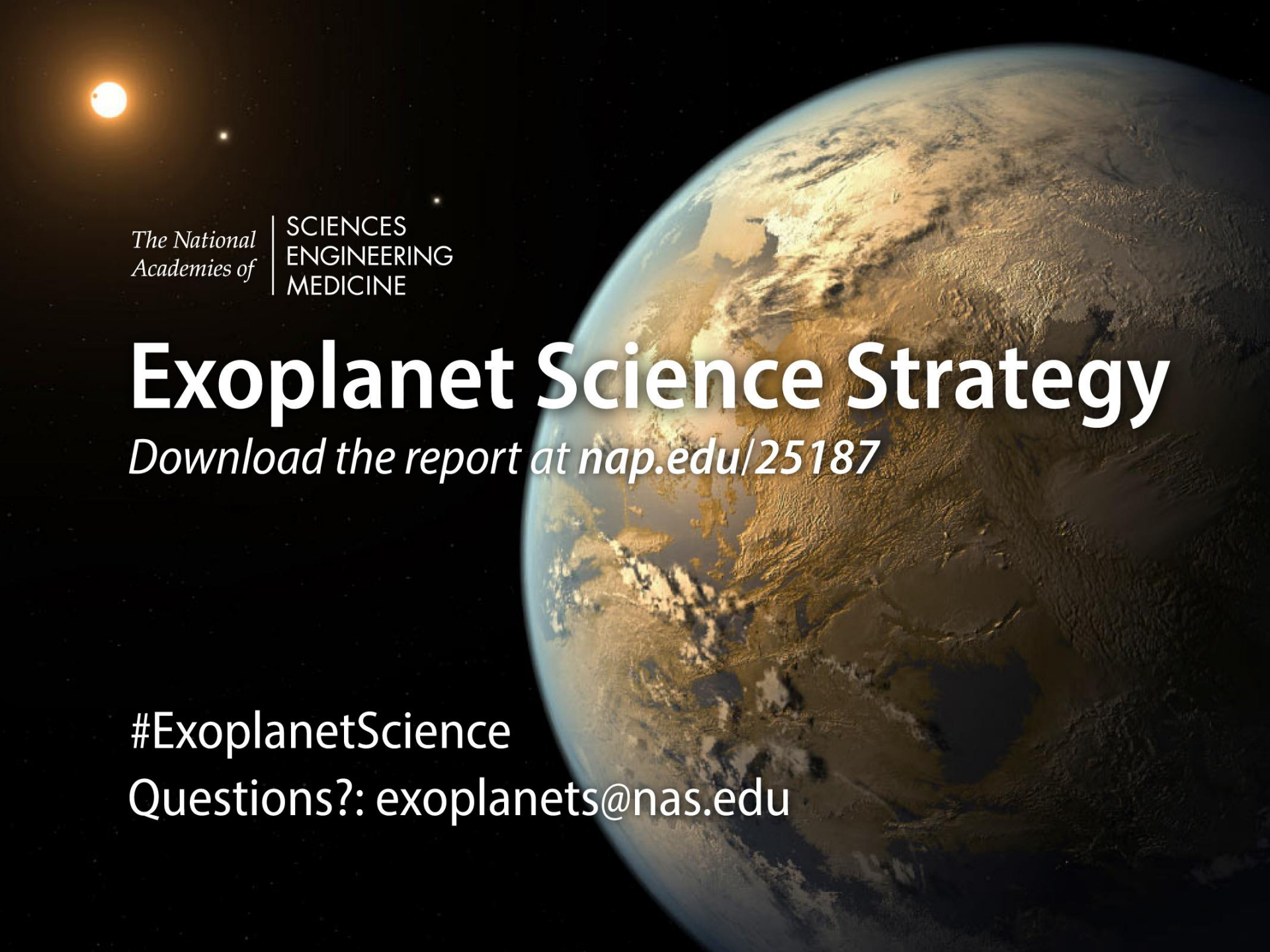
The National Academies of
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Exoplanet Science Strategy
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Report Schedule

