**IceCube Institutional Memorandum Of Understanding (MOU)**

**Scope of Work**

**Michigan State University**

**Tyce DeYoung**

**Ph.D Scientists** (Faculty Scientist/Post Doc Grads): **10** (6 4 8)

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| **Maintenance and Operations** | | | | | | | | | | | | |  |
| **Labor Cat.** | **Names** | **WBS L3** | **Tasks** | | **Funds Source** | **WBS 2.1** | **WBS 2.2** | **WBS 2.3** | **WBS 2.4** | **WBS 2.5** | **WBS 2.6** | **Grand Total** |  |
| Program Coordination | Detector Maintenance & Operations | Computing & Data Management | Data Processing & Simulation | Software | Calibration |  |
| KE | DeYOUNG, TYCE | Administration | Executive committee | | Inst. In-Kind | 0.05 |  |  |  |  |  | **0.05** |  |
|  | **DeYOUNG, TYCE Total** | |  | |  | **0.05** |  |  |  |  |  | **0.05** |  |
|  | GRANT, DARREN | Administration | Collaboration Spokesperson | | Inst. In-Kind | 0.50 |  |  |  |  |  | **0.50** |  |
|  | Administration | Executive committee | | Inst. In-Kind | 0.20 |  |  |  |  |  | **0.20** |  |
|  |  | Education & Outreach | Outreach | | Inst. In-Kind | 0.05 |  |  |  |  |  | **0.05** |  |
|  | **GRANT, DARREN Total** | | | | | **0.75** |  |  |  |  |  | **0.75** |  |
|  | KOPPER, CLAUDIO | Core Software | IceTray framework maintenance | | Inst. In-Kind |  |  |  |  | 0.05 |  | **0.05** |  |
|  | Simulation Software | Maintenance of clsim photon propagation tool | | Inst. In-Kind |  |  |  |  | 0.10 |  | **0.10** |  |
|  | Online Filter (P&F) | Diffuse WG co-chair | | Inst. In-Kind |  | 0.25 |  |  |  |  | **0.25** |  |
|  | Offline Data Production | Cloud-based event reconstruction infrastructure development | | Inst. In-Kind |  |  |  | 0.10 |  |  | **0.10** |  |
|  | Distributed computing resources | GPU computing resources | | Inst. In-Kind |  |  | 0.05 |  |  |  | **0.05** |  |
|  | Education & Outreach | IceCube MasterClass | | Inst. In-Kind | 0.10 |  |  |  |  |  | **0.10** |  |
|  | **KOPPER, CLAUDIO Total** | | | | | **0.10** | **0.25** | **0.05** | **0.10** | **0.15** |  | **0.65** |  |
|  | WHITEHORN, NATHAN | Online Filter (P&F) | Diffuse WG co-chair | | Inst. In-Kind |  | 0.25 |  |  |  |  | **0.25** |  |
|  | Core software | IceTray framework maintenance | | Inst. In-Kind |  |  |  |  | 0.05 |  | **0.05** |  |
|  | **WHITEHORN, NATHAN Total** | | | | |  | **0.25** |  |  | **0.05** |  | **0.30** |  |
|  | MAHN, KENDALL | Simulation Software | Integration/development of GENIE for low energy systematics | | Inst. In-Kind |  |  |  |  | 0.05 |  | **0.05** |  |
|  | **MAHN, KENDALL Total** | |  | |  |  |  |  |  | **0.05** |  | **0.05** |  |
| PO | NISA, MEHR | Detector calibration | In-situ DOM sensitivity / angular response calibration from muon neutrinos | | Inst. In-Kind |  |  |  |  |  | 0.10 | **0.10** |  |
|  | Offline Data Production | Cloud-based event reconstruction infrastructure development | | Inst. In-Kind |  |  |  | 0.10 |  |  | **0.10** |  |
|  | Detector monitoring | Monitoring shift | | Inst. In-Kind |  | 0.03 |  |  |  |  | **0.03** |  |
|  | **NISA, MEHR Total** | | | | |  | **0.03** |  | **0.10** |  | **0.10** | **0.23** |  |
|  | LUDWIG, ANDREW | Reconstruction | Likelihood-based muon reconstruction development | | Inst. In-Kind |  |  |  |  | 0.50 |  | **0.50** |  |
|  | **LUDWIG, ANDREW Total** | | | | |  |  |  |  | **0.50** |  | **0.50** |  |
|  | CLARK, BRIAN | Distributed Computing Resources | IceProd site manager at MSU HPCC | | NSF AAPF Fellowship |  |  | 0.10 |  |  |  | **0.10** |  |
|  | **CLARK, BRIAN Total** | | | | |  |  | **0.10** |  |  |  | **0.10** |  |
|  | HALLIDAY, ROBERT | Distributed Computing Resources | IceProd site manager at MSU HPCC | | NSF M&O Core |  |  | 0.25 |  |  |  | **0.25** |  |
|  | **HALLIDAY, ROBERT Total** | |  | |  |  |  | **0.25** |  |  |  | **0.25** |  |
| GR | NOWICKI, SARAH | Reconstruction | DirectReco software support | | Inst. In-Kind |  |  |  |  | 0.10 |  | **0.10** |  |
| **NOWICKI, SARAH Total** | |  | |  |  |  |  |  | **0.10** |  | **0.10** |  |
| RYSEWYCK CANTU, DEVYN | Education & Outreach | IceCube Masterclass | | Inst. In-Kind | 0.02 |  |  |  |  |  | **0.02** |  |
| **RYSEWYCK CANTU, DEVYN Total** | | | |  | **0.02** |  |  |  |  |  | **0.02** |  |
| SANCHEZ HERRERA, SEBASTIAN | Education & Outreach | IceCube Masterclass | | Inst. In-Kind | 0.02 |  |  |  |  |  | **0.02** |  |
| **SANCHEZ HERRERA, SEBASTIAN Total** | | | | | **0.02** |  |  |  |  |  | **0.02** |  |
| MICALLEF, JESSIE | Education & Outreach | IceCube Masterclass | | NSF Grad Fellowship | 0.02 |  |  |  |  |  | **0.02** |  |
| Core Software | Software strike team / CLSim development and maintenance | | NSF Grad Fellowship |  |  |  |  | 0.20 |  | **0.20** |  |
| **MICALLEF, JESSIE Total** | |  | |  | **0.02** |  |  |  | **0.20** |  | **0.22** |  |
|  | PEISKER, ALISON | Education & Outreach | | IceCube Masterclass | NSF Grad Fellowship | 0.02 |  |  |  |  |  | **0.02** |  |
|  | **PEISKER, ALISON Total** | | | | | **0.02** |  |  |  |  |  | **0.02** |  |
|  | HARNISCH, ALEXANDER | Simulation software | | Implementation of BFRv1 ice model in clsim | Inst. In-Kind |  |  |  |  | 0.20 |  | **0.20** |  |
|  |  | Education & Outreach | | IceCube Masterclass | Inst. In-Kind | 0.02 |  |  |  |  |  | **0.02** |  |
|  | **HARNISCH, ALEXANDER Total** | |  | |  | **0.02** |  |  |  | **0.20** |  | **0.22** |  |
|  | TWAGIRAYEZU, JEAN PIERRE | Education & Outreach | | IceCube Masterclass | Inst. In-Kind | 0.02 |  |  |  |  |  | **0.02** |  |
|  | **TWAGIRAYEZU, JEAN PIERRE** | |  | |  | **0.02** |  |  |  |  |  | **0.02** |  |
|  | LE, HIEU | Detector calibration | | In-situ DOM sensitivity / angular response calibration from muon neutrinos | Inst. In-Kind |  |  |  |  |  | 0.10 | **0.10** |  |
|  | **LE, HIEU** | |  | |  |  |  |  |  |  | **0.20** | **0.20** |  |
| **MSU Total** | |  |  | |  | **1.02** | **0.53** | **0.40** | **0.20** | **1.25** | **0.20** | **3.60** |  |

