A Brief History of Canberra's *In Vivo* Counting Data Review Service

~ Including ~

A Tale of Two Uranium Processing Facilities

Presented at the DOE Lung Counting Workshop

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In Vivo Data Review Service – Chronology

- Long ago at RMC, 1975-83 B.C. (before Canberra)
  - Offices located in Philadelphia, Chicago, Northbrook (IL)
  - Data was reviewed and reported [monthly] for ~10 nuclear power plants, and 1 uranium processing site (“Facility A”)
  - Staff included: F. Bronson, D. Richards, D. Groff, L. Booth
  - “Classic” gamma spectroscopy equipment was used for on-site subject counting and final data review:
    - Tennecomp (TPOS) and early DEC (RT-11) computers
    - Harshaw 5” or 8” dia. NaI and 5” dia. CsI/NaI ‘phoswich’ detectors
    - RMCWBC (ALPHA-T) matrix reduction spectral analysis software
    - Primitive data storage media (“Datapacer” tapes, 8” floppy disks)
    - “Crude” quality of spectral data display and printed report format
    - Nevertheless, many thousands of counts were successfully reviewed during this service period

In Vivo Data Review – Chronology (Part B)

- The early years with Canberra (1984 – 1989)
  - All *in vivo* data was reviewed at the "Canberra/RMC" office in Schaumburg (IL), ~1 km from ND (our rival at that time)
  - Data was reviewed/reported for ~10 nuclear power plants, and 2 uranium processing sites ("Facility B" added in '87)
  - Staff included: L. Booth C.H.P., D. Richards, D. Groff
  - Equipment was continually upgraded to include:
    - Better DEC computers: PDP 11/34 (RSX-11M), MicroVAX (VMS)
    - FastScan shields, 4"x4"x16" NaI detectors, Series 35/Plus MCA's
    - ABACOS-II spectral analysis software (with peak area, NID steps)
    - More reliable data storage media (RL02 disks, TK50 tapes)
    - Higher quality spectral data displays and printed report formats
    - LEGe detectors (4 ACT-I's with 20 cm2 area) used at "Facility B"

In Vivo Data Review – Chronology (Part C)

- After our "fusion" with Nuclear Data (1990 – 1994)
  - Data was reviewed at offices in Schaumburg and Itasca IL
  - Our data review service continued for ~10 nuclear power plants and 2 uranium processors ("Facility A", "Facility B")
  - Staff included: L. Booth C.H.P., D. Richards, D. Groff
  - Equipment and software at most nuclear power plants was continually upgraded with:
    - Better DEC (VAX / VMS) computers, AIM's used as MCA's
    - Genie-VMS / ABACOS-Plus spectral data analysis software
  - No equipment/software changes were made at the two uranium processing sites during this period:
    - "Facility A" – PDP-11/34, Phoswich detectors, RMCWBC software
    - "Facility B" – MicroVAX, LEGe/ACT-I detectors, ABACOS-II/LE

In Vivo Data Review – Chronology (Part D)

- After the global "PC revolution" (1995 – present)
  - All data reviewed in Itasca IL (now a much smaller office)
  - At the nuclear power plants, our routine *in vivo* data review service was gradually taken over by their own staff
  - Our standard review service has continued for the two uranium processing sites – "Facility A" and "Facility B" { to be discussed in the remainder of this presentation }
  - "Facility A" upgraded to a PC with "Abacos-GPC" in 1995
  - "Facility B" upgraded to a PC with "Abacos-2000" in 1998
  - Both facilities continue to transfer *in vivo* counting data to Itasca on a monthly basis for final review and reporting
  - Current data review staff includes: D. Groff, D. Richards (L. Booth retired in '98 – now alive and golfing in Florida)

Canberra's *In Vivo* Data Review Procedure

- Receive original counting data from Facility A and Facility B (now sent to the Itasca office on CD's at end of each month)
- Copy count files to our PC with special "data review software"
- Sort data by count type: calibration check, background check, 30-min subject, 5-min whole body scan (Facility A only)
- Sort QA counts chronologically, subject counts alphabetically
- Print and review original analysis results for sorted counts:
  - Demographic info, detector cps ratios, NID results, spectral data plot
- Denote any U-235 results assumed to include significant external contamination, based on:
  - Multiple counts of the same subject showing rapid, significant reduction of detected U-235 activity (after decontamination efforts)
  - Confirmed detection of low-energy (<30 keV) uranium x-ray peaks
- All other U-235 results are assumed to represent internal lung depositions that contribute to internal dose

In Vivo Data Review Procedure - Continued

- Determine whether all significant peaks observed in the spectral plot were properly detected and identified
- Modify or add to the original NID results, when appropriate
- Add other explanatory notes, when appropriate (next slide)
- Print a final report with all modified results, including:
  - A detailed technical discussion of counting system design, calibration methods, system performance, and routing counting procedures
  - A summary of counts performed during the current reporting period
  - An alphabetical listing of all subject counts, with final NID activity results and any explanatory notes
  - Full-page spectral plots for each subject count exceeding site-specific action levels (set by supervisors at each facility)
- Send multiple copies of the final report to the customer
- Archive all counting data and reports at Itasca, as required

Notes Most Often Added to Final Reports

- "External contamination suspected, based on…"
  - Recount(s) showing rapid reduction in detected activity
  - Detection of low-energy (<30 keV) uranium x-rays
- "Results more representative of the true internal burden are available [from another count] during this reporting period"
- "An X-Y [spectral data] plot is attached for this count"
- "Elevated radon daughter nuclide activity detected, indicating likely background fluctuations or possible Ra-226 deposition"
- "Final results include nuclide(s) not in the standard library"
- "Non-standard nuclide result is due to nuclear medicine treatment… [and is not an occupationally-related deposition]"
- "A recount is recommended to assess the true internal deposition"

