



COMMERCIAL SPACE TRANSPORTATION

FAA Should Improve Its Mishap Investigation Process

Accessible Version

December 2023

Why GAO Did This Study

The U.S. commercial space transportation industry, which provides launch and other services for government and private customers, has grown rapidly in recent years. Growth is expected to continue, as commercial space activities expand into new areas. FAA's focus, among other things, is protecting the "uninvolved public"—members of the public not involved in commercial space operations but at risk if something goes awry.

GAO was asked to review safety oversight of the industry. This report examines 1) commercial space mishaps from 2000 to mid-January 2023, 2) roles and responsibilities of federal agencies in investigating commercial space transportation mishaps, 3) FAA's mishap investigation process and areas for improvement, and 4) efforts by FAA and others to share safety lessons learned.

GAO examined data on commercial space flights and mishaps; examined documentation from FAA and other relevant federal agencies; and interviewed federal agency officials, executives of launch operators, and other stakeholders.

What GAO Recommends

GAO is making two recommendations to FAA, to 1) develop criteria for determining when the agency will authorize a launch operator to lead a mishap investigation on the agency's behalf and 2) comprehensively evaluate the effectiveness of its mishap investigation process. FAA agreed with our recommendations.

View [GAO-24-105561](#). For more information, contact Heather Krause at (202) 512-2834 or krauseh@gao.gov.

COMMERCIAL SPACE TRANSPORTATION

FAA Should Improve Its Mishap Investigation Process

What GAO Found

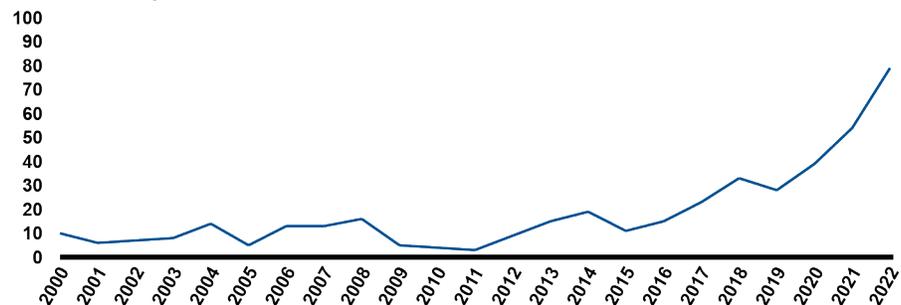
Federal Aviation Administration (FAA) data show that 50 commercial space launches from 2000 through mid-January 2023 resulted in "mishaps"—the industry term for incidents such as catastrophic explosions and other failures. This represents about 12 percent of 433 launches during the period and caused no fatalities, serious injuries, or significant property damage to the public.

FAA is generally the lead agency for mishap investigations, according to FAA data, while coordinating with other agencies through various arrangements. Both FAA and the National Transportation Safety Board (NTSB) have authority to investigate FAA-licensed commercial space mishaps, and they recently signed a new agreement to aid in managing their authorities. These agencies, plus the Department of the Air Force and the National Aeronautics and Space Administration, also have other collaborative mechanisms to address mishaps.

When mishaps occur, FAA can conduct an investigation itself or instead authorize launch operators to lead investigations of their own mishaps under FAA oversight, according to FAA. In practice, however, FAA has authorized operator-led investigations for all mishaps where it had lead investigative authority, GAO found. Agency procedures cite individual circumstances of a mishap as the basis for authorizing an operator-led investigation. However, FAA has not developed criteria to ensure it is appropriately making such determinations. FAA has taken some steps to improve mishap investigations, such as contracting for independent reviews of some operator-led investigations. However, GAO found that FAA has not evaluated the effectiveness of its operator-reliant process. Although stakeholders generally told GAO they support FAA's investigation process, some expressed concerns whether operators can credibly investigate their own mishaps. Without a comprehensive evaluation of its mishap investigation process, FAA cannot be assured its process is effective, especially given the expansion of commercial space operations in recent years.

There is currently no formal mechanism for sharing safety lessons learned, but informal channels have developed among federal agencies and the industry. Previous efforts by FAA to create a formal system were unsuccessful, but FAA officials said they are making a new attempt, including by consulting an advisory committee. NTSB has previously recommended establishing such a system.

Commercial Space Launches, 2000-2022



Source: GAO presentation of Federal Aviation Administration data. | [GAO-24-105561](#)

Accessible Data for Commercial Space Launches, 2000-2022

Calendar year	Licensed (commercial space launches)
2000	10
2001	6
2002	7
2003	8
2004	14
2005	5
2006	13
2007	13
2008	16
2009	5
2010	4
2011	3
2012	9
2013	15
2014	19
2015	11
2016	15
2017	23
2018	33
2019	28
2020	39
2021	54
2022	79

Source: GAO presentation of Federal Aviation Administration data. | GAO-24-105561

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Abbreviations

Aerospace	The Aerospace Corporation
FAA	Federal Aviation Administration
MOA	memorandum of agreement
MOU	memorandum of understanding
NASA	National Aeronautics and Space Administration
NTSB	National Transportation Safety Board

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December 7, 2023

The Honorable Sam Graves
Chairman
The Honorable Rick Larsen
Ranking Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Garret Graves
Chairman
The Honorable Steve Cohen
Ranking Member
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

The U.S. commercial space transportation industry provides launch and other services for government and private customers to send satellites, cargo, scientific payloads, and people to space. Since the first U.S.-licensed commercial space launch in 1989, the industry has today expanded into a multibillion-dollar enterprise, as launch activity has sharply increased—at an average annual rate of nearly 40 percent in recent years. Growth is expected to continue, as commercial space activities expand into new areas, including civilian human spaceflight, new satellite communications, commercial space stations, on-orbit servicing, and new forms of propulsion. Some flights have experienced incidents, ranging from catastrophic explosion at launch to failure to successfully deploy a payload to orbit. None of these incidents—known in the industry as “mishaps”—has resulted in fatalities, or serious injuries or significant property damage to the public. One mishap, however, resulted in the death of a crew member.¹ As the industry continues to expand, safety will remain a key objective, especially if human spaceflight activities become more regular, as anticipated.

¹See National Transportation Safety Board, *In-Flight Breakup During Test Flight, Scaled Composites SpaceShipTwo, N339SS, Near Koehn Dry Lake, California* (Oct. 31, 2014). In particular, the Federal Aviation Administration focuses on risk to the “uninvolved” public, meaning members of the public not involved in space operations but subject to risk if commercial space operations do not go as planned.

The Department of Transportation's Federal Aviation Administration (FAA) is responsible for certain oversight of the commercial space transportation industry, including licensing launch and reentry operations, and can also investigate mishaps that occur with these operations.² Congress has limited FAA's authority, in part, through a regulatory moratorium that generally bars the agency from regulating crew and passenger safety.³ In some situations, other federal agencies can also be involved or conduct mishap investigations. In prior reports, we have identified various challenges FAA faces in regulating this evolving industry. For example, in 2019, we reported that FAA had not sufficiently developed information on the skills and competencies of its commercial space workforce to ensure that the workforce has the requisite skills and competencies to oversee the industry.⁴

Considering these and other developments, you asked us to review commercial space transportation safety and accident investigation oversight. This report examines (1) commercial space mishaps as identified by FAA from 2000 to mid-January 2023, (2) the roles and responsibilities of federal agencies in investigating commercial space transportation mishaps, (3) FAA's investigation process for commercial space transportation mishaps and areas for improvement, and (4) efforts by FAA and others to share safety lessons learned and key considerations for a formal system for sharing lessons learned.

To examine commercial space mishaps, we analyzed information provided by FAA on launches and mishaps occurring from 2000 to early 2023. We examined these data to determine whether they were reliable

²The Secretary of Transportation has delegated the statutory functions for commercial space to the FAA Administrator. 49 C.F.R. § 1.83(b). FAA has the general authority to "conduct investigations and inquiries" into commercial space launch activities. 51 U.S.C. § 50917(b)(1)(A).

³The regulatory moratorium was established in statute in 2004. Commercial Space Launch Amendments Act of 2004, Pub. L. No. 108-492, § 2, 118 Stat. 3974, 3979 (2004). Originally set to expire in 2012, it was extended by statute multiple times. As of October 2023, the moratorium will expire January 1, 2024.

⁴GAO, *Commercial Space Transportation: Improvements to FAA's Workforce Planning Needed to Prepare for the Industry's Anticipated Growth*, [GAO-19-437](#) (Washington, D.C.: May 23, 2019). As of July 2023, FAA had implemented one of four recommendations—that FAA ensure its skills assessment survey collects information from staff on skills and competencies in areas that are both currently needed and may be needed in the future. See also GAO, *Federal Aviation Administration: Commercial Space Launch Industry Developments Present Multiple Challenges*, [GAO-15-706](#) (Washington, D.C.: Aug. 25, 2015).

for our reporting objectives and determined that they were. To identify roles and responsibilities of federal agencies, we examined relevant statutes, regulations, and other documentation. To examine FAA's mishap investigation process, we reviewed relevant documentation from the agency and standards for internal control for the federal government. To review the status of efforts to share safety lessons learned and key considerations for a formal system to share lessons learned, we examined relevant agencies' documentation, including a National Transportation Safety Board (NTSB) recommendation to create such a system. For all objectives, we interviewed officials of FAA, plus NTSB, the National Aeronautics and Space Administration (NASA), and the Department of the Air Force.⁵ We also interviewed 18 stakeholders, including eight launch operators, executives of an industry trade group, three commercial spaceports, four former agency officials, and others we identified based on their subject-matter experience.⁶ Appendix I describes our objectives, scope, and methodology in greater detail.

We conducted this performance audit from November 2021 to December 2023 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.

Background

Commercial space transportation is accomplished through orbital and suborbital operations on vehicles operated by private-sector companies. These companies are commonly referred to as commercial launch

⁵With the establishment of the U.S. Space Force in 2019, the Space Force and the U.S. Air Force became equal services within the Department of the Air Force, according to a Department official. U.S. Air Force roles and responsibilities under interagency agreements addressing commercial space transferred from the U.S. Air Force to the U.S. Space Force, as did East and West Coast launch ranges, the Department official said. The ranges had been in the U.S. Air Force Space Command but now reside in the U.S. Space Force Space Systems Command, the official said.

⁶In this report, we refer to "a few" stakeholders if representatives from two to three entities expressed the view; "some," if representatives from four to six entities expressed the view; and "many," if representatives from seven or more entities expressed the view. Given stakeholders' varied expertise, not every stakeholder provided an opinion on every topic.

providers or launch operators.⁷ Commercial space companies can launch from a variety of facilities, including federal ranges on the East and West Coasts of the U.S. mainland and FAA-licensed spaceports established in several states. Depending on mission needs, one launch site may be more advantageous than another for a particular launch.⁸ According to FAA, the Cape Canaveral complex on the Atlantic Coast in Florida accounts for about 75 percent of commercial space operations.⁹ Figure 1 shows launch sites for FAA-licensed operators as of February 2023, together with the total number of launches by state or other location, for 2000 through 2022.

⁷In this report, we generally refer to the commercial firms as “companies,” “space companies,” or “operators.”

⁸A variety of factors influences desired launch location, including availability of launch infrastructure; desired orbital trajectory; desired open surrounding area, such as an ocean or vacant land; or proximity to commercial air routes. For details, see GAO, *Commercial Space Transportation: FAA Should Examine a Range of Options to Support U.S. Launch Infrastructure*, [GAO-21-154](#) (Washington, D.C.: Dec. 22, 2020).

⁹In May 2023, FAA forecast annual launch and reentry activity to increase from 61 to 123, in a low-end estimate, from fiscal year 2023 to fiscal year 2027; and from 94 to 288, in a high-end estimate. The Department of the Air Force forecasts that even though various efforts are underway to develop spaceports elsewhere, commercial flights will dominate activity at its eastern range at Cape Canaveral Space Force Station in Florida and at its western range at Vandenberg Space Force Base on the central California coast.

