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National Aeronautics and Space Administration

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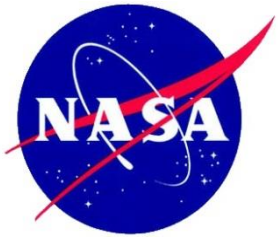
NASA's Management of Its Astronaut Corps

January 11, 2022

Report No. IG-22-007



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RESULTS IN BRIEF

NASA's Management of Its Astronaut Corps

January 11, 2022

IG 22 007 (A 21 005 00)

WHY WE PERFORMED THIS AUDIT

As NASA enters a new era of human space flight, including returning to the Moon and eventually landing humans on Mars, effective management of its astronaut corps—the people who fly its space flight missions—is critical to the Agency's success. Astronauts serve as the face and voice of the Agency's efforts to inspire the next generation of explorers, scientists, and engineers. After reaching its peak of nearly 150 astronauts in 2000, the size of the corps diminished with the end of Space Shuttle missions in 2011 and now stands at 44, one of the smallest cadres of astronauts in the past 20 years. NASA's Flight Operations Directorate, responsible for training NASA astronauts, and NASA's Astronaut Office, responsible for managing the astronaut corps, face several challenges in a post-Shuttle era, including:

- meeting the Agency's goal of deep space travel;
- maintaining and expanding a presence in low Earth orbit, in particular on the International Space Station (ISS or Station);
- executing space flight missions on multiple vehicles; and
- aiding in the design and development of other systems for Artemis missions.

In this report, we examined NASA's management of its astronaut corps, specifically the extent to which NASA's processes for sizing, training, and assigning the corps are aligned with the Agency's current and future missions and objectives. To complete our work, we interviewed Agency officials from the Human Exploration and Operations Mission Directorate at Headquarters, Johnson Space Center, Kennedy Space Center, and Marshall Space Flight Center, and reviewed Agency documentation guiding NASA's management of the astronaut corps and human space flight operations.

WHAT WE FOUND

The processes NASA uses to size, train, and assign astronauts to specific missions are primarily calibrated toward meeting the current needs of the ISS. For example, NASA's process for sizing the astronaut corps is designed to ensure that a sufficient number of astronauts are available to meet the Agency's flight manifest needs, which includes maintaining a planned crew of between three and four astronauts on the Station over the next 5 years. However, the astronaut corps is projected to fall below its targeted size or minimum manifest requirement in fiscal year (FY) 2022 and FY 2023 due to attrition and additional space flight manifest needs. More concerning, the Astronaut Office calculated that the corps size would exactly equal the number of flight manifest seats NASA will need in FY 2022. As a result, the Agency may not have a sufficient number of additional astronauts available for unanticipated attrition and crew reassignments or ground roles such as engaging in program development, staffing Astronaut Office leadership and liaison positions, and serving as spokespeople for the Agency. In light of the expanding space flight opportunities anticipated for the Artemis missions, the corps might be at risk of being misaligned in the future, resulting in disruptive crew reorganizations or mission delays.

Over time, the specific skillsets needed within the astronaut corps have evolved with the Agency's space flight missions—from Apollo's need for test pilots to the Station's need for scientists and mission specialists. As the Artemis program offices work with the Flight Operations Directorate and Astronaut Office to identify required skillsets for space flight missions beyond the ISS (including pilots, medical doctors, and scientists), the composition of skillsets within the corps may need to be augmented to ensure sufficient capacity to execute Artemis missions. However, astronaut skillset data is not consistently collected, comprehensively organized, or regularly monitored or updated. The Chief and Deputy Chief of the Astronaut Office said they can use various tracking systems, if needed, but given the small number of astronauts in the corps they primarily rely on their own informal knowledge to inform skillset decisions. While this kind of informal decision making has been used to manage ISS missions, it might not be effective as the size of the corps increases, still-evolving Artemis requirements are incorporated into astronaut training, and attempts to track skillsets over time for multiple missions become more complex.

The Astronaut Office's personnel databases also lack comprehensive demographic information specific to the astronaut corps. This poses a challenge to assessing whether NASA is meeting Agency and Administration diversity, equity, inclusion, and accessibility objectives. In recent years, the Agency has prioritized these efforts and announced its intent to land the first woman and first person of color on the Moon as part of the Artemis missions. Additionally, the Administration has made recent requests to the Astronaut Office to provide greater detail on diversity within the corps. Current data limitations restrict NASA's ability to fully measure its progress towards meeting broader diversity, equity, inclusion, and accessibility goals—a significant issue given that astronauts are among the most publicly visible employees at the Agency.

As the Agency prepares for crewed Artemis missions, astronaut training needs will change. As with sizing, the current astronaut training framework is primarily aligned to ISS mission requirements. The Astronaut Office is in the process of developing a framework for Artemis training, but this framework has not been formally chartered nor have any Artemis crews been announced. As such, specific mission-focused training for the Artemis II mission—the first crewed Artemis flight—has not yet begun. While the Astronaut Office estimates training for the Artemis III and successor missions will require approximately 2 years, even with the projected delays to Artemis II and III launches the Agency could be overestimating the time available to develop and implement the necessary training framework and regimen across key Artemis systems, including the Orion Multi-Purpose Crew Vehicle (Orion), next-generation spacesuits, Human Landing System (HLS), and Gateway. Delays in moving beyond the current ISS-focused approach for current and future astronauts increase the risk of delays in developing the necessary training to meet Artemis mission goals.

WHAT WE RECOMMENDED

To ensure the astronaut corps is aligned to meet current and future mission needs, we made four recommendations, including for NASA's Director of the Flight Operations Directorate and the Chief of the Astronaut Office to further centralize and maintain its collection, summary, and monitoring of detailed astronaut data—including skills, certifications, training, and demographics—to better support the sizing and alignment of the astronaut corps, and to help inform recruiting and training of astronauts to fulfill NASA's strategic goals, including continuing to expand the diversity of the astronaut corps. To ensure the training process for future Artemis missions is developed with sufficient time for implementation and revision, the Director of the Flight Operations Directorate and the Chief of the Astronaut Office should coordinate with Artemis program offices to complete the development and chartering of the framework of Artemis boards and panels to ensure alignment with future mission training needs for new vehicles and missions, including Orion, next-generation spacesuits, HLS, and Gateway.

We provided a draft of this report to NASA management who concurred with our recommendations. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

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Acronyms

ETRIP	Expedition Training Requirements Integration Panel
FOD	Flight Operations Directorate
FY	fiscal year
HEOMD	Human Exploration and Operations Mission Directorate
HLS	Human Landing System
HSFO	Human Space Flight Operations
ISS	International Space Station
ITCB	International Training Control Board
OIG	Office of Inspector General
PPBE	Planning, Programming, Budgeting, and Execution

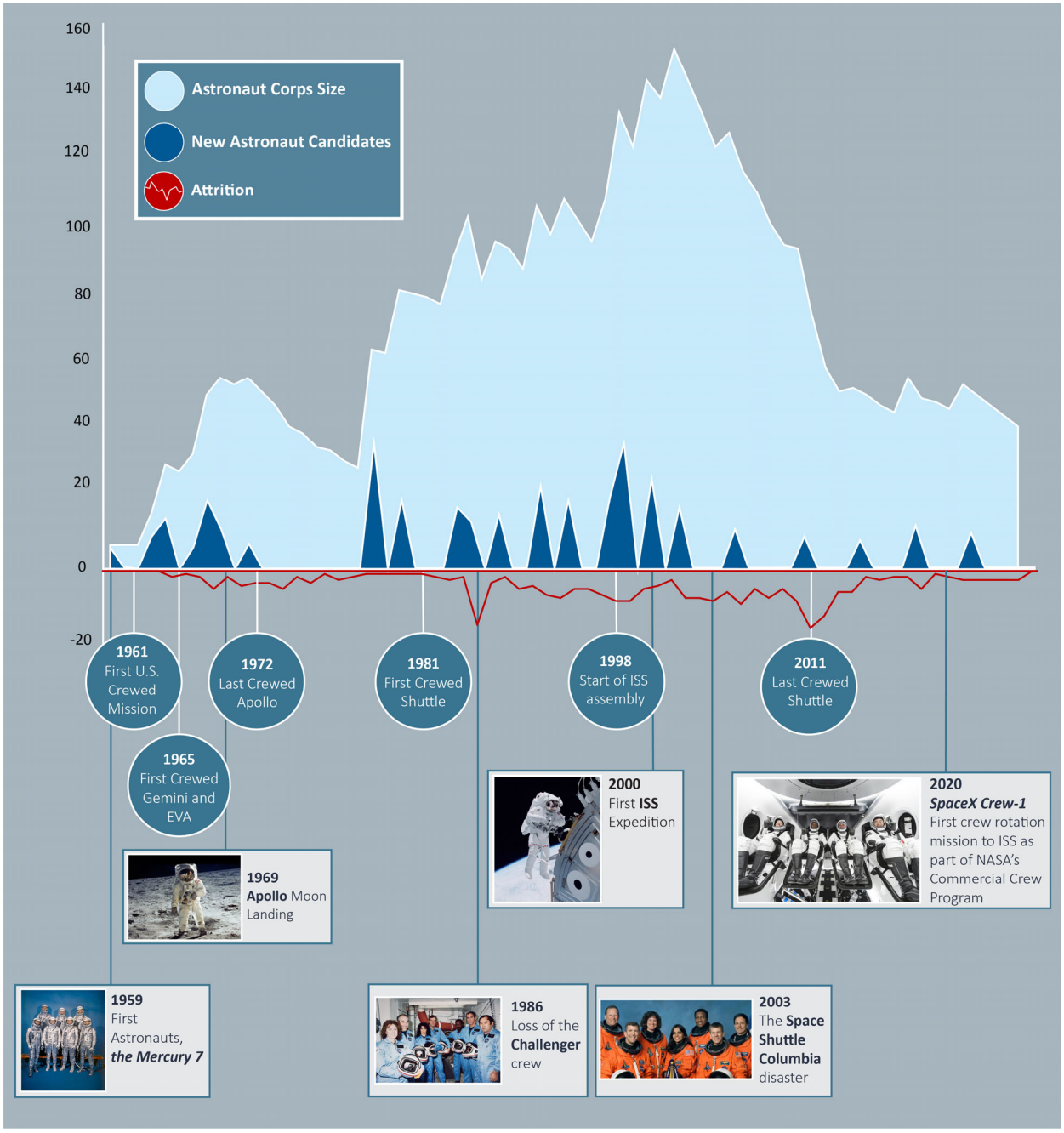
INTRODUCTION

As NASA enters a new era of human space flight, including returning to the Moon and eventually landing on Mars, effective management of its astronaut corps—the people who train to fly space flight missions—is critical to the Agency's success. Astronauts serve as the face and voice of the Agency's efforts to inspire the next generation of explorers, scientists, and engineers. After reaching its peak of nearly 150 astronauts in 2000, the size of the corps has diminished with the end of Space Shuttle missions in 2011 and now stands at 44, one of the smallest cadres of astronauts in the past 20 years. NASA's Astronaut Office faces several challenges at this moment in time, including meeting the Agency's goal of deep space travel; maintaining and expanding a low Earth orbit presence, in particular on the International Space Station (ISS or Station); executing space flight missions on multiple vehicles; and aiding in the design and development of systems for Artemis missions to the Moon. In this report, we examined NASA's management of its astronaut corps, specifically the extent to which NASA's processes for sizing, training, and assigning the corps are aligned with the Agency's current and future missions and objectives. See Appendix A for details on the audit's scope and methodology.

