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Report to Congressional Addressees

January 2021

ENVIRONMENTAL LIABILITIES

NASA's Reported Financial Liabilities Have Grown, and Several Factors Contribute to Future Uncertainties

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GAO-21-205

GAO Highlights

Highlights of GAO-21-205, a report to congressional addressees

January 2021

ENVIRONMENTAL LIABILITIES

NASA's Reported Financial Liabilities Have Grown, and Several Factors Contribute to Future Uncertainties

Why GAO Did This Study

Decades of NASA's research for space exploration relied on some chemicals that can be hazardous to human health and the environment. NASA identified 14 centers around the country with hazardous chemicals that require environmental cleanup and restoration. NASA's Environmental Compliance and Restoration Program oversees the agency's environmental cleanup. NASA's environmental liabilities estimate is reported annually in the agency's financial statement. Federal accounting standards require agencies responsible for contamination to estimate and report their future cleanup costs when they are both probable and reasonably estimable.

This report describes (1) NASA's environmental liabilities for restoration projects from fiscal years 2014 to 2019—the most recent data available at the time of our review—and (2) factors that could contribute to uncertainties in NASA's current or future environmental liabilities. GAO reviewed NASA financial statements, guidance, and other relevant reports and interviewed NASA officials from headquarters and three centers, selected because of changes in their reported liabilities.

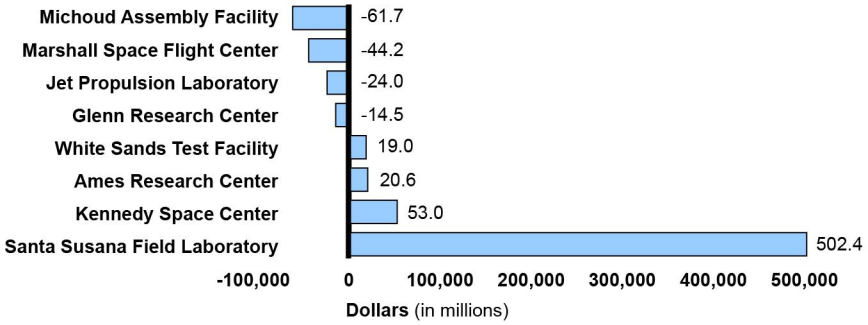
NASA provided technical comments on a draft of this report, which were incorporated as appropriate.

View GAO-21-205. For more information, contact Allison Bawden at (202) 512-3841 or bawdena@gao.gov.

What GAO Found

The National Aeronautics and Space Administration (NASA) estimated cleanup and restoration across the agency would cost $1.9 billion as of fiscal year 2020, up from $1.7 billion in fiscal year 2019. This reflects an increase of $724 million, or 61 percent, from 2014. NASA identified contamination at 14 centers around the country, as of 2019. Five of the 14 centers decreased their environmental liabilities from 2014 to 2019, but liability growth at the other centers offset those decreases and contributed to the net increase in environmental liabilities. Santa Susana Field Laboratory, California, had about $502 million in environmental liabilities growth during this period (see fig.). Nearly all this growth resulted from California soil cleanup requirements that NASA did not anticipate.

These NASA Centers Reported Increases or Decreases in Restoration Project Environmental Liabilities Greater Than $10 Million Between Fiscal Years 2014 and 2019



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-21-205

Data table for These NASA Centers Reported Increases or Decreases in Restoration Project Environmental Liabilities Greater Than $10 Million Between Fiscal Years 2014 and 2019

	Amount (millions)
Michoud Assembly Facility	-$61.7
Marshall Space Flight Center	-$44.2
Jet Propulsion Laboratory	-$24.0
Glenn Research Center	-$14.5
White Sands Test Facility	$19.0
Ames Research Center	$20.6
Kennedy Space Center	$53.0
Santa Susana Field Laboratory	$502.4

NASA's reported fiscal year 2019 environmental liabilities estimate for restoration projects does not include certain costs, and some factors may affect NASA's future environmental liabilities, potentially increasing or decreasing the federal government's fiscal exposure. Certain costs are not included in the fiscal year 2019 estimate because some projects are in a developing stage where NASA needs to gather more information to fully estimate cleanup costs. Further, NASA limits its restoration project estimates to 30 years, as the agency views anything

beyond 30 years as not reasonably estimable. Sixty of NASA's 115 open restoration projects in fiscal year 2019 are expected to last longer than 30 years. With regard to factors that could affect future environmental liabilities, NASA is assessing its centers for contamination of some chemicals it had not previously identified but does not yet know the impact associated cleanup will have on the agency's liabilities in part because standards for cleaning up these chemicals do not yet exist. New cleanup requirements for emerging contaminants could increase NASA's environmental liabilities and create additional fiscal exposure for the federal government. Additionally, NASA is committed, through an agreement with the state of California, to clean soil at Santa Susana Field Laboratory to a certain standard, but the agency issued a decision in September 2020 to pursue a risk-based cleanup standard, which the state of California has opposed. According to NASA, a risk-based cleanup standard at Santa Susana Field Laboratory could decrease NASA's environmental liabilities and reduce the federal government's fiscal exposure by about $355 million.

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Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended
COVID-19	Coronavirus Disease 2019
DTSC	State of California's Department of Toxic Substances Control
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency

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NASA	National Aeronautics and Space Administration
NETS	NASA's Environmental Tracking System
PCB	Polychlorinated biphenyl
PFAS	Per- and polyfluoroalkyl substances
PFOA	Perfluoroctanoic acid
PFOS	Perfluoroctane sulfonate
RCRA	Resource Conservation and Recovery Act of 1976
SEIS	Supplemental Environmental Impact Statement
TCE	Trichloroethylene
VOC	Volatile Organic Compound

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
A Century of Non-Partisan Fact-Based Work

441 G St. N.W.
Washington, DC 20548

January 15, 2021

The Honorable Eddie Bernice Johnson
Chairwoman
The Honorable Frank D. Lucas
Ranking Member
Committee on Science, Space, and Technology
House of Representatives

The Honorable Brian Babin
Space and Aeronautics Subcommittee
Committee on Science, Space, and Technology
House of Representatives

The National Aeronautics and Space Administration (NASA) spent decades testing rockets, conducting research, and performing other activities across the United States in support of its exploration mission in space, including landing the first human on the moon in July 1969. These efforts involved the use of chemicals, some of which were released to the environment. Some of these chemicals are known to damage the environment and harm human health, including the potential for internal organ damage, cancers, and childhood development issues. In addition, NASA's use of these chemicals created a fiscal exposure for the federal government.[1] NASA is required to follow certain laws, agreements, federal guidelines, and court decisions that establish standards, procedures, or requirements for NASA's cleanup mission.

Federal accounting standards require agencies responsible for cleaning up contamination to estimate future cleanup and waste disposal costs and to report such costs as environmental liabilities in their annual financial statements.[2] NASA reports its environmental liabilities as costs related to (1) restoration projects; (2) property, plant, and equipment disposal; and (3) asbestos cleanup. In fiscal year 2020, NASA reported

[1]Fiscal exposure refers to responsibilities, programs, and activities that may explicitly or implicitly expose the federal government to future spending. Federal agencies clean up contamination or waste at federal sites pursuant to various laws, such as the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended (CERCLA), and the Resource Conservation and Recovery Act (RCRA) of 1976.

[2]Federal Accounting Standards Advisory Board, *FASAB Handbook of Federal Accounting Standards and Other Pronouncements, as Amended* (Washington, D.C.: June 30, 2017).

more than $1.9 billion in environmental liabilities for restoration projects, which made up nearly 90 percent of NASA's total reported environmental liabilities. This reflects an increase of approximately $180 million from fiscal year 2019, which is the most current year included in our review. As of fiscal year 2019, NASA identified contamination at 14 of its sites—which we refer to as centers—and reported $1.7 billion in environmental liabilities for associated restoration projects.[3]

The federal government's environmental liabilities have been growing for the past 20 years, and this growth is likely to continue even as the federal government spends billions each year on cleanup efforts. In 2017, GAO identified the federal government's environmental liabilities as a high-risk issue, in part because environmental liabilities represent the fourth-largest liability on the federal government's financial statements and because of continued growth in environmental liabilities.[4] In fiscal year 2017, the federal government's estimated environmental liabilities were $465 billion and had increased to $595 billion by fiscal year 2019. The Department of Energy accounted for the largest share of the federal government's fiscal year 2019 environmental liabilities, with $505 billion, or 85 percent. The Department of Defense accounted for the second-largest share at $76 billion, or about 13 percent. NASA's liabilities were the fourth largest in the federal government in 2019. We performed our work under the authority of the Comptroller General to conduct evaluations in light of congressional interest in the federal government's environmental liabilities.

This report describes (1) NASA's environmental liabilities for restoration projects, including changes in recent years; and (2) factors that could contribute to uncertainties in NASA's current or future environmental liabilities for restoration projects.

To determine NASA's environmental liabilities for restoration projects and factors that could contribute to uncertainties in NASA's current or future

[3]See app. I for a list of the 14 centers that NASA reported as having environmental liabilities.

[4]GAO, *High Risk Series: Progress on Many High-Risk Areas, While Substantial Efforts Needed on Others,* GAO-17-317 (Washington, D.C.: Feb. 15, 2017). GAO's High Risk Series identifies federal programs and operations that are high risk due to their vulnerabilities to fraud, waste, abuse, and mismanagement or that need transformation.

environmental liabilities for restoration projects,[5] we reviewed relevant NASA documents and interviewed officials from NASA, including from three NASA centers: Jet Propulsion Laboratory in California, Kennedy Space Center in Florida, and Santa Susana Field Laboratory in California. When selecting these centers, we considered increases and decreases in environmental liabilities between fiscal years 2014 and 2019—the most recent years of environmental liabilities reported at the time of our review—the number of open restoration projects at the centers, and the potential that additional restoration projects could be required in the future and result in increased environmental liabilities. We also reviewed NASA's criteria for estimating environmental liabilities. We focused our review on restoration projects because these projects accounted for about 90 percent of NASA's environmental liabilities in fiscal year 2019. We use the term "environmental liabilities" to refer to environmental liabilities for restoration projects. NASA officials estimate and manage environmental liabilities through NASA's Environmental Tracking System (NETS), which we assessed for reliability and found NETS to be sufficiently reliable for our purpose of determining NASA's estimated environmental liabilities, and we note the uncertainties associated with those estimates. In addition, NASA has one project with environmental liabilities attributed to its headquarters location for personnel who manage restoration projects at NASA's centers. Since this project is not an active cleanup project, we did not include NASA headquarters as a center where restoration projects are taking place. However, we do include NASA headquarters' environmental liabilities when discussing the agency's overall environmental liabilities, as NASA includes these liabilities in its required annual financial statement reporting. For a fuller discussion of our methodology, see appendix I.

