United States General Accounting Office

GAO

Report to Congressional Requesters

April 2002

DIFFUSE SECURITY THREATS

Technologies for Mail Sanitization Exist, but Challenges Remain

GAO-02-365

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United States General Accounting Office
Washington, DC 20548

April 23, 2002

The Honorable Henry A. Waxman
Ranking Minority Member
Committee on Government Reform
House of Representatives

The Honorable Danny K. Davis
Ranking Minority Member
Subcommittee on Civil Service, Census, and
Agency Organization
Committee on Government Reform
House of Representatives

The attacks of September 11, 2001, and recent anthrax exposures have heightened long-standing concerns about the proliferation of biological weapons and the United States's ability to quickly respond to exposure to such weapons. In particular, the United States needs to identify technologies that can be used to protect against biological weapons, such as anthrax, without harming humans. In light of these concerns, you requested that we identify the technologies that the United States Postal Service (USPS) is currently using to sanitize the mail. In addition, you asked that we identify the major issues associated with these technologies, including current applications, occupational safety matters, effects on materials, testing, operations and processing capabilities, costs, and implementation.

To address these objectives, we met with officials from USPS, the Armed Forces Radiobiology Research Institute, and industry experts; reviewed literature and documents on commercially available ionizing radiation technologies; and visited existing irradiation facilities in Lima, Ohio, and Bridgeport, New Jersey. In addition, we reviewed the strengths and limitations for the forms of ionizing radiation technologies we assessed. We also analyzed acquisition and life-cycle costs for ionizing radiation technologies. However, due to the proprietary, competition- sensitive nature of these costs, we did not include them in this report.

We performed our work from November 2001 through March 2002, in accordance with generally accepted government auditing standards.

On February 13, 2002, we provided a detailed briefing to your office on the results of this work. The purpose of this report is to provide the briefing slides to you. These slides are included as the appendix.

In our briefing, we reported that ionizing radiation has emerged as the leading current technology for mail sanitization. This technology is commonly used for sterilizing medical products; preparing food for human consumption by reducing the bacterial contamination of meat, poultry, eggs, and vegetables; and delaying the ripening or sprouting of fresh fruit to control insects and parasites in foods. When sufficient dosages are used, ionizing radiation can also decontaminate biological weapons such as anthrax. However, ionizing radiation may have adverse effects on mailed material (e.g., some paper products may be scorched), and it may not be directly applicable to some types of mail such as parcels, boxes, and large packages. In addition, applying ionizing radiation (irradiation) in a mail-processing environment requires taking radiation and biohazard precautions, such as shielding the radiation source with concrete vaults and wearing protective gear if there are known contaminants.

While USPS currently has two contracts to irradiate the mail, there are many issues that must be addressed to expand the use of ionizing radiation technology. For instance, the USPS will need to assess (1) how it will integrate this technology with the current mail-processing equipment and (2) the technology's associated costs, schedule, benefits, and risks.

We shared the results of our work with the postmaster general and chief executive officer of the USPS, and the agency generally agreed with our findings. For several specific areas of our briefing, USPS offered suggestions for revision, which we have incorporated where appropriate.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution of it until 30 days from the date of this letter. At that time, we will provide copies to the chair of the House Government Reform Committee; the chairmen and ranking minority members of the House and Senate Committees on Appropriations; the Subcommittee on International Security, Proliferation and Federal Service, Senate Committee on Governmental Affairs; the postmaster general and chief executive officer, USPS; and other interested parties upon request. This report will also be available at our Web site at www.gao.gov.

Should you or your offices have any questions concerning this report, please contact me at (202) 512-6412 or Madhav Panwar, director, at (202) 512-6228. We can also be reached by e-mail at rhodesk@gao.gov and panwarm@gao.gov, respectively. Individuals making key contributions to the briefing and this report were Sushil Sharma, David Gootnick, Nabajyoti Barkakati, Rahul Gupta, Karen Richey, and Yvette Banks.

Sincerely yours,

Keith A. Rhodes
Chief Technologist, Applied Research and Methods

Appendix


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Sanitization of U.S. Mail
Assessment of Ionizing Radiation Technologies
and Related Issues
Briefing for the Committee on Government Reform
and
the Subcommittee on Civil Service, Census, and Agency Organization
House of Representatives
February 13, 2002

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Purpose and Outline

To provide an assessment of existing ionizing radiation technologies that the United States Postal Service (USPS) is using to sanitize mail and issues related to those technologies.

Outline:

- Objectives, Scope, and Methodology
- Background
- Summary
- Ionizing Radiation
- Vendor Operations and Processing Capabilities
- Costs
- Long-Term Implementation Issues
- Conclusions
- Further Work Needed

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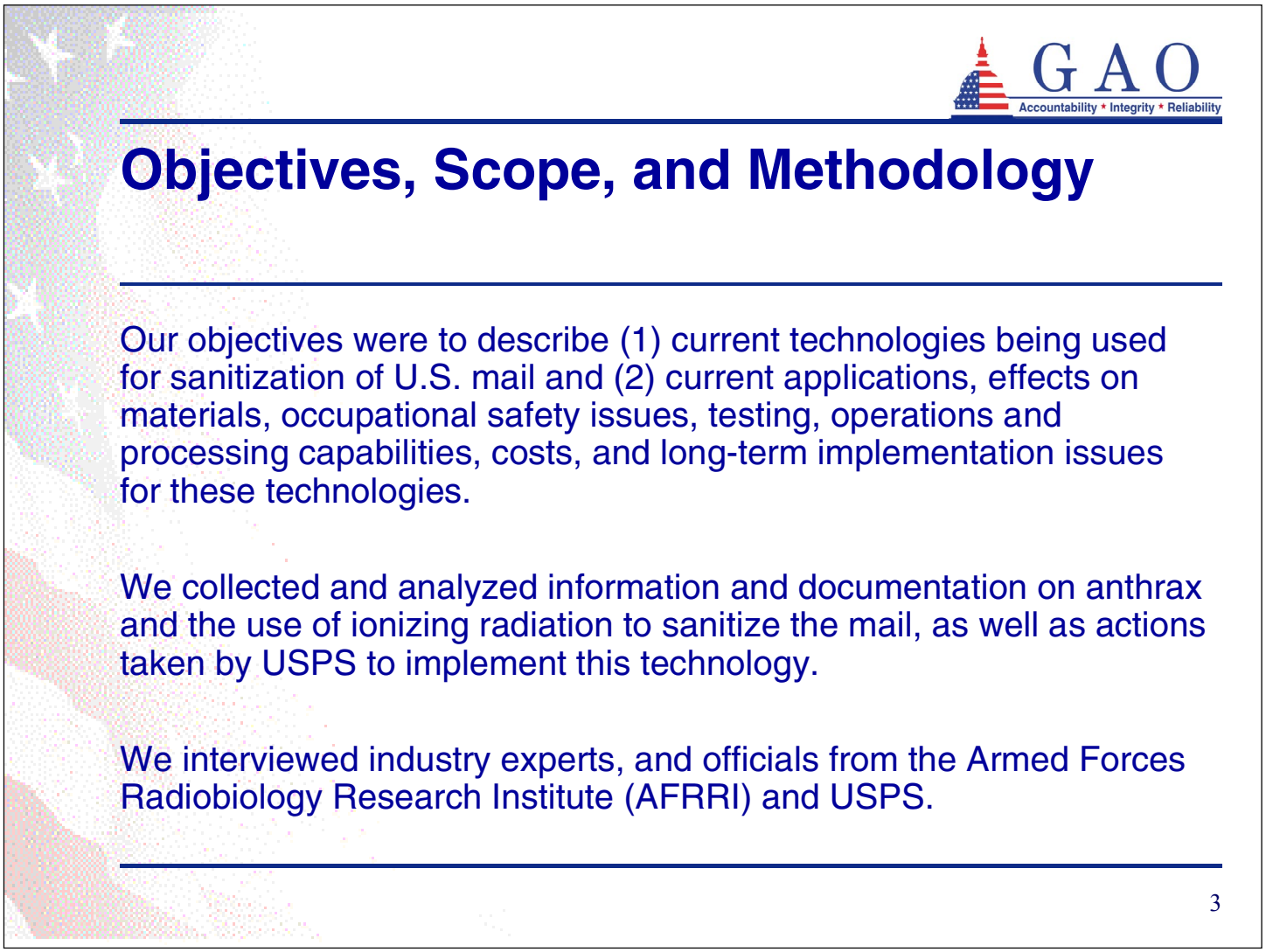
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Objectives, Scope, and Methodology
Our objectives were to describe (1) current technologies being used for sanitization of U.S. mail and (2) current applications, effects on materials, occupational safety issues, testing, operations and processing capabilities, costs, and long-term implementation issues for these technologies.
We collected and analyzed information and documentation on anthrax and the use of ionizing radiation to sanitize the mail, as well as actions taken by USPS to implement this technology.
We interviewed industry experts, and officials from the Armed Forces Radiobiology Research Institute (AFRRI) and USPS.
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Objectives, Scope, and Methodology *(continued)*

