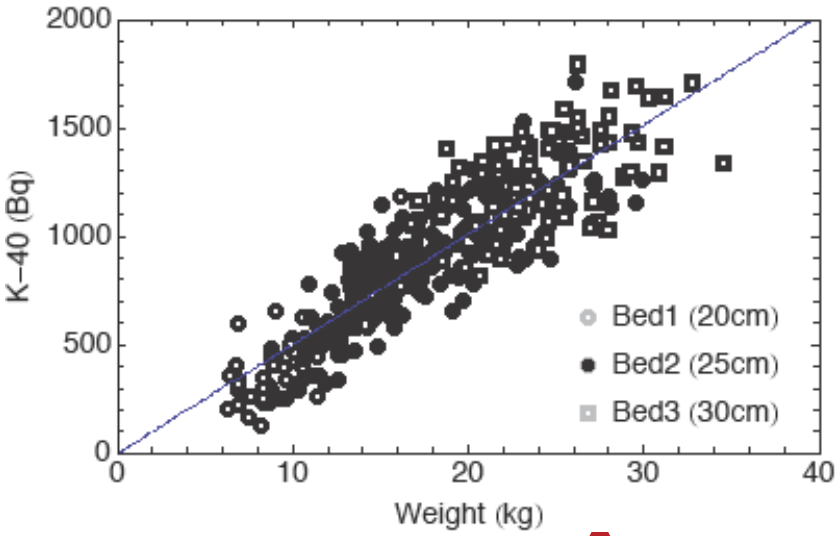
NHK TV coverage
4-min movie, hope it works

CANBERRA

Performance

- **Background: ~13% lower than standard FastScan**
  - **Corrected for number of detectors**
- **Efficiency: ~2x higher than standard FastScan**
  - **Corrected for number of detectors**
  - **Because detectors closer to each other and closer to subject**
- **MDA < goal; typically 1-2 Bq/kg**
  - **MDA using Currie method;**
  - **Predicted in orange; measured black**
- **K40 found in all subjects at ~expected level**
  - **~51 Bq/kg; linear with weight**
  - **Good indication that system works**
- **No Cs134 or 137 in 1st 365 subjects**

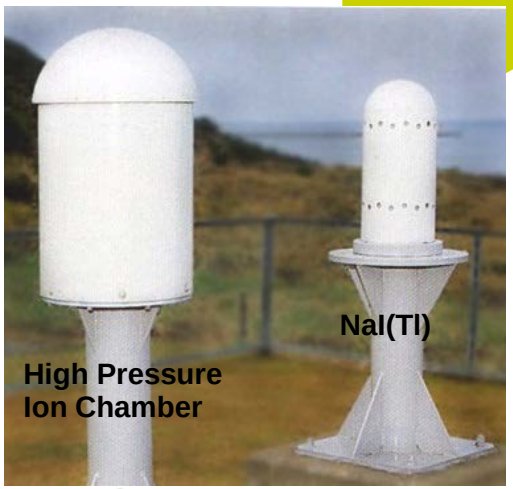




CANBERRA

Environmental monitoring posts

- Located in major population centers near NPPs [22 around both Fukushima Tepco sites]
- High Pressure Ion Chamber
- NaI spectrum
- Moving filter air particulate monitor
- Real time doserate available to public on website and at monitor



Environmental Monitoring Post after losing the battle with a Tsunami

- **Nice elegant system for normal NPP operations**
- **Emergency response issues:**
  - **Too few in affected areas where population was**
  - **No Iodine collection devices [major population dose]**
  - **Air samplers don't work when power was down [all 22]**
  - **Doserate system runs few more days on batteries**
  - **No real-time communication after loss of power**

