United States Government Accountability Office

Report to Congressional Addressees

June 2017

SATELLITE ACQUISITIONS

Agencies May Recover a Limited Portion of Contract Value When Satellites Fail

GAO-17-490

GAO Highlights

Highlights of GAO-17-490, a report to congressional addressees

June 2017

SATELLITE ACQUISITIONS

Agencies May Recover a Limited Portion of Contract Value When Satellites Fail

Why GAO Did This Study

Acquiring and fielding satellites are high stakes endeavors. Each year, DOD, NASA, and NOAA spend billions of dollars acquiring satellites. Unlike with other major acquisitions, such as ships or aircraft, an agency can only determine the quality of a satellite after it is launched. That means any defects that occur may be impossible to repair, and in space, a single failure can be catastrophic for a mission's success. As a result, contractor performance is critical to a program's success, and contract incentives can be particularly important in aligning government and contractor interests—both in achieving mission success and ensuring responsible financial management.

This report addresses (1) the types of contracts DOD, NASA, and NOAA use to develop satellites, (2) how selected programs structure on-orbit incentives, and (3) what recourse, if any, the government has in the event of satellite failure or underperformance. To conduct this work, GAO analyzed contract obligations data and documentation for 19 current satellite programs; reviewed policies and guidance regarding contact types and incentives; selected 12 case studies to determine incentive structures and recourse options; and interviewed program and contracting officials at each agency, as well as commercial representatives and industry experts.

What GAO Recommends

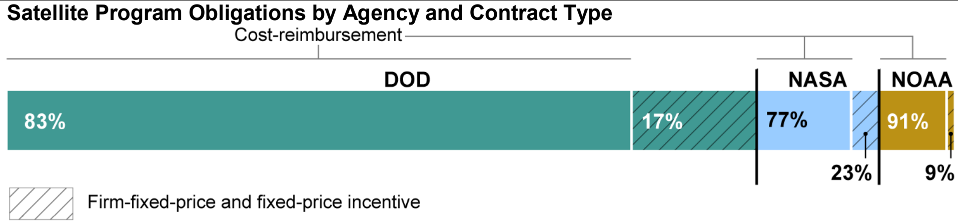
GAO is not making any recommendations in this report.

View GAO-17-490. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

Given high development risks and uncertain requirements in satellite programs, most government satellite acquisitions use cost-reimbursement contracts. When lower-risk items are being acquired, such as standard spacecraft and communications satellites, agencies used firm-fixed-price contracts. Overall, across 19 programs GAO reviewed at the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), about $43.1 billion of $52.1 billion was obligated on cost-reimbursement contracts and orders, while the remaining $9 billion were on firm-fixed-price and fixed-price incentive contracts and orders.

Satellite Program Obligations by Agency and Contract Type



DOD – Department of Defense NASA – National Aeronautics and Space Administration
NOAA – National Oceanic and Atmospheric Administration

Source: GAO analysis of Federal Procurement Data System-Next Generation (FPDS-NG) data, agencies' contract files, and contract data reported by agencies. | GAO-17-490

Most of the 12 selected programs that GAO reviewed contained an on-orbit incentive—incentives based on successful performance in space; however, they varied widely in terms of the amount at-risk for the contractor and the timing of payments. For example, the on-orbit incentives included on the contracts and orders for the 12 selected programs ranged from no on-orbit incentive to approximately 10 percent of the contract value. GAO also found variation in how the at-risk amount was spread out over a satellite's mission life. For example, some contracts included on-orbit incentives that covered a satellite's entire mission life while other contracts covered only a portion of the mission life.

The government's recourse in the event of a catastrophic satellite failure is limited, relative to its overall investment. Given the small on-orbit incentive amounts included in contracts, the government's maximum financial recovery potential is modest. This is by design, however, as on-orbit incentives are not intended to make the government whole in the event of total failure. The government accepts this level of risk, in part because such failures are rare, according to government and industry experts. Also, it is unclear whether larger on-orbit incentives would reduce on-orbit failures given numerous other factors that affect a program's success, including requirements stability, design maturity and contractor experience. As a result, the most cost effective way to limit the government's loss in the rare case of a catastrophic failure may be to reduce cost growth and schedule delays by using best practices during satellite development, as GAO has previously recommended.

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Abbreviations

AEHF	Advanced Extremely High Frequency
CPAF	cost-plus-award-fee
CPARS	Contractor Performance Assessment Reporting System
CPFF	cost-plus-fixed-fee
CPIF	cost-plus-incentive-fee
DCI	data collection instrument
DMSP	Defense Meteorological Satellite Program
DOD	Department of Defense
FAR	Federal Acquisition Regulation
FFP	firm-fixed-price
FFRDC	federally funded research and development center
FPAF	fixed-price-award-fee
FPI	fixed-price incentive
FPDS-NG	Federal Procurement Data System-Next Generation
GEO	geosynchronous earth orbit
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement (mission)
GPS	Global Positioning System
GRACE-FO	Gravity Recovery and Climate Experiment Follow-On
HEO	highly elliptical orbit
ICESat-2	Ice, Cloud, and Land Elevation Satellite-2
JPL	Jet Propulsion Laboratory
JPSS	Joint Polar Satellite System
JWST	James Webb Space Telescope
LDCM	Landsat Data Continuity Mission
MMS	Magnetospheric Multiscale
MUOS	Mobile User Objective System
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
OCO-2	Orbiting Carbon Observatory 2
SBIRS	Space Based Infrared System
SMAP	Soil Moisture Active and Passive
SMC	Air Force’s Space and Missile Systems Center
SWOT	Surface Water and Ocean Topography
TDRS	Tracking and Data Relay Satellite
TESS	Transiting Exoplanet Survey Satellite
WGS	Wideband Global SATCOM

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
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Congressional Addressees

The Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) spend billions of dollars each year on major satellite acquisition programs to satisfy a diverse set of missions, from protected communications and global positioning, to weather and deep space observations. Satellite acquisitions are unique because, unlike other types of acquisitions, such as for ships or aircraft, testing in an operational environment—space—is extremely difficult. Moreover, satellites, each of which can cost over $1 billion, are purchased in limited quantities; defects likely cannot be fixed once a satellite has been launched; and a single failure can be catastrophic to the mission. As a result, when satellites fail prematurely or do not meet mission requirements once they are on-orbit, the government can lose billions of dollars in investments, years of technology development and production, and opportunities to utilize advanced capabilities to conduct important undertakings, such as scientific research and national defense. For example, in 2015, a NASA science mission experienced a partial satellite failure on-orbit; while the value of the failed instrument was in the tens of millions of dollars, NASA estimated the loss of investment to the mission in the hundreds of millions of dollars.

With so much at stake, especially at a time when more resources may be needed to protect space systems and to recapitalize the space portfolio, the government places great emphasis on mission success during the satellite acquisition process. Many factors can affect a program's success, including, for example, requirements and funding stability, technology and design maturity, government and contractor experience, and launch vehicle reliability. Contractor performance is also critical for program success. When contracting for satellite programs, the government weighs the use of various contract types and incentive structures to motivate optimal contractor performance and achieve mission success while at the same time, controlling costs and meeting schedule milestones. Contract terms such as on-orbit incentives, which are incentives based on successful on-orbit performance, can be important for aligning the interests of the government and contractors, and for achieving mission success while ensuring responsible financial management. We have reported on how the government shares risk with contractors for space acquisitions for many years.[1]

To assess DOD, NASA, and NOAA's contract and incentive structures, under the authority of the Comptroller General to conduct evaluations on his own initiative, we examined (1) the types of contracts and incentive structures government satellite programs use to develop satellites and why, (2) how selected programs structure on-orbit incentives, and (3) government options for recourse, if any, when a satellite fails or underperforms.

To determine the types of contracts and incentive structures government satellite programs use to develop satellites and the reasons why, we analyzed contract obligations data from the Federal Procurement Data System-Next Generation (FPDS-NG) for 19 programs, comprising all current major satellite programs across DOD, NASA, and NOAA. To assess the reliability of the FPDS-NG data, we reviewed relevant internal control documents and data quality summaries. We determined that the FPDS-NG data were sufficiently reliable for the purposes of this engagement. For DOD, we included major defense acquisition programs, and at NASA and NOAA, we included programs with a life-cycle cost greater than $250 million.[2] See appendix I for a description of the missions, costs, and quantities for each program in our review. For our analysis, we included each program's development and production contracts and orders for the spacecraft and instruments and generally excluded contracts and orders related to launch, ground systems, maintenance, operations, and support services if they were separate contracts and orders. If these items or services were included within the development and production contract or order, we included them in our analysis. For each contract and order, we determined the predominant contract type for the design, development, and production of the satellites

[1]GAO, *NASA Procurement: Approach to Sharing Risk Under Certain Research and Development Contracts Is Starting to Change*, GAO/T-NSIAD-92-12 (Washington, D.C.: Mar. 18, 1992).

[2]We defined current major satellite acquisition programs as Earth-orbiting satellite acquisition programs in development, production, or with at least one satellite on-orbit within its mission life as of September 2016 and NASA's James Webb Space Telescope (JWST), given that JWST is the largest major program within NASA's portfolio. To maintain consistency with selection criteria used in our annual assessments of NASA's major projects, we used a $250 million life-cycle cost threshold. For more on our annual NASA project assessments, see *NASA: Assessments of Major Projects,* GAO-16-309SP (Washington, D.C.: Mar. 30, 2016).

on the contract. We also reviewed DOD, NASA, and NOAA policies and guidance on contracting and incentives, and Federal Acquisition Regulation (FAR) and agencies' FAR supplements for regulations and procedures on contracting.

To determine the range of on-orbit incentive structures and government options for recourse should a satellite fail or underperform, of the 19 major satellite programs in our review, we selected 12 programs as case studies for more in-depth review based on program size, contract type, contractor, mission, or notable on-orbit performance characteristics. Our selected case study programs included:

DOD

- Global Positioning System (GPS) IIF,
- GPS III,
- Mobile User Objective System (MUOS),
- Space Based Infrared System (SBIRS), and
- Wideband Global SATCOM (WGS) Blocks I, II, and II Follow-On;

NASA

- Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2),
- James Webb Space Telescope (JWST),
- Soil Moisture Active and Passive (SMAP),
- Tracking and Data Relay Satellite (TDRS) K, L, M, and
- Transiting Exoplanet Survey Satellite (TESS);

NOAA

- Geostationary Operational Environmental Satellite (GOES)-R series (GOES R, S, T, U) and
- Joint Polar Satellite System (JPSS).