Figure 1: Launch Sites for FAA-Licensed Operators, as of February 2023, with Total Launches by State or Other Location, 2000-2022



Sources: GAO presentation of Federal Aviation Administration (FAA) data and Map Resources. | GAO-24-105561

Accessible Data for Figure 1: Launch Sites for FAA-Licensed Operators, as of February 2023, with Total Launches by State or Other Location, 2000-2022

Launch sites

Launch site name	Launch site location
na	Marshall Islands (Pacific)
Rocket Lab	New Zealand
Spaceport Cornwall	United Kingdom
Andersen Air Force Base	Guam
Wallops Flight Facility	Virginia
Kennedy Space Center	Florida
Cape Canaveral Space Force Station	Florida

Letter

Launch site name	Launch site location
Space Florida	Florida
Pacific Spaceport Complex	Alaska
Vandenberg Space Force Base	California
Mojave Air and Space Port	California
Spaceport America	New Mexico
Blue Origin: Launch Site One	Texas
SpaceX	Boca Chica, Texas

Sources: GAO presentation of Federal Aviation Administration (FAA) data and Map Resources. | GAO-24-105561

Total flights

Flight location	Flight total
Virginia	18
Florida	191
Alaska	7
California	64
New Mexico	24
Texas	49
Oklahoma	3
Flights from other locations:	73
• Australia	
• Marshall Islands	
• New Zealand	
• Pacific Ocean	

Sources: GAO presentation of Federal Aviation Administration (FAA) data and Map Resources. | GAO-24-105561

^aOperations include FAA-licensed and FAA-permitted flights. According to FAA, a permitted flight is for research and development to test design concepts, equipment, or operating techniques; showing compliance with requirements as part of obtaining a license; or crew training for a launch or reentry, using the design of the rocket or vehicle for which the permit would be issued. Licensed launch sites can change over time, and those shown here are as reported by FAA as of February 2023.

^bColocated with the Wallops Flight Facility in Virginia is the Mid-Atlantic Regional Spaceport, an FAA-licensed spaceport.

FAA Safety Oversight and Licensing Requirements for Mishap Investigations

FAA's Office of Commercial Space Transportation generally oversees the safety of the commercial space industry through its authority to license

launches and reentries, and to investigate mishaps.¹⁰ In regulating commercial space, FAA has a dual role—since, by law, it is responsible for both regulating and promoting the commercial space industry.¹¹

FAA does not regulate postlaunch, in-orbit activities, agency officials told us. The agency also does not certify launch vehicles, as FAA does for aircraft in the commercial aviation industry. Instead, officials told us, the agency’s focus is on protecting the safety of the “uninvolved public”—members of the public not involved in commercial space operations but at risk if something goes awry. Under this approach, FAA does not necessarily seek to assure the success of missions, agency officials told us, nor does it focus on individual company success or particular outcomes, such as successfully getting payloads to orbit. Instead, when a mishap occurs, the objective is that the operation “fail safely.” FAA requires remedies for failure or poor performance of safety-critical systems, officials told us.

As part of its licensing of commercial space operations, FAA requires space companies to create an FAA-approved mishap investigation plan.¹² Among other things, these plans contain procedures for investigating mishaps, should one occur, including creation of a mishap investigation team; securing evidence; identifying witnesses and conducting interviews; selecting a method of analysis to identify the likely cause; reviewing flight data; maintaining wreckage for examination; and developing corrective actions. Companies prepare these plans with guidance from FAA, before FAA accepts them and approves a launch or reentry license, agency

¹⁰Generally, FAA licenses launches and reentries in the United States as well as by a U.S. person or entity anywhere in the world, unless an operation is by and for a government entity. 51 U.S.C. § 50904; 14 C.F.R. § 400.2(a). Even when launching from a military range, such as the Cape Canaveral Space Force Station, an FAA-licensed launch remains under the oversight of FAA with respect to mishap investigations.

¹¹Specifically, FAA’s mission is to “encourage, facilitate, and promote commercial space activity by the private sector,” and to “promote public-private partnerships to build, expand, modernize, or operate space infrastructure,” while also encouraging, facilitating, and promoting the “continuous improvement of the safety of launch vehicles designed to carry humans.” 51 U.S.C. § 50903.

¹²For commercial space launch licenses granted prior to March 10, 2021, the mishap investigation plan was distinct from an *emergency response plan*, which covers dissemination of public information and notification of appropriate local officials following a mishap. 14 C.F.R. § 431.45. These licenses could cover commercial space launches that occur through March 10, 2026. For most commercial space licenses granted after March 10, 2021, these requirements—mishap investigation and emergency response requirements—were consolidated. 14 C.F.R. § 450.173.

officials said.¹³ FAA does not identify particular investigative or analytic steps that launch operators should follow in a mishap investigation, officials said. Instead, the agency's performance-based standards allow operators to determine the investigative steps that work best for them, the officials said.¹⁴ FAA typically reviews the plans when they are submitted with a license application. Later, during a license renewal or modification, or following a mishap, the agency may review a plan again, agency officials told us.

Commercial Spaceflight Activity

Commercial spaceflight activity, after remaining level in the early years of the past 2 decades, has been increasing rapidly in recent years, according to FAA data we reviewed. Specifically, there were 383 FAA-licensed commercial launches from 2000 through 2022. There have also been an additional 46 "permitted," or experimental, commercial spaceflights, for a total of 429 flights from 2000 through 2022.¹⁵ Since 2016, when a rapid expansion of commercial spaceflight activity began, the number of FAA-licensed commercial launches has grown at an average annual rate of 39 percent. For 2022, FAA reported 79 commercial space launches, for an average of one launch about every 5

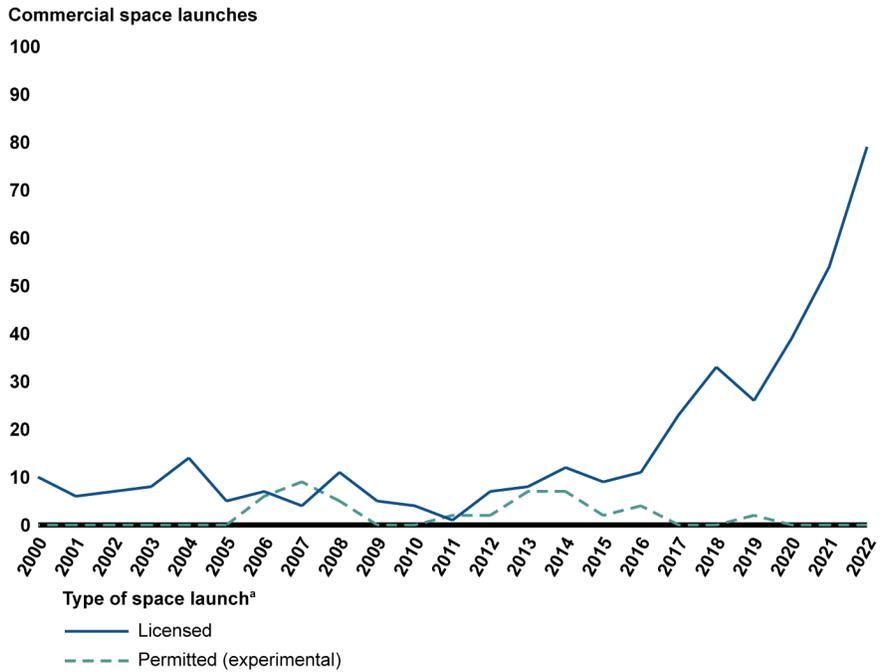
¹³According to information posted on FAA's website, a vehicle operator license may authorize launch, reentry, or both. The license covers specified pre- and post-flight operations. In addition to the mishap investigation plan requirement, as part of the licensing process, applicants must submit, among other things, information on proposed operations, mission description, unique mission aspects, vehicle description, launch or reentry site(s), program schedule, and safety information, according to FAA guidance documentation. According to FAA, safety review is the principal component of vehicle operator license evaluations. Generally, the safety review consists of evaluating the applicant's safety organization, system safety processes, and flight safety analysis, as well as quantitative risk criteria for launch, reentry, and vehicle disposal, according to FAA guidance documentation. In addition, among other things, FAA examines a license application to determine whether it presents issues affecting U.S. national security or foreign policy interests; reviews the planned payload; analyzes environmental impacts; and determines if there is evidence of financial responsibility to cover possible losses, according to the documentation.

¹⁴In Advisory Circular 450.173-1, FAA provides guidance to operators for developing a mishap plan and complying with regulations on mishap reporting, response, and investigation requirements.

¹⁵According to FAA, a permitted flight is for research and development to test design concepts, equipment, or operating techniques; showing compliance with requirements as part of obtaining a license; or crew training for a launch or reentry, using the design of the rocket or vehicle for which the permit would be issued.

days. Figure 2 shows the trend in each type of launch, with licensed launches accounting for the great bulk of all activity.¹⁶

Figure 2: Number of U.S. Commercial Space Launches, by Type, 2000-2022



Source: GAO presentation of Federal Aviation Administration (FAA) data. | GAO-24-105561

Accessible Data for Figure 2: Number of U.S. Commercial Space Launches, by Type, 2000-2022

Calendar year	Licensed (commercial space launches)	Permitted (experimental space launches)
2000	10	0
2001	6	0
2002	7	0
2003	8	0
2004	14	0
2005	5	0
2006	7	6
2007	4	9

¹⁶There currently are no active permits for experimental commercial space operations, according to FAA.

Calendar year	Licensed (commercial space launches)	Permitted (experimental space launches)
2008	11	5
2009	5	0
2010	4	0
2011	1	2
2012	7	2
2013	8	7
2014	12	7
2015	9	2
2016	11	4
2017	23	0
2018	33	0
2019	26	2
2020	39	0
2021	54	0
2022	79	0

Source: GAO presentation of Federal Aviation Administration (FAA) data. | GAO-24-105561

^aLaunches include FAA-licensed and FAA-permitted activity. According to FAA, a permitted launch is for research and development to test design concepts, equipment, or operating techniques; showing compliance with requirements as part of obtaining a license; or crew training for a launch or reentry using the design of the rocket or vehicle for which the permit would be issued.

Thus far, a relatively small number of companies account for commercial spaceflight activity. As of August 2023, FAA reported 12 companies as holding active launch licenses.¹⁷ One company held a reentry license.¹⁸ However, the number of companies involved may increase significantly, according to FAA information we reviewed. As of mid-2022, dozens of companies were in prelicensing discussions with the agency, for projects including launch/reentry facilities, launch and reentry vehicles, spaced-rated high-altitude balloons, winged rocket-powered space vehicles, and payload services.

¹⁷They were: Orbital Sciences, Northrop Grumman Systems Corp., SpaceX, United Launch Alliance, Rocket Lab Global, Astra Space, Firefly Aerospace, Virgin Galactic, Blue Origin, Exos Aerospace, ABL Space Systems, and Relativity Space.

¹⁸SpaceX. Under agency regulations, “reentry” means to return or attempt to return, purposefully, a reentry vehicle and its payload or human being, if any, from Earth orbit or from outer space, to Earth. 14 C.F.R. § 401.7.

Mishaps, of Various Causes, Have Increased as Commercial Space Activity Has Grown

Among 433 commercial spaceflights logged from 2000 to mid-January 2023, FAA identified 50 mishaps.¹⁹ According to FAA officials, none of the mishaps resulted in fatalities, or serious injuries or significant property damage to the public. Although mishaps have involved catastrophic launch explosion or system failure in flight, according to records we reviewed and FAA officials, public safety can be protected if the effects are confined to predefined ground, air, and overwater hazard areas.²⁰ Reflecting the increased pace of launches, half of all mishaps experienced have occurred in the last 3 years alone, according to FAA officials. As activity continues to grow, the number of mishaps is also expected to increase, they said.

In commercial space transportation, mishaps are an expected part of the industry's development, according to FAA officials, space company executives, and others to whom we spoke, as operators gain experience with new designs.²¹ As FAA officials put it to us, the industry approach is to "fail fast, fail safely, and fail forward," so that deficiencies can be identified and corrected, provided that public safety is not jeopardized. A commercial space trade group said this approach allows companies more freedom to innovate rather than rely on outdated approaches and technology. As one launch operator executive told us, compared with

¹⁹Of the 50 mishaps, 45 involved licensed operations, and 5 involved permitted operations. FAA officials told us that if recently adopted rules had been in effect earlier, the number of outcomes designated as mishaps could have been lower and, thus, the number of reported mishaps could have been lower. In an explanation of the proposed rules, FAA recognized the difference between operational missions and higher-risk experimental missions. As a result, FAA developed regulations establishing a test-induced damage exception. Under this exception, an applicant can avoid the mishap definition for certain damage that occurs within the scope of testing activities coordinated with FAA in advance of the test. See 14 C.F.R. § 450.175.

²⁰FAA officials noted that not all mishaps involve complete mission failures. Some of the 50 mishaps involved performance of secondary mission objectives, following successful completion of the primary mission, the officials said. Other mishaps occurred during pre- or postflight ground activities, they said.