We conducted this performance audit from April 2020 to January 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that

[5]NASA defines restoration projects as those addressing activities required under federal, state, or local laws, or other legally enforceable agreements at NASA-owned or NASA-operated property. Restoration projects include investigation activities such as sampling, analysis, monitoring, and modeling related to contamination from NASA operations. Additionally, restoration projects may include containment, cleanup, environmental closures (including tanks, landfills, and other environmentally regulated facilities or units), attenuation, land-use controls, oversight, land parcel purchase, long-term operations and maintenance, provision of alternate drinking or potable water supplies, and evaluation of remedial alternatives.

the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Since its formation in 1958, NASA has been researching and developing human and robotic spaceflight to explore space. Some of these efforts have resulted in environmental liabilities that NASA is required to report, consistent with the accounting standards for reporting federal environmental liabilities. Specific legal requirements govern environmental cleanup, and NASA has established a program to manage the remediation projects it carries out to ensure their compliance with these legal requirements.

Federal Environmental Liabilities and Accounting Standards

Federal accounting standards require agencies to report environmental liabilities in their annual financial statements.[6] According to federal accounting standards, costs for cleanup work must be included in environmental liabilities estimates when they are both probable and reasonably estimable.[7] In determining whether an agency's environmental cleanup responsibilities meet the probable criterion, the agency must establish its legal liability or financial responsibility for the project and determine that it is more likely than not that it will have to conduct the cleanup. For projects that do not meet the level of probable—that is, where there is a less than 50 percent chance that a financial liability will be incurred, referred to by NASA as "reasonably possible"—federal accounting standards do not require reporting of associated costs in the agency's environmental liabilities estimate. However, NASA guidance requires that the agency disclose these costs in the notes of its financial statement. Once the federal accounting standards' probable criterion is met, agencies are to determine whether cleanup costs are reasonably estimable. In determining whether costs are reasonably estimable,

[6]Federal accounting standards define "liability" as a probable future outflow or other sacrifice of resources as a result of past transactions or events.

[7]"Probable" relates to whether a future outflow of resources will be required—specifically, that it is "more likely than not" that the agency will incur a financial liability. "Reasonably estimable" relates to the ability to reliably quantify in monetary terms the outflow of resources that will be required.

agencies are to consider a completed study—such as a remedial investigation/feasibility study—or prior experience with a similar site or similar site conditions. Assuming a study has been completed, or the agency or other entity has experience with a similar site or similar site conditions, then the agency is to make its best effort to estimate liability for financial statement purposes, provided technology exists to remediate the site. When reasonable estimates cannot be generated, such as cleanup costs at sites where no feasible remedy exists, then environmental liabilities estimates do not include cost estimates for that work.[8] Environmental liabilities estimates and related supporting documentation are evaluated as part of NASA's annual financial statements audit. NASA received an unmodified (clean) opinion from its independent auditor on its fiscal year 2019 financial statements.

Legal Requirements Governing Environmental Cleanup

Cleanup projects at NASA centers are governed by a number of federal laws—some of which establish standards for state programs—that define the roles of federal agencies and states in addressing hazardous waste, as well as cleanup agreements among NASA and the relevant states that implement these laws.[9] NASA has cleanup agreements with state regulators for some centers. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and the Resource Conservation and Recovery Act (RCRA) are the two key federal laws that govern NASA's cleanup at its centers.[10]

[8]Where NASA is legally responsible for environmental cleanup, but no existing technology is known to be available for cleaning up a particular site, the known costs for which NASA is responsible, such as a remedial investigation, feasibility studies, and costs to contain the contamination, are recorded as a liability.

[9]When NASA was created in 1958, property from other government agencies, including some with existing environmental issues, was transferred to the new agency.

[10]In the late 1970s, toxic waste sites, such as Love Canal, received national attention when the public learned about the risks to human health and the environment. In response, Congress enacted CERCLA on December 11, 1980, which required federal agencies responsible for contamination to clean it up. Other laws also govern cleanup and establish the basis for contaminant cleanup levels. For example, under the Toxic Substances Control Act, the Environmental Protection Agency (EPA) is responsible for assessing and managing risks to human health and the environment of existing chemicals. The Safe Drinking Water Act authorizes EPA to regulate contaminants in public drinking water systems.

CERCLA. CERCLA, which became law in 1980 and is commonly known as Superfund, authorizes the federal government to respond to releases or threatened releases of hazardous substances. Under CERCLA's National Contingency Plan—which establishes procedures needed to respond to releases and threatened releases of hazardous substances—federal agencies, including NASA, must consider certain criteria when selecting cleanup approaches at its sites. CERCLA cleanup remedies must meet two "threshold criteria" to be considered for selection. Specifically, (1) they must provide overall protection of human health and the environment; and (2) they must comply with "applicable or relevant and appropriate requirements," which may include federal or state standards for cleanup.[11] Five of the 14 NASA centers are on the CERCLA National Priorities List, which designates sites with significant contamination or that pose a threat of releasing hazardous substances, pollutants, or contaminants.[12]

RCRA. RCRA, as amended, regulates the management of facilities that treat, store, or dispose of hazardous wastes and requires a permit for such facilities. Permits must require corrective action for all releases of hazardous waste from such facilities and contain relevant compliance schedules. Under RCRA, the Environmental Protection Agency (EPA) may authorize a state to implement its own hazardous waste management program in lieu of the respective federal program, so long as the state program is at least as stringent. State programs may be more stringent than the federal program. The Federal Facilities Compliance Act of 1992 specifically makes federal agencies like NASA subject to state

[11]Five other selection criteria, used to analyze and compare alternative remedies that have met the threshold criteria, are called "primary balancing criteria." These five criteria include (1) long-term effectiveness and permanence; (2) reduction of toxicity, mobility, or volume through treatment; (3) short-term effectiveness; (4) implementability; and (5) cost. State and community acceptance of the remedy are modifying criteria that must also be considered in remedy selection.

[12]CERCLA provides a site assessment process that includes site inspections and a system to rank hazards to determine whether a site should be placed on the national priorities list. The five NASA centers on the National Priorities List are (1) Ames Research Center (as part of the former Naval Air Station Moffett Field), (2) Armstrong Flight Research Center (as part of Edwards Air Force Base), (3) Jet Propulsion Laboratory, (4) Langley Research Center (co-listed with Langley Air Force Base, now called Joint Base Langley-Eustis), and (5) Marshall Space Flight Center (co-listed with Redstone Arsenal).

regulation under RCRA.[13] Under RCRA's corrective action provisions, NASA must clean up hazardous waste contamination at its RCRA-permitted sites by implementing remedial measures that protect human health and the environment. Five of the 14 NASA centers are conducting cleanup under RCRA.[14]

Agreements. In addition to federal laws, some NASA centers have agreements with state regulators that implement state cleanup requirements and governs various environmental restoration projects. These agreements generally identify applicable cleanup standards and establish schedules for cleanup implementation. Five of the 14 NASA centers have agreements with states to conduct cleanup.[15]

Environmental Restoration at NASA

Environmental Compliance and Restoration Program

NASA began identifying and characterizing contamination across the agency in the 1980s. NASA's Environmental Compliance and Restoration program is responsible for cleaning up hazardous materials and wastes released to the surface or groundwater at NASA centers and other sites where the agency is legally obligated to address hazardous pollutants. NASA headquarters' Environmental Management Division manages the Environmental Compliance and Restoration program and provides guidance on how to comply with federal, state, and local environmental

[13]Under this authority, states may issue formal administrative actions, such as a compliance order or corrective action order requiring specified actions and milestones and providing for penalties for noncompliance.

[14]The five centers conducting cleanup under RCRA include (1) Kennedy Space Center, (2) Michoud Assembly Facility, (3) Santa Susana Field Laboratory, (4) Wallops Flight Facility, and (5) White Sands Test Facility. Cleanup conducted under RCRA at the Santa Susana Field Laboratory is for groundwater.

[15]According to agency documentation, Glenn Research Center has a consent order with the state of Ohio to conduct its cleanup. Goddard Space Flight Center in Maryland and Johnson Space Center in Texas conduct cleanup under state voluntary cleanup programs. Stennis Space Center conducts its cleanup under Mississippi's state superfund program. In addition to conducting cleanup under RCRA, Santa Susana Field Laboratory is under an administrative order on consent with the state of California for soil cleanup.

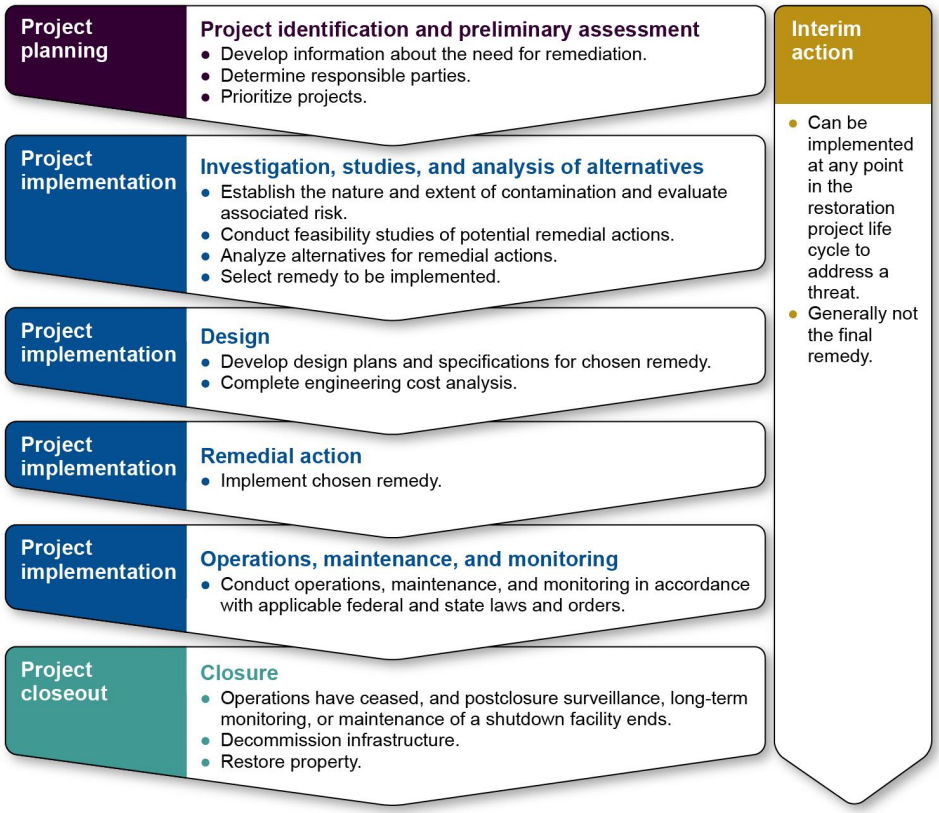
laws and regulations. The Environmental Management Division also distributes funding to the centers. The Environmental Compliance and Restoration program is also the main program providing direction, oversight, analysis, and management for restoration projects across the agency. NASA centers develop environmental liabilities estimates for their projects and plan for each project's funding needs.