In addition, we analyzed acquisition and life-cycle costs for ionizing radiation technologies. However, due to the proprietary, competition-sensitive nature of the vendor costs, we did not include them in this report.

We conducted our review at USPS offices in Washington, D.C., and Merrifield, Virginia. We also visited existing irradiation facilities for the two vendors–Titan Corporation (Titan) in Lima, Ohio, and Ion Beam Applications (IBA) in Bridgeport, New Jersey (N.J.). We conducted our review from November 2001 through March 2002, in accordance with generally accepted auditing standards.

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Background
USPS Anthrax Crisis

Statistics as of December 6, 2001:

- 4 known letters containing anthrax
- 11 confirmed cases of inhalation anthrax; 5 deaths
- 7 confirmed and 4 suspected cases of cutaneous (i.e., skin) anthrax
- 284 USPS facilities tested for anthrax contamination
- 23 USPS facilities found to be contaminated
- 2 USPS facilities (Trenton and Brentwood) remain closed
- 8,424 USPS employees offered antibiotics (D.C., N.J., and N.Y.C.)
- Approximately 1.8 million pieces of mail requiring decontamination

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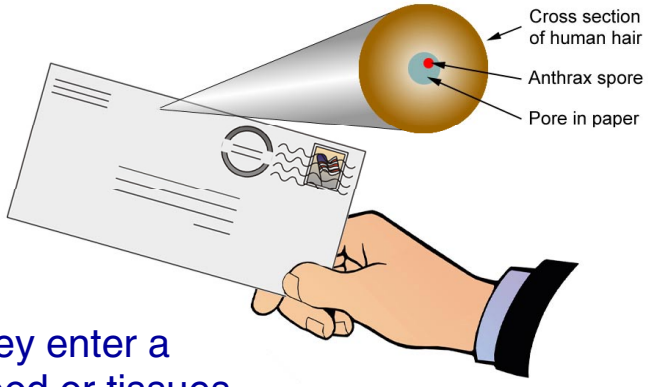
Background

Anthrax Description

Anthrax is an acute infectious disease caused by the spore- forming bacterium *Bacillus anthracis.*



Anthrax spores are

- metabolically inactive,
- able to survive for decades or longer,
- approximately 1 micron in diameter, and
- killed by dry heat at 320°F for 2 hours.

Anthrax spores germinate when they enter a favorable environment, such as blood or tissues.

Three types of anthrax infection can occur: cutaneous (skin), inhalation, and gastrointestinal.

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Background
Anthrax as a Weapon

At least 17 nations are believed to have offensive biological weapons programs.

At least 7 of our potential adversaries have worked to develop an offensive biological warfare capability using anthrax.

Iraq has admitted to producing and weaponizing anthrax.

The former Soviet Union produced hundreds of tons of weapons-grade anthrax spores. In 1979, the accidental release of a gram of anthrax spores, from a military microbiology facility in one of the former Soviet Union territories, resulted in at least 79 cases of anthrax, leading to 68 deaths.

Expert opinion varies on the ability of individuals or small groups to obtain and disseminate anthrax.

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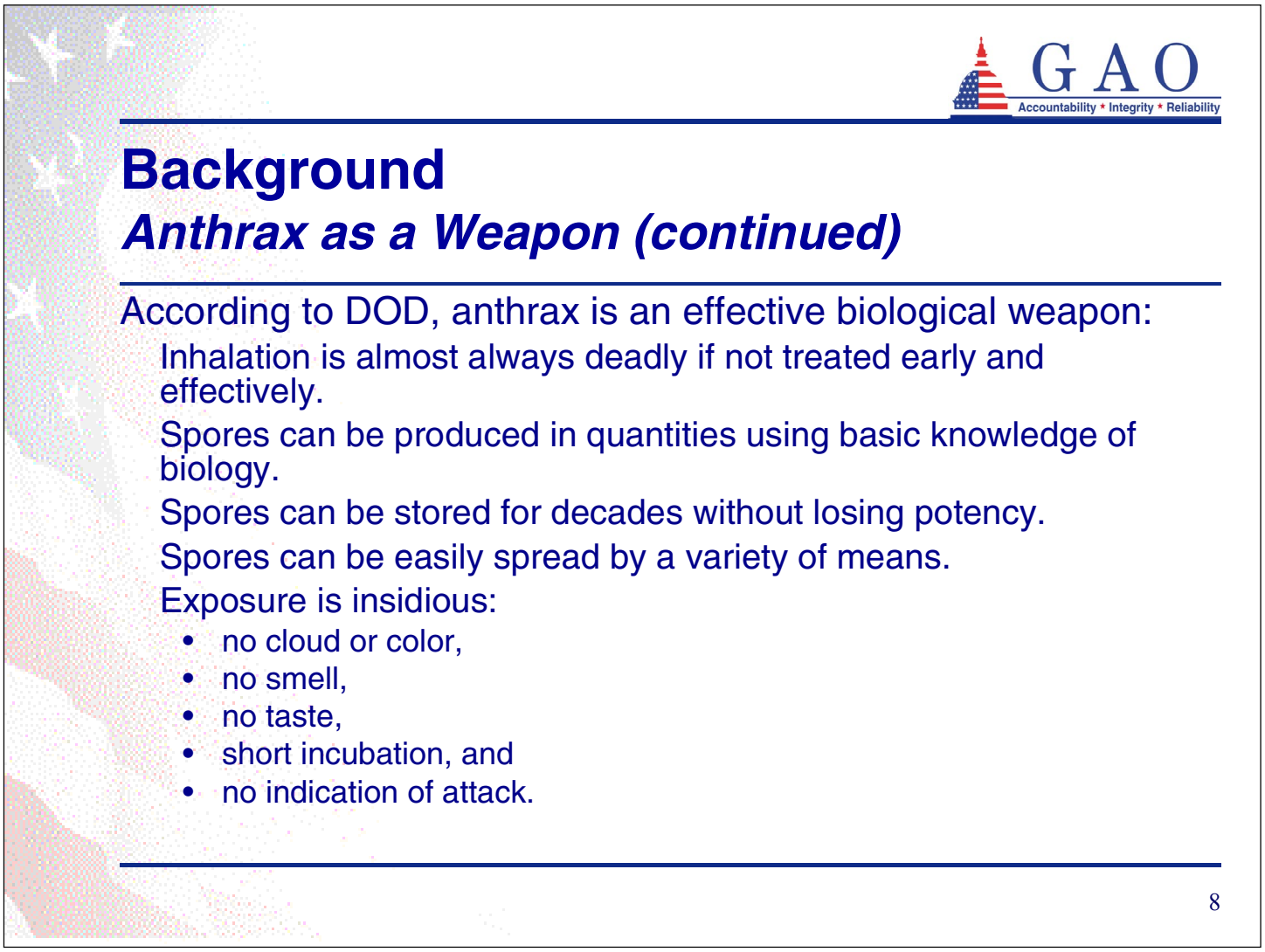
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Background
Anthrax as a Weapon (continued)
According to DOD, anthrax is an effective biological weapon:
Inhalation is almost always deadly if not treated early and effectively.
Spores can be produced in quantities using basic knowledge of biology.
Spores can be stored for decades without losing potency.
Spores can be easily spread by a variety of means.
Exposure is insidious:
• no cloud or color,
• no smell,
• no taste,
• short incubation, and
• no indication of attack.
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Summary