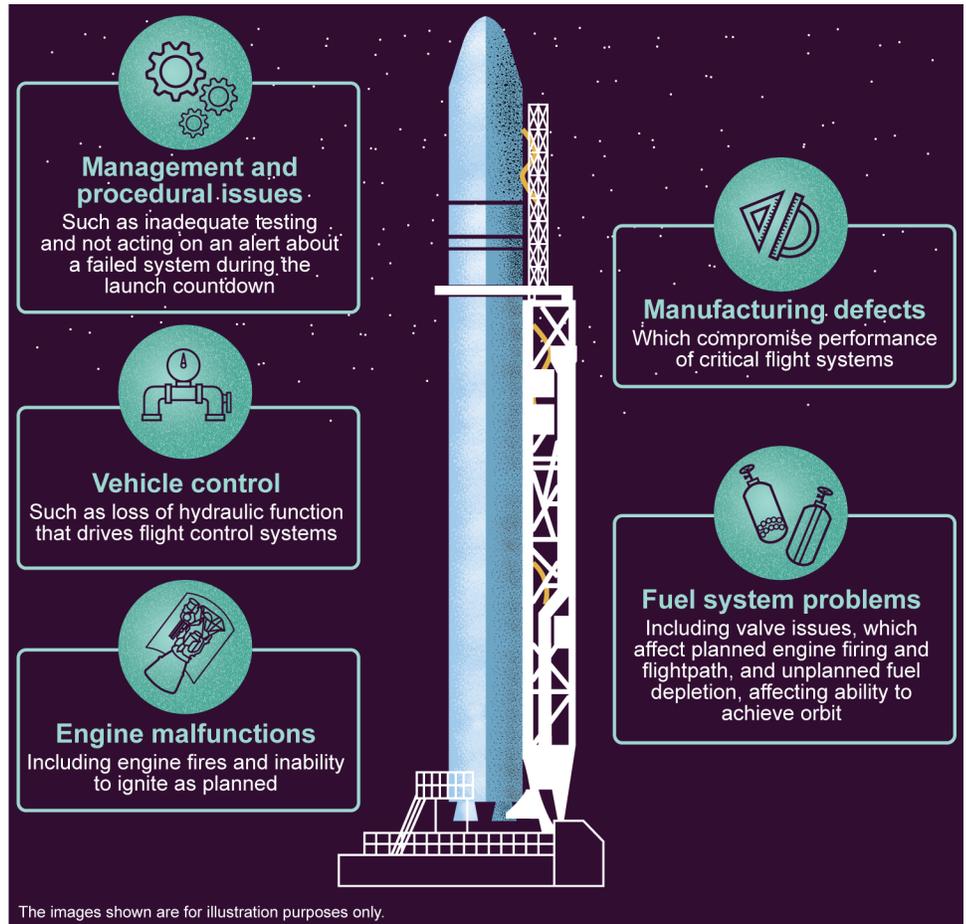
²¹In 2004, Congress found that the national goal of "safely opening space to the American people and their private commercial, scientific, and cultural enterprises should guide federal space investments, policies, and regulations." Space transportation is inherently risky, Congress declared, and a critical responsibility for the Department of Transportation, delegated to FAA, is regulation of the operations and safety of commercial space transportation. 51 U.S.C. § 50901; 49 C.F.R. § 1.83(b).

commercial aviation, where any failure is likely to be catastrophic, the commercial space sector is comfortable with a high likelihood of failure because the system already has provisions to protect public safety. Instead, the executive said, the focus is on reducing the *consequences* of the expected failures. An executive of another launch operator told us that under FAA's approach, the company in some situations will pursue higher-risk strategies to more quickly improve a rocket's design, as long as a failure would not result in damage to the public.

According to our review of FAA mishap documentation, mishaps have a variety of causes.²² Figure 3 shows examples of the types of causes we identified. Among all mishaps, early operations of a new vehicle design fail more often, according to data collected by AXA XL, a space insurance company. See appendix II for details.

²²In addition to officially recognized mishaps, other significant incidents may also occur that are not classified as mishaps, FAA officials told us. For example, an incident may take place as part of testing but is deemed outside the scope of licensed activity—meaning it was activity not for the purpose of preparing a particular vehicle for launch or associated post-flight ground operations. One such incident, for example, was an April 2019 event, when a SpaceX vehicle exploded during a launchpad test. According to FAA, the company had been testing vehicles generally, and it was not known which vehicle would become an actual flight vehicle. But once a vehicle has been identified for flight, activities taking place preflight fall under the scope of the license, according to FAA officials.

Figure 3: Examples of Types of Commercial Space Mishaps



Source: GAO icons, illustration, and analysis of Federal Aviation Administration (FAA) mishap documentation. | GAO-24-105561

Accessible Data for Figure 3: Examples of Types of Commercial Space Mishaps

- Management and procedural issues: Such as inadequate testing and not acting on an alert about a failed system during the launch countdown
- Manufacturing defects: Which compromise performance of critical flight systems
- Vehicle control: Such as loss of hydraulic function that drives flight control systems
- Fuel system problems: Including valve issues, which affect planned engine firing and flightpath, and unplanned fuel depletion, affecting ability to achieve orbit
- Engine malfunctions: Including engine fires and inability to ignite as planned

Source: GAO icons, illustration, and analysis of Federal Aviation Administration (FAA) mishap documentation. | GAO-24-105561

To officially determine when a mishap occurs—and hence whether an investigation will follow—recently adopted FAA regulations redefine a

mishap as event(s) associated with the licensed or permitted activity that result in one of nine outcomes, as shown in table 1.

Table 1: Federal Aviation Administration (FAA) Classification of Event as Mishap, Adopted in 2021

Result of Event(s) to Qualify as Mishap Under FAA Definition

1. Fatality or serious injury
2. Malfunction of a safety-critical system
3. Failure of the licensee's or permittee's safety organization, safety operations, safety procedures
4. High risk, as determined by FAA, of causing a serious or fatal injury to any space flight participant, crew, government astronaut, or member of the public
5. Substantial damage, as determined by FAA, to property not associated with licensed or permitted activity
6. Unplanned substantial damage, as determined by FAA, to property associated with licensed or permitted activity
7. Unplanned permanent loss of a launch or reentry vehicle during licensed activity or permitted activity.
8. Impact of hazardous debris outside the planned landing site or designated hazard area.
9. Failure to complete a launch or reentry as planned in a preflight report submitted to FAA

Source: Federal Aviation Administration (FAA) regulations; 14 C.F.R. § 401.7. | GAO-24-105561

This definition is one of several definitions of mishap among FAA, NTSB, NASA, and the Department of the Air Force. FAA and other agencies involved in commercial space activities define mishaps differently, based on their own missions and purposes. FAA currently has two sets of definitions. The agency adopted the definition in table 1 as part of extensive revisions to FAA's commercial space regulations in 2021. FAA also currently maintains a separate legacy definition of mishap, applicable generally to licenses issued prior to implementation of the newer agency rules in March 2021.²³ Stakeholders told us that the differing definitions among FAA and other agencies generally do not present significant operational issues. But some stakeholders said that overall safety oversight could benefit from more standardized definitions, by providing a common understanding that would facilitate better communication and understanding. The Department of the Air Force has undertaken a multiagency effort to coordinate mishap definitions. Appendix III provides

²³See 14 C.F.R. § 401.5. This older definition focuses on the occurrence of certain events or value of damage caused to items such as a payload, launch vehicle, or a launch or reentry facility. Under a 5-year transition period, all FAA-issued commercial space licenses will be subject to the new definition of a mishap no later than March 10, 2026.

more detail on different definitions among the agencies and the Department's initiative.

FAA Is Generally the Lead Investigative Agency for Mishaps and Coordinates with Other Agencies through Interagency Agreements and Other Means

Both FAA and NTSB have the authority to conduct investigations of commercial space mishaps. In practice, one of these two agencies will serve as the lead investigative agency in mishap investigations. For the 50 mishaps that occurred from 2000 through mid-January 2023, FAA was the lead investigative agency for all but one. NASA and the Department of the Air Force do not have the responsibility to serve as the lead investigative agency for FAA-licensed launch mishaps but may participate in some FAA or NTSB investigations, or conduct a concurrent investigation, although the latter is unusual.

FAA: FAA officials told us the agency has authority to investigate all licensed launch mishaps.²⁴ Consistent with this, FAA has been the lead investigative agency for 49 of the 50 mishaps involving FAA-licensed launches that occurred during the period of our review, from 2000 through mid-January 2023. According to agency documentation, the objective of FAA investigations is to determine the cause of a mishap and identify preventative measures or corrective actions.²⁵ FAA investigations are focused primarily on public safety, according to officials. When FAA has been the lead investigative agency, FAA's practice has been to authorize launch operators to lead investigations into their own mishaps, under agency supervision.²⁶ FAA will aid in an investigation when NTSB is the lead investigative agency, according to an interagency agreement.

²⁴51 U.S.C § 50917 grants FAA authority to investigate commercial space launch mishaps. FAA officials also said that relevant provisions of law—chapter 509 of Title 51—taken as a whole, establish the agency's investigative authority. FAA Order 8020.11D provides internal policies and procedures for undertaking investigations.

²⁵Federal Aviation Administration, *Mishap Response Program (P008F)* (2018).

²⁶FAA regulations require operators to conduct an investigation when a mishap occurs. 14 C.F.R. §§ 417.111(h), 450.173(e).

NTSB: NTSB also has authority to investigate commercial space mishaps. By statute, NTSB has authority to investigate accidents related to the transportation of people or property when the agency makes certain determinations, such as that the accident is catastrophic or involves problems of a recurring character.²⁷ Further, according to an interagency agreement, NTSB will also investigate mishaps involving a fatality or serious injury or where damage from debris to property not associated with the activity or site could reasonably have been expected to cause death or serious injury. According to agency officials, NTSB's safety recommendations can be addressed to a range of entities, and the purpose of the recommendations is to prevent a similar mishap from occurring.

According to our review, NTSB has been the lead in one mishap investigation—the only mishap with a fatality, involving a crew member.²⁸ The investigation was conducted in accordance with the NTSB “party” process,²⁹ with FAA named as party to the investigation.³⁰ The parties took part in the fact-finding phase of the investigation, after which NTSB determined the probable cause of the mishap and issued safety recommendations to prevent a similar mishap. Unlike investigations by

²⁷By statute, NTSB must investigate when it decides “(i) the accident is “catastrophic; (ii) the accident involves problems of a recurring character; or (iii) the investigation of the accident would carry out this chapter [NTSB’s authorizing statutes].” 49 U.S.C. § 1131(a)(1)(F). Under a memorandum of agreement between FAA and NTSB, NTSB conducts investigations that involve a fatality, or severe injury or damage to property from debris that could reasonably be expected to cause death or serious injury and the property is not associated with commercial space launch or reentry activities or the launch site.

²⁸National Transportation Safety Board, *In-Flight Breakup During Test Flight, Scaled Composites SpaceShipTwo, N339SS, Near Koehn Dry Lake, California*.

²⁹The NTSB party process is outlined in regulation. 49 C.F.R. § 831.11. To aid its investigations, NTSB designates organizations or companies as parties to an investigation. Only those entities whose employees, functions, activities, or products were involved in the accident and that can provide suitable qualified technical personnel to actively assist in an investigation are granted party status. 49 C.F.R. § 831.11(a)(1). All party members follow directions and instructions of NTSB. 49 C.F.R. § 831.11(a)(4). They do not participate in analysis of information or report writing but are invited to submit proposed findings of cause and proposed safety recommendations, which are made part of the public docket, according to NTSB. The party system allows for subject matter experts to be included in the investigation while maintaining NTSB’s independence, NTSB officials told us.

³⁰According to NTSB, the Department of Transportation is a party to all NTSB investigations because it is the oversight authority. The other parties to the investigation were Scaled Composites, Virgin Galactic, and Butler Parachutes.

FAA and other federal agencies, NTSB's reports and the agency's safety recommendations are released publicly to the extent the law allows.

NTSB and FAA authorities related to investigating commercial space mishaps overlap, but agency officials have told us that, guided by interagency agreements, they have worked to determine the lead investigative agency for all mishaps to date.³¹

NASA: NASA does not have primary responsibility for mishap investigations involving FAA-licensed flights.³² However, agency officials told us NASA may participate as an observer of another agency's mishap investigation, or could also elect to conduct an investigation by an "independent review team." NASA has undertaken two such independent investigations, according to agency officials. NASA officials told us the agency may elect to conduct its own investigation if the mishap involves an FAA-licensed launch that was conducted under contract to NASA or involves launch vehicles, launch vehicle systems, or components similar to those NASA uses—a process that it calls "fleet following." NASA officials said the agency has three types of investigative interest, focusing on

- crew;
- cargo transportation, such as to the International Space Station; and
- NASA science missions.