Restoration Projects

NASA centers work with regulators to plan cleanup activities and execute restoration projects in accordance with approved project plans.[16] NASA centers use NETS—an automated application and database—created to track their restoration projects and to estimate associated cleanup costs. As of fiscal year 2019, NASA had 115 open restoration projects in NETS, some of which are related to contamination NASA previously identified and is actively remediating and others that are not yet in an active phase of cleanup. NASA will open a restoration project in NETS when it begins gathering information on the potential release of contamination, even if it has not yet established its responsibility for cleanup. Figure 1 illustrates the phases of a NASA restoration project.

[16]A project plan defines the scope of the project, the implementation approach, and the environment within which the project operates. NASA headquarters uses the project plan to determine if the project is fulfilling its agreement.

Figure 1: Phases of a NASA Environmental Restoration Project



Source: GAO analysis of National Aeronautics and Space Administration (NASA) guidance. | GAO-21-205

Text for Figure 1: Phases of a NASA Environmental Restoration Project

Interim Action

- Can be implemented at any point in the restoration project life cycle to address a threat.
- Generally not the final remedy.

Project Planning

Project identification and preliminary assessment

- Develop information about the need for remediation.
- Determine responsible parties.
- Prioritize projects.\

Project Implementation

Investigation, studies, and analysis of alternatives

- Establish the nature and extent of contamination and evaluate associated risk.
- Conduct feasibility studies of potential remedial actions.
- Analyze alternatives for remedial actions.
- Select remedy to be implemented.

Design

- Develop design plans and specifications for chosen remedy.
- Complete engineering cost analysis.

Remedial action

- Implement chosen remedy.

Operations, maintenance, and monitoring

- Conduct operations, maintenance, and monitoring in accordance with applicable federal and state laws and orders.

Project Closeout

Closure

- Operations have ceased, and postclosure surveillance, long-term monitoring, or maintenance of a shutdown facility ends.
- Decommission infrastructure.
- Restore property.

Source: GAO analysis of National Aeronautics and Space Administration (NASA) guidance. | GAO-21-205

Environmental Liabilities Funding

NASA centers input information into NETS each year on desired funding levels to support their environmental restoration projects. NASA's Environmental Management Division prioritizes projects for funding based on risk, according to (1) potential for human exposure from off-site migration, (2) inclusion on the CERCLA National Priorities List, and (3) federal and state regulatory agreement cleanup requirements. NASA

officials at headquarters and two centers we spoke with said that funding generally has been adequate to fund their restoration projects over the past few years. NASA officials said that because the funding for restoration projects comes from a single account, and because NASA has 6 years to obligate funds that have been appropriated and has an additional 5 years to expend its obligations, the agency has flexibility in distributing the funding among centers to address priorities. NASA's appropriations to address environmental liabilities have been generally consistent between fiscal years 2014 and 2019, averaging approximately $68 million per year.[17]

Environmental Liabilities Estimates

Each year, NASA uses a portion of its budgetary resources to fund work to address its environmental liabilities, but the majority of NASA's environmental liability remains unfunded as estimated future costs. Generally starting in February, NASA annually updates its estimates for the portion of environmental liabilities that remains unfunded. Centers use NETS to annually update their unfunded environmental liabilities estimates for each restoration project. According to NASA guidance, a restoration project is estimable if the remedy has been selected based on completion of a study or if the agency has experience with similar projects and technology is available to fully address the contamination. As part of a project estimate, centers are to identify any relevant disclosure items. Disclosures identify situations where cleanup activities and associated costs are uncertain or where NASA's legal liability or financial responsibility for cleanup has not yet been established. Environmental liabilities are reported in NASA's financial statements in November, along with notes regarding uncertainties as captured by NASA's disclosures.

NASA Identified Contaminants at 14 Centers and Reported That Its Environmental Liabilities Increased by 45 Percent Since 2014

As of fiscal year 2019, NASA identified chemical contaminants needing cleanup at 14 centers, and the agency's reported associated

[17]NASA's spending in a given year to address its environmental liabilities may exceed the amount it was appropriated for that year, since funds can be obligated over a 6-year period and are available for 5 years after being obligated.

environmental liabilities were $1.7 billion in fiscal year 2019—an increase of $542 million, about 45 percent, from fiscal year 2014.[18] Most of the increase—$502 million—occurred at one site, NASA's Santa Susana Field Laboratory.

NASA Has Identified Contaminants Requiring Cleanup at 14 Centers

Since the 1980s when it began identifying contaminants that require cleanup, NASA has reported chemical contaminants in water, soil, and physical property at 14 of its centers. Some of these contaminants can cause risk to human health. NASA has been cleaning up its centers for decades, and many of its projects are mature, meaning that NASA officials have selected and implemented remedies and that some projects have been completed or are near completion, according to NASA officials. The officials said that this cleanup has reduced the risk to human health at many centers over the years. However, many projects remain to be completed at these 14 centers.

For example, according to a NASA report documenting the history of contamination at Santa Susana Field Laboratory, decades of rocket engine testing (see fig. 2) at Santa Susana Field Laboratory, about 30 miles northwest of Los Angeles, California, resulted in release of chemicals to the soil and groundwater. Rocket engine testing—which began in 1948 and continued until 2006—required the use of solvents, petroleum-based fuels, and oxidizers, which were used to support the combustion of rocket propellant. Contaminants from these products include volatile organic compounds (VOC), polychlorinated biphenyls (PCB), and other compounds that can be harmful to the human body if enough of the contaminant to cause injury enters the body. With significant exposure, some VOCs can affect the nervous system, while others affect internal organs. The effect of chemicals such as PCBs on human health vary, depending on the significance of exposure. According

[18]Fiscal years 2014 through 2019 were the most recent data available at the time of our review. Values are not adjusted for inflation. Based on the Gross Domestic Product Price Index from the U.S. Department of Commerce, Bureau of Economic Analysis, total inflation from fiscal year 2014 to fiscal year 2019 was about 8.3 percent. These environmental liabilities reflect NASA's estimates but are subject to uncertainties, as described in the next section.

to the Department of Health and Human Services,[19] there is evidence that PCBs can disrupt hormone production in humans, based on experiments in animals. In addition to risk to human health, some of these contaminants can adversely affect wildlife and the environment. For example, according to NASA, wildlife species, including birds, could suffer some minor, but permanent, adverse health effects because of accumulation of chemicals through continued, long-term exposure to soil contamination.[20]

Figure 2: Rocket Engine Testing at NASA's Santa Susana Field Laboratory in 1965

Source: National Aeronautics and Space Administration (NASA). | GAO-21-205

At Jet Propulsion Laboratory in Pasadena, California, workers disposed of various chemicals—such as solvents, solid and liquid rocket propellants,

[19]The Department of Health and Human Services' Agency for Toxic Substances and Disease Registry issues toxicological profiles for hazardous substances. The profiles are peer reviewed and include health information, including levels of exposure significant enough to cause significant health effects.

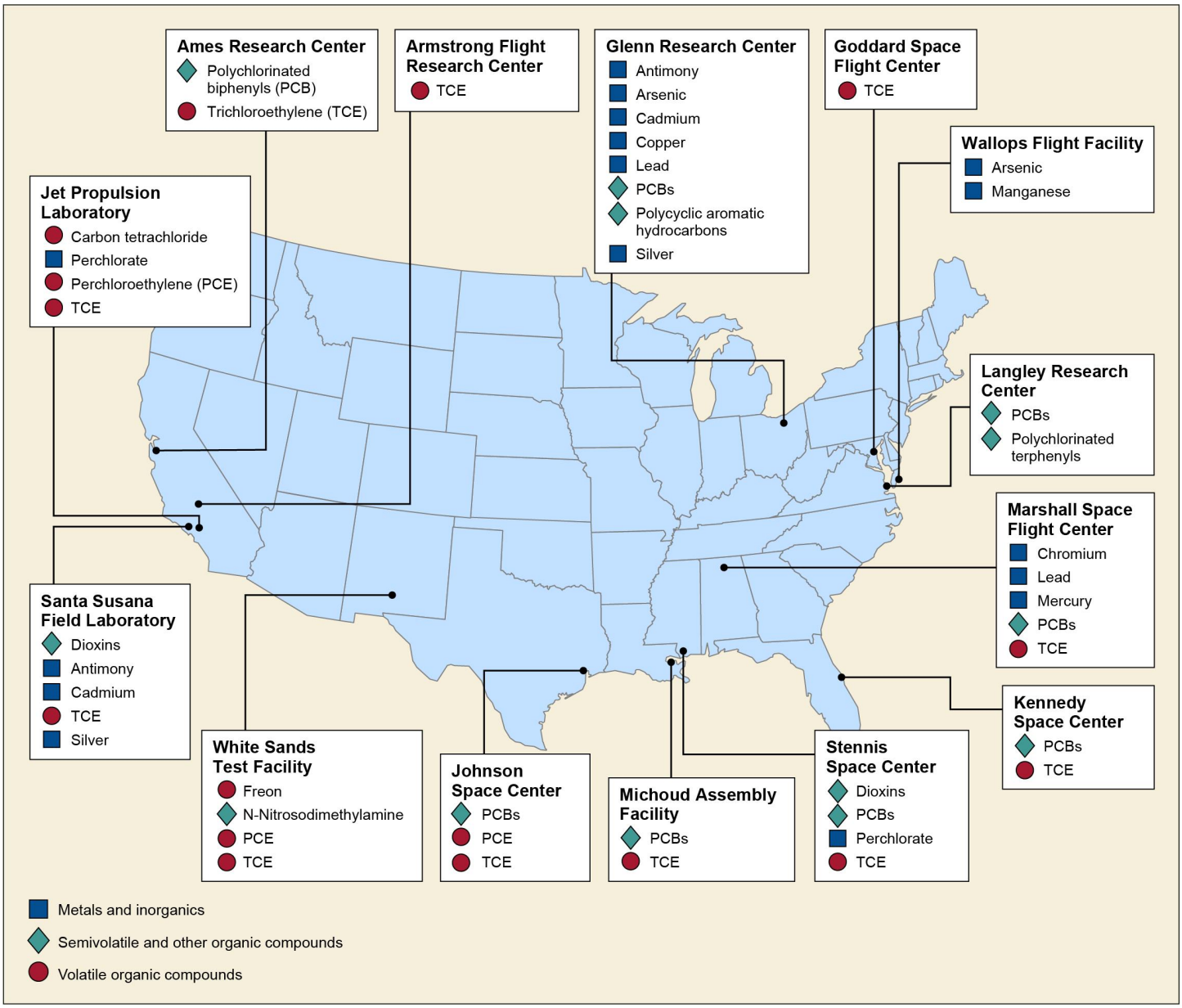
[20]NASA, *Final Supplemental Environmental Impact Statement for Soil Cleanup Activities at Santa Susana Field Laboratory* (Ventura County, CA: July 24, 2020).