Ionizing radiation is the leading current technology being used for sanitization of U.S. mail, assuming effective dosage can be uniformly delivered to the target.

Two forms of ionizing radiation that can be used to sanitize the U.S. mail are electron beam (e-beam) and x-ray. Both have strengths and limitations.

- E-beams provide high-volume mail sanitization, but have limited penetration (i.e., are not effective for large packages).
- X-rays can penetrate deeper than e-beams, but they are not as efficient.

Current applications of ionizing radiation include sterilizing medical products and preparing food for human consumption.

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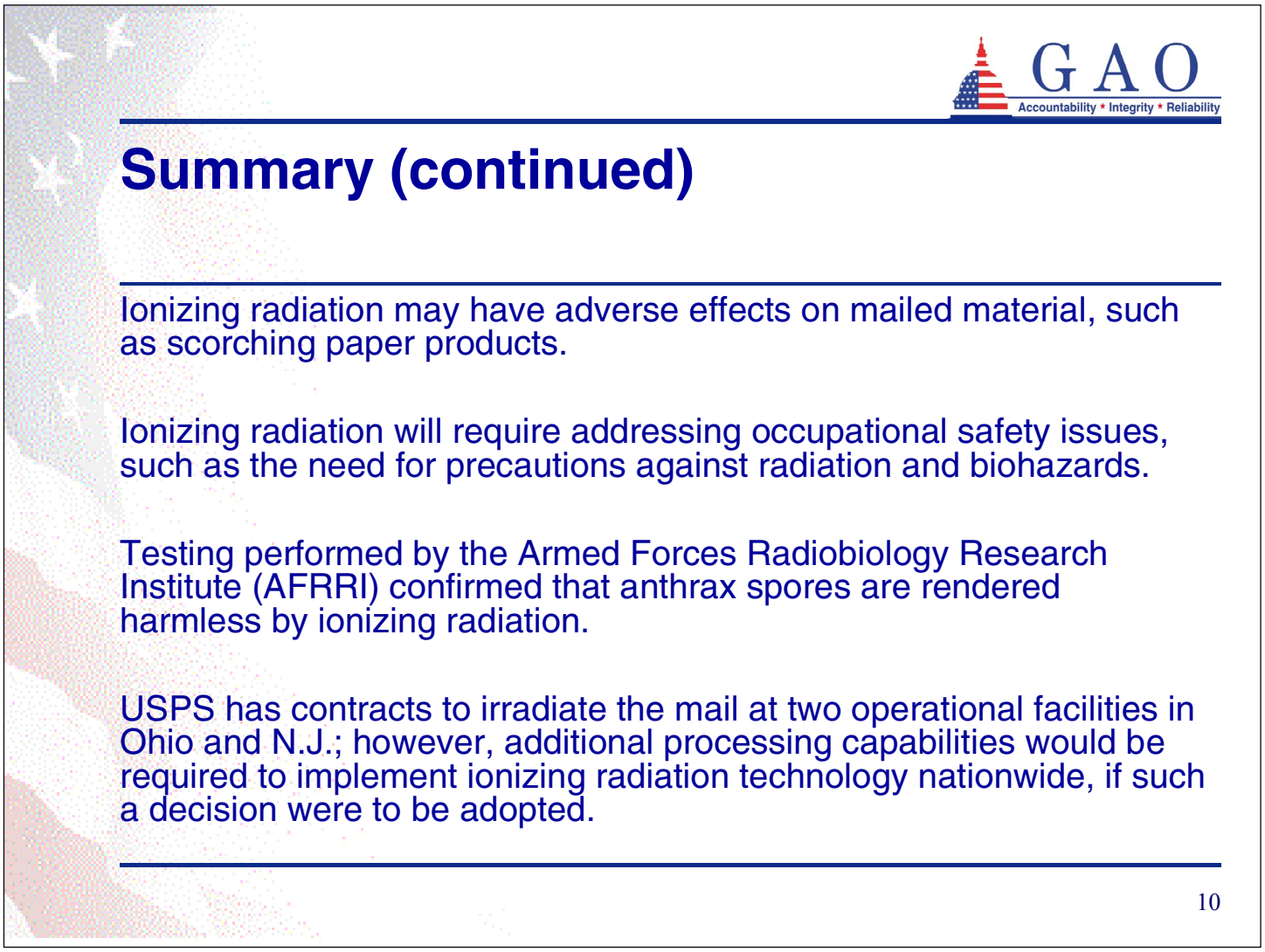
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Summary (continued)
Ionizing radiation may have adverse effects on mailed material, such as scorching paper products.
Ionizing radiation will require addressing occupational safety issues, such as the need for precautions against radiation and biohazards.
Testing performed by the Armed Forces Radiobiology Research Institute (AFRRI) confirmed that anthrax spores are rendered harmless by ionizing radiation.
USPS has contracts to irradiate the mail at two operational facilities in Ohio and N.J.; however, additional processing capabilities would be required to implement ionizing radiation technology nationwide, if such a decision were to be adopted.
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Summary (continued)

USPS requested funding, through June 2002, to sanitize the mail. Long-term vendor cost estimates to irradiate the mail nationwide range between approximately $880 million to about $4.2 billion over a ten-year period.