An independent NASA investigation would generally be focused on overall mission execution, including crew safety, rather than a focus of third-party public safety, as with FAA investigations, according to NASA officials. A NASA investigation would not necessarily produce different

³¹Overlap occurs when multiple agencies or programs have similar goals, engage in similar activities or strategies to achieve them, or target similar beneficiaries. See GAO, *Fragmentation, Overlap, and Duplication: An Evaluation and Management Guide*, [GAO-15-49SP](#) (Washington, D.C.: Apr. 14, 2015). NTSB and DOT both have investigative authority related to other modes of transportation. NTSB must investigate civil aircraft and certain railroad accidents. 49 U.S.C. §§ 1131(a)(1), 1132. DOT, through FAA in relation to aviation safety, has the authority to conduct investigations concerning aviation safety. 49 U.S.C. § 40113. NTSB must also "establish the facts, circumstances, and cause or probable cause" of certain railroad accidents. 49 U.S.C. § 1131(a)(1). Similarly, the Federal Railroad Administration, by delegation from the Secretary of Transportation, may investigate certain railroad accidents and incidents. 49 U.S.C. § 20902(a); 49 C.F.R. § 1.89(a).

³²Specifically, NASA officials said NASA does not have primary responsibility for mishap investigations during FAA-licensed flights for mishaps that occur during FAA-licensed mission phases.

results but might, for example, examine different issues, in accord with NASA objectives, the officials said. In addition, NASA can choose to examine matters outside the scope of FAA-licensed launch and reentry operations, they said.

Department of the Air Force: The Department of the Air Force also does not have primary responsibility for mishap investigations involving FAA-licensed flights. Department officials may participate as official observers of a mishap investigation conducted by NTSB, and they may be offered party status to an NTSB investigation. In certain situations, such as an interagency mission, the Department may choose to conduct its own parallel, privileged, safety investigation, a Department official told us, but has not yet done so. In addition, for a mishap on an FAA-licensed flight occurring on a Department of Defense range, or involving a common launch vehicle, system, or components, the Department of the Air Force may conduct an independent analysis of materials gathered in the mishap investigation, the Department official said. Citing differing agency objectives, the official said Department-led mishap investigations focus solely on root cause, in order to prevent future mishaps.

Given their authorities, interests, and expertise, the agencies have developed a series of formal and informal arrangements to help determine which agency should lead a mishap investigation and the role of other agencies in the investigation. Some agency officials told us that even with the overlap in authority and jurisdiction, these arrangements help make the process of determining which agency should lead mishap investigations work.

Interagency Agreements

The four agencies—FAA, NTSB, the Department of the Air Force, and NASA—have entered into a series of agreements over time that define agency roles and responsibilities for mishaps and address other matters, such as achievement of mutual goals. These agreements include

- **a 2000 MOA between FAA and NTSB:** FAA and NTSB signed a memorandum of agreement (MOA) in January 2000, which updated an appendix to a 1975 agreement and detailed relationships, notification procedures, coordination requirements, and reporting responsibilities for FAA and NTSB for accident investigations involving

commercial space launch activities.³³ This MOA was in effect for the majority of mishaps that have occurred and was superseded by an MOA signed by FAA and NTSB in 2022;

- **a 2004 MOU between FAA, NTSB, and the Department of the Air Force:** This 2004 memorandum of understanding (MOU) did not supersede the 2000 agreement but established an agreement to include the Department of the Air Force's role in space launch accidents and mishaps. It also stipulated that Department officials could participate as "observers" to an NTSB investigation, or they could be offered "party status" to an NTSB investigation in accordance with regulation and in appropriate circumstances.³⁴ The MOU reiterated that NTSB or FAA will be the lead investigative agency for commercial space mishaps, with the Department of the Air Force as the lead agency for mishaps involving Department-certified launches (as distinct from FAA-licensed launches);
- **a 2021 MOU between FAA and NASA:** This agreement was intended to help provide a framework related to the agencies' requirements, to exchange knowledge, and to collaborate in areas of mutual interest. The agreement provides that FAA and NASA will coordinate on lessons learned from mishap investigations and on an approach for sharing safety data with the public to enhance understanding of the risks of space; and
- **a 2022 MOA between FAA and NTSB:** In September 2022, FAA and NTSB entered into an MOA that replaced the 2000 MOA between FAA and NTSB.³⁵ The 2022 agreement states that NTSB will take the lead in an investigation if the mishap involves (1) a fatality or serious injury to any person; or (2) damage to property from debris that could reasonably be expected to cause death or serious injury, and the property is not associated with launch or reentry activities or the launch site. The MOA also specifies processes to promote coordination between both agencies during a mishap investigation,

³³In 1989, the Office of Commercial Space Transportation and NTSB first signed an appendix specific to responsibilities for accidents involving commercial space launch activities.

³⁴The MOU states that the Department of the Air Force may be offered party status to an NTSB investigation "in accordance with the provisions of 49 C.F.R. Part 831, in appropriate circumstances." 49 C.F.R. Part 831 contains regulations establishing NTSB's investigation procedures.

³⁵According to agency officials, the agencies attempted to update the 2000 agreement in 2014; however, the efforts did not succeed. Officials told us they could not recall why this occurred.

including exchange of data, public release of information, and timeliness of the investigations. In addition, the MOA states that when NTSB investigates a mishap of an FAA-licensed launch, NTSB shall designate FAA as a party under NTSB's party system of accident investigation, and when FAA leads the investigation, NTSB will be an official observer.³⁶ However, even before the 2022 MOA, industry participants told us it was generally understood that NTSB would take the investigative lead in more serious incidents.³⁷

The 2022 FAA-NTSB MOA does not affect the existing authorities of the two agencies,³⁸ and officials acknowledged that, as a result, there is still the potential for overlap to occur in matters not addressed in the agreement. They said they have agreed to address such matters as they may arise. According to FAA officials, FAA and NTSB agreed the two agencies would not debate their respective roles and, instead, decided to leave the issue to Congress for any consideration.³⁹

Other Collaborative Mechanisms

Officials described other collaborative mechanisms aimed at supplementing the formal authorities and agreements. These mechanisms can foster agency collaboration and coordination, and aid

³⁶According to a prior interagency agreement, FAA would have been automatically granted party status, even prior to the 2022 FAA-NTSB MOA, for mishap investigations in which NTSB was the lead investigative agency.

³⁷Legacy FAA regulations required operators to comply with an NTSB investigation. This language was dropped in a 2020 FAA rulemaking revising many of FAA's commercial space launch and reentry license regulations. See Streamlined Launch and Reentry Licensing Requirements, 85 Fed. Reg. 79,566 (Dec. 10, 2020) (codified at 14 C.F.R. ch. 3).

³⁸*Memorandum of Agreement Between National Transportation Safety Board & Federal Aviation Administration Concerning Commercial Space Mishap Investigations*, § 2(d) (Sept. 9, 2022).

³⁹As of August 2023, there were proposed efforts to clarify agencies' roles in mishap investigations. In addition, in November 2021, NTSB issued a proposed rule. Commercial Space Investigations, 86 Fed. Reg. 63,324 (proposed Nov. 16, 2021). The proposed rule would codify commercial space investigations into its regulations and states that NTSB investigations have priority over any investigation of another department or agency. It would establish notification requirements for launch operators and when the NTSB would conduct an investigation. FAA and others have objected to the proposed rule, saying it represents an expansion of NTSB authority. The proposed rule is still pending, and NTSB has indicated it will issue an amended proposal.

investigation of commercial space mishaps. Among them are the following:

- In 2017, FAA, NTSB, NASA, and the Department of the Air Force formed an entity known as the Quad-Agency Working Group.⁴⁰ According to NASA officials, the group meets at least quarterly to help members understand each other's processes and procedures, ensure proper execution of the interagency agreements, and build relationships. The Quad-Agency Working Group's activities include engaging in tabletop exercises, where government and industry stakeholders simulate mishap scenarios to understand each entity's procedures and to address potential issues before an actual mishap response is required. The group does not have regulatory authority or an official role in mishap investigations. Instead, it is an informal forum to provide guidance on mishap prevention and investigation, according to agency officials. An NTSB official noted the importance of having relationships among the agencies established before a mishap occurs, to facilitate a smoother response and investigation when one does occur.⁴¹
- The Space Safety Council is a forum chaired by the Department of the Air Force chief of space safety, focusing on Department space safety issues. Some council activities are open to space stakeholders, such as FAA, NASA, NTSB, industry, and academia, which regularly attend meetings, a Department of the Air Force official told us. The council does not have an active role in mishap investigations, the Department official said, but it does influence development of mishap prevention and investigation policies, programs, and guidance. It meets semi-annually to address areas including pre-launch, launch, reentry, orbital, and ground-based operations, the official said.
- FAA, NASA, and the Department of the Air Force in 2004 chartered the interagency Common Standards Working Group. As described by a Department of the Air Force official, the working group's focus is protecting the public and critical assets from hazards of launches and

⁴⁰NTSB officials noted the group had been meeting since before 2008, with a formal charter signed in 2017.

⁴¹In addition, to aid in determining the lead investigative agency for a mishap, the Quad-Agency Working Group uses what is known as the "Tri-fold"—a grid-style, at-a-glance compilation for launches involving NASA missions. The Tri-fold identifies the investigative authority based on phase of flight during which a mishap occurs and consequences of the incident. It addresses dozens of possible scenarios for NASA missions, and FAA officials told us the fact the need was apparent for such a guide demonstrates the complexity of the current regulatory and investigative regime.

reentries, and developing a framework of common safety standards and recommended practices for the space launch industry.

FAA Authorizes Space Companies to Lead Mishap Investigations but Has Not Fully Documented Its Process or Evaluated Effectiveness

FAA Authorizes Space Companies to Lead Mishap Investigations, Under Agency Oversight

FAA Decision to Authorize Space Companies to Lead Mishap Investigations

When a commercial space mishap occurs, and FAA is the lead investigative agency, FAA decides on a case-by-case basis whether to conduct an investigation itself, agency officials told us, or to instead authorize the company involved to lead the mishap investigation, on FAA's behalf and under agency oversight.⁴² FAA officials told us they make their decisions to authorize operator-led investigations depending on the level of investigation required, which is largely based on severity of the mishap or its consequences and may also take into consideration the level of public interest.⁴³ However, in practice, FAA authorized the operator involved to lead the investigation of its mishap for all 49 mishaps

⁴²In any case, regardless of an official FAA investigation, agency regulations require an operator to investigate mishaps. 14 C.F.R. §§ 417.111(h), 450.173. The distinction is that operator-led investigations, as authorized by FAA, are done on FAA's behalf and under agency oversight. The *authorization* for an operator-led investigation does not amount to FAA legally *delegating* its investigative authority to the company involved in the mishap, FAA officials told us. As the authorizing agency for an operator-led investigation, FAA maintains ultimate investigative authority, FAA said.

⁴³Agency mishap response procedures refer to "the nature and consequences of a mishap."

for which FAA had lead investigative authority, according to our review of agency data.⁴⁴

FAA relies on the operator-led approach, agency officials told us, because, given highly specialized vehicle designs among companies, the agency does not have adequate resources for in-house investigations. For FAA to develop the capability to investigate mishaps in-house would be an immense undertaking that would mean investigations would take 10 to 20 times longer, officials told us. In addition, they said, operators know their vehicles best and, when trying to identify root cause of a failure, an intimate knowledge of vehicle design is necessary.⁴⁵

FAA Oversight of Operator-Led Investigations

After FAA has authorized an operator to lead a mishap investigation, the agency sends an email to the operator, detailing the agency's expectations for the investigation, according to agency officials. FAA expects the operator to implement its previously approved mishap investigation plan. The expectations further include notice of, and access to, company investigation-related meetings or reviews; regular status updates; access to records and data; and review of results.⁴⁶ According to FAA, when a mishap occurs, the operator's license remains active and is not suspended. However, FAA's regulations require that, unless otherwise approved by FAA, the operator must identify and implement

⁴⁴In the 50th case—involving the only mishap fatality to date, in which NTSB took the investigative lead—FAA approached NTSB to take the lead, out of concern FAA did not have sufficient resources, a former FAA official told us. NTSB officials, however, told us that NTSB initiated its investigation immediately after the fatal mishap under its authority, and notified FAA of its decision.

⁴⁵If event(s) take place that do not rise to the level of a mishap, FAA may nevertheless elect to further pursue the matter, agency officials told us. On the basis of the nature of the event or systems involved, FAA may request information from a launch operator, they said. For example, this could include if additional data were required to make a determination whether the event was, in fact, a mishap. FAA may also request information to verify accuracy of modeling assumptions compared with actual flight data, to verify expected vs. actual flight environments, or to determine if an operator deviated from its established procedures.