In Vivo Counting System Upgrade History ~ Facility A ~

- The original system was installed by RMC in 1976
  - Supine subjects were positioned in a “bed-style” steel shadow shield
  - Harshaw 5” dia. “phoswich” detectors, 2 above chest, 2 below back
  - Original computer/MCA was a Tennecomp TP 5/11 (TPOS)
  - In 1981: upgraded to a DEC PDP 11/34 (RSX-11M) with dual RL02 disks and a Tracor-Northern [gasp!] model 1750 MCA
  - In 1987: replaced the MCA with a Canberra [yippee!] Series 35/Plus
  - “RMCWBC” analysis software (based on the Oak Ridge “ALPHA-T” matrix reduction method for NaI spectra) was used until 1995
- A completely new system was installed by Canberra in 1995
  - The design of this “dual-purpose” counter is shown in the next slide
  - System includes 4 LEGe detectors (28cm2 area in two ACT-II’s)
  - IBM PC (OS/2) with Abacos-GPC software (based on Genie-PC)
  - In 1998: a new PC (Windows) was installed with Genie/Abacos-2000

Canberra Dual Purpose Counting System ~ Installed at Facility A in 1995 ~

- <u>Shield Walls</u>
  6-inch thick steel

- <u>Lung Counter</u>
  2 ACT-II's
  4 28cm^2 LEGe's
  (with anti-Compton shields)
  10 - 400 keV

- <u>Whole Body Counter</u>
  1 NaI detector
  (5" x 3" x 16")
  Total Body Scan
  100 - 2000 keV

In Vivo Counting System Upgrade History ~ Facility B ~

- Original system was installed by Canberra in 1987
  - Subjects are positioned in a semi-reclined chair inside a total-enclosure shielded chamber (see next slide)
  - Shield walls have multiple layers (6” steel plus Pb and Cu)
  - 4 LEGe detectors (20 cm2 area in 4 ACT-I’s) are mounted above the subject’s chest
  - Other original components used from 1987 to 1998: DEC MicroVAX (VMS) computer, TK50 tape drive, Canberra Series 35/Plus MCA, Abacos-II/LE software
  - Upgraded components used from 1998 to present: IBM PC (Windows), CD writer, AIM MCA’s (2 needed for 4 detectors), Abacos-2000 software (based on Genie-2000)

Canberra LEGe Lung Counting System
~ Installed at Facility B in 1987 ~

- <u>Shield Walls</u>
  6-inch thick steel,
  0.25-inch Pb layer,
  thin inner Cu liner

- <u>Detector Array</u>
  4 ACT-I's
  4 20cm^2 LEGe's
  (no anti-Compton shields)
  10 - 400 keV

- <u>Chair</u>
  Fixed recline angle
  Adjustable height

Counting System Performance – Currie MDA

$$\text{MDA (Bq)} = \frac{[4.65\ (\text{Bkg})^{1/2} + 2.71]}{(1800)(\text{Efficiency})(\text{Yield})}$$

Bkg	=	Gross counts in a limited channel ROI corresponding to a specific peak energy (reference subject present in shield)
1800	=	Count time in seconds
Efficiency	=	Counts per gamma emitted from lung activity deposition
Yield	=	Gammas per disintegration for a specific nuclide energy

