Astro2020 APC White Paper

Title: Extreme Precision Radial Velocity (EPRV) Working Group
Type of Activity: Ground Based Project

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Introduction.

The National Academies of Science, Engineering, and Medicine recently published the Exoplanet Science Strategy (ESS) report. The statement of task was as follows:

"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."

One of primary recommendations of this report was that:

"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." – National Academies of Science, Engineering, and Medicine Exoplanet Survey Strategy Report.

Notably, a very similar recommendation was made by the Astro2010 Decadal Survey, and therefore this recommendation was immediately actionable. As a result, the response from NASA and NSF was as follows:

NASA and NSF are jointly commissioning a community-based "Extreme Precision Radial Velocity (EPRV) working Group" to develop a blueprint for a strategic EPRV initiative.

The purpose of this white paper is to describe the EPRV Working Group, whose primary responsibility is to lay out the blueprint mentioned above.

Background: The National Academies Exoplanet Survey Strategy Findings and Recommendation.

The National Academies of recently published the Exoplanet Science Strategy (ESS) report which documented findings and recommendations regarding the importance of exoplanet mass measurements. Knowledge of a planet's mass (along with a knowledge of its radius) is essential to understand its bulk composition and to interpret spectroscopic features in its atmosphere. The study of Earth-like planets orbiting Sun-like stars will require mass measurements to the sensitivity required to understand such worlds. Two report findings are:

1. 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.
2. 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.

The ESS report recommended that "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". In response to this recommendation, NASA is commissioning the Extreme Precision Radial Velocity (EPRV) Working Group to recommend a ground-based program architecture and implementation plan to achieve the goal intended by the ESS report findings. This document establishes the plan for the EPRV Working Group deliverables, work flow and membership.

Deliverables.

The EPRV Working Group is established to deliver to the NASA Astrophysics Division (APD) and the NSF Division of Astronomical Sciences (AST) a report, as a first step, that includes a recommendation the best ground-based program architecture and implementation to achieve the goal of measuring the masses of temperate terrestrial planets orbiting Sun-like stars. In the Working Group deliverable recommendation and at decision points of the subsequent Initiative (if implemented) possible ground-based solutions will be identified. If ground-based solutions are not found then another study may be considered for a space-based solution. The recommendation will define a roadmap that NASA/APD and NSF/AST can carry out jointly or separately to achieve the necessary breakthrough in extreme precision radial velocity measurement.

The report will be delivered by March 2020, after which the EPRV Working Group will be disbanded. The report will include scope, schedule, and planning-level funding requirements.

The report may include both directed and competed scope. No selection criteria for specific competed scope will be developed, and all products and deliberations of the EPRV Working Group will be conducted and documented in an open forum.

NASA/APD and NSF/AST will discuss the report's findings within the context of the existing NASA-NSF Exoplanet Observational Research (NN-EXPLORE)[1] partnership agreement. NASA and NSF will consider the recommendations for implementation through their own processes.

Community Participation.

NASA/APD and the NSF/AST are best served by a process that ensures transparency, inclusiveness, and consensus by the scientific and technical community. International participation is planned. The EPRV Working Group structure is illustrated in Figure 1.