⁴⁶According to FAA guidance, analysis of the root cause of a mishap should begin with identifying systems that had the ability to contribute to the event, and then proceed to iteratively investigating areas of concern until finding a true root cause. This process typically ends at an organizational root cause linked to design, operations, or both. Data and physical evidence to be collected and preserved during the investigation include debris, vehicle drawings, inspection and maintenance records, vehicle flight telemetry, and witness statements, according to the guidance.

preventative measures (corrective actions) to avoid a recurrence of the mishap prior to returning to flight.⁴⁷

During the operator-led investigation, FAA will “provide active oversight of all investigation activities, to include, but not limited to, analyses, discussions, and the final report review and approval process,” according to agency mishap response procedures. FAA officials told us that the agency’s oversight of operator-led investigations can encompass a range of activities. FAA may go into the field to make observations of the mishap site or ensuing investigation.⁴⁸ The agency participates in operator team meetings, reviews test results, and monitors to see that the company follows its preapproved mishap investigation plan. FAA officials said they can also bring in subject-matter experts from among agency staff and invite stakeholders into the investigation as observers.⁴⁹ FAA also monitors development and implementation of corrective actions, officials said, and agency subject-matter experts will review all data that applies to safety concerns. Overall, they told us, FAA oversight includes daily activities of the mishap investigation, both remote and in-person, as deemed appropriate for a particular investigation.

In some cases, FAA has directed operators to conduct further inquiries in their operator-led investigations, officials told us, including when FAA does not believe the operator has identified organizational cause. In the case of one mishap, for example, the operator-led investigation determined that a piece of hardware had not been qualified for flight, officials told us. Once that technical cause was identified, FAA directed the company to look organizationally at what could have been done differently in qualifying the hardware for use. If the company had tested

⁴⁷14 C.F.R. § 450.173(f).

⁴⁸FAA may also go on-site before a launch. Officials told us that for each launch, FAA analysts assign a probability of failure. If the probability is sufficiently large, together with other factors that might be relevant, FAA staff may elect to attend the launch, officials told us.

⁴⁹NTSB officials told us the board has been an observer on almost all operator-led mishap investigations, by participating in operator team meetings, taking part in testing, reviewing test results, and reviewing draft mishap investigation reports. It does so for overall knowledge and to understand findings and lessons learned for any future investigation, the officials said. Under the 2022 FAA-NTSB memorandum of agreement, if NTSB investigates, FAA will be a party to the NTSB investigation; and if FAA investigates, NTSB will be an official observer of the FAA investigation.

the final assembly, a failure probably would have been discovered prior to flight, the officials said.

In reviewing the companies' draft investigation reports, FAA officials said they will make suggestions and offer guidance on report content, as necessary, such as to ensure key findings or analysis are included. Given the extent of agency involvement in overseeing mishap investigations and preparing subsequent mishap investigation reports, the officials told us, approval of an operator's final investigation report is generally expected upon submission. As one launch operator told us, for example, because FAA was closely involved in the operator-led investigation, review of the final report was perfunctory.

FAA officials also said they adjust the agency's level of involvement in the company's investigation, as necessary, for circumstances of a mishap and experience level of the company involved. For example, officials cited three mishaps in recent years in which FAA involvement was in greater depth, due to factors such as involvement of a vehicle's safety system in the mishap or a launch operator using an unapproved flight analysis. In addition, a company might be conducting its first investigation and need a more hands-on approach from FAA, agency officials said. Meanwhile, for launch operators more experienced in mishap investigations, FAA oversight might be targeted at more specific items, agency officials told us. An executive of one operator, who has been through the mishap investigation process, said FAA did not offer much direction on specific conduct of the investigation. Instead, FAA provided a broad goal for the probe—focusing on public safety—and the company was able to structure the investigation as it preferred. FAA was also clear in distinguishing its public safety focus from overall mission success, the executive said.

As part of operator-led mishap investigations, FAA also expects space companies to self-report relevant regulatory compliance issues discovered in the course of the investigation, such as violation of FAA regulations or license terms and conditions, according to agency officials.⁵⁰ FAA told us that in about 11 percent of mishaps, there have been findings of noncompliance specifically related to the mishap. Most all compliance investigations lead to subsequent compliance action, officials said, with such investigations typically focused on launch countdown issues. FAA officials told us that based on their experience

⁵⁰According to FAA mishap procedures, for every mishap, an element of compliance investigation is required, and operator-led investigations have compliance monitoring requirements.

with operators, they do not believe that space companies have ever failed to self-report compliance issues identified in operator-led mishap investigations. They said they have never seen an operator willfully seek to hide a violation of an FAA regulation.⁵¹

Recent Changes to FAA's Mishap Investigation Process

Expedited return-to-flight: In 2020, FAA began a new practice in which operators conducting operator-led mishap investigations can be cleared to return to flight before completion of the investigation and determination of the root cause, provided that “safety-critical” systems are ruled out as the cause of the mishap, among other factors.⁵² The agency relies on operators to provide a list and description of each safety-critical system as part of its application for a public safety determination.⁵³ This practice, which FAA adopted after industry inquired about the possibility of doing so, is known as a “public safety determination.” It allows operators to resume launches more quickly and maintain flight schedules following a mishap than if approval was withheld until completion of the investigation, officials said. The determination can be made after a multistep FAA review process that begins when an operator submits a request for such a determination, according to the agency.⁵⁴ The process is in keeping with the agency’s focus on public safety when licensing, and not mission assurance, officials told us.

⁵¹For disposition of such compliance matters, FAA officials told us that if the agency observes, or operators report, noncompliance during a mishap investigation, FAA provides the relevant information to safety inspectors assigned to the mission or the Office of Commercial Space Transportation’s Compliance and Enforcement team for further investigation. FAA seeks to keep mishap investigations and noncompliance investigations separate, when possible, to encourage open sharing of information, the officials told us.

⁵²In addition to safety-critical systems, FAA takes into account the nature and consequences of the mishap, adequacy of existing flight safety analysis, safety organization performance, and environmental factors, agency officials said.

⁵³Under its regulations, FAA defines “safety-critical” as essential to safe performance or operation. A safety-critical system, component, process, or other item is one whose proper recognition, control, performance, or tolerance is essential to ensuring public safety and the safety of property. 14 C.F.R. § 401.7. Given differences in launch vehicles, safety-critical systems may vary considerably across vehicles, FAA officials told us.

⁵⁴FAA relies on data provided by the operator and other sources, as necessary, officials said. Other sources may include a federal launch range, a launch site operator utilized for the launch, or other federal agencies. FAA relies on its general licensing authority, 51 U.S.C § 50905, to make public safety determinations, agency officials told us.

Through its contacts with operators, FAA is encouraging operators to make use of the public safety determination process for earlier return-to-flight. If an operator is unaware of the process, FAA will provide details of the option and may advise an operator to submit a request, agency officials told us. As of March 2023, the agency had granted such approvals in four cases. The first instance in which FAA granted a public safety determination came after a battery failure on a commercial flight led to loss of thrust, and the vehicle failed to reach orbit, according to agency information we reviewed. After reviewing public safety-related issues, FAA authorized return-to-flight under a modification of the launch license. In all, agency officials described the public safety determination process as evolving and said FAA's initial implementation has worked well and been favorably received by the industry. Overall, they said, it allows FAA to perform its public safety role, including early identification and addressing of potential public safety risks, while allowing the quicker return-to-flight.

New requirement for identifying root cause: The purpose of a mishap investigation, according to FAA documentation, is twofold: First, to identify the immediate event(s) that set off a series of events to cause the anomaly—known as proximate cause—as well as the fundamental reason the anomaly occurred—known as root cause. The second purpose is to identify and adopt preventative measures or corrective actions to avoid recurrence of the event. Even though a mishap may not have resulted in fatalities, serious injuries, or public property damage, if the operator does not identify and address the underlying cause, it may endanger public safety during a future launch in different conditions, according to the agency.⁵⁵

Over time, FAA has encouraged—and now requires—identification of the underlying, or root, cause that produced the failure. First, it was identified as a best practice for mishap investigations; later, it was elevated in prominence through inclusion in internal agency mishap investigation procedures.⁵⁶ Then, in 2021, FAA implemented its new regulations requiring, among other things, that operators investigate root cause of the

⁵⁵Federal Aviation Administration, Streamlined Launch and Reentry Licensing Requirements, 84 Fed. Reg. 15,296, 15,352 (proposed Apr. 15, 2019).

⁵⁶Federal Aviation Administration, *Mishap Response Program (P008F)*: secs. 9 and 10, respectively. Although current mishap procedures call for investigation of root cause, FAA officials could not say when those provisions first entered the procedures. Prior to when it was adopted into the procedures, identifying root cause was recognized as a best practice, the officials said.

mishap and report results to FAA.⁵⁷ FAA officials told us that codifying this requirement into agency regulations, versus including it in an agency procedures manual, has the effect of imposing the requirement on operators.

FAA officials told us the agency needs to improve its oversight of operator-led mishap investigations to better ensure root cause is identified in those investigations.⁵⁸ To observe findings on mishap causes, we examined mishap investigation reports completed before the regulations requiring identification of root cause became effective; however, while no requirement existed for operators, DOT internal agency mishap investigation procedures did include determining if root cause was identified. We found instances where operator-led mishap investigation reports, while identifying technical cause of a mishap, did not appear to identify root cause, as defined in FAA mishap response program documentation.⁵⁹ For example, following one mishap, the operator-led investigation identified cause as a structural failure, without further inquiry on why or how the failure took place.

We reviewed 40 mishap investigation reports completed under the previous regulations, before the new regulations required identification of root cause. Asked about our findings, FAA officials acknowledged to us that a number of mishap investigation reports, while addressing proximate cause, have not addressed root cause. They attributed omission of root cause to the fact that FAA's mishap program and procedures have developed over time. Further, they said the agency should have done a better job to see if root cause was identified in the company-prepared mishap investigation reports. They cited the new regulatory requirement for identifying root cause and said FAA can do a better job during its review of operators' mishap investigation reports. Also, the officials acknowledged that operators' mishap investigation reports have been of varying formats, length, and method of presentation. The agency is now recommending, in guidance to operators, that they use a more standard format in preparing those reports, the officials said.

⁵⁷14 C.F.R. 450.173(e).

⁵⁸In some cases, as a former FAA administrator noted, identifying root cause may not be possible; for example, if physical evidence is damaged or destroyed in the mishap.

⁵⁹As noted earlier, root cause means the fundamental reason an anomaly occurred, according to FAA mishap response program documentation.

Outside reviews: In 2020, FAA contracted with an independent research center—The Aerospace Corporation (Aerospace)—to provide third-party reviews of selected operator mishap investigations, according to Aerospace executives and FAA officials.⁶⁰ FAA officials told us the intent was to obtain technical support and subject-matter expertise in mishap investigations.⁶¹ FAA told us the agency’s considerations for determining whether Aerospace will conduct a mishap investigation review include the current workload and availability of FAA resources, the nature and complexity of the mishap, the consequences and impact of the mishap, and the urgency of the investigation. As of August 2023, Aerospace had reviewed four operator-led mishap investigations, with reviews of several others in progress. According to FAA, the agency seeks Aerospace’s independent assessment of the operator’s performance during its mishap investigation, as well as identification of any issues of concern, lessons learned, or suggested process improvements for either the operator or FAA.⁶²

FAA officials said they intend to continue working with the research center and are evaluating the best method of sharing results identified in the Aerospace reports with launch operators and the public.⁶³ According to FAA officials, options under consideration include postmishap reviews among operators, Aerospace, and FAA; some method for publicly sharing anonymous lessons learned or common themes; FAA internal mishap case studies; and sharing of lessons learned and common themes with government participants through the Quad-Agency Working Group.

⁶⁰Aerospace is a federally funded research and development center under the sponsorship of the Department of Defense, with headquarters in El Segundo, Calif. According to Aerospace, it is committed exclusively to the space enterprise and performs technical analyses and assessments for government, civil, and commercial customers.

⁶¹In particular, FAA officials said the agency turns to Aerospace to supplement FAA resources or to support mishap investigations when agency resources are unavailable. Aerospace tasks include working closely with launch operators doing analysis for a mishap, performing ground tests, and gathering information for determination of root cause, Aerospace executives told us.

⁶²FAA has no plans to make Aerospace reports public, agency officials said, because the reports may contain operator proprietary information and other information subject to certain export restrictions or otherwise protected by law from public disclosure.

⁶³FAA, pleased with the Aerospace results, has now “largely defaulted” to requesting Aerospace support for all mishaps, agency officials said, but each determination is made on a case-by-case basis.

In examining the Aerospace reviews, we found they identified larger, more systemic issues as mishap causes, which the operator-led investigations did not include. For example, one operator-led mishap investigation identified two likely direct causes of the mishap but did not consider systemic issues. By contrast, the Aerospace report for that investigation went beyond the narrower technical issues in the operator report to consider broader matters, citing issues with several of the company's basic developmental processes.