Long-term issues, such as integrating ionizing radiation into the mail process, have not yet been fully defined by USPS.

USPS will need to determine

- the amount and types of mail to be processed,
- the location and number of sites to irradiate mail,
- the mix of technologies needed to irradiate mail, and
- the costs, benefits, and risks associated with these technologies.

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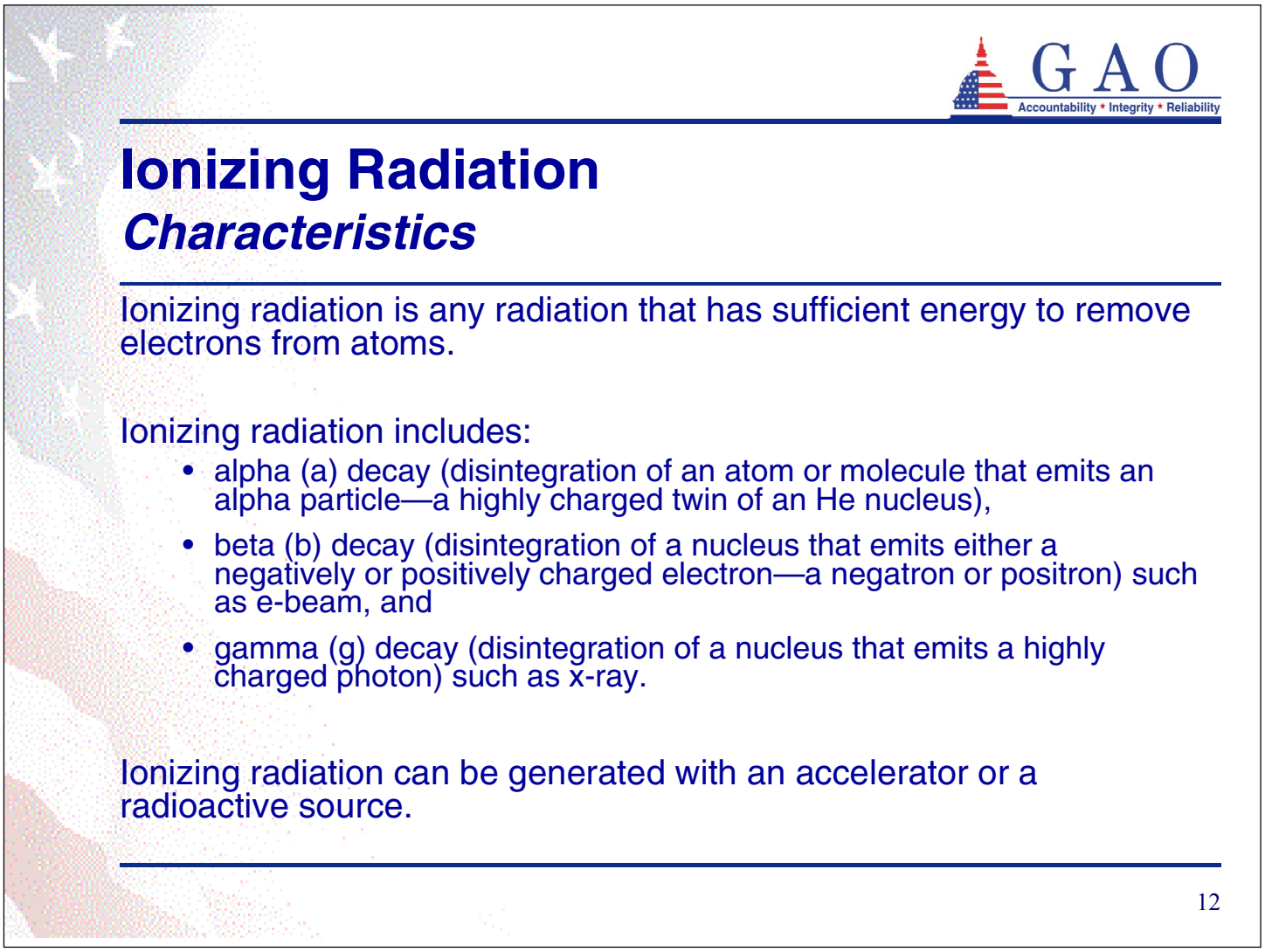
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Ionizing Radiation
Characteristics
Ionizing radiation is any radiation that has sufficient energy to remove electrons from atoms.
Ionizing radiation includes:
• alpha (a) decay (disintegration of an atom or molecule that emits an alpha particle—a highly charged twin of an He nucleus),
• beta (b) decay (disintegration of a nucleus that emits either a negatively or positively charged electron—a negatron or positron) such as e-beam, and
• gamma (g) decay (disintegration of a nucleus that emits a highly charged photon) such as x-ray.
Ionizing radiation can be generated with an accelerator or a radioactive source.
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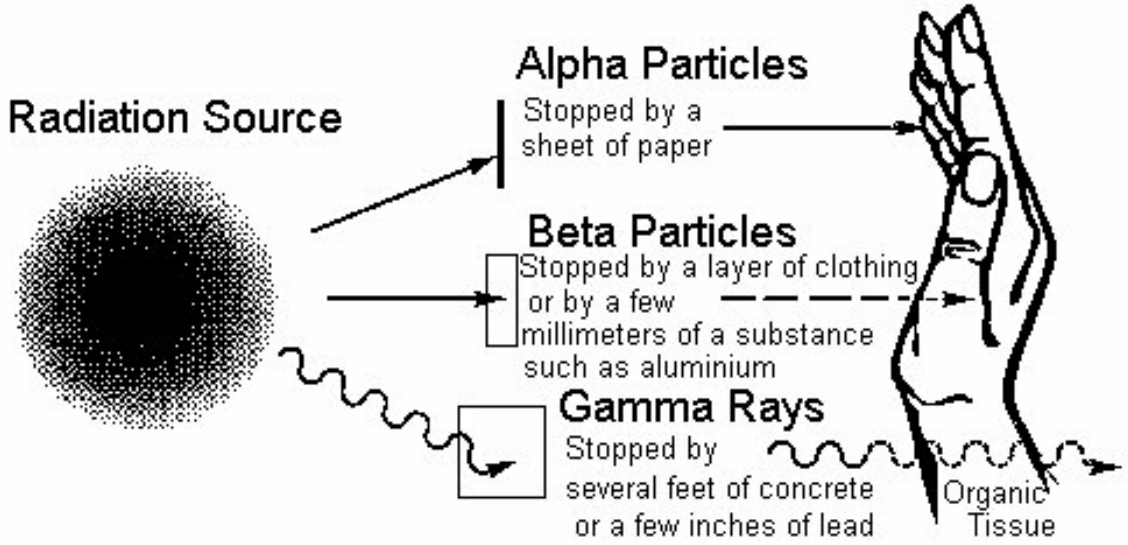
Ionizing Radiation
Characteristics (continued)



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Ionizing Radiation
Characteristics (continued)

Ionizing radiation:

- E-beams are generated by a heated filament. A voltage gradient accelerates the electrons through a vacuum tube. Electrons can also be accelerated by using radio frequency (RF) microwave power.
- X-rays are generated by bombarding a metal (usually a heavy metal) with high-velocity electrons.
- Gamma rays are generated by the decay of radioactive sources. However, because the presence of highly radioactive sources may present additional safety hazards to workers, gamma ray irradiation was eliminated as a method of sanitizing the mail.

