Legacy Science Program

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PREPARED BY	ORGANIZATION	DATE
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Change Record

Version	Date	Sections	Change Description
1	2017-08-04	All	Writing up the initial idea.
2	2017-11-13	All	Incorporating comments from GXH.
3	2018-03-02	All	Feedback from Sci Ops. Group and MM: execution of LSPs starts after First Look Science activities.
4	2018-09-18	All	Comments from SAC and STRR.
5	2019-02-25	Section 4	Including figures on archival data usage of NASA Great Observatories
A	2019-05-20	All	Replaced figures with higher-resolution versions and prepared document PDF for approval and release
A.1	2019-10-21	All	Updated based on comments for SDR RIDS from the SAC. Section 1 mentions KSGs, Section 4 updated to BI/BP.
B	2020-01-03	All	Prepared document for approvals and release as v.B

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1 Introduction

The next-generation Very Large Array (ngVLA) Legacy Science Program (LSP) is designed to support observing or archival projects that require significant resources (e.g., a dedicated team, computing, software development, etc.) to carry out those observations, develop tools, and perform non-standard data reduction/processing and associated analyses that are outside the reach of NRAO expertise and/or the scope of normal ngVLA Science Operations. These projects will also be expected to provide the greater community with Enhanced Data Products (EDPs), analysis software, tools, and other services that go beyond what can be done through the NRAO Science Ready Data Product (SRDP) initiative.

This program is largely modeled after the highly successful NASA Legacy/Key Science Programs that have generated both tremendous science yields and community engagement across all wavelengths and scientific disciplines. As such, this program is motivated by a desire to enable major science observing projects throughout the ngVLA operational lifetime. The goal is to create a substantial and coherent collection of archived observations that can be used by subsequent ngVLA researchers, ultimately leading to new PI-led observing projects. Further, the ngVLA LSP will likely play a fundamental role in accomplishing each of the community-developed ngVLA Key Science Goals as described in the ngVLA Science Requirements.

Legacy Science projects are distinguished from typical PI-led general observing investigations by the following fundamental principles:

- They are large and coherent science projects, not reproducible by any reasonable number or combination of smaller general observing investigations.
- They have general and lasting importance to the broader astronomical community for which the ngVLA data will yield a substantial and coherent database.
- They generate raw and pipeline-processed data that enter the public domain immediately upon NRAO processing and validation, thereby enabling timely and effective opportunities for follow-on observations and for archival research, with both the ngVLA and other observatories.
- They provide the community with some combination of deliverables, such as EDPs, analysis software/tools[1], etc.

Unlike general observing programs, ngVLA LSPs will be awarded funding to ensure that the programs are successfully completed in a timely manner, including the delivery of data products or analysis tools by the selected teams. The funding level shall be commensurate with the proposed work effort. Funding to support the LSP shall be included in the overall operations budget of the ngVLA.

2 Anticipated Number of Programs Awarded and Frequency

The number of LSPs shall not exceed the total funding cap for the designated period, with an expectation of one to three awards every other year throughout the ngVLA's operational lifetime. This will commence after First Look Science (FLS) activities, with the first call occurring during the later stages of Early Science operations when the system and its capabilities are better understood. Early Science LSPs will likely be smaller (in scope and longevity), given that the full array capabilities will not be available (e.g., see Table 1). As such, they will require less financial support. Such a cadence will allow for projects to be completed prior to the commencement of additional projects, keeping annual observing pressure constant for LSPs (i.e. <15%) and proper management of the supporting budget.

[1] Any data analysis software/tools developed by the community will have to undergo a review process, be written under an agreed-upon open source license, and be delivered with the products.

The first round of LSPs executed during Early Science will play an important and necessary role for the project as they provide a mechanism for the community to contribute significantly to ngVLA commissioning and science validation efforts (e.g., by helping to enable and validate new observing modes). Such programs, along with FLS, will also allow for ngVLA data to be placed into the public domain early on, enabling the entire community to begin working with ngVLA data starting at first light. Having access to such data will both help build the ngVLA community and aid with the scientific and technical preparation of future PI-led proposals.