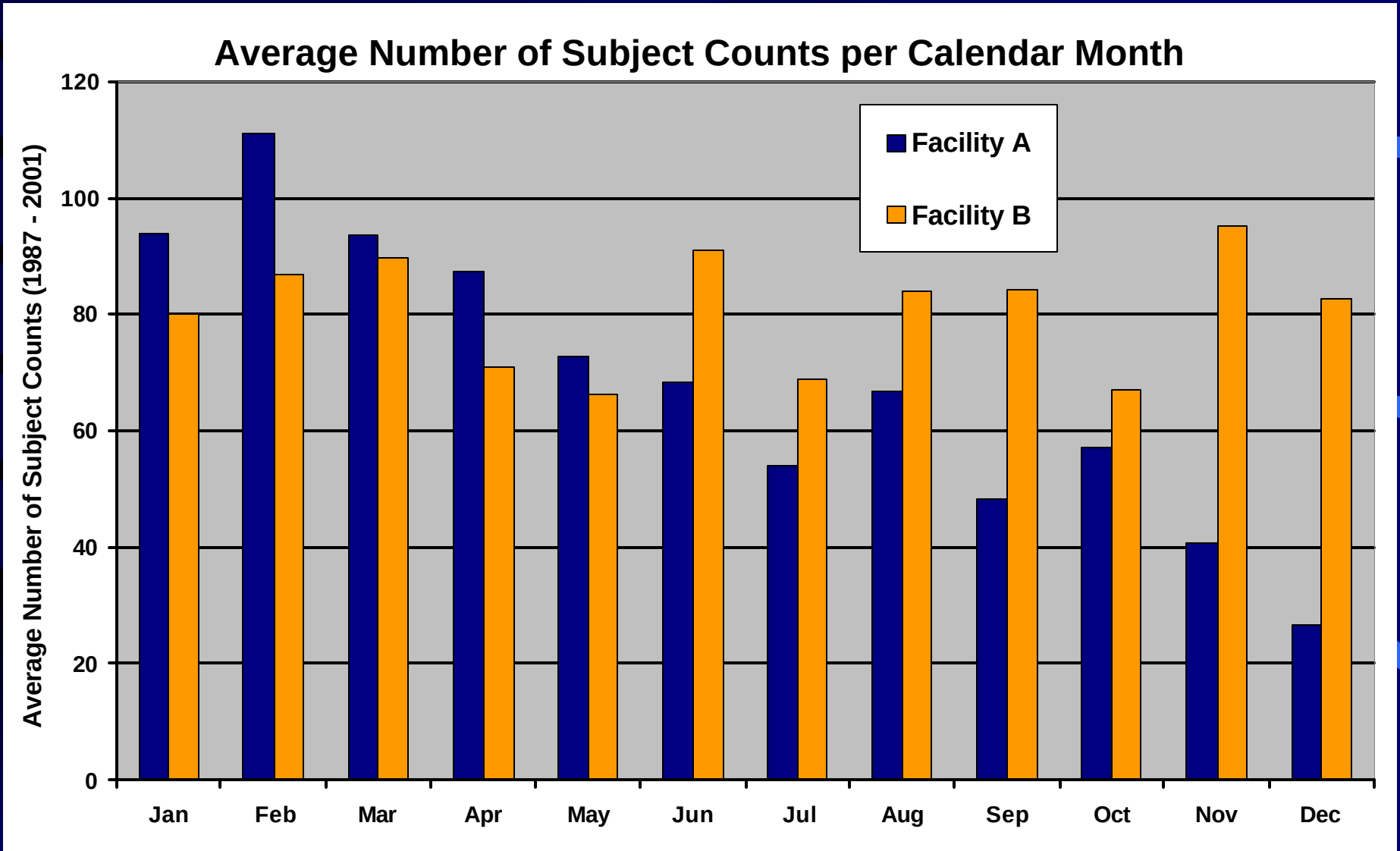
Current U-235 MDA Values

Subject CWT	- Facility A -	- Facility B -
1.5 cm	2.5 Bq (32 *u*g)	3.7 Bq (47 *u*g)
2.5 cm	3.3 Bq (42 *u*g)	4.8 Bq (61 *u*g)
3.5 cm	4.4 Bq (56 *u*g)	6.4 Bq (81 *u*g)
4.5 cm	5.8 Bq (73 *u*g)	8.3 Bq (105 *u*g)

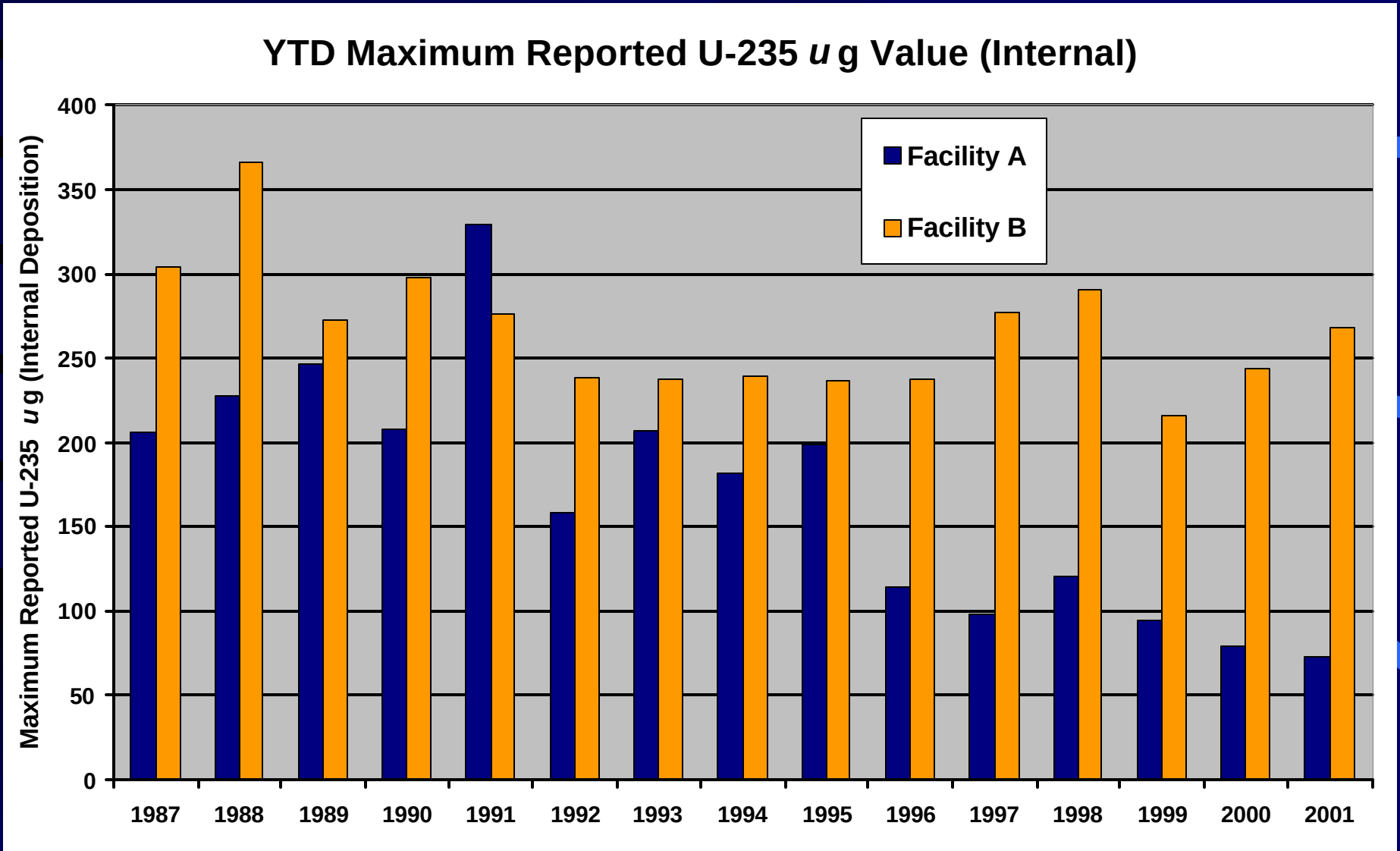
Summary of *In Vivo* Counting Results (1987 – 2001 at Facility A and Facility B)