cooling tower chemicals, and analytical laboratory chemicals—in unlined pits, a common practice during the 1940s and 1950s, according to NASA documentation.[21] NASA officials said that the practice of using pits to dispose of hazardous waste, such as perchlorate and trichloroethylene (TCE), contaminated nearby groundwater, some of which is used as a drinking water source for nearby communities.

Figure 3 shows the key contaminants that NASA identified at 14 centers that, depending on the extent of exposure, can affect human health or the environment.

[21]NASA, *Record of Decision for the Operable Unit 1 On-Facility Groundwater and the Operable Unit 3 Off-Facility Groundwater* (Pasadena, CA: February 2018).

Figure 3: Key Contaminants NASA Identified at 14 of Its Centers, as of Fiscal Year 2019



Sources: National Aeronautics and Space Administration (NASA); Map Resources (map). | GAO-21-205

Notes: Some contaminants can degrade into other contaminants that also require cleanup. For example, TCE degrades into 1,2-dichloroethene, vinyl chloride, and ethene.

Glenn Research Center consists of two locations in Ohio, and the contamination from metals is only at one location, the Plum Brook Station, and originated largely with discharges at firing ranges and at locations used for burning miscellaneous waste.

Silver Contamination from Photographs

Some sources of contamination can seem unusual. In one case, the destruction of classified photographs led to silver contamination. According to NASA officials, they used photographs for assessing and documenting rocket engine tests at Santa Susana Field Laboratory. NASA burned the photographs that it did not need and discarded the ash in a dumpsite. Photographic paper contains silver, which resulted in silver contamination that required cleanup at the dumpsite.

Source: National Aeronautics and Space Administration (NASA). | GAO-21-205

- **Metals and Inorganics.** NASA identified metals and inorganic chemicals at six of the 14 NASA centers, including metals such as arsenic, lead, and mercury and inorganic chemicals such as perchlorate. Perchlorate is often used in rocket motors, fireworks, gunpowder, and explosives. When heated as a component of rocket fuel, perchlorate begins a chain reaction, producing large amounts of heat and rapidly expanding gases that can cause a rocket to be lifted upward. NASA used perchlorate as a rocket fuel component. The space shuttle solid rocket boosters contained nearly 70 percent ammonium perchlorate. Although recent studies on humans do not show an adverse health effect, studies in animals have shown that exposure to perchlorate can induce a wide range of effects on hormone production in the thyroid gland. The hormones are necessary for the normal function of several internal organ systems, including the cardiovascular system and neuromuscular system.
- **Semivolatile and Other Organic Compounds.** NASA identified semivolatile and other organic compounds at 10 of the 14 NASA centers.[22] Semivolatile organic compounds are typically found in products like cleaning agents, pesticides, flame-retardants, floor coverings, and plasticizers. One of the semivolatile organic compounds that NASA identified is dioxin, which can be formed from burning certain organic material and can also be formed as byproducts from chemical processes used to make certain products, such as herbicides. NASA identified dioxin at Santa Susana Field Laboratory. This might have occurred when fuels were burned or during wildfires, including a major fire at Santa Susana Field Laboratory in 2018. At Stennis Space Center, NASA identified dioxin associated with Agent Orange, a once commonly used herbicide made infamous by its use as a defoliator during the Vietnam War. Several studies have linked dioxin to the risk of several types of cancer in humans.
- **Volatile Organic Compounds.** NASA identified volatile organic compounds at 11 of its 14 centers. Volatile organic compounds are typically found in products like solvents, paints, pharmaceuticals, and refrigerants. One of the volatile organic compounds that NASA identified is TCE. NASA used TCE as a solvent and degreaser. EPA reports that the most common routes of human exposure to TCE are inhalation as a result of vapors from contaminated groundwater that

[22]Semivolatile organic compounds are a subgroup of volatile organic compounds, which together consist of a large group of chemicals used in thousands of common products characterized by their high vapor pressure. Semivolatile organic compounds emit fewer vapors than volatile organic compounds.

have intruded into building air space and from ingestion of contaminated drinking water. NASA has identified TCE in the groundwater at several of its centers. Human and animal studies have linked significant exposures of TCE to adverse effects on the central nervous system and immune system. The Department of Health and Human Services reports that insufficient data exist to determine health effects of TCE at lower exposure levels.

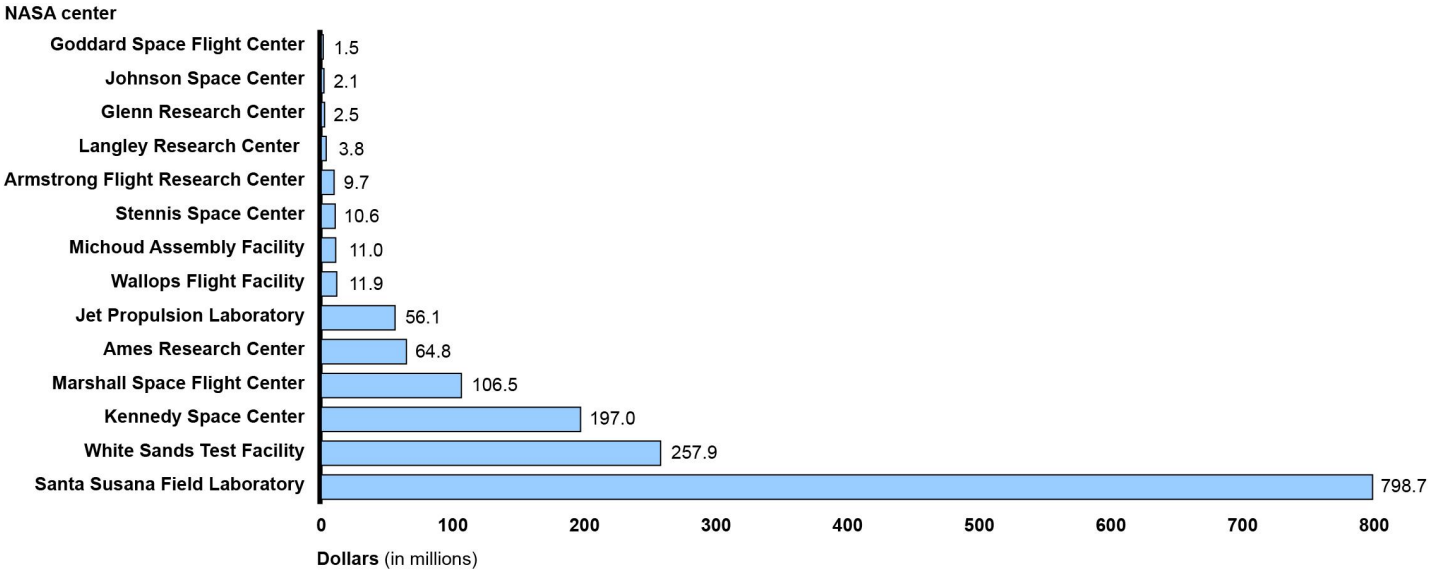
NASA's Reported Environmental Liabilities Have Increased by Over 45 Percent Between Fiscal Years 2014 and 2019 for a Variety of Reasons

NASA reported $1.7 billion in estimated environmental liabilities in its fiscal year 2019 financial statement, an increase of $542 million—or about 45 percent—from fiscal year 2014.[23] NASA officials said they have obligated $124 million toward projects included in their $1.7 billion reported environmental liabilities, leaving $1.6 billion in estimated environmental liabilities that will need to be funded in the future.[24] Of the $1.6 billion in unfunded environmental liabilities, nearly 80 percent is concentrated in three centers: Santa Susana Field Laboratory, White Sands Test Facility in New Mexico, and Kennedy Space Center. Figure 4 shows the unfunded environmental liabilities for each center.

[23]Our analysis was based on fiscal years 2014 through 2019, which were the most recent data available at the time of our review. NASA reported its fiscal year 2020 environmental liabilities for restoration projects as more than $1.9 billion, which reflects an increase of $724 million, or 61 percent, from 2014.

[24]NASA officials said that the $124 million has been obligated. NASA's spending in a given year to address its environmental liabilities may exceed the amount it was appropriated for that year, since funds can be obligated over a 6-year period and are available for 5 years after being obligated. These environmental liabilities reflect NASA's estimates but are subject to uncertainties, as described in the next section.