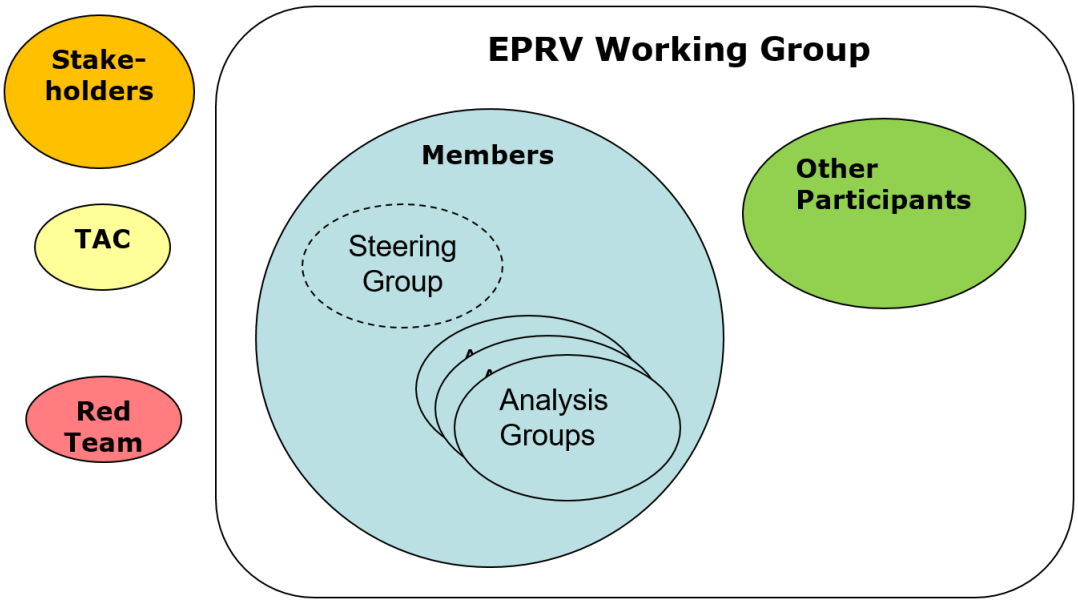


Figure 1. EPRV Working Group

The following groups will participate in the EPRV Working Group:

1. A **Steering Group** is a subset of the Members and is responsible for approving membership of subgroups termed Analysis Groups. Steering Group members may be part of, and participate in, the Analysis Groups. The Steering Group assists the Chairs in setting agendas. The Steering Group will provide periodic briefings to the NASA and NSF stakeholders. The Steering Group is formed by the Chairs with the concurrence of the stakeholders.

[1] https://exoplanets.nasa.gov/exep/NNExplore/

2. **Members** of the Working Group represent the breadth of science, technology, engineering, and programmatic (schedule, cost) expertise necessary to deliver the report recommendations. Members are identified with inputs from the Steering Group and invited by the Chair with the concurrence of the stakeholders. Members are tasked to develop the EPRV Working Group report and support the formulation of recommendations. The Chairs intend the recommendation to be arrived at by consensus of all Members. Members will provide analysis and recommendations through Analysis Group participation; individuals may serve on more than one group as expertise and time permits, including:
    a. Analysis Groups; as many as needed to define, analyze and develop options and program architectures. Teams are drawn from the Membership and Participants.
    b. Evaluation Team: one of the Analysis Groups will perform initial evaluations of the science, technical, and programmatic merit of architecture options and bring these to the full Working Group for consideration.
    c. At-Large Members
3. **Participants:** Other Participants consist of consultants, guests, and observers and are invited by the Steering Group to contribute as needed. Participants include subject-matter experts necessary to inform the recommendations. Expectations on the frequency and degree of participation are lower than for the Members. These Participants are welcome to participate in the full EPRV Working Group deliberations.
4. **Chairs** (of the collective Steering Group, Membership and Working Group) will facilitate the Working Group, are accountable to the Stakeholders, are responsible for bringing the Members and ideally the full Working Group to a consensus report including recommendations by the required date, and will support briefings of the final recommendation to stakeholders and the community.

The following groups are welcome to participate in the EPRV Working Group deliberations:

5. **Stakeholders** are representatives of NASA/APD and the NSF/AST. The stakeholders establish this Working Group through these Terms of Reference. The formal recommendation from the EPRV Working Group may be addressed solely to NASA/APD, solely to NSF/AST, or jointly to both Agencies at the discretion of the stakeholders.
6. The **ExoTAC**[2] (**Exoplanet Technical Assessment Committee**) members perform an independent assessment of the process and results of the Working Group and deliver that assessment to NASA/APD concurrently with the EPRV Working Group report. The ExoTAC are invited to observe all Working Group deliberations. The ExoTAC delivers its assessment directly to the Stakeholders.
7. A **Red Team** is accountable to the Steering Group will be convened to improve the quality of the final report.
8. Others may be added to the Working Group email list at the discretion of the Chairs.

[2] https://exoplanets.nasa.gov/exep/technology/technology-overview/

C. Work Flow

The intended work flow is illustrated in Figure 2.

