Assessment of NASA's Nexus for Exoplanet System Science Initiative

Public Report

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1. Executive Summary

This Assessment Team was convened by NASA to gather lessons learned from the first six years of operation of the Research Coordination Network (RCN) Nexus for Exoplanet System Science (NExSS). The stated goals of the assessment were to identify lessons learned that could be applied to other NASA RCNs to enhance their productivity and to evaluate whether the NExSS concept itself is appropriate to continue as an RCN.

Research Coordination Networks are virtual collaboration structures that help support groups of investigators to communicate and coordinate their research across disciplinary, organizational, divisional, and geographic boundaries. As such, NASA's Nexus for Exoplanet System Science RCN was established in 2015 to foster interdisciplinary collaboration in the study of exoplanets and their habitability. It was designed to help organize participating research teams from both academic institutions and NASA centers and to acquire new knowledge about exoplanets and exoplanetary systems on the conviction that these research areas needed scientists collaborating from a range of disciplines to address the basic questions in this fast-growing field.

NExSS goals include an investigation of how different, or how similar, exoplanets are from each other; an assessment of what components are present on particular exoplanets and especially in their atmospheres; learning how the stars and neighboring exoplanets interact to support (or not support) the potential for life; gaining a better understanding of how the initial formation of planets affects habitability, and investigating what role climate plays in creating a habitable (or not) planet. All of these goals feed into identifying what scientists might look for in terms of signatures of life on exoplanets.

The Assessment Team convened 13 virtual meetings, developed, distributed, and evaluated responses to a variety of short surveys of NExSS participants and leaders, and discussed our findings. All virtual meetings were attended by one or both NASA representatives, Lindsay Hays (for the Planetary Science Division) and Eric Mamajek (for the Astrophysics Division), who both served as guides to the structure and mission of NExSS and provided input on the direction and findings of this report.

The Assessment Team found that NExSS has been broadly successful in achieving many of its goals and has contributed positively to the advancement of the field. Specifically NExSS succeeded in fostering new connections resulting in new science investigations and is particularly valuable for early career scientists. True to its charter to inform NASA space observatory observations, NExSS sparked important JWST ERS and Cycle 1 programs. The Assessment Team also identified areas in which NExSS might be improved in the future. The stated goals and actual operational processes of NExSS are somewhat complex and are difficult to convey crisply. The Assessment Team itself had to frequently return to questions of management and organization to seek clarification. Likewise the selection process and roles for various levels of leadership are not always fully transparent. Currently the representation of investigators from various NASA Divisions is not uniform with Astrophysics and Heliophysics being particularly over- and under-represented, respectively. Greater attention to recruitment and streamlining the process of joining the network could improve program diversity. Finally, the Assessment Team found that the all-volunteer model for NExSS leadership and the overall lack of support for process (e.g., handling email lists) has not scaled well with the growth of NExSS.

2. Assessment Schedule and Process

The NASA Nexus for Exoplanet Systems Science (NExSS) was initiated in 2015, and at the request of NASA, an assessment of the program was undertaken by members of the scientific community. The intent of the review was: 1) to gather lessons learned from the first six years of operation of NExSS to enhance the productivity of all Astrobiology program research coordination networks (RCNs) and 2) to evaluate whether this topic is appropriate to continue as a focus for an RCN. Ultimately the Team did not consider this latter question. Members of the Assessment Team were recruited from a broad range of expertise and institutions, selected by the Assessment co-leads, and confirmed by the NASA program leads. Team members met virtually to review progress reports submitted by the NExSS co-leads and to also meet with NExSS stakeholders. Leads of the NExSS teams were interviewed by the members of the Assessment Team to assess successes and challenges of building bridges across NASA's Science Mission Directorate (SMD), the other networking groups, and the community as a whole. Survey questions were sent out to the broader NExSS community and reviewed by the committee. Early career participants in NExSS and alumni members of NExSS teams were also interviewed by the Assessment Team to assess success and challenges, especially for early career investigators.

The Assessment Team met virtually between January and April 2023 to conduct interviews and to discuss interviews and survey results. The schedule is listed below.

Meeting Day 1: Introductions and briefing from NASA officials
Meeting Day 2: Discuss the progress reports from the NExSS Leads
Meeting Day 3: Finalize survey questions to collect information from NExSS stakeholders
Meeting Day 4: Discuss preliminary survey results and formulate interview questions
Meeting Day 5: Review final survey results and finalize interview questions
Meeting Day 6: Interview current NExSS co-leads
Meeting Day 7: Interview early career scientists in NExSS
Meeting Day 8: Discussion of interviews from Days 6 & 7
Meeting Day 9: Interview former members of NExSS

The next stage of work (Meeting Days 10-13) consisted of continued discussions and writing the report, the latter of which occurred both synchronously and asynchronously. Co-Chairs Nicolle Zellner and Mark Marley briefed NASA leadership on the findings, and the report was delivered on May 16, 2023.

