RMS questions of interest — ngVLA — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 The project office's 1/3/2020 response to the RMS panel's question about construction phasing presents a scenario in which $\sim 33\%$ of the collecting area (and cost) would be deferred to construction years 11–15. In this scenario, additional observing time could be used to achieve full-ngVLA sensitivities starting in 2034. What is the basis for the estimate of "77% additional observing time to compensate" in this scenario, which is less than a naive factor of $(2/3)^{-2}$? What portion of the science case would *not* be recoverable as of 2034 even with extra observing time, considering both the KSGs and the broader range of ngVLA science (e.g., as envisioned by relevant Astro2020 white papers and/or the ngVLA Science Book)?

Q2 What would be the key differences in capability between ngVLA and SKA1-mid, and in what respects would the two instruments be complementary?

Q3 If ngVLA were not equipped with band 6 (70–116 GHz) receivers, to what extent would the ngVLA KSGs *not* be recoverable either by ALMA, or by ngVLA at lower frequencies?

Q4 Does the planned collecting area of the SBA relative to that of the rest of ngVLA reflect the fact that not all ngVLA projects would require short-baseline observations? If not, does the undersubscription of the ALMA Compact Array (ACA) relative to the ALMA 12 m array represent an informative precedent? What possible paths are envisioned for ngVLA projects that would need *zero-spacing* observations to obtain them?

Q5 How robust are the models for the abundance of (millisecond) pulsars in the vicinity of the Galactic Center that suggest a likely outcome for KSG4?

Q6 How would the formal SETI agreement to support commensal science fit within the "Open Skies" framework for managing proprietary data?

Q7 For KSG5, why is 200 Mpc the right horizon distance to use for next-generation gravitational wave facilities on the timescale of ngVLA? Would event rates at that distance be sufficient to answer the questions raised? How reliable are the predictions that all sources would be detectable at that distance, given uncertainties in geometry and ISM density?

Technical/Risk/Cost/Schedule/Management:

Q8* What are the current prospects for obtaining $\sim 25\%$ international partnership support for ngVLA? If there were an ngVLA/SKA agreement for reciprocal access, could SKA partners still be incentivized to contribute financially to ngVLA?

Q9* What confidence level do the project office's Monte Carlo analyses associate with NRCC's Basis of Estimate for the cost of the antennas?

Q10 The ngVLA RFI response states that "all planned observing modes and data processing and product capabilities will be delivered as part of construction." Does this commitment allow for the staged deployment of correlator modes and associated software capabilities, or would all need to be available at a specific "first light" juncture? If staged deployment is possible, how would the rollout of new capabilities be tied to early science?

Q11 How would the ngVLA design and cost be affected by the elimination of band 6 (70–116 GHz)?

Q12 If it were found necessary to reduce the bandwidth or bit-depth of data in the 2030s due to a shortfall in affordable IT capability, what overall impact would be expected on the science capabilities? When would a better understanding of the IT cost/capabilities be expected, and would an anticipated shortfall drive any modifications to the deployment plan?

Q13 Has the project office taken a critical look at the impacts of 5G RFI on the data products, assuming both conservative and worst-case scenarios, to determine if any design modifications are needed to meet the science goals?

Q14 What are the frequency range and spectral resolution of the water vapor radiometers (WVRs)? Is there a risk that their performance could be compromised by RFI from 5G networks? If it were found that the WVR phase corrections do not work 50% of the time, what would be the impact on observing efficiency?

Q15 If security concerns in Mexico made it difficult to site telescopes there, how would the loss in *uv* coverage impact the ability of ngVLA to achieve its KSGs? Are there any backup sites in the US that could help mitigate the loss of Mexican stations?

Q16 Are there any technical risk implications of the commitment to use CASA to process ngVLA data? Could the CASA data model and measurement set concept represent a bottleneck for data processing? What is the basis of the assumption of 50% reuse of existing code?

Q17 What are the contingency plans for ensuring that longer delays in data delivery due to unrealized efficiencies in parallelized imaging algorithms do not result in loss of scientific viability?

Q18 What project management tools and approaches would be used to integrate software development fully into the development, construction, and commissioning of ngVLA as a whole?