Identifying the full scope of cause is significant because assessment of cause leads to determining appropriate preventative measures or corrective actions. This, in turn, is designed to avoid recurrence of the mishap.⁶⁴ FAA officials acknowledged that the results of the Aerospace reviews provide a broader explanation of mishap cause than the operator-led investigations but said that does not necessarily indicate the operator-led investigations are too narrow or insufficiently comprehensive. FAA expected a broader analysis, officials told us, because the agency asked Aerospace to include its observations.⁶⁵

⁶⁴Currently, FAA oversees the implementation of corrective actions cited in a mishap investigation in three ways, agency officials told us: (1) actions identified in the mishap investigation and implemented by time of completion of the mishap investigation report, (2) as part of a license modification, and (3) as part of FAA's safety inspection process. FAA is now working to develop a method for verifying full implementation of all corrective actions identified during mishap investigations, officials said. This process may be completed by the end of fiscal year 2024 and could lead to new ways for verifying corrective action implementation, the agency officials said.

⁶⁵Relatedly, NASA has conducted two independent investigations of mishaps involving FAA-licensed flights. As with the Aerospace reviews, we observed that the NASA findings were broader than the operator-led investigations in identifying mishap cause. In one, involving failure shortly after launch, the operator-led investigation cited an engine problem as the highly probable technical root cause. NASA, by contrast, could not isolate a single technical root cause, but identified what it said were three credible causes broader in nature than the operator finding. In the other instance, involving a tank on the launch vehicle, the operator-led investigation concluded the most probable cause was a material flaw. NASA, however, again had broader findings, more centered on the operator and its basic processes. NASA officials told us the agency has provided summary results of its findings to FAA. FAA officials told us the agency receives only publicly available summaries of the NASA reports. As a result, the NASA reports are of limited utility for FAA because they lack underlying technical data, information on tests performed by NASA, or NASA's evaluation criteria/methodology employed, FAA officials said. NASA officials said their agency's investigations involve proprietary and export-controlled data, as well as privileged witness information, which limit distribution.

Views of FAA's Operator-Led Mishap Investigation Process

Generally, FAA officials, industry stakeholders, and operators supported FAA's approach of authorizing operator-led investigations. Some stakeholders raised questions about whether operators can independently investigate their own mishaps, and operators we spoke with discussed steps they take to maintain the independence of their investigations.

FAA: According to FAA officials, the industry has demonstrated it can conduct complex, robust investigations. Nonetheless, FAA officials acknowledged potential benefits to conducting its own investigations in-house, if it were able to do so. These include the ability to conduct independent probes, and the potential to more broadly identify organizational issues as mishap causes, which could help prevent future mishaps, the officials said. However, due to specialized, near-unique vehicle designs among operators, the officials said, it would be extremely difficult for FAA to develop the expertise necessary for in-house investigations, and the investigations would take many times longer. Given that, in the alternative, FAA relies on subject-matter experts, who focus on functional areas, such as propulsion, officials said. In particular, the experts focus on understanding systems and asking questions about how operations take place, in order to oversee the investigations, FAA officials said.

Launch operators and other stakeholders: Operators and other industry stakeholders we spoke with generally supported the FAA approach of authorizing operator-led investigations. Like FAA, space companies cite their staffs as being the most familiar with their respective technologies.

Nonetheless, a few industry stakeholders questioned whether launch operators can be impartial or effective investigators of their own mishaps, whether they can be relied upon to self-report compliance issues found in the course of mishap investigations, or whether the new expedited return-to-flight policy is sound. Several stakeholders cited the general notion of independence and questioned whether a company can credibly investigate itself. NTSB officials told us that launch operators leading investigations inherently have an interest in the findings and in conducting a probe into their own activities. A commercial space insurer told us that, especially with newer operators and their mishaps, there are always

questions about whether investigations are sufficiently rigorous, owing to inexperience.

Some launch operators we interviewed described to us how, internally, they take steps to support operator-led probes and maintain independence of their investigations. For example, one operator cited a segregation-of-duties approach, in which the company separates staff who worked on the program experiencing the mishap from the staff investigating the event. Similarly, another operator said it typically assigns a lead investigator from a safety organization that is an independent unit within the company.⁶⁶ Another operator cited assignment of the investigation to a member of senior management with technical experience to run the probe—to both provide independence and sufficient seniority and organizational authority to force an investigation where it needs to go.

Stakeholders also cited other factors they said can provide incentives for conducting credible operator-led investigations. Marketplace incentives are one, with operators wanting, for example, to maintain customer confidence, avoid damage to sales, and not trigger repercussions in financial markets that might disadvantage the company.

Insurance requirements can also provide a safety incentive, according to an executive of a space insurer. As part of licensing launches and reentries, FAA requires launch operators to provide evidence of funds to compensate for the expected “maximum probable loss”—certain claims from death; bodily injury; or damage to property as a result of a licensed activity, including as a result of a mishap.⁶⁷ The most common and preferred method for doing so is purchase of insurance for third-party liability and damage to government property, according to the insurance

⁶⁶Segregation of duties is a principle of internal controls generally. See, for example, GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: Sept. 2014), principles 10.12-10.14.

⁶⁷14 C.F.R. §§ 440.7, 440.9(a), (f). Statute also requires a licensee to obtain liability insurance or demonstrate financial responsibility to compensate for the maximum probable loss. 51 U.S.C. § 50914. A licensee must also sign a reciprocal waiver of claims agreement with certain parties involved in the launch or reentry (contractors, subcontractors, customers, contractors and subcontractors of customers, and space flight participants). Under this agreement, each party consents to waive any future claims against the other involved parties, assuming financial responsibility for damage to life or property it sustains from an activity carried out under the applicable license. 51 U.S.C. § 50914(b).

executive.⁶⁸ Especially in the case of new launch vehicles, the executive told us, the insurance company will closely examine safety matters, such as safety zones and method for flight termination.

FAA Has Not Documented Criteria for Authorizing Operator-Led Investigations or Evaluated Effectiveness of Mishap Investigations

Criteria for Authorizing Operators to Lead Investigations

FAA has written procedures for mishap investigations.⁶⁹ These cover a range of areas, including operator mishap investigation plans, FAA's actions when a mishap occurs, mishap investigations, oversight of an operator-led investigation, and mishap response training.

Although FAA told us it determines on a case-by-case basis whether the agency itself, or space companies involved, will lead mishap investigations, the agency has no specific criteria among its procedures for making those case-by-case determinations. Agency mishap procedures cite "nature and consequences" of the mishap as the basis for making a decision whether an investigation will be operator led. Agency officials further told us that considering those factors includes the level of investigation thought to be required, which is largely based on severity of the mishap and its consequences and, possibly, the level of public interest. However, agency documentation does not define what would represent the varying nature, consequences, degree of public interest, or level of investigation required. FAA officials told us that current procedures are not more specific by design, because the agency wants to maintain flexibility, given the many kinds of mishaps that can occur. However, as a result, FAA does not have clear standards by which to determine whether to authorize operators to lead investigations and, by extension, cannot ensure consistency in its decisions.

⁶⁸The federal government shares liability risks with the commercial space launch industry for mishaps that result in damages to third parties or federal property. In 2018, we reported that FAA did not fully address mandated requirements for commercial space launch insurance, as specified in the U.S. Commercial Space Launch Competitiveness Act. We made four recommendations to the agency; as of September 2023, all remained open. See GAO, *Commercial Space Launch Insurance: FAA Needs to Fully Address Mandated Requirements*, [GAO-18-57](#) (Washington, D.C.: Jan. 16, 2018).

⁶⁹See, for example, Federal Aviation Administration, *Mishap Response Program (P008F)*; and *Mishap Notification and Response Handbook (P008F-1)*.

We spoke with FAA field staff at a launch facility, who likewise described a lack of specific criteria regarding whether an operator should lead the mishap investigation. When a mishap occurs, the field staff will recommend to headquarters staff whether the investigation should be operator led, the staff told us. However, there are no written rules or criteria for that recommendation, the staff said. Instead, recommendations are based on judgment and experience over time, they told us. They also said that other factors, including whether outside observers will join the investigation and how active a role they might play, could also affect the field staff's recommendation. FAA could also elect to conduct its own investigation concurrent with one conducted by an operator, the staff told us, although they could not recall that happening.

Internal control standards for the federal government call for documenting policies for agency operations, consistent with organizational objectives, and at an appropriate level of detail to allow effective monitoring of the process.⁷⁰ Without specific criteria for making the case-by-case determinations, FAA cannot ensure that it is appropriately assessing and determining whether an operator should lead an investigation of its own mishap. Having no clear standard, FAA also cannot effectively monitor those determinations. Agency officials told us that mishap procedure documentation provided to us is being updated to reflect agency organizational changes, but they did not cite revisions to criteria for determining whether to authorize investigations to be led by operators.

Evaluation of Effectiveness and Outcomes of Operator-Led Mishap Investigations

Internal control standards for the federal government provide that agencies should monitor and evaluate activities on an ongoing basis, with particular attention warranted when there are changes at the entity or in the operating environment.⁷¹

FAA officials acknowledged that the agency has not evaluated the effectiveness or outcomes of its mishap investigation process. As described earlier, FAA has relied exclusively on operator-led investigations in cases where the agency is the lead investigative authority, with officials saying FAA lacks adequate resources to conduct

⁷⁰GAO-14-704G: principle 12.

⁷¹GAO-14-704G: principle 16.

such work internally. Moreover, when FAA has brought in outside technical support to review operator-led investigations, FAA officials acknowledge, that assistance has provided broader insights into mishap causes than the operator investigations. A changing operating environment also underscore FAA's need to ensure that its mishap investigation process is effective. Among other things, FAA's commercial space workload is growing, as launch activity increases. With this growing workload, the agency has elected to reduce its staffing level for operator inspections, which officials said is a risk-based approach for the inspections.⁷² At the same time, reflecting the greater activity, FAA also requires more staff overall for commercial space activities, officials told us.

FAA officials told us that, generally, the agency conducts periodic reviews of its procedures. In this case, there is no particular reason for not having done a formal evaluation of the mishap investigation process, the officials said, only that they have not specifically focused on that area.

Without a comprehensive evaluation of the effectiveness of its operator-led mishap investigation process, FAA cannot be assured that its safety oversight is best achieving agency objectives in an area of critical importance. Such an evaluation could include, among other things, assessing recent changes to the agency's mishap process, including expedited return-to-flight and requirements to identify root cause; scope, conduct, and independence of operator-led mishap investigations; and integration of outside reviews into the investigation process.

FAA and Others Have Shared Lessons Informally, and Stakeholders Identified Key

⁷²FAA officials told us that, due to the increased pace of launches, the agency has decreased the size of its safety inspection teams for individual launches, while focusing on safety-critical risks. Previously, a safety inspection team supporting one operation would have seven members; now, in instances where observed risk is not as high, smaller teams of three are assigned, with some team members taking dual roles. This allows support of the increased pace of launches. The smaller teams will not be used on crewed missions, however, because the risk is too high, the officials said.

Factors to Consider for a Formal Lessons-Learned System

No Formal Lessons-Learned System, but Informal Channels for Sharing Lessons Exist

Federal officials and industry stakeholders told us there is currently no formal mechanism for sharing safety lessons learned from commercial space mishap investigations. However, federal agencies and industry have developed a number of informal channels for sharing information that could help improve safety. These include

- interagency working groups, including the Quad-Agency Working Group and the Department of the Air Force Space Safety Council;
- FAA, which, to a limited extent, acts as an informal clearinghouse of information among space companies. Companies told us that through activities such as licensing and on-site inspections, FAA staff share experience gained from working with other companies to improve safety but without disclosing identities or proprietary information of the other operators. FAA officials acknowledged this process to us. In addition, when operators are developing mishap plans during the licensing process, FAA may offer guidance on plan development based on agency experience;
- standards-setting organizations, which gather together various industry participants and subject-matter experts, to develop industry standards. Information that could help improve safety can be shared in these forums when stakeholders assemble for discussions that inform the development of the standards;
- the mishap investigation observation process, in which federal agencies observe investigations for which they are not the investigative authority; or the NTSB party process, in which agencies can become a party to an NTSB investigation. In doing so, the agencies generally have access to safety information gathered through the mishap investigations. NTSB officials, for example, told us that NTSB serves as an observer because it wants to learn as much

as possible about failures and safety matters, and there are relatively few incidents overall;⁷³ and

- discussions between space companies, launch site operators, and other federal agencies. NTSB officials, for example, told us they have had direct meetings with several space companies with questions about particular aspects of their operations. The agency has also conducted outreach to spaceports. Such contacts are not formal proceedings, but space companies have been interested in consulting on both cargo and human spaceflight matters to gather information about ways to improve safety. Officials from the Department of the Air Force, which operates launch facilities on both the East and West Coasts, told us that informal contacts with space companies occur on a daily basis and include such topics as launch vehicle design reviews and safety issues. Information may also be shared at industry meetings and conferences.

Industry Has Had Concerns, but FAA Is Renewing Efforts to Create a Formal System for Sharing Lessons Learned

FAA officials said they attempted to create a voluntary system for reporting lessons learned in 2010, but companies chose not to participate. Table 2 shows why a lessons-learned system has historically been difficult to achieve, according to concerns expressed by stakeholders we interviewed.