3. Background on the NExSS Program

In the past decade, the field of exoplanet astrobiology advanced from statistical predictions on the prevalence of terrestrial planets to studies of M dwarf planetary targets accessible to observation with the James Webb Space Telescope (JWST) and the extremely large telescopes (ELTs). In the longer term, the Astro2020 Decadal Survey (NASEM, 2021) gave top priority to the Habitable Worlds Observatory (HabWorlds or HWO), a large high-contrast direct-imaging space telescope, capable of imaging and acquiring spectra of nearby terrestrial exoplanets in their stars' habitable zones. This prioritization was "inspired by the vision of searching for signatures of life on planets outside of our solar system" (NASEM, 2021), and HabWorlds will be the first NASA facility specifically designed to search for life on exoplanets. Question 12 of the Origins, Worlds and Life Planetary Science Decadal (NASEM, 2022) emphasized the

synergies between studying Solar System planets and those in other planetary systems and the insights to be gained from studying Earth environments and terrestrial life.

NASA recognized that to plan these ambitious upcoming missions, and to interpret the data returned by current and future telescopes, signposts to identify whether a given planet is habitable, and whether or not it supports life are needed. This in turn requires the study and identification of the complex interactions between biospheres and their planetary and stellar hosts. Addressing such complexity requires input from many domains of science, including planetary sciences, astronomy, chemistry, Earth sciences including atmospheric science and biogeochemistry, heliophysics, and ecology. These disciplines are often separated by the institutions within which they exist, and the funding stovepipes that support their research. At NASA, they are supported via four divisions in its Science Mission Directorate (SMD): Planetary Science Division (PSD), Astrophysics Division (APD), Heliophysics Division (HPD), and Earth Science Division (ESD). Recognizing the strategic need to advance exoplanet astrobiology science, and the tactical requirement to integrate input from across these divisions, NASA created a Research Coordination Network (RCN), the Nexus for Exoplanet Systems Science (NExSS).

3.1 Defining NExSS

NExSS is an interdisciplinary research coordination network (RCN) of scientific community members dedicated to the study of planetary habitability and the search for life on exoplanets. NExSS was founded in 2015 and addresses the complexity inherent in exoplanet characterization by leveraging research funded by the four NASA science divisions to create a community designed to accelerate discovery and characterization of potential life-bearing worlds with current and future NASA missions. NExSS aims to facilitate interdisciplinary research among the exoplanet research community to address intellectual and academic goals that also have ramifications for mission planning and execution. NExSS brings together astrophysicists, planetary scientists, Earth scientists, and heliophysicists to create a "systems science" approach to NExSS science goals.

NExSS research addresses fundamental questions related to planet formation, planetary evolution, habitability and signs of life. This research is inherently interdisciplinary. The goal was for NExSS members to work together to understand planets in context throughout their formation and coevolution with their parent star and planetary system; investigate the diversity of exoplanet characteristics and learn how their properties and evolution can create the conditions for life; understand how to identify the best exoplanet targets for life searches; and learn how to recognize, and search for, signs of habitability and life on exoplanets.

3.2 NExSS Membership and Leadership

NExSS membership is open to any scientist working in NExSS science areas. NExSS currently numbers 410 members and 66 teams at 114 institutions in 15 countries, with 90% US membership and 10% international. Scientists are invited to join the Steering Council for NExSS once they have been awarded a grant for a relevant project proposed to NASA's research and analysis (R&A) programs in the Interdisciplinary Consortia for Astrobiology Research (ICAR; PSD), Exobiology (PSD), Habitable Worlds (PSD), Exoplanets Research Program (XRP; APD, PSD, HPD, ESD), Astrophysics Theory (APT; APD), Astrophysics Data Analysis Program (APD), and Living With a Star (HPD) programs. If a scientist is not already a NExSS member via proposal selection in a participating NASA program and they are working in a relevant area, they can apply for NExSS Affiliate membership via a short application. Both of the 2018 National Academy of Science reports on Astrobiology (NASEM, 2019) and Exoplanets (NASEM, 2018)

supported NExSS-like collaborations and activities, and as a result, more ROSES funding solicitations (e.g., Habitable Worlds, XRP) are cross-divisional.