- The next 8 slides summarize the final reported results for these facilities from 1987 to 2001:
  - Results for Facility B in 1987 are from Sept. to Dec. only
  - U-235 is the nuclide of primary concern at both facilities
  - All U-235 results are reported in units of micrograms (*u*g)
    { 1 *u*g U-235 = 2.14E-6 uCi = 7.92E-2 Bq }
  - U-235 results are segregated as "internal" depositions vs. "external" contamination
  - Specific U-235 action levels and internal dose values are determined by supervisory personnel at each facility
  - Detection of other nuclides (Pb-212, Pb-214, Ac-228, Th-234, Am-241) is NOT discussed in this summary

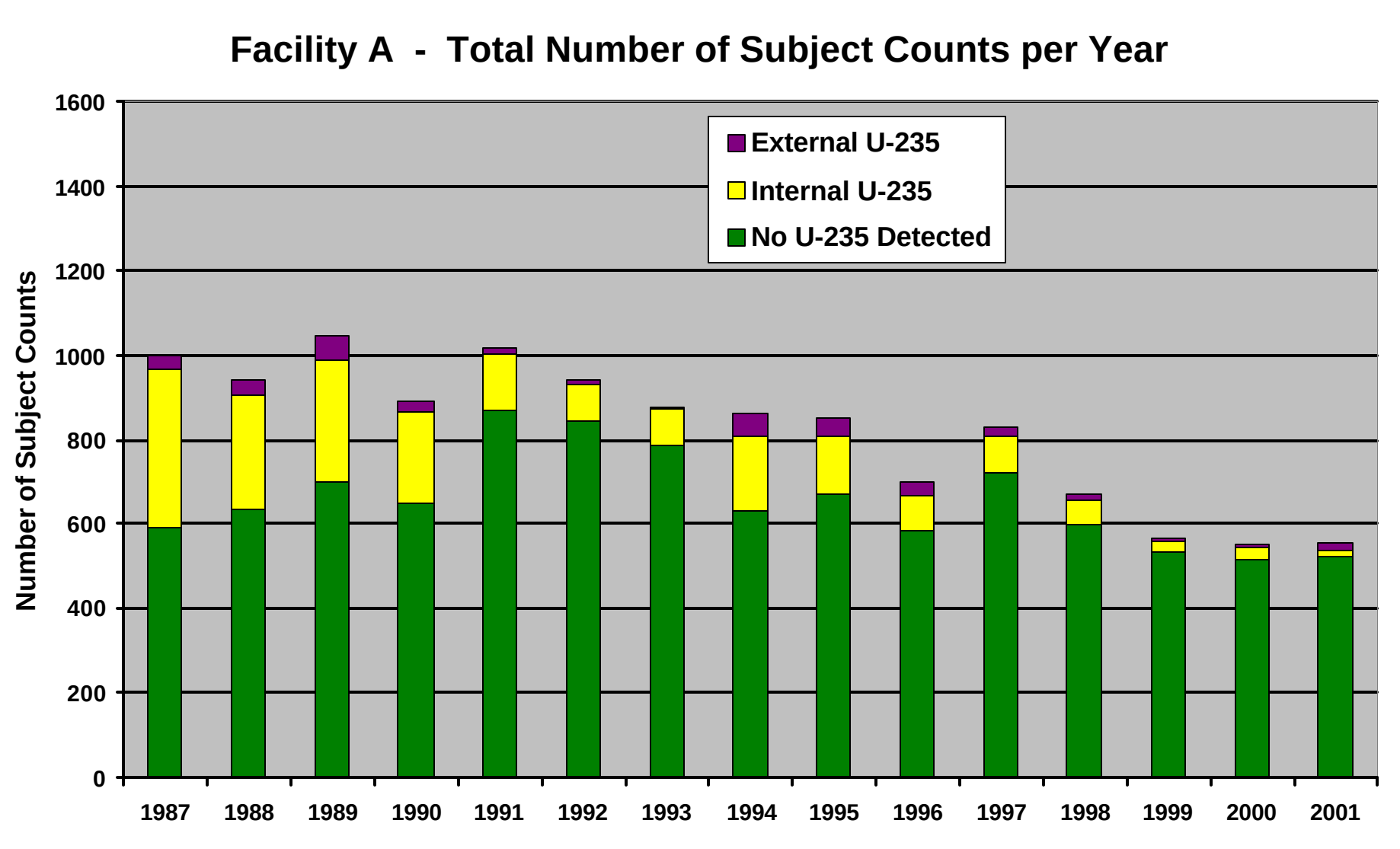
Both Facilities – Counts vs. Calendar Month