Background

Since its inception in 1959, the astronaut corps, based at Johnson Space Center (Johnson), has fluctuated in size, technical expertise, and training emphasis depending on mission and program demands. From its peak during the Shuttle era, the corps is now near its smallest size ever. Figure 1 illustrates these fluctuations amid changes in space flight mission priorities.

Figure 1: NASA's Astronaut Corps through the Years (1959 to 2025)



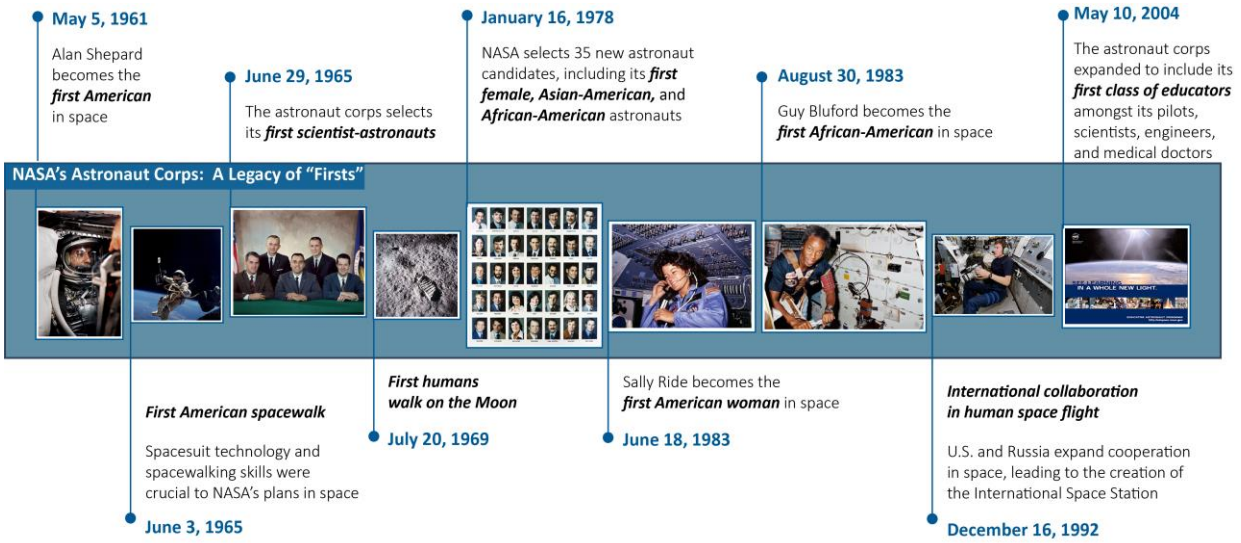
Source: NASA Office of Inspector General (OIG) presentation of NASA information.

Note: Extravehicular activities (EVA or more commonly known as spacewalks) are activities performed by astronauts outside spacecraft in orbit above the Earth.

The demographic makeup of the astronaut corps has also changed over time from a group of all white male pilots in 1959 to a diverse group representative of a wider variety of demographics and skills

today.[1] NASA started selecting a broader mix of specialists for the corps beginning in 1965 by including doctors, scientists, and engineers and later by expanding to the more general category of mission specialists in 1978. In addition to broadening its range of technical backgrounds, NASA hired its first female, Asian-, and African-American astronauts in 1978, its first Hispanic/Latino-American astronaut in 1980, and first member of a Native American tribe in 1996.[2] Figure 2 provides a timeline of historic moments of increased diversity within the corps. Today's astronauts represent a diverse group of men and women equipped with multiple skillsets, comprised of civil servants hired directly by NASA and detailees from the Armed Forces.

Figure 2: Historic Moments for NASA's Astronaut Corps



Source: NASA OIG presentation of NASA information.

Agency Missions and Core Values

Astronauts play a key role throughout NASA, both in terms of space exploration missions and helping to achieve the Agency's broader goals and objectives. For instance, the ISS Program has depended on the astronaut corps to help design, develop, and operate one of NASA's longest running and only currently operational human space flight mission. NASA relies on the corps to perform system upgrades and maintenance as well as research vital to preparing for NASA's upcoming Artemis human space flight missions to the Moon. From July 2011 to August 2020, NASA's Human Exploration and Operations Mission Directorate (HEOMD) coordinated flights to the ISS for astronauts only on Russia's Soyuz vehicle. Over the past 11 years, NASA has worked with its commercial crew partners and, as of May 2020, is now leveraging this partnership with the Space Exploration Technologies Corporation

[1] For the purposes of this audit, the term "astronaut" refers to a government astronaut, as defined in the Commercial Space Launch Competitiveness Act of 2015, employed or detailed to NASA. The Act distinguishes a government astronaut from a space flight participant. Our report reviews NASA's management of its "government astronauts" and does not address private citizen astronauts or other commercial space flight participants. Commercial Space Launch Competitiveness Act, Pub. L. No. 114–90 (2015).

[2] The Agency's collection of demographic information on the astronaut corps has been inconsistent over time and across demographic categories such as race, national origin, gender, region, and profession.

(SpaceX) to transport astronauts to the ISS.[3] In December 2020, NASA named 18 astronauts to the *Artemis Team* to serve as crew of upcoming Artemis missions to the Moon.

In addition to relying on NASA astronauts, the Agency relies on international cooperation to achieve its space exploration goals. Specifically, NASA astronauts work with their international counterparts aboard the Station. NASA and its international partners are also developing the systems for and that will execute the Artemis missions. For context, these ISS partners have similar, albeit smaller, astronaut corps: the Canadian Space Agency with 4 astronauts; the European Space Agency with 7 astronauts; the Japan Aerospace Exploration Agency with 7 astronauts; and Russia's Roscosmos with 30 astronauts.[4] Beyond cooperation with international partners on the ISS, other nations, like China with at least 18 astronauts, India with 4 astronauts, and the United Arab Emirates with 4 astronauts, have astronaut corps involved in space exploration.

NASA's astronauts also serve as the faces and voices of the Agency, serving as some of the highest profile spokespeople for NASA to employees, students, and the public. For instance, as part of the Artemis missions, NASA plans to land the first woman and first person of color on the Moon. This goal is in line with other commitments the Agency has made to advance diversity, equity, inclusion, and accessibility including the 2015 *Promising Practices for Equal Opportunity, Diversity, and Inclusion;* the 2019 *Unity Campaign;* and the 2021 *Mission Equity*.[5] In response to six Executive Orders issued in 2021, the Agency is looking to identify whether new policies, regulations, or guidance may be necessary to advance equity and opportunities in Agency actions and programs; diversity and equal opportunity at NASA; and opportunities for NASA to leverage its data, expertise, and missions to help historically underserved communities.[6] When NASA launched Mission Equity, members of the astronaut corps served and continue to serve as the spokespeople for the effort.

Organizational and Funding Structure

The Astronaut Office, which manages the astronaut corps, is organized and funded through a complex matrixed structure across multiple offices, programs, and facilities as shown in Figure 3.

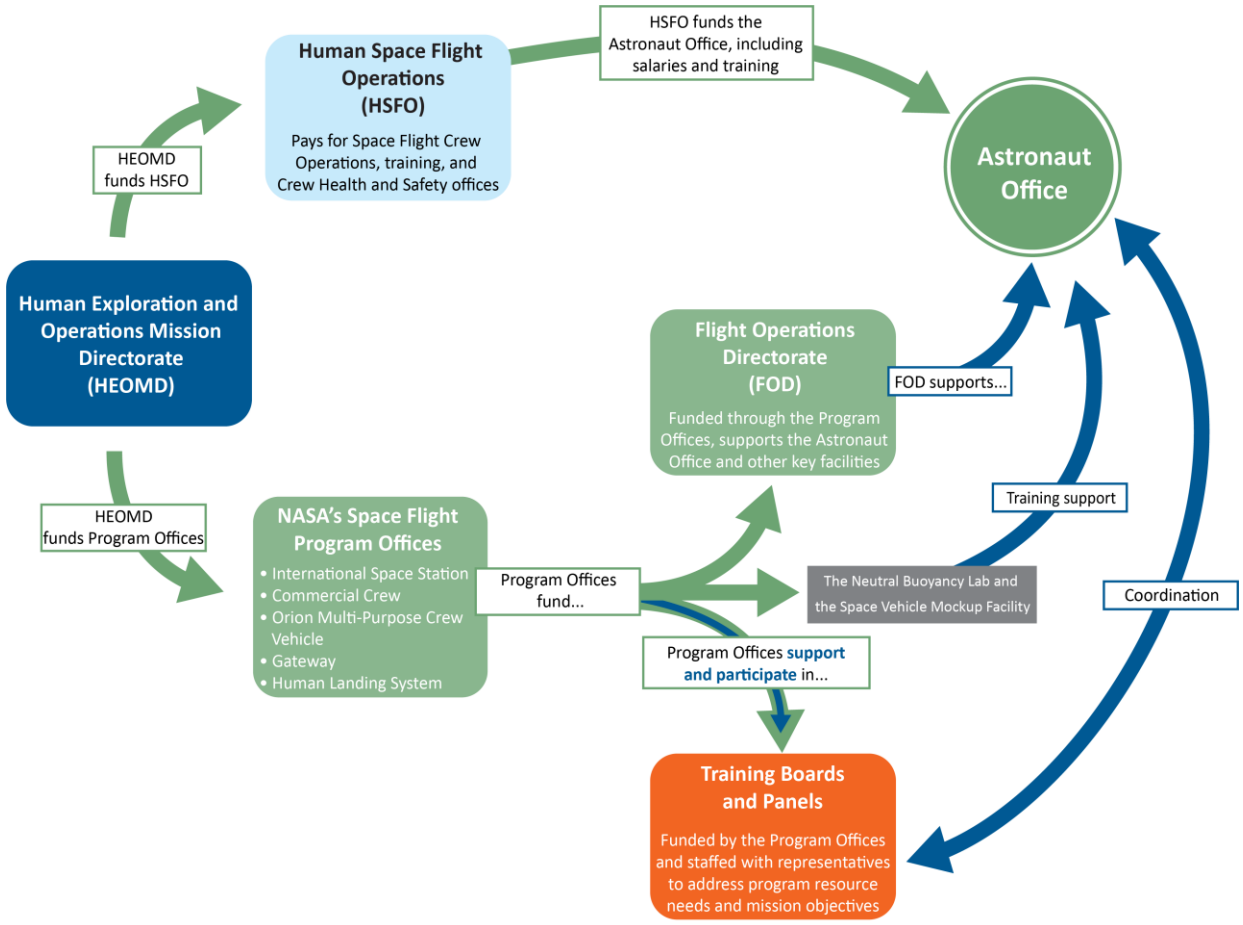
[3] As of January 2022, SpaceX is the only commercial crew partner operating astronaut transportation to the ISS aboard its Crew Dragon spacecraft. Boeing's Starliner vehicle has experienced a series of significant setbacks and it is unclear when it will be operational.

