



3D Printing: Opportunities, Challenges, and Policy Implications of Additive Manufacturing

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CG Forum on Nanomanufacturing (GAO-14-181SP)

- Issues discussed:
 - The future of nanomanufacturing
 - U.S. investments in nanotechnology R&D and current challenges to U.S. competitiveness in nanomanufacturing
 - Ways to enhance U.S. competitiveness
 - Issues in addressing environmental, health, and safety (EHS) implications of nanomanufacturing



United States Government Accountability Office

Report to the Chairman, Committee on Science,
Space, and Technology, House of Representatives



Nanomanufacturing

**Emergence and Implications on U.S.
Competitiveness, the Environment,
and Human Health**

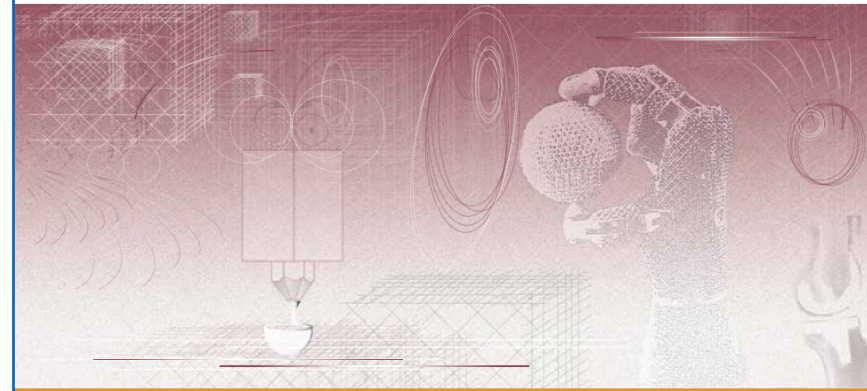
HIGHLIGHTS OF A FORUM

Convened by the Comptroller General
of the United States

January 2014
GAO-14-181SP

CG Forum on 3D Printing (GAO-15-505SP)

- Issues discussed:
 - Opportunities for additive manufacturing to directly produce parts and products
 - Key challenges to using additive manufacturing to produce functional parts
 - Key policy implications for additive manufacturing for direct part production



