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Radiation Measurement Experiences and Lessons to be Learned in Response to the Fukushima NPP Accident

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Preparation for this presentation

- **Previous experience at things like this**
  - **TMI - On-site 36 hours after the accident, for the next ~1mo**
    - Managed the Radiation Management Corporation team responding to this accident
      - Mobile WBC at TMI during the accident and for the next many months
      - Operated mobile gamma spec laboratory – did most of the effluent measurements from unmonitored release points
      - On-site counting lab during the decon project
      - Off-site environmental monitoring program – including 1 truck of chocolate per day
  - **Chernobyl – several trips to Ukraine**
    - Supplied 7 mobile WBC in support of Population monitoring + 2 more to the plant
    - Worked with the German team performing these population studies
- **Published or on-line literature about instrumentation there**
  - **Extensive data available about this accident – some of it is correct and useful**
    - much of it in Japanese; electronic translation software is still only marginally understandable
- **Health Physics Society Professional Development School - Fukushima**
  - **This is a small part of a lecture I gave as one of the instructors**
- **Personal experience in Japan**
  - **Part of AREVA initial response team first 4-5 months**
  - **Since then assisting our Japan office in business development efforts**
  - **19.5 trips to Japan since the accident; 5.5 months in Japan; 1.2 mo on airplanes = 3mSv**
  - **My major project the past ~2 year period**
  - **Our team prepared many concepts and proposals, some of which were actually accepted**

Key points from this presentation

- Purpose is to inform, educate, and learn for the future
- Yes, some things could have been improved, but the things that the professionals responding did were very good, considering the circumstances
- Real doses are quite low, even among workers
    - Good Rx design, Rx operations and response, HP response
- Imagined doses and associated harm are high, among workers and population
- ALARA should apply to both real and imagined dose, and the economic consequences of imagined dose/activity. It is critically important to the success of the NPP industry
    - Education, dissemination of reliable quality information
- Measurement ideas that were proposed are shown in this presentation. Most have not been accepted [so far], but many are still good ideas, so are included.

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Comparison to TMI and Chernobyl

Item of comparison	TMI	Chernobyl	Fukushima
Reactors present, damaged	2, 1	4, 1	6+4, 4
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	No
Population evacuation	140,000 v	350,000 m	200,000 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

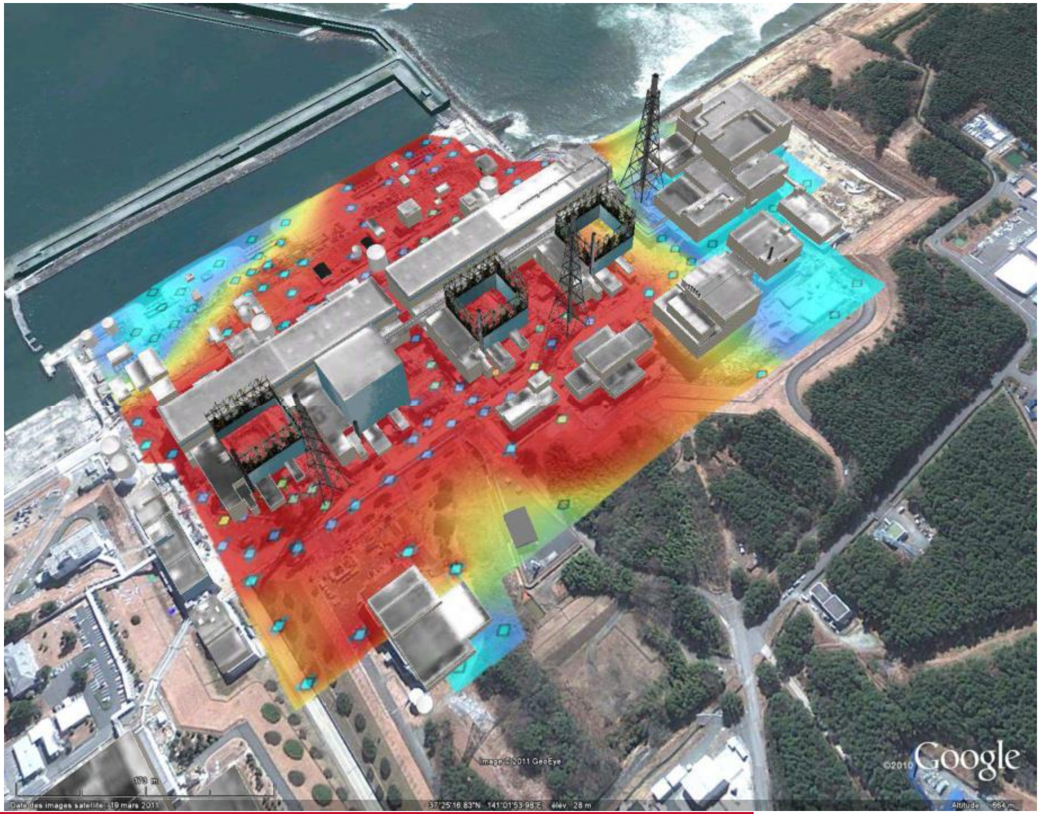
EARLY PHASE
ON-SITE ISSUES

generally as Canberra input to the AREVA response effort

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 just walked around with Colibri doserate meter
  - With integral GPS and logging
- Map created using CEA radiological mapping algorithms licensed by Geovariences



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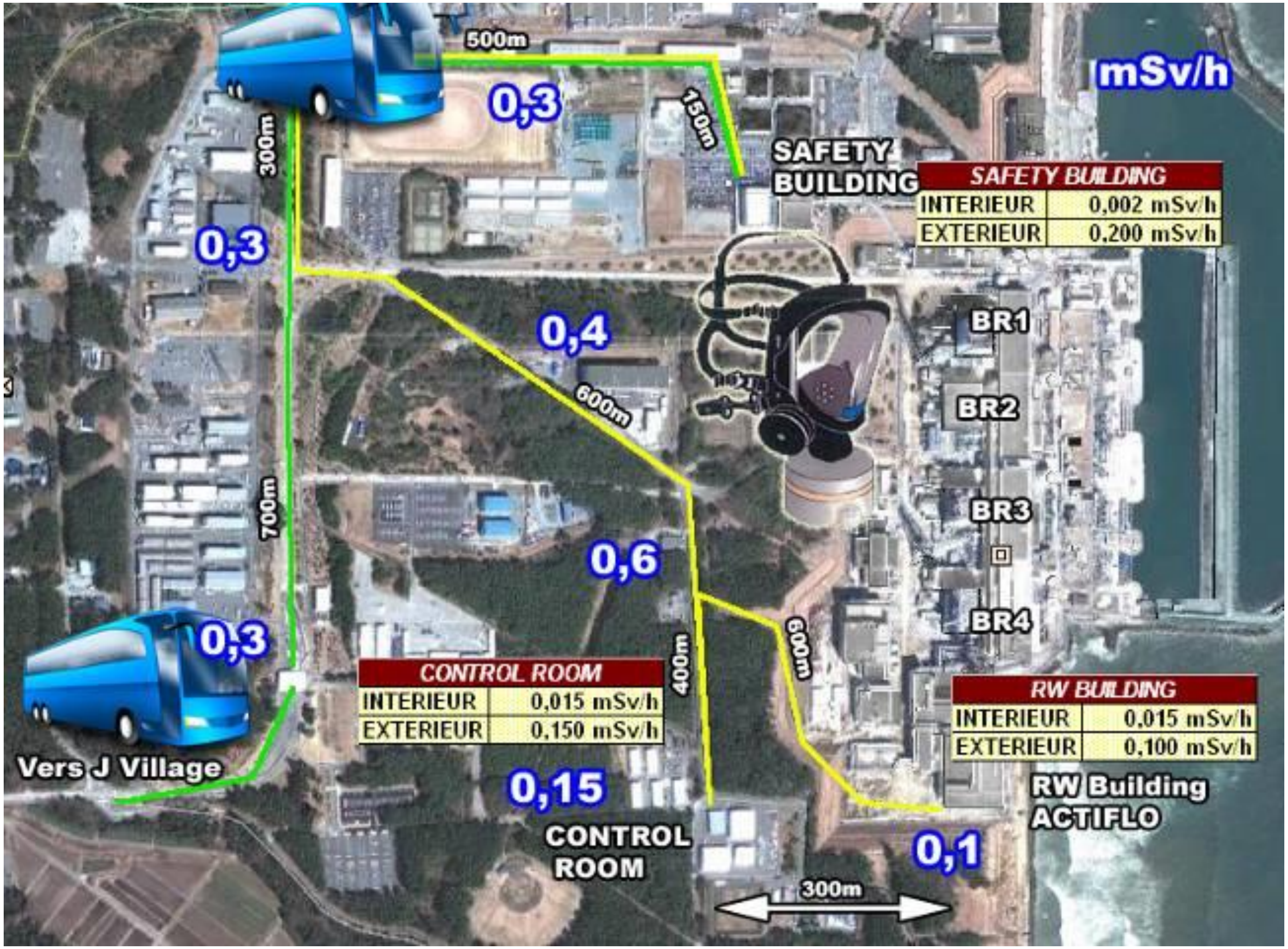
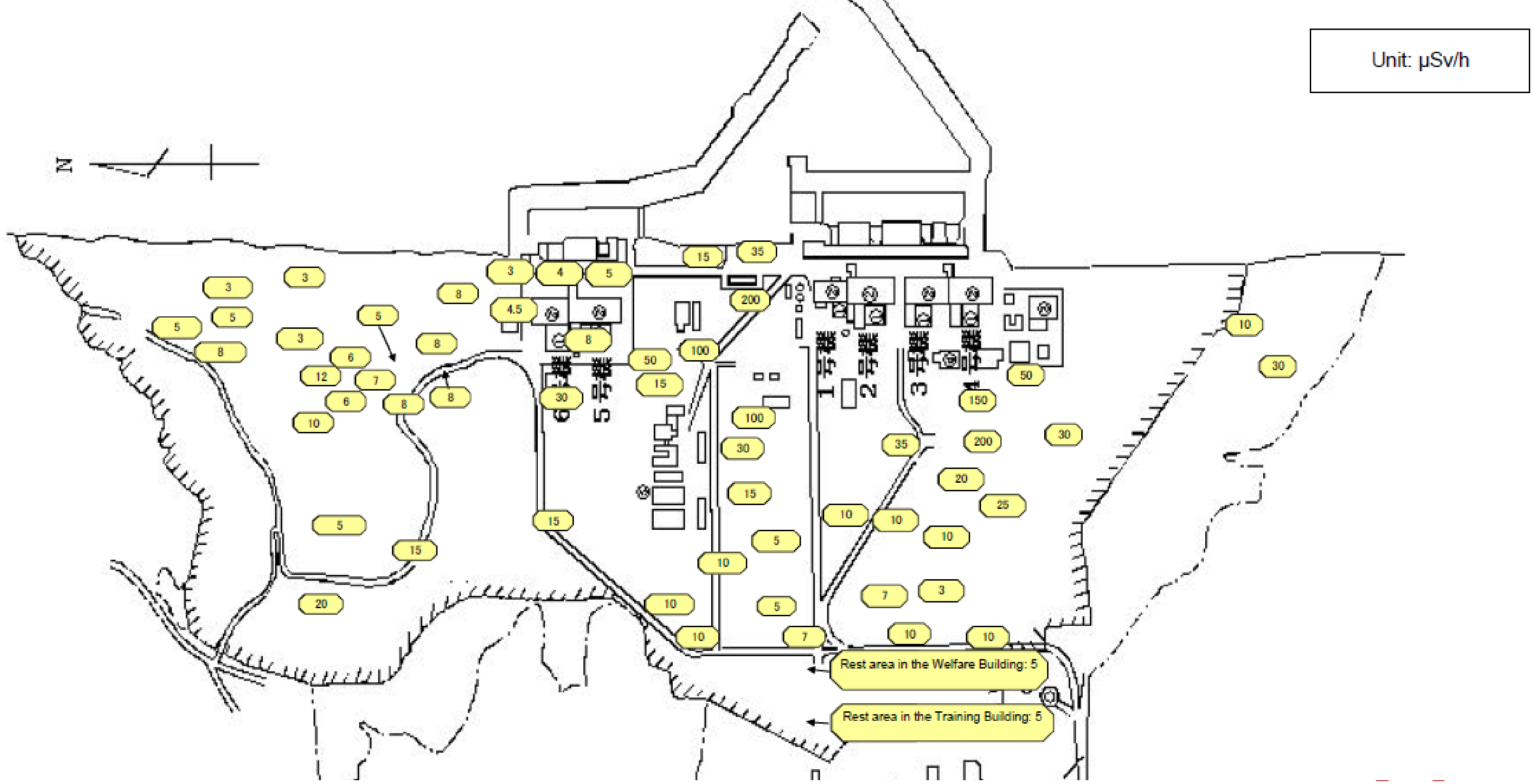
Map used by AREVA team for dose optimization planning
- where to put water processing equipment
- lowest dose route to get there



January 2013TEPCO map of site

- **ISO-doserate contour map would be more informative to workers**
- **5uSv/hr in rest areas**