NExSS members receive no additional funding beyond that obtained in their parent R&A proposal(s) and are kept up to date on collaboration and professional opportunities through email announcements, Slack space discussions, publication bulletins, and a regular Newsletter. NExSS members also support a Science Communications Working Group (SCWG), with Newsletter, Social Media, Website (nexss.info), and Science Nugget teams working to inform the community.

NExSS is organized as shown in Figure 1. Co-leads selected by NASA leadership are responsible for overall organization and direction of NExSS. The PIs of NExSS-relevant proposals make up the NExSS Steering Council which advises the Co-Leads. PIs and their team members are responsible for proposing and organizing NExSS-led activities to benefit the community's science. These may be solely NExSS led or cross-organized in partnership with other community organizations such as the other Interdisciplinary Consortia for Astrobiology Research (ICAR), RCNs, and the Program Analysis Groups (PAGs). These activities are usually financially supported by separate proposals to the NASA Topical Workshops, Symposia, and Conferences (TWSC) program. Although organized by NExSS, participation in NExSS activities is open to the broader science community, and NExSS team membership is not required to join NExSS science working groups, or participate in workshops, conferences and other community activities. NExSS leadership reports that there have been over 400 papers published with NExSS acknowledgement and over 10,000 citations to NExSS papers in the literature. These data are available at the NExSS Publications Statistics folder.

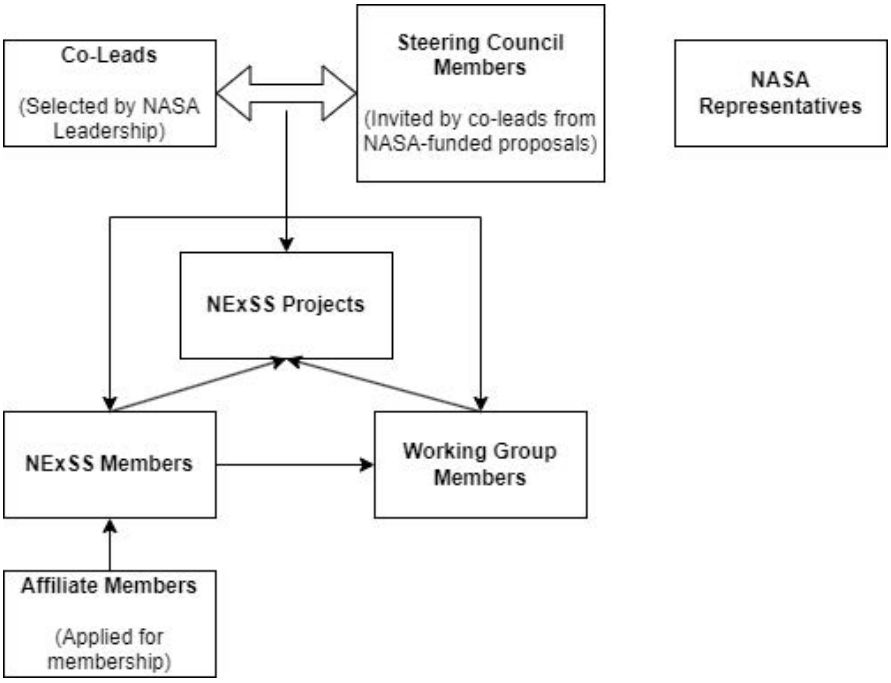

Figure 1: NExSS organizational structure.

3.3 NExSS Objectives and Goals

NExSS is guided by four strategic objectives and six goals.

3.3.1 Strategic Objectives

- To establish common goals for exoplanet research across divisions in SMD
- To further the strategic objective to explore exoplanets as potentially habitable and inhabited worlds outside our solar system
- To leverage existing programs in SMD to advance the field of exoplanet research, specifically research in comparative planetology, biosignature and habitat detection, and planet characterization
- To establish a mechanism to break down the barriers between divisions, disciplines and stovepiped research activities

3.3.2 NExSS Goals and Metrics

NExSS investigators will

- Carry out and propose interdisciplinary research through new collaborations
- Develop programs for using existing space telescopes/NASA facilities to advance NASA science objectives.
- Make important contributions to science cases for future flight missions
- Identify new targeted technologies needed but not reported elsewhere
- Provide and increases cross-divisional inputs to decadal review efforts for PSD and APD
- Enhance US leadership of international cross-disciplinary exoplanet researchers

4. Findings

The Findings in this Section represent the consensus of the Assessment Team based on discussions and evaluations of the available materials. These materials included the NExSS report, interviews, and survey responses from NExSS leadership and participants.

