

## Budget Justification

## University of California

The University of California serves as the lead institution and provides technical, scientific and management support.

**Personnel:** The personnel supported on this grant are located at the University of California, Berkeley Radio Astronomy Laboratory and Astronomy Department.

Aaron Parsons will serve as Principal Investigator and develop power spectrum algorithms and pipelines. We request funding for 1 month/year beginning in Year 2. The monthly rate for year 2 is projected to be \$11,011.

Dan Werthimer will serve as chief digital architect. We request funding for 12 months/year at 20%. The monthly rate for year 1 is \$9463.

David DeBoer will serve as Project Manager/Project Engineer. We request funding for 12 months for all years, at 75% in years 1-4 and 50% in year 5. The monthly rate for year 1 is \$12,600.

David MacMahon will serve as R&D Engineer for the digital system, including design, installation and support. We request funding for 12 months for all years, at 75% in year 1-4, 25% in year 5. The monthly rate for year 1 is \$8,859.

Matt Dexter will serve as R&D Engineer for the digital system, including design, installation and support. We request funding for 12 months for all years, at 50% in years 1 and 2, 75% in years 3 and 4 and 25% in year 5. The monthly rate for year 1 is \$8,859.

Calvin Cheng will serve as analog and digital technician, including design, installation and support. We request funding for 12 months for all years, at 10% in years 1 and 5, 50% in years 2 - 4. The monthly rate for year 1 is \$6,433.

Adrian Liu will provide post-doctoral algorithm design and implementation support. We request funding for 12 months/year at 100% for years 3-5.

We will hire two graduate student researchers. We request funding for 12 months/year at .4927 FTE. The monthly rate for year 1 is \$5,153. Salary is increased at a rate of 2% per year for academic staff, and 3.5% per year for non-academic staff to allow for a cost of living adjustment.

We will hire one undergraduate support staff. We request funding for 12 months/year at 25% for all years.

Composite Fringe benefits are:

	FY15	FY16	FY17	FY18	FY19
Undergrad/GSR	0%	0%	0%	0%	0%
Staff	44.6%	47.6%	50.5%	51.3%	51.3%
Academic	36.8%	39.5%	42.1%	42.6%	42.6%

Rates beyond June 30, 2014, are estimates and are provided for planning purposes only. Future benefits rates are subject to review and approval by the Department of Health and Human Services on an annual or bi-annual basis. Therefore, regardless of which rates are used to estimate the cost of fringe benefits at the proposal stage, the fringe benefit costs ultimately charged to the sponsored project will always be based on the DHHS-approved fringe rates in existence at that time.

The Graduate Student Researchers will receive remissions of Fees, Health Insurance and Non-California Resident Tuition per semester at a rate of \$15,141 per semester in year one. A 10% per year escalation in fees are calculated. Graduate Student fee remission, health insurance and non-California resident tuition remissions are not included in the Indirect Costs calculation.

**Equipment:** As the managing institution, Berkeley will procure most of the South African deployed equipment for the project. Funds are requested for the following pieces of equipment:

- *Year 1:* Site relocation and HERA-37 construction.
  - antenna components, sub-assemblies and installation: \$230k
  - initial infrastructure and PAPER Move: \$208k
  - limited upgrade to PAPER electronics: \$30k
- *Year 2:* HERA-127 construction
  - antenna components, sub-assemblies and installation: \$775k
  - node fabrication and installation: \$192k
  - site infrastructure: \$153k
  - limited correlator upgrade: \$38k
  - monitor and control: \$30k
- *Year 3:* HERA-331 construction
  - antenna components, sub-assemblies and installation: \$1,268k
  - node fabrication and installation: \$314k
  - correlator: \$152k
  - monitor and control: \$30k
- *Year 4:* HERA-568 construction
  - antenna components, sub-assemblies and installation: \$1,479k
  - node fabrication and installation: \$366k
  - correlator: \$191k
  - monitor, control and storage: \$30k

- *Year 5: Operations*

- storage: \$30k

**Travel:** We request \$104k for domestic and foreign travel support, consisting of airfare, lodging, and per diem for (a) domestic team meetings, (b) one conference per person per year and (c) travel to the South African site for more extensive periods for a subset of the team.

**Materials and Supplies:** Funds are requested for the following miscellaneous expenses over five years.

- Page charges (\$5k): \$1000/yr over five years
- Licenses (\$17k): \$3500/yr over five years
- Computers (\$5k): \$5000 in year 1
- Laboratory materials (\$15k): \$5000/yr over first three years
- Shipping of equipment to South Africa: (\$175k): \$10k, \$35k, \$65k, \$65k

**Indirect Costs:** The rate of 56.5% is used to determine the estimated Indirect Cost. The total indirect cost is calculated using the modified total direct cost base (which excludes equipment, graduate student tuition and fees). This reflects the On-Campus Organized Research Facilities and Administrative Cost Rate established by the institution and DHHS in an agreement dated 27 July 2007.

## University of Washington

The purpose of this subcontract is to ...

**Personnel:** The personnel supported on this grant are located at ...

**Travel:** We request foreign travel support, consisting of airfare, lodging, and per diem for ...

**Materials and Supplies:** Funds are requested for ...

**Indirect Costs:** Indirect cost is calculated at the University's federally negotiated rate for on-campus research at 56.5% of MTDC from July 1, 2013 through June 30, 2015. The rate increases to 57.0% starting July 1, 2015. Modified Total Direct Cost (MTDC) excludes equipment, capital expenditures, and charges for patient care, tuition remission, rent, scholarships, fellowships, and subcontracts except for the first \$25,000. A copy of the University's federally negotiated indirect cost rate agreement effective June 29, 2012 with the U.S. Department of Health and Human Services (DHHS) can be found at the following link: <http://www.spo.berkeley.edu/Policy/fa.html>.