Various manufacturers produce equipment to generate ionizing radiation such as linear accelerators, Dynamitrons, and Rhodotrons.

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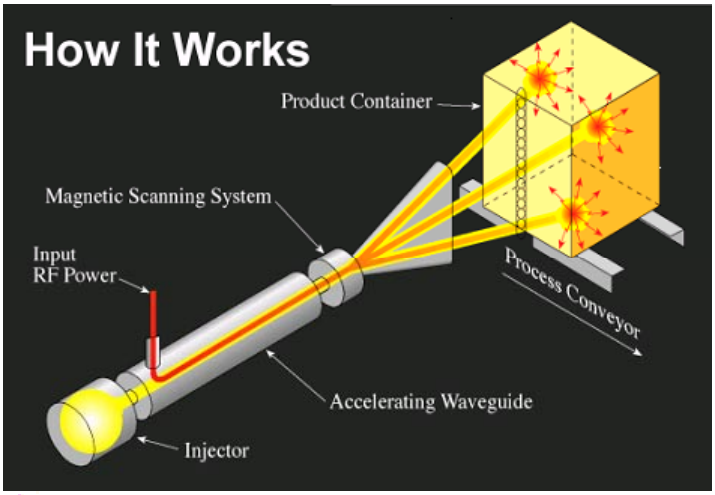
Ionizing Radiation
LINAC (Linear Accelerator)

Electrons emitted from a heated filament are accelerated, under the action of an electric field, in a long vacuum pipe then spread using a magnetic scanning device to provide full treatment of products.



Source: © 2002, Titan Corporation.

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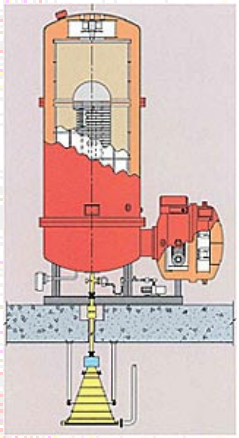
Ionizing Radiation
Dynamitron



Source: © 2002, IBA.

Dynamitrons work on the same principle as television tubes. Electrons are generated by a heated filament, which forms the electron gun; a voltage gradient draws the electrons away from the gun and accelerates them through the vacuum tube.

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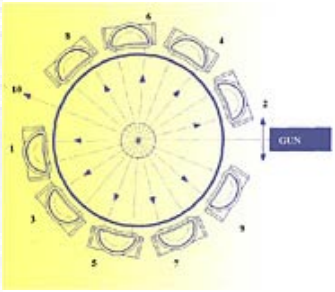
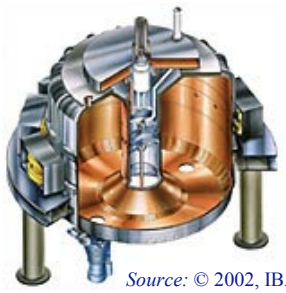
Ionizing Radiation
Rhodotron

Electrons are accelerated as they pass through properly oriented electrical fields.





Source: © 2002, IBA.

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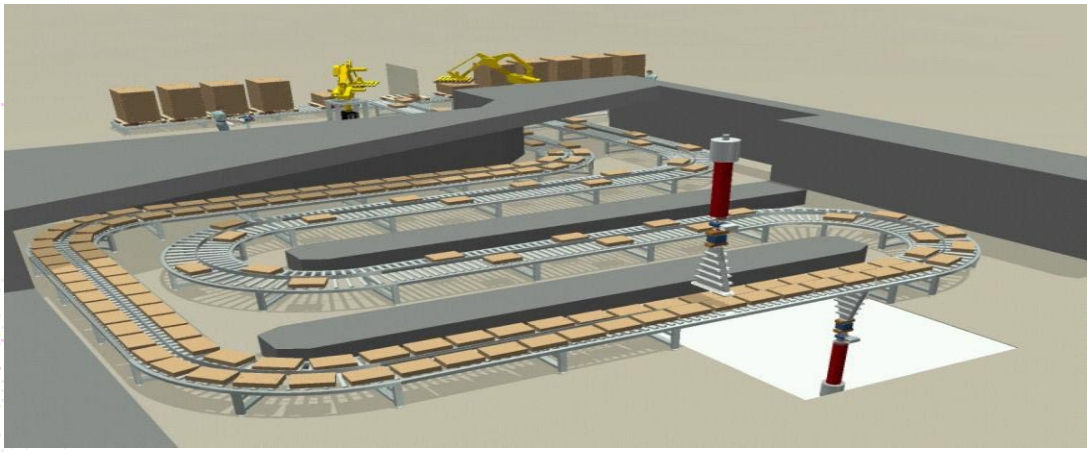
Ionizing Radiation
Titan's Concept

Double-sided mail irradiation



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Ionizing Radiation
Current Applications

Range of radiation dose[a] by target type:

- <1 kGy is used to delay physiological processes, such as ripening or sprouting of fresh fruits and vegetables, and to control insects and parasites in foods
- 1-30 kGy is used to reduce bacterial contamination of meat, poultry, eggs, spices, and vegetables for human consumption
- 10-40 kGy is used for medical product sterilization

Irradiation Target	Net Effect	Dose Range (kGy)
Food	Delay ripening, insect deinfestation	<1-30
Medical products	Sterilization	10-40
Polyolefin foams and heat-shrinkable materials	Crosslinking and memory imparted	40-250
Rubber and fluoropolymers	Vulcanization and degradation	80-1500
Gemstones	Coloration	10,000+

[a]Radiation dose is measured in kilograys (kGy).

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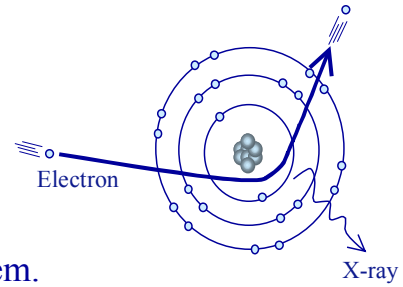
Ionizing Radiation
E-beams and X-rays

E-beam machines can also be designed to produce x-rays to irradiate parcels and large boxes.

X-rays are emitted when a high-speed e-beam bombards a suitable metallic target, such as tungsten.



- This process generates heat and requires a cooling system.
- 99 percent of the e-beam's power is lost as heat.
- The throughput (amount of material irradiated in a given time) is greatly reduced.