3D Printing

Opportunities, Challenges, and Policy
Implications of Additive Manufacturing

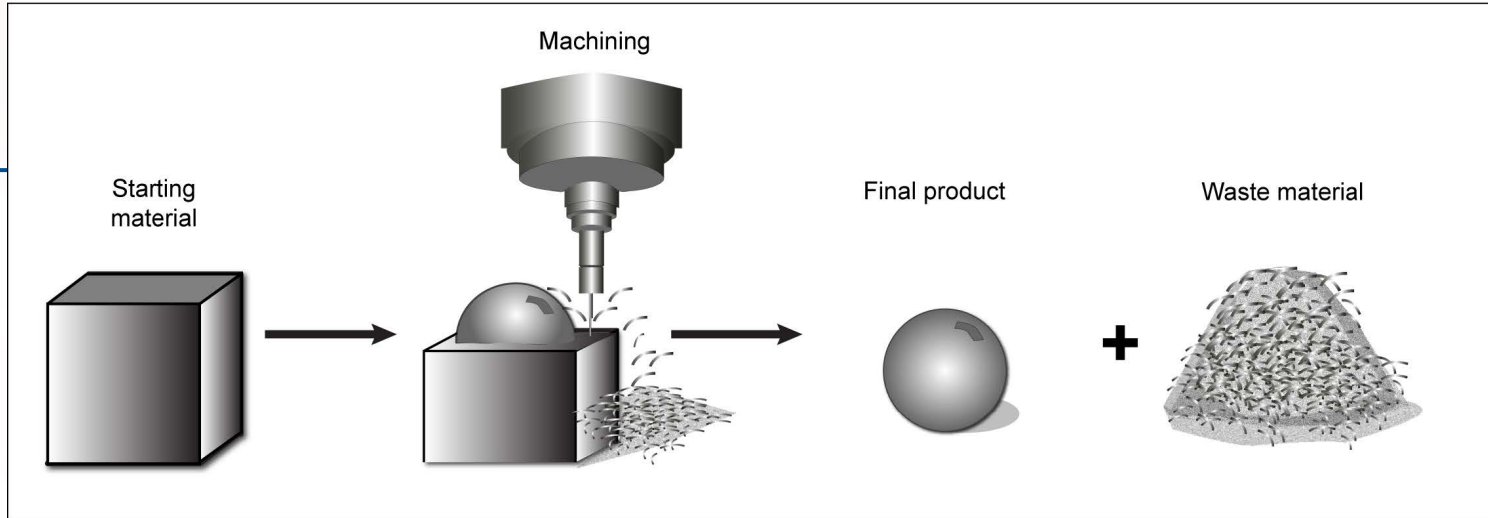
HIGHLIGHTS OF A FORUM

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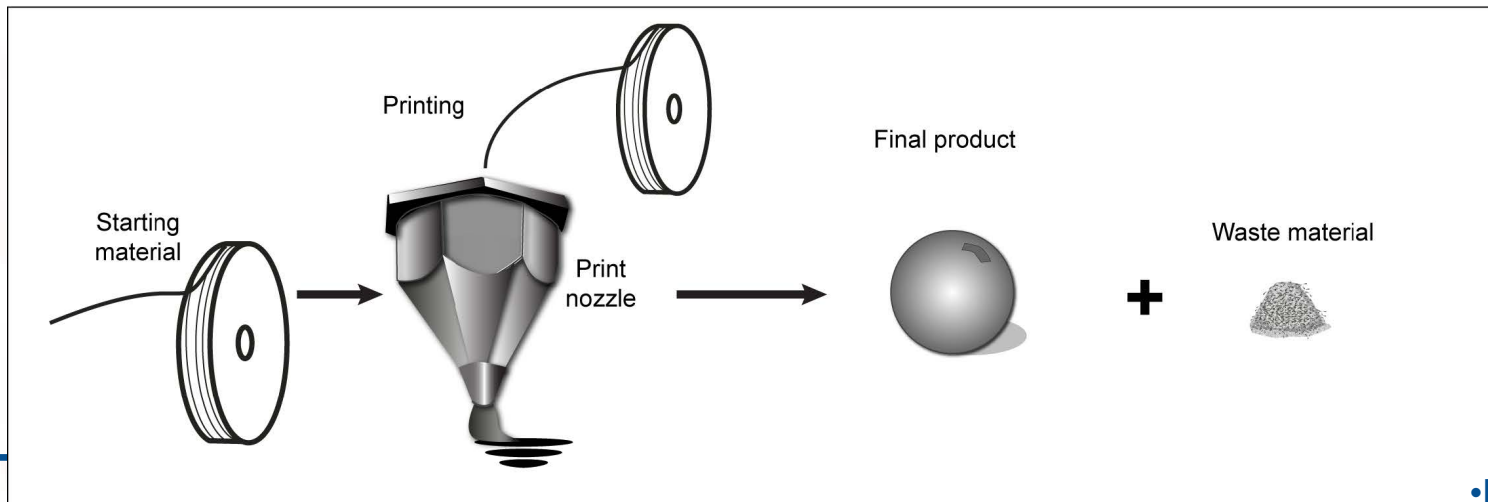
June 2015
GAO-15-505SP