## Arizona State University

The purpose of this subcontract is to ...

**Personnel:** The personnel supported on this grant are located at ...

**Travel:** We request foreign travel support, consisting of airfare, lodging, and per diem for ...

**Materials and Supplies:** Funds are requested for ...

**Indirect Costs:** Common cost recovery on salaries, fringe benefits, travel, materials, and services are charged at ...

## Massachusetts Institute of Technology

The purpose of this subcontract is to ...

**Personnel:** The personnel supported on this grant are located at ...

**Travel:** We request foreign travel support, consisting of airfare, lodging, and per diem for ...

**Materials and Supplies:** Funds are requested for ...

**Indirect Costs:** Common cost recovery on salaries, fringe benefits, travel, materials, and services are charged at ...

## University of Pennsylvania

The University of Pennsylvania (Penn) group will host the central computing cluster and data archive for HERA. Penn currently performs this function for PAPER. The cluster will be maintained by an IT professional. Penn will also ensure that data flows smoothly from South Africa to the central storage, and thence to collaborators as necessary.

In addition, building on our experience with the PAPER data compression in South Africa, we will provide the quality assurance (QA) of raw data, including both software and hardware checking and reporting on the data in real time. This will be the responsibility of the postdoctoral fellow and the graduate student, with the goal of making science quality data available by early in year 2.

Finally, we continue our investigation of polarization effects on the reionization power spectrum, providing feedback on the performance of the antenna design, providing polarization calibration, and pioneering polarization leakage mitigation techniques as necessary. This, combined with power spectrum analysis, will form the basis for a graduate student thesis.

**PI** One month of summer salary per year is requested for the co-PI at the standard rate for 5 years.

**IT Professional** Ten percent of an IT professional is requested for 5 years, to maintain the computing and storage cluster at Penn. This level of commitment is consistent with the experience gained with the PAPER cluster.

**Postdoctoral Fellow** A postdoctoral fellow is requested for the first two years of the grant to lead the implementation of the data verification and quality assurance pipeline, which is an outgrowth of the PAPER compression and data monitoring system. This will allow data from the HERA-37 array to be rapidly brought to science quality.

**Graduate Student** Graduate student support is requested for one student over the 5 year life of the project. The graduate student will work on the data QA software and commissioning, and will continue the investigation of polarization effects of the HERA antennas. The time period is sufficiently long to bring the student to complete thesis from construction and commissioning to science based on HERA data.

**Travel** Domestic travel is included to allow for collaboration meetings and coordination of data reduction efforts between institutions. While videoconferencing and internet exchange will be actively pursued, our experience with PAPER and MWA suggests that an in-person “busy week” is an extremely effective method of rapidly moving data analysis forward. Foreign travel is budgeted to allow multiple multi-person visits the South African telescope site and to scientific collaborators, for similar reasons.

**Publication page charges** Because HERA will be generating data from day 1 based on the existing PAPER infrastructure, we expect to be able to generate science papers even in the first year of the grant. The budget includes one modest length paper per year.

**Shipping** We have budgeted for shipping both the QA Cluster (see below), with 25% shipping in year 1, and the remainder in year 3. In addition, in the later years of the project, it may become necessary to physically ship data via tape or disk, and we have allowed for this possibility to bring data back to the US.

**Quality Assurance Computing Cluster** Subsequent to the initial data taking, and running in parallel to the compression process, the data will be subject to a series of tests determining data health and quality. We expect that this will take approximately an 8 node cluster. The budget allows for 2 nodes in the first year for prototyping of the software. This is the same size as the current PAPER cluster, and working on an identical data rate. The remainder of the cluster will be built in year 3 to handle the increased data volume.

**Main US Computing and Storage Cluster** The central storage and main computing cluster for PAPER has been maintained at Penn, currently consisting of 22 compute

nodes and  $\sim 140$  TB of fast-access, RAIDed storage. We have extrapolated the data rate to HERA-568, allowing for compression, and have budgeted for approximately 2 PB of storage to hold compressed versions of multiple seasons of data at Penn for subsequent data analysis on the computing cluster, or for distributions of subsets to collaborators. Based on extrapolations from the PAPER data reduction, and allowing for Moore's Law, we expect that a 32-node computing cluster will be adequate for reducing the HERA-568 data. The budget reflects purchasing both the larger cluster and the bulk of the storage in years 3 and 4 to take maximum advantage of increases in computing power and disk capacity.

**Indirect Costs:** Common cost recovery on salaries, fringe benefits, travel, materials, and services are charged at the standard rate.

### University of California, Los Angeles

The purpose of this subcontract is to ...

**Personnel:** The personnel supported on this grant are located at ...

**Travel:** We request foreign travel support, consisting of airfare, lodging, and per diem for ...

**Materials and Supplies:** Funds are requested for ...

**Indirect Costs:** Common cost recovery on salaries, fringe benefits, travel, materials, and services are charged at ...

### National Radio Astronomy Observatory

The purpose of this subcontract is to ...

**Personnel:** The personnel supported on this grant are located at ...

**Travel:** We request foreign travel support, consisting of airfare, lodging, and per diem for ...

**Materials and Supplies:** Funds are requested for ...

**Indirect Costs:** Common cost recovery on salaries, fringe benefits, travel, materials, and services are charged at ...