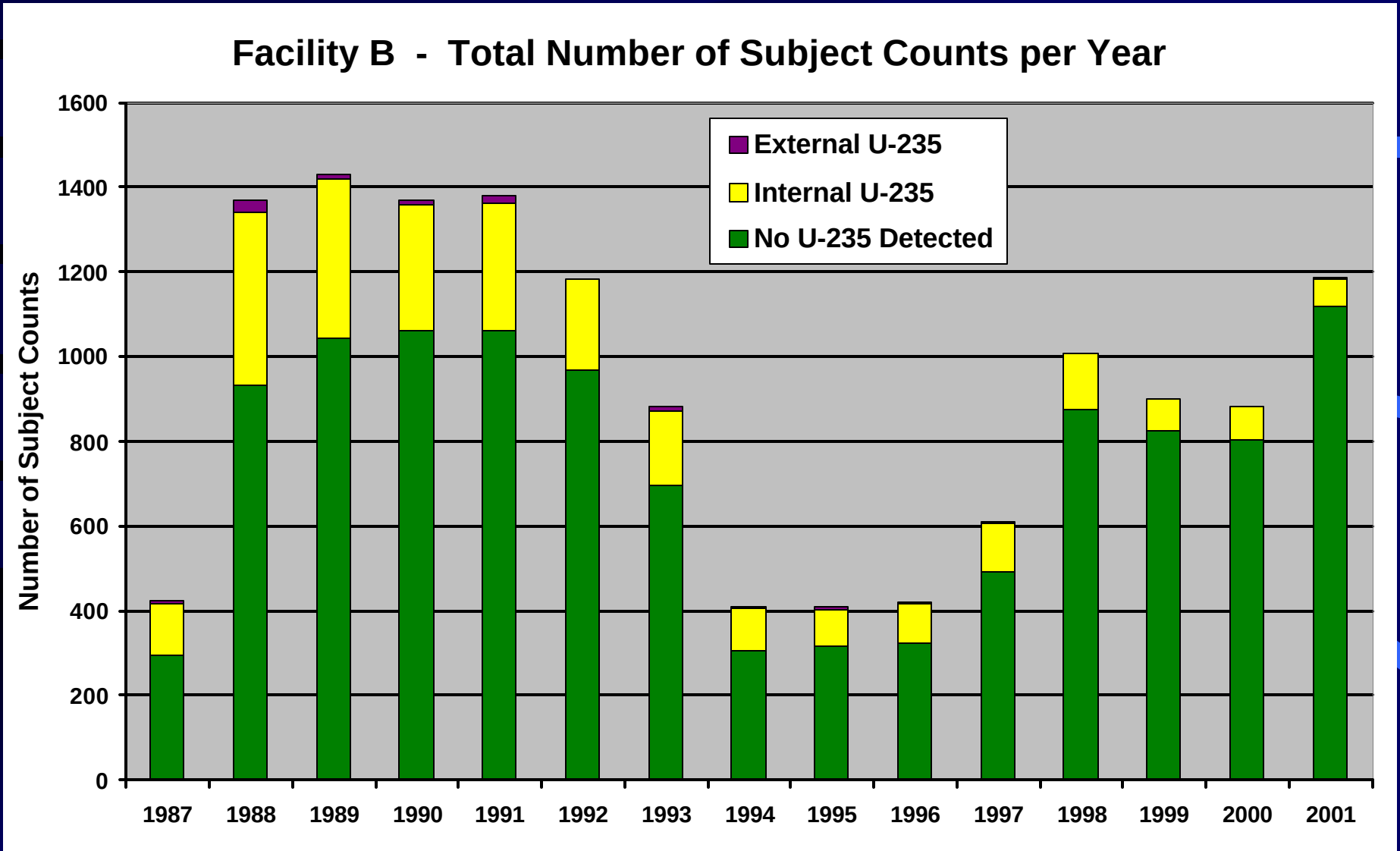
Both Facilities – Maximum Internal U-235 *u*g



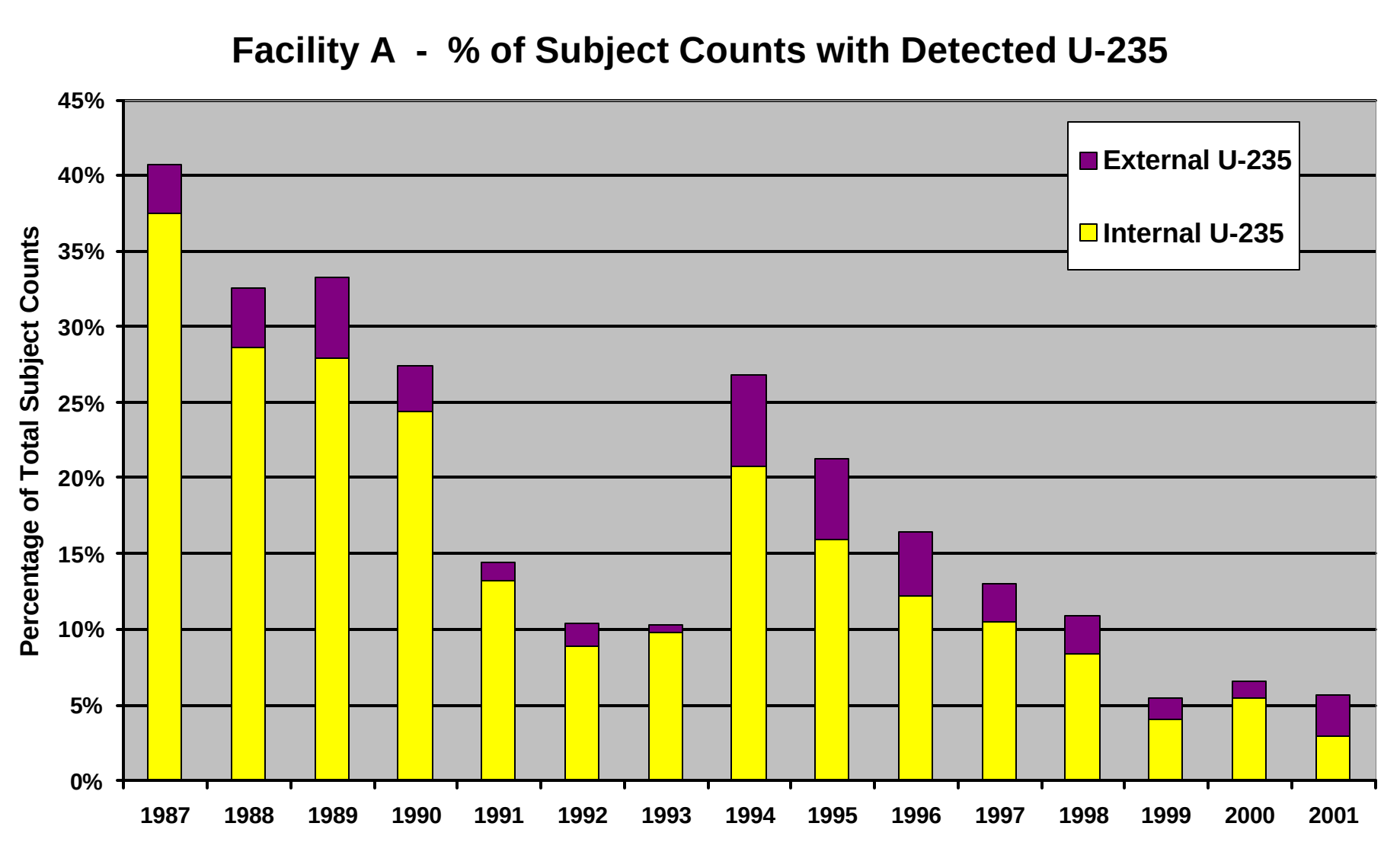
Facility A – Annual Subject Count Totals