Survey Map of the Entire Fukushima Daiichi Nuclear Power Station
(Used in the Measurement Performed on January 7-8, 2013)



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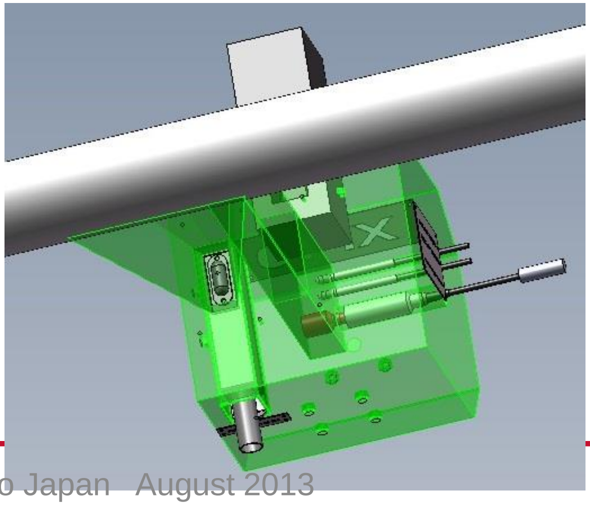
AREVA-Veolia-Canberra water processing system

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



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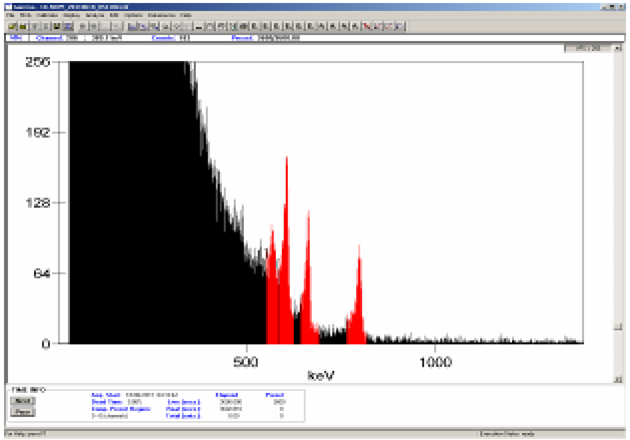
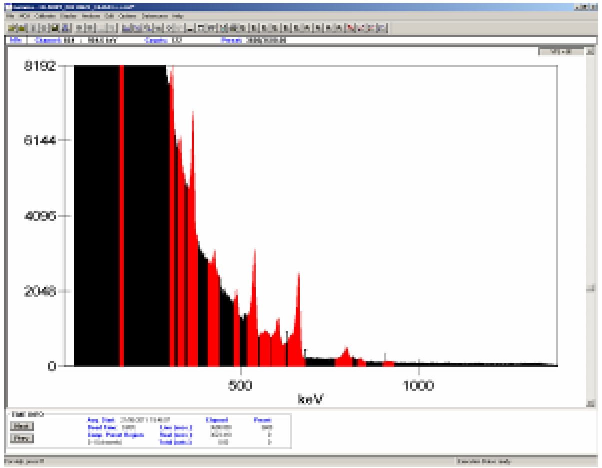
Activity determination via CZT gamma spectrometry measurement channels

XI-10 CZT 500

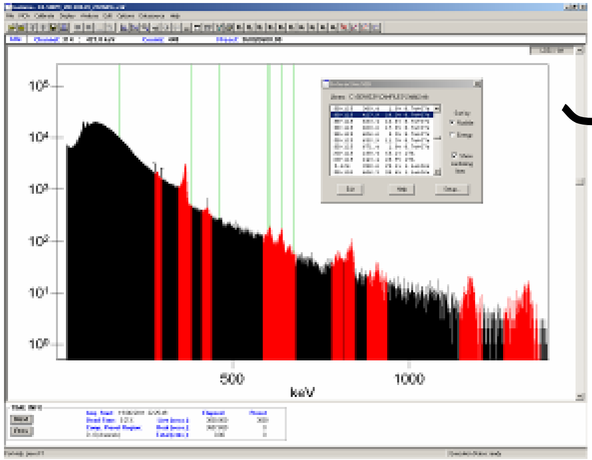


Cs134 and Cs137

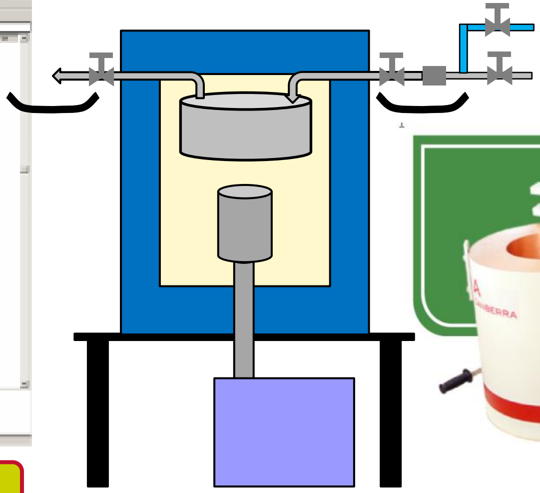
- Unit DF was higher than expected
- Output concentration too low to be measured
- Proposed more sensitive automatic system instead of grab samples (not accepted)



I131 and Sb125



I131 Sb125 and Co60



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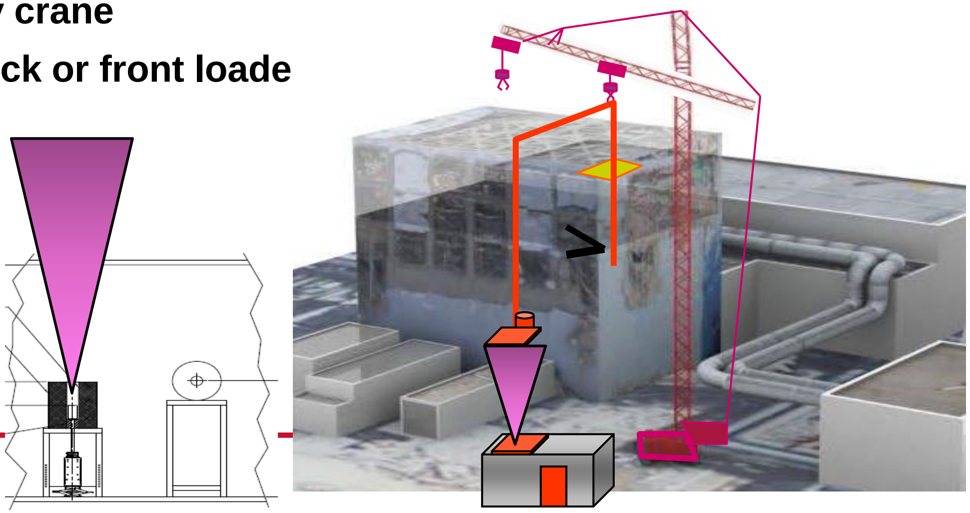
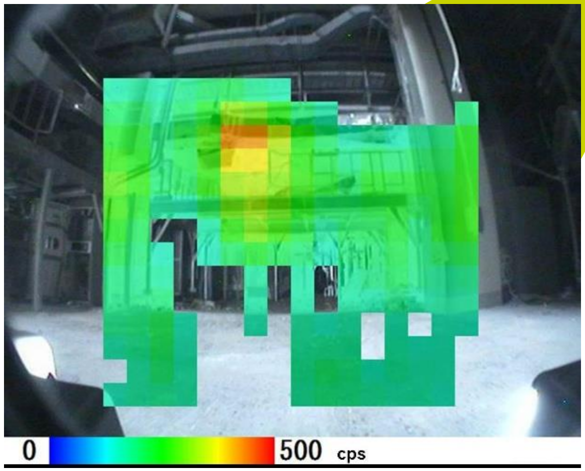
Sorting waste during demolition

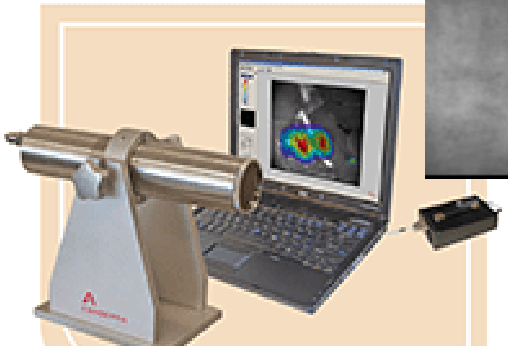
- Part of AREVA plan for waste retrieval
- Sort into proper radiological category early to save money and dose later when processing waste
- Create categories of waste based upon likely future waste processing and disposal methods
  - E.g. <1 Bq/g; 1 – 100 Bq/g; 100-10,000; >10,000
- Have separate containers for those categories
- Use imaging system on crane to identify hot debris
- Use remotely operated gamma spec station
  - 10' ISO container
  - Shielded and collimated Ge detectors
  - One pointing up for items suspended by crane
  - One pointing to the side for items on truck or front loade
- Short count time
  - 15 seconds for 100 Bq/g
  - 120 sec for 1 Bq/g
- Not implemented

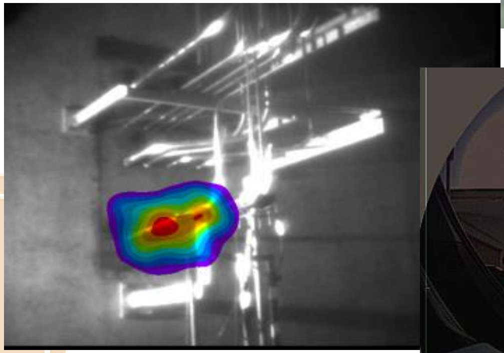


Gamma Imaging activities

- Many “research” prototypes tried
- Complex, large, poor resolution, so far
- Don’t think that any are in routine use yet
- Our commercial unit quite well suited, but not tried yet



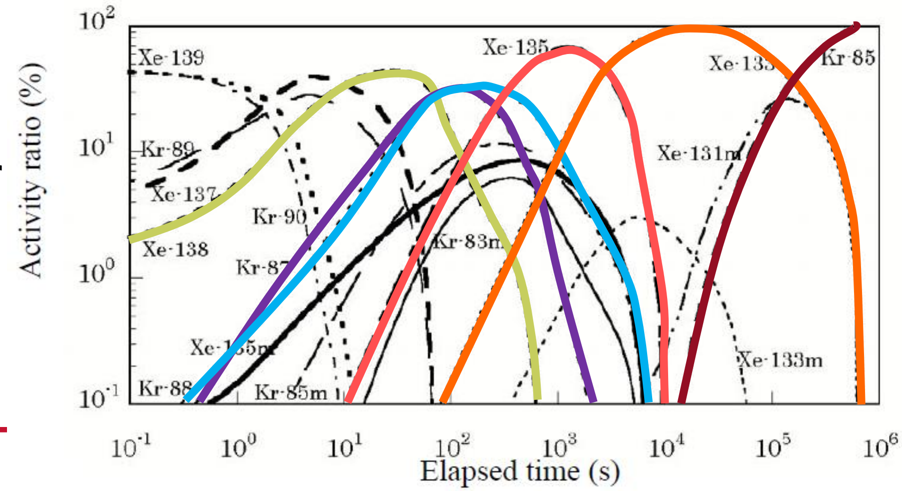




Where is the core and is it stable

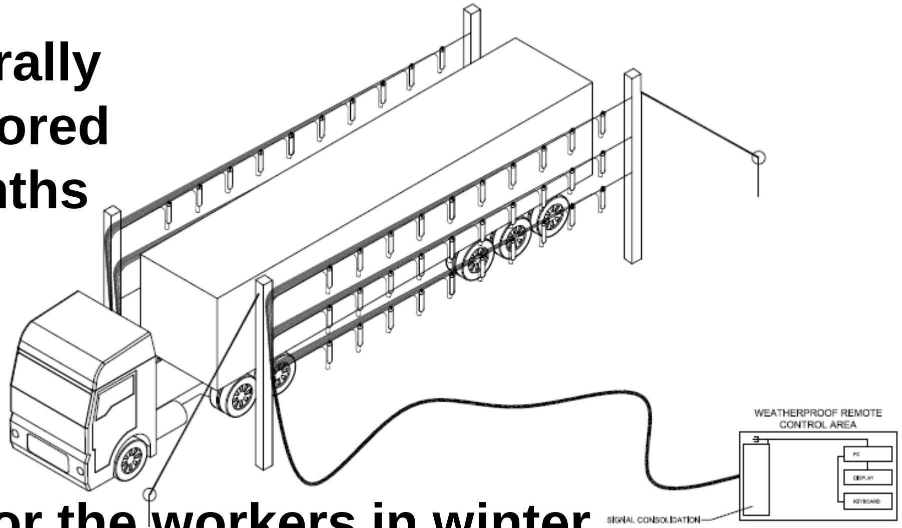
- **In late summer 2011, outside observers, notably the US INPO team, raised concerns about the status of the core**
  - **Where is it ? Best guess Unit 1 melted thru, unit 2-3 inside RPV**
  - **How stable is it ?**
    - **OK now, but want early warning of anything making it less stable**
    - **E.g.: another earthquake, debris removal, fuel removal activities**
    - **INPO called this "Monitoring the approach to criticality"**
- **Proposal B – very sensitive off-gas monitoring**
  - **Gasses quite prolific early fission products with nice high energy gammas**
  - **Gasses can escape the water fairly easily and quickly**
  - **Ratio of gas concentrations can tell the time of the fission**