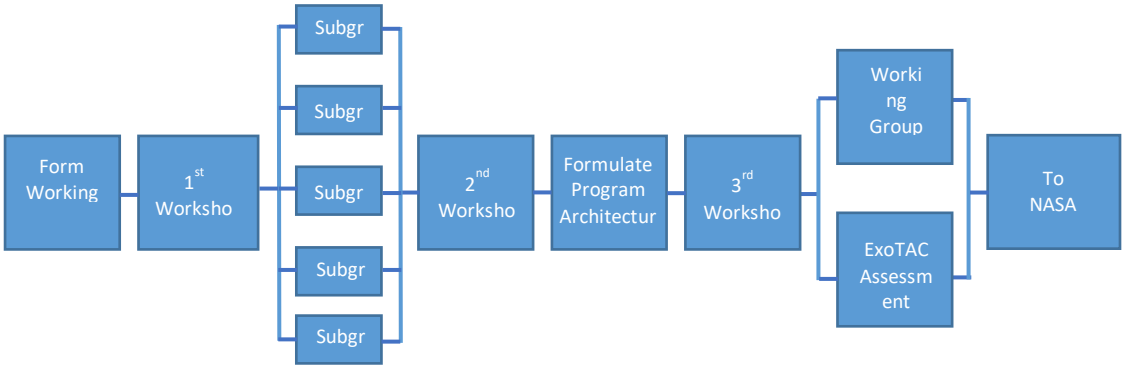


Figure 2. Work Flow.

1. Coordination meetings/teleconferences with NASA and NSF.
2. Form a Steering Group and invite community experts to participate in the Working Group including an open call for nominations.
3. Kickoff telecon with Steering Group.
4. Kickoff telecon with EPRV Working Group.

1st Workshop:

5. Establish objectives (requirements, figures of merit), confirm with stakeholders.
6. Review the current status and limitations of precision radial velocity measurements.
7. Define targets for near-term and long-term radial velocity precision.
8. Form Analysis Groups and appoint leads for specific areas of development.

Multi-Month Activity:

9. Formulation and analysis by the Analysis Groups.

2nd Workshop:

10. Analyze and prioritize options within each Analysis Group, weighted in terms of benefit (impact), urgency, likelihood, feasibility.
11. Roadmaps: Define comprehensive multi-element roadmaps based on strongest options from each Analysis Group.

3rd Workshop (if necessary):

12. Evaluate these Roadmaps versus the success criteria for the recommendation. Balance these Roadmaps against existing programs and priorities at NASA and NSF.

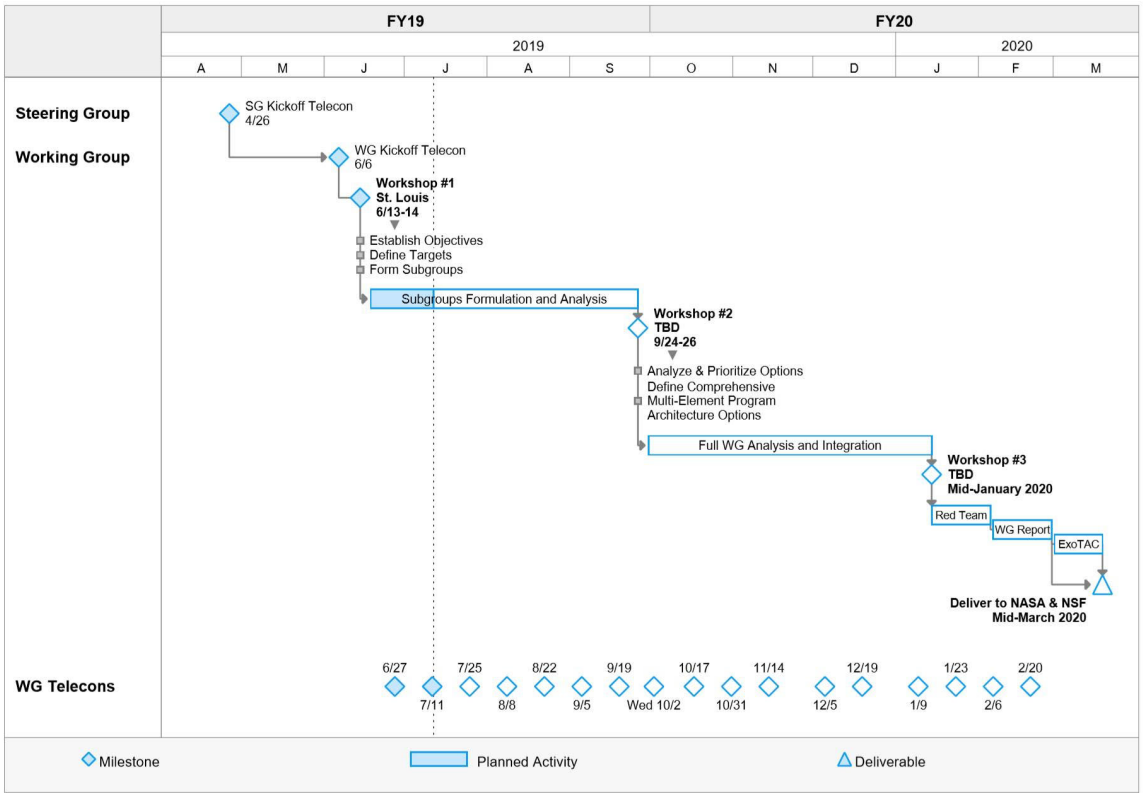
13. Reach consensus on a recommendation.
14. Present recommendation jointly to NASA/APD and NSF/AST, along with a parallel independent assessment performed by the Exoplanet Technical Assessment Committee.