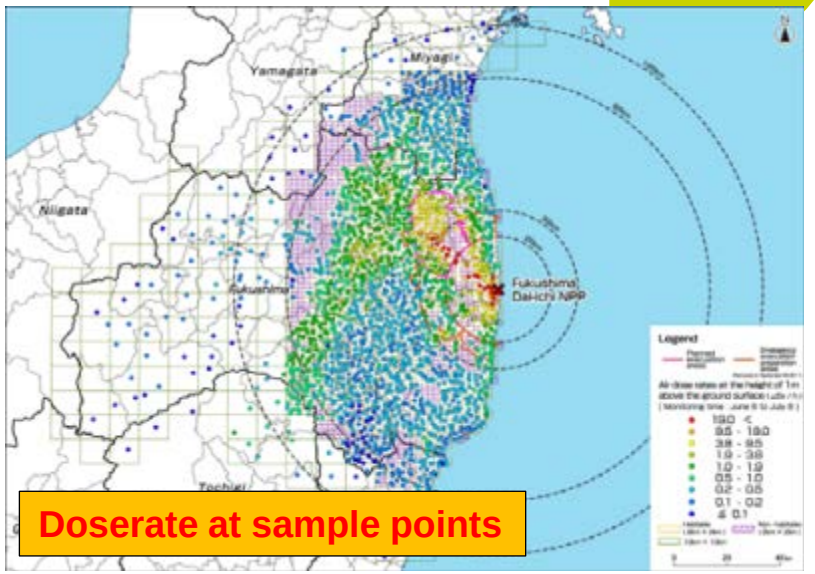
CANBERRA

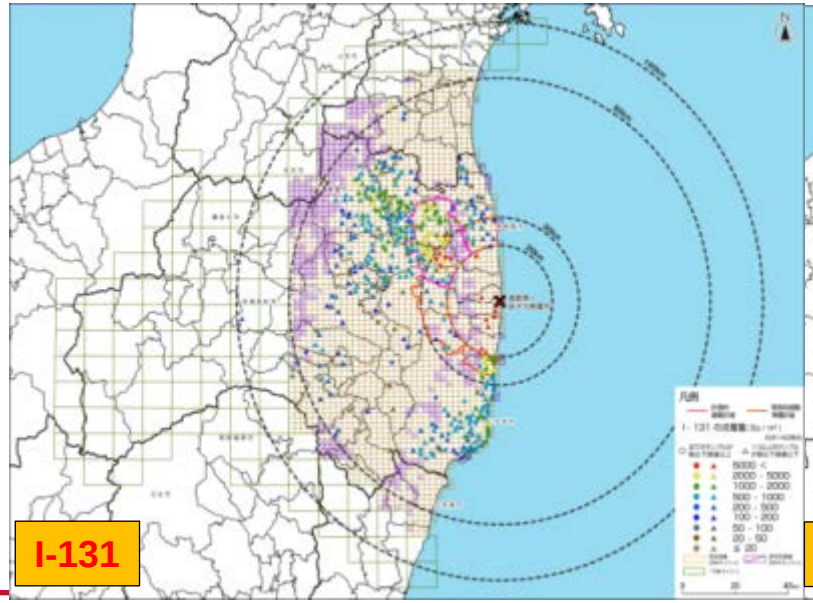
Ground deposition measurements and maps

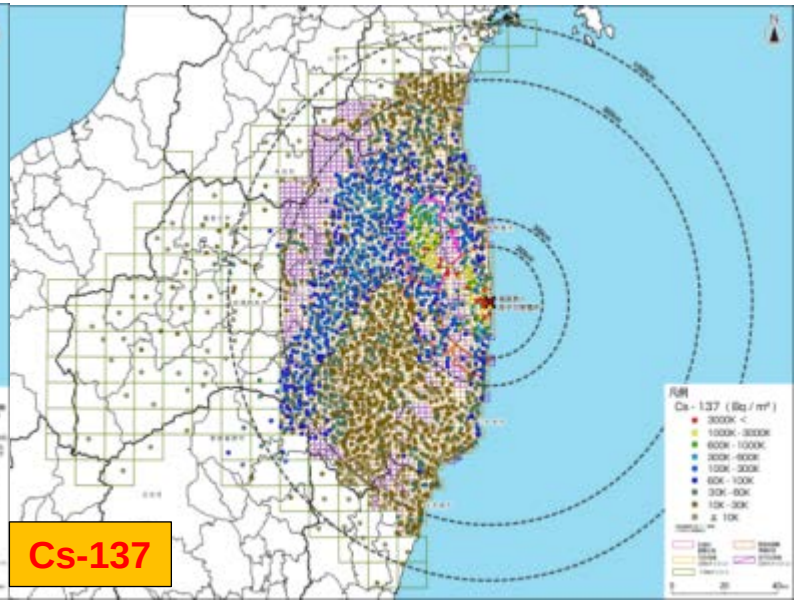
- Jun-July 2011 JAEA began this massive project
- 2200 locations, soil samples + doserate [440 people]
- Vehicle doserate where roads [291 people]
- Ge gamma spec of soil from all locations
  - Cs137 Cs134 I131 Te129m Ag110m
- Sr89 Sr90, 100 targeted locations
- Pu238 Pu239+240, 100 locations
- Maps released as available, starting Aug30 2011
- Vertical depth – Geoslicer
- River water Cs I Pu Sr
- River bottom sediment Cs I
- River suspended sediment Cs I
- Well water Cs I Sr
- Pu241 and I129 via AMS
- http://ramap.jaea.go.jp/map/

Ground deposition measurements

- Doserate at sample points [Rt] and on roads [Left] - same
- Concentration of Cs137 [same as Cs134]
- Concentration of I131; note differences from Cs137
- Ag110m much like I131
- Sr89/90 found
- Pu also found