4.1 Meeting goals outlined at the creation of NExSS

4.1.1. Investigators carry out and propose interdisciplinary research through new collaborations

NExSS decides what activities to pursue through a combination of generating ideas through grassroots efforts and strategic choices made by the NExSS Steering Council. These interactions have included topical conferences and workshops, and collaborations identified through the NExSS Science Working Groups. The NExSS Leads provided examples of activities that resulted in scientific collaborations and led to scientific products and/or the development of additional activities.

The NExSS leadership team reported that these activities are often conceived in NExSS meetings and science working groups, and they would not have occurred without the NExSS framework to bring together and support interested community leaders and participants. Perhaps the best example provided of this is that the NExSS-organized HabWorlds workshop catalyzed the creation of the CUISINES planetary model intercomparison group, which eventually developed into the CUISINES NExSS Science Working Group, and organized a series of NExSS workshops, including the THAI workshop on TRAPPIST-1 3D general circulation model (GCM) intercomparisons. That workshop resulted in improvements in the models that were compared, and at least three publications from scientists who previously did not work together.

Beyond this one flagship example, however, the Assessment Team found it difficult to rigorously judge the extent to which various collaborations would not have arisen organically, in the absence of NExSS.

> **Finding:** NExSS has demonstrably catalyzed interdisciplinary, community interactions in ways that have benefited the community.

4.1.2. Develop programs for using existing space telescopes/NASA facilities to advance NASA science objectives.

NExSS led two major community activities to develop exoplanet observing programs for JWST. The first of these was the development of the JWST Transiting Exoplanet Community Early Release Science (ERS) Team, starting in 2016, led by then NExSS Co-Lead Natalie Batalha and involving 81 team members (46 from the US and 35 from ESA/Canada). This activity was initially proposed and developed in 2016 in a NExSS Steering Committee in-person meeting and was followed up with discussions boards, weekly telecons, a Slack channel and joint proposal development. This NExSS-led ERS team was ultimately highly successful, receiving 23% of all the allotted JWST ERS time. This activity has resulted in multiple scientific papers so far.

The second NExSS-led community activity was the JWST TRAPPIST-1 Community Initiative which started in 2019 and is co-led by NExSS Co-Lead Victoria Meadows and Michaël Gillion from the University of Liege. This collaboration grew to include 173 international community members with participation split almost evenly between the US and Europe. The collaboration enabled those proposing to observe the TRAPPIST-1 system of planets to obtain ephemerides, compare notes, coordinate proposals, request additional collaborators, and share information on observing best practices and stellar subtraction. The collaboration has held two in-person meetings, and several virtual ones, as well as providing a Slack space. In Cycle-1 the Initiative submitted 10 coordinated proposals to characterize the evolution, and potential habitability and biosignatures, and garnering data on several of the TRAPPIST-1 planets. These datasets are now being reduced by multiple teams, who are cross comparing results, and that data is being analyzed by multiple groups of modelers, who are also comparing and refining results. For Cycle-2, the initiative again submitted about 10 proposals on the TRAPPIST-1 system spanning small, medium, and Treasury size.

> **Finding:** NExSS co-Leads initiated two major JWST observing collaborations that rapidly grew to include both NExSS and broader community members. The success of catalyzing broad involvement means the final product may be `NExSS initiated', rather than 'NExSS created', but the programmatic goal was fulfilled in either case.

4.1.3 Makes important contributions to science cases for future flight missions

The NExSS leadership provided several examples of NExSS contributions in this area. As one specific example provided by NExSS leadership, Figure 1-1 of the Astrophysics Decadal Survey was heavily informed by NExSS research and a NExSS workshop. The figure showed how the Large Ultraviolet Optical Infrared Surveyor (LUVOIR) space telescope and the Habitable Exoplanet (HabeX) observatory concepts would obtain spectra that could identify signs of life throughout Earth's history, including the dramatically different biospheres that existed prior to the rise of detectable levels of oxygen (O_2) in the planet's atmosphere, and was thus included in the final reports from both teams. The influence of NExSS was also present in the report from the Lynx X-ray Observatory team and the Origins Space Telescope team, the latter of which incorporated biosignatures into its science case. The approach to this included

biosignature gasses and search strategies from the NExSS-led workshop on exoplanet biosignatures. All four teams — HabEx, LUVOIR, Lynx, and Origins — discussed the important role of the host star on the habitability of exoplanets, one of NExSS's major cross-cutting themes and the result of direct participation of NExSS team members in these missions, as Science and Technology (STDT) members, in the study offices of the missions, and as red team reviewers for the concept final reports.