- **Ge noble gas monitor**
  - **Similar to OL3 and Taishan NPPs**
  - **Large Ge, large pressurized gas chamber**
- **First proposed mid 2011**
- **Proposals requested again; situation still open**



Vehicle Contamination Monitor for TEPCO

- Vehicles leaving the site were generally un-monitored or ineffectively monitored [high background] the first few months
- We proposed this to TEPCO as part of the AREVA team
- Not accepted
- Added roof to improve conditions for the workers in winter
- Still labor-intensive and many non-ALARA man-hours in 3uSv/hr field



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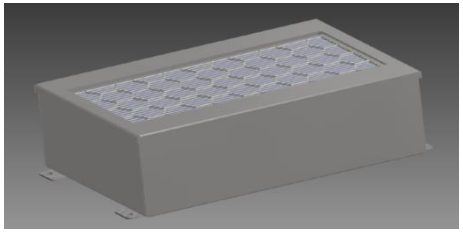
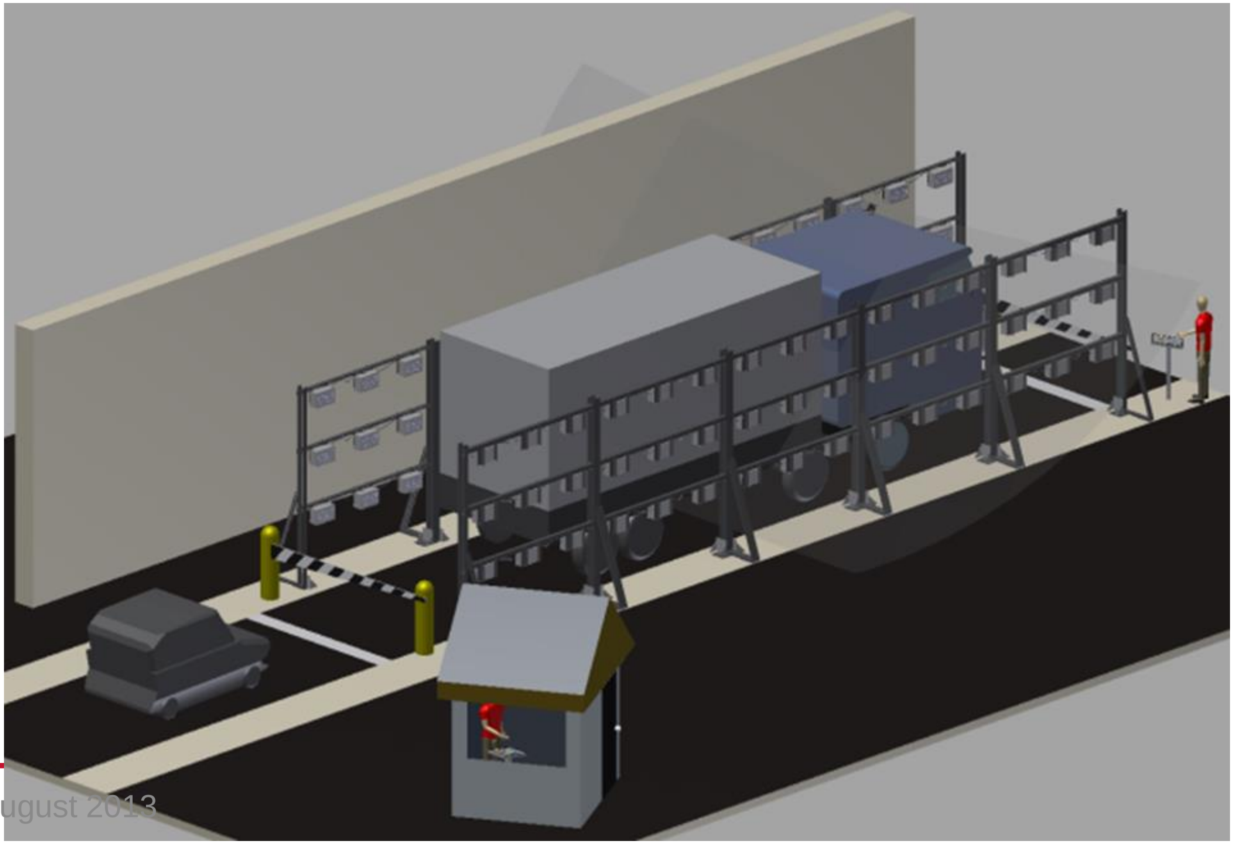
Vehicle Contamination Monitor – part 2

- **Revised design to conform to new TEPCO specs Fall 2012**
  - **4 Bq/cm2 in max 1000cm2 area; 0.3 uSv/hr bkg**
  - **40 Bq/cm2 in maximum 1000cm2 area at 3 uSv/hr**
- **Busses, trucks, minivans, cars**
- **We proposed using 78 large area B-Gamma sensors**
  - **From our Argos Total Body contamination monitor**
  - **Beta channel for surface contamination**
  - **Gamma channel to find radioactivity in cargo**
- **Special software to interpret and display present the results**
- **No contract awarded; not sure why**





Radiation measurement labs

- Contamination and high background shut down the on-site NPP lab
- Samples for radioassay being taken off-site – still
  - Inefficient use of labor for transport
  - Delayed time in response
- No mobile labs [I operated one after the TMI accident]
- As part of the AREVA team, prepared proposals for transportable RadioChemistry Sample preparation Laboratory, and Radiometric Sample Assay laboratory
- Could be built off-site and transported complete to site
- Could be relocated as site remediation progresses
- Same concept used at TMI, Chernobyl, and various D&D jobs
- Concrete block shielding walls could be added if needed

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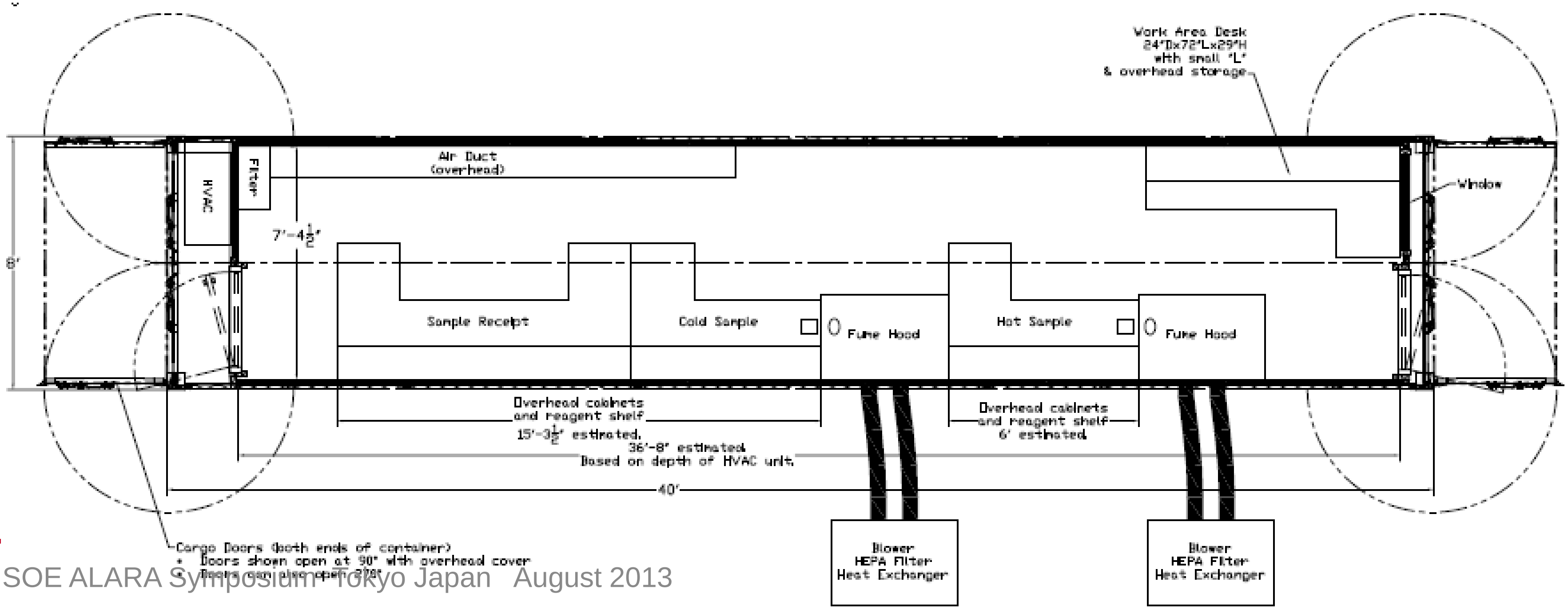
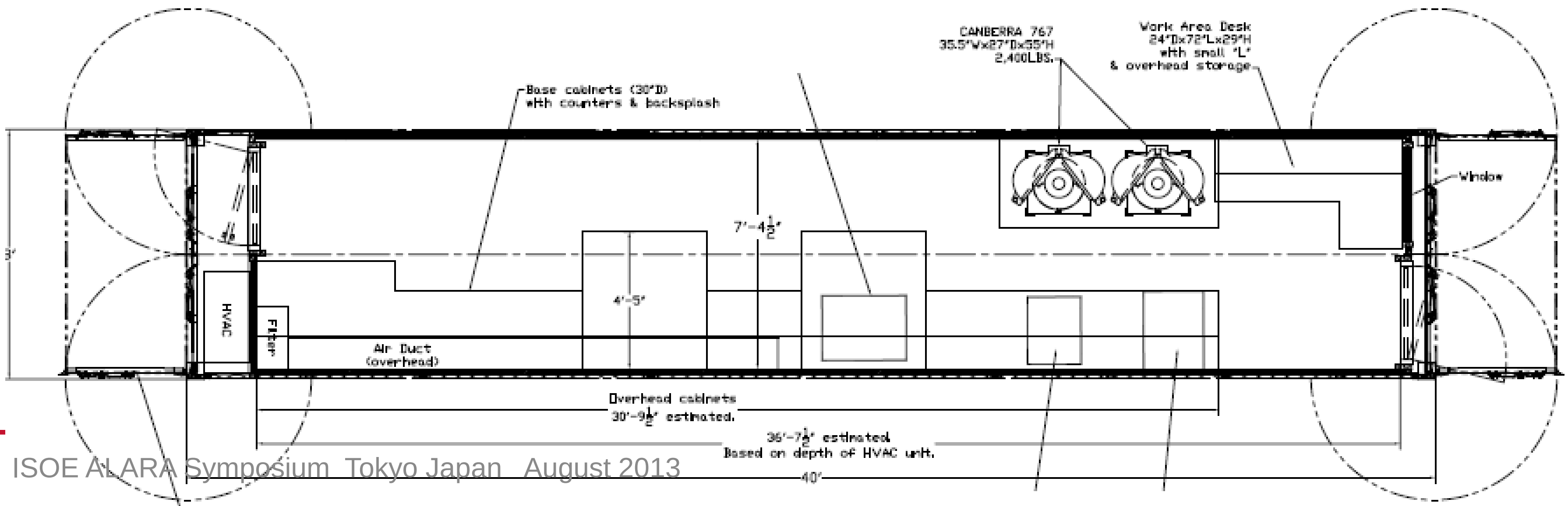
RadioChemistry Laboratory

- **40' long ISO Shipping Container, extra height, covered entrance**
  - **Laboratory furniture installed at factory; ready to operate within a few days of site arrival**
  - **Air contamination monitors and dose rate monitors**
- **Sample receipt area with contamination checking radiometric equipment**
- **Two work areas – one for hot samples, one for low level samples**
- **Two radioisotope fume hoods with external HEPA filters on exhaust**
- **Sample preparation equipment and measurement equipment not defined yet**
- **Water supply and drains to be defined – either plumbed or from containers**



Radiometric Sample Assay Laboratory

- **40' long ISO Shipping Container, extra height, covered entrance**
  - **Shields installed at factory, all equipment calibrated at factory, ready to operate within 2-3 days after container installation and electrical connection.**
  - **Air contamination monitors and dose rate monitors**
- **Sample receipt area with contamination checking radiometric equipment**
- **Dual low energy Ge detectors with shields**
- **Liquid Scintillation Counter with automatic sample changer**
- **Alpha spectroscopy system with 6 channels**
- **Gross alpha/beta counter with automatic sample changer**
- **Portable spectroscopy for field gamma spectral measurements**



Air contamination, respiratory protection

- Is radiation the biggest hazard here ?
- Are respirators ALARA ?   Probably not, now that I-131is gone and once the first rainy season is over
- Use more alarming CAMs – several on-site already
- More ALARA to use personnel air particulate samplers and frequent WBCs to prove respirators not needed