Across the 12 case study programs, there were 23 contracts or orders and 56 space vehicles. For each case study, we analyzed contract files and conducted interviews with program and contracting officials at DOD, NASA, and NOAA to discuss contract types and incentive structures, rationale for the use of specific contract types and incentive structures, on-orbit performance, and programmatic outcomes.

In addition to the case studies above, we reviewed the Defense Meteorological Satellite Program 19 (DMSP-19) because of its recent on-orbit failure.[3] We reviewed DMSP-19's follow-on storage, maintenance, and support contracts. These contracts contained information on the on-orbit incentives and relevant options for government recourse after the on-orbit failure occurred.

For the seven remaining satellite programs at DOD and NASA that were not included in our case studies, we developed agency-specific data collection instruments (DCI) that we pre-tested, administered, and from which we analyzed the information collected. We tailored the DCIs to each agency based on agency policies and guidelines for contracting to obtain program-specific contract details, values, obligations to-date, special clauses used, incentive structures, and performance periods. The seven programs for which we used the DCIs to collect information included:

DOD

- Advanced Extremely High Frequency (AEHF);

NASA

- Global Precipitation Measurement (GPM) Mission,
- Gravity Recovery and Climate Experiment Follow-On (GRACE-FO),
- Landsat Data Continuity Mission (LDCM),
- Magnetospheric Multiscale (MMS),
- Orbiting Carbon Observatory 2 (OCO-2), and
- Surface Water and Ocean Topography (SWOT).

We also interviewed officials from a nongeneralizable sample of commercial companies: Ball Aerospace, DigitalGlobe, IntelSat, Lockheed Martin, and ViaSat to identify how selected commercial companies use on-orbit incentives and how commercial satellite acquisitions differ from government satellite acquisitions. In addition to commercial satellite companies, we also consulted satellite insurance brokers and one underwriter, to obtain information on the likelihood of satellite failures in the commercial and government markets, the general capacity of the

[3]DMSP-19 suffered a catastrophic failure in the second year of its mission life when the Air Force lost the ability to control the satellite.

commercial satellite insurance market, and the dollar amounts associated with insuring commercial satellites. We reviewed Aerospace Corporation studies and briefings and interviewed Aerospace Corporation officials to identify the point during the life of a satellite in which most satellite failures occur, the frequency of government satellite failures, and to identify the various categories of satellite failures. See appendix II for additional details on our scope and methodology.

We conducted this performance audit from March 2016 to June 2017 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

In any acquisition, the contract type provides the foundation for incentivizing a contractor's performance and is just one element of the contract, which may also include performance, cost, or delivery incentives, and other contract terms and conditions that incentivize performance. The type of contract used for any given acquisition inherently determines how risk will be distributed between the government and the contractor. Since the contract type and the contract price are interrelated, they must be considered together. The government's objective is to negotiate a contract type and price (including cost and the contractor's fee or profit) that will result in an acceptable level of risk to the contractor, while also providing the contractor with the greatest incentive for effective and efficient performance.[4]

Incentive contracts, which include award fee contracts, are designed to attain specific acquisition objectives by including incentive arrangements that (1) motivate contractor efforts that might not otherwise be emphasized, and (2) discourage contractor inefficiency and waste. One of the main characteristics of award fees and other incentives is how they are administered in the contract. Award fees are generally *subjectively*

[4]In federal contracting, the terms "profit" and "fee" refer to the amount of money paid to the contractor above and beyond either a fixed price or a contractor's reimbursable costs. The term "profit" is generally associated with fixed-price incentive contracts, and the profit is already included in the overall price of the contract, and the term "fee" is generally associated with cost-reimbursement contracts.

determined and incentive fees are generally *objectively* determined. When incentive arrangements are done properly, the contractor has profit motive to keep costs low, deliver a product on time, and make decisions that help ensure the quality of the product. Our prior work has shown, however, that incentives are not always effective tools for achieving desired acquisition outcomes and that, in some cases, there are significant disconnects between program results and incentives paid. Additionally, we have repeatedly found that some agencies did not have methods to evaluate the effectiveness of award fees.[5] More recently, in March 2017, we found that fixed-price incentive shipbuilding contracts did not always lead to desired outcomes, and that the Navy had not assessed whether adding incentives improved contractor performance. We made recommendations to the Navy, including that it conduct a portfolio-wide assessment of its use of additional incentives on fixed-price incentive contracts across its shipbuilding programs. DOD agreed with our recommendations.[6]

Numerous contract types are available to the government to provide flexibility in acquiring the supplies and services agencies need, including satellite acquisitions. Table 1 provides an overview of typical contract types and how they may be used to acquire satellites.

[5]GAO, *Defense Acquisitions: DOD Has Paid Billions in Award and Incentive Fees Regardless of Acquisition Outcomes,* GAO-06-66 (Washington, D.C.: Dec. 19, 2005); *NASA Procurement: Use of Award Fees for Achieving Program Outcomes Should Be Improved,* GAO-07-58 (Washington, D.C.: Jan. 17, 2007); *Federal Contracting: Guidance on Award Fees Has Led to Better Practices but Is Not Consistently Applied,* GAO-09-630 (Washington, D.C.: May 29, 2009).

[6]GAO, *Navy Shipbuilding: Need to Document Rationale for the Use of Fixed-Price Incentive Contracts and Study Effectiveness of Added Incentives,* GAO-17-211 (Washington, D.C.: Mar. 1, 2017).

Table 1: Typical Contract Types and General Use in Government Satellite Acquisitions

Contract type	Characteristics	Generally appropriate for use when…
Firm-fixed-price	• Price is not subject to any adjustment on the basis of contractor's cost experience. • Provides maximum incentive for contractor to control costs.	• Requirements are well-defined and technical risks are low. • Acquiring commercial items or other items with reasonably detailed specifications, such as satellite buses with proven designs.
Fixed-price incentive	• Provides for adjusting profit and establishing final contract price by application of a formula, known as a share line, based on the relationship of total final negotiated cost to total target cost. • In accordance with the share line, government and contractor share responsibility for cost increases or decreases compared to the agreed upon target cost. When the final cost is less than the target cost, the contractor's profit will be greater than if the final costs were more than the target cost.	• Firm-fixed-price is not suitable and placing partial responsibility for cost on contractor will incentivize effective cost control and performance, such as when programs are in the early production phase and the satellite being built has a cost history from prior builds.
Cost-plus-incentive-fee	• Government pays contractor allowable incurred costs to extent prescribed in contract. • Fee is initially negotiated and later adjusted by a formula (known as a share ratio), based on the relationship of total allowable costs to total target costs. • Target cost, target fee, minimum and maximum fees, and fee adjustment formula are specified at contract inception. After performance, amount of fee paid is determined by the negotiated formula.	• Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase. • A target cost and a fee adjustment formula can be negotiated that will likely motivate the contractor to effectively manage its work.
Cost-plus-award-fee	• Government pays contractor allowable incurred costs to extent prescribed in contract. • Base fee, which may be zero, is fixed at contract inception. • Award fee is determined by subjective evaluation of the contractor's performance.	• Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase. • Government cannot establish predetermined objective incentive fee targets. • Likelihood of meeting acquisition objectives will be enhanced by the use of award fee. • Additional administrative effort required to monitor and evaluate performance is justified by the expected benefits.
Cost-plus-fixed-fee	• Government pays contractor allowable incurred costs to extent prescribed in contract. • Negotiated fee is fixed at the inception of the contract and does not vary with actual cost but may be adjusted as a result of changes in the performed work. • Provides minimal incentive to control costs.	• Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase • Performing research, preliminary exploration or study, and the level of effort required is unknown.

Contract type	Characteristics	Generally appropriate for use when…
Cost with no fee	• Government pays contractor allowable incurred costs to extent prescribed in contract. • Contractor receives no fee.	• Requirements are not fully defined, technologies and design are not sufficiently mature, or integration risk is too great to use a fixed-price contract, such as when programs are in the technology development or engineering and manufacturing development phase • Research and development work, particularly with nonprofit educational institutions or other nonprofit organizations.

Source: GAO analysis of the Federal Acquisition Regulation, Defense Federal Acquisition Regulation Supplement, and DOD guidance. | GAO-17-490

When determining the contract and incentive structure for satellite acquisitions, the government may consider a number of factors:

- **Where the satellite is in the acquisition phase.** Satellite contracts can include design, development, integration, and testing, and can cover more than 15 years. The government can tailor the contract type and fees to meet the specific circumstances of the acquisition, for example, the phase of the acquisition cycle. Figure 1 shows the notional acquisition phases for a satellite.

Figure 1: Notional Government Satellite Acquisition Life-Cycle

Check-out: the period from launch to when the satellite is determined to be operational
On-orbit: any time after launch, including check-out, during which a satellite is in its intended orbit
Mission life: the length of time during which a satellite is expected to be operational
Post mission life: the period after mission life in which a satellite is still fully or partially operational

Source: GAO analysis of Department of Defense and National Aeronautics and Space Administration policies. | GAO-17-490

During the design and development phase, when technology risks are higher, the government typically uses cost-reimbursement contracts. When the government is acquiring a “production-model” satellite, or a copy of a satellite with a proven design and build, a fixed-price contract may be used. In addition, for the on-orbit phase, the government typically negotiates with the contractor regarding the amount of incentives related to successful on-orbit performance.

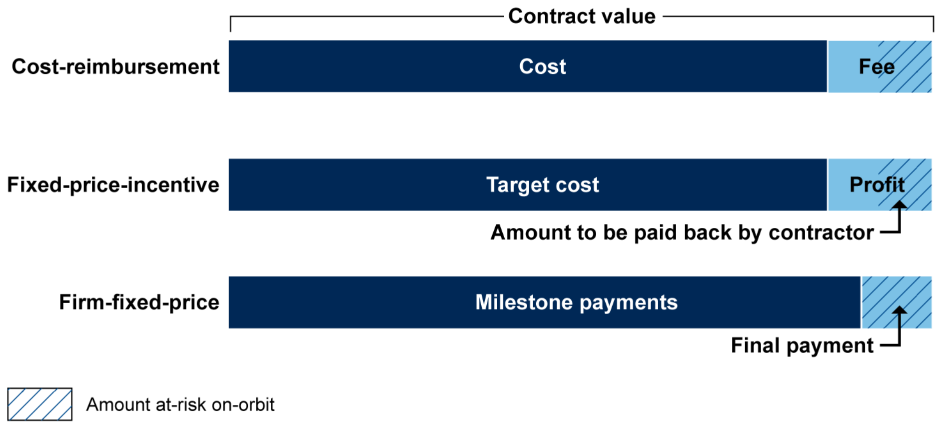
- **Which satellite component is being acquired.** Satellites are generally comprised of the bus and the instruments or payloads. The bus is the body of the satellite. It carries the payload and is composed of a number of subsystems, like the power supply, antennas, telemetry and tracking, and mechanical and thermal control subsystems. The bus provides electrical power, stability, and propulsion for the entire satellite. The payload of a satellite, which is carried by the bus, refers to all the devices or instruments a satellite needs to perform its mission, and can differ for each type of satellite. Some examples include cameras to take pictures of cloud formations for a weather satellite, and transponders to relay television signals for a communications satellite. Generally, developing payloads is riskier than developing buses.

