

Exoplanet Exploration Program (ExEP) Science Plan

Eric Mamajek, Deputy Program Chief Scientist

NASA Exoplanet Exploration Program

Jet Propulsion Laboratory

California Institute of Technology

January 7, 2018, ExoPAG 17, National Harbor MD





NASA Exoplanet Exploration Program

Astrophysics Division, NASA Science Mission Directorate

NASA's search for habitable planets and life beyond our solar system



Program purpose described in
2014 NASA Science Plan

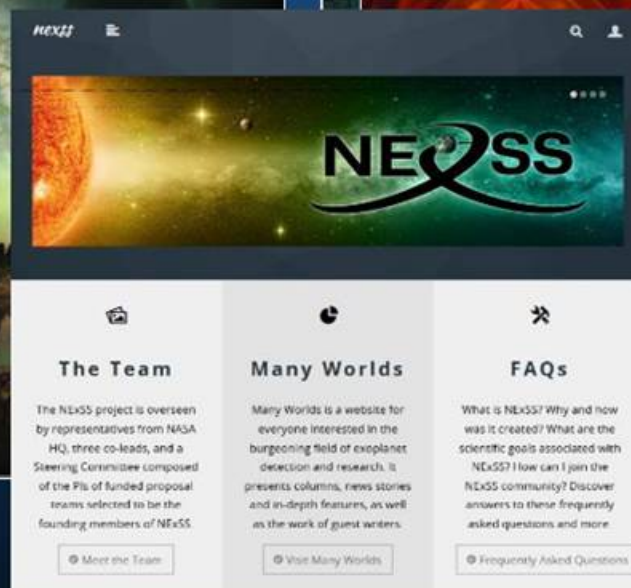
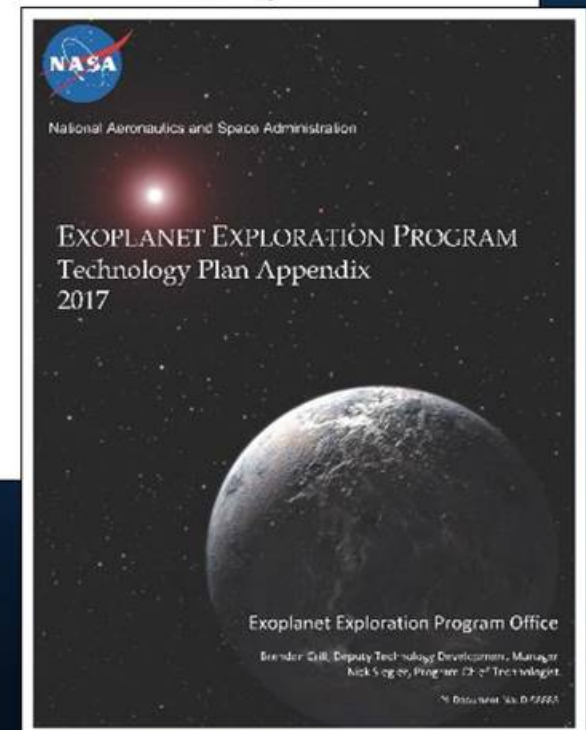
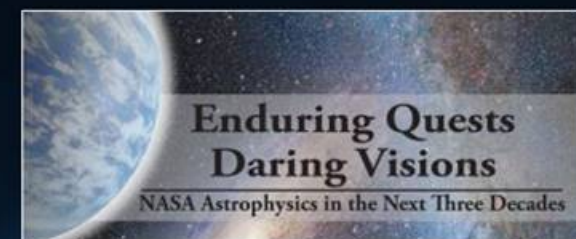
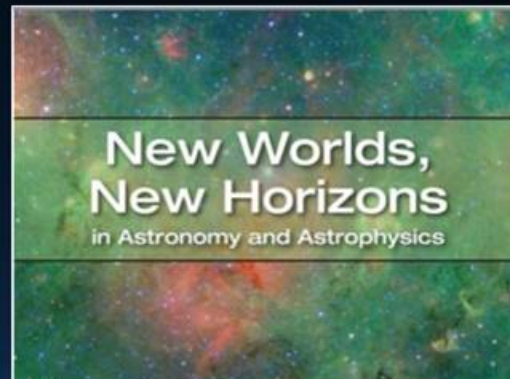
- 1. Discover planets around other stars**
- 2. Characterize their properties**
- 3. Identify candidates that could harbor life**

ExEP serves the science community and NASA by implementing NASA's space science vision for exoplanets