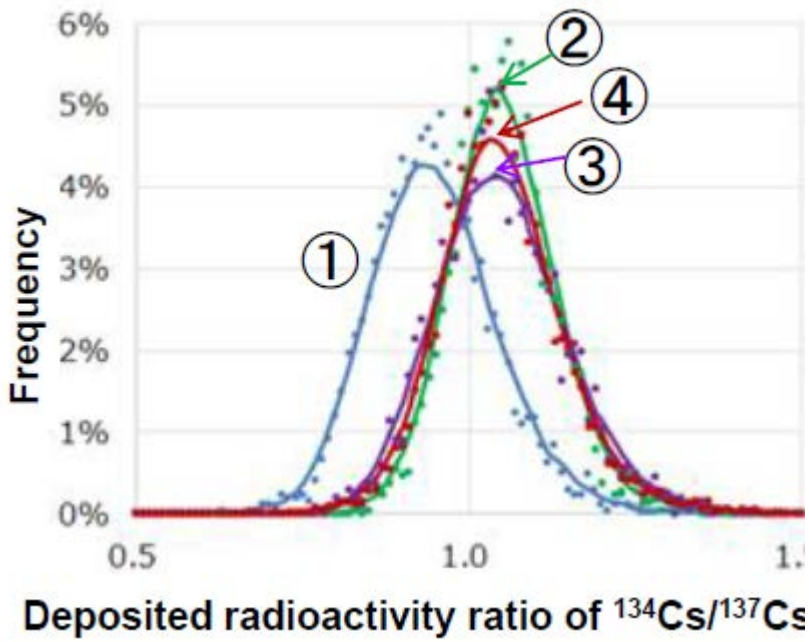


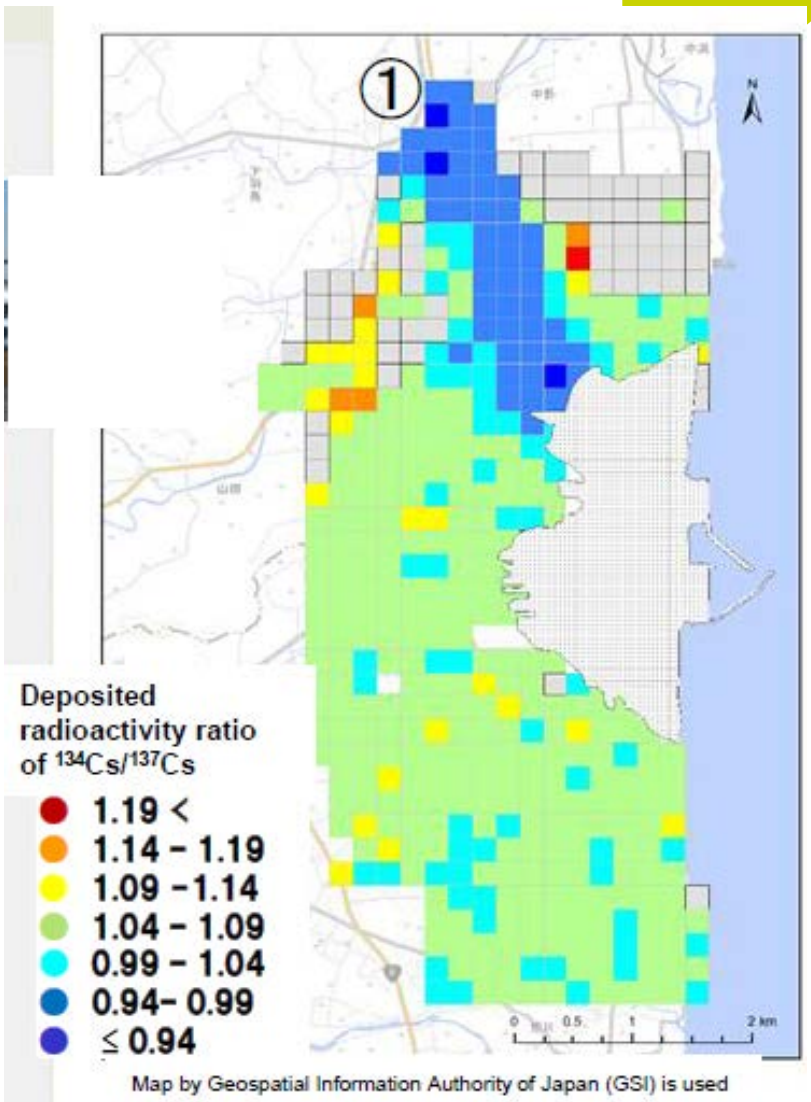


CANBERRA

Contamination from various Reactors

- **Analysis of nuclide ratios can tell which reactor caused the deposition**
- **At time of accident Rx1 had Cs134:137 10% higher than Rx2&3**

