Budget Justification

Scope and Phasing of the IceRay Task. IceRay is scheduled as a three-year multi-university investigation. In the first year season at South Pole (FY-09) we plan to install two remote radio-detectors in proximity to the IceCube detector. These detectors will make almost exclusive use of ANITA technology so that little R&D work is required beyond making them deployable in the deep Antarctic Ice. Getting two detectors into the ice is important since it will allow us to study radio correlations between detectors as well as correlations with the IceCube detector.

In the second season at South Pole (FY-10), we plan to install two more radio-detectors near IceCube. These four detectors will yield more detailed information on the correlations between detectors, trigger formation schemes(using electronic pulses), radio propagation through the ice as well as possible IceCube-radio correlations (so-called reverse triggers)

In the third year of the proposal we plan to concentrate fully on the data analysis and the development of more detailed simulations, and the reconciliation of simulation results with the actual harvested data. To this end, we hope in the third year to cap our efforts by proposing for the actual construction of IceRay-36, a 50 square-kilometer GZK neutrino detector, starting in the FY-11 season.

Direct Labor Costs. The University of Hawaii-Manoa (H) budget includes a full-time post-doctoral fellow, a graduate student fully devoted to the project, and two months of ”casual-hire” for the PI, Professor Morse, since he is not an employee, but is ”Affiliate Graduate Faculty” at UH. As such, he pays nominal fringe benefits, and normal overhead is charged on his compensation. Post-doctoral fellows at UH are supported via stipends, since they are involved in ”post-doctoral training”. They do not receive fringe benefits, and their stipend is not subject to overhead. Graduate students are subject to fringe benefits charges at 8.34and normal university overhead.

The post-doc and graduate student will be responsible for the assembly, and integration of ANITA components into the IceRay detector units. Testing will include operating the units in the UH anechoic chamber and transferring the data to the Central DAQ. Analysis Software to run the Central-DAQ will be provided by our colleagues at OSU and Wisconsin. The post-doc and graduate student will also serve as daily liaisons between our IceRay collaborators as well as the IceCube experiment. The PI will work with the cognizant IceCube task leaders to ensure that IceRay works within the guidelines of ”no-interference” to normal operations of the IceCube detector, and to coordinate between the various IceRay university groups, and to participate in the deployment, analysis, and modeling of IceRay.

Travel. Travel includes support for three to four domestic person trips per year to work with our colleagues, mostly at OSU and Madison (IceCube headquarters), and also to attend the semi-annual IceCube meetings. We also include support for two to three foreign trips to attend the annual IceCube meeting hosted by our European Collaborators, and to consult with our European IceCube collaborators that will also be analyzing the IceRay data.

Other Direct Costs. We include in the budget incidental materials and supplies based on our experience with similar projects.

Equipment and Fabrication. The IceRay array will consists of 4 remote radio-Cherenkov detector stations and a Central-DAQ data collecting station located in the IceCube Laboratory (ICL) at the South Pole. The remote stations basically consist of a suite of antennas connected to low-noise 50 kb amplifiers (LNAs), further amplified with secondary amplifiers (SSAs)). Coincidences between antennas provide the local trigger and the resulting signals are time-digitized and sent back to the ICL for integration with other detectors signals and analysis. The UH is concentrating of the remote stations, while Wisconsin and OSU are constructing the ICL Central-DAQ. The detector unit cost is about 70 k$ per station (without cables), and the detailed Central DAQ cost is about 30 K$ to operate the four detectors. The table also includes the projected costs for the entire IceRay-36 structure.

Indirect Costs. F&A costs are included at the Universities negotiated rate with the cognizant agency.

Estimated Costs for the Full IceRay.

TABLE IV: *Estimated hardware construction and deployment costs for the two arrays considered here, along with the cost basis.*

item	IceRay-36 $K	AURA-18 $K
Engineering design	250	250
Station costs	3000	1620
Cable costs	600	450
Drilling (3 holes/station)	...	1600
Surface deployment	600	300
Central DAQ/power system	300	300
TOTAL	4750	4520

Costs for these arrays scale according to the number of stations. In each case the common elements for the arrays are a set of order 12-16 antennas which comprise the standalone detector, receiver and digitizer blocks for each antenna, local trigger detection electronics and signal transmission electronics for an electro-optical cable. We assume that the central Data Acquisition (DAQ) system can rely on IceCube infrastructure for housing of the system and power distribution.