<https://exoplanets.nasa.gov>



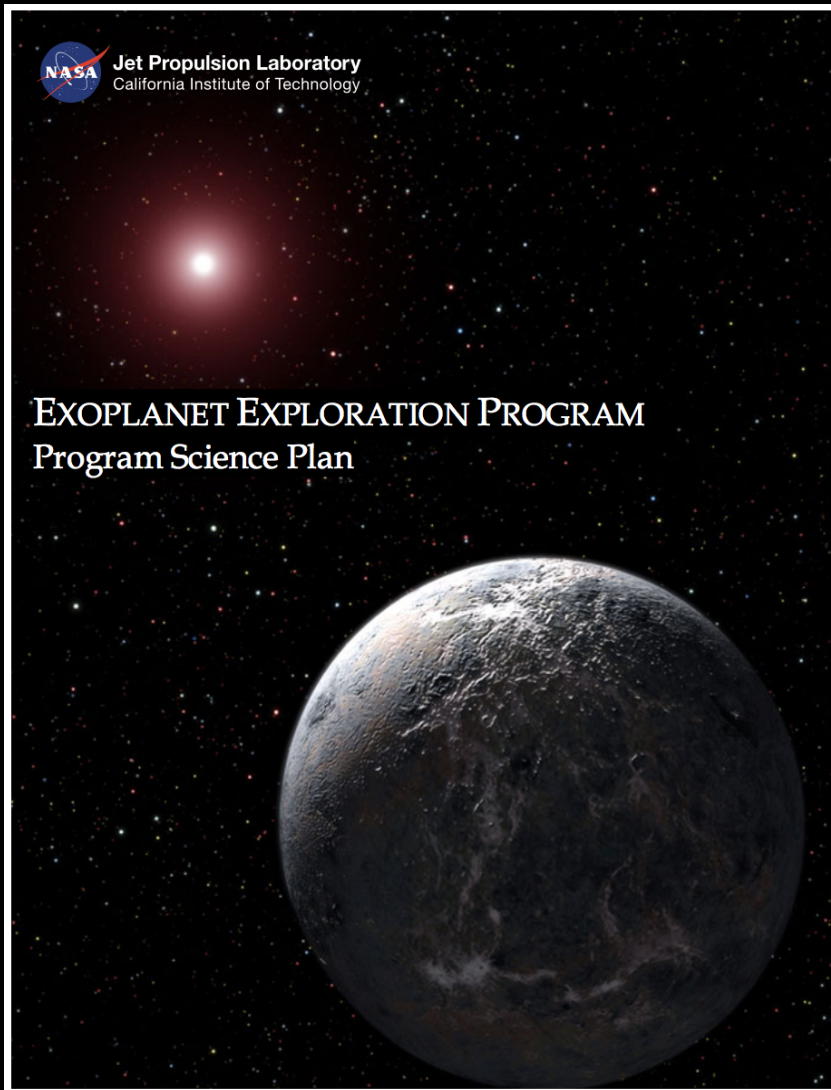
Foundational Documents for the Exoplanet Exploration Strategy Study



Steps that will enable direct imaging and spectra of habitable exoplanets

- Understand the frequency of HZ rocky planets
- Measure the astronomical backgrounds
- Make precursor and follow-up observations to measure exoplanet masses and orbits, where possible
- Measure host star properties that affect habitability
- Develop our understanding of exoplanet atmospheres, biosignatures, and biosignature false positives
- Ready the starlight suppression technology
- Close in on the mission architecture

ExEP Science Plan Overview



“The purpose... is to articulate NASA’s Exoplanet Exploration Program (ExEP) plan for 1) obtaining the scientific information needed to define the science requirements for future exoplanet space missions; and 2) supporting follow-up investigations needed to interpret the results of current/upcoming missions in support of program objectives.

The Plan lays out the scientific challenges that must be addressed, specifies the programmatic approach to the scientific investigations that are needed to support Program objectives, and describes how the science program will be conducted.”