3 Anticipated Funding Support Levels

Funding to support LSPs shall be incorporated into the overall ngVLA operations budget, similar to the ALMA development program, which sets aside about $5M annually for the development of future ALMA capabilities. The exact funding level per program shall be rigorously justified by each proposal and commensurate with the required work to complete the project successfully. The funding requests shall be evaluated as part of the peer-review process.

Funding levels for individual projects are anticipated to be at the $2–4M level over about three years (see Table 1). The first call will likely be released during the second half of Early Science, with three or so proposals each awarded at the $2M level. For full science operations, a call will be issued every other year with two or so programs each supported at the $3M level for each call. This commitment therefore requires $3M annually available for LSPs in the ngVLA operations budget.

Funding Period	Number of LSPs	Funding per LSP	Funding per Year	Total Money Required over the Period
First Look Science (2027–2028)	Community provided with a series of science products obtained during initial CSV activities that can be used to help inform future Early Science and LSP proposals.			
Early Science (2028–2034)	PI-proposed science observations carried out over a series of ~5 calls using commissioned antennas as they become available during construction. These data can be used to help inform LSP proposals.			
Early Science LSPs (2031–2034)	3	$2M	$2M	$6M
Cycle 1 (2034–2036)	2	$3M	$3M	$6M
Cycle 2 (2036–2038)	2	$3M	$3M	$6M
Cycle 3 (2038–2040)	2	$3M	$3M	$6M
Cycle 4 (2040–2042)	2	$3M	$3M	$6M
Cycle 5 (2042–2044)	2	$3M	$3M	$6M
Totals	**13**			**$36M**

Table 1 – Potential Early Science and first ten-year funding cycle.

4 Broader Impacts/Broadening Participation

The primary goal of the ngVLA LSP is to ensure that the community receives the highest scientific return from the facility by supporting observing or archival projects that require significant resources that are outside the reach of NRAO expertise and/or the scope of normal ngVLA Science Operations. Importantly, the program will also enable a series of compelling Broader Impact and Participation initiatives. As discussed above, the ngVLA LSPs will provide significant benefits to the greater astronomical community. Placing ngVLA data immediately into the public domain gives all astronomers access to first-hand experience in reducing and analyzing ngVLA data for their particular science.

This program will help grow the ngVLA user base in several ways. For instance, having data readily available gives PIs the opportunity to construct more scientifically compelling and technically sound proposals for General Observing. Furthermore, by eventually having large, coherent sets of EDPs readily available from each LSP, astronomers will be able to incorporate them into their existing science. We anticipate such datasets will also lead to broader participation in ngVLA research by acting as the foundation for new citizen science initiatives.

EDPs have been shown to be heavily used by the community. This impact is evidenced in Figure 1, which plots the fraction of publications from NASA's Great Observatories resulting from archival data as a function of time. Currently, nearly half of all Great Observatories publications are completely dependent on archival data usage. Furthermore, in the case of *Spitzer*, over 50 percent of all *Spitzer* publications make use of their Legacy Program Products (see Figure 2). This productivity is a likely result of the EDPs being scientifically reliable and useable by anyone familiar with standard astronomical products and tools, therefore spreading their use well beyond the instrument's traditional user community. Consequently, there is every reason to anticipate a similar heavy usage of ngVLA LSP EDPs, especially given the additional complexities associated with processing and imaging interferometric data.