Q19 Are there plans or ambitions for pipeline processing to take direction-dependent effects into account when generating science-ready data products (SRDPs; see p15 of the Preliminary System Requirements document)? Are there plans or ambitions to include

polarization calibration as part of the standard calibration pipeline (see p52 of the Preliminary System Requirements document)?

Q20 Is the "Science Operations Center and Data Center" described on p4 and p49 of the RFI response (but not obviously present in WBS element 1.15 on p98) included in the ngVLA cost estimate?

Q21 At what point in the construction and commissioning of ngVLA would the existing VLA be expected to cease operations, considering the planned reuse of buildings at the VLA site?

Q22 Noting that atmospheric phase stability and opacity can vary substantially across the 70–116 GHz window, can the project team model what fractions of ngVLA observing time would be useable in different parts of that window for (a) baselines within the main array core, and (b) baselines extending to the main array spiral arms? (Reasonable simplifying assumptions can be made for (b), given the current lack of atmospheric measurements away from the VLA site.)

Q23 How feasible would it be to retain a sufficiently large pool of qualified workers to maintain such a large, geographically separated array of antennas?

Q24 Have other design options for the LBA sites been considered (different diameter antennas, smaller numbers of dishes, etc.)?

Q25 Would the currently proposed sites for the LBA clusters allow sufficient separation between elements to avoid shadowing problems?

RMS questions of interest — CMB-S4 — 2020.01.13

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Science:

Q1 Section 5.6 of the DSR refers to "a quasi-realtime alert system linked to the transient alert mechanisms in the wider community... [that will] require on-site computing and analysis software that runs autonomously." What data products (alerts, difference maps, etc.) would be provided by this system to the community, with what astrometric accuracy, and on what timescales relative to observations?

Q2 Section 1.3.1 of the RFI response identifies "failure to meet our LAT angular resolution requirements" as a threat to Science Goal 3 (only); would such a failure also be a threat to Science Goal 2, as suggested by the use of color in Figure 1?

Q3 Science Goal 4 refers to measurement of "many gamma-ray burst afterglow light curves"; does "many" here refer to the number of afterglows detected (estimated to be ~ 1700 in Section 1.5.1 of the DSR), or the number that can be effectively identified as afterglows?

Q4 What are the possible decision pathways for (re)deploying a subset of the SATs to Chile?

Q5 The ultra-deep low-resolution survey is described as targeting "the 3% if the sky with the lowest foreground contamination" (p14 of RFI response); is this area already known, and if not, how would it be selected? Can the project team comment on what new steps would be needed to characterize foregrounds "at much higher precision" (p47 of RFI response) than has been done by existing experiments?

Technical/Risk/Cost/Schedule/Management:

Q6* How does CMB-S4 view itself in relation to the Simons Observatory, LiteBIRD, PICO, and any other concepts for CMB projects on the ground and missions in space? Does the CMB-S4 team see these projects/missions as essential for CMB-S4, helpful for CMB-S4, and/or competitive with CMB-S4 in their scientific and/or technical aspects?

Q7* What is the Basis of Estimate for the "$10M investment in a hybrid photovoltaic / battery / diesel power plant" (p34 of RFI response) as a backup to a site-wide power solution in Chile?

Q8 Can the project team provide more information about the "in-kind contributions with a value of 10-15% of the project scope" that are "under discussion and expected" (per p4 of the RFI response)?

Q9 Does the project team's experience building and operating facilities at the South Pole suggest that sufficient logistical support of CMB-S4 activities (including transport) could become a limiting factor for the project?

Q10 Has agreement been reached on sharing of intellectual property across the detector and readout fabrication centers?

Q11 What is the project team's approach to managing a large and diverse collaboration so that its size and complexity do not become a source of risk?

Q12 Are the hardware and software capabilities necessary for generating transient science data products included at full scope within the project budget? Could bandwidth constraints on data transfer from the South Pole limit the effective use of that site's data stream for transient science?

Q13 How, if at all, would the limited rate of data transfer from and limited access to the South Pole affect the rapidity with which a redeployment of SATs to Chile could take place?

RMS questions of interest — DSA-2000 — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 What is the project team's plan for securing funds to serve data to the community, and is there a contingency plan (or partnership) being explored if that funding cannot be secured?