Figure 4: Unfunded Environmental Liabilities for Restoration Projects at 14 NASA Centers, as of Fiscal Year 2019



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-21-205

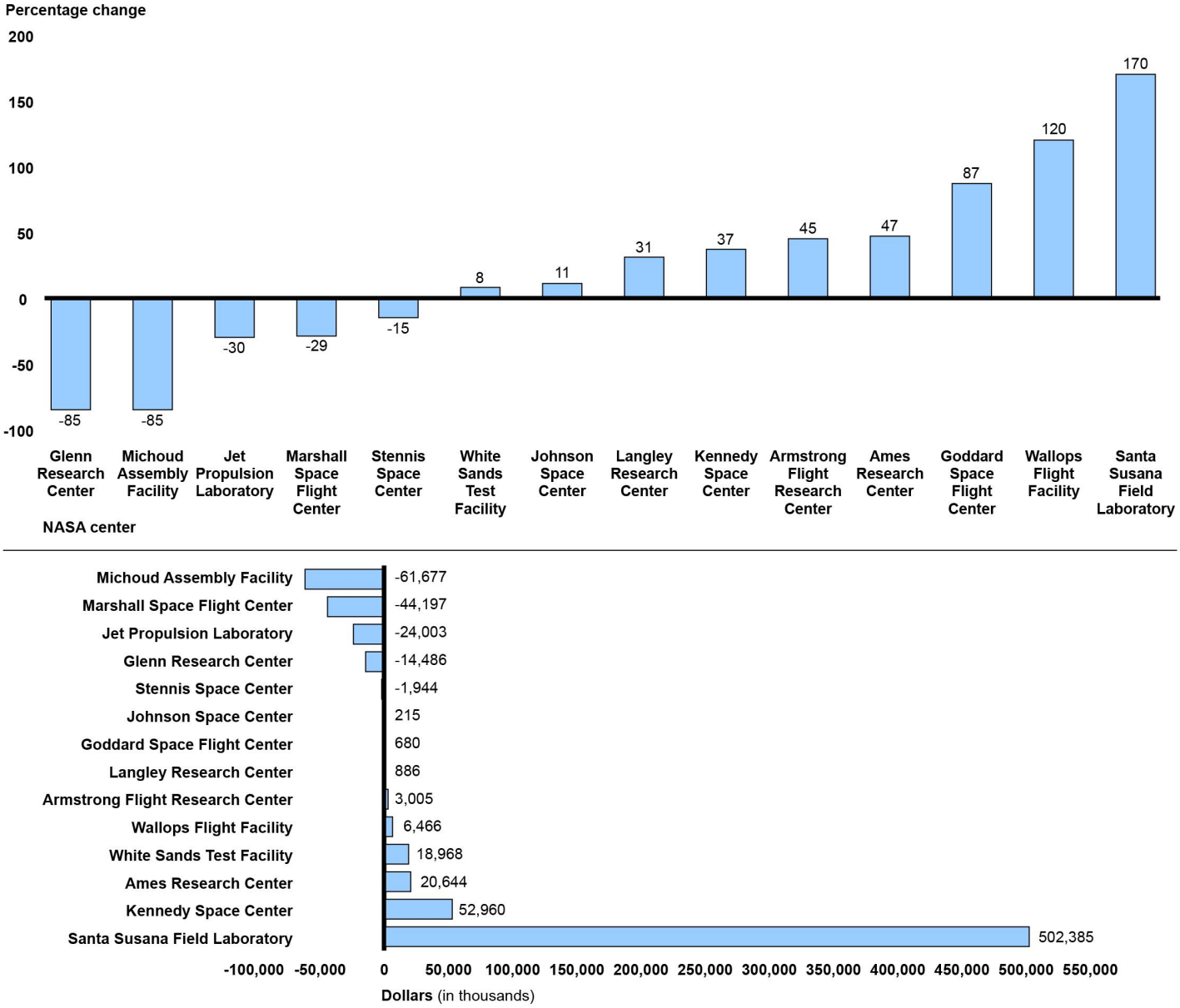
Data table for Figure 4: Unfunded Environmental Liabilities for Restoration Projects at 14 NASA Centers, as of Fiscal Year 2019

	Amount (millions)
Goddard Space Flight Center	1.5
Johnson Space Center	2.1
Glenn Research Center	2.5
Langley Research Center	3.8
Armstrong Flight Research Center	9.7
Stennis Space Center	10.6
Michoud Assembly Facility	11.0
Wallops Flight Facility	11.9
Jet Propulsion Laboratory	56.1
Ames Research Center	64.8
Marshall Space Flight Center	106.5
Kennedy Space Center	197.0
White Sands Test Facility	257.9
Santa Susana Field Laboratory	798.7

Note: An additional $71.5 million in unfunded environmental liabilities in fiscal year 2019 is attributed to NASA headquarters for personnel who manage restoration projects at NASA's centers.

Over 6 years, NASA centers' unfunded environmental liabilities have shown both increases and decreases. From fiscal year 2014 to fiscal year 2019, five of NASA's 14 centers decreased their unfunded environmental liabilities, but unfunded liability growth at the other nine centers offset those decreases and contributed to the net increase in the agency's overall unfunded environmental liabilities. Figure 5 shows the percentage and dollar change in unfunded environmental liabilities at NASA centers from fiscal years 2014 to 2019. NASA officials at headquarters and at the three centers we interviewed said that the growth in NASA's environmental liabilities from fiscal year 2014 to fiscal year 2019 was not due to lack of funding.

Figure 5: Percentage and Dollar Change in Unfunded Environmental Liabilities for Restoration Projects at 14 NASA Centers Between Fiscal Years 2014 and 2019



Source: GAO analysis of National Aeronautics and Space Administration (NASA) data. | GAO-21-205

Data table for Figure 5: Percentage and Dollar Change in Unfunded Environmental Liabilities for Restoration Projects at 14 NASA Centers Between Fiscal Years 2014 and 2019

	Percent change
Glenn Research Center	-85%
Michoud Assembly Facility	-85%
Jet Propulsion Laboratory	-30%
Marshall Space Flight Center	-29%
Stennis Space Center	-15%
White Sands Test Facility	8%
Johnson Space Center	11%
Langley Research Center	31%
Kennedy Space Center	37%
Armstrong Flight Research Center	45%
Ames Research Center	47%
Goddard Space Flight Center	87%
Wallops Flight Facility	120%
Santa Susana Field Laboratory	170%

Change in environmental liabilities between fiscal years 2014 and 2019 (dollars in thousands)

	Amount in thousands
Michoud Assembly Facility	-$61,677
Marshall Space Flight Center	-$44,197
Jet Propulsion Laboratory	-$24,003
Glenn Research Center	-$14,486
Stennis Space Center	-$1,944
Johnson Space Center	$215
Goddard Space Flight Center	$680
Langley Research Center	$886
Armstrong Flight Research Center	$3,005
Wallops Flight Facility	$6,466
White Sands Test Facility	$18,968
Ames Research Center	$20,644
Kennedy Space Center	$52,960
Santa Susana Field Laboratory	$502,385

Note: Fiscal years 2014 through 2019 were the most recent data available at the time of our review. Values are not adjusted for inflation. Based on the Gross Domestic Product Price Index from the U.S.

Department of Commerce, Bureau of Economic Analysis, total inflation over the period was about 8.3 percent.

There are a variety of reasons for changes in the unfunded environmental liabilities at NASA centers. We met with officials from Santa Susana Field Laboratory, Kennedy Space Center, and Jet Propulsion Laboratory to discuss specific reasons for their increases or decreases in environmental liabilities, as follows:

- **Santa Susana Field Laboratory**. Santa Susana Field Laboratory reported the highest growth in unfunded environmental liabilities, which grew by approximately $502 million—about 170 percent—between fiscal years 2014 and 2019. Multiple agencies used the Santa Susana Field Laboratory, which consists of about 2,850 acres. NASA has responsibility for cleaning up approximately 450 acres, while the Department of Energy has responsibility for about 400 acres, and the Boeing Company has responsibility for the remaining 2,000 acres.[25] An Administrative Order on Consent (Administrative Order) between NASA and the state of California signed in 2010 governs NASA's cleanup of soil on its portion of Santa Susana Field Laboratory.[26] The Administrative Order did not include specific contaminant cleanup levels, but it established a process for identifying those levels.[27] In 2013, NASA estimated $209 million for soil cleanup and associated long-term monitoring based on cleanup requirements it expected the state of California to implement. Later in 2013, the state of California released its specific cleanup requirements, which were more stringent than NASA had planned for and which drove the

[25]Santa Susana Field Laboratory first opened in 1948. The Department of Energy became responsible for the civilian nuclear energy research conducted at the site, which continued until 1988 and resulted in radiological contamination. The Boeing Company became responsible for rocket engine testing conducted on behalf of the Air Force for defense purposes. Both NASA's and Boeing's research ended in 2006.

[26]In the Matter of: Santa Susana Field Laboratory, Simi Hills, Ventura County, California, Docket No. HSA-CO 10/11 - 038, Administrative Order on Consent for Remedial Acton (Dec. 6, 2010).

[27]The 2010 Administrative Order stated that "The end state after cleanup of Areas I and II of the site administered by NASA will be background (i.e., at the completion of the cleanup, no contaminants will remain in the soil above local background levels), subject to any special considerations specified." The Administrative Order established a process for the state to determine site-specific, contaminant-specific cleanup levels with the result "to be as close to local background levels as practicable." In June 2013, the state of California's Department of Toxic Substances Control issued a "look-up" table containing the contaminant cleanup levels it would use to evaluate whether NASA's cleanup to the Background Standard under the Administrative Order had been achieved.

growth in the center's environmental liabilities estimate. In August 2018, NASA increased its projected cost of cleaning up Santa Susana Field Laboratory to $555 million and increased its schedule from 15 years to 25 years to meet the state's requirements.

- **Kennedy Space Center.** Kennedy Space Center reported an increase of approximately $53 million, a growth of about 37 percent, between fiscal years 2014 and 2019—the second-highest growth in unfunded environmental liabilities. The Kennedy Space Center's growth in environmental liabilities occurred because, in 2015, NASA officials changed the way they estimated costs for a complex cleanup project at Launch Complex 34, a 125-acre site heavily contaminated with TCE, according to officials.[28]
- **Jet Propulsion Laboratory.** The Jet Propulsion Laboratory—which NASA officials said was the agency's highest-priority center because contaminated groundwater migrated off-site to local drinking water sources—decreased its environmental liabilities by approximately $24 million, about 30 percent, between fiscal years 2014 and 2019. According to a NASA document, Jet Propulsion Laboratory is treating the contaminated groundwater for two nearby water districts, the City of Pasadena and the Lincoln Avenue Water Company. In addition, Jet Propulsion Laboratory has been funding facilities to treat drinking water for these two water districts since the early 1990s. According to NASA officials, Jet Propulsion Laboratory has a mature restoration program, and cleanup requirements have not changed in recent years, which has allowed for the center's continued progress toward reducing its unfunded environmental liabilities.

NASA's Reported Environmental Liabilities for Restoration Projects Do Not Include Certain

[28]Launch Complex 34 is the most complex and contaminated site at Kennedy Space Center, according to NASA officials. Prior to 2015, NASA considered the cleanup technology used at other contaminated sites at Kennedy Space Center to be impractical for use at Launch Complex 34. However, in 2014, NASA officials decided to treat Launch Complex 34 the same way as the other contaminated sites, which resulted in the $53 million increase in the Kennedy Space Center's environmental liabilities in 2015.