Meeting #1: March 6-7, 2018 in Washington, DC

Meeting #2: April 19-20, 2018 in Irvine, CA

Meeting #3: June 5-6, 2018 in Washington, DC

Report Delivery to NASA: August 31, 2018

Public Release of Report: September 5, 2018

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Statement of Task

In preparation for and as an input to the upcoming decadal surveys in astronomy and astrophysics and planetary science, the National Academies of Sciences, Engineering and Medicine will appoint an ad hoc committee to perform a study with the following objectives:

- Survey the status of the field of exoplanet science, including the use of current and planned facilities such as Transiting Exoplanet Survey Satellite, the James Webb Space Telescope, the Wide Field InfraRed Survey Telescope, and any other telescope, spacecraft, or instrument, as appropriate;
- Recommend an Exoplanet Science Strategy that outlines the key scientific questions for exoplanet science and research and related near-, medium-, and far-term measurement and technology goals. The Strategy will include the search for life in the universe as well as cross-discipline opportunities in Earth science, astrophysics, heliophysics, and planetary science.
- Discuss which of the key goals of the committee's Strategy could be addressed via current decadal survey recommended priority activities and also identify opportunities for coordination with international partners, commercial partners, and not-for-profit partners;

In the course of conducting this study, the committee will consider and regularly consult with the concurrent study “State of the Science of Astrobiology,” in the area of assessing habitability, searching for signs of life, and other relevant areas of scientific overlap. Also the committee will not revisit or redefine the scientific priorities or mission recommendations from previous decadal surveys.

Authorization Language

NASA Transition Authorization Act of 2017

SEC. 508. <<NOTE: 51 USC 20301 note.>> EXTRASOLAR PLANET EXPLORATION STRATEGY.

(a) Strategy.--

(1) In general.--The Administrator shall enter into an arrangement with the National Academies to develop a science strategy for the study and exploration of extrasolar planets, including the use of the Transiting Exoplanet Survey Satellite, the James Webb Space Telescope, a potential Wide-Field Infrared Survey Telescope mission, or any other telescope, spacecraft, or instrument, as appropriate.

(2) Requirements.--The strategy shall--

(A) outline key scientific questions;

(B) identify the most promising research in the field;

(C) indicate the extent to which the mission priorities in existing decadal surveys address the key extrasolar planet research and exploration goals;

(D) identify opportunities for coordination with international partners, commercial partners, and not-for-profit partners; and

(E) <<NOTE: Recommendations.>> make recommendations regarding the activities under subparagraphs (A) through (D), as appropriate.

(b) Use of Strategy.--The Administrator shall use the strategy--

(1) to inform roadmaps, strategic plans, and other activities of the Administration as they relate to extrasolar planet research and exploration; and

(2) to provide a foundation for future activities and initiatives related to extrasolar planet research and exploration.

(c) Report to Congress.--Not later than 18 months after the date of enactment of this Act, the National Academies shall submit to the Administrator and to the appropriate committees of Congress a report containing the strategy developed under subsection (a).

Scientific Goals

Goal 1: Understand the formation and evolution of planetary systems as products of the process of star formation, and characterize and explain the diversity of planetary system architectures, planetary compositions, and planetary environments produced by these processes.

This leads to three scientific findings that will guide our strategy:

FINDING: Current knowledge of the demographics and characteristics of planets and their systems is substantially incomplete. Advancing an understanding of the formation and evolution of planets requires two surveys: First, it requires a survey for planets where the census is most incomplete, which includes the parameter space occupied by most planets of the Solar System. Second, it requires the characterization of the atmospheres and bulk compositions of planets spanning a broad range of masses and orbits.

FINDING: An understanding of planet formation requires a census of protoplanetary disks, young planets, and mature planetary systems across a wide range of planet-star separations.