Q2 How unique are the planned H I and OH spectral line data products compared with those for other current and planned line surveys?

Technical/Risk/Cost/Schedule/Management:

Q3* Can the project team provide a more detailed Basis of Estimate for the costs of developing and operating the science software pipeline and archive?

Q4 What is the project team's proposed approach for staffing, developing, and validating an on-site fabrication facility for spun aluminum reflectors?

Q5 Will the dishes for the 6-antenna prototype array be spun on site, or will commercial segmented dishes be used? If the latter, how useful will tests of the prototype array be in assessing the performance of the final antennas?

Q6 Is the Owens Valley site, which appears simplest in terms of environmental impact, large enough to accommodate the proposed 15 km array? Has RFI been a problem for DSA-110 or other Owens Valley facilities (e.g., EOVSA)?

Q7 Has RFI monitoring already been done at sites other than OVRO and Deep Springs? Are such sites within 10 km of an existing power line that could handle the electrical load of DSA-2000?

Q8 Will forward modeling of the array performance include possible effects of RFI? What dynamic range is required of the receivers and fiber links so that RFI in a narrow frequency band does not subtly corrupt images in other frequency channels? Has the project team taken a critical look at the impacts of 5G RFI on the data products, assuming both conservative and worst-case scenarios, to determine if any design modifications are needed to meet the science goals?

Q9 Can the project team provide proof-of-concept evidence from existing facilities for the successful excision of RFI in real-time processing?

Q10 When are science operations with DSA-110 expected to commence? Will there be time to fold lessons from DSA-110 into the design for DSA-2000?

Q11 What are the current prospects for securing $26M (of a total $96M cost) from non-federal partners?

Q12 What assumptions about mean time between failures (MTBF) and rate of repair inform the project's maintenance plan?

Q13 What is the minimum number of antennas that must be on line simultaneously in order to enable the proposed approach of eliminating visibility-based deconvolution? (If the answer depends on whether antennas are unavailable because they are down for maintenance, or were never built due to a project descope, please specify.)

Q14 The sensitivity calculations presented in the RFI response assume 100% beam-forming efficiency. Has a more realistic efficiency been estimated that takes into account various losses (phase noise, quantization, etc.)?

Q15 Cost estimates for data storage and backup have been derived by scaling from DSA-110, but can those approaches be realistically scaled to meet expected needs? Are there new disk or tape technologies coming on line that could reduce these costs?

Q16 Can the project team describe in more detail the envisioned VLBI mode of operation? For example, how will the data stream be formatted, time stamped, and recorded for correlation with other VLBI sites? How and where will the VLBI correlation be performed?

Q17 Would eliminating the spectral line component of the survey significantly impact cost, e.g., by simplifying RFI mitigation and/or significantly decreasing the required spectral resolution (and thus the total data volume)?

RMS questions of interest (2) — DSA-2000 — 2020.01.31

This set of additional questions is focused exclusively on technical, risk, cost, schedule, and/or management issues. In its responses, the team is welcome to refer to previously submitted written materials, e.g., its response to earlier question of interest Q3.

Q18 Following on the earlier question of interest Q8,[1] will a detailed end-to-end signal path simulation be done that takes into consideration not only RFI, signal path linearity, and dynamic range, but also gain and phase stability of open loop signal paths, and the challenges of a wide and chromatic primary beam width?

Q19 Can the project team provide a more detailed breakdown of the Work Breakdown Structure (WBS) — ideally, linked to FTE estimates with unit costs for FTEs — that would allow for more accurate validation of the cost and feasibility of development and construction?

Q20 Can the project team provide a high-level operations model that justifies the operations FTE headcount?

Q21 A key programmatic risk appears to be the retention of the skills of the small "hero team" driving this project. What, if any, mitigation plan exists to retire or manage this risk?

[1] "Will forward modeling of the array performance include possible effects of RFI? What dynamic range is required of the receivers and fiber links so that RFI in a narrow frequency band does not subtly corrupt images in other frequency channels? Has the project team taken a critical look at the impacts of 5G RFI on the data products, assuming both conservative and worst-case scenarios, to determine if any design modifications are needed to meet the science goals?"

RMS questions of interest — FASR — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 Are there plans or ambitions to develop a nighttime science case for FASR?