Costs, and Some Factors May Affect Future Liabilities

NASA's fiscal year 2019 reported environmental liabilities estimate of $1.7 billion does not include some costs associated with projects in a developing stage or costs for monitoring and operations expected to last greater than 30 years. Additionally, NASA has identified some cleanup activities that it may eventually need to fund, but NASA has not included the associated costs as environmental liabilities because NASA has not yet established its responsibility for the cleanup. Furthermore, emerging contaminants for which NASA does not yet know the cleanup standards that will be required or the nature and extent of contamination across the agency, as well as the possibility of changes to soil cleanup requirements at Santa Susana Field Laboratory, may affect NASA's future environmental liabilities.

NASA's Reported Environmental Liabilities Estimate Does Not Include Some Costs Because of Uncertain Conditions or Incomplete Data

NASA reported $1.7 billion in environmental liabilities in its fiscal year 2019 financial statement, but certain costs associated with open cleanup projects are not included in this estimate. Federal accounting standards require agencies to report reasonably estimable liabilities. Consistent with federal accounting standards, NASA considers cleanup activities nonestimable if, for example, conditions surrounding the cleanup are uncertain or technical data for developing an estimate are incomplete or unreliable.[29] NASA uses its NETS database to capture information about open restoration projects, including reasons why projects may not be fully estimable. Specifically, NASA classified at least 25 of the 115 open restoration projects in fiscal year 2019 as not fully estimable because the projects were in a developing stage or NASA needed to conduct additional sampling, analysis, or data collection to provide a more complete estimate. Specific examples include the following:

- At Glenn Research Center, NASA identified contaminants below one of its buildings but, according to NASA documents, the agency cannot

[29]If a restoration project has both estimable and nonestimable components, NASA includes the estimable costs as part of the project liability estimate and documents in NETS that the project also has nonestimable components.

fully delineate the extent of contamination until the building is demolished. As a result, NASA reports that costs to remediate the contamination are currently nonestimable. According to NASA documents, demolition of the building has been delayed indefinitely per a new agreement with the state of Ohio's Environmental Protection Agency, so it is unclear when Glenn Research Center will begin including these cleanup costs in its environmental liability estimate.

- At Michoud Assembly Facility in Louisiana, NASA identified soil and groundwater contaminated with TCE and has implemented systems to remediate contamination and to help contain the flow of groundwater to keep TCE from migrating off-site. However, according to NASA documents, four of the contaminated sites are located beneath buildings or other infrastructure, making them technically and logistically difficult to address with existing technology. According to NASA, the agency plans to complete remediation at other sites at Michoud Assembly Facility and then propose to the state of Louisiana that NASA continue monitoring and containing the contamination onsite. As of fiscal year 2019, costs for cleanup at these four Michoud Assembly Facility sites were not included in NASA's environmental liabilities estimate.
- At Wallops Flight Facility in Virginia, NASA and the U.S. Army Corps of Engineers are jointly investigating potential groundwater contamination, but NASA will not know its responsibility for cleanup or financial liability until the investigation is complete and a cleanup remedy has been selected.[30] As a result, NASA's environmental liabilities estimate for Wallops Flight Facility does not include costs for the full scope of work on this project.

Additionally, 60 of the 115 open restoration projects are not fully estimable because they are expected to take longer than 30 years to complete. NASA's policy is to only estimate liabilities for 30 years because the agency views anything beyond 30 years as too uncertain to be estimable. As a result, costs for cleanup activities extending beyond the 30-year time frame are not included in the agency's reported

[30]Additionally, according to NASA documents, under the terms of a Memorandum of Agreement with the Department of the Army, NASA is responsible for long-term monitoring at Formerly Used Defense Sites at Wallops Flight Facility. NASA classifies these long-term monitoring costs as nonestimable because the projects are still in the investigative stage and are currently being managed by the U.S. Army Corps of Engineers.

environmental liabilities estimate. Activities that could extend beyond the 30-year estimable time frame include long-term operations and monitoring. For example, according to NASA officials, approximately 100,000 pounds of TCE originally contaminated the groundwater at Launch Complex 34 at Kennedy Space Center.[31] NASA installed a hydraulic containment system to capture and treat groundwater in the most contaminated area and monitors natural attenuation for the remaining plume.[32] NASA officials said that active cleanup at this site could take centuries to complete and that the contaminated plume will likely remain for over 500 years, therefore involving long-term monitoring.

NASA Has Not Established Its Responsibility for Some Known or Suspected Contamination

NASA identified some potential cleanup activities that it may be required to fund in the future based on known or suspected contamination, but the agency has not established its responsibility for the work involved. In accordance with federal accounting standards, NASA does not report these costs as environmental liabilities. As a result, NASA's fiscal exposure may be higher than what is reported as environmental liabilities in the agency's annual financial statements.

Federal accounting standards require agencies to report liabilities that reach the level of probable. The level of probable means that an agency has established its legal liability or financial responsibility for the project and that the agency has determined that it is more likely than not that it will have to conduct the cleanup. However, NASA also documents known or suspected contamination in NETS when it considers the likelihood of having to conduct the cleanup as reasonably possible, even though federal accounting standards do not require reporting of these costs.[33] In such cases, NASA documents the project—or components of it—as

[31]The contaminated groundwater plume at the Kennedy Space Center's Launch Complex 34 encompasses an area of 330 acres and extends to a depth of approximately 80 feet below land surface. The dissolved plume is comprised of approximately 700 million gallons of impacted groundwater and contains an estimated 3,000 to 6,000 pounds of chlorinated volatile organic compounds.

[32]According to NASA officials, as of November 2020, groundwater remediation has reduced contaminants in an 8-acre area almost to the allowable contaminant levels that EPA has established.

[33]Projects classified as reasonably possible are those where NASA has determined that there is a less than 50 percent chance, but greater than a remote chance, that the agency will incur a financial liability.

reasonably possible in NETS. For example, at Jet Propulsion Laboratory, NASA has an active groundwater cleanup project that also has some associated cleanup activities classified as reasonably possible. For this groundwater cleanup project, NASA deemed it reasonably possible that it would need to (1) conduct further investigation into the extent of perchlorate contamination originating from Jet Propulsion Laboratory, as some stakeholders have questioned the results of NASA's original investigation; (2) fund some costs to repair water treatment equipment in order to keep the equipment functioning year-round; and (3) conduct 2 additional years of groundwater monitoring at certain water treatment sites. These three cleanup activities—estimated at $1.4 million—are not included in the agency's environmental liabilities estimate because they have not risen to the level of probable—that is, NASA has not determined that it is more likely than not that the activities will be necessary. Instead, the costs are documented in the narrative portion of the agency's financial statement.

Emerging Contaminants and Potential Changes to Some Cleanup Requirements May Affect NASA's Future Environmental Liabilities

Developing conditions and responsibilities may affect NASA's future environmental liabilities, including emerging contaminants and potential changes to soil cleanup requirements at Santa Susana Field Laboratory. New cleanup requirements for emerging contaminants could increase NASA's environmental liabilities and create additional fiscal exposure for the federal government. Changes to soil cleanup requirements at Santa Susana Field Laboratory could decrease NASA's environmental liabilities and reduce the federal government's fiscal exposure.

Emerging Contaminants

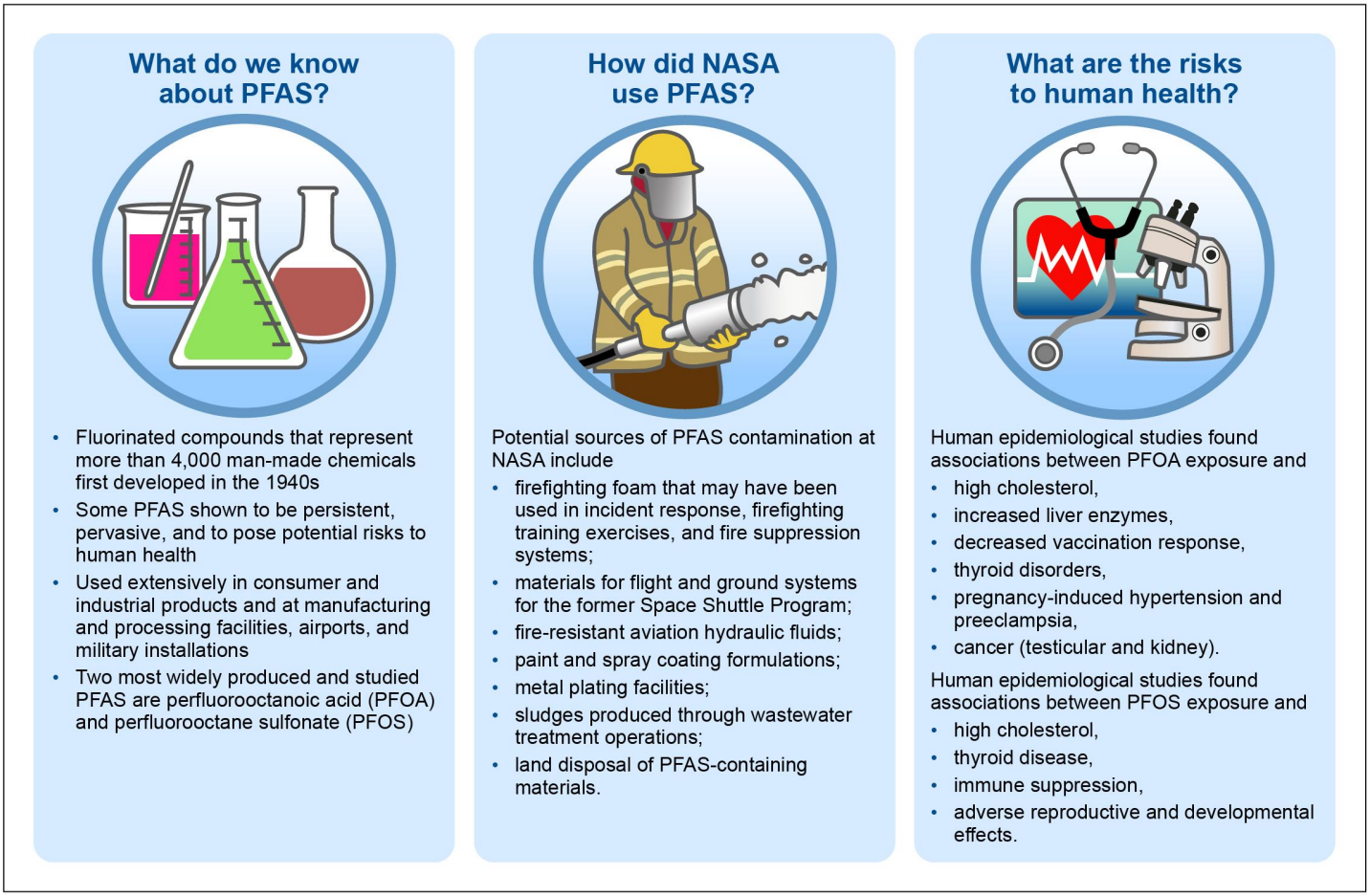
Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the two most widely studied chemicals from a class of compounds known as per- and polyfluoroalkyl substances (PFAS). PFAS are manmade chemicals used in a wide range of consumer and industrial products,

including firefighting foams, typically at airports and on military bases.[34] At NASA, for example, Wallops Flight Facility historically conducted fire training activities where firefighters used a common firefighting foam—known as aqueous film forming foam—containing PFAS compounds (see fig. 6).[35]

[34]See our previous work on PFAS: GAO, *Drinking Water: Status of DOD Efforts to Address Drinking Water Contaminants Used in Firefighting Foam*, GAO-18-700T (Washington, D.C.: Sept. 26, 2018); and *Drinking Water: DOD Has Acted on Some Emerging Contaminants but Should Improve Internal Reporting on Regulatory Compliance,* GAO-18-78 (Washington, D.C.: Oct. 18, 2017).