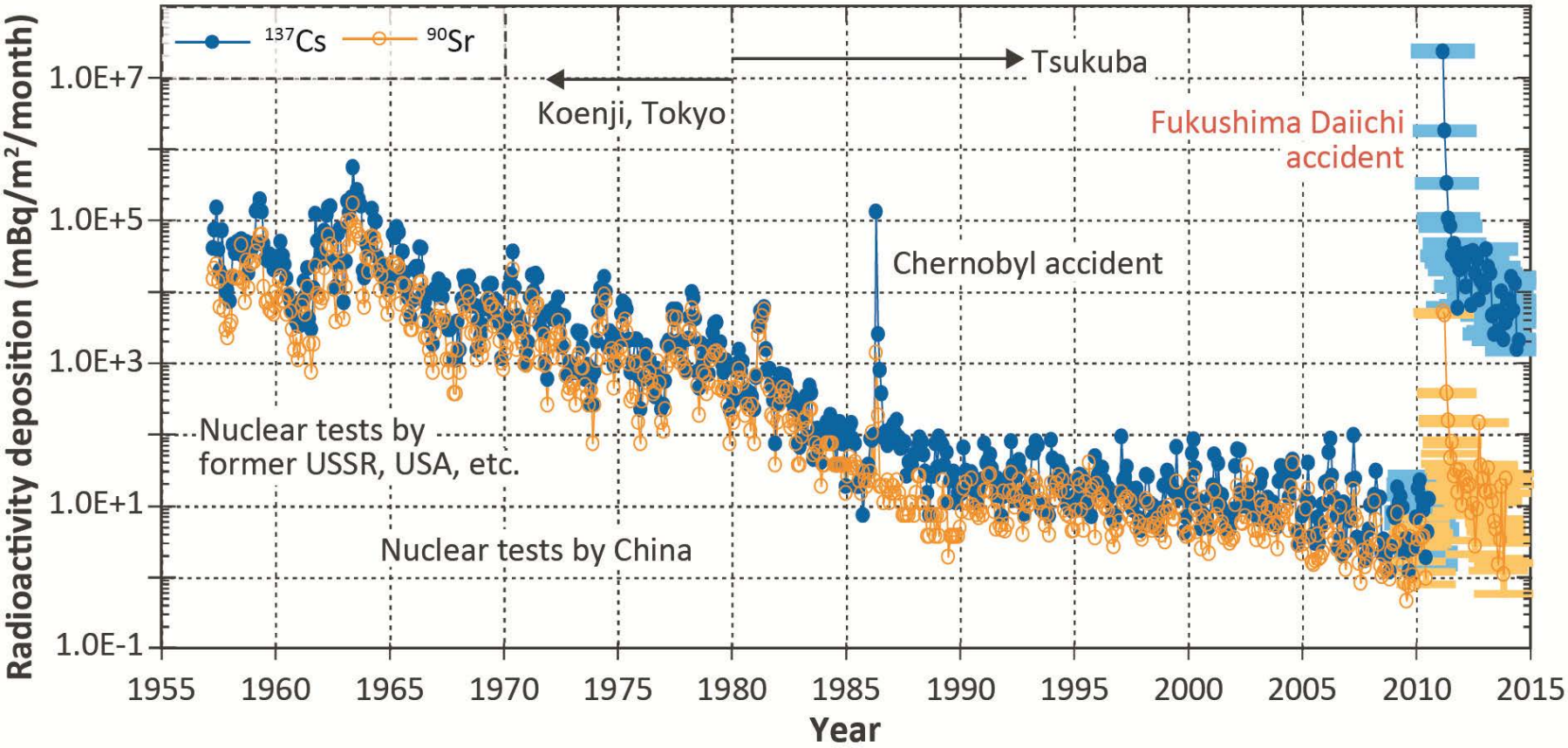




CANBERRA

Historical Perspective

- Cs137 and Sr90 Monthly Deposition Rates since 1957
- Fukushima data for Futaba town – 5km NW, center of plume
- Total weapons deposition ~10% of plume deposition Cs137, 10x Sr90



Food radiation limits

- **Initial limits were low in Japan, and got even lower March 2012**

Country	Water	Milk	Food	Baby food
European Union (note1)	1000	1000	1250	400
USA	1200	1200	1200	1200
Japan <Mar 2012	200	200	500	200
Japan >Mar 2012	10	200	100	50

  - **Units are Bq/kg of total radioactivity [Cs134+Cs137]**
  - **Note 1: The EU limits for food from Japan are the same as the Japan limits**
  - **K-40 comparison: milk, people, most vegetables ~50-100 Bq/kg**
- **If using detector other than Ge, then must show activity is less than half these limits**
- **Being interpreted as applicable to small items individually**
- **Difficult to economically measure these low levels**
- **Very important for local economy to show food is clean**
  - **"perfect" food is very important culturally in Japan**

CANBERRA

Area around Fukushima very important for food production in Japan

- Fish
  - Fresh
  - Processed
- Spinach
- Wakame (seaweed)
- Rice

Source: Nikkei Business (18 Apr 2011)

CANBERRA

Many new food measurement systems now in Japan

FoodSpec™
Radiological Food Analysis System

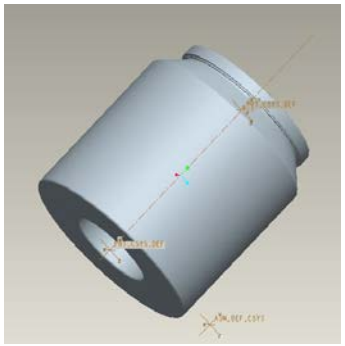
Turn-key system capable of identifying and quantifying virtually all nuclides found in a sample