> **Finding:** NExSS research and NExSS activities contributed to all four mission concept studies considered for the Astro2020 Decadal.

4.1.4 Identifies new targeted technologies needed but not reported elsewhere

NExSS leadership ultimately determined that this metric is not well suited to NExSS. This is because the "feeder programs" for NExSS do not include the technology development programs such as APD's Strategic Astrophysics Technology (SAT) program. As such, the NExSS community does not have the expertise for research on new technologies or identification of new technologies. Team leads reported that in their estimation, the role of NExSS is better suited to be "upstream" of this, in the identification of science drivers, including science cases and science measurement requirements, that require or would be enhanced by new technologies. A specific example of this is ultraviolet (UV) starlight suppression, which has a low technology readiness level (TRL). However, NExSS research has repeatedly demonstrated the utility of the UV to the interpretation of exoplanet biosignatures and is the science driver for further technology development for either UV coronagraphy or a UV-capable starshade for the Habitable Worlds Observatory.

NExSS has, however, had an influence on laboratory work beyond that done by its team members. NExSS created a "Laboratory Astrophysics Gap List" (Fortney et al., 2016), which identified necessary studies to enhance our ability to model exoplanets and to interpret their spectra. This list provided motivation for specific lab-based measurements in support of future observational and theoretical work.

> **Finding:** The Assessment Team concurred with the NExSS co-Leads that a focus on technology needs is not well suited to the program. Instead identifying science needs and gaps that can feed to the appropriate technologist communities is a good use of the NExSS framework.

4.1.5 Provides and increases cross-divisional inputs to decadal review efforts for PSD and APD

Multiple NExSS community members were involved in the decadal survey process, including writing and coordinating the submission of white papers emphasizing cross-cutting science themes, chairing sub-panels, and presenting mission concepts to the sub-panels.

> **Finding:** NExSS has provided, and increased, input to the decadal survey process.

4.1.6 Enhances US leadership of international cross-disciplinary exoplanet researchers

As stated in Section 3.2, NExSS currently numbers 410 members and 66 teams at 114 institutions in 15 countries, with 89.8% US membership and 10.2% international. This has allowed a pool of investigators around the world to support and enhance telescope observations (4.1.2), specifically via the JWST ERS Team (81 team members: 46 from the US and 35 from ESA/Canada) and the JWST TRAPPIST-1 Community Initiative (173 international community members with participation split almost evenly between the US and Europe), both led or co-lead by US investigators

Finding: NExSS has enhanced US leadership opportunities.

4.2 Effectively bringing together research communities

One of the main goals of NExSS was to establish interdisciplinary collaborations and interdisciplinary projects that would bring together scientists from different disciplines and divisions within NASA to study exoplanets. While these kinds of interactions have occurred (e.g., 4.4.1, 4.1.6), the Assessment Team found that the current demographic of funding programs and the lack of interdisciplinarity as an evaluation criterion for submitted proposals means that little is done by NASA to enable interdisciplinary projects. As a result, based on survey and interview responses, it appears that many of the NExSS-affiliated funded projects are mostly Astrophysics projects done by Astrophysicists. We note that a survey of the community is not fully reflective of the members of the community. However, based on responses to the surveys and interviews, the perception of the Assessment Team is that NExSS is dominated by astrophysics research. This may now be alleviated by the new checkboxes on proposals about which RCN a proposer is interested in joining and could be enhanced by expanding to programs like Solar System Workings (SSW) and Living With a Star (LWS).

Finding: The overall majority of the NExSS participants and leadership are associated with the Astrophysics division; only a small fraction of the funded projects/participants are associated with other divisions.

4.3 Concrete examples of NExSS enabling or enhancing progress that was unexpected

NExSS leadership reported that many new collaborations including junior researchers were formed through NExSS. NExSS also provided many opportunities for career building and community networking. In particular, the Professional Advancement Workshops Series (PAWS) supports career development through a range of opportunities including, but not limited to, careers in research. This and other early-career engagement efforts clearly supported the career development of early career scientists and future space science managers. However, it is important to recognize that the early-career members themselves were the organizers for many of these opportunities, and the effort required to have these opportunities involved substantial volunteer work hours. Leadership reported that this is mitigated in part by support from the NExSS NASA Postdoctoral Management Program (NPMP) co-lead position.

Finding: There is high value for early career researchers involved in the NExSS program significantly enhanced by leveraging NPMP opportunities.

NExSS leadership reported that researchers engaged in modeling planetary processes who would potentially be competing against each other were instead enabled to collaborate and improve their work through sharing information and expertise with the CUISINES collaboration being the flagship example.