FINDING: Characterizing the masses, radii, and atmospheres of a large number of exoplanets with a range of physical and orbital parameters for a diverse set of parent stars will yield fundamentally new insights into the formation and evolution of planets and the physics and chemistry of planetary environments.

Scientific Goals

Goal 2: Learn enough about the properties of exoplanets to identify potentially habitable environments and their frequency, and connect these environments to the planetary systems in which they reside. Furthermore, researchers need to distinguish between the signatures of life and those of nonbiological processes, and search for signatures of life on worlds orbiting other stars.

This leads to two scientific findings that will guide our strategy:

FINDING: The concept of the habitable zone has provided a first-order technique for identifying exoplanets that may be able to harbor life. A multiparameter holistic approach to studying exoplanet habitability, using both theory and observation, is ultimately required for target selection for biosignature searches.

FINDING: Inferring the presence of life on an exoplanet from remote sensing of a biosignature will require a comprehensive framework for assessing biosignatures. Such a framework would need to consider the context of the stellar and planetary environment, and include an understanding of false negatives, false positives, and their observational discriminants.

A Space-Based Exoplanet Imaging Mission is Needed

FINDING: A coronagraphic or starshade-based direct imaging mission is the only path currently identified to characterize Earth-size planets in the habitable zones of a large sample of nearby Sun-like stars in reflected light.

FINDING: Recently acquired knowledge of the frequency of occurrence of small planets, and advances in the technologies needed to directly image them, have significantly reduced uncertainties associated with a large direct imaging mission.

RECOMMENDATION: NASA should lead a large strategic direct imaging mission capable of measuring the reflected-light spectra of temperate terrestrial planets orbiting Sun-like stars.

Ground-Based Telescopes Will Play an Essential Role

FINDING: The GMT and TMT will enable profound advances in imaging and spectroscopy of entire planetary systems, over a wide range of masses, semimajor axes, and wavelengths, potentially including temperate Earth-size planets orbiting M-type stars.

FINDING: The technology roadmap to enable the full science potential of GMT and TMT in exoplanet studies is in need of investments, leveraging the existing network of U.S. centers and laboratories and current 8-10 meter class facilities.

FINDING: GMT and TMT, equipped with high-resolution optical and infrared spectrographs, will be powerful tools for studying the atmospheres of transiting and nontransiting close-in planets, and have the potential to detect molecular oxygen in temperate terrestrial planets transiting the closest and smallest stars.

FINDING: The detection of young planets in disks will provide the ground truth for the time scale of planet formation and permit studies of the dynamical interaction between disks and planets. With the high spatial resolution of the GMT and TMT, researchers will be able to search the inner parts of planet-forming systems.

RECOMMENDATION: The National Science Foundation (NSF) should invest in both the GMT and TMT and their exoplanet instrumentation to provide all-sky access to the U.S. community.

WFIRST Will Provide Critical Exoplanet Data and Pave the Way for a Direct-Imaging Mission

FINDING: A microlensing survey would complement the statistical surveys of exoplanets begun by transits and radial velocities by searching for planets with separations of greater than one AU (including free-floating planets) and planets with masses greater than that of Earth. A wide-field, near-infrared (NIR), space-based mission is needed to provide a similar sample size of planets as found by Kepler.

FINDING: A number of activities, including precursor and concurrent observations using ground- and space-based facilities, would optimize the scientific yield of the WFIRST microlensing survey.

FINDING: Flying a capable coronagraph on WFIRST will provide significant risk reduction and technological advancement for future coronagraph missions. The greatest value compared to ground testing will come from observations and analysis of actual exoplanets, and in a flexible architecture that will allow testing of newly developed algorithms and methods.

FINDING: The WFIRST-Coronagraph Instrument (CGI) at current capabilities will carry out important measurements of extrasolar zodiacal dust around nearby stars at greater sensitivity than any other current or near-term facility.

RECOMMENDATION: NASA should launch WFIRST to conduct its microlensing survey of distant planets and to demonstrate the technique of coronagraphic spectroscopy on exoplanet targets.