FoodScreen™
Radiological Food Screening System

Turn-key system for rapid screening of processed or raw food products for key nuclides of concern (^{131}I, ^{134}Cs and ^{137}Cs)

- **About 300 sold by Canberra**
  - **Perhaps 2x more by others**

- **About 700 sold by Canberra via Aloka**
  - **Perhaps 3-4x more by others**
- **New MB designed for new lower levels**

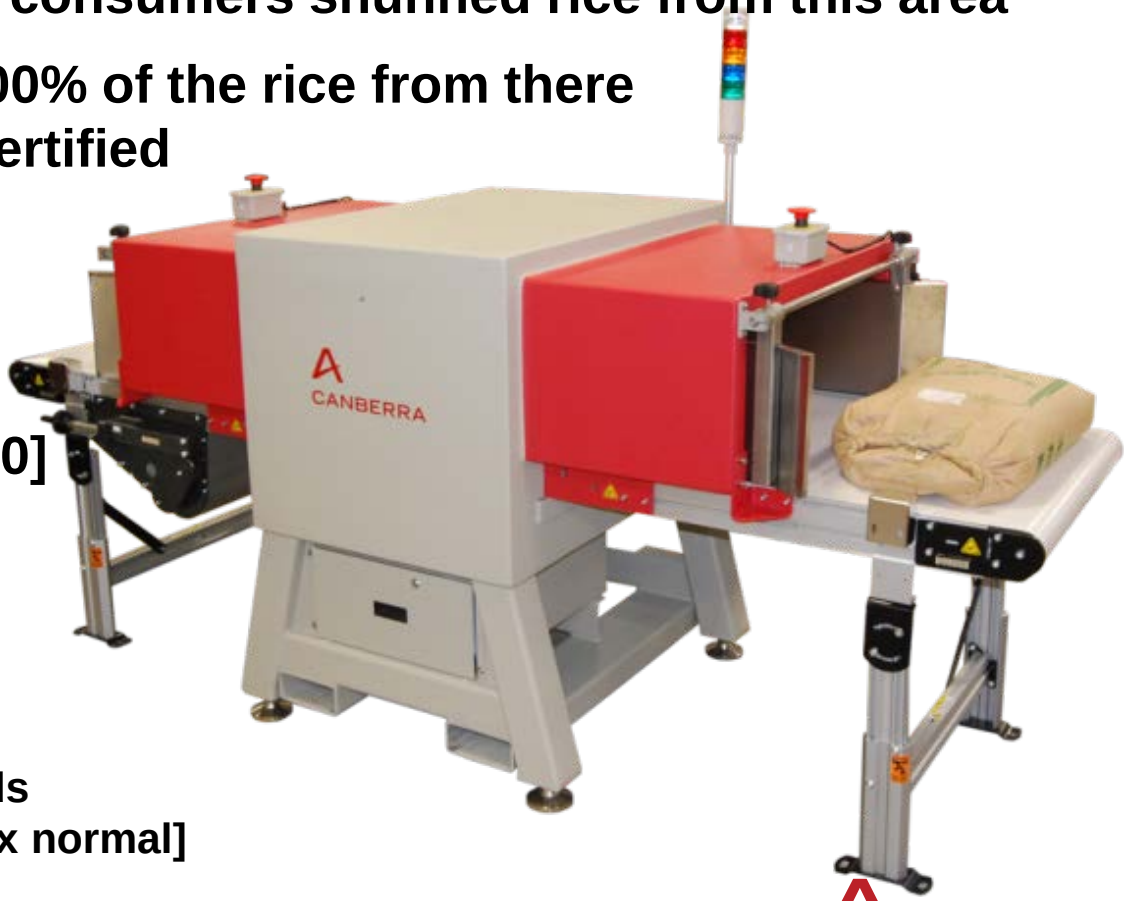


Both can easily measure <10 Bq/kg in a few min.

CANBERRA

Rice, and other food products

- Fukushima prefecture known for producing high quality rice
- Traditional statistical sampling regimes still allowed some rice above regulatory levels to escape the local embargo area
- Widely reported in press; consumers shunned rice from this area
- Prefecture decreed that 100% of the rice from there would be measured and certified to be clean
- QR sticker to get results
- 5 companies supplied ~150 systems [Canberra 30]
  - Designed, built and delivered in 6-8 months
  - Large NaI detector
  - 30 kg rice bags
  - MDA - 13Bq/kg in 10seconds in 1uSv/hr background [~10x normal]



CANBERRA

Rice warehouse with 4 counters

- After each bag is counted, results are loaded into national database where consumer can view assay for that bag
- After first season of counting, expected 20,000 bags over limit but only found 71; too bad, no Ge systems.
- Units easily converted to assay boxes of apples, peaches, fish, …

CANBERRA

Persimmons [gaki]

- Japanese persimmon when semi-dried and cured with sojou is very tasty and expensive – very good cash crop from the Fukushima region [Ampo-gaki]
- When fresh, Cs generally <100, OK; when dried commonly >100Bq/kg = bad
- But since expensive, people commonly only eat one – therefore rules interpreted to apply to single gaki = ~6 Bq each !!
- 6 Bq per fresh gaki is OK [<100Bq/kg]
  6 Bq per dried gaki is Bad !! [>100Bq/kg]
- Need better definition in regulations - US too