Subtractive vs. Additive Manufacturing

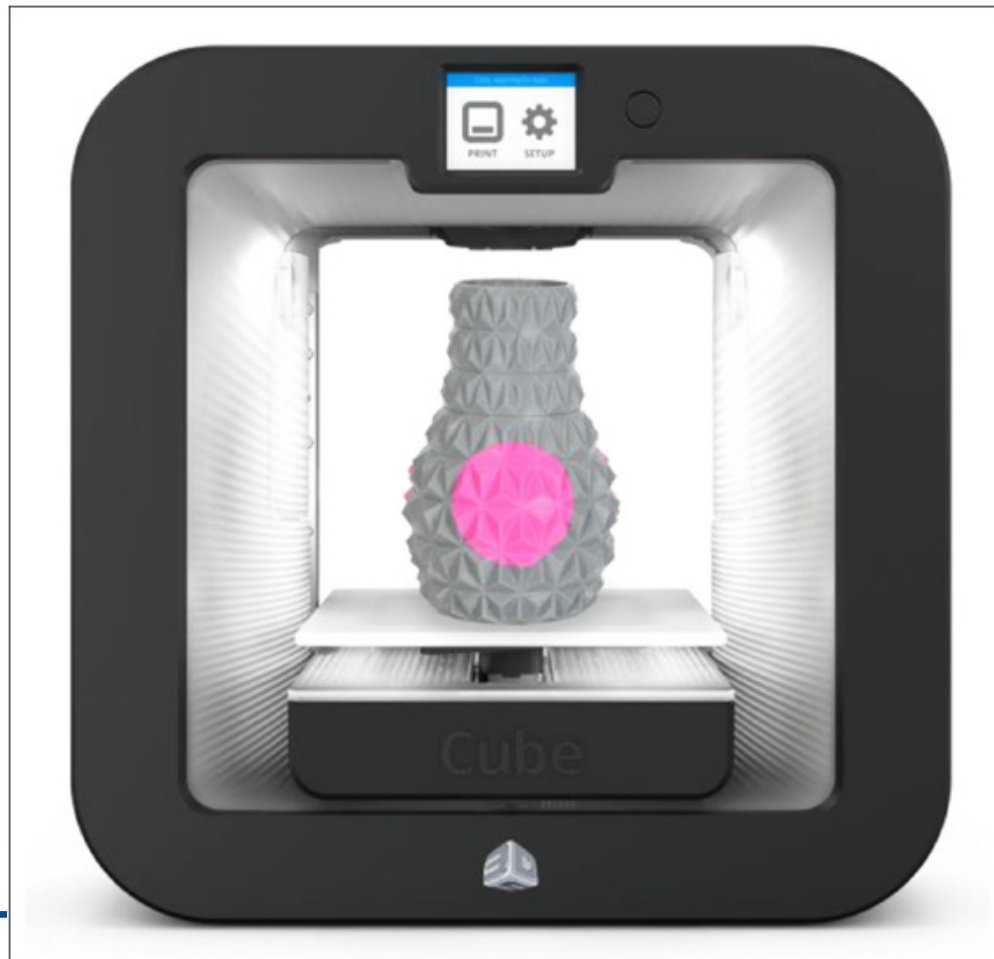
Subtractive manufacturing



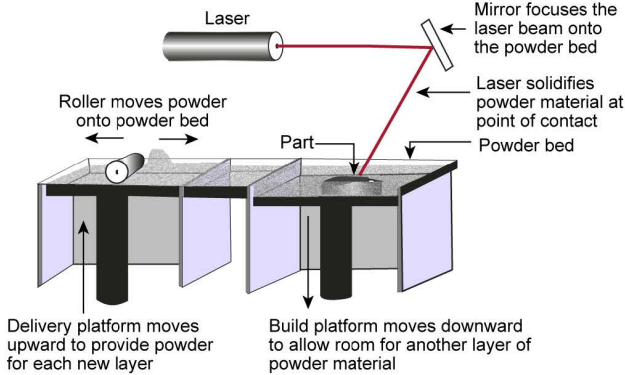
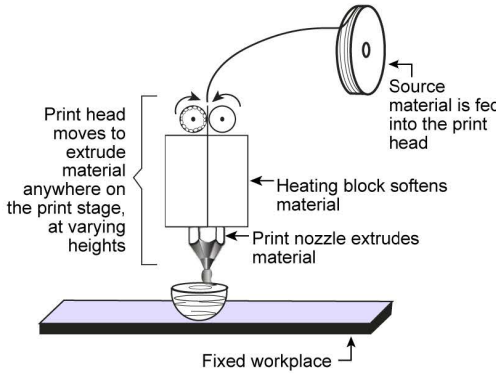




Additive manufacturing



Desktop Systems



	Powder bed fusion	Material extrusion
Machine	 <p>Internal build volume: 9.85 x 9.85 x 12.8" (250 x 250 x 325 mm)</p>	 <p>Internal build volume: 16 x 14 x 16" (460 x 355 x 406 mm)</p>
Process	 <p>Labels in diagram: Laser Mirror focuses the laser beam onto the powder bed Laser solidifies powder material at point of contact Powder bed Part Roller moves powder onto powder bed Delivery platform moves upward to provide powder for each new layer Build platform moves downward to allow room for another layer of powder material</p>	 <p>Labels in diagram: Source material is fed into the print head Heating block softens material Print nozzle extrudes material Print head moves to extrude material anywhere on the print stage, at varying heights Fixed workplace</p>
Example product	 <p>Aerospace seat belt buckles</p>	 <p>Taillight prototype</p>