[35]These firefighting training activities date from the late 1970s to 1988. The firefighting foam was also used to extinguish fires from an aircraft crash that occurred at Wallops Flight Facility in 1998. Since 2016, in collaboration with local, state, and federal agencies, NASA has routinely tested for the presence of PFAS in groundwater monitoring wells and drinking water wells at Wallops Flight Facility and a nearby Virginia town.

Figure 6: Per- and Polyfluoroalkyl Substances (PFAS) Background, Use at NASA, and Human Health Risks



Source: GAO analysis of National Aeronautics and Space Administration (NASA) and Environmental Protection Agency (EPA) documents. | GAO-21-205

Text of Figure 6: Per- and Polyfluoroalkyl Substances (PFAS) Background, Use at NASA, and Human Health Risks

1. What do we know about PFAS?

- Fluorinated compounds that represent more than 4,000 man-made chemicals first developed in the 1940s
- Some PFAS shown to be persistent, pervasive, and to pose potential risks to human health
- Used extensively in consumer and industrial products and at manufacturing and processing facilities, airports, and military installations
- Two most widely produced and studied PFAS are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS)

2. How did NASA use PFAS?

   Potential sources of PFAS contamination at NASA include

- firefighting foam that may have been used in incident response, firefighting training exercises, and fire suppression systems;
- materials for flight and ground systems for the former Space Shuttle Program;
- fire-resistant aviation hydraulic fluids;
- paint and spray coating formulations;
- metal plating facilities;
- sludges produced through wastewater treatment operations;
- land disposal of PFAS-containing

3. What are the risks to human health?

   Human epidemiological studies found associations between PFOA exposure and

- high cholesterol,
- increased liver enzymes,
- decreased vaccination response,
- thyroid disorders,
- pregnancy-induced hypertension and preeclampsia,
- cancer (testicular and kidney).

   Human epidemiological studies found associations between PFOS exposure and

- high cholesterol,
- thyroid disease,
- immune suppression,
- adverse reproductive and developmental effects.

Source: GAO analysis of National Aeronautics and Space Administration (NASA) and Environmental Protection Agency (EPA) documents. | GAO-21-205

EPA has not established a maximum contaminant level for PFOA and PFOS under the Safe Drinking Water Act nor has the agency established

soil, groundwater, or surface water standards.[36] In May 2016, EPA established health advisories for PFOA and PFOS, which are nonenforceable and nonregulatory declarations that provide information on potentially harmful contaminants not subject to drinking water regulations.[37] In March 2020, EPA made a preliminary determination to regulate PFOA and PFOS under the Safe Drinking Water Act.[38] EPA expects to make its final determination by January 2021 on whether to regulate PFOA and PFOS.[39] Following a positive regulatory determination, EPA has up to 24 months to propose a drinking water regulation and an additional 18 months to promulgate the final rule.[40] According to NASA documentation, some states have adopted the levels established in the EPA's health advisories as drinking water targets, while others have developed or are deriving their own regulatory or screening values—some of which are more stringent than the levels in the EPA's health advisories.[41]

In addition, NASA has not yet established the nature and extent of PFOA or PFOS contamination at its centers. NASA is conducting preliminary assessments at 15 locations across the agency where past or present

[36]The Safe Drinking Water Act, Pub. L. No. 93-523, 88 Stat. 1660 (enacted Dec. 16, 1974), codified as amended at 42 U.S.C. §§ 300f to 300j-26, requires EPA to establish legally enforceable standards for public water systems that generally limit the levels of specific contaminants in drinking water that can adversely affect public health.

[37]EPA, *Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)* (May 2016); and *Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)* (May 2016). EPA health advisories provide information on contaminants not subject to drinking water regulations, including those that can cause human health effects and are known or anticipated to occur in drinking water. EPA health advisories provide an estimate of the daily exposure to the human population that is likely to be without risk or harmful effects over a lifetime.

[38]85 Fed. Reg. 14,098 (Mar. 10, 2020). According to EPA documents, in the proposed regulatory determination for PFOA and PFOS, the agency requested additional information on other PFAS substances and comment on potential monitoring requirements and regulatory approaches for PFAS chemicals. See 85 Fed. Reg. 14,135.

[39]If EPA were to promulgate PFOA and PFOS maximum contaminant levels under the Safe Drinking Water Act, the concentration may be applied as a standard for remedial actions under Section 121 of CERCLA to protect current or potential sources of drinking water. See 42 U.S.C. § 9621.

[40]42 U.S.C. § 300g-1(b)(1)(E).

[41]Even when there is a promulgated federal standard, states may choose to adopt standards that are more stringent.

activities may have resulted in a release of PFAS into the environment.[42] According to NASA's planning document, the agency-wide effort was scheduled for completion in January 2021, but officials said the agency has experienced some delays from having to cancel a site visit to one of the centers due to Coronavirus Disease 2019 (COVID-19). However, NASA officials said they have been able to mitigate the delays and expect the final agency-wide report to be complete in the spring of 2021. According to NASA officials, the preliminary assessments revealed areas of concern at several centers, and the agency plans to conduct further sampling and evaluation in fiscal years 2021 and 2022. NASA officials said that planning and estimating PFOA and PFOS cleanup projects is difficult because of the absence of federal standards and the unknown extent of contamination across the agency. As a result, NASA officials are uncertain how the contamination will affect the agency's environmental liabilities in the future. Officials noted that they may not begin PFOA and PFOS cleanup until standards are in place.

Santa Susana Field Laboratory

NASA's responsibilities for soil restoration at Santa Susana Field Laboratory are in dispute. NASA's 2010 Administrative Order with the state of California committed NASA to clean up soil on its portion of Santa Susana Field Laboratory to a Background Standard, but the contaminant cleanup levels for a Background Standard were not defined by the state of California's Department of Toxic Substances Control (DTSC) until 2013. In July 2020, NASA completed its Final Supplemental Environmental Impact Statement (SEIS), pursuant to the National Environmental Policy Act, for soil cleanup at Santa Susana Field Laboratory.[43] In the SEIS, NASA identified its preferred cleanup

[42]The 15 locations include some, but not all, of the 14 centers that have already identified contaminants that we have listed in our report. According to NASA's planning document, the preliminary assessments are to focus on the PFAS that EPA has identified as emerging contaminants, which include PFOA and PFOS. The objectives of NASA's preliminary assessments are to (1) complete site and source characterizations of areas where past or present activities may have resulted in a release of PFAS; (2) qualitatively characterize the migration potential of released PFAS through the environment (e.g., soil, groundwater, surface water, or air); and (3) identify potential targets for exposure to PFAS in the environment.

[43]NASA, *Final Supplemental Environmental Impact Statement for Soil Cleanup Activities at Santa Susana Field Laboratory*. National Environmental Policy Act of 1969, Pub. L. No. 91-190, 83 Stat. 852 (enacted Jan. 1, 1970), codified as amended 42 U.S.C. §§ 4321 – 4347.

alternative as the Suburban Residential Standard. A Background Standard is intended to return the environment to its natural state prior to the introduction of contaminants and, according to NASA, does not take into account the future use of the land. According to NASA, a Suburban Residential Standard would use a risk-based process that takes into account the reasonably foreseeable future use of the land in order to identify the appropriate cleanup levels.[44] According to NASA documents, both the Background Standard and the Suburban Residential Standard are protective of human health.[45] NASA anticipates that land at Santa Susana Field Laboratory will be restricted for use and development in the future, so the Suburban Residential Standard represents a conservative potential land use scenario, according to NASA.[46] NASA also cited several technical and logistical challenges with cleaning the soil to a Background Standard.[47]

DTSC responded to NASA's SEIS asserting that NASA's decision to consider alternatives other than cleanup to a Background Standard was in conflict with NASA's legal obligations under the 2010 Administrative Order. DTSC stated that NASA should have considered alternatives for how it could comply with the Administrative Order in the least impactful

[44]According to NASA, a risk-based strategy is the accepted methodology employed by EPA and the state of California when selecting a site cleanup remedy and that it is the process used for site cleanup activities conducted under CERCLA, the National Oil and Hazardous Substances Pollution Contingency Plan, and applicable California State law.

[45]NASA's exposure scenario for the Suburban Residential Standard assumes that both adults and children would be exposed to soil 24 hours per day, 350 days per year, for a total of 26 years, with no threat to health. NASA calculated an approximately 1 in 1,000,000 possibility for an exposed individual to experience health concerns, such as cancer, under this scenario.

[46]The Boeing Company (Boeing) owns the majority of land at Santa Susana Field Laboratory, including land adjacent to the NASA-administered portions of Santa Susana Field Laboratory. Boeing is not subject to the 2010 Administrative Order with the state of California and is instead conducting risk-based cleanup according to the future land use of the property. According to NASA documentation, in 2017, Boeing filed a conservation easement in partnership with the North American Land Trust for its portion of Santa Susana Field Laboratory land. The easement restricts future land use by prohibiting residential or agricultural development on the site in perpetuity; however, the easement alone does not designate a cleanup standard. Subsequently, Boeing announced soil remediation plans to conduct cleanup to a Recreational Standard, which is a less stringent standard than the Suburban Residential Standard. As of February 2020, DTSC had not accepted Boeing's proposed recreational cleanup levels.