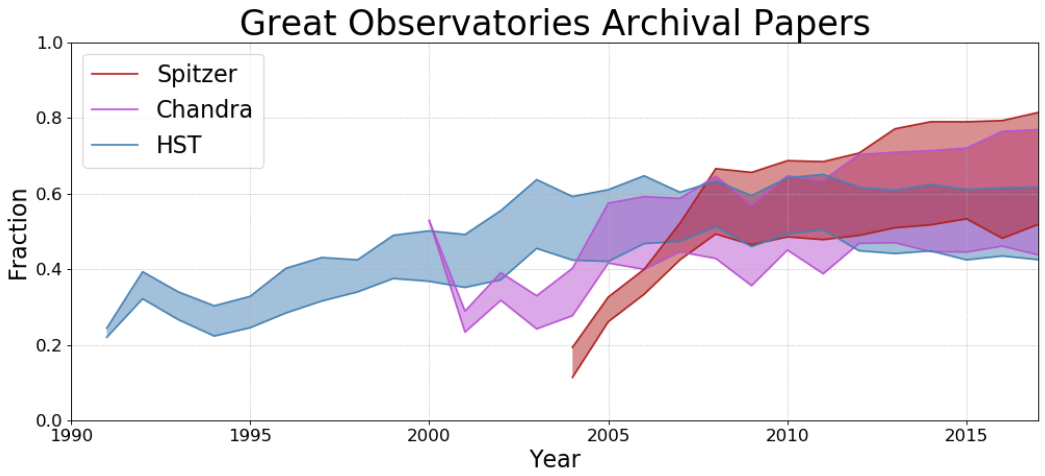

Figure 1 – The fraction of publications from NASA's Great Observatories resulting from archival data plotted as a function of time. The lower part of the shaded region represents the purely archival papers. The upper part includes papers that had a mixture of PI and archival data.

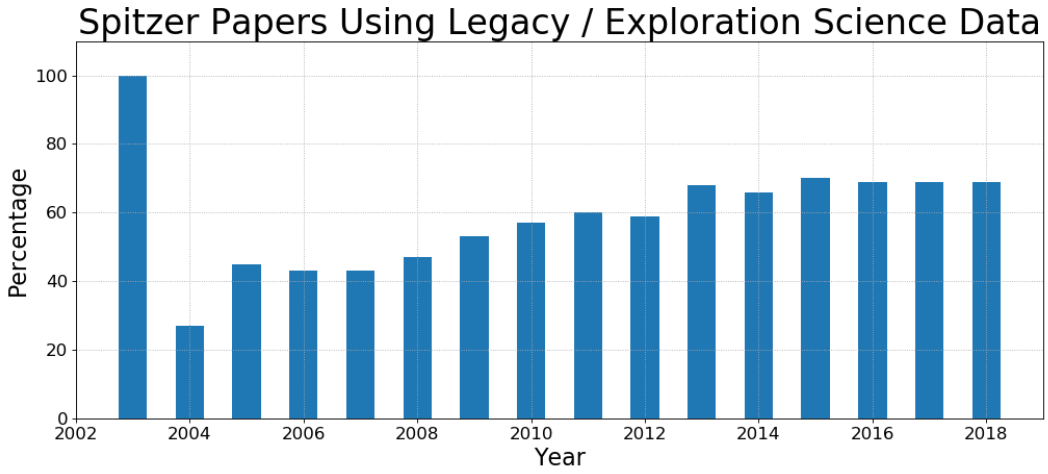

Figure 2 – The fraction of Spitzer publications that made use of Legacy Science products by year.

Creating a competitive process to obtain large amounts of ngVLA time and resources will ultimately help build the ngVLA community across wavelengths. This is in large part because the ngVLA, by design, will be an extremely flexible instrument with the ability to contribute significantly to many scientific areas, which should in turn lead to substantial participation from the entire astronomical community. There is already evidence for such wide usage with ALMA, given the highly competitive nature of its general observing proposal cycle. Thus, the ngVLA LSP will bring more astronomers into the radio astronomy observer pool, a circumstance that is healthy for the field intellectually and programmatically because it will help to grow the support and advocacy base.

By additionally making substantial funding available to support ngVLA LSPs, the user base will almost certainly expand to additional members of the community that are drawn to financial support. There is clear evidence that the community has the ability to become highly adaptable in taking advantage of funding opportunities independent of wavelength. More importantly, such funding will also provide faculty members at US academic institutions the necessary resources to support students and postdocs, making them ngVLA users and increasing the numbers of astronomers in general. In doing so, the program will help alleviate some of the stress being felt by the astronomical community via a fixed amount of funding to support their science in a time when NSF research grants are tremendously competitive. This program will additionally invoke a competitive advantage to the US community given that ngVLA will be open worldwide and that the EU is now offering large grants in support of scientific projects to EU-based teams.

5 Appendix

5.1 Acronyms and Abbreviations

Acronym	Definition
ALMA	Atacama Large Millimeter Array
EDP	Enhanced Data Product
EU	European Union
FLS	First Look Science
LSP	Legacy Science Program
NASA	National Aeronautics and Space Administration
ngVLA	Next Generation Very Large Array
NRAO	National Radio Astronomy Observatory
PI	Principal Investigator
SRDP	Science-Ready Data Products
US	United States
VLA	Jansky Very Large Array