- **Number of contracts used to acquire satellite components.** The government can choose to award one contract for the development and production of the satellite bus and all associated payloads, or it can award separate contracts for the development and production of the bus and each individual instrument. In the contracts we reviewed, DOD typically awarded a single contract to a prime contractor for the development of the bus and payloads, and according to officials, the prime contractor often awards contracts to subcontractors to provide the various instruments and parts. In contrast, for the NASA contracts and orders we reviewed, NASA typically awarded separate contracts and orders to multiple contractors to develop the bus and each instrument.
- **Number of space vehicles being acquired on a contract.** The government can acquire a single satellite or multiple satellites under one contract, and one contract may also include components for multiple satellites. Further, depending on the mission, an agency may buy a single satellite (such as for scientific discovery) or blocks of satellites (such as for global communications).

On-Orbit Performance Incentives

The quality and performance of a satellite—including whether it meets on-orbit requirements—usually cannot be determined until after it launches and reaches its intended orbit. Satellite development and production contracts may include on-orbit performance incentives aimed at ensuring that the satellite will meet performance requirements. Because the incentive is not earned until a satellite successfully demonstrates its performance on-orbit, an on-orbit performance incentive can be thought of as the dollar amount at risk if the contractor fails to meet the performance requirements specified in the contract (see figure 2).

Figure 2: Portion of Notional Government Satellite Contract Value at Risk Due to On-Orbit Performance by Contract Type



Source: GAO analysis of Department of Defense and National Aeronautics and Space Administration guidance. | GAO-17-490

On-orbit incentives are typically documented in a satellite contract's fee plans or in contract clauses. There are generally three mechanisms for on-orbit performance incentives: negative incentives, positive incentives, and withholding of milestone payments. Agencies can use a combination of these when designing on-orbit incentives, which are generally tied to objective performance criteria, such as successfully getting into the right orbit and achieving critical performance parameters once there.

When using negative incentives, the government generally pays the contractor incentives as the contractor completes work during the development or production phase. The contractor would have to pay back some or all of the incentives if the satellite fails to meet on-orbit performance parameters. With positive incentives, the government assesses satellite performance in any given period, such as 6 or 12 months, to determine how much the contractor earns for that period. The amount at risk for the contractor could be the same for a positive incentive or a negative incentive.

Firm-fixed-price contracts for satellite programs may have progress or performance-based payment plans that require fixed payments to be made upon successful completion of milestones, such as preliminary design review, final system test, and successful on-orbit check-out. If a satellite fails prior to check-out, the government may withhold the final milestone payment from the contractor.

Because satellite acquisitions are unlike other acquisitions, the Air Force's Space and Missile Systems Center (SMC) and NASA have tailored guidance on space acquisitions, and each specifically addresses on-orbit performance incentives.[7]

- SMC's March 2007 incentives guide states that on-orbit incentives should be clearly written to ensure enforceability, and require fully demonstrable performance in order to earn fee.[8] The guidance also specifies that the contract should contain specific descriptions as to the rights of the parties in the event of a failure, caused either by the contractor or by the government. One senior SMC contracting official stated that their contracting directorate maintains a repository of on-orbit incentive plans and contract clauses that have been implemented. These incentives arrangements can be used as guides for SMC programs as they develop new contracts.
- NASA's FAR supplement generally requires certain contracts for hardware deliverables worth more than $25 million to include performance incentives.[9] In the case of satellite acquisitions, the on-orbit incentives serve as performance incentives. In addition, NASA's FAR supplement requires that for cost-plus-award-fee contracts for end items, where the true quality of contractor performance cannot be measured until the end of the contract, only the last evaluation is final.[10] This allows NASA to evaluate the contractor's total performance—after the end item is delivered—against the award fee plan to determine the total earned award fee from the contract award fee pool. In other words, under this "re-look provision," the total award fee is not earned until the satellite has demonstrated its performance on-orbit.

In addition to on-orbit performance incentives, it is important to acknowledge the totality of the incentives and other terms in satellite contracts that are designed to motivate contractors to achieve the cost, schedule, and performance goals of the program. In many cases, multiple incentives are used to achieve such goals. The FAR provides that when

[7]The Air Force is the lead service for the vast majority of military space acquisitions. The Air Force's Space and Missile Systems Center develops, acquires, fields, and sustains many military space systems.

[8]Air Force Space and Missile Systems Center, *Incentives Guide* (Mar. 7, 2007).

[9]NASA FAR Supplement § 1816.402.

[10]NASA FAR Supplement § 1816.405.

multiple incentives are used, a balance must be achieved in which no incentive is either so insignificant that it offers little reward for the contractor, or so large that it overshadows other areas and neutralizes their motivational effect.[11] In addition, it requires all multiple incentive contracts to include a cost incentive that precludes rewarding a contractor for superior technical performance when their cost outweighs their value. For satellite programs, achievement of full mission performance is the primary objective, but cost and schedule goals also play key roles in a program's success. Our body of prior work has shown that most major government satellite programs experience significant cost growth and schedule delays due to unmatched resources and requirements, immature technologies at program start, and inconsistent application of knowledge-based practices throughout the life of a program.[12] As a result, although some programs may have successful on-orbit performance, they may also have had major cost overruns and schedule delays along the way.

Satellite Failure Definitions and Causes

There are many nuances when it comes to satellite failures. These can be especially important when considering government opportunities for recourse should a satellite fail or underperform. The Aerospace Corporation (Aerospace), a federally funded research and development center (FFRDC) that provides engineering and technical support to national security space programs, categorizes satellite anomalies based on the criticality or severity of the anomaly and distinguishes them based on their impact on the mission.[13] For the purposes of this report, a *catastrophic failure* results in the total loss of a satellite, or a satellite that will never meet any of its mission requirements; a *partial failure* results in a satellite that fails to meet some of its mission requirements or that loses a redundant system.

When satellites fail, they often do so in the first few months they are in orbit. Aerospace reported in 2012 that mission-impacting anomalies—or

[11]FAR Subsection 16.402-4.

[12]GAO, *Space Acquisitions: Actions Needed to Expand and Sustain Use of Best Practices,* GAO-07-730T (Washington, D.C.: Apr. 19, 2007) and *Space Acquisitions: Challenges Facing DOD as it Changes Approaches to Space Acquisitions,* GAO-16-471T (Washington, D.C.: Mar. 9, 2016).

[13]FFRDCs are sponsored and funded by the government to meet specific long-term technical needs that cannot be met by existing in house or contractor resources. They are managed by universities, not-for-profit entities, nonprofit organizations, or industrial firms.

failures—that occur during the first 120 days of a satellite's on-orbit life account for approximately 40 percent of all such failures that occur during the first 3 years of operation. Causes of failure during a satellite's first 3 years of operation varied according to Aerospace, but the top three reasons identified were issues related to a satellite's design, parts, and software.[14]

Agencies Generally Use Cost-Reimbursement Contracts with Incentives for Satellite Acquisitions

Given high development risks and the likelihood of requirements changes in satellite programs, most government satellite acquisitions use cost-reimbursement contracts. New technologies and unstable requirements mean satellite program officials are unlikely to accurately predict development costs and schedules, making cost-reimbursement contracts a prudent choice. When lower-risk items are being acquired, such as standard spacecraft and communications satellites, agencies are more likely to use firm-fixed-price contracts. In both cases, agencies tend to use incentives in their contracts to help achieve cost, schedule and performance goals.

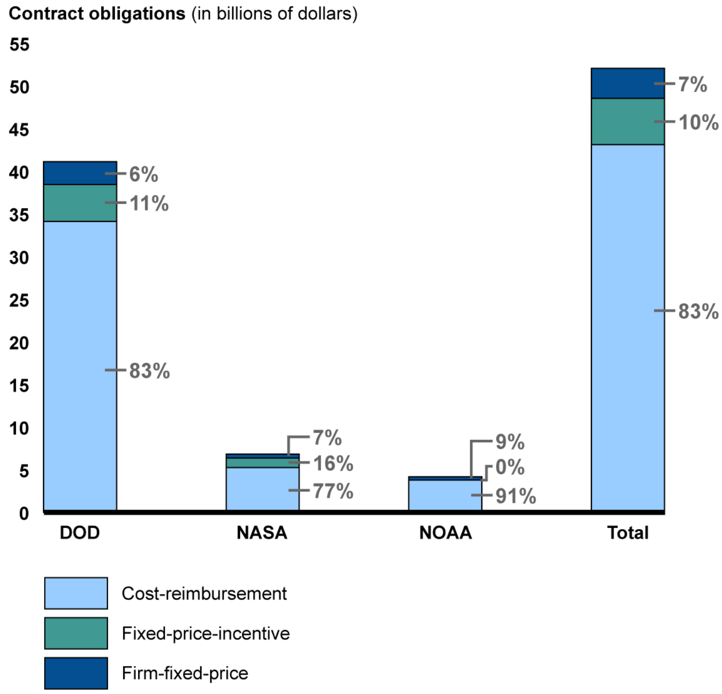
Agencies Primarily Used Cost-Reimbursement Contracts to Acquire Satellites Given Development Risk

Across the 19 programs we reviewed at DOD, NASA and NOAA, about $43.1 billion of $52.1 billion (83 percent) was obligated on cost-reimbursement contracts and orders, while the remaining $9 billion (17 percent) of obligations were on firm-fixed-price and fixed-price incentive contracts and orders.[15] DOD satellite obligations comprised nearly 80 percent of the government satellite acquisitions in our review (see figure 3).

[14]The Aerospace Corporation, *Findings and Lessons Learned from Operational Anomaly Trending and Analysis* (October 2012), reported specifically that the top reasons for satellite failures in the first 3 years were (1) design issues due to inadequate or incomplete analysis that may have led to an unexpected behavior of the design, (2) parts issues, mostly due to random hardware failures or degradation, which could be alleviated through more perceptive parts screening during integration and test, and (3) software issues, which may call for better software verification efforts.

[15]This data is as of September 2016. Of the approximately $9.0 billion obligated on fixed-price contracts, $5.4 billion was fixed-price incentive while $3.5 billion was firm-fixed-price.