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Ionizing Radiation

E-beam

Strengths:

- High volume
- Effective for anthrax and bacterial spores
- Consistent results when packaging density is maintained
- Not toxic, corrosive, or staining

Limitations:

- Limited penetration
- High-density materials will inhibit penetration (packing density must be maintained)
- Limited to letters and flat mail
- Source must be shielded
- Raises temperature of mail to 150°F or greater
- Scorches some materials
- Degrades certain materials
- Produces ozone in bagged mail

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Ionizing Radiation
X-rays

Strengths:

- Deep penetration
- Effective for anthrax and bacterial spores
- Packaging not critical
- Handles items such as parcels and boxes
- Density not issue for mail
- Not toxic, corrosive, or staining

Limitations:

- Limited conveyor speed and radiation power (slower throughput)
- High cost (less than 10 percent as efficient as e-beam)
- Activation of irradiated material
- Source must be shielded
- Raises temperature of mail to 150°F or greater
- Scorches some materials
- Degrades certain materials
- Produces ozone in bags

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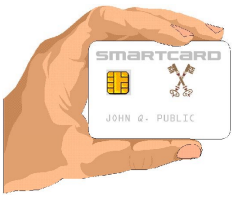
Ionizing Radiation

Examples of Effects on Materials

- Live material (possibly killed)
- Lab samples (destroyed)
- Pharmaceuticals (potency altered)
- Food (altered taste)
- Eyeglasses and other glass products (fogged)
- Film (damaged)
- Smart Cards (possible data loss)
- Some paper products (scorched)



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Ionizing Radiation
Occupational Safety Issues

Radiation safety requires shielding, processing safeguards, dosimeter[1] monitoring of employees, and radiation safety and quality control officers.

Biohazard precautions require procedures for facility bio-safety, personal protective gear, environmental monitoring, and disposal of materials.

The Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and state public health authorities all regulate radiation safety issues.

If gamma radiation is used, environmental clean-up and nuclear waste issues emerge.

[1]A dosimeter measures the amount of radiation applied to a target.

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Ionizing Radiation
Testing

Mail sanitization is a stringent and standardized process that renders treated anthrax in the mail harmless for humans, according to Armed Forces Radiobiology Research Institute (AFRRI).

Mail can be sanitized by delivering sufficient doses of ionizing radiation to disrupt or destroy DNA, RNA, proteins, and other cell components, rendering bacteria harmless.

Ionizing radiation renders anthrax spores harmless; however, the spores will remain detectable by advanced techniques.

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Ionizing Radiation
Testing (continued)

Armed Forces Radiobiology Research Institute (AFRRI) conducted tests which confirmed that anthrax spores are rendered harmless by ionizing radiation. The tests were conducted at three sites:

- AFRRI Laboratory,
- Lima, Ohio, and
- Bridgeport, N.J.

The French achieved similar results testing the effects of cobalt-60 on anthrax.

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Ionizing Radiation
Testing (continued)

AFRRI's Study: *The Efficacy of Electron Beam to Decontaminate Chemical and Biological Warfare Agents: Phase One* (July 30, 2001). This study

- tested a series of chemical and biological agent surrogates under very controlled conditions to determine the kill effectiveness of e-beam, and
- established dose values to render *Bacillus anthracis-Sterne strain* and *Bacillus subtilis var. globigii* (BG-anthrax simulant) ineffective.

The efficacy of the standard minimum dose was tested on-site at Lima, Ohio, and Bridgeport, N.J.

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Ionizing Radiation
Testing (continued)

On November 1, 2001, AFRRI tested the efficacy of the standard minimum dose at Lima under the following on-site conditions:

- packaging and orientation of mail,
- conveyor speed and radiation power (to determine throughput), and
- electron energy (to determine penetration).

On-site conditions demonstrated that

- delivered dose is 1 to 2 times standard minimum dose (dosimetry), and
- BG simulant is rendered harmless as verified by negative cultures.

Similar results were achieved on site at the Bridgeport facility.

Testing with BG simulant confirmed that the established minimum dose deactivates spores.

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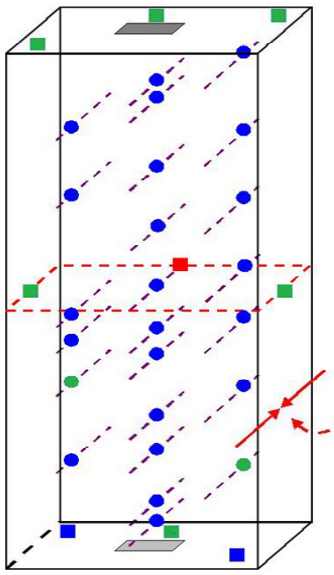
Ionizing Radiation
Testing (continued)



Dosimetry Results

Dose Map of Titan "Test Box"

Dosimeters on envelope (●)

Dosimeters on box inner surface (■)

- Dose range 60-70 kGy
- Dose range 71-100 kGy
- Dose range 100+ kGy

Electron beam direction in red

Absorbed dose measured with NIST alanine reference dosimeters

Note: NIST represents the National Institute of Standards and Technology.

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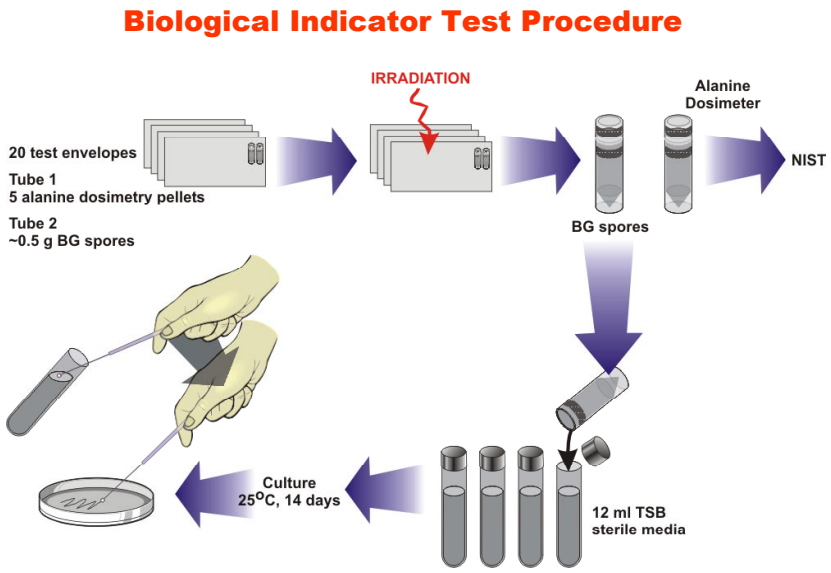
Ionizing Radiation
Testing (continued)

AFRRI's lab tests confirmed that after irradiation the cultures for *Bacillus subtilis var. globigii* (BG-anthrax simulant) were negative



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Operations and Processing Capabilities
Ionizing Radiation Vendors

USPS had contracts with two vendors, IBA and Titan, to initially irradiate mail that was backlogged from the Brentwood and Trenton mail processing facilities.

Currently, these vendors are under contract to irradiate letters and flats addressed to congressional and government offices in ZIP Codes 202, 203, 204, and 205.

Neither of these vendors is irradiating parcels or large boxes because the x-ray equipment is not ready.

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Operations and Processing Capabilities
IBA: Current Facility

IBA has a facility in Bridgeport, N.J. that is being used to irradiate mail.

The facility has a single Rhodotron capable of generating both e-beam and x-rays.

It was originally designed to irradiate
- polymers at high (>200 kGy) dosage using e-beam, and
- frozen food (hamburgers) at low dosage using x-ray.