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| **IceCube Upgrade** | | | | | | | | | | | |  |
| **Labor Cat.** | **Names** | **WBS L3** | **Tasks** | **Funds Source** | **WBS 1.1** | **WBS 1.2** | **WBS 1.3** | **WBS 1.4** | **WBS 1.5** | **WBS 1.6** | **Grand Total** |  |
| Project Management | Drilling | Sensors | Comms, Power, Timing | Calibration | Data Systems |  |
| KE | DeYOUNG, TYCE | CPT Management | Management | NSF |  |  |  | 0.50 |  |  | **0.50** |  |
|  | **DeYOUNG, TYCE Total** | |  |  |  |  |  | **0.50** |  |  | **0.50** |  |
|  | GRANT, DARREN | mDOMs | MSU mDOM production facility | Inst. In-Kind |  |  | 0.25 |  |  |  | **0.25** |  |
|  | **GRANT, DARREN Total** | |  |  |  |  | **0.25** |  |  |  | **0.25** |  |
| EN | NG, CHRISTOPHER | Downhole Cable Assemblies | Penetrator Cable Assemblies, Main cable mechanical/ string hardware | NSF |  |  |  | 0.75 |  |  | **0.75** |  |
|  | Surface Cables | Surface cables and junction boxes | NSF |  |  |  | 0.15 |  |  | **0.15** |  |
|  | Northern Test System | Design and set up NTS | NSF |  |  |  | 0.10 |  |  | **0.10** |  |
|  | **NG, CHRISTOPHER Total** | | | |  |  |  | **1.00** |  |  | **1.00** |  |
|  | FERGUSON, BRIAN | Downhole Cable Assemblies | Main cable electrical design, procurement | NSF |  |  |  | 0.95 |  |  | **0.95** |  |
|  | Surface Cables | Surface cables and junction boxes | NSF |  |  |  | 0.05 |  |  | **0.05** |  |
|  | **FERGUSON, BRIAN Total** | |  |  |  |  |  | **1.00** |  |  | **1.00** |  |
| PO | HALLIDAY, ROBERT | Downhole cable assemblies | Engineering support | Inst. In-kind |  |  |  | 0.10 |  |  | **0.10** |  |
| Northern Test System | Design and set up NTS | Inst. In-Kind |  |  |  | 0.10 |  |  | **0.10** |  |
| **HALLIDAY, ROBERT Total** | |  |  |  |  |  | **0.20** |  |  | **0.20** |  |
| **MSU Total** | |  |  |  |  |  | **0.25** | **2.70** |  |  | **2.95** |  |