⁷³A Department of the Air Force official noted that all Department safety investigation analysis is considered “privileged safety information,” and by law, can only be used for Department of Defense mishap prevention. Such information is solely to maximize military readiness and combat capability, the official said, and sharing with other agencies is not authorized.

Table 2: Concerns Cited by FAA and Industry Stakeholders for Creating a Lessons-Learned System

Concern about implementing a lessons-learned system	Details
Revealing proprietary business information	Sharing lessons learned may compromise proprietary business information. One company, for example, expressed concern it might be at a competitive disadvantage if other companies could glean proprietary information from such a system. Another company said sensitive business information could be revealed when identifying and analyzing mishap causes.
Limited transferability of lessons learned across launch operators	Even if there was a lessons-learned system, information from one company would be of limited applicability to other launch operators, due to the specialized nature of different companies' designs. Even vehicles with similar functions may use different means to achieve them.
Fear of being penalized and attracting negative publicity	Sharing information about safety conditions or actions leading to a mishap could reveal violations and lead to penalties. Negative publicity from sharing safety-related information could lead to possible loss of business, or other issues, such as financial market repercussions or attracting regulatory attention, even if attempting to focus on safety. With relatively few operators and mishaps, it would be easy to deduce the identity of an operator involved in a mishap.
Disclosing national security or other sensitive information	A U.S. regulatory regime controls the export of defense and military-related technologies and accompanying technical data to safeguard U.S. national security and foreign policy interests. Stakeholders expressed concern that distributing safety-related information, or details of mishaps and corrective actions, could disclose sensitive information.

Source: GAO analysis of interviews with FAA officials and industry stakeholders. | GAO-24-105561

In 2015, following an investigation of the mishap involving the industry's lone fatality to date, NTSB recommended that FAA continue to work to implement a database of lessons learned from commercial space mishap investigations. NTSB's recommendation included that FAA should collaborate with the spaceflight industry and encourage industry members to voluntarily submit lessons learned from mishaps to that database.⁷⁴ FAA endorsed the recommendation at the time and still supports the idea of such a system. FAA has taken some actions to address the recommendation, such as exploring a voluntary safety data-sharing framework for emerging commercial human space flight operations. NTSB acknowledges that FAA has made progress. However, this recommendation remains open.

In February 2023, FAA officials told us they are revisiting their efforts to create a lessons-learned system. In May 2023, they approached industry stakeholders through FAA's Commercial Space Transportation Advisory Committee—a group of industry participants, such as launch companies, and others—to gauge current interest in implementing a lessons-learned

⁷⁴National Transportation Safety Board, *In-Flight Breakup During Test Flight, Scaled Composites SpaceShipTwo, N339SS, Near Koehn Dry Lake, California*.

system.⁷⁵ The advisory committee will be tasked with providing a recommendation on whether the industry would find such a system useful. FAA officials told us that the time may now be right for such an effort because the industry has evolved, and companies recognize the value of information-sharing. Further, the officials said they hope to attract more industry interest by including lessons learned about FAA's process, such as how to submit viable license applications.

If industry reaction to the system is negative, officials said, FAA will press ahead and continue to seek advice from the advisory committee, given the potential safety benefits. When industry comes to understand why such a system is good for space companies, it will be supportive, especially as the industry matures, the officials said.

Several developments since NTSB's 2015 recommendation could support the agency's renewed effort to establish a lessons-learned system.

- The standards-setting organization ASTM International has created a standard for classifying safety-related events. The objective of this effort was to create a comprehensive list of event classifications and to guide industry on how to characterize safety-related events, executives told us. This information could be used as the basis to develop a database of safety-related events in the future. ASTM executives said the standard is intended to provide a common understanding of how events would be characterized in any lessons-learned system in the future.
- The Aerospace Corporation, which has an extensive database of commercial space operations and incidents, told us it would consider ways to populate its data into a lessons-learned system, provided that proprietary concerns could be addressed. They told us the database contains technical and programmatic information for every launch and space vehicle going back to the launch of Sputnik in 1957, including information about problems encountered, corrective actions taken, and lessons learned. Aerospace said that if appropriate screening could be implemented, its database could yield useful lessons-learned information.
- NASA, which maintains extensive flight safety data, told us it may also be willing to contribute its information to a lessons-learned system.

⁷⁵The Commercial Space Transportation Advisory Committee was established in 1984 to provide information, advice, and recommendations to the FAA Administrator on critical matters concerning the U.S. commercial space transportation industry, including safety.

NASA maintains its Mishap Information System repository, which is a custom-developed system for capturing and tracking mishaps, close calls, corrective actions, and hazards involving NASA operations. In addition, NASA collects information about mishaps through what it calls “fleet following”—that is, by examining, as relevant, what happens on capsules or launch vehicles of the type used by NASA but flown by others.⁷⁶

Stakeholders Generally Support a Formal Lessons-Learned System and Identified Key Factors for Creating One

Federal agencies, space companies, and others to whom we spoke generally expressed support for the concept of a formal lessons-learned system. For example, sharing safety lessons can help prevent future mishaps, according to one safety consultant with experience in the space industry. NTSB officials said that greater discussion of safety matters, and understanding of mishaps and problems, would help with overall industry safety. Also, one launch operator said that while there may not be a great volume of lessons learned that are applicable to all space companies, there could still be a significant impact in sharing a relatively few lessons that have broad applicability across the industry.⁷⁷

⁷⁶A Department of the Air Force official noted that Department safety investigation reports and materials are restricted by law and policy, so that much of its data would be unavailable for use in an interagency lessons-learned database. Under certain circumstances, the official said, a Department mishap could lead to a separate, releasable legal investigation, from which information could be made available for incorporation into a lessons-learned database.

⁷⁷In general, these views expressed by commercial space industry participants align with key practices we and others have identified on the importance of identifying and applying lessons learned to limit the chance of recurrence of previous failures or difficulties. Lessons learned serve to communicate knowledge more effectively and ensure that beneficial information is factored into planning, work processes, and activities. As we and others have previously found, agencies can learn lessons and use that knowledge to change behavior. For examples of our work in this area, see GAO, *2020 Census: A More Complete Lessons Learned Process for Cost and Schedule Would Help the Next Decennial*, [GAO-23-105819](#) (Washington, D.C.: Mar. 2, 2023); *Telecommunications: GSA Needs to Share and Prioritize Lessons Learned to Avoid Future Transition Delays*, [GAO-14-63](#) (Washington, D.C.: Dec. 5, 2013); *Federal Real Property Security: Interagency Security Committee Should Implement A Lessons-Learned Process*, [GAO-12-901](#) (Washington, D.C.: Sept. 10, 2012); and *NASA: Better Mechanisms Needed for Sharing Lessons Learned*, [GAO-02-195](#) (Washington, D.C.: Jan. 30, 2002). We also identified lessons-learned practices from reports by the Center for Army Lessons Learned, *Establishing a Lessons Learned Program*.

Given historical concerns about creating a lessons-learned system, stakeholders identified situations where some sharing of lessons learned might be more feasible, and types of information that companies might be more amenable to sharing.

- **Common systems.** Although launch vehicles have specialized designs, stakeholders told us that there are some functions, such as safety systems, that are common to all and, thus, might be good candidates for information-sharing. For example, one launch operator told us it has been beneficial to share methods of securing the site and protecting the uninvolved public during a launch. Other stakeholders told us that functions of common interest, such as problems involving pressure, materials, and compatibility, lend themselves to lesson-sharing because they have broad applicability across systems and do not generally involve proprietary material.⁷⁸
- **Management practices and human factors.** As one research organization told us, people are common to all systems. Thus, it could be beneficial for launch operators to share information about management practices and human factors that may be helpful in preventing mishaps. NTSB has likewise cited the broad importance of human factors.⁷⁹ In addition, in our review of mishap investigations, we identified some instances where the cause of the mishap was traced primarily to management practices and human factors, rather than to the specialized technology of the launch vehicle or operator. For example, one mishap occurred when a flight was aborted. The problem, however, was traced back to a human factor, rather than a particular technology of the launch vehicle. In other mishaps we reviewed, investigation reports cited further examples of human factors within management control. FAA officials acknowledged to us that lessons learned based on such human factors are generally more applicable across the industry than those involving proprietary technology.

⁷⁸For example, one launch company discovered an incompatibility between an oxidizer and titanium tubing and plumbing. The company did considerable testing with NASA to understand when the equipment could become explosive. The company published a series of specifications, with NASA, to the entire community, warning of potential dangers with the system, which were not previously known.

⁷⁹As NTSB found in its 2015 report on the Scaled Composites SpaceShipTwo fatal mishap: "Human factors should be emphasized in the design, operational procedures, hazard analysis, and flight crew simulator training for a commercial space vehicle to reduce the possibility that human error during operations could lead to a catastrophic event." NTSB also found FAA's permit review for the flight was deficient for failing to recognize human-caused hazards.

- **Process-oriented information.** Space companies told us they may be more willing to share process-oriented information versus design-oriented data, because process-oriented information is seen as less sensitive to proprietary concerns. For example, one space company noted a particular fuel oxidizer that must be handled carefully. This information is not necessarily related to a unique design and may be something other launch operators and federal officials would benefit from knowing.

In addition, to facilitate development of a lessons-learned system, stakeholders cited factors that should be considered to enhance prospects for success:

- **Industry involvement:** Collaboration with industry will be vital to the success of the system, according to a former FAA official. A launch operator executive also noted that while the general model of a lessons-learned system might be known from experience in other settings, it must be adapted to a relatively low volume of flights in the commercial space industry. It must be clear in advance to participants what the data collected will be used for. Building trust among FAA and launch operators will be important, the executive said.
- **Anonymous and nonpunitive:** According to stakeholders we interviewed, space companies need to feel comfortable sharing lessons learned without fear of disclosure of proprietary information or repercussions, such as regulatory enforcement actions or marketplace reactions. Some stakeholders said one way to do this is to exempt certain information included in a lesson-learned system from disclosure.
- **Structure:** Stakeholders suggested a structure with FAA or a trusted third party as the hub, collecting safety-related information and screening it for commercially sensitive, or other, information before release. According to some stakeholders, FAA is well-positioned to do so because it has already established relationships within the commercial space industry. Another option would be an industry-managed effort, with space companies collecting information and screening out sensitive material themselves. According to one stakeholder, the companies are in the best position to know which information is beneficial to share with other companies. FAA officials told us the agency would support any of these options for structuring a lessons-learned system.

Conclusions

The commercial space industry is expanding rapidly, with the number of launches up substantially, thousands of new satellites deployed to orbit, new technologies emerging, and new space companies entering the industry. This growth will present a greater workload and new challenges for FAA, as it seeks to protect public safety. FAA has taken some steps to address safety oversight, including contracting for independent reviews of the results of operator-led investigations and issuing regulations requiring operators to determine mishap root cause. The agency has also revived an effort to implement a safety lessons-learned system, at a time when conditions may be more favorable for such an initiative.

However, gaps remain in FAA's mishap investigation process. Specifically, without clear criteria for determining when it should authorize operators to lead investigations of their own mishaps, FAA cannot make reliable, consistent determinations on which entity should lead those investigations. This jeopardizes effective oversight and investigation of mishaps. In addition, FAA's mishap investigation process is critical to the agency's effort to protect public safety. Although FAA officials told us they generally review procedures periodically, the agency has not evaluated the effectiveness of this process. It is vital that FAA evaluate and address any gaps in its investigation process to ensure safe operations in the rapidly expanding commercial space industry.

Recommendations

We are making two recommendations to FAA:

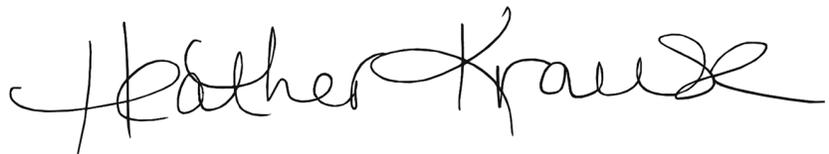
- The Administrator of FAA should direct the Office of Commercial Space Transportation to develop criteria for determining when the agency will authorize a launch operator to lead a mishap investigation on FAA's behalf. (Recommendation 1)
- The Administrator of FAA should direct the Office of Commercial Space Transportation to comprehensively evaluate the effectiveness of the office's mishap investigation process. (Recommendation 2)

Agency Comments

We provided a draft of this product to FAA, NTSB, NASA, and the Department of the Air Force for review and comment. In its comments, reproduced in appendix IV, the Department of Transportation concurred with our recommendations and stated it will provide a detailed response to each recommendation within 180 days of the report's issuance. The department also provided technical comments, which we incorporated as appropriate. NTSB, NASA, and the Department of the Air Force also provided technical comments, which we incorporated as appropriate.