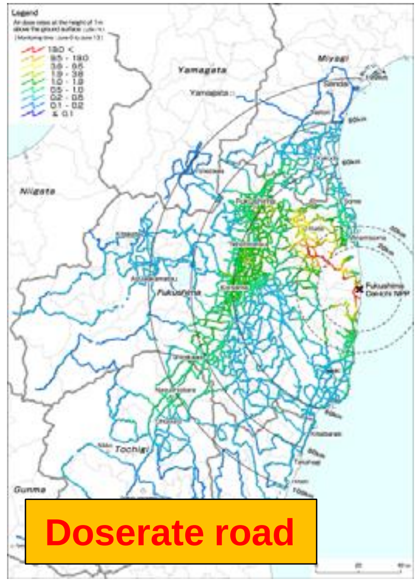
ENVIRONMENTAL AND OTHER OFF-SITE ISSUES

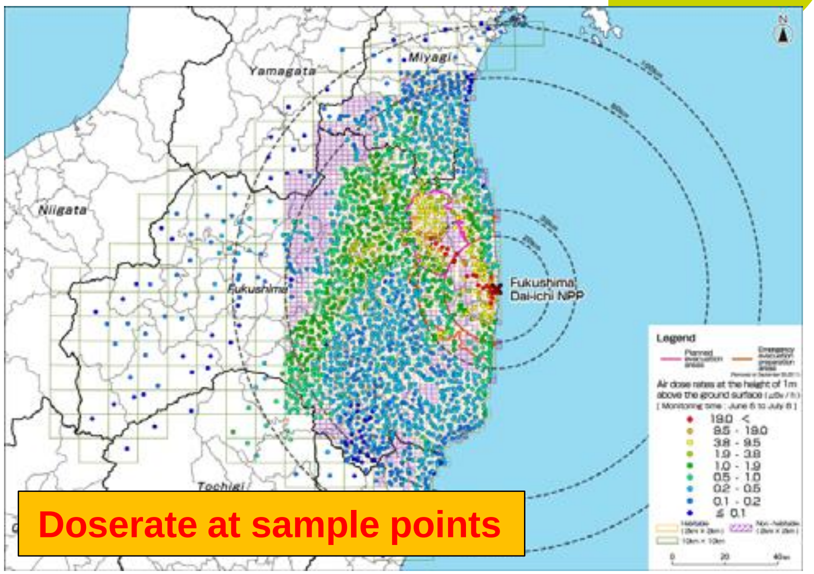
Ground deposition measurements and maps

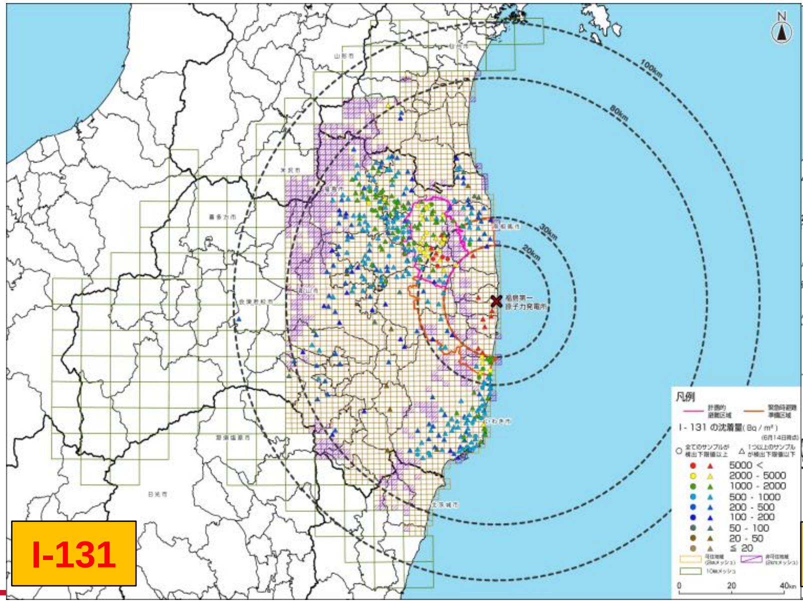
- **Jun-July 2011 JAEA began this massive project**
- **2200 soil locations, sample + doserate [440 people]**
- **Vehicle doserate where roads [291 people]**
- **Ge gamma spec at all locations**
  - **Cs137 Cs134 I131 Te129m Ag110m**
- **Sr89 Sr90, 100 targeted locations**
- **Pu238 Pu239+240, 100 locations**
- **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 in progress**
- http://ramap.jaea.go.jp/map/

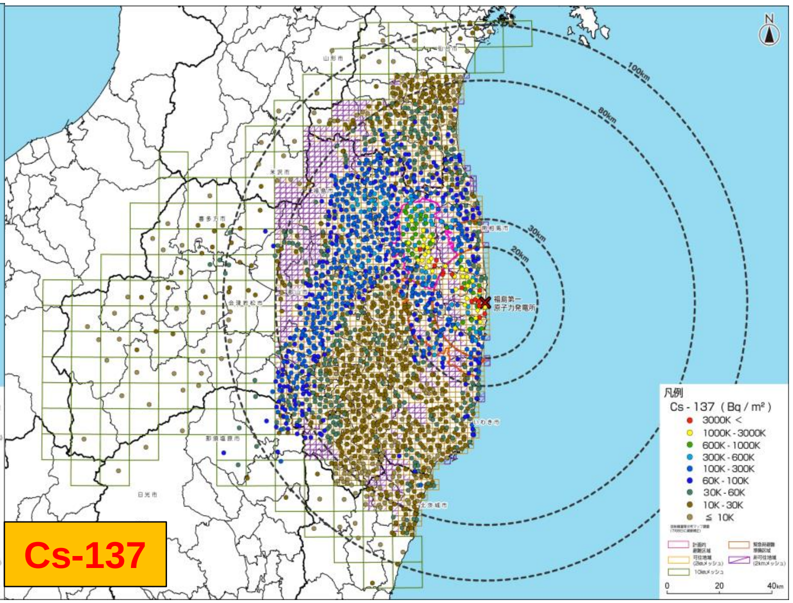
Ground deposition measurements

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



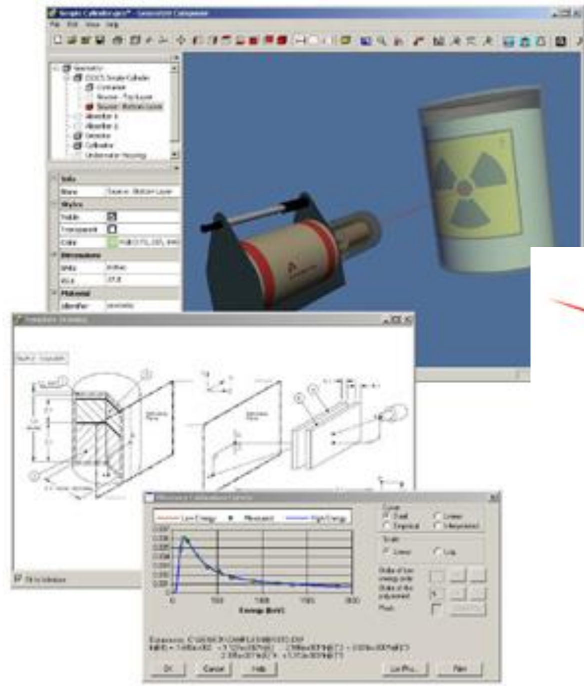






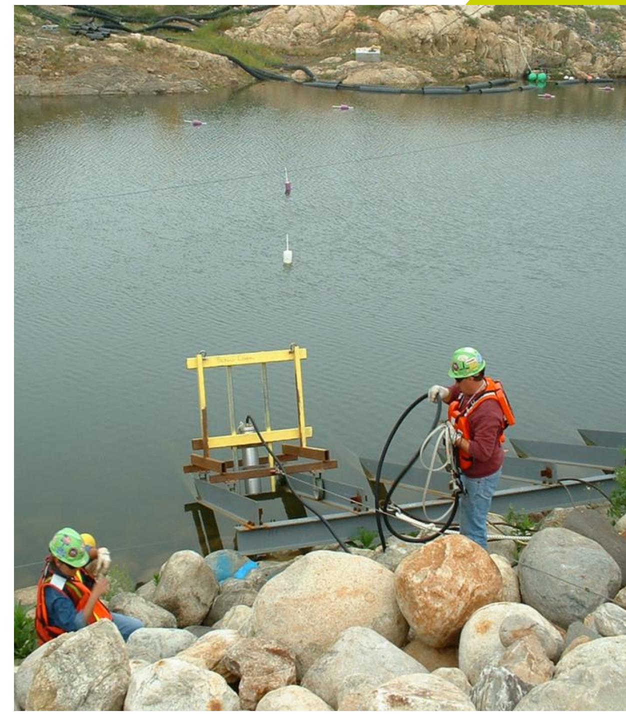
ISOCS – Ge quantitative measurement system

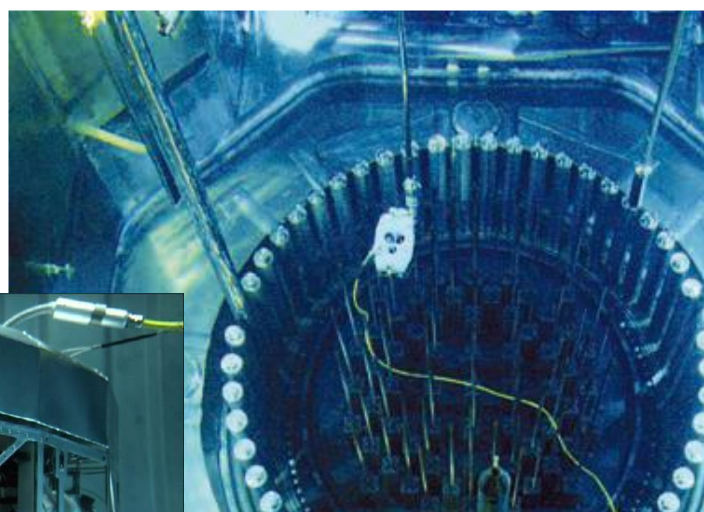
- Very common for D&D projects in US and Europe, but very few in Japan
- Ge detector, shield, MCA, gamma spec software
- Mathematical efficiency calibration software - No radioactive sources needed
- Calibrations valid from 10 to 7000 keV
- 21 geometry templates for common container shapes and sample distributions
- ~30 new orders since accident [most for detector and software]
- Don’t really know much about how they are being used

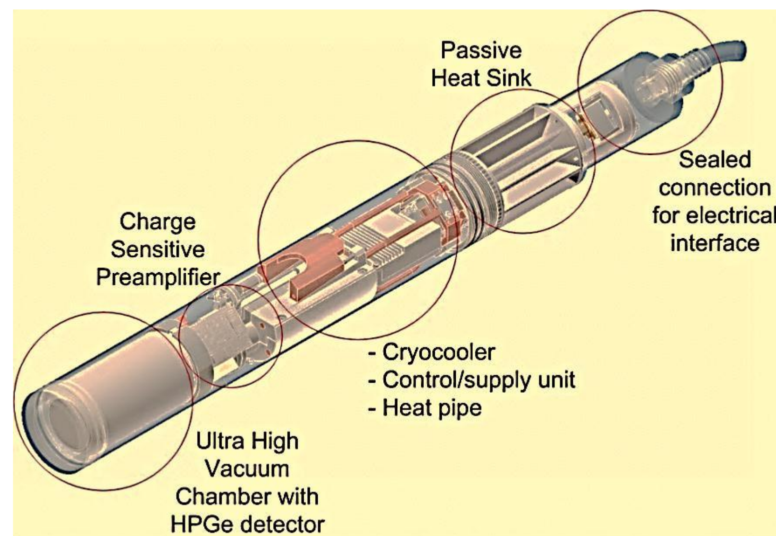


Underwater measurements

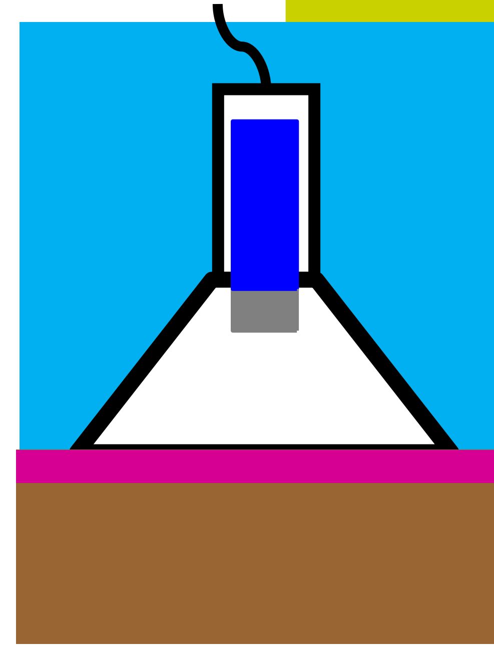
- **Desire to know the inventory of radioactivity at the bottoms of rivers and lakes and seas**
- **Taking samples difficult and unreliable**
- **Proposed several alternatives**
  - **LN cooled Ge – any size detector**
    - Used many times before – Maine Yankee at right
  - **Electrically cooled Ge**
    - Limited power means modest size Ge
  - **ROV submarine with LaBr scintillator**
    - Routinely done by AREVA in NPP jobs
- **Selected the ROV + LaBr option**