**Faculty:**

Tyce DeYoung (IL) – ExecCom, Upgrade L2 for CPT, 100% IceCube

Darren Grant – Spokesperson, outreach, Upgrade DOM production 100% IceCube

Claudio Kopper – Diffuse WG co-convener, software development, offline processing support, outreach, 100% IceCube

Kirsten Tollefson – 50% IceCube (50% HAWC)

Nathan Whitehorn – Diffuse WG co-convener, software development, 50% IceCube (50% SPT)

Kendall Mahn – low energy systematics/GENIE, 5% IceCube (95% DUNE, T2K)

**Scientists and Engineers:**

Chris Ng – engineering support for Upgrade WBS 1.3, 1.4, 100% IceCube

Brian Ferguson – engineering support for Upgrade WBS 1.4, 25% IceCube

**Post Docs:**

Mehr Nisa DOM response/simulation calibration using neutrino-induced muons, monitoring shifts, 50% IceCube (50% HAWC)

Thesis/Analysis topics: galaxy cluster search, low energy solar dark matter search

Robert Halliday IceProd and distributed computing support, Upgrade cable design/engineering support, NTS timing support, 100% IceCube

Thesis/Analysis topics: multi-flavor source searches

Brian Clark (funded by NSF AAPF) IceProd and distributed computing support, 75% IceCube (25% ARA)

Thesis/Analysis topics: diffuse spectrum measurement, EHE neutrino searches

Andrew Ludwig Reconstruction software development, 100% IceCube

Thesis/Analysis topics: galaxy cluster search

**Ph.D. Students:**

Sarah Nowicki 100% IceCube

Thesis/Analysis topics: DirectReco event reconstruction, atmospheric muon neutrino measurements

Devyn Rysewyk Cantu 100% IceCube

Thesis/Analysis topics: Extended Galactic source search, IceACT R&D

Sebastian Sanchez Herrera 100% IceCube

Thesis/Analysis topics: Anti-neutrino tagging at low energy using Michel electrons

Jessie Micallef (funded by NSF Grad Fellowship) Core Software: Software strike team

Thesis/Analysis topics: Next-generation oscillation analysis, machine learning for low energy event reconstruction

Alison Peisker (funded by NSF Grad Fellowship) 30% IceCube (70% HAWC)

Thesis/Analysis topics: HAWC/IceCube transient searches

Alexander Harnisch 100% IceCube

Thesis/Analysis topics: TBD

Jean Pierre Twagirayezu 100% IceCube

Thesis/Analysis topics: TBD

Hieu Le DOM response/simulation calibration using neutrino-induced muons, 100% IceCube

Thesis/Analysis topics: TBD

**Computing Resources:**

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|  | **2020** | |
|  | **CPU Cores** | **GPU Cards** |
| **IceCube** | 1200 | 60 |

The Michigan State IceCube group provides the collaboration access to several large computing clusters maintained and administered by the Michigan State High Performance Computing Cluster in the Institute for Cyber-Enabled Research. The HPCC includes more 21,716 computing cores and 478 GPUs (mix of Tesla V100, K80, and K20). The IceCube group has purchased 750 cores and 8 GPUs in the cluster.

Cluster scheduling policy allows opportunistic use of all compute resources by campus users with job lengths <4 hours. Jobs making use of specialized resources, such as GPUs, have priority over all other jobs queued for those nodes. Computing resources listed reflect the average levels made available for collaboration distributed processing over the past 60 days. Note that actual throughput is lower due to central processing system failure to claim available resources (675 CPUs, 15 GPUs) and job eviction due to inaccurate advertised job run time requirements (110 CPUs, 25 GPUs).