Finding: NExSS has facilitated a level of engagement within the modeling community that provides a role model for the entire space science community.

4.4 The diversity of topics covered by the RCN

As noted in Section 4.2, the funded proposals that are associated with NExSS are dominated by topics covered through the Astrophysics Division with limited participation and contributions from investigators funded by NASA's other three divisions. This issue has been partially addressed by allowing Affiliate membership in NExSS. For example, members conducting research at the boundaries of Heliophysics and Planetary Science are allowed to join NEXSS and make meaningful contributions as Affiliates. However, this approach is limiting.

Finding: Because the diversity of projects is dependent on what is supported by NASA and connected to the RCNs, NASA could improve the diversity of topics covered by NExSS through greater coordination between the science divisions. For example, selecting cross-disciplinary projects for the relevant programs would ensure that the PIs of cross-disciplinary projects are connected with the relevant RCNs.

4.5 Membership structure and how it serves NExSS overall

The application process for NExSS membership states that any PI of a selected NASA proposal under a well-defined program may join the NExSS Steering Committee. Others may join NExSS as Affiliate Members. The assessment found that while the process is well-defined, it is not well-followed and enforced. The inclusion of new PIs in NExSS depends on NASA Program Officers notifying the NExSS co-Leads of selections where the PI indicated an interest in this RCN, and according to the website, the NExSS Leads have the responsibility to reach out to funded PIs to invite them to join NExSS.

There are potential gaps in this process, however. For example, there are several new XRP selections that would be highly relevant to NExSS, but these teams are not included in NExSS at this time. Discussions with PIs suggest that they indicated an interest in NExSS but have not yet been contacted. It is not clear from the information available whether the system within NSPIRES failed to identify these programs as relevant, or if the communication process between the Program Officers and NExSS leadership needs to be more formalized to ensure that no interested participants miss out on the opportunity for participation. Although a system is in place for proposal PIs to check boxes indicating interest in NExSS, the Assessment Team identified concerns that this mechanism doesn't work in practice.

4.6 Assessing whether or not the NExSS RCN activities represent the community in terms of DEIA, as defined by NASA

From the survey responses gathered by the Assessment Team, the NExSS Leads reported that NExSS does not have any support to track diversity across its entire membership. However, all NExSS events and groups considered diversity, equity, inclusion, and accessibility (DEIA) goals in defining their programs and, in case of limited participation, the list of participants. Diversity in gender, career stage, position type, type of home institution, geography are among the factors that are reportedly considered to ensure diversity, especially in roles that provide visibility or opportunities. Additionally, activities have included intentional actions to create an inclusive, equitable, and accessible environment for participants. Examples of this include ensuring people agree to the Rules for NExSS Participation (last updated in 2020), reminding people of that agreement at meetings, and enforcing the agreement in the course of meetings.

4.7 Leadership structure and how it serves NExSS overall

As described on the NExSS website and seen in Figure 1, the organizational structure of NASA consists of NASA HQ representatives, four co-leads, and a Steering Committee composed of the PIs of selected teams. NASA HQ selects civil-servants from PIs at Goddard and the Jet Propulsion Laboratory (JPL) and university co-Leads from amongst the ICAR PIs. Once PIs have joined, they in turn can nominate members of their teams to become members of NExSS. Non-funded scientists with broadly relevant research interests can apply via a webform to become an Affiliate Member of NExSS. In addition to the formal definitions of each classification, several other groupings are mentioned in various documents including "leadership team," "management team," and "working groups."

Through interviews and surveys, the Assessment Team learned that there is substantial dedication of leadership that has brought NExSS to its existing state. As described in Section 3.2, there are also Working Groups, with varying degrees of success, depending on both the leadership of the Working Group and the support of the Steering Committee (see Appendix).

Finding: A leadership selection process focused on required skills for co-Leads and open to all Steering Committee members may broaden the potential Leadership pool. Involving the Steering Committee in Leadership selection may bring a more diverse perspective to Leadership selection, appropriate for a bottom-up network.

Finding: The NExSS website is not totally transparent in how various leadership positions are filled including how co-Leads and Steering Committee members are selected. The website also lacks a description of the roles and duties of the various positions within NExSS. Such lack of transparency may lead to a barrier for others not familiar with NExSS to make the effort to join and could limit participation.

Co-leads reported that their service as a co-Lead requires on average 0.10-0.25 FTE for a combination of administrative tasks and meeting organization. Support for this time is not explicitly provided by NEXSS and must either come from the co-Lead's employer through overhead or be taken out of the grant relevant to NExSS.

