# *Standardization of Nuclear Component Off-Carrier Processing*

ASTM E61 New Orleans, LA

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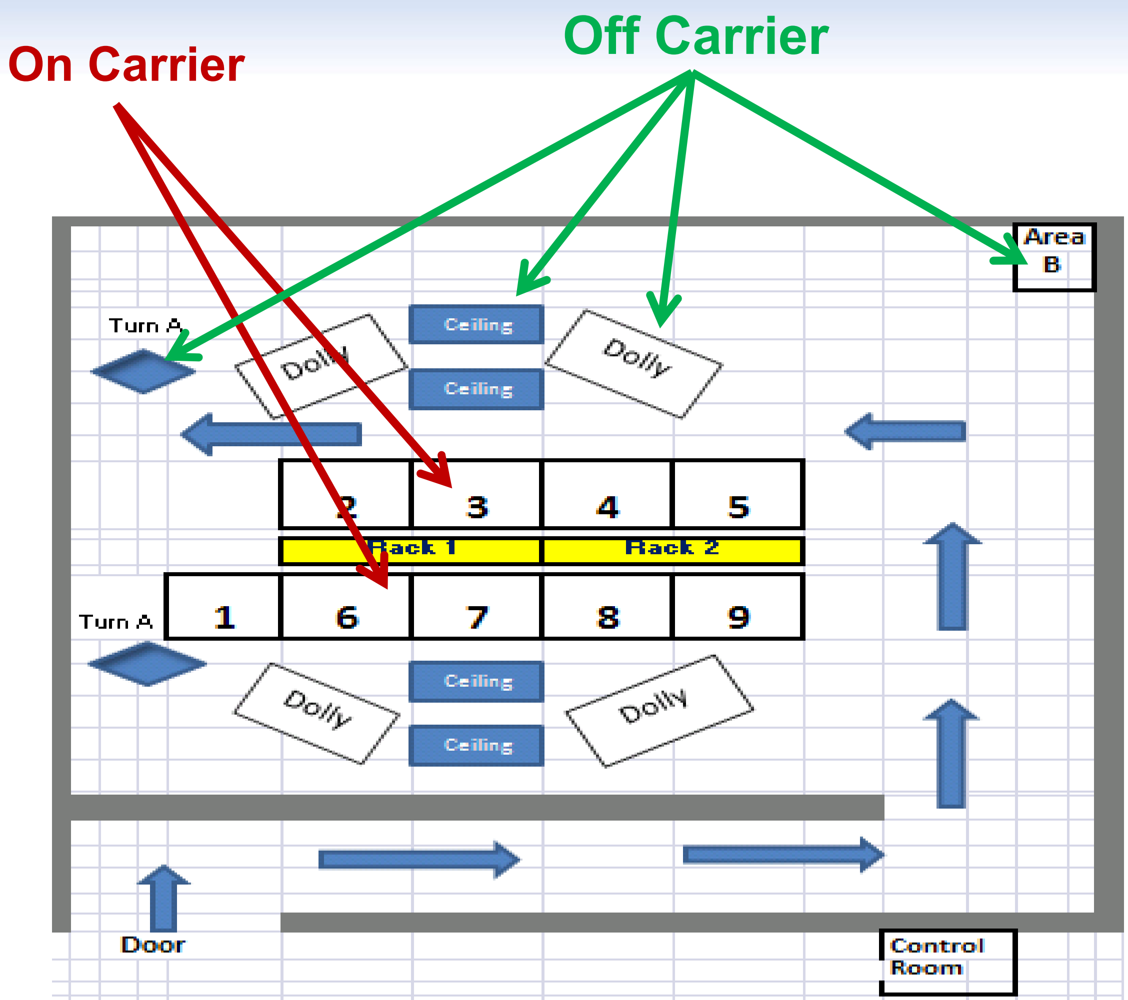
# History of Nuclear Component Processing

- Nuclear components processed as early as 1984
- Increased requests for STERIS Isomedix to provide gamma photons for component EQ testing
- Decreasing number of suppliers for EQ radiation exposures
  - Homeland Security Compensatory Challenges
  - Academic institutes closing programs (University of Maryland?)
- "Off-Carrier" opportunities
  - Long exposure times/dose-rates prohibit use of carrier/tote systems

# Whippany Off-Carrier Locations

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# Current Process

- Each component is unique and requires unique mapping
- Facility places dosimeter at min and max positions on component (or phantom material)
- Dosimeter is run for >2 hours to establish a dose rate
- Dose rate is extrapolated to determine a timer setting required to meet min dose
- Component is left in the cell until timer setting is met
- Component released

# April 2014 NRC Inspection

**Summary of Nonconformance 99901145/2014-201-01**

*On April 3, 2014, Steris was audited by the US NRC, Electrical Vendor Inspection Branch, Division of Construction Inspection and Operational Programs, Office of New Reactors . From an outcome of the inspection:*