[4] For the purposes of this report, we use the term "astronaut" to refer to all government space explorers, recognizing other nations use different terminology to refer to their space explorers.

[5] NASA's 2015 *Promising Practices for Equal Opportunity, Diversity, and Inclusion* collated diversity and inclusion practices from the Centers into a single report. The 2019 *Unity Campaign* focused on helping Agency organizations and people work more effectively together by fostering an Agency-wide identity and greater employee engagement. NASA's 2021 *Mission Equity* is an Agency effort to assess its programs, procurements, grants, and policies, and examine what potential barriers and challenges may exist for communities that are historically underrepresented and underserved.

[6] Executive Order 13985, *Advancing Racial Equity and Support for Underserved Communities Through the Federal Government* (January 20, 2021); Executive Order 13988, *Preventing and Combating Discrimination on the Basis of Gender Identity or Sexual Orientation* (January 20, 2021); Executive Order 14020, *Establishment of the White House Gender Policy Council* (March 8, 2021); Executive Order 14021, *Guaranteeing an Educational Environment Free From Discrimination on the Basis of Sex, Including Sexual Orientation or Gender Identity* (March 8, 2021); Executive Order 14031, *Advancing Equity, Justice, and Opportunity for Asian Americans, Native Hawaiians, and Pacific Islanders* (May 28, 2021); and Executive Order 14035, *Diversity, Equity, Inclusion, and Accessibility in the Federal Workforce* (June 25, 2021).

Figure 3: Agency Framework Supporting and Engaging the Astronaut Corps (as of September 2021)



Source: NASA OIG from NASA-provided information.

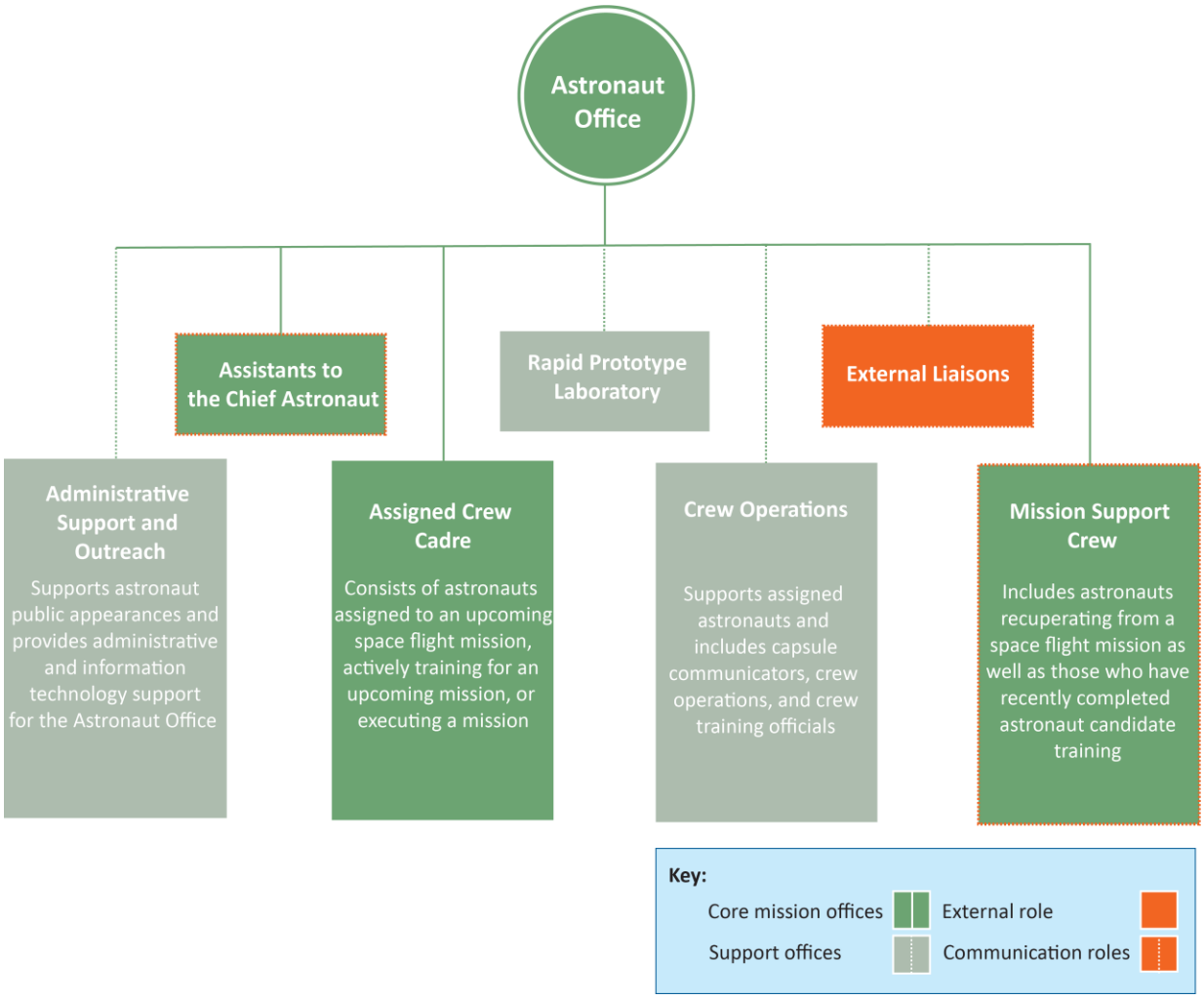
Note: In September 2021, NASA announced it was splitting HEOMD into the Space Operations Mission Directorate and the Exploration Systems Development Mission Directorate. The reorganization was ongoing as of December 2021 and has not yet identified the division of responsibilities, including management and funding of the realigned programs.

Astronaut Office Organization Structure

The Astronaut Office is managed by the Flight Operations Directorate (FOD) at Johnson, as shown in Figure 4. FOD works with the Astronaut Office to select astronaut candidates, ensure that space flight readiness training supports mission requirements, recommend flight crew assignments, direct and manage flight crew activities, and assign astronauts to technical and leadership support roles when not actively training for or flying missions.[7]

[7] In this report, we refer to astronaut candidates as individuals NASA has selected to train to become astronauts. We use the term applicants to refer to those that apply for selection to become astronaut candidates.

Figure 4: Astronaut Office Organizational Structure



Source: NASA OIG from NASA-provided information.

Within FOD are 11 technical offices or divisions, including the Astronaut Office, that support the astronaut corps, as shown in Figure 5. For example, the Operations Division supports crew during space flight and the Flight Integration Division works to develop the training regimen to prepare astronauts for specific space flights. FOD and the Astronaut Office also work with Human Space Flight Operations' (HSFO) Space Flight Crew Operations and Crew Health and Safety offices at the Headquarters level under HEOMD.[8] The astronaut corps is also integrated throughout the Agency and relied upon to help develop processes, procedures, systems, and vehicle development for key programs, such as the Human Landing System (HLS).[9]

[8] The Space Flight Crew Operations and Crew Health and Safety offices are responsible for astronaut training, readiness, and health, while NASA's Human Research Program funds research development of human health and performance countermeasures, knowledge, and technologies that enable safe, reliable, and productive human space exploration.

[9] As part of NASA's Artemis missions, specifically Artemis III, the HLS is the vehicle that will transport astronauts from the Orion Multi-Purpose Crew Vehicle in lunar orbit to the surface of the Moon.

Figure 5: Flight Operations Directorate Organizational Structure

Source: NASA OIG from NASA-provided information.

[a] Assistant Directors are not part of an official office or division, but serve as liaisons between FOD and Program Offices.

Astronaut Office Funding

HEOMD funds the Astronaut Office through a similarly complex funding structure. According to FOD officials, the Astronaut Office receives an annual budget of approximately $13 million as a subset of the HSFO annual budget, which was approximately $105 million in fiscal year (FY) 2021. The $105 million in HSFO's FY 2021 budget was broken down into approximately $83 million for the Space Flight Crew Operations office—which, as shown in Figure 3, includes direct funding to the Astronaut Office—and $22 million for the Crew Health and Safety office. HSFO's funding covers the Astronaut Office's basic expenses such as the salaries of astronauts and employees of the Astronaut Office and space flight readiness training.[10]

[10] NASA conducts space flight readiness training in T-38 aircraft. HSFO, through Space Flight Crew Operations, covers the cost of the T-38 trainer and other mission-essential aircraft.

Additionally, major HEOMD programs—such as the ISS and HLS—provide funding to FOD to support astronaut corps facilities and activities like planning, training, and flying human space flight missions. This funding flows through FOD from programs such as the ISS, Orion Multi-Purpose Crew Vehicle (Orion), and HLS. As of June 2021, about 50 percent of FOD's civil servant workforce was funded by the ISS Program. However, their work supports the broader HEOMD mission and programs and is not specific to the ISS Program. Refer to Figure 3 for an overview of the funding flow within the Agency supporting the astronaut corps.

Astronaut Corps Sizing Process

NASA's astronaut corps is unique in its mission, technical skillsets, and the manner in which it is sized. The process of recruiting, hiring, and providing basic training for an astronaut is time-intensive—approximately 4 years. As a result of this long process and potential gap in available astronauts, the Astronaut Office conducts an annual assessment of the corps' current size and anticipated future gaps to ensure it can meet the Agency's mission goals and objectives. After assessing the various inputs to determine the total number of astronauts needed for space flight missions over the next 5 years, the Astronaut Office adds a safety margin to calculate the "minimum manifest requirement"—that is, the targeted size of the astronaut corps.[11] If a current or future shortfall is identified in the corps size analysis calculations, the Astronaut Office begins the process of hiring a new astronaut candidate class. From 2016 to 2021, the number of space flight missions per year ranged from three to four flights (on Soyuz and Crew Dragon), with a minimum crew manifest ranging from four to six NASA astronauts per year.

Astronaut Corps Recruitment

Leadership from the Astronaut Office, FOD, and Johnson use the results of the corps size analysis to determine when to recruit a new candidate class. The selection process begins when the Chief Astronaut notifies FOD and Johnson Human Resources that a new class is needed. NASA policies and procedures to guide the selection process are documented in *Astronaut Candidate Selection Work Instruction*, which is maintained by Johnson's Human Resources Office. This document incorporates requirements for the vacancy announcement, ranking of candidates, members and participants involved in selection and concurrence, astronaut skill group definitions, and timeframes for the selection process. The process includes multiple levels of resume and reference review, two rounds of interviews, and physical and psychological tests. The process is time- and labor-intensive, typically taking 14 months or longer. The sizing calculation identifies a potential need to hire and, once that need is determined to be great enough, the selection process begins. During the selection process, additional annual sizing calculations may occur and will inform the number of applicants ultimately selected.

Prior to November 2021, NASA recruited two astronaut candidate classes over the past decade, the first in 2013 and a second in 2017. NASA selected 8 candidates out of the more than 6,000 applicants in 2013 and 12 candidates out of the more than 18,000 that applied in 2017. These two candidate pools contained a diverse group of applicants. The 2013 applicant pool was 78 percent male and 22 percent female, while the 2017 applicants were 58 percent male, 18 percent female, and 24 percent who chose

[11] The term "safety margin" references staffing of additional astronauts to meet flight manifest requirements.

not to identify.[12] In 2013 and 2017, respectively, applicants were 1.7 and 0.2 percent Native American Indian, 6.2 and 5.3 percent Asian and Pacific Islander, 3.8 and 2.6 percent African-American or Black, 9.9 and 1.7 percent Hispanic or Latino, and 78.4 and 55.9 percent Caucasian, White, or non-minority. In 2017, 9.5 percent identified as multi-racial. A new candidate class that began in 2019 but was delayed by the COVID-19 pandemic received more than 12,000 applications with a class of 10—4 women and 6 men—announced in December 2021. Given the long recruiting timeframe and the basic training period, the next candidate class will not be available for assignment any earlier than the beginning of 2024.

NASA 2021 Astronaut Candidate Class

Source: NASA.

Given NASA's upcoming space flight mission profiles, this new cohort of astronauts will spend more time and travel farther into deep space than previous astronauts. With the addition of commercial crew vehicles and preparations for missions beyond low Earth orbit, NASA is adjusting its astronaut corps sizing, training, assignment, and mission alignment. Although the first Artemis mission, an uncrewed lunar orbital test flight, has yet to fly, in 2021 NASA planned to select and begin training crew for the first crewed mission, Artemis II. Currently, the Astronaut Office anticipates announcing the Artemis II crew after successful completion of the Artemis I launch. In our November 2021 report, we projected delays in the current schedule for the Artemis missions that will likely result in additional time to develop the framework and process for training and assigning astronauts to those missions.[13] Also in November 2021, the Administrator announced that the Artemis I mission would be delayed to February 2022 and the Artemis II mission would be delayed until no later than May 2024—pushing the Artemis III lunar landing mission into 2025.

Future Health Risks and Mitigation

Prior to conducting a space flight mission, astronauts are required to be medically qualified to ensure their safety and mission success. Humans living in space experience a range of physiological changes that can affect their ability to perform necessary mission functions and, in the long term, increase their risk of developing cancer, damaged vision, reduced bone strength, and other damage to their health and well-being. Postflight, astronauts complete reconditioning programs to assist them in returning to preflight health and fitness levels and reenter the pool of astronauts available for future assignments.

As NASA moves from low Earth orbit missions on the ISS to deep space Artemis missions, it has begun the process of reviewing its policies and conducting additional studies on the health impacts longer duration missions and missions beyond low Earth orbit have on astronauts and their ability to be medically cleared for space flight—both for ISS and Artemis missions.[14] External oversight bodies like the National Academies of Sciences, Engineering, and Medicine have also identified hazards related to

[12] In 2017, applicants had the option of not self-identifying gender or race/national origin. In 2017, 24.8 percent of applicants did not self-identify their race or national origin and 24.2 percent did not self-identify their gender.

[13] NASA Office of Inspector General (OIG), *NASA's Management of the Artemis Missions* (IG-22-003, November 15, 2021).

[14] NASA plans to study the health effects on astronauts conducting space flight missions of varying durations, from 6 weeks to 6 months to 1 year.

deep space, specifically radiation exposure.[15] In order for NASA astronauts to participate in Artemis mission space flights, they will have to request health waivers to exceed current maximum space flight radiation exposure standards regardless of gender. The Agency is currently reviewing the Academies' recommendation to increase and standardize the limit. In addition, the Aerospace Safety Advisory Panel's 2020 report discusses the health effects from space exploration beyond low Earth orbit and reiterates the need to collect more data to inform future health and medical standards for astronauts.[16]

[15] National Academies of Sciences, Engineering, and Medicine, *Space Radiation and Astronaut Health: Managing and Communicating Cancer Risks* (2021). In this 2021 report, the National Academies highlighted the impact of radiation on astronaut health and concerns about increased exposure from longer duration and deeper space exploration.

[16] Aerospace Safety Advisory Panel, *Annual Report* (2020).

NASA's Processes for Managing the Astronaut Corps Are Primarily Driven by ISS Needs and Are Not Fully Aligned to Future Mission Requirements

The processes NASA uses to size, train, and assign astronauts to specific missions are primarily calibrated toward meeting the current needs of the ISS rather than future Artemis missions with requirements that are still evolving. At the same time, the Agency's Mission Equity principles are still being defined and the process of aligning the corps to meet these objectives is ongoing. Additionally, multiple years are required to recruit, hire, and train a cohort of astronauts for the Artemis missions and Artemis crewed launches planned for 2024 and 2025 leave little time available to recalibrate the corps to meet current timelines. Moreover, crew assignments are largely at the discretion of the Chief Astronaut and while the Agency has documented a process to guide ISS crew assignments, the process is still evolving for future Artemis missions, specifically for international coordination. While the Astronaut Office has been successful to date in meeting the Station's needs, largely because of the maturity of ISS operations, the Astronaut Office's processes and combination of formal and informal approaches to crew sizing, alignment, training, and assignment may be inadequate for Artemis and other crewed deeper space Agency missions. As the astronaut corps transitions to crewed Artemis missions, the Astronaut Office has to assess its sizing, alignment, training, and assignment processes to ensure it has the astronauts it needs to meet future mission requirements and broader Agency goals and objectives.[17]

NASA's Sizing Process for the Astronaut Corps Is Primarily Aligned to the Current Needs of the ISS Program but May Not Fully Address the Agency's Future Goals

NASA's Corps Sizing Process Is Primarily Focused on ISS Missions

Overall, NASA's approach to sizing its astronaut corps is effective in meeting current ISS requirements, and we found no significant examples of shortcomings with respect to supplying crew for ISS missions.

[17] The astronaut corps currently executes ISS missions in low Earth orbit, which typically occur in 6-month increments, while the planned Artemis missions will occur outside of low Earth orbit (7,400 kilometers away) and consist of a planned 10-day orbit of the Moon (Artemis II) and a lunar landing (Artemis III). Later Artemis missions will include development and use of the Gateway system with potentially longer stays in deep space.

As of September 2021, the corps consisted of 44 flight-ready astronauts for ISS missions.[18] NASA's current process for sizing the astronaut corps is designed to ensure that enough astronauts are available to meet the Agency's flight manifest needs, which currently means maintaining a planned crew of between three and four astronauts on the ISS. A senior Astronaut Office official told us that the annual sizing process is primarily focused on having enough astronauts to fill ISS seats over the next 5 years.[19] Recruitment efforts since 2013 have primarily focused on sizing the corps for the two vehicles that fly to the ISS, Russia's Soyuz and SpaceX's Crew Dragon, and eventually Boeing's Starliner CST-100.[20]

The Astronaut Office assesses the size of the astronaut corps annually, starting by incorporating flight manifest information from HEOMD's space flight programs' *Planning, Programming, Budgeting, and Execution* (PPBE) plans. Laid out as part of NASA's yearly budget-planning process, these plans include funding requirements for the current fiscal year and four fiscal years into the future. According to Astronaut Office officials involved in the sizing process, these budget-planning documents reliably capture human space flight needs and inform seat requirements for both upcoming and future missions. From the PPBE documents the Astronaut Office derives and accounts for the number of astronauts it currently has on orbit, assigned to future flights and in training, in a post-flight recovery period, and assigned to functional areas when they are not assigned to a space flight.[21] Two additional considerations the Astronaut Office takes into account when sizing the astronaut corps are a safety margin of 15 percent and a currently assumed attrition rate of three astronauts per year.

Safety Margin. The Astronaut Office incorporates a safety margin to mitigate against short-term risks related to attrition, crew skills mix, medical qualifications, and to provide flexibility for crew pairing. Using this margin, currently set at 15 percent, the Office calculates the minimum manifest requirement—that is, the targeted size of the astronaut corps.[22] If the Astronaut Office identifies a shortfall in the minimum manifest requirement or crew manifest analysis calculations, it signals the need to initiate a new astronaut candidate class selection.[23]

Rate of Attrition. According to Astronaut Office officials, the attrition rate is evaluated each year based on recent and planned astronaut departures. The Astronaut Office's FY 2021 forecast assumes that three astronauts will leave the corps each year from FY 2021 through FY 2027. However, according to Astronaut Office officials and the Office's crew sizing analysis, they are planning on an accelerated attrition rate of five astronauts per year beginning in FY 2028 to account for the end of the ISS mission. Although currently funded through FY 2024, pending congressional legislation could extend the use of

[18] Although the current 44 flight-ready astronauts are available for assignment to both ISS and Artemis missions, the ISS is the only currently operational space flight mission.

[19] In addition to ISS flight manifest seats, since February 2012 the Astronaut Office has incorporated flight manifest seats for Orion/Artemis missions and has included three to four seats, starting with Artemis I, into each subsequent corps size analysis based on the latest annual guidance from the Orion Program for planned Artemis space flights.

[20] As of January 2022, Boeing's Starliner has not completed an uncrewed test flight to the ISS, a necessary predicate for a crewed test flight. NASA OIG, *NASA's Management of Crew Transportation to the International Space Station* (IG-20-005, November 14, 2019).

[21] Astronauts receive a post-flight recovery period of approximately 6 months to reacclimate to gravity, undergo follow-up health tests, and assimilate to life back on Earth.

[22] The 15 percent margin has been used since 2014. However, due to a lack of documentation it is unclear why the margin changed from 25 percent in 2011 to the current 15 percent starting in 2014. National Research Council, *Preparing for the High Frontier: The Role and Training of NASA Astronauts in the Post-Space Shuttle Era* (2011).

[23] When calculating the size of the astronaut corps, astronaut candidates are not factored in until they complete their initial training and are available for assignment on space flight missions.

the ISS through FY 2028 and potentially as far as FY 2030. Meanwhile, NASA has research activities planned through 2032.[24]

Current Sizing Process Poses Risks to Evolving Mission Needs and Agency Objectives

According to the sizing analysis the Astronaut Office conducted in April 2019, the astronaut corps is projected to fall below its targeted size or minimum manifest requirement in FY 2022 and FY 2023 due to attrition and additional space flight manifest needs.[25] More concerning, the Astronaut Office calculated that the corps size would equal the number of flight manifest seats NASA will need in FY 2022. As a result, there would be no additional astronauts available for ground roles or to cover for unanticipated attrition. To the point, in 2020 the former FOD Director said that as soon as FY 2024, NASA risks not having enough astronauts to execute its flight missions when considering both its safety margin and the Agency's projected flight manifest seat requirements. Beginning in FY 2024, Artemis requirements will add between three and four crew per year to the manifest in addition to ISS requirements of six astronauts per year from FY 2022 to FY 2024, respectively.[26] While NASA's current sizing process is adequate to meet current ISS staffing needs, the sizing process poses a risk to the corps' ability to continue to meet ISS needs along with meeting needs for missions beyond Artemis II and broader Agency objectives, such as Mission Equity.[27]

The Astronaut Office collects and analyzes data on its current corps size, skillsets, technical backgrounds, and other demographics; calculates its safety margin; and monitors likely and planned astronaut attrition. Although the data is currently collected and analyzed in the annual corps sizing calculation, we identified five factors in the Astronaut Office's current sizing process that, in light of the expanding space flights and Agency missions, may leave the corps at risk of being misaligned in the future. If not addressed, these factors could potentially result in disruptive crew reorganizations, extended training periods, or mission delays.