The worlds only automatic persimmon counter

- 12 units installed
- 32 NaI 3x4x2” detectors and MCAs
- Typical count time ~1 minute per 8 items
- MDA: 20 Bq/kg in 80 sec [box], 40sec [tray]

CANBERRA

Other food items that have already been shown to be problem

- Leafy vegetables – early on from deposition
- Wild boar – yes they are in Japan
- Mushrooms, especially dried ones
- Other dried fruits – removing water increases Bq/kg
- Fish – especially bottom fish like flounder; many new headlines
- Cows – especially expensive ones fattened on [radioactive] rice straw
- Hay and silage – feed for cows

CANBERRA

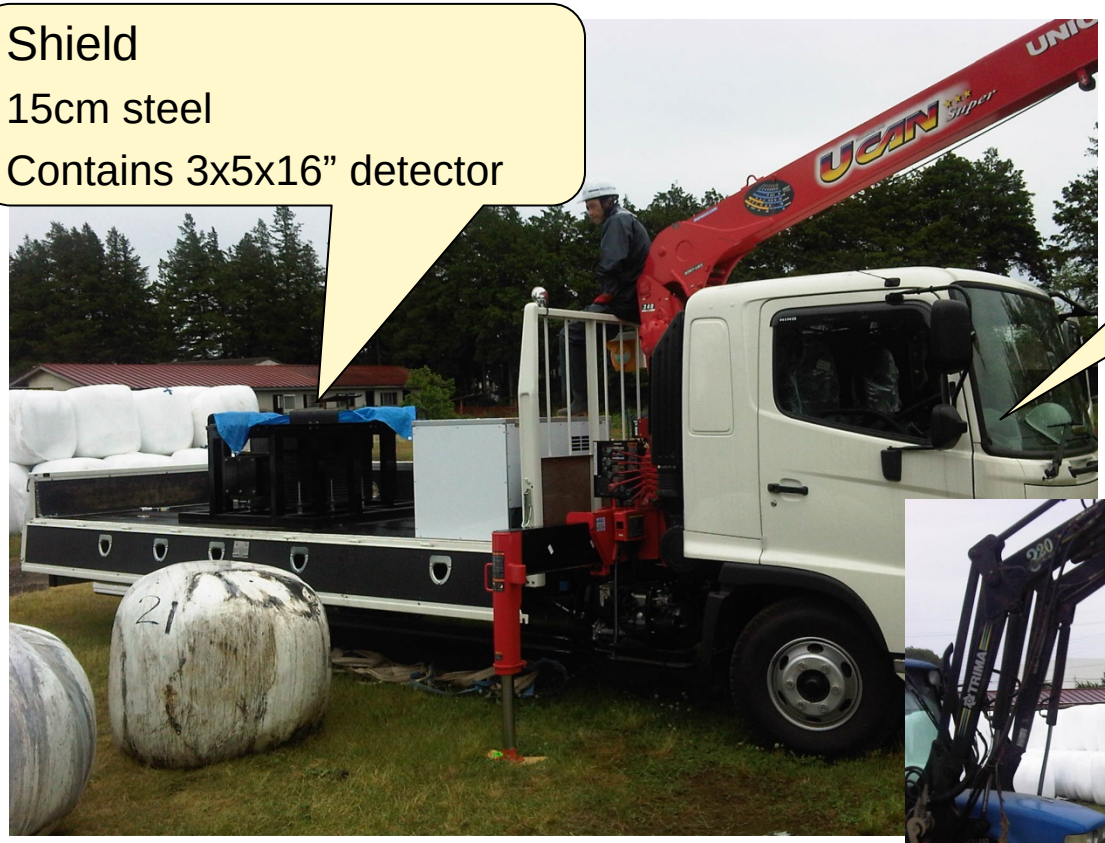
Mobile FR Assay System [FRAS]

to measure food for cows

Shield

15cm steel

Contains 3x5x16” detector



Operator Control Room

weatherproof

heated

contains Laptop PC

MDA = 15 Bq/kg in 20 seconds.

CANBERRA

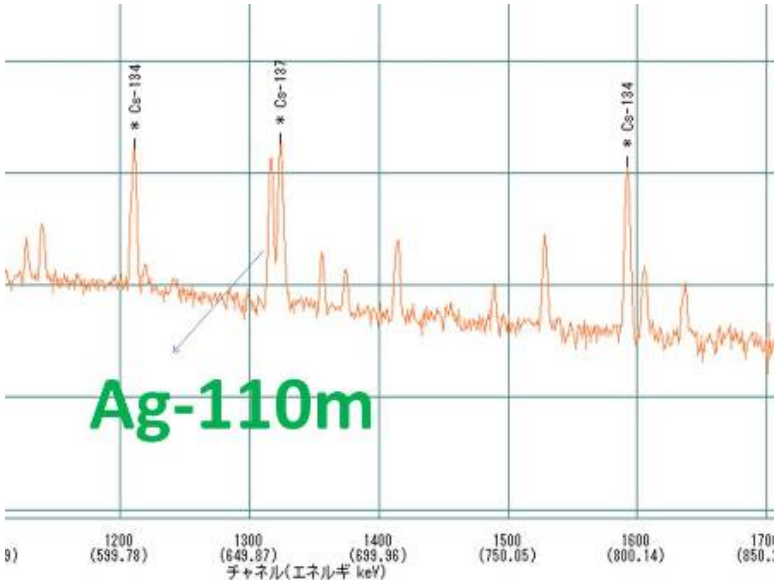
One of the roadside snacks we had while travelling in Cambodia