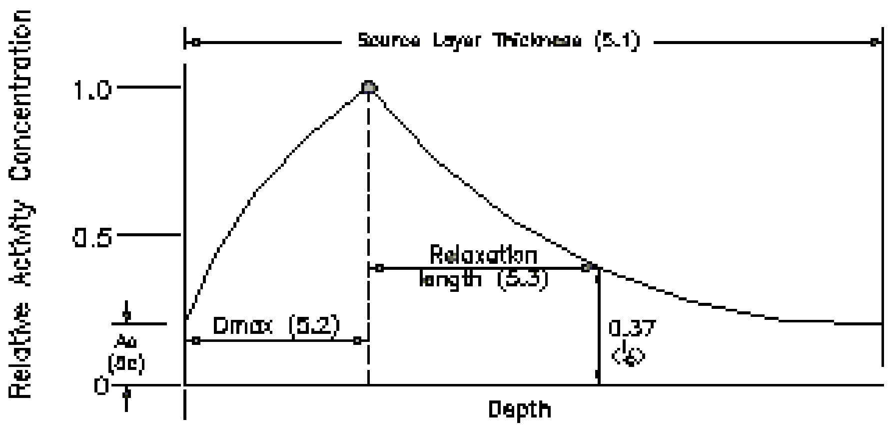


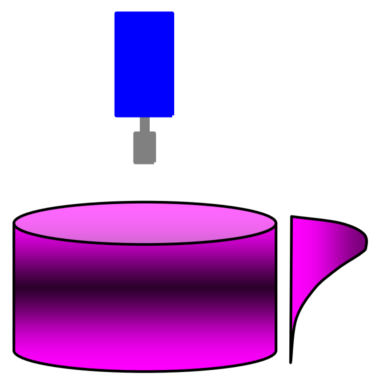


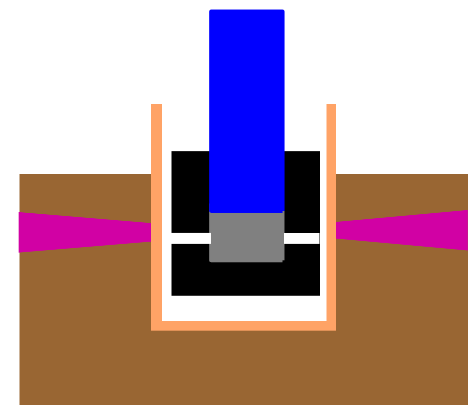
Shallow underwater measurements



- Large number of lakes and ponds [3700] to be measured
- Canals delivering water to rice fields – MANY
- Proposed water displacement tool on detector
- NaI detector to show that results are OK – 1min
- CeBr detector to estimate depth
  - Using Cs134 low and high energy lines and ISOCS calculations to determine depth profile
- Can also use collimated detector for boreholes







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Food measurement

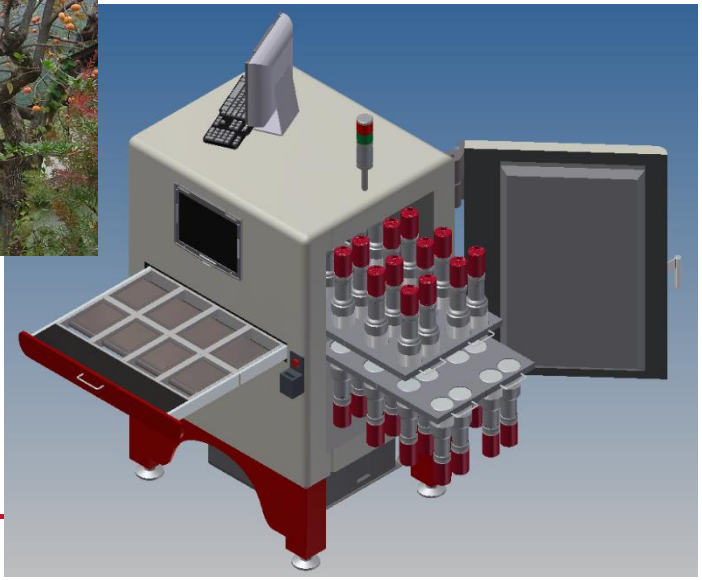
to minimize imagined dose and improve economics in region

FoodSpec™

Rice Bags

FoodScreen™

Persimmons



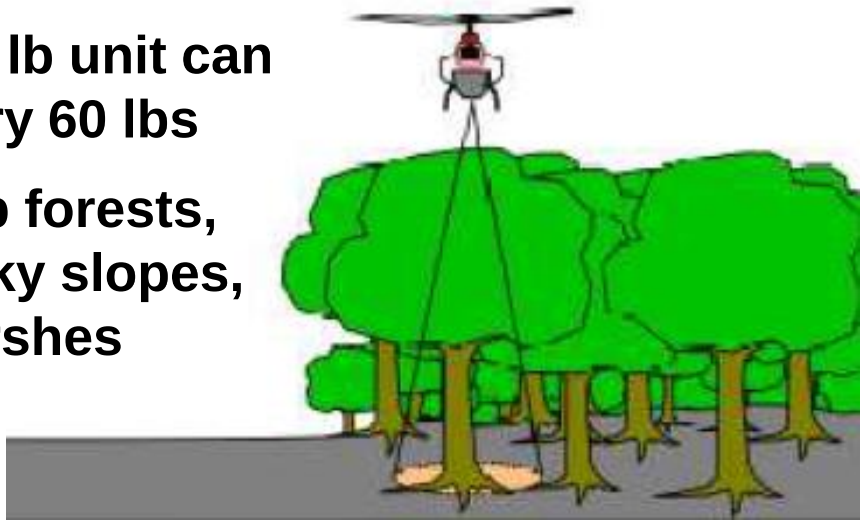
Other food items that have already been shown to be problem

- **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**
- **Hay and silage – feed for cows [building measurement unit]**
- **Cows – especially expensive ones fattened on [radioactive] rice straw**

Forest contamination monitoring with UAVs

- Currently being used close-in to the plant where there is a no-fly rule for aircraft – apparently doesn't apply here.
- Forest contamination very localized
  - Canopy cover, Water runoff, liter buildup

- Need higher resolution maps than higher altitude manned helicopters
- 220 lb unit can carry 60 lbs
- Map forests, rocky slopes, marshes



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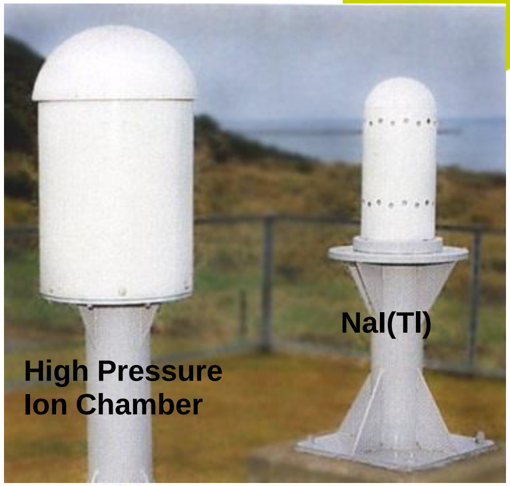
Environmental monitoring posts

- 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 a battle with a Tsunami

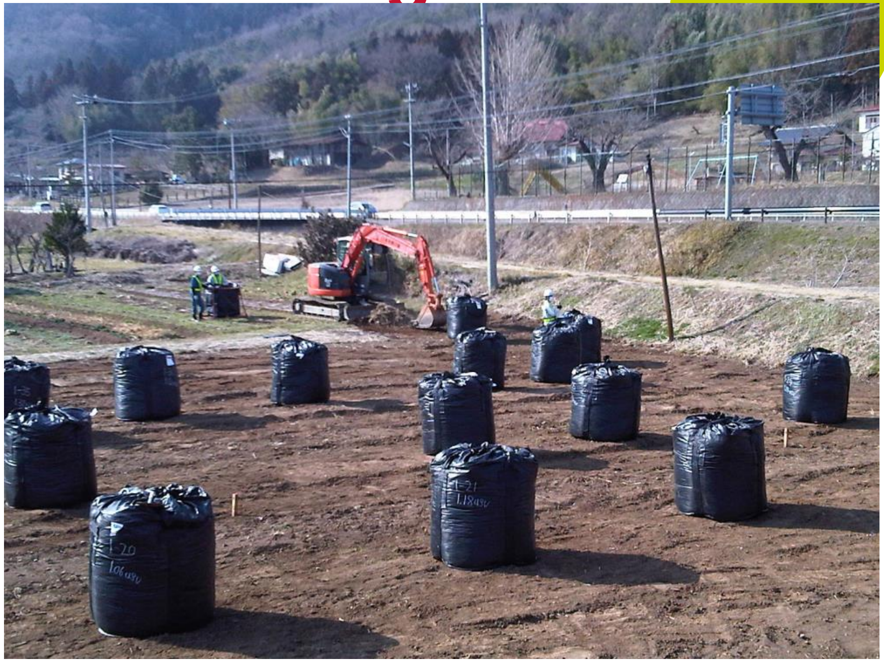
- **Nice elegant system for normal NPP operations**
- **Emergency response issues:**
  - **Too few in affected areas where population was**
  - **No Iodine collection devices [major population dose]**
  - **Air samplers don't work when power was down [all 22]**
  - **Doserate system runs few more days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

Reducing environmental contamination

Washing; removal of top layers; moving top to below surface

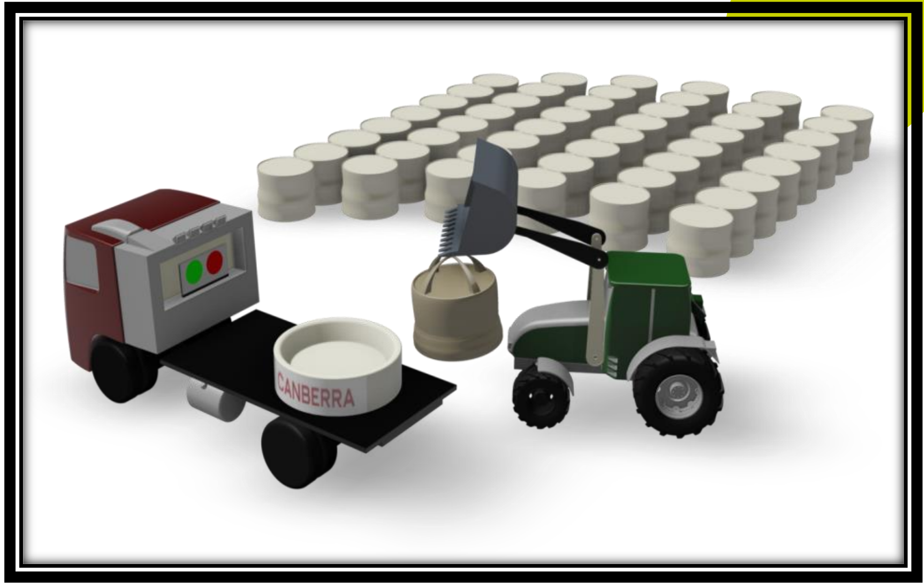
Waste debris measurements - bags

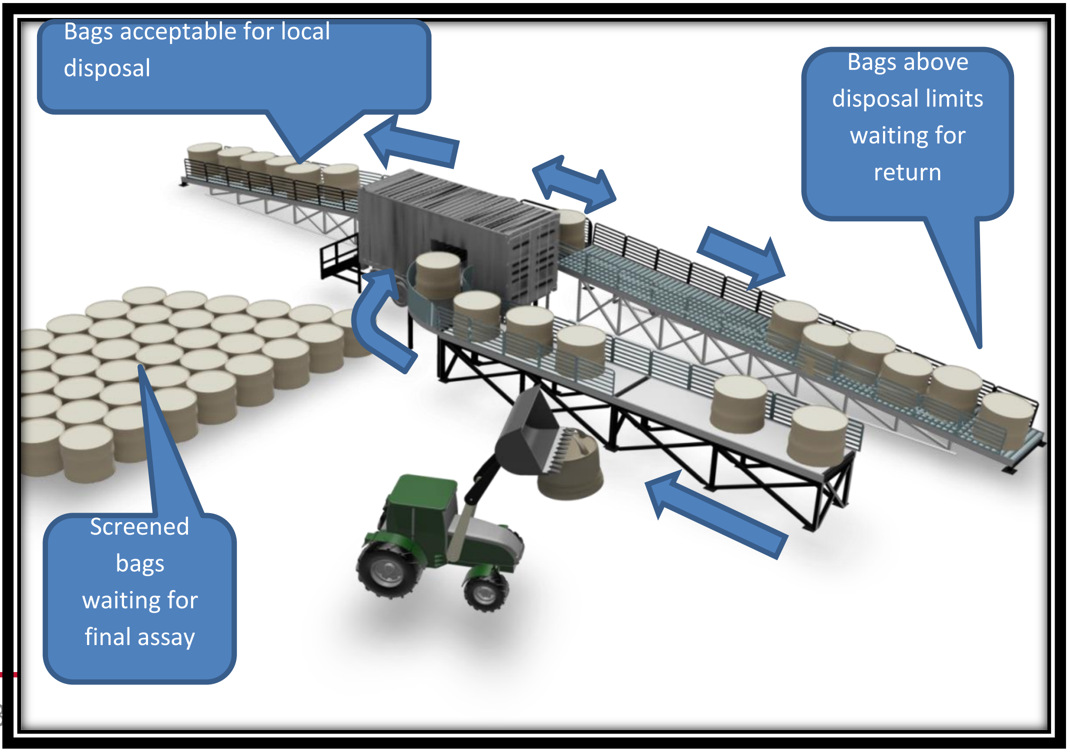
- Immense volumes of radioactive soil, vegetation, and other debris
- Waste collected in 1 m3 Super Sacks
- Bags located at thousands of temporary
  local holding areas
- Will be eventually moved to one of 9 interim storage facilities for consolidation, incineration, and burial
  - 2015 operation estimated