1. The 15 percent safety margin may be inadequate for accurately sizing the astronaut corps to mitigate the risks posed by flying multiple missions on multiple vehicles, with varying durations, and new missions and their potential health impacts on astronauts.
2. The current rate of attrition is lower than historical averages.
3. The demand for astronauts to engage in program development roles is higher now than in the past, given the new Artemis vehicles.

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[24] NASA, *Commercial Spaceflight Division Briefing* (August 2021).

[25] In March 2021, the Astronaut Office conducted its sizing analysis and identified a shortage below the minimum manifest requirement in FY 2023, as well as potential shortages between FY 2025 and FY 2027. Both the 2019 and 2021 Astronaut Office sizing analyses identified the need to initiate a new astronaut candidate class. These analyses were used to inform the 2021 astronaut candidate recruitment process.

[26] The Astronaut Office size analysis conducted in April 2019 informed the decision to recruit an astronaut candidate class in 2020. The 5-year planning window reviewed was from 2019 to 2024. The hiring of the 2020 class was delayed to 2021 due to the COVID-19 pandemic.

[27] Mission Equity is a new Agency-wide Diversity, Equity, and Inclusion initiative that highlights the diversity of the astronaut corps as a public facing part of NASA. It also includes outreach and assessments of the Agency's efforts to reach and engage with underserved populations. Accordingly, assessments of the composition of the astronaut corps will likely be part of this initiative.

4. The Astronaut Office informally monitors and incorporates future mission skillset needs when recruiting new astronaut candidate classes.
5. Diversity and inclusion efforts, including Mission Equity and Artemis mission objectives, might be hampered by a lack of data specific to the astronaut corps.

Inadequate Safety Margin

During the Shuttle era, the safety margin was as high as 50 percent. Starting in 2010, along with significant reductions to the corps size, the safety margin was reduced to 25 percent—attributed in part to budget reductions. In 2011, the National Research Council raised concerns that the then-safety margin of 25 percent would be insufficient based on the medical effects of long-duration space flight as compared to short-term Space Shuttle missions as well as changes to NASA's manifest with the ISS, planned commercial vehicle development, and supporting development of spacecraft for beyond low Earth orbit. The Astronaut Office's current safety margin is 15 percent.[28] While the 15 percent safety margin adequately supports the current needs of the ISS Program, it is unlikely to support the Agency's future space flight requirements, including the Artemis missions. With a corps aligned to a single mission, as it is now with the ISS, the Astronaut Office is in a position to quickly reassign astronauts because all 44 have been selected and initially trained for the same mission. However, as the Agency undertakes new missions with new requirements and new vehicles, fewer astronauts will be trained and available for each mission. The need for ensuring an adequate safety margin is crucial to reducing the risk of insufficient staffing that could impact safety and morale issues and lead to mission delays.

Greater Variation in the Rate of Attrition Could Impact Sizing Needs

The Astronaut Office uses a fixed number of astronauts leaving the corps annually to account for projected attrition rather than using a specific percentage rate of attrition. However, in our judgment, it may be more appropriate for the Astronaut Office to use a percentage rate for the corps analysis because of the variation in the total number of astronauts through the years. To the point, we reviewed astronaut corps attrition data from 1959 to 2020 and found that the average rate of attrition across the entire history of the astronaut corps is 6.8 percent—that is, 5 astronauts per year assuming an average of 73 astronauts overall. However, within that timeframe there were periods of greater variation in the rate of attrition that coincided with the end of space flight missions or vehicles and the announcement of new astronaut candidate classes. For example, from 2004 to 2012 after the announcement that the Shuttle would be retired, the rate of attrition was 11.1 percent—10 astronauts per year given an overall average corps size of 90 astronauts during that period. We also found that attrition generally increased in the year immediately following the selection of a new astronaut candidate class. Between 1959 and 2020, attrition averaged 7.7 percent in each year following the selection of a new class, between 6 and 7 astronauts given an average corps size of 85 astronauts.

However, with the recently announced astronaut candidate selection in December 2021, the current projected attrition of three astronauts per year (6.5 percent of the astronaut corps as of the last size calculation in March 2021) used in the Astronaut Office's sizing calculation will be less than what has historically occurred when new astronaut candidates join the corps. As the potential end of the ISS mission in 2024 or 2030 approaches, the Astronaut Office's use of a fixed number of astronauts leaving the corps annually could benefit from a more robust analysis of historical trends to incorporate the

[28] National Research Council, *Preparing for the High Frontier*.

effects of new candidate classes and mission retirements, such as the Shuttle and soon, the ISS. Astronaut Office forecasting plans include a potential increase in the fixed number from three to five astronauts in 2028 and 2029, presuming an end of ISS operations in 2030. However, this can be further refined to better reflect historical trends along with using historical rates, not a set number of astronauts. As the Artemis missions come to fruition, the Astronaut Office may need to reassess its rate of attrition used for planning future corps sizing and recruitment efforts.

Greater Demand for Astronaut Involvement in Program Development Roles

The demand for astronauts to engage in program development roles is higher now than in the past given the new Artemis vehicles (e.g., Orion, HLS, and Gateway). However, the current sizing process increases the risk that astronauts will not be available to fully support space flight programs that are in design and development phases. As previously discussed, astronauts play a critical role in NASA's space flight programs' design and development efforts. Astronauts are one of many communication channels between program offices and FOD. According to program managers from ISS, Orion, HLS, and Gateway, input from astronauts with flight experience is of particularly high value, especially at the earliest phase of design.[29] Sixty-eight percent of the current astronaut corps has space flight experience and while astronauts with space flight experience are preferred, astronauts without such experience are also assigned to programs in design and development phases. These astronauts can provide perspectives based on their 2 years of basic astronaut training, as well as their relationships with astronauts who have flown in space. Nevertheless, according to several astronauts currently assigned to program offices in the design and development phases, they are often over-committed. In the past, the Astronaut Office included civil servant engineers that worked with ground-assigned astronauts to maintain institutional knowledge of space flight experience, vehicle operations, and execution challenges for these space flights. This changed in 2016 when a reorganization moved these engineers to other parts of FOD. According to astronauts we spoke with, since 2016 astronauts have been spread thin in these ground roles trying to support the space flight programs while also working with FOD engineers to ensure they can understand an astronaut's perspective on various design and operations issues. Several current and former astronauts told us it is a challenge to ensure flight programs are getting candid and continuous perspectives from astronauts while rotating in and out of these ground assignments every couple of years.

Evolving Missions May Require a Different Composition of Skillsets that Are Informally Monitored and Incorporated into Astronaut Recruiting

The specific skillsets of the astronaut corps have evolved with the Agency's space flight missions—from Apollo's need for test pilots to the Station's greater need for scientists and mission specialists.[30] As the Artemis program offices work with FOD and the Astronaut Office to identify required skillsets, including for pilots, medical doctors, and scientists, the composition of skillsets within the corps may need to be augmented to ensure sufficient capacity to execute the Artemis missions. In addition, NASA expects a

[29] The Astronaut Office does not offer input into sizing calculations that account for nonflight duties such as vehicle design and development (e.g., Orion, HLS, or Gateway). Instead, these positions are accounted for in the number of astronauts in post-flight recovery, between flight assignments, and in the 15 percent safety margin.

[30] Although the recruiting process looks to recruit generalists, the selection panel process begins by identifying the best qualified candidates and then groups them into five disciplines—pilots, flight test engineers, biological and medical sciences, physical sciences, and engineering and operations—who then undergo additional reviews through tests and two rounds of interviews. Ultimately the recruiting process aims to identify and select the best candidates and the Agency then relies on astronaut training to ensure mission success.

need for new skillsets may be identified in the coming years as plans for the Artemis missions evolve. For example, geology was recently identified as a specific professional skillset needed for Artemis missions to the Moon and Mars. The corps currently has four astronauts with professional training in geology-related fields, two of whom have been with the corps for over 15 years.

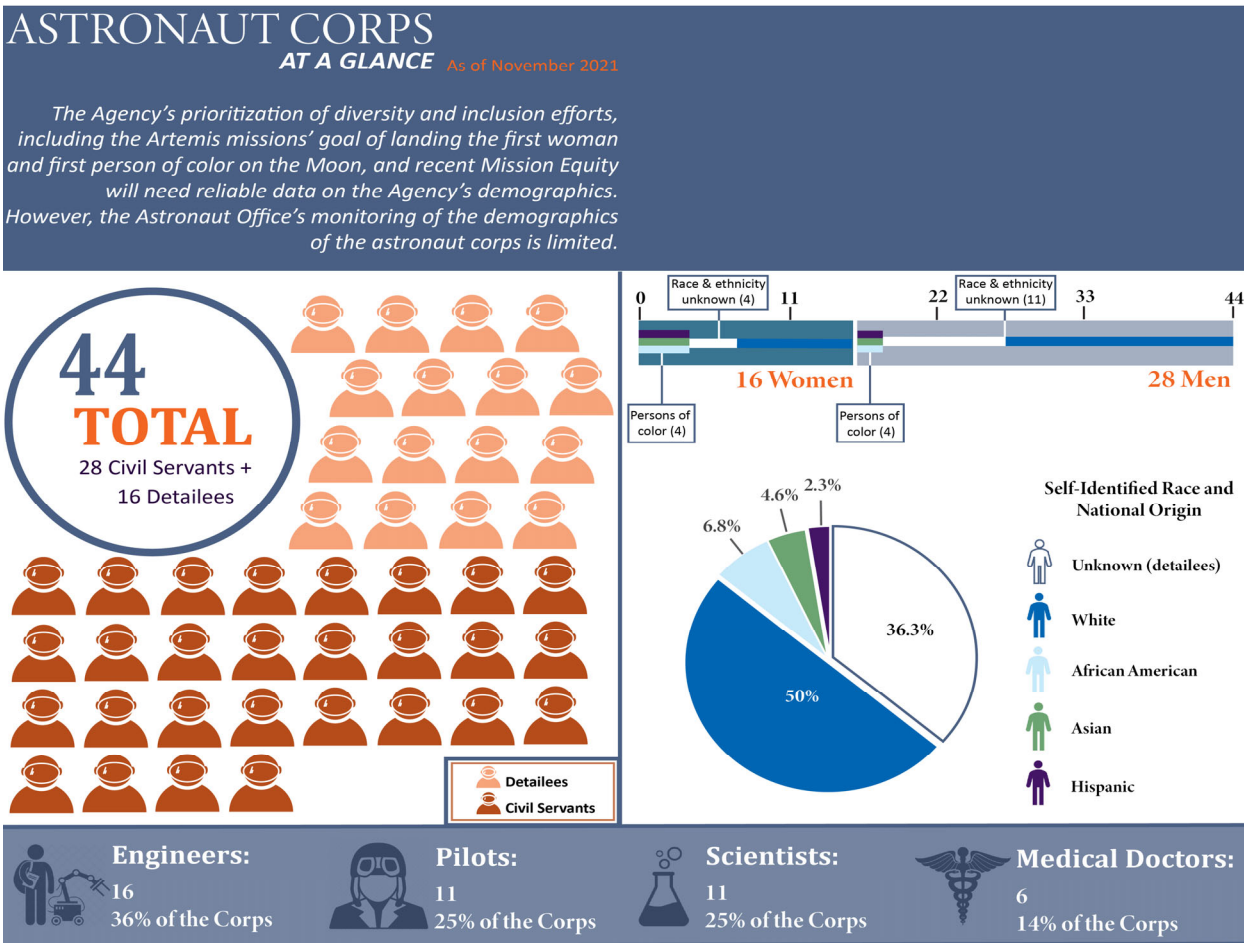
The Astronaut Office maintains separate internal databases with information relevant to the makeup and skillset of the astronaut corps, such as an astronaut's prior career field and degree, space flight experience, training, and competencies in areas such as flight qualification, extravehicular activities, robotics, and Russian language proficiency.[31] However, we found that astronaut skillset data is not consistently collected, comprehensively organized, regularly monitored or updated, or reviewed outside of the candidate selection planning and assignment processes. The Chief and Deputy Chief of the Astronaut Office said they can use these various tracking systems if needed, but given the small number of astronauts they primarily rely on their own informal knowledge of corps membership to inform skillset decisions including consideration of the skillsets needed in a candidate recruiting class. While informal knowledge has been used to manage ISS missions—a mission the Agency has been conducting for over 20 years—we question whether this informal approach will be effective as the size of the astronaut corps increases, still-evolving Artemis requirements are incorporated, and attempts to track skillsets over time for multiple missions become more complex.