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

If you or your staff have any questions about this report, please contact Heather Krause at (202) 512-2834 or krauseh@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 V.



Heather Krause
Director, Physical Infrastructure

Appendix I: Objectives, Scope, and Methodology

This report examines (1) commercial space mishaps as identified by the Federal Aviation Administration (FAA) from 2000 to mid-January 2023, (2) the roles and responsibilities of federal agencies in investigating commercial space transportation mishaps, (3) FAA’s investigation process for commercial space transportation mishaps and areas for improvement, and (4) efforts by FAA and others to share safety lessons learned and key considerations for a formal system for sharing lessons learned.

To examine commercial spaceflight activity and examine mishaps from 2000 to mid-January 2023, we analyzed FAA launch-by-launch data on FAA-licensed commercial launches. We also obtained detailed data from FAA on incidents the agency determined to be mishaps. These two sources included information on launch dates, mishap investigative authority, and launch and mishap details. We assessed the reliability of the data we obtained and determined these data to be reliable for our reporting objectives. This assessment included, for example, interviewing agency officials about data collection methods for launch activity statistics that FAA compiles, plus cross-checking summary mishap information against source documentation.

We further examined FAA licensing data, including for launch sites, launch licenses, reentry licenses, and new launch operators’ prelicensing filings. To compile summary information on types of mishaps experienced in commercial spaceflights, we reviewed FAA mishap investigation reports. We also obtained statistics from a space insurer on mishap history of launch vehicles over time. We examined the definitions of mishap employed by four agencies involved in commercial space activities—FAA, the National Transportation Safety Board (NTSB), the National Aeronautics and Space Administration (NASA), and the Department of the Air Force.

We conducted interviews with FAA, NTSB, NASA, and Department of the Air Force officials, as well as FAA field staff, executives of launch operators, spaceports, an aerospace-oriented federally funded research and development center (The Aerospace Corporation), an industry association, and other knowledgeable stakeholders, including former

agency employees. In all, we conducted 42 such interviews. For our launch operator interviews, we selected all then-currently licensed operators—nine—plus one additional company, formerly licensed but still operating, that had experienced a mishap. We interviewed eight of the 10 companies. For our spaceport interviews, we identified then-currently licensed spaceports and then narrowed our selection to three that we judged represented a variety of sizes and experience. We interviewed all three. For other interviews, we selected subjects as identified over the course of our audit work—through interviews, documents, and our observations—based on our judgment as to relevance and experience. The findings from these interviews are not generalizable to the industry, but the interviews provided common themes, context, a range of perspectives, and illustrative examples.

To examine the roles and responsibilities of federal agencies in investigating commercial space transportation mishaps, we reviewed statutes, regulations, and agreements involving FAA, NTSB, NASA, and the Department of the Air Force. We also interviewed officials at these agencies to discuss their respective roles and responsibilities, and to obtain their views on current agreements for investigation of commercial space mishaps. We also interviewed industry stakeholders, including launch operators, industry experts, spaceport representatives, and an industry association to obtain their views on roles and responsibilities for commercial space mishap investigations.

To examine FAA's investigation process for commercial space transportation mishaps and areas for improvement, we analyzed the FAA mishap data and mishap investigation reports cited above. We analyzed reviews of operator-led mishap investigations done for FAA by The Aerospace Corporation. We similarly analyzed independent mishap investigations by NASA in instances where FAA had authorized operator-led mishap investigations. We reviewed relevant FAA mishap program documentation, including the agency's mishap response program manual and its mishap notification and response handbook. We determined internal controls were significant to the audit objective and used internal control standards for the federal government to assess agency practices.¹ We interviewed FAA, NTSB, NASA, and Department of the Air Force officials, plus launch operators, spaceports, the space insurer cited

¹GAO, *Standards for Internal Control in the Federal Government*, [GAO-14-704G](#) (Washington, D.C.: Sept. 2014).

above, and other knowledgeable stakeholders on a range of mishap-related topics.

To consider efforts by FAA and others to share safety lessons learned and key considerations for a formal system for sharing lessons learned, we examined FAA and NTSB documentation on relevant topics, including an NTSB recommendation to FAA to create such a system. We interviewed FAA officials to obtain an update on the status of implementing the recommendation. In addition, we interviewed FAA, NTSB, NASA, and Department of the Air Force officials; launch providers; and industry stakeholders, to identify mechanisms currently in place to share lessons learned. We also obtained their views on challenges faced in sharing lessons learned and key considerations for creating a lessons-learned system in the future.

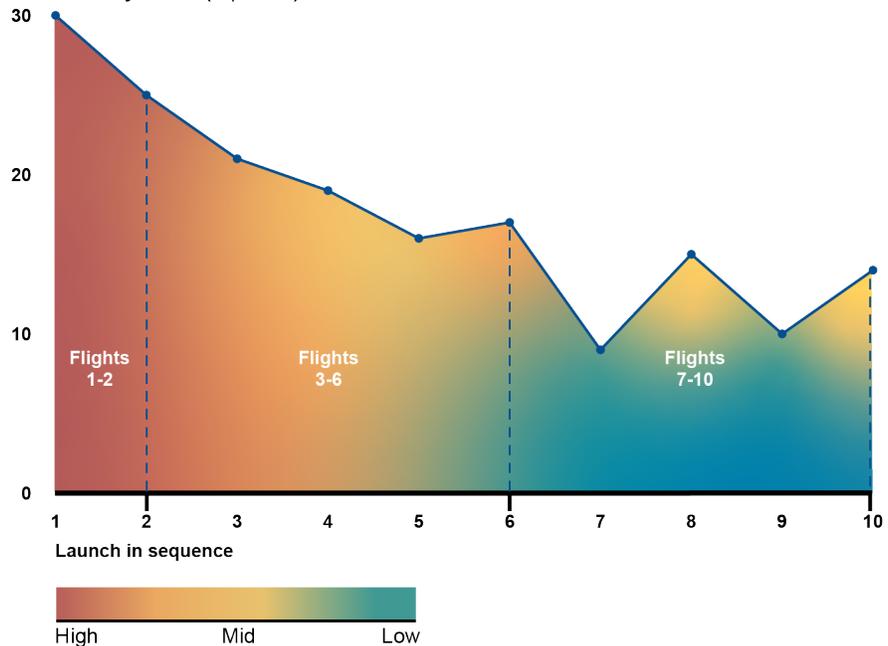
We conducted this performance audit from November 2021 to December 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions 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: Early Flights of a Vehicle Fail More Often

Among all mishaps, early flights of a new vehicle design fail more often. In particular, the early launches of a new rocket model suffer a relatively high failure rate—nearly a third of all missions—according to data collected by AXA XL, a space insurance company.¹ The failure rate then declines as the number of flights of the new model increases and experience grows. Figure 4 shows, across all launch vehicle families, the trend of more failures for new vehicles during their earlier flights, followed by fewer failures, which industry stakeholders attribute to operators gaining more experience with the new designs.

Figure 4: Declining Failure Rate for New Launch Vehicles, over First 10 Flights

Failure rate by launch (in percent)



Source: GAO presentation of AXA XL data. | GAO-24-105561

¹Federal Aviation Administration officials told us the agency does not conduct analysis of aggregated data on mishaps.

**Appendix II: Early Flights of a Vehicle Fail
More Often**

**Accessible Data for Figure 4: Declining Failure Rate for New Launch Vehicles, over
First 10 Flights**

First ten flights	Launch failure rate from high, mid, low (in percent)
1	30 (High)
2	25 (High)
3	21 (High-mid)
4	19 (Mid)
5	16 (Mid-low)
6	17 (Mid-high)
7	9 (Low)
8	15 (Mid)
9	10 (Low)
10	14 (Mid)

Source: GAO presentation of AXA XL data. | GAO-24-105561

The Federal Aviation Administration expects an increase in mishaps as the industry continues to expand with new operators entering the field, and the industry insurer expects more failures with the introduction of new launch vehicles.

Appendix III: Perspectives on Standardizing Mishap Definitions and Efforts to Do So

The Federal Aviation Administration (FAA) and other agencies involved in commercial space transportation define mishaps differently, on the basis of their own missions and purposes. For example, FAA has two sets of mishap definitions, one of them newly established and another, older version to be phased out after a transition period. The Department of the Air Force has five classes of mishaps for Department of Defense missions, with different investigation requirements and timelines, and that consider factors such as the nature of the incident and cost of damage. The National Aeronautics and Space Administration (NASA) likewise has different classes of mishaps.

According to agency officials and other stakeholders, these differing definitions can require effort to navigate but generally do not present significant operational issues. FAA officials told us the agency does not believe there necessarily needs to be a common definition. Although definitions differ among the agencies, the officials said, the agencies also have different missions. There is little practical consequence to having differing definitions under the current system, they said.

Nonetheless, some stakeholders told us that overall safety oversight could benefit from more standardized definitions, by providing a more common reference that would facilitate better communication and understanding. For example, stakeholders told us differing definitions can complicate determinations surrounding launch anomalies and establishing investigative authority, and create confusion in oral exchanges. Common definitions could also help clarify investigative plans; allow better compilation of data for good decision-making, especially across companies; aid mishap investigations and multiagency coordination; and avoid a worst-case scenario in which launch approval could be denied, stakeholders told us. One launch site operator said common definitions would be a significant benefit now and become even more useful in coming years, with the expected growth of the industry. As one agency safety official characterized the current situation to us, each agency's use of terms presents an obstacle to navigate through and, to work effectively together, the agencies need common references.

**Appendix III: Perspectives on Standardizing
Mishap Definitions and Efforts to Do So**

In response to these concerns, the Department of the Air Force has undertaken a multiagency effort to coordinate mishap definitions. According to a Department official, work is now underway among the four agencies—FAA, the National Transportation Safety Board, the Department, and NASA—on how to define a mishap, as a starting point to discuss differing definitions among the agencies. The goal of the initiative, which could conclude in 2024, is to normalize terms among the different agencies, while still recognizing differences among the agencies and their respective missions, the Department official told us.¹ A former FAA official endorsed such an approach, saying that if there are not common definitions, then a means of translating across organizations would be useful.

¹FAA and NASA officials characterized the Department of the Air Force initiative as an effort to create a reference guide, to provide a single document that captures the definitions of accidents, close calls, hazards, incidents, mishaps, and other classifications across agencies. FAA officials also noted it is not an effort to standardize mishap definitions among the agencies.

Appendix IV: Comments from the Department of Transportation

**Appendix IV: Comments from the Department
of Transportation**



**U.S. Department of
Transportation**
Office of the Secretary
of Transportation

Assistant Secretary
for Administration

1200 New Jersey Avenue, SE
Washington, DC 20590

November 13, 2023

Heather Krause
Director, Physical Infrastructure Issues
U.S. Government Accountability Office
441 G Street NW
Washington, DC 20548

Ms. Krause:

The Federal Aviation Administration (FAA) continues to support a record number of commercial space launches as the industry continues to grow exponentially. The FAA has and continues to prioritize and maintain public safety all while ensuring operators meet all regulatory requirements. There have not been any mishaps that have negatively impacted public safety, which indicates that the regulatory framework is working.

The FAA would also like to note that of the 50 commercial space launches from 2000 through mid-January 2023 that resulted in a mishap, seven involved first launches of new vehicles. This demonstrates that not all mishaps result in a failure to complete a mission.

Upon review of the draft report, the Department concurs with GAO's two recommendations to (1) develop criteria to aid in the Office's determination for authorizing operator-led mishap investigations and (2) conduct an evaluation of the effectiveness of the Office's mishap investigation process. We will provide a detailed response to both recommendations within 180 days of the final report's issuance.

We appreciate the opportunity to respond to the GAO draft report. Please contact Gary Middleton, Office of Audit Relations and Program Improvement, at (202) 366-6512 with any questions or if GAO would like to obtain additional details about these comments.

Sincerely,

A handwritten signature in black ink, appearing to read "Philip A. McNamara".

Philip A. McNamara
Assistant Secretary for Administration

Accessible Text for Appendix IV: Comments from the Department of Transportation

November 13, 2023

Heather Krause
Director, Physical Infrastructure Issues
U.S. Government Accountability Office
441 G Street NW

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Sincerely,

**Accessible Text for Appendix IV: Comments
from the Department of Transportation**

Philip A. McNamara
Assistant Secretary for Administration

Appendix V: GAO Contacts and Staff Acknowledgments

GAO Contact

Heather M. Krause, (202) 512-2834 or krauseh@gao.gov

Staff Acknowledgments

In addition to the individual named above, Sara B. Vermillion (Assistant Director), Christophe G. Beaumier, Laura Bonomini, Melanie R. Diemel, Gina M. Hoover, Stephanie A. Purcell, Anna E. Smith, Abby C. Volk, Amelia M. Weathers, and Alicia Wilson made key contributions to this report.

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