The EPRV Working Group is expected to hold approximately 2-3 face-to-face workshops of 1 to 3 days duration and regular telecons. Periodic briefings are provided by the Steering Group to the NASA/APD and NSF/AST stakeholders.

- Workshop #1 (late Spring 2019) will identify subgroup focus, define objectives, establish membership and leadership for each Analysis Group.
- Workshop #2 (Autumn 2019) will review subgroup products, organize the top priorities, and formulate and rank Roadmaps.
- Workshop #3 (January 2020, if necessary) will confirm the evaluation of Roadmaps and reach consensus on recommendations, as needed.

Between workshops the Analysis Groups formulate plans (via teleconferences and e-mail) to make advances in each category.

D. Schedule



E. Membership

Steering Group

Scott	Gaudi	Co-chair	The Ohio State University
Gary	Blackwood	Co-chair	NASA ExEP / Jet Propulsion Laboratory
Andrew	Howard		Caltech
David	Latham		Harvard-Smithsonian Center for Astrophysics
Debra	Fischer		Yale University
Eric	Ford		Pennsylvania State University
Heather	Cegla		University of Geneva
Peter	Plavchan		George Mason University
Andreas	Quirrenbach		Landessternwarte; University of Heidelberg
Jennifer	Burt		Massachusetts Institute of Technology
Eric	Mamajek	Ex officio	NASA ExEP / Jet Propulsion Laboratory
Chas	Beichman	Ex officio	NASA Exoplanet Science Institute / Caltech

Members

Chad	Bender	U. Arizona
Jonathan	Crass	Notre Dame U.
Scott	Diddams	NIST
Xavier	Dumusque	Université de Genève
Jason	Eastman	Harvard CfA
BJ	Fulton	NASA Exoplanet Science Institute / Caltech
Sam	Halverson	MIT
Raphaelle	Haywood	Harvard CfA
Fred	Hearty	Pennsylvania State University
Stephanie	Leifer	NASA/JPL
Johannes	Loehner-Boettcher	UCAR
Annelies	Mortier	Kavli Institute for Cosmology
Ansgar	Reiners	University of Göttingen
Paul	Robertson	UC Irvine
Arpita	Roy	Caltech
Christian	Schwab	Macquarie University
Andreas	Seifahrt	University of Chicago
Andrew	Szentgyorgyi	Harvard-Smithsonian CfA

Ryan	Terrien		Carleton
Johanna	Teske		Carnegie Observatories/DTM
Samantha	Thompson		University of Cambridge
Gautam	Vasisht		NASA/JPL

Participants

Suzanne	Aigrain		Oxford University
Megan	Bedell		Flatiron Institute
Rebecca	Bernstein		Carnegie Observatories
Ryan	Blackman		Yale University
Cullen	Blake		University of Pennsylvania
Lars	Buchhave		Technical University of Denmark
John	Callas	Ex officio	NASA ExEP / Jet Propulsion Laboratory
David	Ciardi	Ex officio	NASA Exoplanet Science Institute / Caltech
William	Chaplain		University of Birmingham
Jessi	Cisewski-Kehe		Yale University
Andrew	Collier-Cameron		Saint Andrews
Matthew	Cornachione		University of Utah
Nadege	Meunier		University of Grenoble
Joe	Ninan		Pennsylvania State University
John	O'Meara		W. M. Keck Observatory
Joel	Ong		Yale University
Sharon	Wang		Carnegie Institution for Science
Sven	Wedemeyer-Boehm		University of Oslo
Lily	Zhao		Yale University

ExoTAC (Exoplanet Technical Assessment Committee)

Alan	Boss	Chair	Carnegie Institution for Science
Rebecca	Oppenheimer		American Museum of Natural History
Joe	Pitman		Heliospace Corporation
Lisa	Poyneer		Lawrence Livermore Laboratory
Stephen	Ridgeway		National Optical Astronomy Observatory