TABLE V: Grassroots costs for IceRay-36, along with cost basis.

IceRay-36 Equipment Cost Estimate				
			Rev. 2.0	GSV + PG, 09/01/2007
		Unit Cost	TOTAL	
Detector Station	**Qty.**	**k$**	**k$**	**Comment, cost basis**
Upper Ground shield	1	2.0	2.0	flexible EMI mesh screen, as built costs
Antennas	16	0.75	12.0	discones (V), batwings (H), as built costs
LNA/receiver	4	7.00	28.0	Miteq LNA, ANITA rcvr design, as built costs
RF cables	16	0.05	0.8	incl. Connectors, as built costs
Power cables/connectors	6	0.20	1.2	shielded D38999 with backshells, as built
Station DAQ EMI housing	1	2.00	2.0	Machined RF-shielded encl., as built
Readout Board	1	5.00	5.0	8 layer boards, as built costs incl. labor
Trigger/FPGA	1	1.00	1.0	Virtex 4/5, RF fan-out, incl. Firmware costs
Digitizer ASIC	2	0.50	1.0	BLAB3 (TSMC 0.25um)
Trigger/discrete components	16	0.40	6.4	filters+square-laws, as built costs
Gbsp transceiver	1	0.80	0.8	OKI Semiconductor, eng. Estimate
Station data cable	1	9.00	9.0	average 3km, Corning ALTOS 24 fiber,$3/m
Station power cable	1	18.00	18.0	3km LDF-5 heliax (for EMI), $6/m
Power Reg/misc.	1	1.20	1.2	DC-DC, housekeeping, as built costs
drilling costs, 24" holes, 50m	3	6.60	19.8	from IceCube firn drill estimate
Single station costs			**108.2**	**$K**
reserves 15%			**16.23**	
Total # of stations	**36**			
Station Subtotal			**4479**	**$K**
Central DAQ			*General Infrastructure not included--use IceCube*	
Gbsp transceiver	60	0.80	48.0	matching links, engineering estimate
Interface Boards	10	3.50	35.0	5 stations/board, engineering estimate
cPCI DAQ crate	2	6.00	12.0	1 + spare, std. Commercial costs
cPCI CPU	2	4.00	8.0	1 + spare "
Processor farm	10	2.50	25.0	event reduction/correlation
Storage media	2	20.00	40.0	RAID systems
Network/comms	1	12.00	12.0	routers, hubs, ICL link
GPS/global clock	2	7.50	15.0	1 system + 1 spare
Power gen/regul.	1	30.00	30.0	mainframe power supply, commercial
Power pods	40	1.00	40.0	modular+spares
Central DAQ Subtotal, incl 15% reserves			**304.8**	**$K**
GRAND TOTAL ESTIMATE			**4784**	**$K**

For IceRay-18 we assume that 3 holes per station will be required for minimal reconstruction of vertex directions, and that the stations will have some additional complexity to accommodate the borehole geometry, including more stringent antenna construction requirements as well as embedded amplifier modules. Thus the single station costs assumed here are about $90K for IceRay-18, and $50K for the IceRay-36. These costs are based on pricing of a station prototype currently under development and are probably good to 15% accuracy based on current and prior vendor prices from almost all of the equipment. Cable costs are assumed to be $10/meter based on conservative costs for a custom electro-optical cable. Drilling costs are based on estimates from other shallow holes drilled on the plateau, and assume that three holes per station will be required for effective direction reconstruction and triggering with a single station.

Table IV give a summary estimate; more detailed costs were developed in a spreadsheet that is reproduced in Table V. The estimated base costs for the hardware and deployment here do not include scientific or professional salaries except for a single line item we include for the engineering design of the arrays. In that case we assume a single engineering man-year, estimated here at $250K. We also do not include here the logistics costs for transport of the hardware and personnel necessary for the construction or deployment to the South Pole.

In both cases, initial estimates give hardware construction and direct deployment costs under $5M. These systems do not require development of any new technology, thus a realistic contingency on these costs is probably well under 30%.