Q2 What are the planned data rights and proprietary period for FASR observations?

Q3 Are there scientific synergies that would be realized if FASR could observe contemporaneously with DKIST and/or COSMO (the latter also under consideration by Astro2020)?

Technical/Risk/Cost/Schedule/Management:

Q4* Section 8 of the RFI response notes that "We estimate that $5.4M is needed over 30 mos to develop and produce the plans needed to position FASR for implementation. Details supporting this assertion can be provided on request." The RMS panel would appreciate receiving these supporting details, provided they can come in the form of a public document to comply with FACA rules.

Q5 How will the project team approach the challenge of reconstituting the formal FASR collaboration?

Q6 Is it certain that the OVRO site can accommodate both DSA-110 (now under construction) and FASR A? How would the merely "acceptable" level of RFI quietness at OVRO above 2 GHz impact the integration times and cleaning algorithms needed to achieve the FASR A science goals?

Q7 How, if at all, would the possible location of FASR B in Green Bank be affected by (a) the possible installation of a planetary radar system on the GBT, and (b) geographical separation from the Owens Valley location where the DSA-2000 project is proposing to build its antenna fabrication facility? Also, in relation to (b), what is the status of FASR's discussions with the DSA-2000 project on the possible use of the latter as a backup source of FASR antennas?

Q8 How much of the automatic data processing pipeline for FASR is already developed, and what still needs development? Are the software packages standard platforms or specialized code that needs research and development? What computing power is anticipated for the processing pipeline?

RMS questions of interest — Simons Observatory — 2020.01.13

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Science:

Q1 To enable the transient science that SO envisions, what data products (alerts, difference maps, etc.) will be provided to the community, with what astrometric accuracy, and on what timescales relative to observations?

Q2 How strongly will SO parameter limits depend on the success and timeline of the LiteBIRD mission?

Technical/Risk/Cost/Schedule/Management:

Q3* Can the project team clarify the relationship between the federal funding request outlined in the APC white paper and the federal funding request outlined in the RFI response? It would be helpful for the panel to understand how and why (the federal shares of) various construction and operations costs have changed, for both SO-Nominal and SO-Enhanced.

Q4* What is the status of SO's discussions with federal funding agencies? Does the project satisfy all of the criteria applied by the DOE Office of Science (SC) when assessing fit with the SC's "Cosmic Frontier" program?

Q5* How does SO view itself in relation to CMB-S4, LiteBIRD, PICO, and any other concepts for CMB projects on the ground and missions in space? Does the SO team see these projects/missions as essential for SO, helpful for SO, and/or competitive with SO in their scientific and/or technical aspects?

Q6* Can the project team provide a copy of the Committee Report from the October 2019 Production Readiness Review for detectors and readouts? (Any additional information relevant to the current assessment of technical risk for the SO readout electronics would also be welcome at the upcoming face-to-face meeting.)

Q7 How would the governance structure of SO be modified to reflect any new (e.g., federal) funding sources?

Q8 Are the hardware and software capabilities necessary for generating transient science data products included at full scope within the project budget?

RMS questions of interest — NANOGrav — 2020.01.13

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Science:

Q1* The APC white paper for NANOGrav identifies a number of existing and possible future U.S. facilities (Arecibo, GBT, VLA, DSA-2000, and ngVLA) that are envisioned to play major roles in its future pulsar search and timing efforts. The white paper suggests some decision rules that connect to potential Astro2020 outcomes (e.g., "In the absence of the ngVLA or DSA-2000, continued access to the GBT and Arecibo is critical"), although it is less explicit on other points (e.g., the possible continued use of existing facilities after new ones come on line). The RMS panel would welcome the science-driven perspective of the NANOGrav team on the core observational capabilities needed to execute its program, to the extent that these capabilities can be described generically and decoupled from specific projects being considered by Astro2020.

Q2 How important is continuity of observations for NANOGrav science? For a pulsar timing effort making a transition from an existing facility to a new one, is it necessary for the two facilities to observe the same set of pulsars over an overlapping time window to ensure continuity of data? If so, what is the requisite overlap time; if not, how long a gap between the end of observations with one facility and the start of observations with the new one can be accommodated?