Diversity Is Not Fully Tracked within the Astronaut Corps, Hampering Mission Equity and Artemis Objectives

In addition to the data limitations discussed above, we also found that the Astronaut Office's personnel databases do not contain comprehensive demographic information—race, national origin, gender, birthplace, education, or disability—specific to astronaut diversity, equity, inclusion, and accessibility nor do they monitor the demographic makeup of the corps over time. In particular, there is limited demographic data for astronauts detailed from the Armed Forces. Additionally, the demographic data for the astronaut corps' civil servants has not been comprehensively tracked over time. Despite these limitations, we reviewed a portion of the astronaut corps—specifically those in the civil service—to provide some demographic context for NASA's current astronaut corps. Figure 6 provides a visualization of the demographics we were able to capture.

[31] Extravehicular activities (more commonly known as spacewalks) are activities performed by astronauts outside spacecraft in orbit above the Earth.

Figure 6: Selected Demographics of the Astronaut Corps



Source: NASA OIG analysis of public information as of November 2021.

Note: NASA collects and reports demographic data on race/national origin for its civil servants in accordance with the specifications set out in Office of Management and Budget Statistical Policy Directive No. 15.

The Astronaut Office's lack of detailed demographic data for its astronauts—both civil servants and detailees—poses a challenge to assessing whether NASA is meeting Agency and Administration diversity objectives. In recent years, the Agency has prioritized diversity and inclusion efforts—including the 2015 *Promising Practices for Equal Opportunity, Diversity, and Inclusion*; the 2019 *Unity Campaign*; and the 2021 launch of *Mission Equity*—and announced its intent to land the first woman and first person of color on the Moon as part of the Artemis missions. Additionally, the Administration has made recent requests to the Astronaut Office to provide greater detail on diversity within the corps. However, the Astronaut Office does not track specific demographic metrics and, beyond ad hoc data collection and analysis, is currently unable to do so due to a lack of data collection, specifically in self-identified Race and National Origin and Ethnicity data fields in the Agency's human capital data system.[32] These

[32] Prior to the 2017 astronaut candidate class, the Johnson Human Resources Office began tracking self-identified astronaut candidate applicant data in an internal database. Johnson Human Resources officials told us they use this information throughout the recruiting process to help monitor the diversity of the candidate pool at each stage of the recruiting and interview process, but noted that in the 2021 astronaut candidate class 31.9 percent of applicants did not disclose race or national origin information. After the astronaut candidate class selection process has ended, the data can be shared with the Astronaut Office, when requested.

limitations restrict NASA's ability to measure its progress towards meeting these broader diversity and inclusion goals—significant issues given that astronauts are perhaps the most publicly visible employees at the Agency. To the point, one astronaut, upon returning from the ISS, emphasized the importance of children seeing someone that looks like them when they see astronauts on television.

The Astronaut Office has not measured diversity and inclusion as part of its assessment of hiring needs to determine if the corps can meet the Agency's Artemis objective of landing the first woman and first person of color on the Moon and still-evolving Mission Equity objectives. Astronaut Office officials reported that they rely on the candidate selection process to ensure it hires a diverse astronaut cadre to meet these objectives. In our judgment, the informality of the Office's data collection and use puts meeting NASA's diversity and inclusion goals at risk.

Astronaut Training Is Adequate for ISS Needs but Needs to Be Updated for Artemis Program Requirements

NASA's current astronaut corps is comprised of astronauts who have been predominantly hired, trained, and assigned to crews bound for the ISS to conduct research, perform maintenance, and assess the functionality of the Station. However, with the upcoming Artemis missions, the Agency's current astronaut training process may be inadequate for meeting new requirements.

Current Training Framework Is Adequate for ISS Needs

Like its approach to sizing the astronaut corps, NASA's approach to astronaut training has also focused largely on meeting ISS mission needs. The training regimen for newly hired astronauts takes approximately 4 years.[33] Astronauts generally complete their initial astronaut candidate training—comprised of robotics training, flight training, and extravehicular activities—in about 2 years. According to training records we reviewed, approximately 40 percent of the initial astronaut candidate training is specific to the ISS. In addition, assignment to an ISS mission requires an additional 18 to 24 months of mission-specific training. Astronauts we spoke with said that initial astronaut candidate training is uniform across new hires and provides a sufficient skills baseline upon which mission-specific and specialized training will prepare astronauts to successfully complete their missions. However, there may be different areas of emphasis depending on the individual, such as more focus on a particular technical area, such as additional robotics, extravehicular activity, or Russian language training. They also said astronaut candidates are partnered with veteran, flight-experienced astronauts from previous astronaut classes to serve as mentors in order to better acclimate into the corps, including during the astronaut candidate training period. FOD, Astronaut Office, and ISS Program officials noted the training astronauts receive for ISS missions has resulted in successful completion of their missions, and we did not identify any major issues resulting from insufficient training.

The Astronaut Office coordinates with FOD and program offices to identify, develop, and formalize training requirements for the astronaut corps. For the ISS mission, the Astronaut Office and ISS Program work with ten ISS-specific and two FOD-led boards and panels to review and revise the training flow for

[33] For the purposes of this report, a training regimen encompasses the training courses and schedule of training identified and designed for a specific astronaut to prepare them for a specific space flight.

missions, as shown in Figure 7.[34] Specifically, the International Training Control Board (ITCB), through a series of boards and panels, manages a set of selected training activities for a specific ISS mission.[35] These training activities are drawn from standardized training content in the Multilateral Advanced Increment Training Plan, which details where astronauts will train in international partner facilities. This training plan is managed by the Expedition Training Requirements Integration Panel (ETRIP), established by the ITCB, which further refines training regimens based on the experience level of the astronaut. The process for identifying training for each specific ISS mission is a coordinated effort between ETRIP, FOD's Flight Integration Division, and the Astronaut Office's training officials. The Astronaut Office codifies this training development regimen in its Quality Management System, a series of guiding documents for the Astronaut Office.[36] Over the past 20-plus years, NASA has refined its framework of ISS boards, panels, and plans to align training to evolving ISS mission requirements. NASA's alignment of its processes—specifically training—to the ISS mission is called the "Single Flow to Launch" approach.[37]

[34] For the purposes of this report, boards and panels encompass groups, boards, panels, and other coordination entities. A Group is a set of personnel appointed to study and report on a particular topic. A Board is a group of personnel constituted as the decision-making body of an organization. A Panel is a small group of personnel brought together to discuss, investigate, or decide on a particular matter.

[35] The ITCB is the top board that governs what a crew needs to be trained for ISS missions. The ITCB establishes the Expedition Training Requirements Integration Panel (ETRIP) to develop and maintain the Multilateral Advanced Increment Training Plan or catalog of full training activities and courses. ETRIP meets and updates this catalog periodically to incorporate new training, such as the addition of U.S. Commercial Vehicles (e.g., SpaceX Crew Dragon).

[36] The *ISS Increment Training Integrator Handbook* and the *ISS Increment Training Integrator Certification Guidebook,* with references to the Station Program Implementation Plan, are specific to ISS requirements. CB-QMS-007 Increment training integrator (ITI) handbook, CB-QMS-008 Increment training integrator (ITI) guide, and Station Program Implementation Plan, Volume 7: Training.

[37] Single Flow to Launch is an approach to training instituted in 2010 after the transition from three-person to six-person crews. With the Single Flow approach, the prime crew is backed up by a portion of the next Soyuz crew, saving half a year of training time. In 2015, the training community further reduced Single Flow training flows by dividing the content into a pre-assignment and assignment phase. Now the majority of the single-system training, up to and including most operator mastery lessons, are completed by the crew during their pre-assignment phase. Crews are assigned to an expedition team approximately 24 months before launch.

Figure 7: International Space Station and Flight Operations Directorate Boards and Panels

Source: NASA OIG from NASA-provided information.

Artemis Missions Will Require Revisions to the Current Training Framework

In preparation for crewed Artemis missions, the Agency's astronaut training needs will change. As previously noted, NASA's current astronaut training framework is aligned to ISS mission requirements and entities—the ISS Program office and the boards and panels. This approach—the ISS-specific Single Flow to Launch, the various boards and panels for mission requirements, and the internal guidance (Quality Management System, handbook, and guidebook)—does not take upcoming Artemis mission requirements into account.

NASA's FY 2022 Budget Request Justification for HSFO cites plans to start Artemis II crew assignment and training in 2021. However, a framework for developing and providing Artemis training is in the process of being developed but has not been formally chartered nor has a crew been announced. As such, specific mission-focused training for the Artemis II mission—the first crewed Artemis flight—has not yet begun. In May 2021, Astronaut Office officials told us that they plan to modify the current ISS training process to account for the Artemis training requirements and, in July 2021, FOD and Astronaut Office officials provided us early planning and coordination documentation. This documentation, specific to Artemis II's crewed orbital flight around the Moon, identifies a timeframe of 18 months prior to launch for development of the framework—including the organizational boards and panels to coordinate across programs and offices to develop the training regimen—and 12 months prior to launch for Artemis II to begin training the assigned crew. Agency documents and officials indicate that training requirements and training instruction for the Artemis II mission are less intensive than what will be required in future Artemis missions that will include use of the HLS and Gateway.

The Astronaut Office estimates training for the Artemis III and successor missions will require approximately 2 years. However, we found that over the course of 20-plus years the Agency has streamlined ISS training from 5 years in length at the start of the ISS Program in 1998 to 2 years currently. The experience with the ISS Program suggests that achieving similar efficiencies in Artemis training requirements will take time and initial training efforts will likely take longer than projected. Even with the projected delays to the Artemis II and III launches, the Agency could be overestimating the time available to develop and implement the necessary training framework and regimen. To the point, the Artemis missions include multiple project and program offices—Orion, spacesuits, HLS, and Gateway—whereas the ISS is a single program office.[38] This will require additional coordination and planning to stand up the boards and panels needed to identify, develop, and implement training for each Artemis space flight including an update to the Astronaut Office's Quality Management System to reflect the addition of Artemis missions.