Local bag proposal

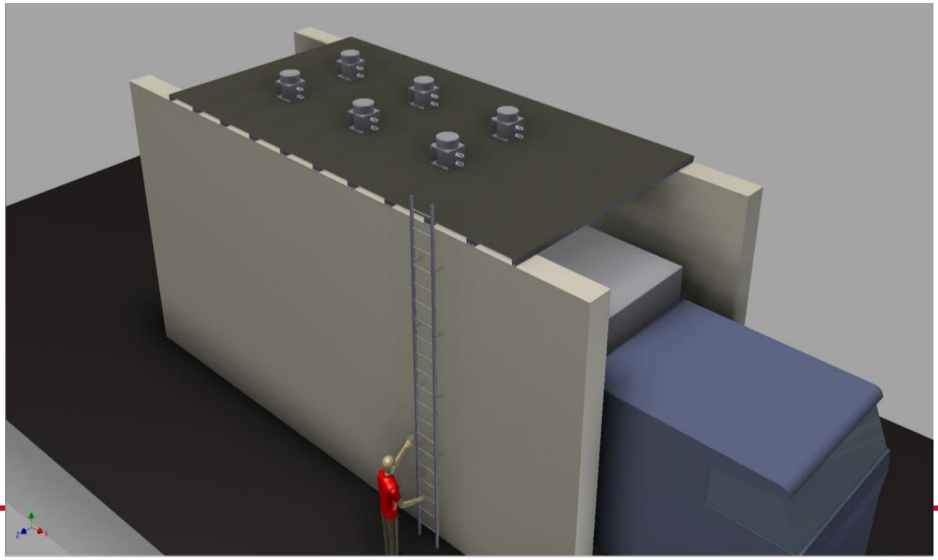
- Allows immediate disposal of very low level bags, not 2016
- Allow lower cost "normal" disposal
- Field unit - screening
  - Easy to transport to local sites over small roads
  - NaI spectroscopy from single point
  - High uncertainty
- Disposal site unit – definitive
  - Dual Ge detectors
  - High quality results
  - Public and technical acceptance

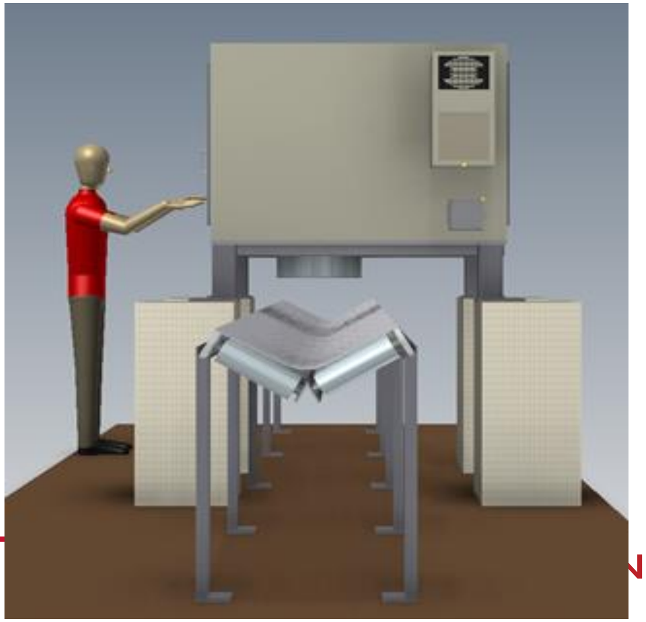




Waste debris measurements at proposed Interim Storage Facility

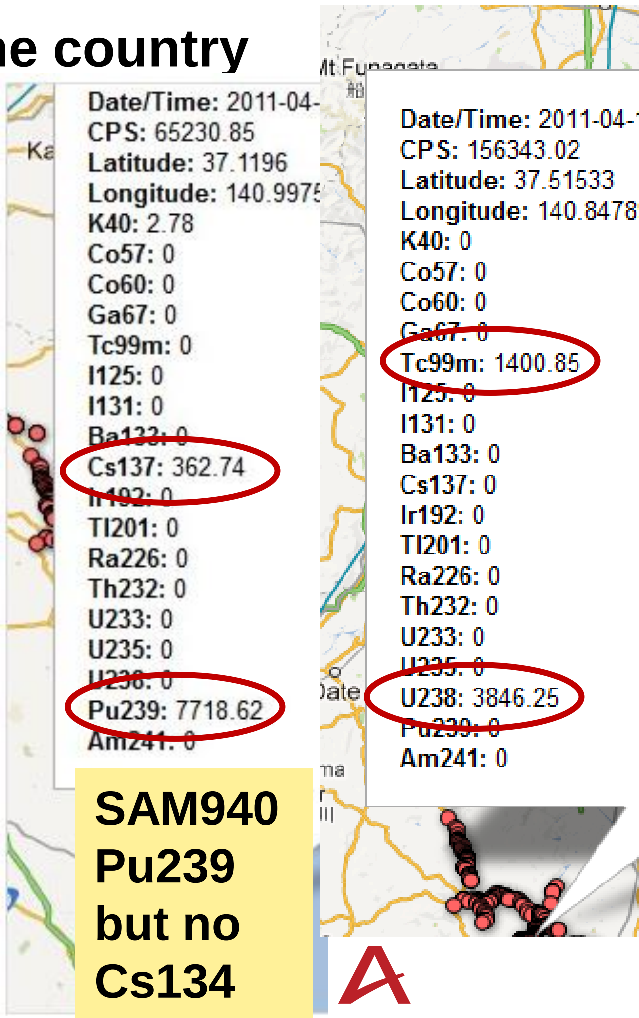
- **Vehicle assay system for incoming vehicles with unprocessed material and exiting vehicles with product**
  - **Multiple NaI detectors for quick measurements**
- **Combustible materials [vegetation, construction debris] to be incinerated**
  - **Proposed system to assay the incinerator ash**
  - **Ge system for monitoring ash on conveyor**
- **Under active consideration – might actually happen**





Many inaccurate measurements

- Many high readings widely reported in the press
  - Press will typically triage data and only report high numbers
- Most bad data in press from poor quality instruments and calibrations
- Low cost portable instruments have flooded the country from China, Russia, Eastern Europe ….
  - One researcher obtained many varieties and did doserate calibration checks; An order of magnitude error not unusual.
- These, plus the good instruments are mostly used and interpreted by untrained and inexperienced hunting for the worst result
  - Contact reading with instruments sensitive to betas
  - Contact readings to report doserate from small areas
  - Bad output results not recognized as such →→→
- Not always a bad thing, however
  - Allowed schools and communities to take quick action and clean up public areas where kids go
  - Found a buried industrial source in Supermarket lot



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NPP WORKERS AND GENERAL POPULATION

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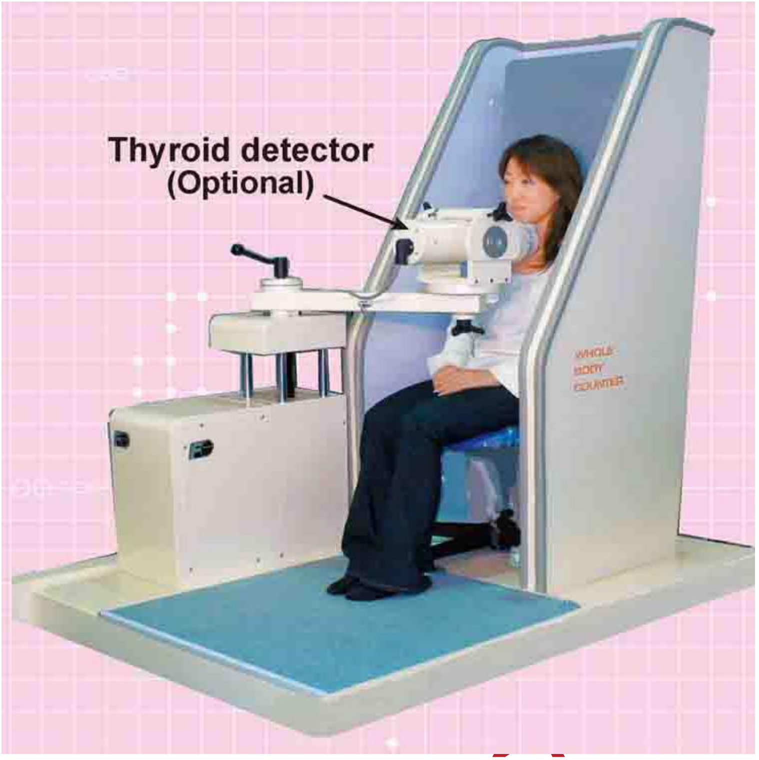
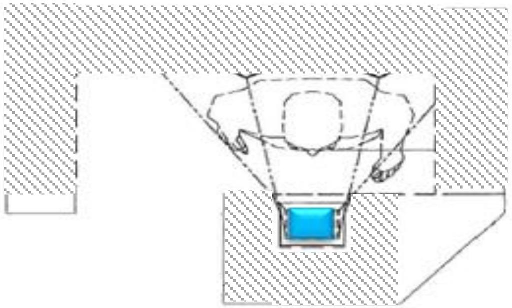
Internal doses of workers

- **4 In-vivo counters at Dai-ichi; 4 more at Dai-ni**
- **WBCs in Japan NPPs all local brands that qualify to local standards**
  - **All chair-types**
  - **All with 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 unusable**
  - **Initially because of power**
  - **After power restored, because of high background**



Worker internal exposures by JAEA

- Most common WBC in rest of world NPPs is Canberra FastScan
  - Full gamma spectroscopy
  - 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

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Worker internal exposures at JAEA-Tokai

- 23 April - 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
  - 560 total [6 female]

J-Village WBC station implemented by TEPCO

- Built two large temporary structures
- Installed Tungsten blankets to reduce background
- One facility for 10 plastic chair-type WBCs
  - Additional shielding
- Other facility for 1 mobile and 1 fixed FastScan
  - Shielding not necessary, but done for consistency
  - Used for all workers >screening level on plastic WBCs

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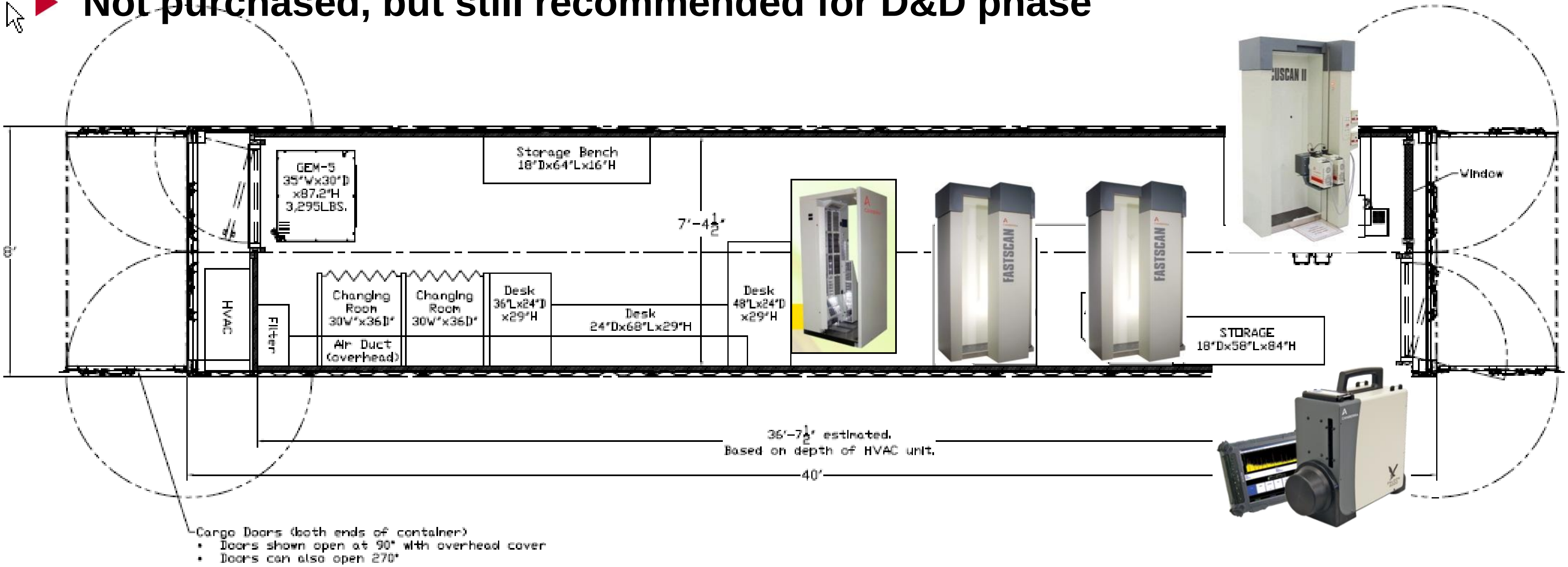
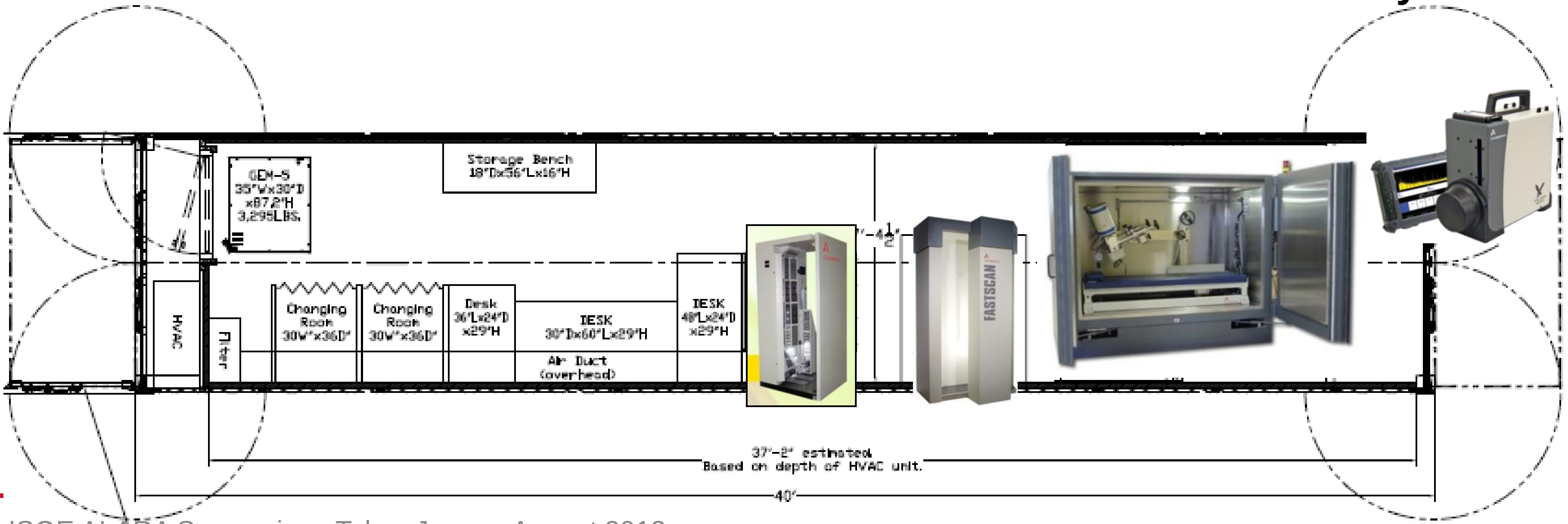
Gamma InVivo Laboratory

- As part of AREVA project, proposed turn-key transportable system
- Can be installed close to site [better worker efficiency]
- 40' long ISO Shipping Container, extra height, covered entrance
- Ready to operate within 2-3 days after container installation and connection.
- GEM Portal monitor as workers walk through door; External contam'n monitor
- Two FastScans for most WBC measurements
- Accuscan-II and portable Ge for difficult cases and emergency alpha
- Not purchased, but still recommended for D&D phase



Alpha InVivo Laboratory

- **As part of AREVA project, proposed turn-key transportable system**
- **Recommended during damaged fuel removal operations when alphas are a potential risk**
- **40' long ISO Shipping Container, extra height, covered entrance**
- **Shields installed at factory, all equipment calibrated at factory, ready to operate within 2-3 days after container installation and electrical connection.**
- **Should be at hospital designated to receive injured workers**
- **U/Pu lung counter for alpha contamination in lung or other parts of body**
- **Also includes external contamination monitor and FastScan total body**



External contamination monitoring

- End of 2011 situation
  - 20uSv/hr field
  - multiple people waiting in line
  - hand-frisker surveys
- Not ALARA
- Inadequate survey method – should be 2-3 min per INPO – in normal background
- Expensive in lost productive labor
- Asked by TEPCO for alternative solution

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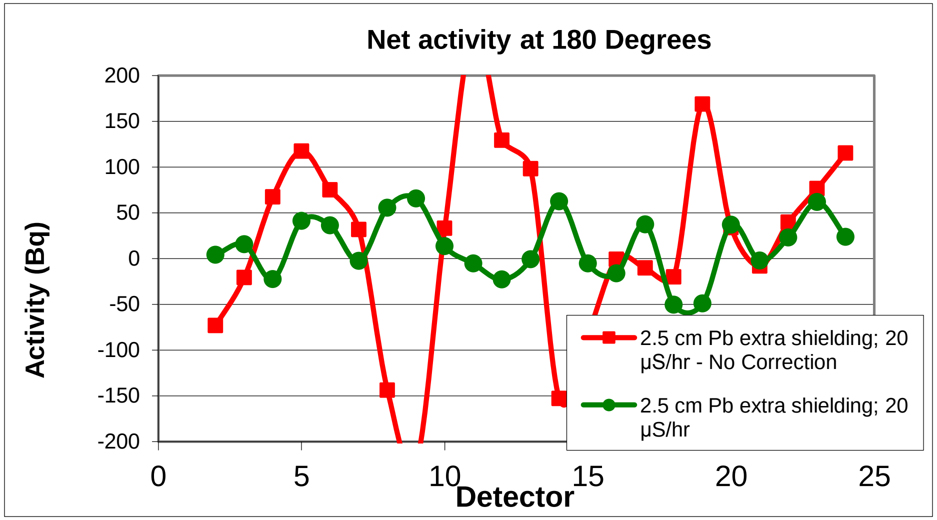
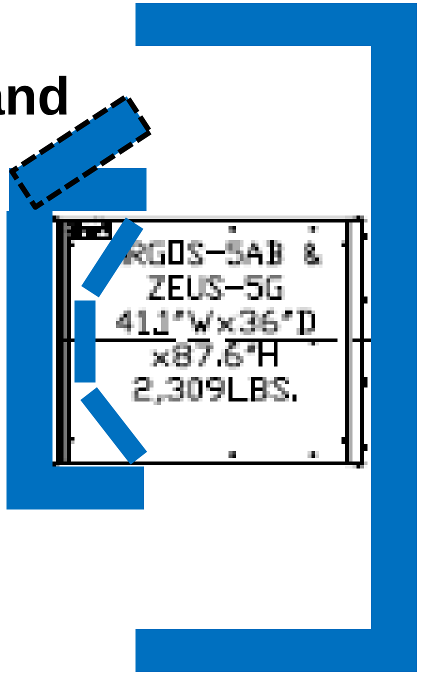
Worker external contamination

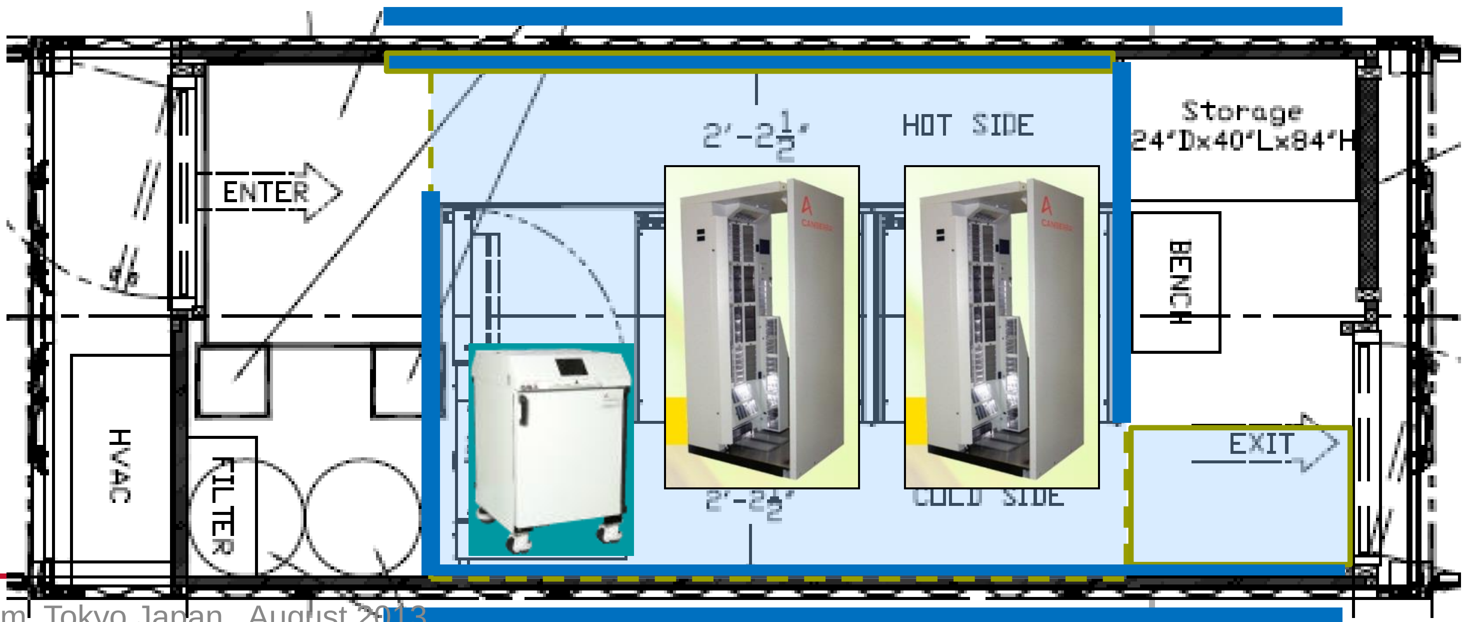
- Requirements:
  - 4 Bq/cm2 in 10x10cm area [400 Bq] in a 20 uSv/hr
- Performance of Argos
  - 1 Bq/cm2 in 10x10cm area [100 Bq] in 0.03 uSv/hr
- Problems cannot be solved by longer count time because of the person changes the background
- Extra shielding not adequate due to scatter
- But OK with combination of additional shielding and subject-size detector-specific correction factors





Shielded Contamination Control Container

- 20' ISO container with 2 Argos;
- Fully assembled and tested at factory; only needs electricity to run
- Can be moved around on site project progresses
- 5cm of Steel can be built into unit walls and floor
- Additional steel can be added to wall[s] and roof on site if needed
- Contains 2 Argos units with Zeus option and Cronos object counter
- No order; person wanted it moved to new job



Population measurements for purposes of dose estimation

and just because it makes people feel better

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**
  - **7 mobile FastScans [6 part of German population counting project]**
  - **1 Accuscan-II, 1 U/Pu Lung counter for cleanup**

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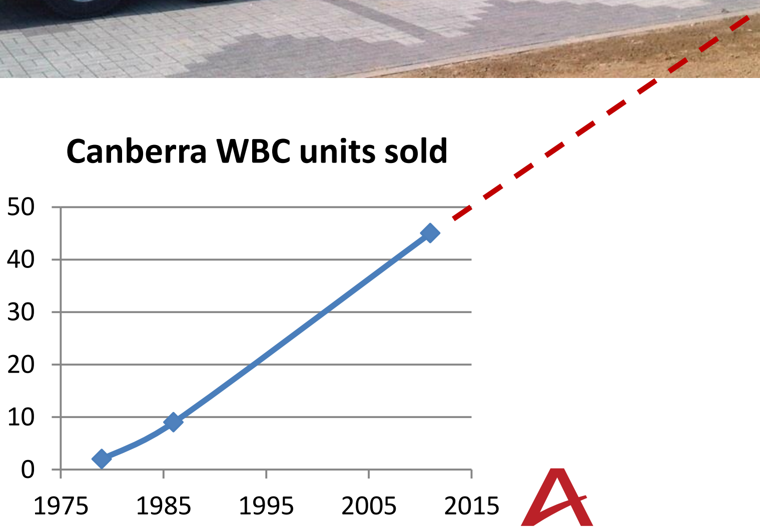
InVivo counting in Japan

- **10 Canberra Chair-types in ‘80s, probably in response to TMI**
- **Modern WBCs in Japan, before the Fukushima accident**
  - **1 Accuscan;   Scanning NaI Bed**
  - **1 Accuscan-II; Scanning Ge**
  - **6 FastScans; 2 mobile**
  - **3 U/Pu Lung counters**
  - **None at NPPs**