Realized Benefits of 3D Printing

- Reduced use of material
- Reduced time to design and produce functional parts
- Ability to produce complex parts that cannot be made with conventional manufacturing processes (i.e., with fewer sub-parts)
- Use of alternative materials with better performance characteristics
- Ability to create highly customized, low-volume parts

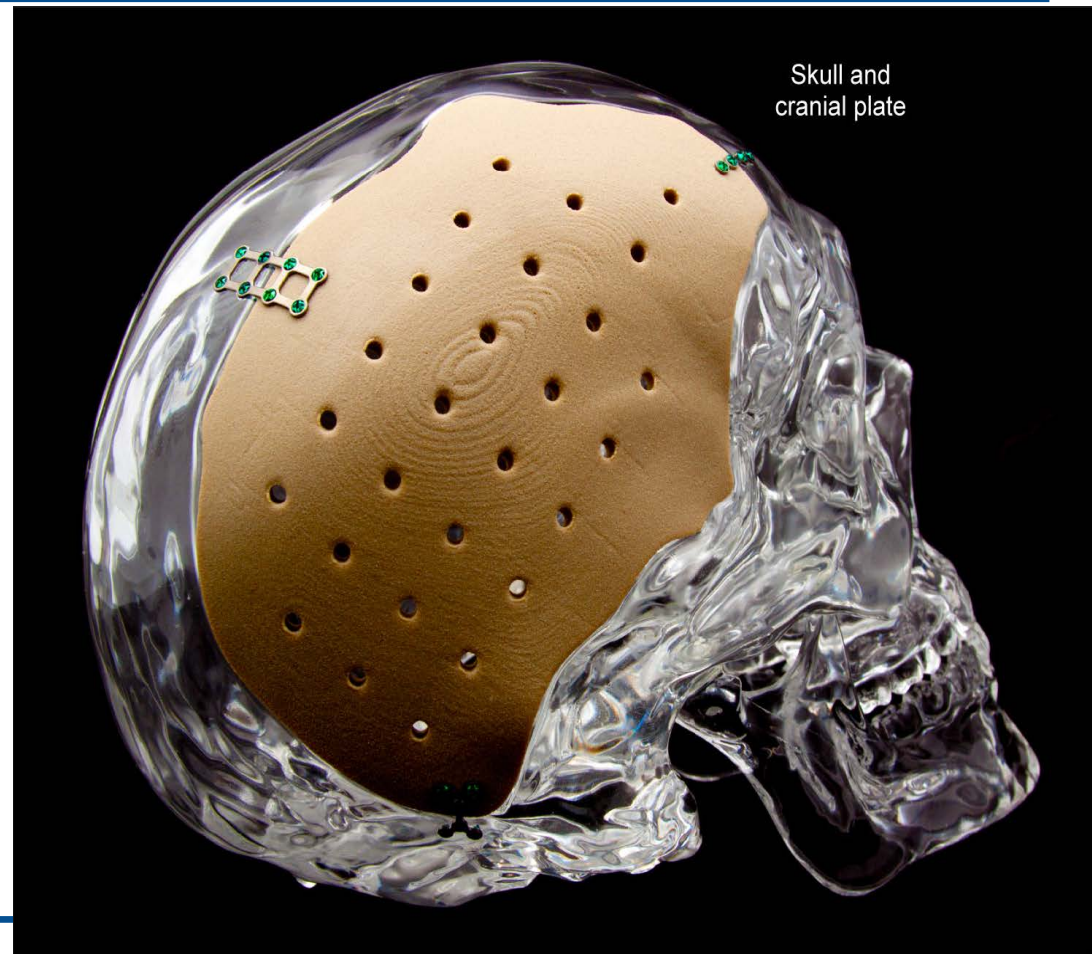
Promised Benefits of 3D Printing

- Reduced overall timeframes
- Support to enhanced tooling for conventional manufacturing lines
- Enhancements to STEAM education due to key emphasis on design
- Simplification of supply chain logistics
- Alternative materials with higher performance

Custom Patient-specific Cranial Implant

Prosthetics are:

- Customizable
- Functionally meet unique needs of patients
- Reduced surgical times
- Better outcomes with fewer side effects
- Deliverable in 1-5 days