Improving the Precision of Radial Velocity Measurements Will Support Exoplanet Missions

FINDING: The radial velocity method will continue to provide essential mass, orbit, and census information to support both transiting and directly imaged exoplanet science for the foreseeable future.

FINDING: Radial velocity measurements are currently limited by variations in the stellar photosphere, instrumental stability and calibration, and spectral contamination from telluric lines. Progress will require new instruments installed on large telescopes, substantial allocations of observing time, advanced statistical methods for data analysis informed by theoretical modeling, and collaboration between observers, instrument builders, stellar astrophysicists, heliophysicists, and statisticians.

RECOMMENDATION: NASA and NSF should establish a strategic initiative in extremely precise radial velocities (EPRVs) to develop methods and facilities for measuring the masses of temperate terrestrial planets orbiting Sun-like stars.

JWST Could Survey Exoplanet Atmospheres and Guide Future Observing Strategies

FINDING: The combination of transiting planet detection with TESS, mass measurements with radial velocities, and atmospheric characterization with JWST will be transformative for understanding the nature and origins of close-in planets. Future space missions with broader wavelength coverage, a larger collecting area, or reduced instrumental noise compared to JWST would have greater reach to potentially habitable planets.

RECOMMENDATION: NASA should create a mechanism for community-driven legacy surveys of exoplanet atmospheres early in the JWST mission.

An Interdisciplinary, Engaged Community is Essential for Exoplanet Science

FINDING: The search for life outside the Solar System is a fundamentally interdisciplinary endeavor. The Nexus for Exoplanet Systems Science (NExSS) research coordination network encourages the cross-disciplinary and cross-divisional collaborations needed to support NASA exoplanet research and missions.

RECOMMENDATION: Building on the NExSS model, NASA should support a cross-divisional exoplanet research coordination network that includes additional membership opportunities via dedicated proposal calls for interdisciplinary research.

An Interdisciplinary, Engaged Community is Essential for Exoplanet Science

FINDING: Theoretical models are essential to plan and interpret observations of exoplanets, and are enabled by robust support via individual investigator grants.

FINDING: The limited lab and ab initio data covering the parameter space relevant to exoplanets is a barrier to accurate models of exoplanet atmospheres and interiors. Mechanisms to increase collaboration between exoplanet astronomers and experimental physicists and chemists would help overcome this barrier.

FINDING: Understanding of exoplanets is limited by measurements of the properties of the parent stars, including stellar mass, radius, distance, binarity, rotation period, age, composition, emergent spectrum, and variability.

RECOMMENDATION: NASA should support a robust individual investigator program that includes grants for theoretical, laboratory, and ground-based telescopic investigations; otherwise, the full scientific yield of exoplanet missions will not be realized.

An Interdisciplinary, Engaged Community is Essential for Exoplanet Science

FINDING: To maximize scientific potential and opportunities for excellence, institutions and organizations can enable full participation by a diverse workforce by taking concrete steps to eliminate discrimination and harassment and to proactively recruit and retain scientists from underrepresented groups.

FINDING: Development and dissemination of concrete recommendations to improve equity and inclusion and combat discrimination and harassment would be valuable for building the creative, interdisciplinary teams needed to maximize progress in exoplanet science over the coming decades.