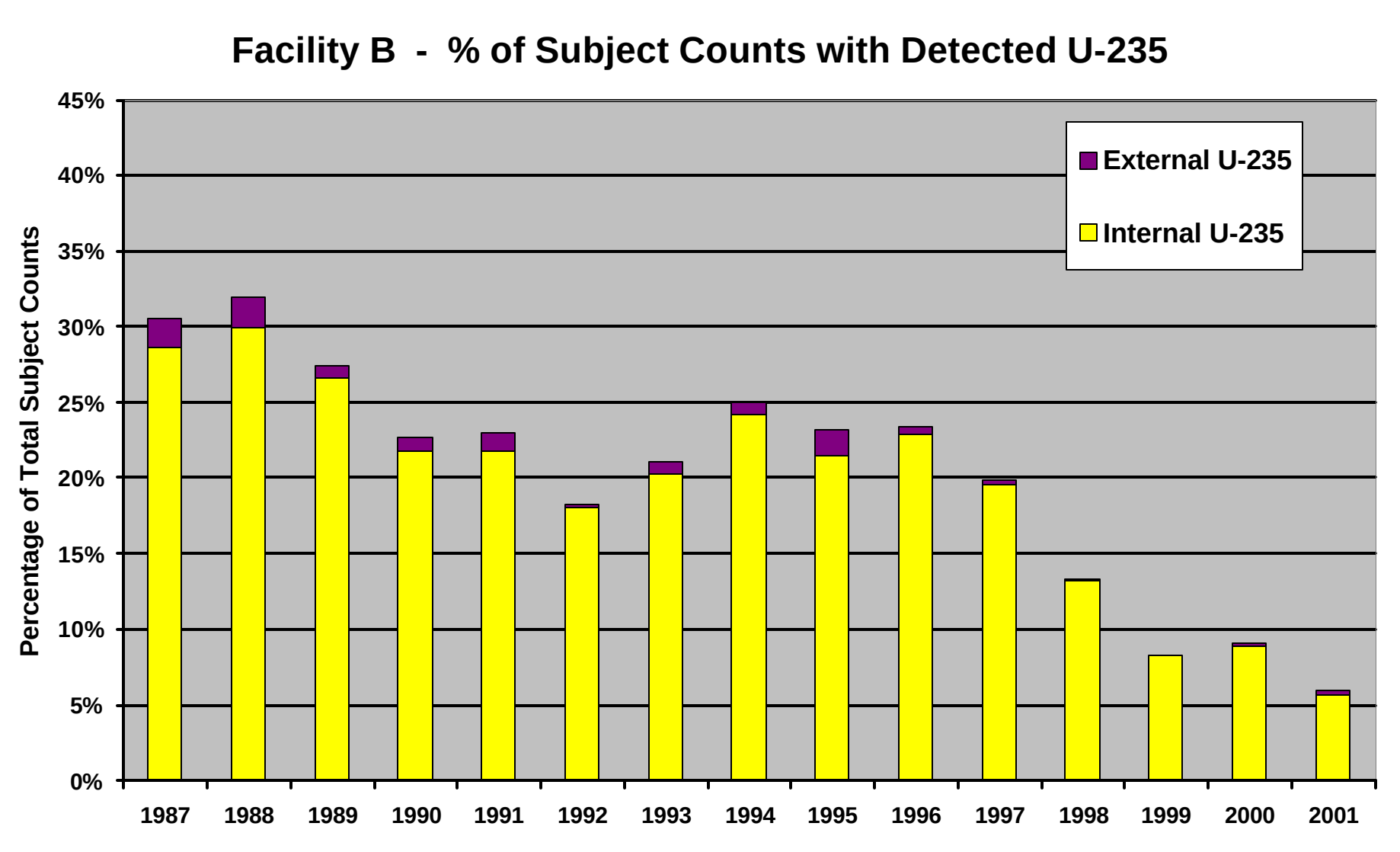
Facility B – Annual Subject Count Totals