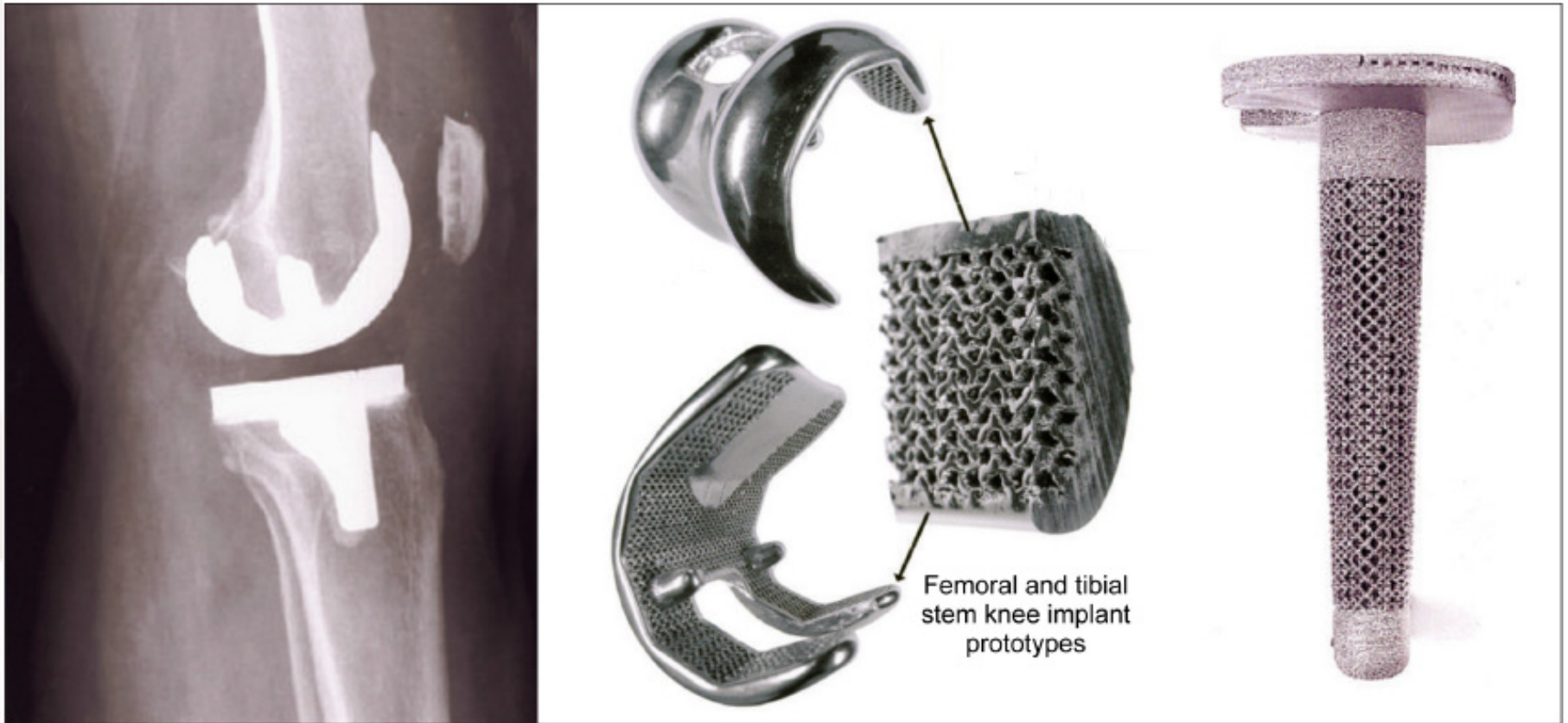
Custom Satellite Propellant Tank



GE LEAP Jet Engine Fuel Nozzle



Complex Custom Knee Implant



Source: Dr. L. E. Murr, University of Texas at El Paso. | GAO-15-505SP

DOD Expeditionary Labs



Key Challenges of Additive Manufacturing

- Ensuring product quality
- Immature and sparse materials science knowledge base
- Lack of standards
- Improved testing capabilities
- Limited design tools and workforce skills
- Need for early adopters (public and private sector) to increase demand for direct part production

Quality Control is a Key Issue

Materials



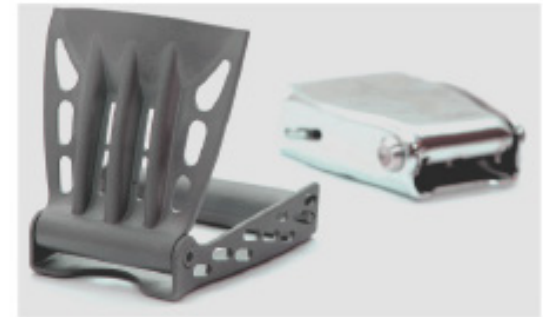
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**Machines and
manufacturing practices**