NASA Project Life Cycle vs. Scope of ExEP Science Plan

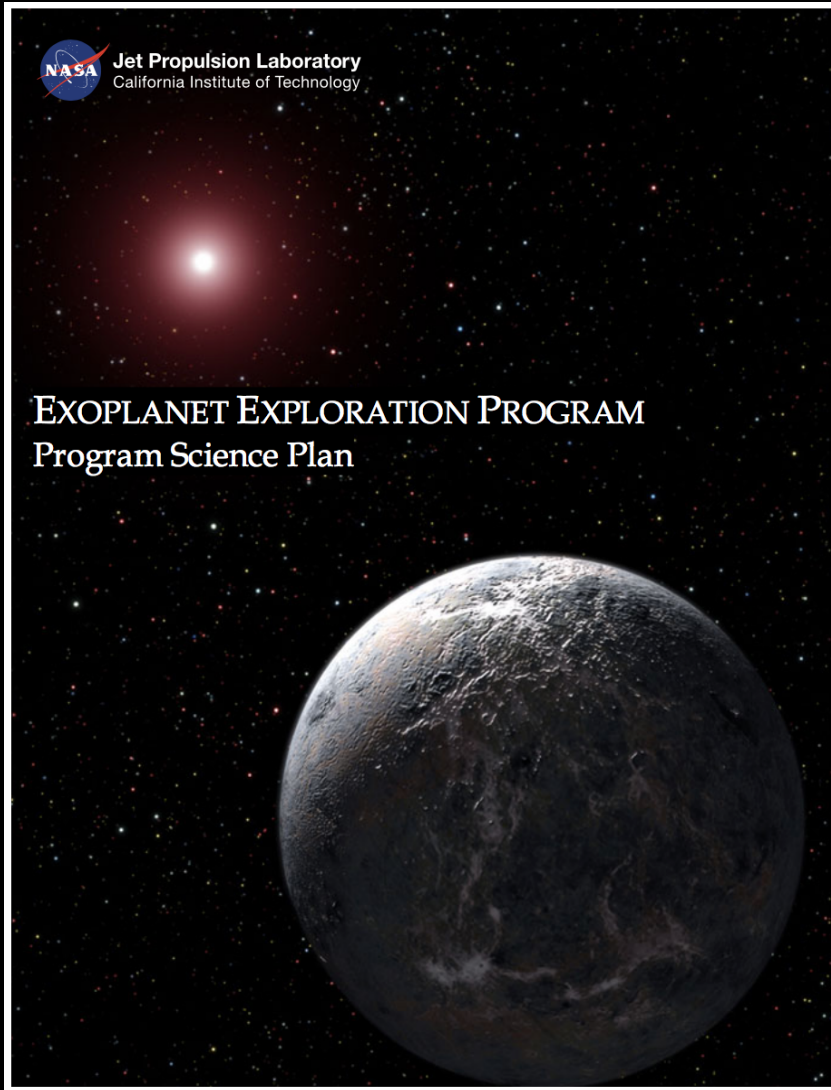
NASA Life-Cycle Phases	Approval for Formulation		Approval for Implementation		IMPLEMENTATION		
Project Life-Cycle Phases	Pre-Phase A: Concept Studies	Phase A: Concept & Technology Development	Phase B: Preliminary Design & Technology Completion	Phase C: Final Design & Fabrication	Phase D: System Assembly, Integration & Test, Launch & Checkout	Phase E: Operations & Sustainment	Phase F: Closeout
Project Life-Cycle Gates, Documents, and Major Events	KDP A FAD Preliminary Project Requirements	KDP B Preliminary Project Plan	KDP C Baseline Project Plan	KDP D	KDP E Launch	KDP F End of Mission	Final Archival of Data

Scope of ExEP Science Plan

Phase A-F (formulation through implementation): Identifying follow-up investigations needed to interpret the results of current/upcoming missions in support of program objectives