- **Crispy crunchy spicy deep-fried tarantulas; finger lickin' good**

CANBERRA

Spiders and Abalone are Little Silver Miners

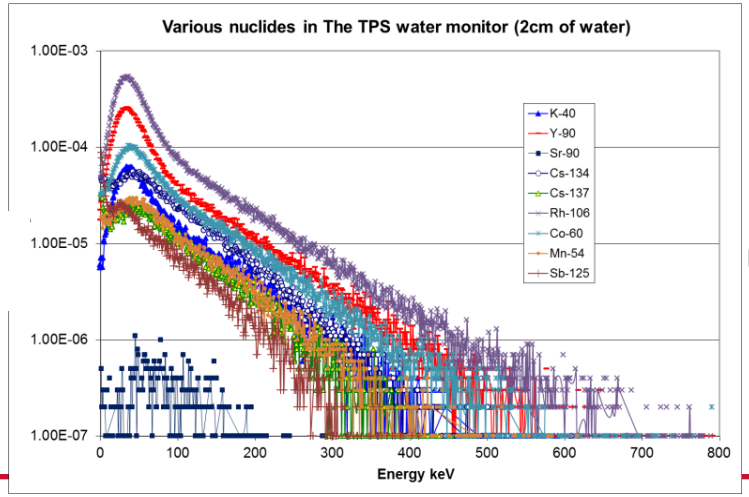
- **Ag110m is present in soil, but several thousand x lower than Cs134/137**
- **In spiders the Ag:Cs ratio is 1000x higher than in the surrounding soil**
  - **Cs-134 + Cs-137 = 3,656 Bq/kg live weight**
  - **Ag-110m = 1,397 Bq/kg live weight**
- ***Bin Mori, University of Tokyo***
- **Scientific minds want to know:**
  - **What about their webs ? Or Japanese silk ?**
  - **Will there soon be a Japanese Spiderman ?**
- **Abalone**
  - **Cs 134+137 = 2,000 Bq/kg, 50x concentration from seawater**
  - **Ag-110m = 410 Bq/kg in meat and 1800 Bq/kg in liver**
  - **Very high preferential uptake of Ag over Cs**
- **Dietary advice**
  - **stay away from Abalone liver**
  - **only consume spiders in moderation**



CANBERRA

Sr90 Water Monitor

- Supplied 5 systems for SrY90 in effluent from water
- Uses Argos Whole Body Contamination monitor sensors
  - Large area [16 x 36cm] very thin plastic beta scintillator
  - Also Beta-Gamma and Alpha-Beta and Gamma-only units
  - Nice module to use – common production item, compact, modular
- Use two Argos sensors looking at both sides of a container of water with thin carbon fiber window
- MCNP simulations for possible nuclides
- MDA = 8 Bq/kg in 60 min [2 Bq/kg with β-γ det]



Waste debris measurements - bags

- Immense volumes of radioactive soil, vegetation, and other debris
- Waste collected in 1 m3 Super Sacks – estimated 30,000,000 bags
- Bags located at thousands of temporary local holding areas
- Will be eventually moved to one of 4 Interim Storage Facilities for consolidation, incineration, and “interim” burial
  - ~~2015~~ ~~2016~~ 2017 operation
- Then, in <30y, be moved somewhere outside of Fukushima Prefecture

CANBERRA

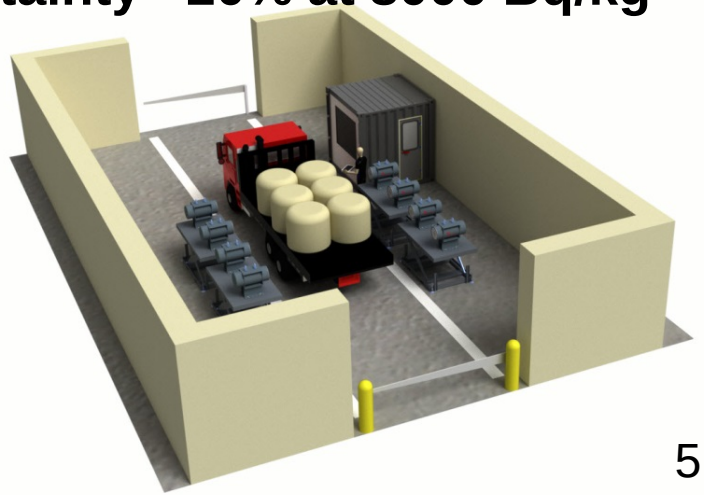
Conveyor Sorting of Contaminated Soil

- **The remediation process for contaminated soil in Fukushima Prefecture involves removing the top ~5-10cm of soil**
- **Soil must be separated into disposal categories: <3000 Bq/kg; 3-8 kBq/kg; >100 kBq/kg**
- **AREVA Back-End BU has designed a transportable device to separate the soil into "above" and "below" the limits;**
- **The unit can process up to 100 tons per hour;**
- **It is currently being demonstrated in Japan**
  - **3 other companies with similar units**