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Final parts



Key Considerations for Policymakers

- **Standards setting** to address quality control and reduced market risk
- **Workforce and training** to fully leverage the possibilities of additive manufacturing
- **Market support and readiness** to grow the infrastructure and support increased use and scaling.
- **Monitor the development of four aspects** that could be affected by future growth in additive manufacturing:
 1. national security,
 2. product liability,
 3. intellectual property, and
 4. environmental, health, and safety
- **National technology strategy is needed**

Current, Projected, and Potential S&T Projects

Current

- TA on freshwater conservation technologies for energy
- TA on freshwater conservation technologies for municipal systems
- TA on small modular and advanced nuclear reactor designs
- TA on multiplex assay biodetection/medical diagnostic systems
- Strategic forum on data analytics in the 21st Century (IoT and privacy/civil liberties)
- Technical performance audit on autonomous biodetection systems for homeland security applications
- Technical performance audit on Swine Enteric Coronavirus Diseases (SECD)
- Technical performance audit of high containment laboratory inactivation protocols
- Best practices guide on technology readiness assessment (TRA)

Projected

- TA on the Internet of Things
- TA on sustainable chemistry technology and commercialization
- TA on freshwater conservation technologies for agriculture
- TA on synthetic biology and the emerging bioeconomy
- Technical performance audit on high level nuclear waste immobilization and storage technologies

Potential TAs (among others)

- Private or commercial use of UAS and privacy/civil liberties implications; Regenerative Medicine; Virtual/crypto-currencies; High-frequency trading technologies
-



GAO Technology Assessment Reports

TECHNOLOGY ASSESSMENT: Using Biometrics for Border Security, [GAO-03-174](#), November 14, 2002

TECHNOLOGY ASSESSMENT: Cybersecurity for Critical Infrastructure Protection, [GAO-04-321](#), May 28, 2004

TECHNOLOGY ASSESSMENT: Protecting Structures and Improving Communications during Wildland Fires, [GAO-05-380](#), April 26, 2005

TECHNOLOGY ASSESSMENT: Securing the Transport of Cargo Containers, GAO-06-68SU, January 14, 2006 [Classification: For Official Use Only]

TECHNOLOGY ASSESSMENT: Explosives Detection Technology to Protect Passenger Rail, [GAO-10-898](#), July 28, 2010

TECHNOLOGY ASSESSMENT: Climate Engineering—Technical Status, Current Perspectives, and Future Prospects, [GAO-11-71](#), July 28, 2011

TECHNOLOGY ASSESSMENT: Neutron Detectors—Alternatives to Using Helium-3, [GAO-11-753](#), September 29, 2011

NANOMANUFACTURING: Emergence and Implications for U.S. Competitiveness, the Environment, and Human Health, [GAO-14-181SP](#), January 31, 2014

Other Key GAO S&T Reports

- **Anthrax: Agency Approaches to Validation and Statistical Analyses Could Be Improved**, [GAO-15-80](#): Dec 19, 2014.
- **Managing Critical Isotopes: Stewardship of Lithium-7 Is Needed to Ensure a Stable Supply**, [GAO-13-716](#): Oct 17, 2013.
- **Combating Nuclear Smuggling: Lessons Learned from Cancelled Radiation Portal Monitor Program Could Help Future Acquisitions**. [GAO-13-256](#): Jun 11, 2013.
- **Information Technology: Consistently Applying Best Practices Could Help IRS Improve the Reliability of Reported Cost and Schedule Information**, [GAO-13-401](#): Apr 17, 2013.
- **Anthrax: DHS Faces Challenges in Validating Methods for Sample Collection and Analysis**, [GAO-12-488](#): Sep 11, 2012.
- **DOD Supply Chain: Suspect Counterfeit Electronic Parts Can Be Found on Internet Purchasing Platforms**, [GAO-12-375](#): Mar 26, 2012.
- **Nuclear Weapons: Actions Needed to Address Scientific and Technical Challenges and Management Weaknesses at the National Ignition Facility**, [GAO-10-488](#): Apr 8, 2010.



Thank you

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