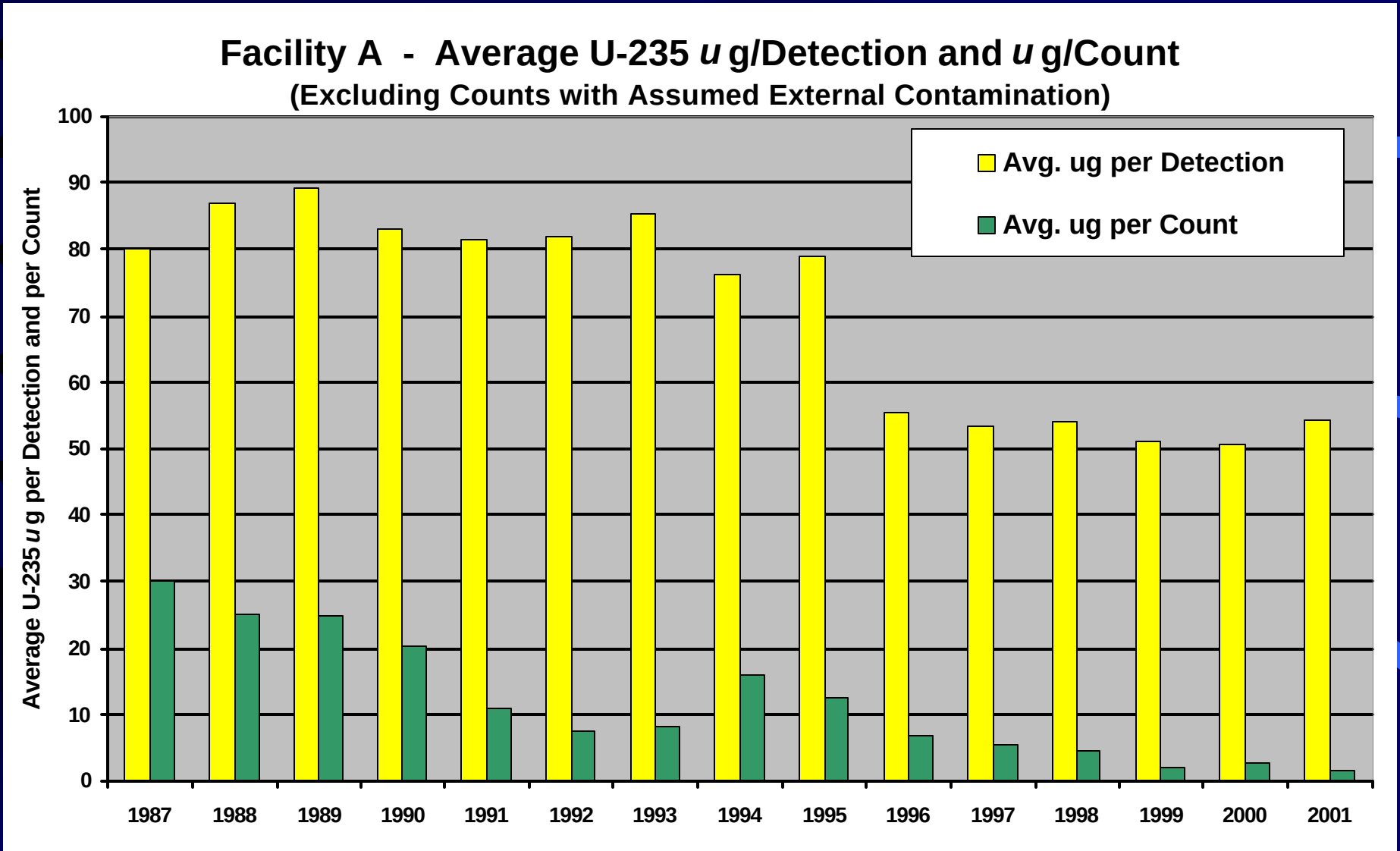
Facility A – U-235 Detections as % of Counts



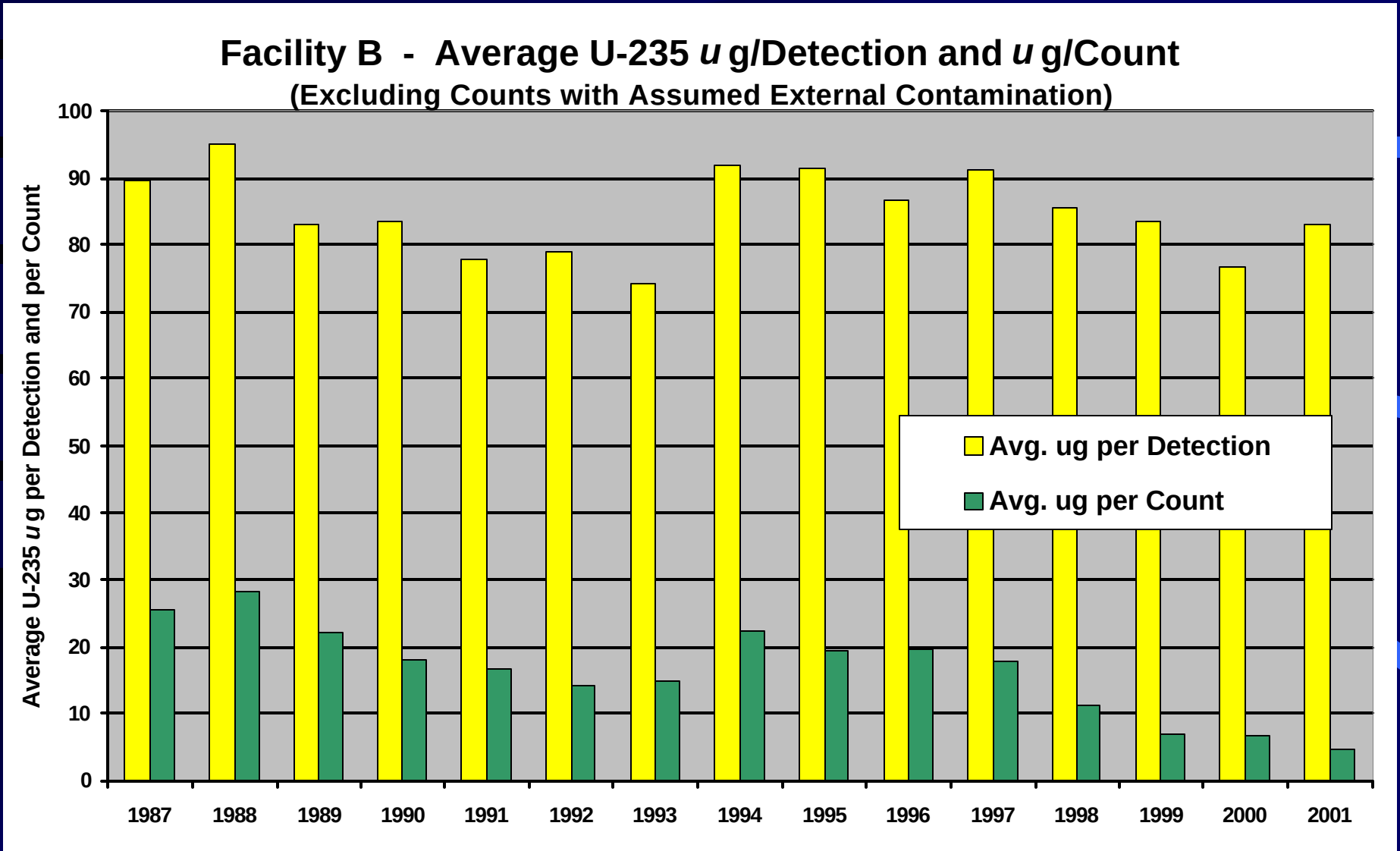
Facility B – U-235 Detections as % of Counts