Finding: This lack of financial and logistical support to the co-Leads is a risk to achieving the goals of NExSS as well as to the successful completion of the co-Leads' NASA funded research projects.

4.8 The structure and progress of the program

The scope and reach of NExSS is quite broad. NExSS management includes managing email lists and regular announcements, as well as keeping track of demographics and coordinating with NASA Program Officers regarding new, relevant funded PIs who may wish to join NExSS. These activities are extensive and may not be an effective use of time and/or resources. As a result, program leaders have less time to focus on organizing relevant workshops and networking events, which are the drivers for the success of the program. A formal all-NExSS meeting has occurred only once, and more similar meetings would be beneficial for the program.

Finding: Prioritization of NExSS activities, either by the Leads or a community survey, would identify those which are most high-priority and productive to continue.

Additionally, interviews with members of the community demonstrate a mixed understanding of the goals and role of NExSS. An evaluation of the messaging and branding of the program's scope would be useful to determine how best to reach the broadest audience, particularly beyond Astrophysics. Clear and consistent description of the program's scope would be effective for coordinating and supporting cross-disciplinary projects.

Finding: A more clearly defined mission and structure for NExSS with guidance on how to participate should be presented when communicating with the broader community.

4.9 The context and future of the program

NExSS science and activities are aligned with the priorities and recommendations of the Astro2020 Decadal's Pathways to Habitable Exoplanets (NASEM, 2021), and the NExSS exoplanet/Solar System synergy activities have potential to support similar interdisciplinary objectives called out in the Planetary Science Decadal (NASEM, 2022). Exoplanet science is now transitioning from physical and chemical characterization of gas giant exoplanets to terrestrial worlds that may support secondary atmospheres and oceans.

This transition is well aligned with the community connections enabled by NExSS. Several upcoming missions could benefit from NExSS community input, including HWO, the Uranus Orbiter and Probe, and potentially directed missions identified by the Heliophysics Decadal Survey as a top priority.

> **Finding:** NExSS is in an important position to organize the broader SMD community input for future strategic missions.

As noted in Section 4.2, cross-division participation on the Steering Committee has been limited, as most topics covered by PIs appear to be more relevant to the Astrophysics Division than the other three divisions. Any activities that sprout — whether cultivated by leadership or not — would expand the impact of NExSS in other ways. These could include community efforts to further characterization of JWST stellar and exoplanet data to enhance science return from all subsequent proposals; integration of planetary systems science models and theory to develop science measurement targets and requirements for upcoming exoplanet characterization missions; and a concerted effort to continue to develop and advance cross-RCN activities that can bring an even broader interdisciplinary community to bear on NExSS goals. In doing so, the full potential of the network of networks that is the RCN structure can be harnessed.

As stated in the discussion and Findings above, NExSS is well placed to continue to contribute to interdisciplinary exoplanet science surrounding planetary habitability. This would particularly be true if the interdisciplinarity and leadership support structure were strengthened. As per guidance of the NASA representatives, however, the Team neither discussed nor issued a specific finding on the future of NExSS.

5. Conclusion

The Assessment Team found that the NExSS program is guided by a group of highly dedicated leaders who have seen it grow substantially in size from the original nucleus of participants. NExSS has succeeded in nurturing interdisciplinary research related to planetary habitability and can point to multiple high-profile successes that exemplify the utility of the structure. Junior researchers have found the structure helpful for making connections and joining this research community.

To help NExSS fulfill its potential, the Assessment Team offered a variety of findings particularly focused on improving the scientific diversity of participants, the diversity of leadership opportunities, and the efficiency of the program administration. If these topics are seriously addressed, the Assessment Team expects that NExSS has the potential to continue into the future as an effective and productive RCN.

As a secondary product of the Assessment, the Team offers some "lessons learned" that might help improve other NASA facilitated RCNs. RCNs should have a crisp mission statement and a concise "elevator pitch" to convey their goals and motivation. The process for joining the RCN should be transparent, easy, and administratively effective. Leadership should be recruited broadly and transparently. The structure to support intra-RCN collaborations should be simple with a minimum of special internal committees. Finally, there should be funding to provide for administrative support to lessen the substantial burden on RCN leadership, particularly if the network is successful and grows large.