*(STERIS)… failed to ensure that the measuring and testing system (e.g. the dosimeters, associated procedures, and dosimetry reading equipment) used to determine the applied radiation dose to nuclear components was properly controlled and calibrated. Specifically, the "Technical Report on Analysis of Dosimetric Uncertainties for Routine Use of the Red 4034 Dosimetry System", dated June 28, 2013, created by Steris for assessing the accuracy of radiation dose measurements, failed to account for all uncertainties in the process as related to the irradiation of nuclear components. Steris failed to account for the* ***density*** *of other product placed into the irradiation chamber,* ***source decay****, and location within the irradiation chamber. As a consequence, the actual radiation dose applied to nuclear components could be less than what was requested by Steris's Customers.*

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

# Next Steps

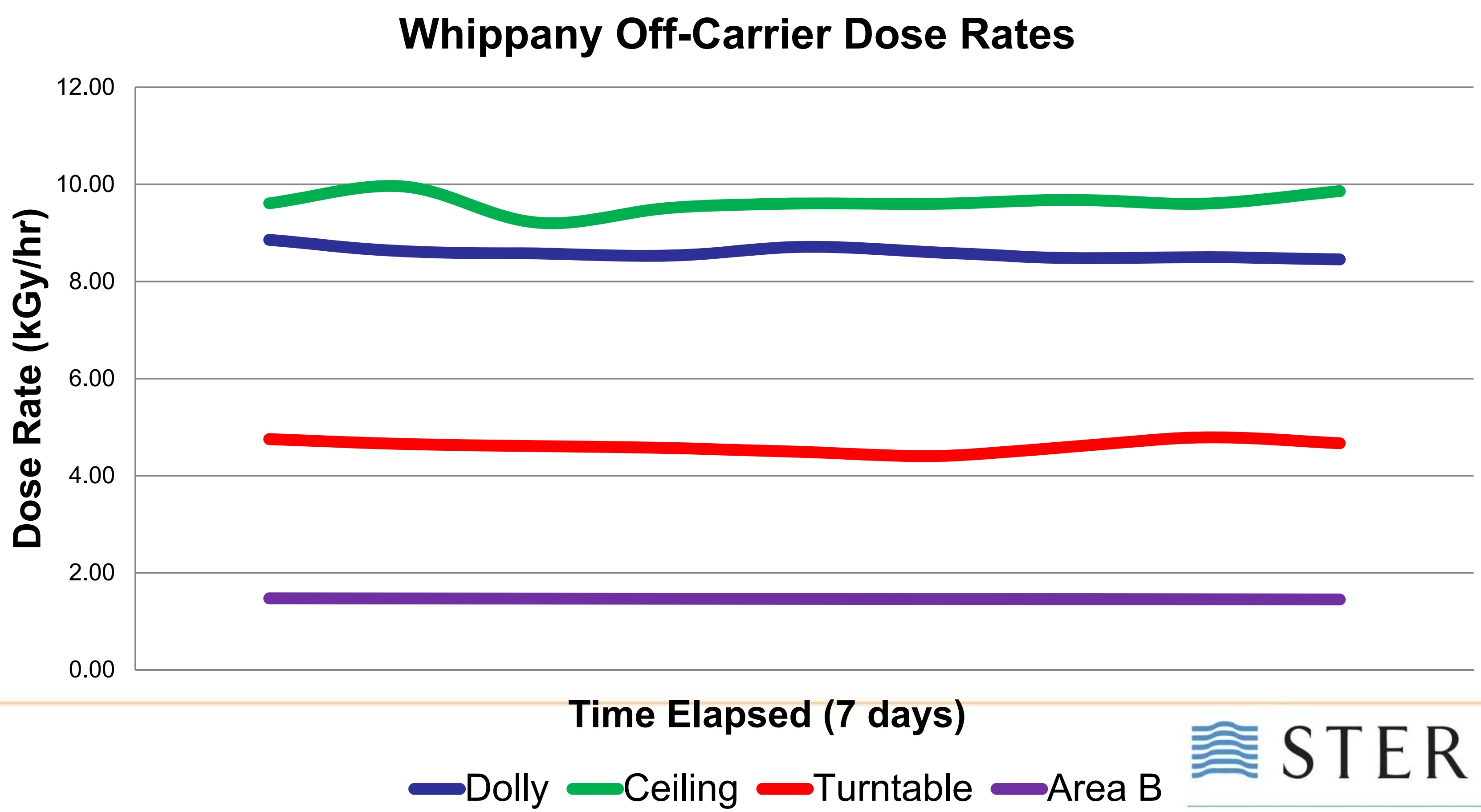
- Determine the effects of on-carrier density variability
- Determine the effects of source decay
- Work with IEEE (Institute of Electrical and Electronics Engineers) to respond to the NRC.

# Accounting for Density

- Attempts to quantify the variability through experimentation:
  - Placed alanine dosimeters at fixed locations
  - Processed for seven days with normal on-carrier processing
  - Dosimeters were changed out @ approximately 100kGy
- Study was completed twice:  May 2014 and September 2014

# Accounting for Density

Based on the cyclical nature of the "On-Carrier" Customers; STERIS assessed density variations and the dose-rate impact on "off-carrier" locations by determining the dose rates over the course of 7 days:

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# Accounting for Density

| Area | Study 1 (May 2014) | Study 2 (Sep. 2014) | Average (σ) |
|---|---|---|---|
| Dolly | 0.034294 | 0.014897 | 2.22% |
| Ceiling | 0.027674 | 0.020105 | 2.30% |
| Turntable | 0.033285 | 0.028154 | 3.01% |
| Area B | 0.038370 | 0.004339 | 1.27%* |

- For a 95% confidence interval and a double tailed distribution (2) the density variability is 6.02%.

* Indicates very low sample size

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# Accounting for Density

- Further Review of Data 2005 – 2015
  - Intercomparison data at all off-carrier areas
  - 3 dose points per area
  - Variance can be represented as:

$$VAR(A,B,C) = VAR(A) + VAR(B) + VAR(C) - COV(A,B) - COV(B,C) - COV(A,C)$$

$$\therefore VAR(A,B,C) = 3\sigma^2_{dosimeter} + \sigma^2_{density}(3 - \frac{t_a}{t_b} - \frac{t_b}{t_c} - \frac{t_a}{t_c})$$

  - And solving for our variability from density:

$$\sigma^2_{density} = \frac{(VAR(A,B,C) - 3\sigma^2_{dosimeter})}{(3 - \frac{t_a}{t_b} - \frac{t_b}{t_c} - \frac{t_a}{t_c})}$$

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# Accounting for Density

$$\therefore\ \sigma_{density} = \begin{cases} 0.01967\ for\ Area\ A \\ 0.02015\ for\ Area\ B \end{cases} \approx 0.0203$$

- For a 95% confidence interval and a double tailed distribution (2) the density variability is conservatively 4.1% derived from historical data.
- This result is lower than from our experimental data, but of the same order of magnitude

# Accounting for Source Decay

| | |
|---|---|
| Cobalt Half-Life (Days): | 1925 |
| Original Cobalt Activity | 100 |

| | Actual kGy/hr | Unadjusted kGy/hr | Actual kGy/day | Unadjusted kGy/hr | Dose Error |
|---|---|---|---|---|---|
| 0 | 100.0000 | 100 | 2400 | 2400 | 0.000% |
| 1 | 99.9640 | 100 | 2399.136 | 2400 | 0.018% |
| 2 | 99.9280 | 100 | 2398.272 | 2400 | 0.036% |
| 3 | 99.8920 | 100 | 2397.409 | 2400 | 0.054% |
| 4 | 99.8561 | 100 | 2396.546 | 2400 | 0.072% |
| 5 | 99.8201 | 100 | 2395.683 | 2400 | 0.090% |
| 6 | 99.7842 | 100 | 2394.82 | 2400 | 0.108% |
| 7 | 99.7483 | 100 | 2393.958 | 2400 | 0.126% |
| 8 | 99.7124 | 100 | 2393.096 | 2400 | 0.144% |
| 9 | 99.6765 | 100 | 2392.235 | 2400 | 0.162% |
| 10 | 99.6406 | 100 | 2391.374 | 2400 | 0.180% |
| 11 | 99.6047 | 100 | 2390.513 | 2400 | 0.198% |
| 12 | 99.5688 | 100 | 2389.652 | 2400 | 0.216% |
| 13 | 99.5330 | 100 | 2388.792 | 2400 | 0.234% |
| 14 | 99.4972 | 100 | 2387.932 | 2400 | 0.252% |
| 15 | 99.4613 | 100 | 2387.072 | 2400 | 0.270% |
| 16 | 99.4255 | 100 | 2386.213 | 2400 | 0.287% |
| 17 | 99.3897 | 100 | 2385.354 | 2400 | 0.305% |
| 18 | 99.3540 | 100 | 2384.495 | 2400 | 0.323% |
| 19 | 99.3182 | 100 | 2383.637 | 2400 | 0.341% |
| 20 | 99.2824 | 100 | 2382.778 | 2400 | 0.359% |
| 21 | 99.2467 | 100 | 2381.921 | 2400 | 0.377% |
| 22 | 99.2110 | 100 | 2381.063 | 2400 | 0.395% |
| 23 | 99.1752 | 100 | 2380.206 | 2400 | 0.413% |
| 24 | 99.1395 | 100 | 2379.349 | 2400 | 0.431% |
| 25 | 99.1038 | 100 | 2378.492 | 2400 | 0.449% |
| 26 | 99.0682 | 100 | 2377.636 | 2400 | 0.467% |
| 27 | 99.0325 | 100 | 2376.78 | 2400 | 0.485% |
| 28 | 98.9969 | 100 | 2375.924 | 2400 | 0.502% |
| 29 | 98.9612 | 100 | 2375.069 | 2400 | 0.520% |
| 30 | 98.9256 | 100 | 2374.214 | 2400 | 0.538% |