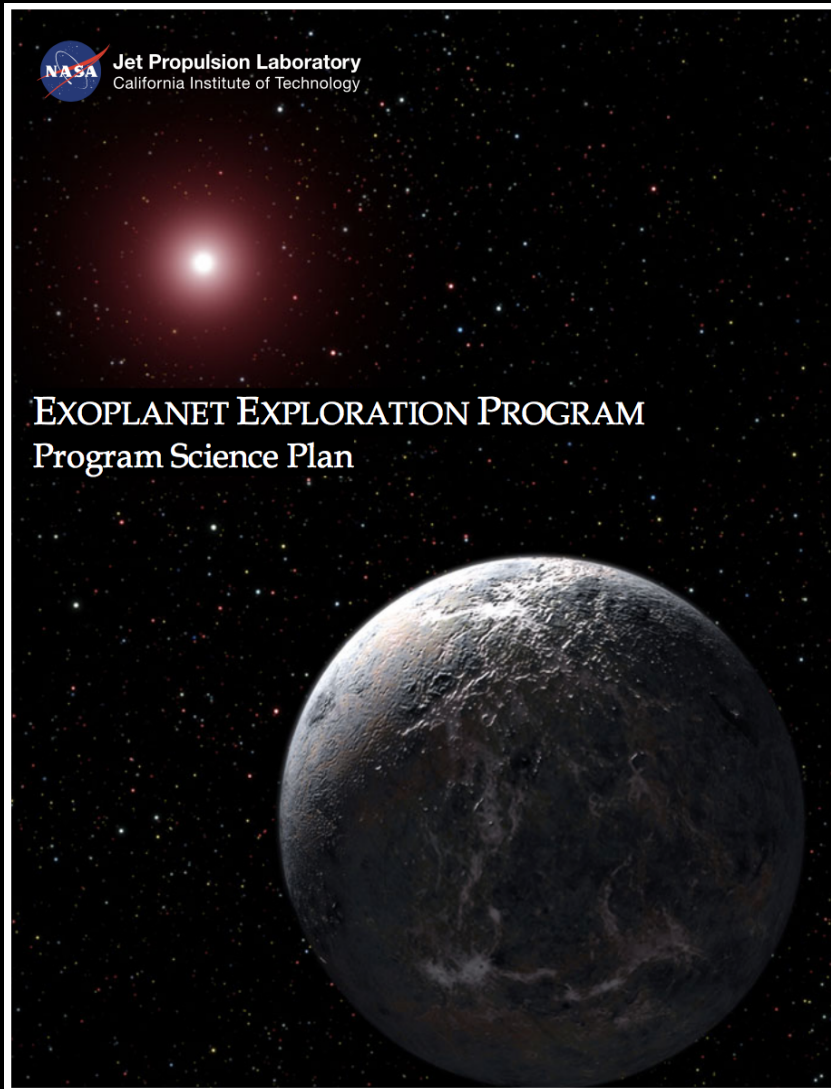
Pre-Phase A (concept studies): Identifying scientific information needed to define the science requirements for future exoplanet space missions

ExEP Science Plan Overview



- **Describes roles of Program Scientists and their interactions with key actors: External Science community, ExoPAG, PIs of NASA science investigations, NExSci, NASA HQ Program Scientists**
- **Gives background on 5 key science areas relevant to Program objectives. Each area is described with a state of the field, current and upcoming missions & facilities, and knowledge needed to inform ExEP Objectives. This provides context for the ExEP Science Gap List (SGL).**
- **Lays out an annual calendar for updating the gap list through community input.**

ExEP Science Plan Overview



- TOC, Introduction, Documentation, Programmatic Framework
- Science Investigation Areas Relevant to ExEP Objectives (Section titles)
 - *Exoplanet dynamics – determination of orbits and masses*
 - *Exoplanet populations*
 - *Exozodiacal dust: exoplanet tracer and obscurer*
 - *Properties of target stars*
 - *Exoplanet atmospheres and biosignatures*
- Bibliography
- Appendix A: Acronym List
- Appendix B: Science Gap List (SGL)
- Currently 73 pages



Snapshot of ExEP Science Gap List

(grouped by topic, no implied priority in ordering)

Spectra of small planets

Modeling exoplanet atmospheres

Spectral signature retrieval

Combining exoplanet demographics from multiple methods

Occurrence rates for small planets (e.g. η_{\oplus})

Quantified science yield comparison between flagships, probes & WFIRST

Systematic strategy for prioritizing flagship mission targets

Nearby star catalog

Achieving RV sensitivity to Earth-like planets: mitigating RV jitter

Community RV facilities for Kepler, K2, TESS follow-up

Search completeness of current prec. RV surveys for direct imaging targets

Dedicated WFIRST/CGI RV precursor programs

Achieving astrometric sensitivity to Earth-like planets

Exozodi as a noise source for flagship imaging of exoplanets

Exozodi substructure as a noise source for exoplanet imaging (flagship)

High resolution imaging in bulk to validate TESS candidates

Projected state of ground-based direct imaging capability

Generation of lightcurves for TESS full frame images

Gap: Occurrence rates for small planets (including η_{\oplus})

Summary: Occurrence rates for Earth-sized planets in G stars hab zones remains highly uncertain. Kepler DR25 occurrence rate analysis not yet done. Critical for assessment of next decadal flagship mission for hab zone exo-Earth detection.

Capability Needed: Analysis of Kepler DR25 occurrence rates including effects of stellar multiplicity, Gaia distances, improved stellar parameters. Goal for the remaining uncertainties in final results to be dominated by intrinsic Kepler uncertainties.

Capability Today: Published analyses by several authors (e.g. Petigura+2013, Burke+2015), ExoPAG SAG13 analysis.