Currently operating in e-beam mode at about 170 kW@10 MeV (17 mA).

X-ray equipment not yet functional at N.J. facility.

Rhodotron irradiating down

Source: © 2002, IBA.

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Operations and Processing Capabilities

IBA: Current Facility (continued)

Receiving room

Inside receiving room

Conveyor system

Control room

Tray that holds mail

Tray with boxes of mail

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Operations and Processing Capabilities
IBA: Current Facility (continued)

Conveyor speed was increased to handle mail.

Roller conveyor system is being used.

Mail must arrive packaged flat, double bagged, boxed, and sealed.

Each box is irradiated twice, once per side.

Sealed boxes are manually flipped over for second pass.

Dosimetry is performed on trays.

Throughput is 4,500 lbs per hour.

Current biohazard precautions include visual inspection of incoming mail in clean area by personnel in full protective gear.

The availability requirement is 90 percent (current USPS contract); IBA estimates over 95 percent at other facilities.

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Operations and Processing Capabilities
Titan: Current Facility

Titan has a facility in Lima, Ohio that is being used to irradiate mail.

The facility has a single accelerator operating at 18 kW@10 MeV (1.8 mA).

USPS purchased eight additional systems that will be used to assess long-term use.

The Lima facility was initially designed to sterilize medical products and has no x-ray equipment.

The availability requirement is 90 percent (current USPS contract); Titan estimates 96 percent at its other facilities in San Diego and Denver that operate 24 hours a day, 7 days a week.

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Operations and Processing Capabilities

Titan: Current Facility (continued)

Tray with boxes of mail

Conveyor system

Box of mail

Control room

Irradiated mail in truck

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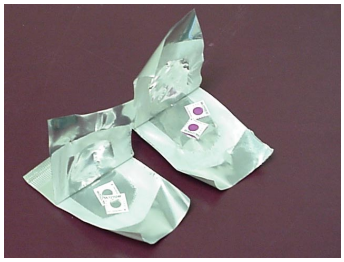
Operations and Processing Capabilities
Titan: Current Facility (continued)

- Conveyor speed was decreased to handle mail.
- Fixed-carrier conveyor system is being used.
- Mail arrives packaged vertically in trays, double bagged, boxed, and sealed.
- Each box is irradiated four times (conveyor rotates boxes automatically for each pass).
- Dosimetry is performed on trays.
- Throughput is 1,000 lbs per hour.
- Current biohazard precautions include masks and gloves in pre-irradiation area.

Dosimeter



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Costs

USPS Request for Supplemental Funding on 11/13/01

Mail Sanitization and Security Requirements
(Dollars in Millions)

Requirements Through June 2002	Estimated Cost	Percent Total
Sanitization[a]	**$ 307.5**	**24%**
Purchase and installation of vacuums and hepafilters	310.0	24%
Biological air monitoring and detection	306.5	24%
Operations and disruptions of mail	152.4	12%
Other costs (testing, antibiotics, gloves, and security)	139.7	11%
Anthrax decontamination	44.9	4%
September 11, 2001-related costs	10.5	1%
Total	**1,271.5**	**100%**
Deduction for initial $175 million emergency funding	$ (175.0)	14%
Total additional request	**$ 1,096.5**	**86%**

[a]Sanitization represents costs for purchasing eight electron beam systems, adjusting for space or renovation requirements, changes to existing material handling systems for revised mail flow, and development of a testing protocol for chlorine dioxide gas.

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Costs

Vendor Long-Term Estimates

Factors affecting cost estimates include:

- volume of mail to be irradiated (pounds per hour),
- conveyor speed,
- machine power, and
- number of locations for installation.

Long-term cost estimates for irradiating mail nationwide range from approximately $880 million to about $4.2 billion over a ten-year period.

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Long-Term Implementation Issues
USPS

USPS issued *Emergency Preparedness Plan for Protecting Postal Employees and Postal Customers From Exposure to Biohazardous Material and for Ensuring Mail Security Against Bioterror Attacks*, March 6, 2002.

GAO will be evaluating the technologies identified in this plan and their implications such as cost, schedule, benefits, and risks.

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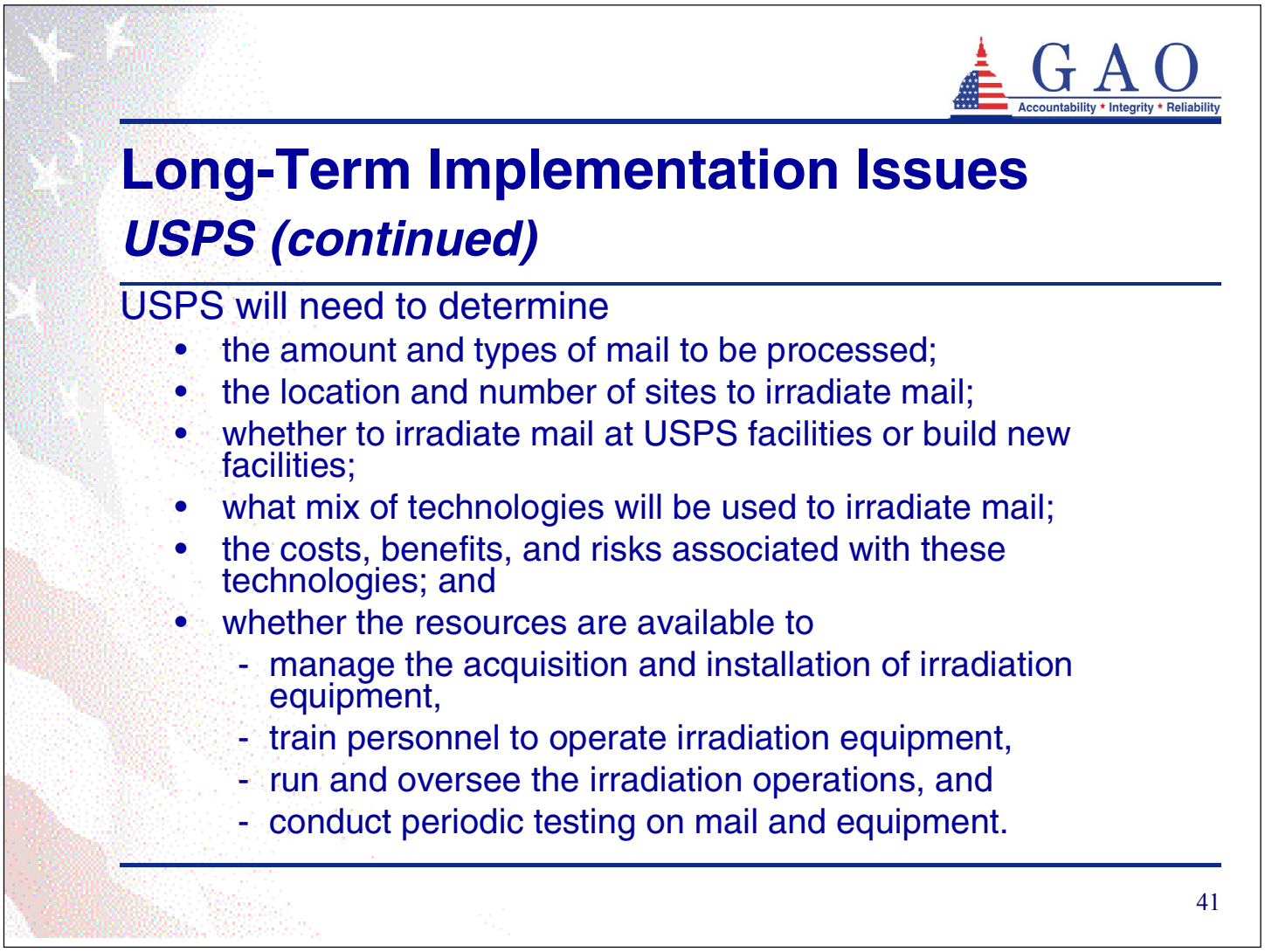
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Long-Term Implementation Issues
USPS (continued)
USPS will need to determine
• the amount and types of mail to be processed;
• the location and number of sites to irradiate mail;
• whether to irradiate mail at USPS facilities or build new facilities;
• what mix of technologies will be used to irradiate mail;
• the costs, benefits, and risks associated with these technologies; and
• whether the resources are available to
- manage the acquisition and installation of irradiation equipment,
- train personnel to operate irradiation equipment,
- run and oversee the irradiation operations, and
- conduct periodic testing on mail and equipment.
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Long-Term Implementation Issues
USPS (continued)