$$1 - \int_0^t \frac{A_0 * \left(\frac{1}{2}\right)^{t/t_{1/2}}}{A_E}\, dt$$

The source decay bias of 0.538% is calculated as the cumulative effects of using a single dose-rate on Day 0 throughout a 30-day irradiation in which the source is decaying at a rate equal to the half-life of Co-60

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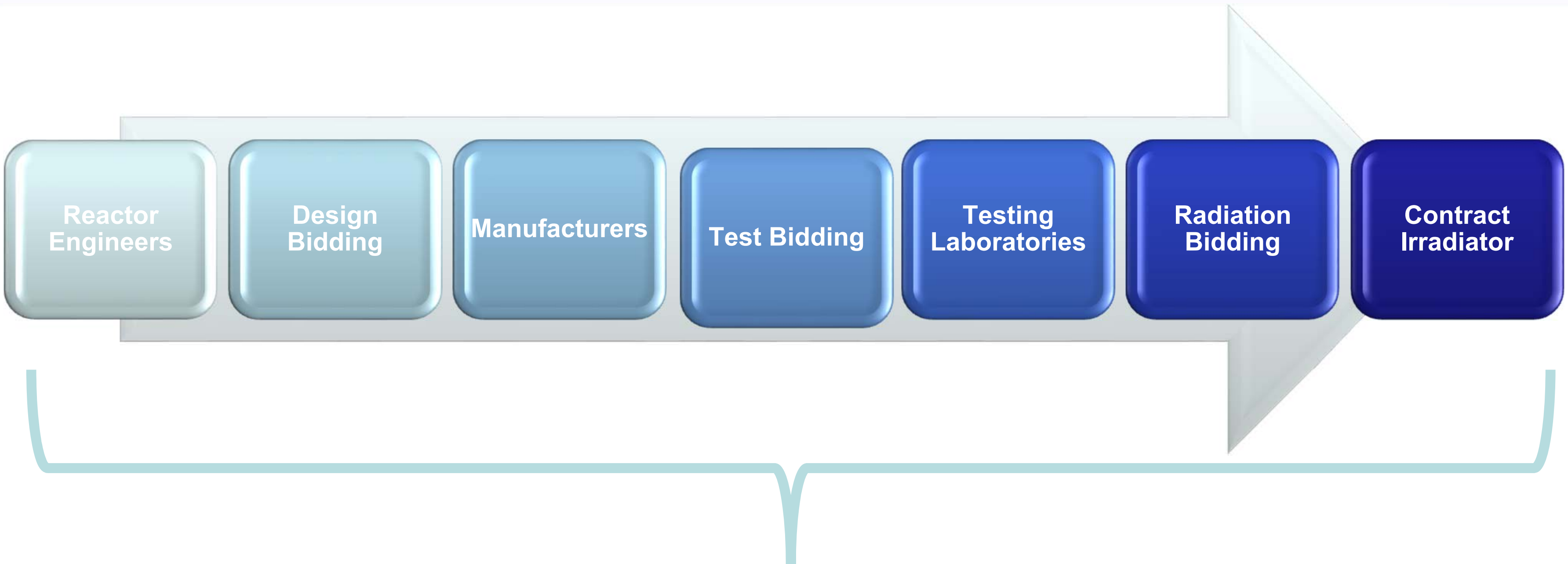
# Opportunities for Standardization



# Opportunities for Standardization

- Other outstanding local questions:
  - Is this method of processing valid?
  - Use of fixed time length to establish dose rate?
  - Is use of a fixed source decay value @ 1 month acceptable?
  - How do we handle dosimetry uncertainty?
  - Does dosimeter placement require standardization?
  - What dose is reported?
  - What's the best method to determine dose rate variability?
    - Is 10 years of data enough? (sure hope so…)
  - What unit do we report dose (Mrad or kGy)?

# Opportunities for Standardization

- Other outstanding global questions:
  - Does ASTM E10 / CIRMS know of this issue?
  - How should end users (power plants) use this data?
  - How do manufacturers use this data?
  - How do testing labs request and report this data?
  - Are these considerations at other facilities?
  - Will the NRC accept this analysis?
    - August 2014 response indicated a “okay for now” mentality