6. Reference List

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7. Appendix

Statement of Task

Assessment of NASA's Nexus for Exoplanet System Science Initiative

(v15, as of 1/9/2023)

A Research Coordination Network (RCN) is a virtual collaboration structure that helps support groups of investigators to communicate and coordinate their research across disciplinary, organizational, divisional, and geographic boundaries. NASA's Nexus for Exoplanet System Science (NExSS) RCN was designed to foster interdisciplinary collaboration in the study of exoplanets and their habitability. Specifically, it was established to help organize participating research teams from both academic institutions and NASA centers, to acquire new knowledge about exoplanets and exoplanetary systems on the conviction that these research areas needed scientists collaborating from a range of disciplines to address the basic questions in this fast-growing field.

The intent of this review is to gather lessons learned from the first six years of operation of NExSS to enhance the productivity of all Astrobiology program RCNs and to evaluate whether this topic is appropriate to continue centering an RCN around.

The key goals of NExSS include an investigation of how different, or how similar, exoplanets are from each other; an assessment of what components are present on particular exoplanets and especially in their atmospheres (if they have one); learning how the stars and neighboring exoplanets interact to support (or not support) the potential for life; gaining a better understanding of how the initial formation of planets affects habitability, and investigating what role climate plays in creating a habitable (or not) planet. All of these goals feed into the ultimate question: what might scientists look for in terms of signatures of life on distant planets?

The review will use readily available data, in addition to discussions with past and present NExSS team members, in order to assess the overall success of this specific RCN with regards to the progress on its stated goals, along with the challenges the NExSS RCN has faced. Additionally, this review of NExSS may assist NASA in increasing the effectiveness of not only this Research Coordination Network (RCN), but other RCNs as well. This review will focus on three areas:

1. The diversity of topics covered by the RCN:
    a. the topics that NExSS is focusing on to continue expanding the field in this area
2. The structure and progress of the program:
    a. deliverables and innovations that NExSS has directly enabled;
    b. lessons learned about how to excel going forward, and that can be applied to help other RCNs
3. The context and future of the program:

a. based on lessons learned, what the future of NExSS could look like;
b. whether there is still more progress to be made in this area, and the rationale for either continuing NExSS with its current focus or shifting focus going forward

Specific questions to be addressed in the panel report should include (with sub-questions presented as examples):

- How much progress has NExSS made towards the goals and metrics of success outlined at its creation?
    - What has NExSS done to leverage existing Programs in SMD to advance the field of exoplanet research?
    - Has NExSS effectively brought together research communities?
    - Are there concrete examples of NExSS enabling or enhancing progress that was unexpected?
- What have been the most successful strategies that NExSS has employed in making the progress that has been achieved?
    - What role has NExSS played in supporting future NASA goals? How has NExSS supported the most recent (and upcoming) decadal surveys?
    - What support has NASA provided that helped NExSS to achieve its goals?
- What have been the challenges that NExSS has encountered?
    - What has NExSS done to break down the barriers between people, divisions, disciplines, and stove-piped research activities?
    - How well has NASA supported NExSS?
- What are some examples of the role NExSS could play moving forward over the next 5 years?
    - What goals and metrics of success could be set?
    - What are some specific examples of future planned activities that could benefit from support beyond the ways that NASA has already provided support?
    - What are the best practices that have been developed in NExSS that could be shared with other RCNs?

The structure of the review will be as follows:

- Co-leads from NASA's Planetary Science Division and Astrophysics Division are appointed, to be aided by PSD and APD division representatives who are either civil servants or IPAs.
- Panelists (8, with two from each division/community, plus at least one Executive Secretary) will be recruited from the community, selected by the Assessment co-leads, and confirmed by the NASA program leads.
- Panelists will meet virtually and spend the first 8 meeting hours reviewing the progress reports submitted by the NExSS co-leads, augmented with additional meetings with NExSS stakeholders, including past and current team members; the second 8 meeting hours will be spent working on the review summary. Honoraria will be up to $350 per 8 hour day. Panel meetings are expected to start the week of January 23, 2023 and end before May 1, 2023.

    - Leads of the NExSS teams will be interviewed by the review panel to assess successes and challenges of building bridges across SMD, the other networking groups, and the community as a whole.
    - Alumni members of NExSS teams will be interviewed by the review panel to assess success and challenges, especially for early career investigators.
    - Available data will be used to assess whether or not the NExSS RCN activities represent the community in terms of DEIA, as defined by NASA.
- Panelists will meet to write the findings and suggest recommendations in a report targeted for 5-10 pages.
    - The report will be authored by the Assessment co-leads.
- Assessment co-leads will present the recommendations to NASA HQ and the NExSS co-leads no later than April 27, 2023, with a limited presentation to the broader scientific community at the regularly scheduled spring PAC and APAC meetings (no later than April 28, 2023).