Q3 For the immediate future, when NANOGrav will be limited to working with existing U.S. facilities (Arecibo, GBT, VLA), how well can the amount of observing time needed for pulsar timing keep up with the sample expansion enabled by pulsar search, within the bounds of typical time allocations? How, if at all, would this situation change with the advent of new U.S. facilities (DSA-2000, ngVLA), or with international facilities through the framework of the IPTA?

Technical/Risk/Cost/Schedule/Management:

Q4 What are the expected impacts of RFI on the proposed NANOGrav program?

Q5 How, if at all, does the relative balance of time invested by U.S. and international telescope resources in search and timing activities affect the role(s) that can be played by members of the NANOGrav team within the IPTA collaboration?

RMS questions of interest — HERA — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 Can the project team provide a more detailed explanation of the challenge of characterizing beams for drift scan telescopes at the requisite level of precision for EoR science? A pedagogical approach would be welcomed by the panel.

Q2 How might the different science goals of a $z < 12$ focused "EoR Imager" and a $z > 12$ focused "Cosmic Dawn Array" translate to different instrumental parameters if both were ultimately built? (A qualitative discussion would be informative even if a quantitative analysis is not yet possible.)

Technical/Risk/Cost/Schedule/Management:

Q3 Is HERA on schedule, and is the initial experiment expected to be complete by the end of 2023? Does the project team already anticipate extending its operating lifetime to 2025 or beyond, perhaps as a testbed for technology improvements?

Q4 Would access to SKA1-low datasets help support the scientific aspirations of the U.S. H I cosmology community in a significant way?

RMS questions of interest — PUMA — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 Science objective F on p9 of the RFI response refers to "daily monitoring of a significant subset of... pulsars discovered by the SKA. What exactly is meant by "a significant subset," and what level of time-of-arrival (ToA) precision can PUMA be expected to deliver?

Technical/Risk/Cost/Schedule/Management:

Q2* Can the project team clarify the relationship between the federal funding request outlined in the APC white paper and the federal funding request outlined in the RFI response? It would be helpful for the panel to understand how and why (the federal shares of) construction and/or operations costs have increased above the rate of inflation.

Q3 What levels of funding is the project team expecting or seeking from NSF and DOE, respectively (for both the 5K and 32K configurations of PUMA)?

Q4 What is the required lifetime of PUMA, and what level of funding does the project team estimate will be needed for the eventual decommissioning of the array?

Q5 What is the status of the project team's negotiations with potential non-federal partners (described in the APC white paper as "private and international participants"?

Q6 What is the forward-looking timescale for mitigating the risks associated with FFT correlation, and how does that timescale fit within the development timeline for PUMA?

RMS questions of interest — ngEHT — 2020.01.13

Questions are grouped in two rough categories, one focused more on science issues and one focused more technical, risk, cost, schedule, and/or management issues. Questions marked with asterisks are those for which the RMS panel hopes to receive at least some feedback *before* its main discussion with the project team.

Science:

Q1 How exactly are ngEHT's science goals connected to its technical specifications? (This question can potentially be addressed by sharing a Science Traceability Matrix, as long as this can be provided in the form of a public document to comply with FACA rules.)

Q2 Is it the case that M87 and Sgr A* will (still) be the only two black holes whose event horizons ngEHT per se will be able to resolve, unless additional space-based baselines become available?

Q3 How many days per year are ALMA and/or NOEMA expected to participate in ngEHT observations? What would be the impact of observing without these anchor stations?

Q4 What would be the impact on ngEHT's scientific capabilities of a delay in the doubling of ALMA's bandwidth?

Technical/Risk/Cost/Schedule/Management:

Q5* For each of ten new 10 m diameter antennas, the envisaged cost is $\sim$ \$6M. What is the Basis of Estimate for this cost?

Q6* What is the Basis of Estimate for the operations cost of approximately \$14M/yr, split equally between the U.S. and foreign partners? Does this value assume that the ngEHT consortium will fully fund the operation of each of the new 10 m telescopes, or is it assumed that partnering "local institutions" will partly fund the operation of these telescopes? What (if anything) would the new telescopes be used for when not participating in ngEHT observing sessions?

Q7 How are the long lead times needed for environmental impact statements expected to impact ngEHT's overall schedule?