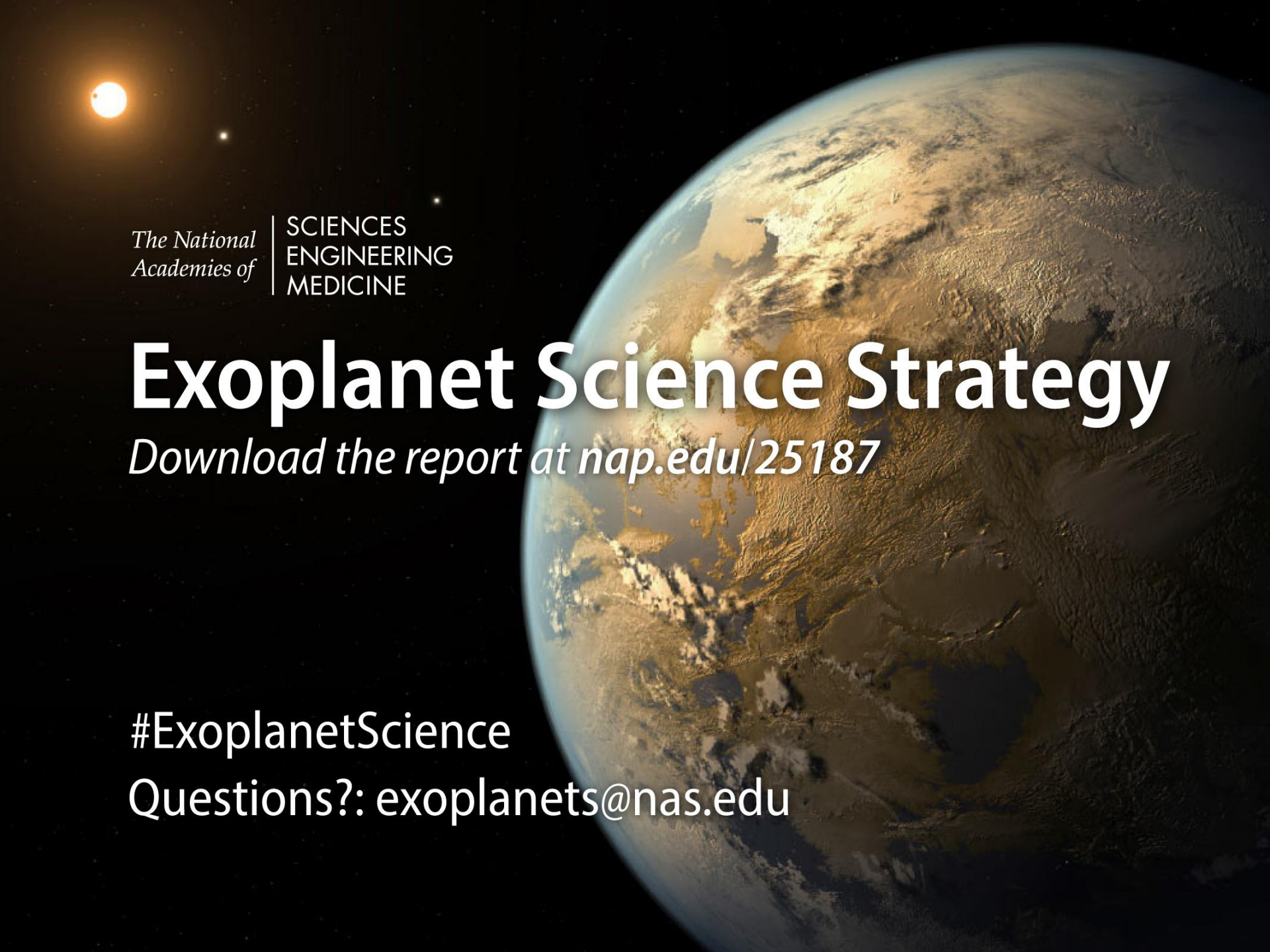
The committee endorses the IA2015 recommendation that, "The decadal survey should address issues of policy making and leadership diversity imbalances as recommendations that can be acted upon by policy makers." To achieve this goal, the Astronomy and Astrophysics and the Planetary Science Decadal Surveys will need to consult with experts beyond the astrophysics and planetary science communities and with members of underrepresented and marginalized groups.

Strategy Timeline

Near-Term Activities (<5 years):
JWST, NExSS, Individual Investigator Grants, and Workforce Development

Medium-Term Activities (5-15 years):
WFIRST, the US-led GSMTs, and an EPRV Initiative

Long-Term Activities (15-20 years):
Space-based direct imaging mission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