Additionally, key Artemis systems such as Orion, next-generation spacesuits, HLS, and Gateway are still in development and results from ongoing health-related risk reduction efforts from the ISS are not due until 2027.[39] These factors could also delay the development and implementation of new training

[38] NASA OIG, *Development of Next-Generation Spacesuits* (IG-21-025, August 10, 2021). Training for an Artemis team of astronauts on next-generation spacesuits has not begun.

[39] For next-generation spacesuits, the OIG reported training needs do not align with projections of when suit hardware will be available and raised concerns that there will not be sufficient quantities of training hardware available for early training to support early Artemis missions (IG-21-025). The HLS statement of work specifies that NASA and the contractor will be jointly responsible for the development of training plans, schedules, product development, training execution, and certification of the crew and flight control team. For Gateway, FOD has responsibility for integrated training, supported by deliverables from projects (including prime contractors and international partners) to develop the proper training.

requirements. While FOD is in the process of establishing boards and panels to oversee the integration of astronaut training regimens and technical requirements related to the Artemis systems, as of November 2021 those boards and panels have not been finalized.

Overall, NASA's current training approach effectively responds to ISS mission needs. However, failure to move beyond the current ISS-focused approach for current and future astronauts in a timely manner increases the risk of delays in developing the necessary training regimen to meet Artemis mission needs and goals.

Crew Mission Assignment Process Is Largely at the Discretion of the Chief Astronaut and Aligned to ISS Program Needs

NASA's crew assignment process is based on the discretion of the Chief Astronaut. Although the Agency has a formal assignment process for ISS missions, the Chief Astronaut also considers additional, informal selection priorities. Moreover, while the Agency has documented a process to guide ISS assignments, it is still developing a process for planned Artemis crew assignments.

NASA's Chief Astronaut Is Responsible for Crew Assignments

The Chief Astronaut, who is typically selected and appointed by FOD and Johnson leadership, makes decisions about crew assignments for space flight missions with concurrence from the directors of FOD and Johnson.[40] An Astronaut Office official reported that given the small size of the astronaut corps, the Chief and Deputy Chief Astronauts are sufficiently knowledgeable of the corps' experience, interpersonal skills, and training to make crew assignment decisions. The Chief Astronaut receives feedback from other Astronaut Office personnel such as Branch Chiefs on proposed assignments, as shown in Figure 8. The crew assignment process varies in length and considers multiple factors, such as the upcoming flights requiring a crew, timing necessary for training to be completed, availability of crew currently assigned and unassigned, technical requirements of the mission, and the skillsets of available crew.

[40] The Chief Astronaut position is rotational. Since the retirement of the Shuttle in 2011, the position has been held by five different astronauts with an average tenure of approximately 29 months. The assignment process is codified within CB-QMS-003 Flight Operations Directorate, *Crew Assignment Process, Revision B* (March 2019).

Figure 8: Astronaut Office Crew Assignment Process

Source: NASA OIG from NASA-provided information.

Factors Influencing Crew Assignments Are Geared Towards ISS Mission Needs

NASA's current crew assignment process is for seats aboard the U.S. commercial SpaceX Crew Dragon vehicle and the Russian Soyuz vehicle bound for the ISS.[41] We identified several specific factors that inform crew assignment decisions, which are either formally documented in Agency guidance or considered informally and prioritized by the Chief Astronaut.

Flight Eligibility. The Astronaut Evaluation Board determines whether astronauts are rated as "eligible" for assignment following completion of astronaut candidate training, after returning from a mission, or ahead of a potential assignment. Astronauts must also be medically qualified by the Crew Health and Safety office prior to a space flight mission. In addition, for specific mission types such as long-duration ones aboard the ISS, the Multilateral Space Medicine Board ensures astronauts are medically qualified.[42]

Specific Skillsets Needed. In FY 2022, NASA plans to execute ISS Expeditions 64 through 67, conduct the first crewed test flight of the Boeing Starliner, and begin training for the Artemis II mission. The Chief

[41] The assignment process includes astronauts for the Boeing CST-100 Starliner and plans (but not for specific astronauts) for future Exploration-class missions beyond low Earth orbit.

[42] NASA considers a long-duration mission to be more than 30 days. The Multilateral Space Medicine Board is responsible for final medical certification of an ISS crew and for oversight of the implementation of medical operations for the ISS.

Astronaut told us that he is considering what skillsets will be required for each vehicle or mission as part of the astronaut assignment process. These skills require either professional training, such as for a doctor or pilot, or skills that can be gained through performance in simulators, such as for extravehicular activities in the Neutral Buoyancy Laboratory or flight simulation at the Space Vehicle Mock-up Facility, performance in ground assignments, or aptitude during training activities, among others.

International Partner Considerations. To ensure that astronauts work well together as an effective and cohesive unit, the Chief Astronaut considers personalities and skillsets of NASA astronauts and their international partner astronauts. This is currently a consideration for ISS missions and is also expected to be a consideration for Artemis missions. As part of this consideration, the Chief Astronaut coordinates with international partners early in the assignment process to better ensure a proper mix of crew skills and qualifications, crew cohesion, and to prevent last minute adjustments to the team, which Astronaut Office officials and astronauts said can damage corps and crew morale.

Other Crew-Related Factors. Additional factors include ensuring a mix of space flight experience, the personality mix of the crew, and foreign language skills. Even the physical size of astronauts has to be taken into account to fit available spacesuits on the ISS.[43] As part of this process, the Chief Astronaut consults with the Astronaut Office Branch Chiefs (e.g., Extravehicular Activities, Assigned Crew Cadre, Crew Operations) and Assistants to the Chief and Program Offices (e.g., ISS, HLS, Orion, Gateway) to ensure all necessary factors have been identified that would affect the crew assignment.

Priority for Flight Opportunities. The current Chief Astronaut told us that he prioritizes astronauts that have yet to complete a space flight when making new crew assignments. This enables the corps to have broader space flight experience, which improves the quality of future space flights. For example, NASA recently transferred two astronauts from the delayed Boeing Starliner missions and assigned them to a SpaceX Crew Dragon to, in part, obtain space flight experience.[44] A former Chief Astronaut told us that it boosts the morale of the astronaut corps to assign astronauts who have waited the longest to fly. One of the astronauts we interviewed agreed with this approach noting that given the gap between space flight opportunities, the Chief Astronaut must balance the need for space flight experience on missions with incentives to keep astronauts in the corps.

Assignment Process for Artemis Missions Is Still Evolving

While NASA has well-established processes and practices for ISS crew assignments, we found that these processes are still evolving for Artemis crew assignments. We identified three processes that, in our judgment, NASA will need to develop or modify from its current astronaut assignment approach to meet the Agency's Artemis mission objectives. These include 1) coordination with international partners, 2) incorporation of Agency diversity and inclusion goals, and 3) medical determination of astronauts for future space flights based on greater clarity of the health risks of radiation exposure.

[43] The lack of a proper fitting spacesuit aboard the ISS in March 2019 led to the cancellation of the first planned all female extravehicular activity, with Astronaut Nick Hague replacing Anne McClain. The extravehicular activity later occurred in October 2019 with Astronauts Christina Koch and Jessica Meir completing a five-and-a-half-hour spacewalk.

[44] Astronauts Nicole Mann and Josh Cassada were previously assigned to missions on NASA's Boeing Crew Flight Test and NASA's Boeing Starliner-1 mission, respectively. NASA decided it was important to make these reassignments to allow Boeing time to complete development of the Starliner while continuing plans for astronauts to gain space flight experience for the future needs of the Agency's missions.

As with its current ISS operations, NASA expects international partner astronauts to participate in Artemis missions. Several international partners have entered into agreements under which they provide equipment and expertise in exchange for an international partner astronaut to participate in an Artemis mission. For example, as of September 2021 a seat on the Artemis II mission is earmarked for an astronaut from the Canadian Space Agency in return for their contribution of a robotic arm for NASA's Gateway system. Seat assignments and international partner roles for Artemis III and beyond have yet to be determined. As such, coordination between NASA and its partner space agencies on mission assignments will be crucial to mission success and international relations. However, we found that a process or forum for negotiating specific crew assignments between the partners has not been developed for Artemis missions. As previously noted, for ISS crew assignments, NASA proposes its selection of astronauts to the Multilateral Crew Operations Panel to achieve international partner consensus. In our judgment, a similar forum could help identify and coordinate skill needs, flight experience, and personality mixes across space agencies for Artemis crew assignments.

In addition to the Agency continuing to develop its processes with international partner assignments, the Artemis missions include additional goals focused on broad Agency diversity and inclusion initiatives. Specifically, as discussed, both the Administration and the NASA Administrator have publicly committed the Artemis mission to landing the first woman and first person of color on the Moon. This aligns with recent Executive Orders and Mission Equity's goal of expanding diversity and inclusion throughout the federal government and NASA. Although the diversity of the astronaut corps continues to increase over time, the consideration of diversity and inclusion is currently not formally documented within the crew assignment process. An Astronaut Office official noted that diversity and inclusion efforts fall within astronaut candidate recruitment activities, not the assignment process. In this way, the Astronaut Office relies on a diverse corps to draw upon to meet the Administration and Agency's goals for the Artemis mission.

Last, NASA is still assessing the health risks astronauts will face during Artemis missions related to radiation exposure. Primarily leveraging the ISS, NASA plans to continue risk reduction for space radiation exposure on crew through 2030. NASA expects that radiation exposure limits, once solidified, will be a major factor in determining the availability of astronauts to be medically qualified to fly human space flight assignments. If Artemis missions effectively medically disqualify astronauts as a result of exceeding the Agency-set maximum level of exposure because of the duration of the mission beyond low Earth orbit, the astronaut corps may need to adjust its corps size and its assignment process.

CONCLUSION

Historically, NASA and its astronauts have faced and met unprecedented challenges, from the first space flight and lunar landing to the launch of and subsequent crewed missions to the first low Earth orbit destination. Overall, the astronaut corps is well managed by the Astronaut Office. However, NASA now faces new demands and challenges with aligning its current corps and recruiting new astronauts to meet the demanding requirements of this new era of multiple missions in low Earth orbit and deep space.

Although NASA's current low Earth orbit ISS mission needs are being met by the astronaut corps through their size, alignment, assignment, and training processes and frameworks, the framework for future Artemis missions, specifically Artemis II and III, has not been established yet. With planned launches in 2024 and 2025, respectively, and even with reported delays to NASA's development of next-generation spacesuits that will likely push Artemis III back to 2025, the margin of time available to identify skillset needs, recruit and hire additional astronaut candidates, develop a framework for Artemis training, and make adjustments to its current processes is quickly diminishing.

As the Astronaut Office is responsible for providing a readied crew for the Artemis III mission to land on the Moon, the Agency will need to clarify what the requirements of that space flight will be specific to skillset and Artemis mission diversity objectives to inform the selection and assignment process for the crew, as well as the training requirements to safely and successfully prepare the crew to complete the mission. Without early Agency input on Artemis III expectations and due to the time needed to recruit and train new hires, the Astronaut Office is unlikely to have sufficient time to meet these requirements through the 2021 astronaut candidate class and would need to rely on the current astronaut corps.