CANBERRA

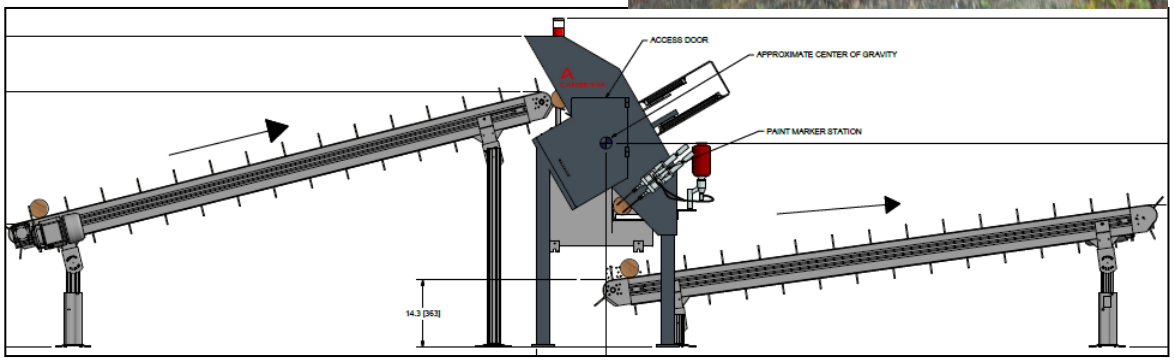
Canberra's Truck Scan

- ~30,000,000 m3 of soil excavated and in 1 m3 sacks
- These sacks will be moved to the Interim Storage Facilities on trucks;
- Demonstrated [fall 2015] a system to perform quantitative gamma spectroscopy on a truck loaded with typically 7-8 sacks;
- Cs-137, Cs-137 determined for each sack
- 8 shielded LED-stabilized NaI detectors
- MDA = ~100 Bq/kg in 10-15 sec.
- Uncertainty ~20% at 8000 Bq/kg



Logs for Timber and Mushroom

- Fukushima area heavily forested
- Logging of cedar is big commercial industry
- Logs to grow Shitake mushrooms also big industry
  - Contaminated logs make contaminated mushrooms
  - Project was to measure mushroom logs with MDA of 12 Bq/kg
  - Contract not awarded



- Current design project is to assay timber logs
  - 6-40cm dia x 4m long
  - < 300 Bq/kg in outer growth layer in 4s as log is moving by down conveyor line

CANBERRA

Things we can do better 1

- **Environmental monitoring stations that are better for accidents**
  - **All 3 Rx accidents had most releases from un-monitored points**
  - **Autonomous power for operation and data communication**
  - **Iodine collection – even better if active measurement**
  - **Air mover is a challenge – currently high power devices; maybe lower power lower sensitivity is OK**
- **Iodine Thyroid measurement capability for large scale rapid deployment, easy for "untrained" operator**
  - **Works OK in presence of short T½ nuclides in early accident phase**
  - **Procedures to do good measurements in elevated background areas**
  - **This may be a good area for these new high res'n scint'n and RT SS detectors**
- **Portable laboratories rapidly available to take near to accident site**
  - **Radiochemistry, radiation measurement, in-vivo, contamination**
- **Rapid response to public fears – reduce public anxiety**
  - **Measure and report: in-vivo adults and babies, pets, other treasured items**
  - **Far earlier than done here**

CANBERRA

Things we can do better 2

- **Accepted values on re-occupation of evacuation zone**
  - **Inform occupants of age-specific risk, as compared to others that they accept**
  - **Inform occupants how to minimize their radiation dose**
  - **Give them tools to minimize, and feel better – recording personnel dosimeter, area doserate meter, food counter, routine in-vivo counts and health checks**
- **Gamma cameras that are practical and affordable**
  - **Light weight; wide dynamic range [or low and high models];**
  - **No off-axis false response**
  - **Progress being made here**
- **Uniform and Internationally accepted levels of radioactivity in food and on export/import of products**
- **Need training process for large number of non-technical radiation measurements that WILL be performed by general public**
  - **E.g. YouTube videos on how to use, how to survey, how to check cal, …**
- **Minimize evacuations**
  - **~600-1600 people died from the evacuation**
  - **KI available earlier to workers and population**

CANBERRA

THANK
YOU!
STOP
935