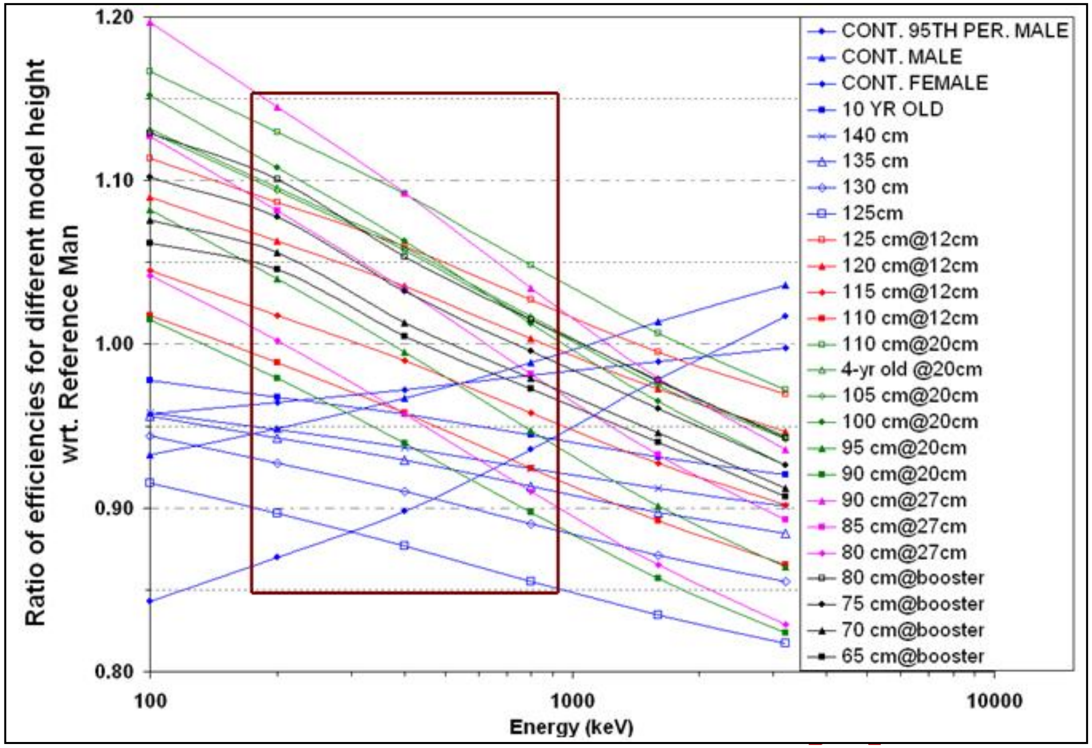
- **After accident**
  - **US Military – 60000 affected workers**
    - 3 FastScans and one Accuscan-II installed at military bases
  - **TEPCO at J Village**
    - 1 new FastScan, 1 mobile from JAEA
  - **Fukushima Prefecture and other locations**
    - >50 FastScans
    - >17 of them Mobile
    - “defacto” standard for population measurements



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 prototype version of ISOCS software 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



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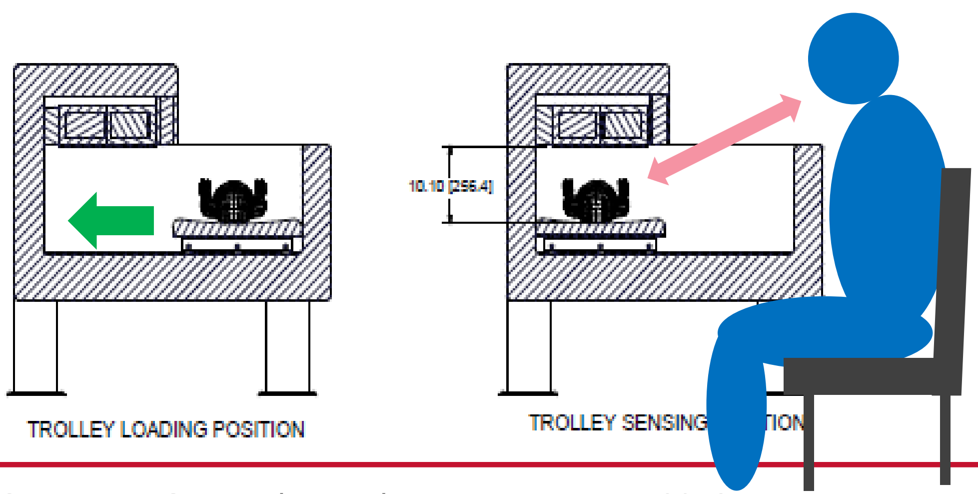
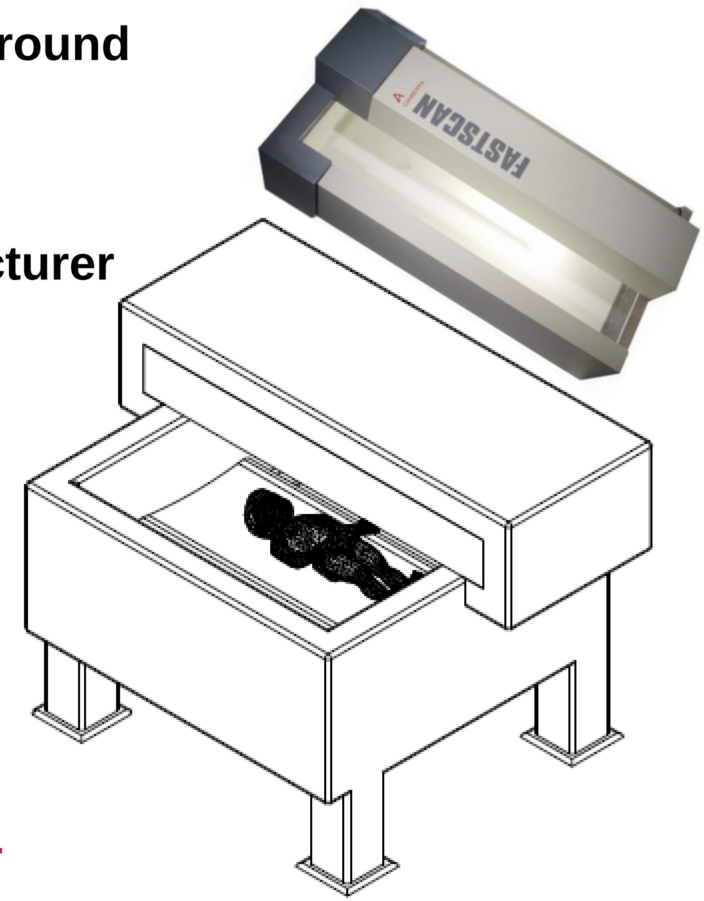
Population in-vivo counting - babies

- Babies are very important to their parents
- Babies have less mass than adults, less Cs134-137
- Babies can’t stand up in FastScan, and if they could would not like it
- Population counts criticized; didn’t detect K-40 therefore Cs results suspect
- Design proposed is similar to horizontal FastScan; 4 large detectors
- Need shielding above counter to reduce background
  - Cs 134/7 on roofs; K40 in building walls and ceiling
- Opening allows parent to see and touch child
- Three units to be built; local shielding manufacturer





WBC of residents by JAEA at Tokai

- Asked by Fukushima prefecture
- 3000 July, Aug 2011
- 4000 Sep - Jan 2012
- 20,000 total - present
- 2 FastScans + Chair WBC
  - 100 per day average
- Process:
  - Registration
  - Explanation of process
  - Surface contamination check
  - WBC
  - Dose calculation
  - Explanation of results !!

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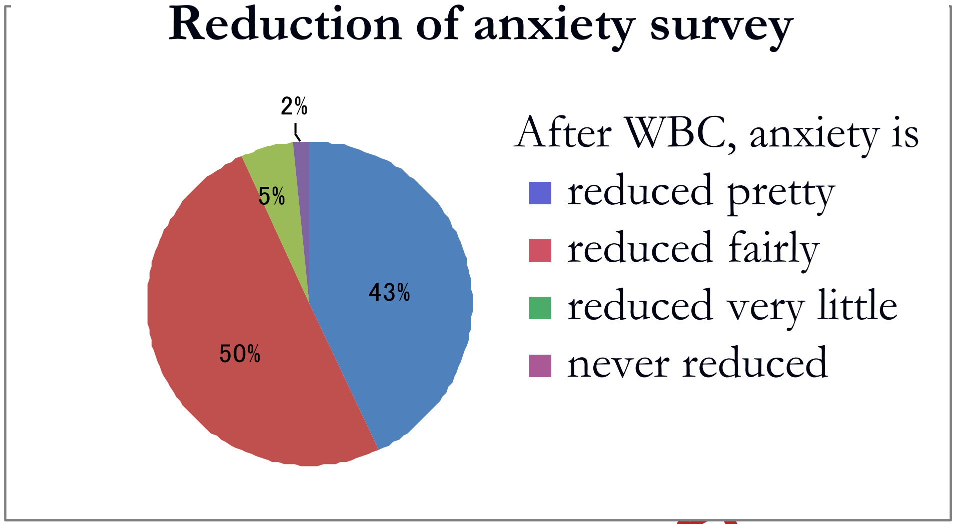
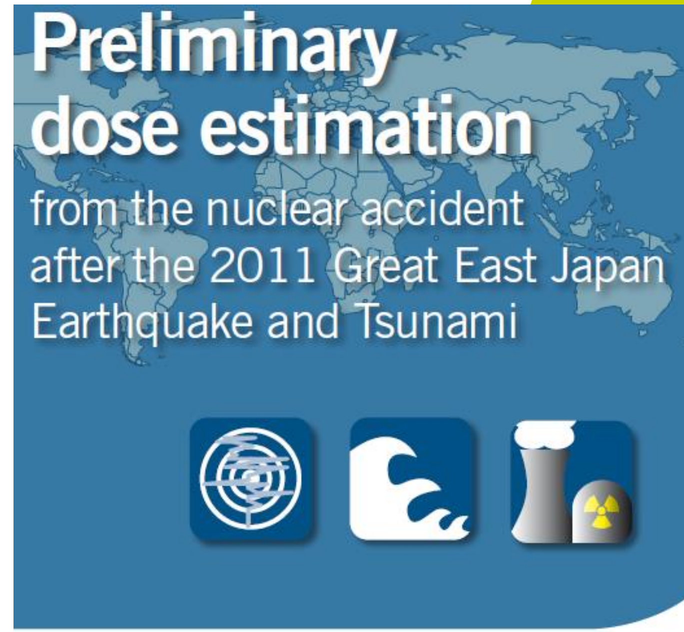
Communication

The result was explained to a residents by JAEA expert in a manner of interview or phone consultation.

Many residents replied that WBC and consultation is effective for reduction of anxiety on radiological health effect.



Dose Pathways



- Very good report by WHO
- Indicates distribution of internal dose
  - External, Inhalation, Ingestion

Table below: EXT / INH / ING

World Health Organization

Group	Dose range	Adult	Child	Infant
Close-in to NPP	1-50 mSv	90/10/0	80/10/10	80/10/10
In FU pref	1-10 mSv	50/0/50	50/0/50	20/0/80
Nearby pref	0.1-10	80/0/20	80/10/10	80/0/20
Rest of Japan	0.1-1	30/0/70	30/0/70	20/0/80

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THINGS WE CAN DO BETTER

Things we can do better 1/3

- **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 w/o power is OK**
- **Iodine Thyroid measurement capability for large scale rapid deployment, easy for "untrained" operator**
  - **Short T½ nuclides to not cause problems**
  - **Procedures to do good measurements in elevated background areas**
- **Portable laboratories 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**

Things we can do better 2/3

- **Accepted values on re-occupation of evacuation zone**
  - Inform users of age-specific risk, as compared to others that they accept
  - Inform users 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
- **Make rad instruments easy for “untrained” people to use**
  - Contamination monitors rather than hand-frisking
  - Concept of stable background unrealistic
  - Background is elevated, variable in time, variable in space
- **Reactor instrumentation that can survive accidents and reliable give the status of the core**
  - Multiple instruments, independent, alternate power sources
- **Gamma cameras that are practical**
  - Light weight; wide dynamic range [or low and high models]; no off-axis false response
- **Internationally accepted and common standards for radioactivity in food and on export/import of products**

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Things we can do better 3/3

- **Need training process for large number of non-technical radiation measurements done by general public**
  - E.g. YouTube videos on how to use, how to survey, how to check cal, …
- **Better portable spectroscopy instruments**
  - More smart and automatic
  - Easily configurable [automatic?] for "normal" and "accident" conditions
  - This may be a good area for these new high res'n scint detectors
- **Reality check about all these instrumentation improvements:**
  - Accidents don't drive commercial companies to make new instruments
  - Instruments ONLY for accident use won't be useful during accidents; best to design instruments for routine use that can also be used in accidents
- **Minimize evacuations**
  - ~600 people died from the trauma of the evacuation
  - Make KI available earlier to workers and population


THANK YOU!
935
STOP