Figure 3: Satellite Program Obligations by Agency and Contract Type as of September 2016



DOD = Department of Defense
NASA = National Aeronautics and Space Administration
NOAA = National Oceanic and Atmospheric Administration

Source: GAO analysis of Federal Procurement Data System-Next Generation (FPDS-NG) data, agencies' contract files, and contract data reported by agencies. | GAO-17-490

Note: We did not include the Defense Meteorological Satellite Program 19's (DMSP-19) contract data in this analysis because the contracts used for the DMSP-19 case study were for follow-on storage, maintenance, and support, rather than for satellite development and production.

Government satellite programs are often designed to develop and incorporate innovative technologies unavailable in the commercial market. We reported in 2010 that DOD accepts greater technology and development risks with space acquisitions, and as such, costs associated with technology invention are difficult to estimate.[16]

For our 12 in-depth case study programs, 15 of the 23 contracts and orders we reviewed were cost-reimbursement type contracts (see appendix III for more detailed information on the contract types for our

[16]GAO, *Briefing on Commercial and Department of Defense Space System Requirements and Acquisition Practices,* GAO-10-315R (Washington, D.C.: Jan. 14, 2010).

case study programs).[17] Several of the contract files for these programs cited technical complexity leading to uncertainties in cost performance or uncertain requirements as reasons their program used cost-reimbursement contracts. According to one program's contract files, a firm-fixed-price contract would not be appropriate for the design and development of the satellite's primary instrument because of the program's aggressive performance goals and flexible launch dates. In 2010, we reported that firm-fixed-price contracting normally does not work for DOD space systems because programs tend to start with many unknowns about the technologies and costs needed to develop satellites.[18] Since our 2010 report, however, DOD has begun to consider acquisition approaches that might be more productive using fixed-price contracts such as disaggregating large satellites and advancing technology incrementally.[19] One senior SMC contracting official noted that in recent years, SMC has acquired a number of satellite programs on a fixed-price basis. In these instances, once the programs matured the technologies and reduced risks, the programs were able to shift to a production-type state and use fixed-price contracts.

Five of the 23 case study contracts and orders used firm-fixed-price type contracts, mostly to acquire lower-risk items. These included standard spacecraft buses (meaning, those with proven designs) and communications satellites, both of which have relatively lower technical risks. For example, some NASA and NOAA programs we reviewed used firm-fixed-price orders to acquire spacecraft buses from the NASA "catalog," which contains proven designs from multiple contractors. In some cases, such as communication satellites, the commercial market produces satellites that government programs can use with only minor modifications. These satellites have typically been used in a commercial market—lowering technical risk—and may also have adequate pricing

[17]There are more contracts than case study programs in our review, because some programs used multiple contracts to acquire satellites. We specifically focused on the contract type related to the design, development, and production for the satellites. For two DOD contracts that included multiple satellites, some satellites were on cost-reimbursement contract line item numbers (CLIN) while others were on fixed-price incentive CLINs. Because the preponderance of the CLIN values for these contracts were cost-reimbursement, we categorized the entire contract as cost-reimbursement.

[18]GAO-10-315R.

[19]GAO, *DOD Space Systems: Additional Knowledge Would Better Support Decisions about Disaggregating Large Satellites,* GAO-15-7 (Washington, D.C.: Oct. 30, 2014).

data available to accurately estimate costs, both of which lend themselves to firm-fixed-price contracting.

The remaining three of the 23 case study contracts and orders we reviewed used fixed-price-incentive contracts to acquire additional satellites in production. For instance, DOD's SBIRS program bought its first four satellites under cost-reimbursement contracts, but bought the next two satellites with a fixed-price-incentive contract. According to the SBIRS contract file, program officials deemed the fixed-price incentive contract type the most appropriate because, given the maturity of the satellite vehicle design, they believed they could assess a fair and equitable ceiling price for the acquisition.[20] Fixed-price incentive contracts can be complex, as noted in SMC's guide to structuring incentives for fixed-price contracts, issued in November 2012.[21] For example, how risk is apportioned on a fixed-price-incentive contract may resemble that of a cost-reimbursable contract or a firm-fixed-price contract, depending on the share ratio—a calculation which represents the allocation of cost risk between the government and the contractor—and the ceiling price.[22] The guide also notes that fixed-price-incentive contracts can lead to unintended, negative outcomes if structured poorly or managed improperly.

Satellite Acquisition Programs Generally Used Incentives to Help Achieve Cost, Schedule, and Performance Goals

All of our 12 case study programs used incentives—including award fees, incentive fees, or some combination of the incentives—to motivate contractors to achieve cost, schedule, or performance goals. Program officials told us they used award fees during the development phase to incentivize the contractor to achieve specific, short-term goals. With each award fee determination, which, for example, may occur every 6 months, the government can focus the contractor on specific tasks or areas. Program officials also said that award fee determinations can be effective in changing contractor behavior. For example, one NASA program official

[20]The ceiling price is generally the maximum amount the government pays a contractor, except for adjustments under other contract clauses.

[21]SMC, *Guide to Structuring Incentives in a Fixed-Price Environment* (Nov. 14, 2012).

[22]When the range between the target cost of a contract and the ceiling price is wide, and the government is responsible for a greater proportion of any cost overruns, the contractor has less incentive to control costs, similar to a cost-plus-fixed-fee contract. When the range between the target cost and ceiling price is narrow, and the government and contractor have an equal share in any cost overruns, this provides the contractor with greater incentive to control costs, similar to a firm-fixed-price contract.

stated that during a particular award fee period, they informed the contractor that it needed to address planning for a complicated spacecraft thermal vacuum test that was behind schedule.[23] The official said that after program officials documented their concerns in award fee letters, contractor performance improved, resolving the issue. Table 2 provides examples of how the government tied incentives to cost, schedule, and performance objectives for selected case studies.

Table 2: Examples of How the Government Tied Incentives to Cost, Schedule, and Performance Goals for Satellite Acquisitions

Type	Cost	Schedule	Performance
Award fee	For one program, the contractor received an "unsatisfactory" rating for cost performance because the contractor experienced over a 100 percent increase over the baseline. This rating contributed to the contractor's low overall award fee score and as a result, the contractor did not earn any of the award fee that period.	For one program, the contractor received an "unsatisfactory" rating for schedule performance because the instrument delivery date slipped by several months due to rework taking longer than expected, among other issues. This rating contributed to the contractor's low overall award fee score and as a result, the contractor did not earn any of the award fee that period.	For one program, the contractor's fee could be reduced depending on how degraded the instrument was—no reduction in fee if fully operational, 15 percent reduction if slightly degraded, 40 percent reduction if moderately degraded, 75 percent reduction if severely degraded, and 100 percent reduction if the instrument failed.
Fixed-price incentive or cost-plus-incentives	For one program with a fixed-price-incentive contract, the contractor overran the target cost for two spacecraft and other associated costs by 38 percent and the ceiling price by 10 percent. The government paid 90 percent of the contractor's total incurred costs.	For one program, the contractor has an opportunity to earn a total of $6 million for achieving three key milestone deliveries ahead of schedule. The contractor earned 94 percent of the $2 million fee available for the first milestone and program officials stated the fees helped motivate the contractor to stay on schedule.	For one program, the contractor can earn two incentive payments together worth nearly 5 percent of the contract value for successful demonstration of on-orbit performance, with one payment after launch and one payment one year into the mission.

Source: GAO analysis of DOD, NASA, and NOAA documents. | GAO-17-490

However, in addition to the 12 in-depth case study programs, several of the NASA programs in our review included contracts or orders with FFRDCs, academic institutions, or non-profit organizations that did not include incentives. In most of these cases, NASA awarded cost-plus-fixed-fee or cost with no fee contracts or orders. For example, several programs used cost-plus-fixed-fee orders issued from an indefinite delivery / indefinite quantity contract between NASA and the California Institute of Technology, a private nonprofit educational institution, which

[23]Thermal vacuum tests are used to test spacecraft and components in a simulated space environment.

establishes the relationship for the operation of the Jet Propulsion Laboratory (JPL), an FFRDC.[24] The contract includes both service and product deliverables and encompasses a large number of discrete programs and projects. According to NASA procurement officials, the desired program outcomes or objectives and performance requirements are defined in task orders issued under the contract. NASA officials stated that when there are no fees to pay or withhold from a contractor, NASA still has tools available to motivate contractor performance. In these instances, agencies rely on non-fee incentives, such as providing positive or negative evaluations of contractors in the Contractor Performance Assessment Reporting System (CPARS).[25] The CPARS evaluations may affect the ability of FFRDCs and academic institutions to secure future contracts. Officials also stated the general reputation of contractors are important in winning future contracts. NASA officials also stated that with science missions, the academic institutions are self-motivated because they are interested in the data that satellites are collecting and within the science community, there is a sense of pride to be associated with a successful NASA mission.

On-Orbit Incentives Varied among Selected Programs

Eleven of the 12 selected in-depth case study programs we reviewed used contract incentives tied to on-orbit performance on at least one contract. We found, however, that the characteristics of the on-orbit incentives—such as the amounts at risk or the timing of the incentive payments—varied widely. In one instance, a satellite program held the contractor's entire fee at risk pending demonstration of satellite performance, but in other cases, the at-risk amount was a portion of the total fee or profit on the contract. Timing of payments also differed on a program-by-program basis, and in some cases, satellites within the same program had distinctive incentives. When asked how they developed on-orbit incentives for their respective contracts, program officials cited

[24]The California Institute of Technology has operated JPL as an FFRDC since 1959 to meet certain government research and development needs.

[25]CPARS is the single government-wide system for reporting contractor past performance information. The FAR notes the relationship between incentives and contractor performance, stating that although different subparts address recording contractor performance information and determining fees under award or incentive fee contracts, the fee amount paid to contractors should be reflective of the contractor's performance and the past performance evaluation should closely parallel and be consistent with the fee determination. See FAR 42.1500.