[47]According to NASA officials, in January 2018, the agency also commented on DTSC's draft Programmatic Environmental Impact Report, raising concerns about the implementability of cleanup to the Background Standard. As of December 2020, NASA officials said their comments have not yet been addressed.

manner rather than considering alternatives that do not comply with the requirements of the Administrative Order. DTSC also disagreed with NASA's discussion in the SEIS of the technical and logistical difficulties it faced in cleaning soil to a Background Standard. DTSC stated that it was committed to working with NASA to resolve all challenges and assure compliance with the Administrative Order but that it did not plan to renegotiate the soil cleanup commitments.

Soil Remediation at NASA's Santa Susana Field Laboratory Sites

- 2010: NASA entered into an Administrative Order on Consent (Administrative Order) with California's Department of Toxic Substances Control (DTSC) that required NASA to clean soil to a Background Standard but did not establish specific soil cleanup levels.
- 2013: DTSC issued the numerical contaminant cleanup levels to define the Background Standard required in the Administrative Order.
- 2014: NASA issued an Environmental Impact Statement (EIS) that limited the EIS assessment of cleanup alternatives to the Background Standard alternative.
- 2019: NASA issued a draft Supplemental Environmental Impact Statement (SEIS), citing the need for a supplemental assessment based of a significant increase in estimated soil removal volumes since the 2014 EIS was completed. The SEIS considered cleanup to a Background Standard, as well as alternatives.
- January 2020: DTSC issued a letter to NASA reasserting its position that NASA should adhere to the Background Standard it agreed to in the 2010 Administrative Order.
- July 2020: NASA issued its final SEIS and identified its preferred cleanup alternative as the Suburban Residential Standard, a cleanup level necessitating less soil excavation than the Background Standard required by the 2010 Administrative Order.
- September 2020: DTSC issued a letter to NASA reasserting its position that NASA should adhere to the Background Standard it agreed to in the 2010 Administrative Order.

- September 2020: NASA issued its Record of Decision selecting the Suburban Residential Standard cleanup alternative.
- As of December 2020, NASA and DTSC have not resolved the matter, and NASA has not initiated soil cleanup.

Source: GAO analysis of National Aeronautics and Space Administration (NASA) documents. | GAO-21-205

In September 2020, NASA issued its Record of Decision for soil cleanup at Santa Susana Field Laboratory, which selected the Suburban Residential Standard as the cleanup standard NASA would pursue. According to NASA officials, the first step toward modifying the contaminant cleanup levels would be negotiations with DTSC but could require formal dispute resolution.[48] If the parties agree to change the contaminant cleanup levels to the Suburban Residential Standard, NASA estimates a potential decrease of approximately $355 million in environmental liabilities due to a significant reduction in the amount of soil that would need to be excavated for disposal.[49] However, in September 2020, DTSC issued a letter to NASA reasserting its position that NASA should adhere to the Background Standard required by the 2010 Administrative Order. As of December 2020, DTSC had not issued its Program Environmental Impact Report or final decision on soil cleanup requirements, which NASA officials said is necessary before the matter can be resolved and NASA can begin soil cleanup (see sidebar).[50]

Agency Comments

We provided a draft of this report to NASA for comment. NASA provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Administrator of NASA, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or bawdena@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made key contributions to this report are listed in appendix II.

[48]The 2010 Administrative Order provides for a formal dispute resolution process.

[49]NASA estimated it would need to excavate and dispose of 870,000 cubic yards of soil for cleanup to a Background Standard and 247,000 cubic yards of soil for cleanup to a Suburban Residential Standard.

[50]NASA officials stated that the agency expects to begin soil cleanup at Santa Susana Field Laboratory after DTSC completes its final Program Environmental Impact Report and approves NASA's soil cleanup plan. However, NASA has begun interim groundwater cleanup and demolition of test stands, according to officials.

Allison Bawden
Director, Natural Resources and Environment

Appendix I: Objectives, Scope, and Methodology

The objectives of our review were to describe (1) what is known about the National Aeronautics and Space Administration's (NASA) environmental liabilities for restoration projects, including changes in recent years; and (2) what factors could contribute to uncertainties in NASA's current or future environmental liabilities for restoration projects. We performed our work under the authority of the Comptroller General to conduct evaluations in light of congressional interest in the federal government's environmental liabilities.

For the purpose of this review, we focused our assessment of NASA's environmental liabilities on restoration projects,[1] which is one of three environmental cleanup programs at NASA and which accounted for 88 percent of NASA's $1.7 billion in environmental liabilities for fiscal year 2019. The other two programs include asbestos and end-of-life disposal of property, plant, and equipment, which collectively accounted for the remaining balance. We specifically excluded asbestos and end-of-life disposal of property, plant, and equipment because NASA manages each of these programs differently from restoration projects and because they collectively constituted a small portion of NASA's overall environmental liabilities. Throughout our report, we use the term "environmental liabilities" to refer to environmental liabilities for restoration projects. We reviewed increases and decreases in environmental liabilities between fiscal years 2014 and 2019, the most recent 5 years of environmental liabilities reported at the time of our review.

Also for the purpose of this review, we identified three NASA centers to obtain detailed information about their environmental restoration projects.

[1]NASA defines restoration projects as those addressing activities required under federal, state, or local laws, or other legally enforceable agreements at NASA-owned or NASA-operated property. Restoration projects include investigation activities such as sampling, analysis, monitoring, and modeling related to contamination from NASA operations. Additionally, restoration projects may include containment, cleanup, environmental closures (including tanks, landfills, and other environmentally regulated facilities or units), attenuation, land-use controls, oversight, land parcel purchase, long-term operations and maintenance, provision of alternate drinking or potable water supplies, and evaluation of remedial alternatives.

We selected the centers from a list of 14 at which NASA has identified contamination. Table 1 is a list of the 14 centers.

Table 1: List of 14 Centers at Which NASA Has Identified Contamination

Center	Location
Ames Research Center	Moffett Field, CA
Armstrong Flight Research Center	Edwards Air Force Base, CA
Glenn Research Center	Cleveland, OH
Goddard Space Flight Center	Greenbelt, MD
Jet Propulsion Laboratory	Pasadena, CA
Johnson Space Center	Houston, TX
Kennedy Space Center	Central Florida
Langley Research Center	Hampton, VA
Marshall Space Flight Center	Huntsville, AL
Michoud Assembly Facility	New Orleans, LA
Santa Susana Field Laboratory	Ventura County, CA
Stennis Space Center	Southern Mississippi
Wallops Flight Facility	Wallops Island, VA
White Sands Test Facility	Southern New Mexico

Source: National Aeronautics and Space Administration | GAO 21-205

The centers we selected included Jet Propulsion Laboratory, Kennedy Space Center, and Santa Susana Field Laboratory. We selected these centers based on decreases and increases in environmental liabilities, the number of open restoration projects, and the potential that additional cleanup could be required in the future and result in increased environmental liabilities. Specifically, we selected Jet Propulsion Laboratory because it had a significant decrease in unfunded environmental liability. We selected Kennedy Space Center because it had the second highest growth in unfunded environmental liability and also had the largest number of projects among all of NASA's centers. About one-third of NASA's 115 listed projects reside at Kennedy Space Center. We selected Santa Susana Field Laboratory because it had the highest increase in unfunded environmental liability and because its 2010 Administrative Order with the state of California suggested levels of cleanup would be necessary beyond what NASA had originally planned for.

To determine NASA's environmental liabilities for restoration projects, we reviewed relevant NASA documents and interviewed officials from NASA, including from the three NASA centers we identified for further data collection. We also reviewed NASA's criteria for estimating environmental liabilities. NASA officials estimate and manage environmental liabilities through NASA's Environmental Tracking System (NETS). We assessed

NETS for its reliability by reviewing prior NASA Office of the Inspector General reports that had performed previous assessments. One such report, issued in 2014, made a recommendation to improve weaknesses in NASA's data reliability management. We followed up with both the Office of the Inspector General and NASA officials to determine the status of NASA's response to that recommendation. We also interviewed NASA officials on how they maintained and managed NETS, including safeguarding the information, authorizing access and revisions to data fields, and providing guidance and training on use of NETS. In addition, according to NASA guidance, center officials must review each of their restoration project estimates and validate that the project estimate is reasonable and adequately documented. Headquarters officials conduct a similar review of restoration project estimates for projects that represent 90 percent of the agency's total estimated liabilities. We found NETS to be sufficiently reliable for our purpose of determining NASA's estimated environmental liabilities, and we note the uncertainties associated with those estimates. In addition, NASA has one project with environmental liabilities attributed to its headquarters location for personnel who manage restoration projects. Since this project is not an active cleanup project, we do not include NASA headquarters as a center where restoration projects are taking place. However, we do include NASA headquarters' environmental liabilities when discussing the agency's overall environmental liabilities, as NASA includes these liabilities in its required annual financial statement reporting.

To determine factors that could contribute to uncertainties in NASA's current or future environmental liabilities for restoration projects, we reviewed relevant NASA documents and interviewed officials from NASA. We collected data on NASA's environmental restoration projects from NETS, including the annual funding profile for centers and projects, and reports on the status of projects and any limitations to estimating future costs. We reviewed the NETS report where NASA documents its reasoning for classifying projects or components of projects as not fully estimable. We also reviewed the NETS report where NASA documents its reasoning for classifying projects or components of projects as reasonably possible—that is, situations where the agency has determined that there is a less than 50 percent chance, but more than a remote chance, that it will incur a financial liability in the future. We interviewed NASA officials at headquarters and the three selected NASA centers in our review about factors that could contribute to uncertainty in their future environmental liabilities, including emerging contaminants and soil cleanup requirements that are in dispute at Santa Susana Field Laboratory.

We conducted this performance audit from April 2020 to January 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Allison Bawden, (202) 512-3841 or bawdena@gao.gov

Staff Acknowledgments

In addition to the individual named above, the following individuals made contributions to this report: Janice Poling (Assistant Director); Robert Sánchez (Analyst-in-Charge); Mark Braza; Lilia Chaidez; William Gerard; N'kenge Gibson; Charlotte E. Hinkle; Richard Johnson; Donna Morgan; Jose Ramos, Jr.; Dan Royer; Molly Tracy; and Breanna Trexler.

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