Facility A – Average U-235 *u*g Values



Facility B – Average U-235 *u*g Values



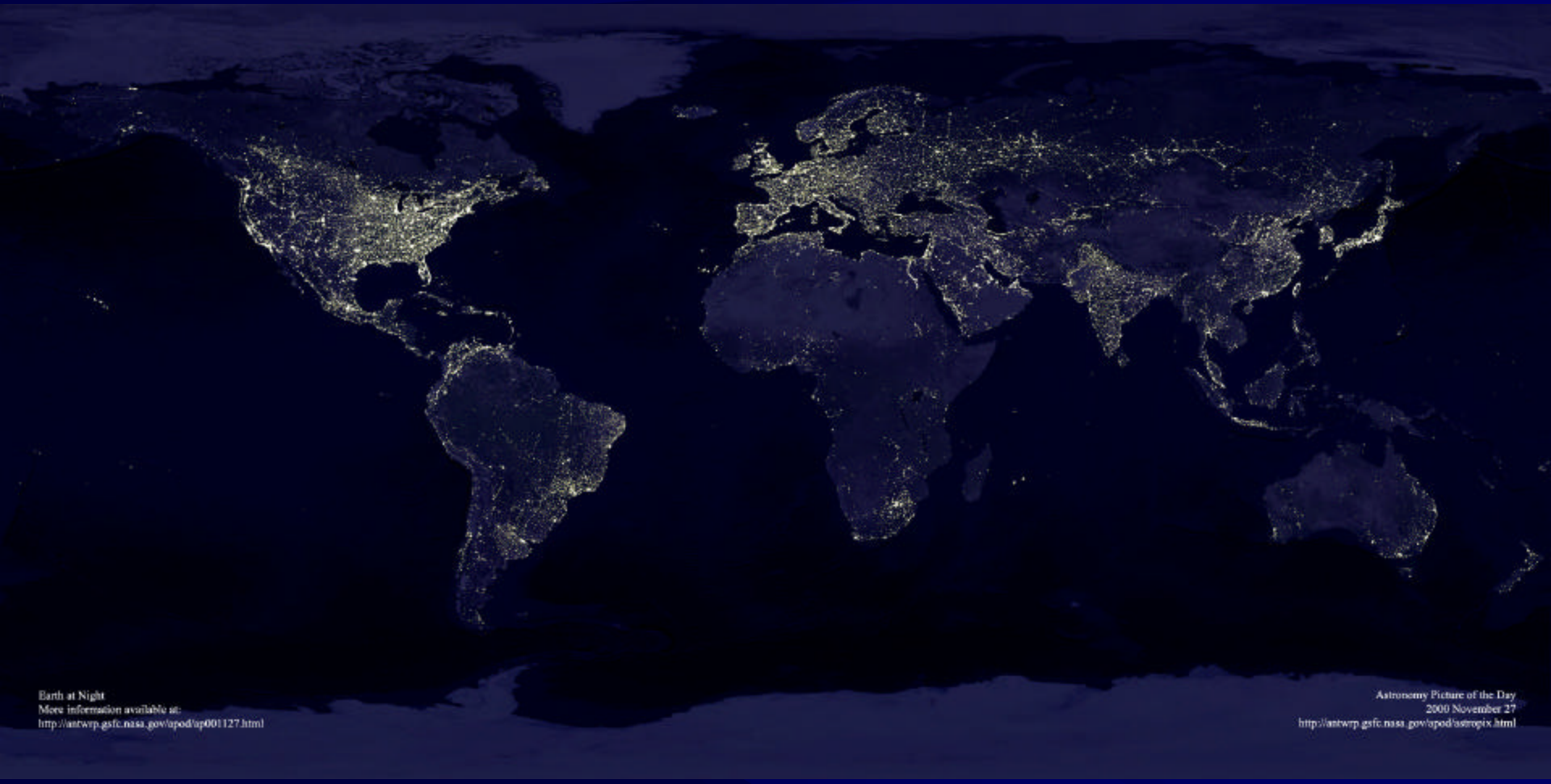
Observed Trends (from 1987 to 2001)

- Avg. monthly counting throughput from January – December:
  - Decreases significantly at Facility A, relatively constant at Facility B
- Maximum internal U-235 *u*g result reported during each year:
  - Facility A: highest in 1991 (329), generally decreasing to <100 in 2001
  - Facility B: highest in 1988 (367), relatively constant (~250) thru 2001
  - All assigned internal doses remained below regulatory limits
- Fluctuation in annual subject count totals from 1987 to 2001:
  - Gradually decreased from ~1000 to ~600 counts/year at Facility A
  - Decreased from ~1400 (1988-91) to ~400 (1994-96), then gradually increased to ~1200 in 2001 (due to significant variations in production levels and workforce requirements)
- Variation in U-235 detections as a percentage of total counts:
  - Facility A: generally decreased from ~35% (1987-89) to ~6% in 2001
  - Facility B: generally decreased from ~30% (1987-89) to ~6% in 2001

Conclusions

- The significant decrease in U-235 detections over the past 15 years at both facilities shows continuous improvement in their engineering controls, site operating procedures, and radiation worker training
- Canberra's *in vivo* counting data review service has been a valuable tool for documenting this favorable trend, and for complete, accurate, and defendable reporting of bioassay results
- Canberra hopes to continue our long-term contract for *in vivo* data review service with these two facilities for many years to come!

Thank you for your attention!



Do you have any questions?