Ionizing radiation equipment will require

- new or modified facilities,
- concrete (about 10-12 ft) and steel shielding,
- conveyor design and installation,
- appropriate permits (OSHA, EPA, and local certification), and
- additional venting or cooling capacity.

Government and industry need to define standards for mail irradiation and monitoring.

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Long-Term Implementation Issues *Contractors*

IBA

- Existing facility in Gainesville, Florida—owned by the U.S. Department of Agriculture—has the shielding needed, as well as skilled workers.
- Rhodotron and Dynamitron production:
  - -- one Rhodotron and one Dynamitron in stock, and
  - -- about 6 months are needed to prepare for production.

Titan

- Accelerators:
  - -- a number of accelerators available for installation, and
  - -- additional production requires 6 to 9 months of lead time.

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Conclusions

- Ionizing radiation technologies can kill anthrax spores.
- Current irradiation facilities are not designed specifically to sanitize mail.
- Enhancements to mail security should be risk-based and, to the extent practicable, done in conjunction with enhancements to mail operations and efficiency.
- E-beams have high throughput and low penetration (can only penetrate 3 to 6 inches of mail).
- X-rays have low throughput and high penetration (can penetrate 14 to18 inches of mail).
- Both ionizing radiation technologies adversely affect some material in the mail.

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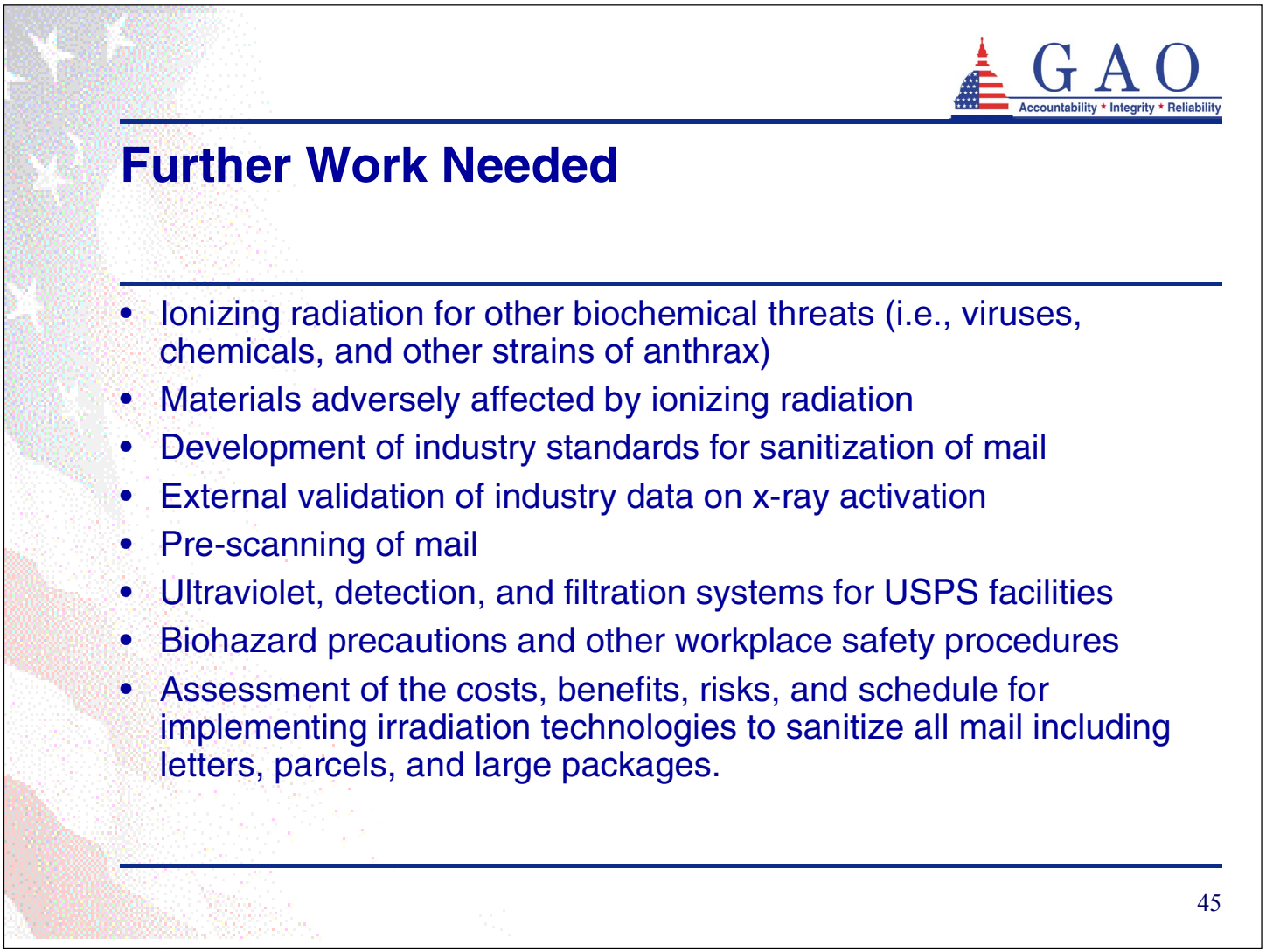
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Further Work Needed
• Ionizing radiation for other biochemical threats (i.e., viruses, chemicals, and other strains of anthrax)
• Materials adversely affected by ionizing radiation
• Development of industry standards for sanitization of mail
• External validation of industry data on x-ray activation
• Pre-scanning of mail
• Ultraviolet, detection, and filtration systems for USPS facilities
• Biohazard precautions and other workplace safety procedures
• Assessment of the costs, benefits, risks, and schedule for implementing irradiation technologies to sanitize all mail including letters, parcels, and large packages.
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