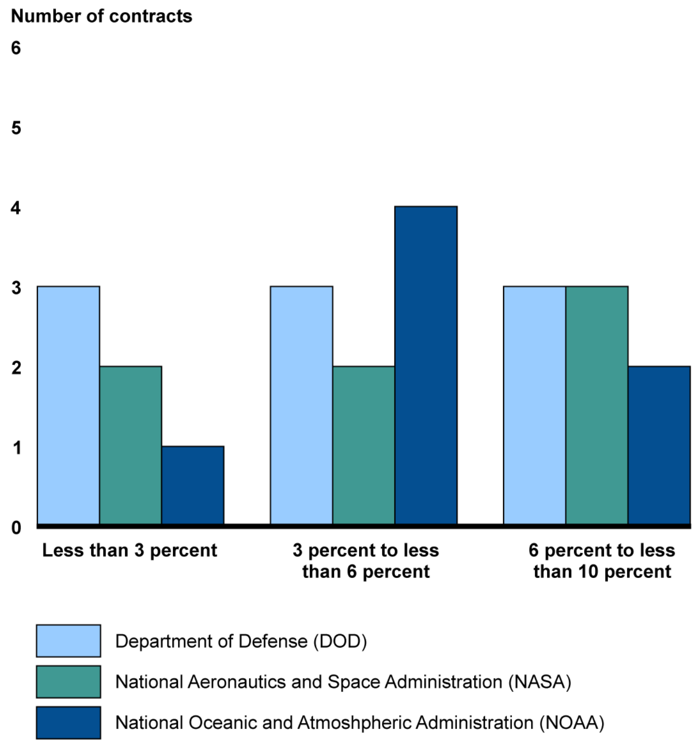
considerations such as other incentives in the contract, agency acquisition preferences, and past history.

Selected Programs Had Diverse On-Orbit Incentive Amounts and Payment Timing

On-orbit incentives varied widely across our 12 case study programs and in some cases, incentives varied between satellites under the same contract. To compare on-orbit incentives across these programs, we identified the two key characteristics that define each set of incentives—specifically, the amount and timing of the incentives.

On-orbit incentive amount. Based on our analysis of 23 contracts and orders representing our 12 case study programs, we found that the amount of on-orbit incentives relative to the overall contract value varied widely (see figure 4).

Figure 4: On-Orbit Percentage of Overall Contract Value for Selected Programs at DOD, NASA and NOAA



Source: GAO analysis of DOD, NOAA, and NASA contracts. | GAO-17-490

Note: The 12 selected programs represented 23 contracts and orders, as some programs have multiple contracts.

On-orbit incentives included on the contracts and orders for our 12 case study programs ranged from no on-orbit incentive to approximately 10 percent of the contract value (see appendix III for more information on the on-orbit incentive amounts by contract).[26] In some cases, on-orbit incentives were only a portion of the contractor's expected fee or profit. For one contract we reviewed, the contractor's full fee was contingent upon successfully demonstrating that the satellite met on-orbit performance requirements. Most of the contracts and orders we reviewed included multiple satellite vehicles, and the on-orbit incentive could vary by vehicle. For example, in one DOD contract we reviewed, the at-risk amount for the entire contract was 7 percent, but the at-risk amount for individual vehicles ranged from 5 percent to 13 percent.

The at-risk amount for individual satellites can also change depending on contractor performance during satellite development. Several contracts we reviewed define the potential on-orbit incentive amount as a percentage of the total award fee available, rather than a specific dollar amount. This means that poor contractor performance during the satellite development phase could reduce the amount of the on-orbit incentive. For example, if the total award fee for a contract is $100, and the on-orbit incentive is defined as 50 percent of the available award fee, the contractor could potentially earn $50 for on-orbit performance. If, however, the contractor loses $30 in potential award fee during the satellite development phase due to poor performance, the most the contractor could earn for on-orbit performance falls to $35 (50 percent of $70). Similarly, in one contract we reviewed, the at-risk amount on-orbit was capped as the lesser of 50 percent of the contractor's realized profit or 50 percent of the target profit. In this case, if the contractor's realized profit was zero dollars, there would be no payback to the government in the event of a failure.[27]

Because on-orbit incentives are realized near the end of a contract performance period, they can grow in importance to the contractor, relative to other incentives. For example, a contracting officer for one of our case study programs said that his program's contract placed an equal priority on both on-orbit performance and cost and schedule incentives,

[26]Because program-specific contract incentive information is proprietary, in this report we refer to them generically.

[27]In this case, the payback cap applies at the contract level, not for an individual satellite. This means that if one satellite fails and the contractor reaches the payback cap, there is no payback amount for any subsequent failures.

but the contractor lost most of the cost incentives due to cost overruns. The contracting officer said that the on-orbit incentive was the largest remaining incentive available to the contractor, so in this case, the contractor was more intent on earning the on-orbit incentive and less focused on controlling costs—a potentially bad situation for the program.

Incentive timing. The timing of an on-orbit incentive represents how the at-risk amount is spread out over a satellite's mission life. For some of the contracts and orders we reviewed for selected case study programs, the on-orbit incentives covered a satellite's entire mission life. There were some contracts and orders, however, for which the on-orbit incentives covered only a portion of the mission life. Given that when satellites fail, it is usually early in their mission life, three of the five firm-fixed-price satellite contracts or orders in our case study programs had milestone payment plans that ended once the on-orbit vehicle completed its check-out. Under this arrangement, depending on the terms of the contract, the government could potentially withhold the last milestone incentive payment if a catastrophic failure occurred prior to check-out, but would not have on-orbit incentives that lasted the remainder of the mission life. In these cases, the government assumes all of the risk once the vehicles complete check-out. Similarly, the on-orbit incentives for one of the SBIRS contracts covered the first 4 years of the satellite's mission life.

The WGS Block II and Block II follow-on contracts have a unique on-orbit incentive structure that includes a 10-year negative incentive followed by a 4-year positive incentive for the satellite's 14-year mission life. The negative incentive includes calculations to determine how much money the contractor has to pay the government if its satellite fails to meet performance requirements during the first 10 years. The positive incentive, starting at year 11 of the satellite's mission life, allows the contractor to offset any negative incentives assessed during that satellite's first 10 years. At the end of 14 years, the government adds up the positive and negative incentive amounts to determine what, if anything, the contractor has to pay back.

Satellite or component storage on the ground may also affect on-orbit incentives. For example, the GPS IIF contract reduces the on-orbit performance period by 25 percent if any of the first six vehicles is stored on the ground for 4 years; more if stored longer.

Contracting Officials across Selected Programs Cited Several Considerations in Developing On-Orbit Incentives

DOD, NASA, and NOAA officials cited several factors when developing on-orbit incentives for their respective programs, including the other incentives in the contract, agency acquisition preferences, and individual program history.

- **The overall contract.** Program officials do not view on-orbit incentives in isolation, but rather as part of the larger negotiated agreement with the contractor. Officials told us that during contract negotiations, they may be willing to reduce the amount of fee on-orbit or alter the timing of on-orbit incentives, in return for contractor concessions in other areas. Programs negotiated overall incentives for a contract as well as how the incentives were spread out over the contract, including how much was tied to on-orbit performance. Officials said contractors generally prefer front-loaded incentives, whereas agencies may tend to prefer placing incentives at the end of the contract. The resulting contract and incentive structure depends on what the government and the contractor can agree to.
- **Acquisition philosophy.** Program officials told us on-orbit incentives reflect the acquisition policies, leadership preferences, and prevailing agency practices at the time the contract is being drafted. For example, DOD promotes the use of incentive fees, where possible, over award fees, to encourage greater use of objective fee criteria. Program officials also said they typically look at other satellite program contracts in their respective agencies, explaining that incentives for new programs may be structured based on what other programs have agreed to.
- **Program history, staff, and contractor experience.** Program history can affect incentive structures in different ways. In the case of WGS, the on-orbit incentives for the Block II follow-on contracts were modeled after the incentives in the Block II contract. Further, program officials said they also modified past incentives or established new incentives based on their own contracting experience. They told us that prior experience executing specific incentive structures lends itself to structuring incentives the same way again. Similarly, they said that contractors may seek to negotiate incentive provisions based on their company's past experience.

Government's Recourse Is Limited When a Satellite Fails

The government's recourse in the event of a catastrophic satellite failure on-orbit is generally limited to recovery of a portion of the on-orbit incentive. As discussed above, the on-orbit incentive amount on any given satellite contract can vary widely but is uniformly less than 10 percent of the total satellite contract value. In all likelihood, the amount retained by or paid back to the government would be even less, as what the government may actually recoup depends on the circumstances of the failure. For example, if a contract includes no-fault provisions, when one contractor is at fault for the total loss of a satellite, the government may still be responsible for paying fees to the remaining contractors—whose products were not to blame for the failure. By design, on-orbit incentives are only a portion of the total contract value and therefore will not make the government whole in the event of total failure. Overemphasizing on-orbit incentives could result in the contractor losing sight of cost and schedule goals. Further, the government accepts more of the on-orbit risk than the contractor, in part because catastrophic failures are rare, according to satellite studies and industry experts we spoke to.

Modest Payback to Government When Satellites Fail

For our 12 case study programs, we found that the aggregate on-orbit incentive amount at risk is around 4 percent of the aggregate contract value.[28] This means that in a worst-case scenario in which all of the satellites failed prior to checkout, the maximum amount the government could recoup or withhold from the contractors is 4 percent of the total contract value. What the government could actually recoup or withhold depends on the terms of the contract and the circumstances of the failure, such as the extent to which technical parameters are met, the timing of the failure, and whether the contractor is found to be at fault.

Two satellites among the programs we reviewed experienced catastrophic or partial failures—DMSP-19 and SMAP. Program officials said the DMSP-19 spacecraft contractor repaid $2.7 million plus interest to the government as a result of the failure, but there was no repayment or payments withheld in the case of SMAP.

[28]For contracts and orders we reviewed with on-orbit incentives, the highest on-orbit incentive was less than 10 percent of the total contract value and the lowest was just over 1 percent.

- DMSP-19 suffered a catastrophic failure in the second year of its 5-year mission life when the Air Force lost the ability to control the satellite.[29] There were two prime contractors on the DMSP contracts—one for the spacecraft and one for the sensors. According to program officials, the spacecraft contractor was found to be at fault for the failure, and had to reimburse $2.7 million in fee plus interest.[30] Program officials stated that the sensor contractor was not responsible for the failure and therefore did not have to repay any fee.
- SMAP experienced a partial failure. One of SMAP's two primary sensors—the radar—failed, while the other—the radiometer—is operating as intended. NASA was unable to identify the exact cause, but determined that the failure was related to the radar's high-powered amplifier power supply. According to NASA's SMAP mishap investigation report, without the radar, SMAP will not be able to meet mission requirements because the radiometer alone cannot meet resolution requirements. Because JPL built SMAP under a task order with no on-orbit incentives, the government had no monetary recourse when the radar sensor failed.[31] The mishap investigation report estimated that the SMAP radar failure resulted in more than $550 million in losses, though the cost of the radar accounted for only 11 percent of that amount. Most of the estimated losses were related to investments in the science of the mission. However, NASA officials told us that the total science value of the shortfall in capability is highly uncertain. These officials noted that although not operating to its full resolution, SMAP provides higher resolution and more accurate soil moisture and sea surface salinity data than any prior NASA missions.

No-fault provisions can have implications for satellites with multiple prime contractors, as mentioned in the DMSP example. If one contractor is at

[29]The Air Force controlled the satellite by sending encrypted commands that the satellite decrypted and passed to the satellite's computer. The decryption device lost power so the satellite can no longer decrypt messages it receives. It is still flying and transmitting information, but the Air Force expects its performance to degrade over time.

[30]DMSP-19 is unique in that it was built in 1995 and stored until 2014. The initial production contracts were completed in the late 1990s. The Air Force then awarded sustainment contracts. When those contracts expired, the Air Force awarded the current sustainment contracts.

[31]It is important to note that while the government had no recourse following the SMAP radar failure, the outcome was similar to what would have happened under a positive on-orbit incentive approach. If a satellite with a positive on-orbit incentive failed, the government would simply not pay the incentive. With a negative incentive, the contractor may have had to payback some previously earned fee.

fault for the total loss of a satellite, the government may still be responsible for paying fees to the remaining contractors—whose products were not to blame for the failure—even though the satellite on which their products were riding was a total loss.

Representatives from commercial companies we spoke with said they typically purchase insurance to mitigate their risk in the event of satellite losses. According to satellite insurance company representatives, insurance for any one satellite is generally spread across multiple insurance companies, each of which insures only a portion of the total value of the satellite. The cost of insuring the launch and full mission life of a commercial satellite could add 10 to 20 percent of its total contract value, according to one insurance broker we spoke with, even though relatively few satellites suffer significant failures. He noted that, at this time, the small market of satellite insurance providers would not have the capacity to insure many government satellites, given their high costs to build and launch.

Overemphasizing On-Orbit Incentives May Not Benefit Programs

While tying some of a satellite contract's incentive to on-orbit performance can help focus a contractor on building a quality satellite, overemphasizing performance through on-orbit incentives can unintentionally cause the contractor to lose sight of cost or schedule. For example, JWST program officials stated that the $56 million on-orbit incentive fee in the initial JWST contract encouraged the contractor to exceed performance requirements at the expense of cost and schedule. In other words, the cost and schedule incentives were relatively less significant to the contractor than the on-orbit performance incentive. In December 2014, we found that when the contract was renegotiated in December 2013, the JWST program and the contractor agreed to replace the on-orbit incentive with award fees that could be used to incentivize cost and schedule goals during development.[32] Since that time, JWST officials told us the renegotiated award fees had contributed to better cost and schedule outcomes. Further, in another program's contract negotiation documents we reviewed, the government was willing to put less of the contractor's fee at-risk on-orbit in exchange for lower overall fees, which would reduce the contract price. Conversely, negotiation

[32]GAO, *James Webb Space Telescope: Project Facing Increased Schedule Risk with Significant Work Remaining,* GAO-15-100 (Washington, D.C.: Dec. 15, 2014).

documents reflected that the government considered accepting higher overall fees in exchange for putting more of the contractor's fee at-risk.

Also, it is unclear whether increased on-orbit incentives would decrease the likelihood of on-orbit failures. Program officials expressed a wide range of views on the relative importance of on-orbit incentives in achieving successful outcomes. Program officials agreed that poorly designed incentives might lead to bad program outcomes, but there was no consensus on the effect of well-designed incentives. Officials we spoke with believed that on-orbit incentives were important, but the reasons cited were sometimes more related to how they can used in negotiations with the contractor—leading up to contract award and, in some cases, for contract modifications—than achieving successful on-orbit performance. Attributing positive on-orbit performance directly to on-orbit incentives is challenging, given the many factors that contribute to a satellite program's success, including requirements and funding stability, technology maturity, and government and contractor experience. Further, on-orbit incentives are unlikely to flow down to the workers who actually build a satellite, or to sub-contractors who produce key parts and components. On-orbit incentives can span 10 years of performance, so the people who were directly involved in building a satellite may not even be with the company when the incentives are paid out.

Although contractors may be motivated to achieve on-orbit performance through on-orbit incentives, they are also motivated by other factors. For example, in 2005, we found that various considerations, such as securing future contracts with the government, can be stronger motivators than earning additional profit.[33] Officials from agencies and commercial companies that we spoke to confirmed that this is still true today. Specifically, program officials we interviewed stated that contractors react strongly to negative CPARS evaluations, as this could affect their ability to win future contracts. Officials also noted that contractors take pride in their work and believe in the missions their satellites support. They believed that contractors would do their best to succeed even without on-orbit incentives. They said that universities and FFRDCs are also motivated to do well because they are personally invested in advancing their scientific pursuits. According to program officials and commercial company representatives that we spoke to, the commercial satellite market is small but competitive, and satellite failures generate bad

[33] GAO-06-66.

publicity that could affect a company's ability to win commercial contracts and future government business.

Finally, satellite acquisition programs tend to have far more cost and schedule challenges than performance issues. We have a large body of work identifying cost growth and schedule delays for space programs, including some in our case studies, and have made a number of recommendations to address the causes of these challenges.[34] For example, we have previously recommended that agencies should improve their program cost estimates, separate the process of technology discovery from acquisition, and match resources and requirements at program start.[35] The cost growth for some of our case study programs is much larger than their on-orbit incentives. For example, JWST has experienced more than $3.6 billion in cost growth. That exceeds the combined on-orbit incentives for all 56 of the satellite vehicles in our case study programs. Similarly, the first two GPS III satellites have experienced more than $600 million in cost growth. That is more than double the entire amount of on-orbit incentives for all 10 GPS III satellites currently under contract.

A number of government officials and commercial companies we spoke with did not express concerns about the extent to which satellites experience catastrophic failures. Studies of satellite reliability vary depending on the timing and scope of the analysis, but the analyses we reviewed indicated that between 2 and 4 percent of satellites, including both government and commercial programs, experience a catastrophic

[34]GAO, Defense *Acquisitions: Improvements Needed in Space Systems Acquisition Management Policy,* GAO-03-1073 (Washington, D.C.: Sept. 15, 2003), *Defense Acquisitions: Despite Restructuring, SBIRS High Program Remains at Risk of Cost and Schedule Overruns,* GAO-04-48 (Washington, D.C.: Oct. 31, 2003); *DOD is Making Progress in Adopting Best Practices for the Transformational Satellite Communications System and Space Radar but Still Faces Challenges,* GAO-07-1029R (Washington, D.C.: Aug. 2, 2007) *Space Acquisitions: DOD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems,* GAO-07-96 (Washington, D.C.: Nov. 17, 2006); *Space and Missile Defense Acquisitions: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs,* GAO-11-404 (Washington, D.C.: June 24, 2011); *Space Acquisitions: DOD Delivering New Generations of Satellites, but Space System Acquisition Challenges Remain,* GAO-11-590T (Washington, D.C.: May 11, 2011); *James Webb Space Telescope: Actions Needed to Improve Cost Estimate and Oversight of Test and Integration,* GAO-13-4 (Washington, D.C.: Dec. 3, 2012); GAO-16-329SP; and *Space Acquisitions: Challenges Facing DOD as it Changes Approaches to Space Acquisitions,* GAO-16-471T (Washington, D.C.: Mar. 9, 2016).

[35]GAO-03-1073, GAO-07-1029R, GAO-07-96, and GAO-13-4.

failure before the end of their mission lives. Aerospace officials we spoke with said the failure rate for government satellites is around 2 percent, and that this is somewhat remarkable given that government satellites are often highly complex. Further, many government satellites utilize new, unproven technologies which pose more risk than commercial satellites; commercial satellites tend to use proven designs and rely more on mature technologies. As a result, it appears the most cost effective way to limit the government's loss in the event of a catastrophic failure may be to reduce cost growth and schedule delays by using best practices during satellite development, as we have previously recommended.

Agency Comments

We provided a draft of this report to DOD, NASA, and NOAA for their review and comment. DOD and NOAA provided technical comments, which we incorporated as appropriate. NASA had no technical or written comments.

We are sending copies of this report to the appropriate congressional committees, the Secretaries of Defense and Commerce, and the NASA Administrator. In addition, the report will be available at no charge on GAO's website at http://www.gao.gov.

If you or your staff have questions about this report, please contact me at (202) 512-4841, or chaplainc@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 major contributions to this report are listed in appendix IV.

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The Honorable John McCain
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The Honorable Jack Reed
Ranking Member
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The Honorable Bill Nelson
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The Honorable Mike Rogers
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The Honorable Jim Cooper
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Appendix I: Descriptions of Missions, Costs, and Quantities for Satellite Programs in GAO Review

The following tables present the missions, original total program costs and quantities, current total program costs and quantities, and the number of satellites in orbit as of March 2017 for all 19 of the programs included in our review. The total acquisition or project costs include development and production costs of the space vehicles and in some cases, costs associated with the ground systems, launch vehicles, and other costs outside of the satellite vehicles. As a result, the total costs for a given program will be larger than the contracts values discussed in this report.

Table 3: Department of Defense (DOD) Satellite Programs

Program	Mission	Original total acquisition cost (in fiscal 2017 dollars) and quantity[a]	Current total acquisition cost (in fiscal year 2017 dollars) and quantity[a]	Number of satellites in orbit as of March 2017
Advanced Extremely High Frequency (AEHF)	Replenish the existing Milstar system with higher-capacity, survivable, jam-resistant, worldwide secure communication capabilities for strategic and tactical warfighters.	Cost: $6.910 billion Quantity: 5	Cost: $15.046 billion Quantity: 6	3 of 6
Global Positioning System (GPS) IIF[b]	To provide positioning, navigation and timing service to civil and military users worldwide.	Cost: No separate data available because it is part of the NAVSTAR GPS program. Quantity: 2	Cost: No separate data available because it is part of the NAVSTAR GPS program. Quantity: 12	12 of 12
GPS III[b]	To supplement and eventually replace a constellation of multiple generations of satellite that provide global positioning, navigation, and timing capability to both military and civil users worldwide.	Cost: $4.275 billion Quantity: 8	Cost: $5.772 billion Quantity: 10	0 of 10
Mobile User Objective System (MUOS)[b]	Expected to provide a worldwide, multiservice population of mobile and fixed-site terminal users with increased narrowband communications capacity and improved availability for small terminal users.	Cost: $7.291 billion Quantity: 6	Cost: $7.403 billion Quantity: 6[c]	5 of 5[c]

Program	Mission	Original total acquisition cost (in fiscal 2017 dollars) and quantity[a]	Current total acquisition cost (in fiscal year 2017 dollars) and quantity[a]	Number of satellites in orbit as of March 2017
Space Based Infrared System (SBIRS)[b]	Being developed to replace the Defense Support Program and perform a range of missile warning, missile defense, technical intelligence, and battlespace awareness missions. SBIRS is to consist of four geosynchronous earth orbit satellites, two sensors on host satellites in highly elliptical orbit, two replenishment satellites and sensors, and fixed and mobile ground stations.	Cost: $4.986 billion Quantity: 5	Cost: $19.184 billion Quantity: 6	3 of 6
Wideband Global SATCOM (WGS)[b]	Provides worldwide communications services to U.S. warfighters, allies, and other special users.	Cost: $1.295 billion Quantity: 3	Cost: $4.269 billion Quantity: 8 (does not include 2 funded by international partners)	9 of 10

Source: GAO presentation of data from DOD's Selected Acquisition Reports, with cost data reported in fiscal year 2017 dollars, and other DOD data. | GAO-17-490

[a]Each program's acquisition cost includes research and development and procurement costs and does not include acquisition-related operation and maintenance costs.

[b]Denotes GAO case study programs.

[c]The current cost and quantity reported are as of the December 2015 Selected Acquisition Report. As of March 2017, the quantity was reduced to 5.

Table 4: National Aeronautics and Space Administration (NASA) Space Projects

Project	Mission	Baseline total project cost (in then year dollars) and quantity[a]	Current total project cost (in then year dollars) and quantity[a]	Number of satellites in orbit as of March 2017
Global Precipitation Measurement (GPM) Mission	Seeks to improve the scientific understanding of the global water cycle and the accuracy of precipitation forecasts.	Cost: $975.9 million (baseline fiscal year 2010) Quantity: 1	Cost: $928.1 million (estimate from Feb. 2014) Quantity: 1	1 of 1
Gravity Recovery and Climate Experiment Follow-On (GRACE-FO)	Continue and expand upon the 2002 GRACE mission, which remains in operation. It will provide high-resolution models of Earth's gravity field and insight into water movement on and beneath the Earth's surface over a 5-year period. These models will provide rates of ground water depletion and polar ice melt and enable improved planning for droughts and floods.	Cost: $431.9 million (baseline fiscal year 2014) Quantity: 2	Cost: $431.9 million (latest estimate Feb. 2016) Quantity: 2	0 of 2

Project	Mission	Baseline total project cost (in then year dollars) and quantity[a]	Current total project cost (in then year dollars) and quantity[a]	Number of satellites in orbit as of March 2017
Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)[b]	A follow-on mission to ICESat designed to measure changes in polar ice-sheet mass and elevation. These measurements will provide a better understanding of the mechanisms that drive these changes and their associated effect on global sea level.	Cost: $860.3 million (baseline fiscal year 2013) Quantity: 1	Cost: $1.1 billion (latest estimate Feb. 2016) Quantity: 1	0 of 1
James Webb Space Telescope (JWST)[b]	Large, infrared-optimized space telescope designed to help understand the origin and destiny of the universe, the creation and evolution of the first stars and galaxies, and the formation of stars and planetary systems. It will also help further the search for Earth-like planets.	Cost: $4.964 billion (baseline fiscal year 2009) Quantity: 1	Cost: $8.825 billion (latest estimate Feb. 2016) Quantity: 1	0 of 1
Landsat Data Continuity Mission (LDCM)	Seeks to extend the ability to detect and quantify changes on the Earth's surface at a scale where natural and man-made causes of change can be differentiated. It is the successor mission to Landsat 7.	Cost: $941.7 million (baseline fiscal year 2010) Quantity: 1	Cost: $931.2 million (estimate from Feb. 2013) Quantity: 1	1 of 1
Magnetospheric Multiscale (MMS)	Will investigate how magnetic fields around Earth connect and disconnect, explosively releasing energy via a process known as magnetic reconnection. MMS will provide a three-dimensional view of this fundamental process, which occurs throughout the universe and is one of the most important drivers of space weather.	Cost: $1.083 billion (baseline fiscal year 2009) Quantity: 4	Cost: $1.123 billion (estimate from Feb. 2015) Quantity: 4	4 of 4
Orbiting Carbon Observatory 2 (OCO-2)	Designed to enable more reliable predictions of climate change and is based on the original OCO mission that failed to reach orbit in 2009. It is making precise, time-dependent, global measurements of atmospheric carbon dioxide. These measurements will help scientists better understand the processes that regulate atmospheric carbon dioxide and its role in the carbon cycle.	Cost: $349.9 million (baseline fiscal year 2010) Quantity: 1	Cost: $427.6 million (estimate from Feb. 2015) Quantity: 1	1 of 1

Project	Mission	Baseline total project cost (in then year dollars) and quantity[a]	Current total project cost (in then year dollars) and quantity[a]	Number of satellites in orbit as of March 2017
Soil Moisture Active and Passive (SMAP)[b]	Provide new information on global soil moisture and its freeze/thaw state enabling new advances in hydrospheric science and applications. These measurements will improve understanding of regional and global water cycles and climate changes, and improve the accuracy of weather, flood, and drought forecasts.	Cost: $916.5 million (baseline fiscal year 2012) Quantity: 1	Cost: $914.6 million (estimate from Feb. 2015) Quantity: 1	1 of 1
Surface Water and Ocean Topography (SWOT)	Will use its wide-swath radar altimetry technology to take repeated high-resolution measurements of the world's oceans and freshwater bodies to develop a global survey. This survey will make it possible to estimate water discharge into rivers more accurately, and help improve flood prediction.	N/A	Cost: $647 million - $757 million (estimate is preliminary and as of Feb. 2016) Quantity: 1	0 of 1
Tracking and Data Relay Satellite (TDRS) K, L, M[b]	Contribute to the existing network by providing continuous high-bandwidth digital voice, video, and mission payload data, as well as health and safety data relay services to Earth-orbiting spacecraft.	Cost: $451.3 million (baseline fiscal year 2010) Quantity: 2	Cost: $426.5 million (estimate from Feb. 2013) Quantity: 2[c]	2 of 3[c]
Transiting Exoplanet Survey Satellite (TESS)[b]	Use four identical, wide field-of-view cameras to conduct the first extensive survey of the sky from space. The mission's goal is to discover exoplanets—or planets in other solar systems—during transit, the time when the planet's orbit carries it in front of its star as viewed from Earth.	Cost: $378.4 million (baseline fiscal year 2015) Quantity: 1	Cost: $351.7 million (latest estimate Feb. 2016) Quantity: 1	0 of 1

Source: GAO presentation of NASA data. | GAO-17-490

[a]All cost information is presented in nominal then-year dollars for consistency with budget data. Because of changes in NASA's accounting structure, its historical cost data are relatively inconsistent. As such, we used then-year dollars to report data consistent with the data NASA reported to us. Then year dollars include the effects of inflation and escalation. Current baseline costs for all projects are adjusted to reflect the cost accounting structure in NASA's fiscal year 2009 budget estimates. For the fiscal year 2009 budget request, NASA changed its accounting practices from full-cost accounting to reporting only direct costs at the project level.

[b]Denotes GAO case study programs.

[c]NASA has launched TDRS K and L and plans to launch TDRS M in the summer of 2017. The cost data presented only reflects a quantity of 2.

Table 5: Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Satellite Programs

Program	Mission	Baseline estimated life-cycle cost (in then year dollars) and quantity	Current estimated life-cycle cost (in then year dollars) and quantity	Number of satellites in orbit as of March 2017
Geostationary Operational Environmental Satellite (GOES)-R Series[a]	A collaboration between NOAA and NASA, the GOES-R series, which includes GOES R, S, T, and U, will provide continuous imagery and atmospheric measurements of Earth's Western Hemisphere, total lightning data, and space weather monitoring to provide critical atmospheric, hydrologic, oceanic, climatic, solar, and space data.	Cost: $7.6 billion Quantity: 2	Cost: $10.9 billion (through 2036) Quantity: 4	1 of 4
Joint Polar Satellite System (JPSS)[a]	A collaboration between NOAA and NASA, JPSS will deliver key observations for essential products and services, including forecasting severe weather, assessing environmental hazards, and provides continuity of critical global observations, including atmosphere, oceans, and land.	Cost: $11.9 billion (estimate as of May 2010 for life cycle of 2010-2024, including $2.9 billion spent on National Polar-orbiting Operational Environmental Satellite System) Quantity: 2	Cost: $11.3 billion (estimate as of Dec. 2014 for life cycle of 2010-2025, including $2.9 billion spent on National Polar-orbiting Operational Environmental Satellite System) Quantity: 2[b]	0 of 4[b]

Source: GAO presentation of NOAA data. | GAO-17-490

[a]Denotes GAO case study programs.

[b]NOAA plans to launch 4 JPSS satellites. NOAA has only purchased 2 spacecraft to date, but has awarded contracts for 4 sets of instruments. The costs presented do not include the third or fourth JPSS satellites.

Appendix II: Objectives, Scope, and Methodology

To assess the Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and the Department of Commerce's National Oceanic and Atmospheric Administration's (NOAA) contract and incentive structures, under the authority of the Comptroller General to conduct evaluations on his own initiative, we examined (1) the types of contracts and incentive structures government satellite programs use to develop satellites and why, (2) how selected programs structure on-orbit incentives, and (3) government options for recourse, if any, when a satellite fails or underperforms.

To determine the types of contracts and incentive structures government satellite programs use to develop satellites and the reasons why, we analyzed contract obligations data from the Federal Procurement Data System-Next Generation (FPDS-NG) as of September 2016 for 19 programs, comprising all current major satellite programs across DOD, NASA, and NOAA. To assess the reliability of the FPDS-NG data, we reviewed relevant internal control documents and data quality summaries. We determined that the FPDS-NG data were sufficiently reliable for the purposes of this engagement. For DOD, we included major defense acquisition programs, and at NASA and NOAA, we included programs with a life-cycle cost greater than $250 million.[1] For our analysis, we included each program's development and production contracts and orders for the spacecraft and instruments and generally excluded contracts and orders related to launch, ground systems, maintenance, operations, and support services if they were separate contracts and orders. If these items or services were included within the development and production contract or order, we included them in our analysis. For each contract and order, we determined the predominant contract type for the design, development, and production of the satellites on the contract. We also reviewed DOD, NASA, and NOAA policies and guidance on contracting and incentives, and Federal Acquisition Regulation (FAR) and agencies' FAR supplements for regulations and procedures on contracting.

To determine the range of on-orbit incentive structures and government options for recourse should a satellite fail or underperform, of the 19 major satellite programs in our review, we selected 12 programs for in-

[1]We defined current major satellite acquisition programs as Earth-orbiting satellite acquisition programs in development, production, or with at least one satellite on-orbit within its mission life as of September 2016 and NASA's James Webb Space Telescope (JWST) given that JWST is the largest major program within NASA's portfolio.

depth analysis as case studies based on program size, contract type, contractor, mission, or notable on-orbit performance. For each case study, we analyzed contract files and conducted interviews with program and contracting officials at DOD, NASA, and NOAA to discuss contract types and incentive structures, rationale for the use of specific contract types and incentive structures, on-orbit performance and programmatic outcomes. Across the 12 case study programs, there were 23 contracts and orders and 56 space vehicles (see table 6).

Table 6: GAO Satellite Program Case Studies and Associated Number of Contracts and Orders and Space Vehicles

Agency	Program name	Number of contracts or orders GAO reviewed	Number of space vehicles total
DOD	Global Positioning System (GPS) IIF	1	12
	GPS III	1	10
	Mobile User Objective System (MUOS)	1	5
	Space Based Infrared System (SBIRS) (all three blocks)	3	6
	Wideband Global SATCOM (WGS) Blocks I, II, and II Follow-On	3	10
NASA	Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	2	1
	James Webb Space Telescope (JWST)	1	1
	Soil Moisture Active and Passive (SMAP)	1	1
	Transiting Exoplanet Survey Satellite (TESS)	2	1
	Tracking and Data Relay Satellite (TDRS)	1	3
NOAA	Geostationary Operational Environmental Satellite (GOES)-R Series	2	4
	Joint Polar Satellite System (JPSS)	5	2
	Total	**23**	**56**

Source: GAO analysis of DOD, NASA, and NOAA contracts. | GAO-17-490

To determine the at-risk on-orbit incentive amount by contract or order, we reviewed contract clauses and fee plans for each of the 23 contracts and orders associated with the 12 case study programs to calculate the amount of money the contractor would not be paid or would need to pay back in the case of a catastrophic failure. We calculated the at-risk amount based on a hypothetical “worst case scenario” for each contract or order, in which the maximum payback or forgone payment would be assessed for a complete failure of the satellites. The at-risk amounts included milestone payments that would be withheld, award and incentives fees that would not be paid, and amounts that would need to be paid back by the contractor. These at-risk amounts were divided by the current value of the contract or order to calculate a percentage of contract or order value that would be at risk. The contract scope varied across our case study contracts. For example, some contracts included costs associated with developing ground systems or sustainment costs whereas others only included satellite development and production costs. However, the contract scope did not significantly alter the at-risk calculations. For all of the contracts and orders we reviewed, regardless of scope, the at-risk amounts were less than 10 percent of the contract value.

For the seven remaining satellite programs at DOD and NASA that were not included in our case studies, we developed agency-specific data collection instruments (DCI) that we pre-tested, administered, and from which we analyzed the information collected. We tailored the DCIs to each agency based on agency policies and guidelines for contracting to obtain program-specific contract details, values, obligations to-date, special clauses used, incentive structures, and performance periods. We determined that the data collected from the DCIs were sufficiently reliable for the purposes of this engagement. The seven programs for which we executed DCIs included:

DOD

- Advanced Extremely High Frequency (AEHF);

NASA

- Global Precipitation Measurement (GPM) Mission,
- Gravity Recovery and Climate Experiment Follow-On (GRACE-FO),
- Landsat Data Continuity Mission (LDCM),
- Magnetospheric Multiscale (MMS),
- Orbiting Carbon Observatory 2 (OCO-2), and
- Surface Water and Ocean Topography (SWOT).

In addition to the case studies above, we reviewed the Defense Meteorological Satellite Program 19 (DMSP-19) because of its recent on-orbit failure. We reviewed DMSP-19's follow-on storage, maintenance, and support contracts rather than the development and production contracts because at the time of the failure, work was being performed under the follow-on contract. These contracts contained information on the on-orbit incentives and relevant options for government recourse after the on-orbit failure occurred.

We also interviewed officials from a nongeneralizable sample of commercial companies: Ball Aerospace, DigitalGlobe, IntelSat, Lockheed Martin, and ViaSat to identify how selected commercial companies use on-orbit incentives and how commercial satellite acquisitions differ from government satellite acquisitions. We selected the companies based on the type of satellites they build or acquire. In addition to commercial satellite companies, we also consulted satellite insurance brokers from Marsh and one underwriter, XL Catlin, to obtain information on the likelihood of satellite failures in the commercial and government markets, the general capacity of the commercial satellite insurance market, and the dollar amounts associated with insuring commercial satellites. We reviewed Aerospace Corporation studies and briefings and interviewed Aerospace Corporation officials to identify the point during the life of a satellite in which most satellite failures occur, the frequency of government satellite failures, and to identify the various categories of satellite failures.

We conducted this performance audit from March 2016 to June 2017 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 III: Contract Type and On-Orbit Incentives At-Risk for GAO Satellite Program Case Studies

The 12 in-depth case study satellite programs we reviewed included 23 contracts and orders. For these contracts and orders, we determined the predominant contract type for the design, development, and production of the satellites; and percent of contract value at-risk for on-orbit performance; which are presented in the tables below. We determined the percent of contract value at-risk for on-orbit performance for each contract or order by dividing the maximum dollar amounts the contractor would not be paid or would have to pay back in the event of a catastrophic failure by the current contract value.

Table 7: Department of Defense (DOD) Contracts for Selected Satellite Acquisition Programs

Program	Contract work description	Contract type	Contract value *As of date*	Percentage of contract value at-risk for on-orbit performance
Global Positioning System (GPS) IIF	Spacecraft and payloads *12 space vehicles*	Space vehicles 1-3: CPAF Space vehicles 4-12: FPI	$3.9 billion *May 2016*	Less than 3 percent
GPS III	Spacecraft and payloads *10 space vehicles*[a]	Space vehicles 1-10: CPIF / AF	$3.7 billion *August 2016*	6 percent to less than 10 percent
Mobile User Objective System (MUOS)	Spacecraft and payloads *5 space vehicles*	Space vehicles 1-2: CPIF / AF Space vehicles 3-5: FPI / AF	$5.0 billion *March 2017*	3 percent to less than 6 percent
Space Based Infrared System (SBIRS)	Geosynchronous earth orbit (GEO) 1-2, highly elliptical orbit (HEO) 1-2 payloads, ground systems	CPAF	$9.5 billion *July 2016*	Less than 3 percent
	GEO 3-4, HEO 3-4 payloads	CPAF	$3.3 billion *August 2016*	3 percent to less than 6 percent
	GEO 5-6	FPI	$1.9 billion *August 2016*	6 percent to less than 10 percent
Wideband Global SATCOM (WGS)	Block I *3 space vehicles*	FFP	$842.6 million *April 2013*	3 percent to less than 6 percent
	Block II *3 space vehicles*	FPI	$1.2 billion *August 2016*	Less than 3 percent
	Block II Follow-On *4 space vehicles*	FFP	$1.8 billion *June 2016*	6 percent to less than 10 percent

Legend: CPAF = cost-plus-award-fee, CPIF = cost-plus-incentive-fee, CPFF = cost-plus-fixed-fee, FPAF = fixed-price-award-fee, FPI = fixed-price incentive, FFP = firm-fixed-price
Source: GAO analysis of DOD program contracts. | GAO-17-490

[a]The GPS III contract has options for 2 more satellites but we did not include these in the table because the options have not been exercised.

Table 8: National Aeronautics and Space Administration (NASA) Contracts or Orders for Selected Satellite Acquisition Programs

Program	Contract / order work description	Contract / order type	Contract / order value *As of date*	Percent of contract / order value at-risk for on-orbit performance
Tracking and Data Relay Satellite (TDRS)	Spacecraft and payload *3 space vehicles*	FPI	$1.1 billion *May 2016*	6 percent to less than 10 percent
Transiting Exoplanet Survey Satellite (TESS)	Spacecraft	CPFF / IF	$83.4 million *March 2017*	3 percent to less than 6 percent
	Instrument	Cost no fee	$55 million *July 2016*	Less than 3 percent
James Webb Space Telescope (JWST)	Observatory segment	CPAF / IF	$3.6 billion *July 2016*	6 percent to less than 10 percent
Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2)	Spacecraft and missions operations center	FFP	$186.5 million *March 2017*	3 percent to less than 6 percent
	Instrument – 3 lasers	CPAF / IF	$53.0 million *March 2017*	6 percent to less than 10 percent
Soil Moisture Active and Passive (SMAP)	Phase C/D, including project management, systems engineering, and the radar	CPAF	$344.3 million *April 2017*	Less than 3 percent

Legend: CPAF = cost-plus-award-fee, CPIF = cost-plus-incentive-fee, CPFF = cost-plus-fixed-fee, FPI = fixed-price incentive, FFP = firm-fixed-price
Source: GAO analysis of NASA program contracts. | GAO-17-490

Table 9: Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Contracts or Orders for Selected Satellite Acquisition Programs

Program	Contract / order work description	Contract / order type	Contract / order value *As of date*	Percent of contract / order value at-risk for on-orbit performance
Geostationary Operational Environmental Satellite (GOES)-R Series	Spacecraft *4 space vehicles*	CPAF	$1.9 billion *June 2016*	3 percent to less than 6 percent
	Advanced Baseline Imager instrument *4 instruments*	CPAF	$941.0 million *May 2016*	Less than 3 percent
Joint Polar Satellite System (JPSS)	Spacecraft 1[a]	FFP	$339.4 million *March 2017*	6 percent to less than 10 percent
	Spacecraft 2[a]	FFP	$244.5 million *March 2017*	6 percent to less than 10 percent
	Advanced Technology Microwave Sounder instrument *4 instruments*	CPAF	$411.5 million *March 2017*	3 percent to less than 6 percent
	Cross-track Infrared Sounder instrument *4 instruments*	CPAF / FF	$701.8 million *March 2017*	3 percent to less than 6 percent
	Visible Infrared Radiometer Suite instrument *4 instruments*	CPAF / FF	$1.1 billion *March 2017*	3 percent to less than 6 percent

Legend: CPAF = cost-plus-award-fee, CPFF = cost-plus-fixed-fee, FFP = firm-fixed-price
Source: GAO analysis of NOAA program contracts. | GAO-17-490

[a]NOAA plans to launch 4 JPSS satellites. NOAA has only purchased 2 spacecraft to date, but has awarded contracts for 4 sets of instruments.

Appendix IV: GAO Contact and Staff Acknowledgments

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Staff Acknowledgments

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