Compounding these challenges, the Astronaut Office does not have a centralized and comprehensive picture of its corps makeup—such as skillsets and demographic information—that will test its ability to meet Agency missions' goals and diversity objectives. In addition, as the Agency solidifies its plans for Artemis it must coordinate with international partners and overcome challenges related to new and evolving mission requirements, and deep space medical qualifications.

Updated processes for sizing, aligning, training, and assigning the astronaut corps would improve future decision-making and transparency of mission assignments for the ISS, Artemis, and other Agency missions that rely upon the astronaut corps.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To ensure the astronaut corps is aligned to meet current and future mission needs, we recommended the Director of the Flight Operations Directorate and the Chief of the Astronaut Office:

1. Further centralize and maintain its collection, summary, and monitoring of detailed astronaut data—to include skills, certifications, training, and demographics—to better support the sizing and alignment of the astronaut corps, and to help inform recruiting and training of astronauts to fulfill NASA's strategic goals, including continuing to expand the diversity of the astronaut corps.
2. Evaluate whether the 15 percent safety margin is sufficient for the current and near future frequency of space flight missions and document the reasoning behind the selected margin.

To ensure the training process for future Artemis missions is developed with sufficient time for implementation and revision, we also recommended the Director of the Flight Operations Directorate and the Chief of the Astronaut Office:

3. At least 18 months prior to the planned Artemis II launch, coordinate with Artemis program offices to complete the development and chartering of the framework of Artemis boards and panels to ensure alignment with future mission training needs for new vehicles and missions, including Orion, next-generation spacesuits, HLS, and Gateway.
4. Update internal guidance to document the process for identifying and developing training regimens to align with Artemis mission needs.

We provided a draft of this report to NASA management who concurred with our recommendations. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

Management's comments are reproduced in Appendix B. Technical comments provided by management and revisions to address them have been incorporated as appropriate.

Major contributors to this report include Ridge Bowman, Space Operations Director; James Smith, Project Manager; Benjamin Patterson, Amy Bannister, and Daniel Fenzau; and Norman Conley. Emily Bond provided editorial and graphics assistance. Cedric Campbell, Earl Baker, and Shani Dennis provided legal assistance.

If you have questions or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

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Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from November 2020 through December 2021 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. The scope of this audit included NASA's process for determining the size and makeup of its astronaut corps as well as recruiting, training, and assigning NASA astronauts to meet current and future mission requirements.

To evaluate NASA's process for determining the size and makeup of its astronaut corps, we interviewed Agency officials from Johnson's Astronaut Office, including 13 current or former astronauts; FOD; Human Resources Office; Office of General Counsel; and Office of Diversity and Equal Opportunity. In addition, we interviewed officials from NASA's major space flight programs—ISS, Commercial Crew, Orion, HLS, and Gateway. We interviewed officials from NASA's Human Health and Performance and Human Research Program, as well as Agency officials from Headquarters' Office of the Chief Human Capital Officer, Office of Diversity and Equal Opportunity, and HEOMD's HSFO Program office. In addition, we reviewed Agency guidance and documentation regarding astronaut selection criteria, astronaut corps sizing calculations, crew selection process, and diversity and inclusion. We obtained information about NASA astronauts from Agency Human Resources systems and from Agency officials through interviews and data requests, as well as from publicly available information from the NASA website.

To evaluate NASA's process for aligning its astronaut corps to current and planned space flight missions and broader Agency objectives, we interviewed Agency officials from the following:

- Johnson's Astronaut Office, FOD, Human Resource Office, Office of General Counsel, and Office of Diversity and Equal Opportunity;
- the ISS, Commercial Crew, Orion, HLS, and Gateway Program offices;
- the Office of the Chief Health and Medical Officer, Human Health and Health Research Programs, and Johnson Space Medicine Operations Division;
- the Headquarters Office of the Chief Human Capital Officer and Office of Diversity and Equal Opportunity; and
- the HEOMD's HSFO Program office and Commercial Spaceflight Development Division.

We also reviewed relevant Executive Orders regarding ongoing Diversity, Equity, and Inclusion initiatives within the Executive Branch as well as Agency guidance regarding astronaut candidate recruitment and the crew assignment process.

To evaluate NASA's process for identifying training strategies and resources to align the astronaut corps to the Agency's current and future human space flight needs, we interviewed officials from Johnson's Astronaut Office, FOD, and Mission Operations Integration and Safety and Mission Assurance offices, NASA's major space flight programs—ISS, Commercial Crew, Orion, HLS, and Gateway, and HEOMD's HSFO Program office. We reviewed Agency guidance and documentation regarding astronaut training criteria, astronaut corps training regimens, and training development processes including the framework

of current ISS and FOD boards and panels. We obtained information from Agency officials through interviews and data requests, as well as from publicly available information on the NASA website.

To determine NASA's process for astronaut crew assignments, we interviewed officials from Johnson's Astronaut Office, FOD, Human Resources Office, Office of General Counsel, and Office of Diversity and Equal Opportunity. We also reviewed NASA's guidance and documentation on the crew assignment process and ISS Program guidance on the Multilateral Crew Operations Panel. We obtained information on astronaut crew assignments from Agency officials through interviews and data requests. During the audit period, the Agency announced that HEOMD would be reorganized into the Space Operations Mission Directorate and Exploration Systems Development Mission Directorate. As of the date of this audit, it is too early in the reorganization process for us to evaluate its impact on the astronaut corps.

Assessment of Data Reliability

Our audit used limited computer-processed data that we assessed as reliable. Primarily, we reviewed and analyzed NASA human resources data from FY 2021 from NASA's Human Capital Information Environment. We corroborated information with other sources when possible and performed audit steps to validate the accuracy of the provided data. We determined that the data was sufficiently reliable for the purposes of this report.

Review of Internal Controls

We assessed internal controls and compliance with laws and regulations to determine whether NASA is effectively managing its astronaut corps. Control weaknesses are identified and discussed in this report. Our recommendations, if implemented, will improve those identified weaknesses.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General and Government Accountability Office have issued seven reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html and https://www.gao.gov, respectively.

NASA Office of Inspector General

NASA's Management of the Artemis Missions (IG-22-003, November 15, 2021)

NASA's Development of Next-Generation Spacesuits (IG-21-025, August 10, 2021)

NASA's Management of the Gateway Program for Artemis Missions (IG-21-004, November 10, 2020)

NASA's Management of the Orion Multi-Purpose Crew Vehicle Program (IG-20-018, July 16, 2020)

NASA's Management of Crew Transportation to the International Space Station (IG-20-005, November 14, 2019)

NASA's Management and Utilization of the International Space Station (IG-18-021, July 30, 2018)

Government Accountability Office

Strategic Human Capital Management: NRC Could Better Manage the Size and Composition of Its Workforce by Further Incorporating Leading Practices (GAO-17-233, April 27, 2017)

APPENDIX B: MANAGEMENT'S COMMENTS

National Aeronautics and
Space Administration

Mary W. Jackson NASA Headquarters
Washington, DC 20546-0001

January 5, 2022

Reply to Attn of: Space Operations Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Space Operations

SUBJECT: Agency Response to OIG Draft Report, "NASA's Management of its Astronaut Corps" (A-21-005-00)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Management of its Astronaut Corps" (A-21-005-00) dated December 6, 2021.

In the draft report, the OIG makes four recommendations to NASA's Director of the Flight Operations Directorate and the Chief of the Astronaut Office to take action to ensure the astronaut corps is aligned to meet current and future mission needs and to ensure the training process for future Artemis missions is developed with sufficient time for implementation and revision.

Specifically, the OIG recommends the following:

Recommendation 1: Further centralizing and maintaining its collection, summary, and monitoring of detailed astronaut data—to include skills, certifications, training, and demographics—to better support the sizing and alignment of the astronaut corps, and to help inform recruiting and training of astronauts to fulfill NASA's strategic goals, including continuing to expand the diversity of the astronaut corps.

Management's Response: Concur. As mentioned in the report, this data is available and has been utilized to help inform the selection of astronaut candidates. To further centralize going forward, the detailed astronaut data regarding skills, certifications and training will be kept in the Master Assessment and Qualifications History (MAQH) tool within the Astronaut Office. Due to the sensitivity of the data, the demographics of the active astronaut corps will be kept separately in the Flight Operations Directorate and a report detailing this information will be sent to the Chief of the Astronaut Office as needed to support sizing assessments for the astronaut corps.

Estimated Completion Date: May 1, 2022

Recommendation 2: Evaluating whether the 15 percent safety margin is sufficient for the current and near-future frequency of space flight missions and documenting the reasoning behind the selected margin.

Management's Response: Concur. During the Program Planning Budget Execution (PPBE) 24 process in the Spring of 2022, the Astronaut Office will conduct analysis to evaluate if the 15 percent margin currently used in the Astronaut Corps Size Analysis is sufficient and will document the results in the Flight Operations Directorate's PPBE submission and the Astronaut Office's internal files.

Estimated Completion Date: June 1, 2022

Recommendation 3: At least 18 months prior to the planned Artemis II launch, coordinate with Artemis program offices to complete the development and chartering of the framework of Artemis boards and panels to ensure alignment with future mission training needs for new vehicles and missions, including Orion, Next-Generation Spacesuits, Human Landing Systems (HLS), and Gateway.

Management's Response: Concur. The Flight Operations Directorate will finalize and publish the charters for the Artemis Operations Panel (AOP) and Artemis Training Panel (ATP) prior to reaching 18 months to Artemis II launch.

Estimated Completion Date: November 1, 2022

Recommendation 4: Update internal guidance to document the process for identifying and developing training regimens to align with Artemis mission needs.

Management's Response: Concur. The Astronaut Office will update both CB-QMS-007, *Increment Training Integrator Handbook*, and CB-QMS-008, *Increment Training Integrator Certification Guide*, to include the processes for developing Artemis training plans and schedules for assigned crew.

Estimated Completion Date: July 1, 2022

NASA has reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified any information that should not be publicly released.

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please contact Michelle Bascoe at (202) 358-1574.

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Kathryn L. Lueders

APPENDIX C: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
General Counsel
Associate Administrator for Space Operations Mission Directorate
Associate Administrator for Exploration Systems Development Mission Directorate
Associate Administrator for Diversity and Equal Opportunity
Associate Administrator for International and Interagency Relations
Senior Advisor to the Administrator for External Engagement; Diversity and Inclusion; and Science, Technology, Engineering, and Mathematics (STEM) outreach activities
Chief Health and Medical Officer
Deputy Chief Health and Medical Officer
Director, Human Space Flight Operations
Director, Human Research Program
Director, Johnson Space Center
Deputy Director, Johnson Space Center
Director, Kennedy Space Center
Director, Marshall Space Flight Center
Director, International Space Station
Director, Flight Operations Directorate
Chief Astronaut, Astronaut Office
Program Manager, Commercial Crew Program
Program Manager, Human Landing System
Program Manager, Gateway
Program Manager, Orion Multi-Purpose Crew Vehicle

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Energy and Space Programs Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
Subcommittee on Space, Science, and Competitiveness

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Government Reform
Subcommittee on Government Operations

House Committee on Science, Space, and Technology
Subcommittee on Investigations and Oversight
Subcommittee on Space and Aeronautics

(Assignment No. A-21-005-00)