Proposed Mitigation: Encourage proposals and ROSES selections on this topic. Consider dedicated proposal call if the latter are insufficient.

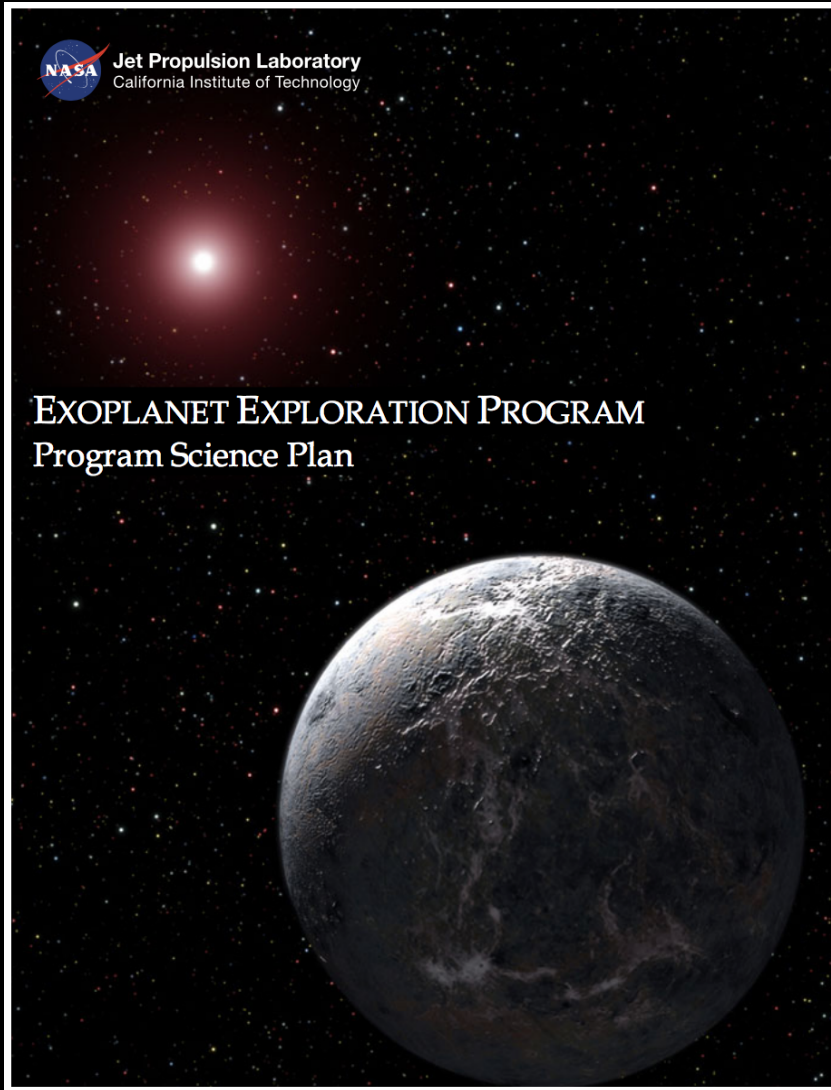
Progress on Mitigation: Activity research area in community. SAG 13 report in progress.



How NASA Funds Exoplanet Science

- **NASA Exoplanet Exploration Program:** K2 Guest Investigator Program, Keck Guest Observer Program, LBTI Exozodi Key Science Team, NN-EXPLORE Program, and WFIRST Science Investigation Teams.
- **General Observer Programs of Missions outside ExEP:** Hubble Space Telescope, Spitzer Space Telescope, Chandra X-ray Observatory, and SWIFT Explorer. +TESS, +JWST, -Spitzer soon.
- **NASA Research & Analysis Programs:** Astrophysics Data Analysis Program (ADAP), Astrophysics Theory Program (ATP), Exoplanet Research Program (XRP), Habitable Worlds Program, NASA Astrobiology Institute (NAI), The Nexus for Exoplanet System Science (NExSS)

ExEP Science Plan Overview



- Plan is undergoing internal review – preliminary version will need to be signed off before circulation
- Preliminary version of plan will be posted post-AAS (within weeks)
- **ExEP is seeking ExoPAG feedback** – especially in identifying *science gaps* relevant to either pre-formulation exoplanet mission studies or support of exoplanet missions either in formulation or implementation (phase A-F)
- Given timing of community input in near future (NAS Exoplanet Strategic Plan 2018, Decadal 2020), ExEP science plan and gap list will evolve accordingly in the near future



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov