V E R I T A S

EXPERIMENTAL OPERATIONS PLAN

prepared and maintained by

VERITAS Project Office

Smithsonian Astrophysical Observatory

Revision 2.0

1 December 2014

VERITAS
Experimental Operations Plan
(EOP)

1. INTRODUCTION

The Very Energetic Radiation Imaging Telescope Array System, VERITAS, near Tucson, AZ, provides the ground-based capability to study extremely energetic gamma rays, ranging in energy from 50 GeV to 50 TeV, potentially produced from a variety of astrophysical sources. The gamma rays are observed from the light they induce as they interact with the Earth's atmosphere. VERITAS permits unprecedented elucidation of the properties of the sources of these gamma rays. The results of the VERITAS studies of these cosmic Tevatrons / Pevatrons often have broad often have broad implications beyond the physics of the sources themselves. Topics addressed include indirect dark matter searches, cosmology, black holes, fundamental physics, and the origin of cosmic rays. VERITAS studies have many multi-messenger (neutrino, cosmic-ray and gravitational wave) astrophysics implications, and complement the ongoing efforts of the Fermi Gamma-ray Space Telescope and the High-Altitude Water Cherenkov (HAWC) observatory.

The collaboration that operates VERITAS is international in scope, and consists of ~100 scientists from 20 institutions in 4 countries.. The U.S. participants in the operation of VERITAS are supported by the Physics (PHY) division of the U.S. National Science Foundation (NSF), the Office of High Energy Physics (OHEP) in the U.S. Department of Energy (DOE), and the Smithsonian Astrophysical Observatory (SAO). Foreign participants are funded by the Science Foundation Ireland in Ireland, the Natural Sciences and Engineering Research Council (NSERC) in Canada, and the Helmholz Association in Germany. The foreign institutions involved in the VERITAS Collaboration are responsible for managing the operational funds that they bring to the project.

This document serves as the VERITAS Experimental Operations Plan (EOP) for the operations phase of the VERITAS facility, hereafter referred to as the **"VERITAS Observatory".** The VERITAS scientific program to be carried out in the operational phase of the facility, hereafter referred to as the **"VERITAS Program"**.

The EOP describes the overall project structure and management at all levels, including agency oversight and the partnership between DOE, SAO and NSF. It establishes the technical scope and baseline against which the agencies will monitor the execution of the project. Operations are supervised by the three agencies via the Joint Oversight Group (JOG). Also described is the risk management assessment associated with VERITAS Observatory operations.

2. PROJECT JUSTIFICATION AND GOALS

The scientific goals of the VERITAS Program are common to DOE/OHEP, NSF/PHY and SAO and have led to a natural partnership for support of the VERITAS Project. The VERITAS proposal was submitted to the 1999 Scientific Assessment Group for Experiments in Non-Accelerator Physics (SAGENAP). The panel endorsed the VERITAS proposal and commented that the "scientific objectives of VERITAS are well motivated." VERITAS was ranked as one of the prioritized moderate initiatives in the 2001 National Academy of Science's Decadal Survey on Astronomy and Astrophysics. The original VERITAS proposal was based on a 7-telescope array and was later proposed as a 4-telescope array with minor loss in scientific capability. The proposed 4-telescope array was favorably reviewed by an NSF proposal review panel in December 2002. The project successfully passed cost, schedule, and management reviews in April 2000 and January 2003 (the Ritz and Yeck reviews respectively).

VERITAS is a third-generation ground-based gamma-ray observatory built upon the pioneering work of the Whipple Observatory, which discovered and subsequently led the study of very high energy (VHE) gamma ray sources. VERITAS was operational prior to the launch of the Fermi Gamma-ray Space Telescope mission, which provides complimentary observations in a partially-overlapping, lower energy range. The recently commissioned HAWC observatory provides complimentary observations in a partially-overlapping, higher-energy range.

The scientific program of VERITAS centers on detecting VHE gamma rays, which are the highest energy electromagnetic radiation detected from cosmic sources. Their production is likely associated with objects under extreme conditions such as black holes, neutron stars, and extremely high concentrations of dark matter. The data provided will allow the investigation of VHE gamma-ray production mechanisms and serve as a probe of these objects. It will also be used for the discovery and study of sources such as black holes, quasars, supernovae and pulsars and will have unprecedented sensitivity for the indirect detection of candidate dark matter particles (above ~200 GeV).

3. PROJECT DESCRIPTION

The scope of the VERITAS Operations Plan is for the operation of a 4-telescope array at the SAO's Fred Lawrence Whipple Observatory. The construction phase of VERITAS began in October 2003 and ended in December 2006 upon completion and after commissioning of the 4-telescope array. VERITAS began regular observations with the full 4-telescope array in September 2007. In Summer 2012 an upgrade of VERITAS was completed, improving both the sensitivity of VERITAS and decreasing its energy threshold.

VERITAS' primary function is to measure the energy and incident direction of gamma-ray photons from space with energies from approximately 50 GeV to 30 TeV. The VERITAS telescopes observe Cherenkov radiation produced by gamma- and cosmic-ray initiated air showers. The imaging atmospheric Cherenkov technique (IACT), developed at the Whipple Observatory, is used to discriminate cosmic gamma rays from the cosmic ray background and to determine their energy and source direction. Air shower images observed using the IACT are roughly elliptical in form. The "shape" of those produced by gamma-ray primaries is relatively compact while the "orientation" of their major-axis is preferentially directed toward the source position; images associated with cosmic rays are somewhat irregular and are randomly oriented. These two properties, shape and orientation, allow more than 99% of the background cosmic ray events to be rejected while retaining the majority of gamma-ray candidates.

VERITAS consists of four 12 meter telescopes each with 345 front aluminized glass mirror segments. The focal plane of each telescope is equipped with a detector, or camera, consisting of 499 2.5 cm photomultiplier tubes (PMT). Sophisticated hardware and software are used to digitize the PMT signals 500 million times per second, implement a high-rate/low dead-time data acquisition (DAQ) system and a multi-level event trigger, perform online analysis and diagnostics, and store the data for later analysis.

4 AGENCY OVERSIGHT and ORGANIZATION

SAO, NSF and DOE have responsibilities for providing general oversight and monitoring of the VERITAS Project to help ensure effective performance and administration, as well as to provide major support and evaluation. The agency program offices charged with responsibility for the VERITAS Project are OHEP within the DOE Office of Science, the PHY Division within the NSF Directorate for Mathematical and Physical Sciences and the Smithsonian Astrophysical Observatory (SAO). The three divisions will act through a single entity – a Joint Oversight Group (JOG) – in exercising their authority for joint oversight, and coordination of the Project.

4.1 NSF, DOE and SAO Joint Oversight Group

The VERITAS Project JOG has the responsibility to see that the VERITAS Project is effectively managed and executed, and will coordinate agency policies and procedures regarding project oversight and management. The JOG will serve as the point of contact for the VERITAS Project Office with SAO, NSF and DOE. The JOG will oversee the implementation of the VERITAS Observatory Plan. Specific responsibilities of the JOG, as well as its membership, are described in the MOU between SAO, NSF and the DOE, which relates specifically to the VERITAS Project.

5. VERITAS PROJECT ORGANIZATION

The VERITAS Collaboration consists of research groups from twenty institutions in four countries, ten of whom are signatories to the VERITAS Teaming Agreement (see Appendix A). The remaining institutions who joined the collaboration during or after the construction phase and are not signatories to the Teaming Agreement. The members of the VERITAS collaboration can be found online (http://veritas.sao.arizona.edu/about-veritas-mainmenu-81/newpeople).

The VERITAS Executive Committee (VEC) serves as the collaboration's governing body. The parties to the Teaming Agreement are members of the VEC, as are two representatives of the other collaborating institutions in VERITAS. The Managing Organization, appointed by the VEC, is the organization that manages the VERITAS Project. The VERITAS Project Office is the organizational subunit of the Managing Organization that is directly involved with executing the Project. The managing organization is appointed by the Teaming Agreement and is currently SAO.

5.1 VERITAS Parties to the Teaming Agreement

5.1.1 Iowa State University The ISU group has been active in ground-based gamma-ray astronomy since 1978. They have specialized in the derivation of energy spectra, in simulations and in data analysis. The faculty members are Frank Krennrich (PI) and Amanda Weinstein. For VERITAS, the ISU group has taken responsibility for Focal Plane Instrumentation (Sub-project 6).

5.1.2 McGill University McGill University in Montreal played a major role in STACEE. McGill's contribution is particularly in the areas of mechanical design and fabrication and in electronic engineering. Recent VERITAS hardware contributions include a new mirror-facet alignment system, an improved LED-based calibration system, and the fabrication of UV-passing observation filters. The McGill group is funded by the Natural NSERC in Canada, and currently has two faculty members, David Hanna (PI) and Ken Ragan.

5.1.3 University College Dublin The Cosmic-ray Group at the University College Dublin (UCD) has roots in the very early days of ground-based gamma-ray astronomy. They built the first imaging camera for the Whipple Observatory and have specialized in the development of data reduction methods. The faculty members at UCD are Dave Fegan and John Quinn (PI). They are funded by the Irish funding agency, Science Foundation Ireland. For VERITAS, the Irish groups have collectively taken responsibility for Telescope Peripherals (Sub-project 3) and Camera Data Acquisition (Sub-project 16).

5.1.4 Purdue University Members of the High Energy Physics Group at Purdue joined the Whipple Collaboration in 1991. They have specialized in optics and optical detectors, and in data acquisition systems, in simulations and in the search for extended sources of gamma rays. The faculty members are John Finley (PI) and Wei Cui. For VERITAS, the Purdue University group is responsible for PMTs (Sub-project 4) and Data Reduction (Sub-project 17).

5.1.5 Smithsonian Astrophysical Observatory The gamma-ray group at SAO has been in existence since 1966. The 10-m optical reflector at the Whipple Observatory was completed in 1968 and remained at the forefront of gamma-ray astronomy until third generation observatories became fully operational starting in 2004. The group emphasis is on observational high energy astrophysics, particularly from extragalactic objects, and is supported by the Smithsonian, the DOE and, in some cases, by NASA. The SAO group is split between the organization's home in Cambridge, MA, and the Whipple Observatory. The PI (Wystan Benbow), who is a permanent federal scientist, and Sue Demski-Hamelin (Project Administrator) are based in Cambridge; Other members are Steve Criswell (VERITAS Project Manager), Pascal Fortin (Observatory Manager), Veronique Pelassa (Deputy Observatory Manager / IT Specialist). For VERITAS, the Smithsonian group is responsible for the overall project integration, management and operation. They are responsible for Mirrors (Sub-project 1), Telescopes (Sub-project 2), Facility (Sub-project 19), and the Project Office (Sub-project 20).

5.1.6 University of California at Los Angeles UCLA has a strong program in particle astrophysics using high-energy gamma rays, cosmic rays, and neutrinos. The faculty members involved in VERITAS are Rene Ong (PI) and Vladimir Vassiliev. Their major effort is on VERITAS. UCLA is responsible for the Level 1 CFD Trigger (Sub-project 8), the Level 3 Array Trigger (Sub-project 10), Data Archiving (Sub-project 18) and Simulations (Sub-project 21).

5.1.7 The University of Chicago For more than fifty years, the Cosmic-ray group at The University of Chicago has been a dominant group in cosmic ray research in the United States with emphasis on space-borne detectors. The group is involved in several ground-based and ballon-borne cosmic ray experiments including those using atmospheric Cherenkov techniques. The group's faculty member is Scott Wakely. For VERITAS, the Chicago group is responsible for High Voltage (Sub-project 5), VME Data Acquisition (Sub-project 13) and Camera Integration (Sub-project 14).

5.1.8 University of Leeds The astrophysics group at the University of Leeds was a member of the Whipple collaboration almost from its inception. This group no longer exists. For VERITAS, the University of Leeds group was responsible for the initial telescope Level 2 Pattern Trigger (Sub-project 9). This responsibility has since been taken on by the Iowa State University and Argonne National Lab groups, as the initial hardware was completely replaced.

5.1.9 University of Utah Ground-based studies of cosmic rays are the major activity of the Center for High Energy Astrophysics at the University of Utah whose current projects include the Telescope Array and VERITAS. The group consists of faculty member Dave Kieda (PI). The Utah group is responsible for Cabling (Sub-project 12) and Calibration (Sub-project 15).

5.1.10 Washington University The gamma-ray group at Washington University though relatively new, is closely allied to the well-established Cosmic-ray Group at WU. Their interests are in detector development and astrophysical and physical interpretation. Currently the group consists of faculty members Jim Buckley (PI) and Henric Krawczynski. For VERITAS, the Washington University group is responsible for the Flash ADCs (Sub-project 7) and for Array Control (Sub-project 23).

5.2 VERITAS Executive Committee (VEC)

5.2.1 Membership Upon signing the Teaming Agreement each party to the agreement appoints one member to the VEC. VEC members serve two-year terms and the terms are staggered in 1-year intervals to ensure continuity. Other VERITAS collaborators select two individuals from among themselves to represent Collaborators on the VEC. There four non-voting *ex-officio* members who act in an advisory capacity; these are the collaboration Spokesperson, the VERITAS Observatory Manager, the VERITAS Project Manager and the coordinator of VERITAS outreach. A VEC Chairperson serves two year terms. His/her replacement is selected at the last meeting of the VEC prior to the expiration of their term. The current VEC chair is Frank Krennrich from Iowa State University. Organizational membership of the collaboration, and of the VEC, may be modified, by a two-thirds vote of the VEC.

5.2.2 Responsibilities The VEC shall:

- determine membership of the Teaming Agreement and of the Collaboration as a whole;
- ensure that VERITAS is carried out in accordance with the terms of the Teaming Agreement;
- be the body with overall budgetary and policy control over VERITAS;
- meet at least twice per year;
- define, appoint, and review, as necessary, such committees as the VEC deems necessary;
- provide guidance to the Managing Organization and Project Office on the content of their management plans;
- review the job descriptions and appointments of the key VERITAS Project Office staff;
- ensure that all agreements between the Managing Organization and sub-awardees do not conflict with the Teaming Agreement;
- review and approve assignment of responsibility for carrying out the Project by defining Sub-project Teams and Team Leaders;
- review and approve proposals pertaining to VERITAS construction, operation and science;
- review and approve proposals pertaining to upgrades to the VERITAS instrument and for additional instruments utilizing the VERITAS site;
- appoint the Project Scientist to be the director of the site-operations of VERITAS. The Project Scientist shall report to the VEC;
- appoint the Project Manager to manage the operations of VERITAS. The Project Manager shall report to the Project Scientist.
- determine the policy on access to observing time on VERITAS;

5.2 VERITAS Science Board (VSB)

The VEC established and determines the membership of a VERITAS Science Board which governs the science program of VERITAS. The scientific governance is described in a VERITAS Science Board Document (see Appendix A). The science organization of VERITAS is shown in Figure 1.

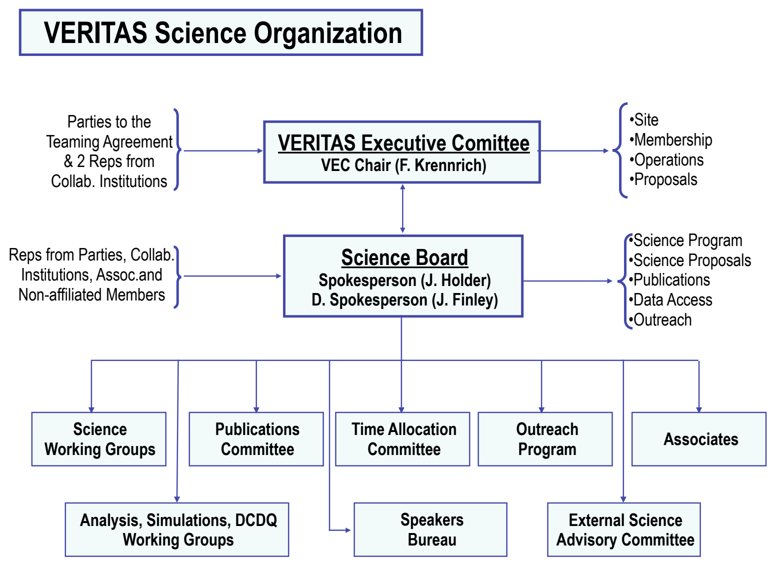

Figure 1: VERITAS Science Organization

5.2.1 Membership The VERITAS Science Board is made up of representatives of each of the Parties and representatives from institutions deemed by the VEC to be Collaborators. VERITAS Members who are not affiliated with a Collaborating Institution (Non-Affiliated Members) are represented collectively by one voting member on the Science Board. VERITAS Associate Members are represented collectively by one voting member on the Science Board. The different classes of membership are described in the Science Board Document. The VEC Chairman, the Project Scientist and the Project Manager, defined in the Teaming Agreement, are *ex officio*, non-voting members of the Board. The VEC Chairman and the Project Scientist vote only in the case that they are also regular members of the Board. The Observatory Manager is an *ex officio*, non-voting, member of the Board.

The VERITAS Science Board will select and be chaired by the Spokesperson (currently Jamie Holder; University of Delaware). A Deputy Spokesperson (currently John Finley; Purdue University) will also be selected by the Science Board. Both the Spokesperson and the Deputy Spokesperson serve two-year terms.

5.2.2 Responsibilities The VSB provides scientific leadership to the Project and is the primary forum for related interactions and decisions. It meets at least twice a year, and typically every few weeks, and has oversight over:

- the science goals and science policy of VERITAS;

- scientific collaboration with individuals not directly associated with VERITAS;
- access to observing time on VERITAS
- data access privileges
- publication of papers and articles, ands act as arbiter in any disputes over authorship;
- representation of VERITAS, and the reporting of results, at conferences and meetings,
- the External Science Advisory Committee (ESAC),
- the education and public outreach program, and
- public information

5.2.3 VSB Committees There are currently three standing (sub)committees of the Science Board:

- The VERITAS Time Allocation Committee (TAC) is responsible for the organization of the VERITAS observing program. This committee consists of representatives elected from the Collaboration on a yearly basis. The committee collects and ranks observing proposals that are submitted, and from the successful proposals, it determines the program of observations. It also carries out the scheduling of the overall observing program. A summary of the general methodology for how the VERITAS observing program is determined can be found in Appendix A. The current chair of the TAC is Manel Errando (Columbia University).
- The VERITAS Publication Committee (VPC) is responsible for oversight of VERITAS talks and publications . The recommended procedures for publication of VERITAS results are discussed in Appendix C of the Science Board Document. The current chair of the VPC is Martin Pohl (University of Potsdam).
- The VERITAS Collaboration Speaker's Bureau (VCSB) organizes VERITAS participation in scientific conferences. The VCSB charge in Appendix A describes the role and responsibilities of the Speaker's Bureau. The current chair of the VCSB is Andy Smith (University of Utah).

5.3 Managing Organization

The Teaming Agreement appoints the SAO to manage the VERITAS Project. The SAO has created the VERITAS Project Office to manage the execution of the Project.

5.4 VERITAS Project Office

The VERITAS Project shall be managed by the SAO, through the VERITAS Project Office, in accordance with the EOP. The VERITAS Project Office is responsible for preparation and maintenance of the EOP, with guidance from the JOG. The Project Office is responsible for implementation of the EOP. The organization of the Project Office is indicated in Figure 2.

5.4.1 Responsibilities The VERITAS Project Office will:

- be responsible for the overall management of VERITAS in accordance with the EOP;
- prepare and submit proposals to U.S. Funding Agencies for site-operations funds;
- serve as the interface with the JOG with regard to the program phase;
- employ VERITAS Project staff;
- carry out the decisions of the VEC;
- report at least once per year to the VEC on the progress of the VERITAS program;
- ensure the collaborators have access to the Project Office and to the experiment's site
- monitor costs and performance of all contracts and sub-awards;

- keep proper records and accounts;
- receive and maintain records of contributions from member institutions;
- adhere to the procedures for authorizing requisitions, commitment, obligation, and expenditure of funds as set forth in its rules and the rules of the Funding Agencies, and
- prepare and submit reports as required by the JOG and the award instruments of the funding agencies.

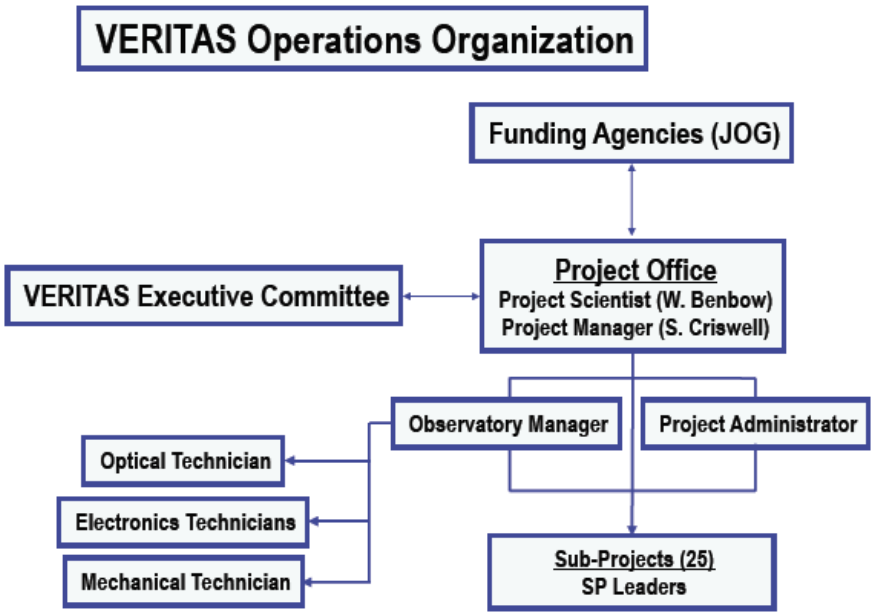

Figure 2: The organization of the VERITAS Project Office.

5.4.2 Personnel Members of the Project Office will be employed by the Managing Organization. Aside from the Project Scientist, they are all based in Arizona and the members include:

Project Scientist The VERITAS Project Scientist reports directly to the VEC and the Science Board, and is responsible for ensuring that their policies are adhered to and their instructions are carried out. He/she is responsible for the VERITAS Project Office and for the overall management of VERITAS. He/she is the PI for all proposals supporting the Project Office and its activities, and is responsible for their implementation. He/she provides direction to the Project Office via the Observatory Manger, and is the primary point of contact with the funding agencies. The present incumbent is Wystan Benbow.

Project Manager The VERITAS Project Manager reports to the Project Scientist and manages the Project Office. He/she provides project management for the total project. He/she has fiscal control of all Project Office finances and is responsible for all site related activities. The present incumbent is Steve Criswell who was the VERITAS Construction Project Manager.

Observatory Manager The Observatory Manager provides assistance to the Project Manager and acts as Project Manager during his/her absence. He/she reports to the Project Scientist. The Observatory Manager supervises the operations staff and all on-site operations activities, including maintenance, equipment installation, and modification of existing equipment. He / she is responsible for for interface with the VERITAS scientists, including operations schedule planning and for coordinating the on-site activities of other groups. He / she is the Project Safety Officer, and is responsible for ensuring that VERITAS adheres to the Smithsonian Institution health and safety requirements. The present incumbent is Pascal Fortin and is an active VERITAS scientist.

Project Administrator The VERITAS Project Administrator is responsible for for all administrative duties related to Project Office activities. He / she maintains the project schedule and the project fiscal records, assists in the preparation of fiscal and other reports. These include annual budget, contract and grant submissions, and the Administrator aids in assembly and submission of the required documentation. He / she reports to the Project Scientist. The present incumbent (0.3 FTE) is Sue Demski-Hamelin.

Deputy Observatory Manager / IT Specialist The VERITAS Deputy Observatory Manager / IT specialist is responsible for maintaining, servicing and upgrading all on-site computer systems. These include computers integral to the telescopes, cameras, camera electronics, calibrations systems and the facility (e.g., array control, local archive, Project staff). He / she is responsible for insuring the compatibility and adherence to established specifications (hardware and software) of all on-site computing systems; he / she is required to be familiar with all software developed for use with VERITAS He / she maintains all VERITAS network hardware, electronic logs, web servers, internet security (e.g. firewalls), email servers, on-site databases and computing clusters. He / she maintains a comprehensive set of system and software documents. He / she also serves as deputy to the Observatory Manager. The present incumbent is Veronique Pelassa and is an active VERITAS scientist.

Electronic Technicians The two Electronics Technicians (ETs), George Jones and Paul (Jack) Musser, are responsible for troubleshooting, repair or replacement of all electronic systems associated with the VERITAS telescopes, cameras, camera electronics, calibration systems, and the test and repair facilities. The ETs have primary responsibility for maintenance of the telescopes and associated alignment and calibration systems. These responsibilities include routine maintenance of telescope positioners, optical alignment hardware and pointing correction hardware, as well as fabrication of any small fixtures used in mounting instruments on the telescopes, etc. They are responsible for maintaining a comprehensive set of operating and maintenance documents for all on-site mechanical and electrical systems, a repair history for all major components, and a log of maintenance and related activities. The ETs also insure that consumables and spares are available. The ETs also serve as the VERITAS Accountable Property Officers. The ETs report to the Observatory Manager.

Optical Technician The Optical Technician (OT), Emmet Roache, is responsible for maintaining the mirror facets and optical support structure of the VERITAS telescopes. He establishes and implements a work schedule such that all 1400 facets are removed, stripped, aluminized, anodized, tested and remounted on the telescopes on a 4-year cycle. The OT cleans the facets (in-situ, on the telescopes) monthly. Mr. Roache is responsible for maintenance and repair of the vacuum coating system, anodizing tank and mirror test stand and for maintaining testing records. He is responsible for maintaining the spare facets inventory and the supply of consumables used in facet re-coating. He is also the Fall Safety Officer, trains all staff / visitors for work at high-distance above ground, and maintains the appropriate safety gear. The OT reports to the Observatory Manager.

Mechanical Technician The Mechanical Technician (MT) is responsible for maintenance of all on-site structures; this includes utility, water, waste disposal and fire control systems. The MT performs general maintenance of the site including roads, walkways, drainages, communication trenches, etc. The MT deals with shipping and receiving, and performs minor vehicle maintenance. The MT is qualified to operate on-site heavy equipment. Their maintenance duties are supplemented by specialized trade/craft assistance (electrician, plumber, carpenter, metal worker, crane operator, etc.) at FLWO. The MT reports to the Observatory Manager.

5.5 VERITAS Groups / Sub-projects

To ensure that VERITAS technical and other developments are coordinated, the Project has been divided into four Groups — Camera, Management, Optics/Mechanical and Software — which encompass twenty-five Sub-projects (SP) (see Appendix B). Sub-projects are the working units and are typically associated with a particular member institution. Unless otherwise stated, member institutions are responsible for maintaining those systems/components which they contributed to the VERITAS Project during its construction.

5.6 VERITAS Technical Working Groups

It is critical to the scientific objectives of VERITAS that the instrument simulations, the data quality monitoring, and the data calibration are as well-considered as possible. Therefore dedicated science working groups have been formed for each of these topics; The charge an implementation strategies for the Simulations Working Group (SimWG) and for the Data Calibration / Data Quality (DCDQ) Working Group are found in Appendix A. Offline analysis working groups also exist to further develop the two standard data reduction packages of VERITAS.

6.0 PROJECT MANAGEMENT

6.1 Reporting, Reviews, Meetings and Advisory Panels

The VERITAS Project Office makes use of a range of tools to serve the needs of project management. The objective of regular reporting is to document technical, cost, and performance results. Meetings, such as the biannual collaboration meetings, promote broad based, typically member initiated, communications while those of a more focused nature (e.g., Software Standards) target a specific goal. These reporting and review procedures play a central role in managing and monitoring the progress of the project.

6.1.1 VEC Initiated Reporting and Reviews As directed by the VEC, each VERITAS sub-project must submit status reports. These reports permit the Project Office to monitor the overall status of the project and include:

- **Quarterly Reports** Each sub-project must submit narrative reports to the project. These reports are required on a quarterly basis.
- **Weekly Reports** During weekly conference calls the Observatory Manager, discusses, by telephone, the status of sub-projects with Sub-project Leaders.

6.1.2 Agency Reporting and Review Requirements The "Funding Agreement" between the Managing Organization (SAO), DOE and the National Science Foundation specifies the frequency and nature of reports which the Project Office is required to provide. Quarterly reports detail such topics as technical and fiscal status. Annual reports summarize quarterly results, provide project and sub-award (i.e., sub-project funding) budgets for the coming year, a listing of publications, etc.. The contents and schedule of these reports are detailed in the aforementioned Funding Agreement.

The JOG attempts to coordinate their reporting and review requirements so as to minimize their impact on the Project Office.

6.1.3 Meetings Meetings, both general and topical, are held regularly. They include:

- **Collaboration Meetings** At least twice per year there will be a general meeting of the entire collaboration. These meetings serve as the primary venue for discussing ongoing analysis, the preparation of papers and the status of observations. During the collaboration meeting the Project Office will provide a summary of the budget and resource status of the project. The VEC and Science Board will each meet during each collaboration meeting.
- **Other Meetings** The VEC meets at least twice per year or more frequently as circumstances dictate; minutes of VEC meetings are kept and distributed to all members. Similarly, the Science Board meets via conference calls at least twice per year and typically once per month; minutes of the meetings are kept and distributed to all members. The Project Office and Sub-project Leaders hold regular weekly telephone conferences.

6.2 Other Management Procedures and/or Policies

6.2.1 Risk Assessment and Management The risk management process consists of four overlapping stages: (1) risk planning, (2) risk identification, (3) risk analysis and (4) risk mitigation and tracking. A risk management program has been developed to address the likelihood of an undesirable event occurring and to minimize the severity of the impact of such an event should it occur. Table 1 shows the areas of VERITAS site-operations risk. The principle areas of risk which were identified included: project funding and personnel changes.

Table 1 VERITAS Site Operations Risk (per annum)

Title	Description	Action Taken	$ at Risk	Chance	Est. $s	Comments
Lightning Strike	Lightning strike takes out a camera or electronics	Install and maintain good lightning protection. We spend significant effort to disconnect and reconnect during the summer monsoon season.	$250,000	20%	$50,000	Location in a valley helps reduce the risk. Non hangared telescope are always at risk. Hangars are expensive.
Funding Reduction	Agencies unable to funds at the requested level or time.	Do good science, meet budgets, meet schedules and hope for the best.	$500,000	10%	$50,000	Funding reductions will first impact scientific output and then time on the sky.
OSS Strike	OSS strikes something at high speed.	Training - We are moving heavy steel with software and we must be vigilant	$50,000	25%	$12,500	Either the gears strip or the OSS deforms. There have been 4 events, & in each the OSS bent what it hit; Solutions developed; No events in 4 years.
Resignation of Electronic technical Staff	At the basecamp we depend heavily on a small group of highly motivated people. The lost of a person will mainly impact system readiness.	Cross train and treat people well.	$50,000	20%	$10,000	$ cost is time to bring new tech up to speed. The Federal system makes retention difficult at times. It took time to get two good techs.

Resignation of Mirror lab staff	Currently one person strips and coats ~400 mirrors a year. If he were to leave, mirror coating would slow down until a new person was hired and trained.	We have documented the procedures and have an ongoing relationship with the engineer who designed the system. He could train a new person.	$100,000	10%	$10,000	Industry does not currently anodize mirrors. There we must figure out how to do this on our own. Cost shown is for one year salary for the new tech and consulting fees for the engineer.
FADC Repair	The FADC boards have had a very low failure rate. Nonetheless, if WU was not available to repair boards, we would loss considerable time educating another group.	We keep spares.	$100,000	10%	$10,000	Costs shown are salary and travel to help bring the new person up to speed.
Post Doc turnover	Considerable expertise will be lost as PD's move on.	The collaboration has modified its rules to encourage PDs to maintain their connection to VERITAS	$30,000	20%	$6,000	
Overhead	The overhead rates of the institutions increase.	Hope for the best.	$10,000	50%	$5,000	Generally does not change by more than 0.5% per year
Positioner Failure Mechanical	A failure of bearings, gear boxes or motors.	Routine maintenance; Healthy supply of spares	$250,000	1%	$2,500	Telescope bearings operate at slow speeds and generally do not fail. Aside from minor problems with the motors and brakes, the positioners are dependable.
Collaborator - Designer turnover	The original designers and maintainers will disperse. For the most part, they have retained their connections to VERITAS.	The collaboration has modified its rules to help retain this staff.	$20,000	10%	$2,000	Most have maintained their involvement with VERITAS after change. Costs shown are salary and travel to help bring the new person up to speed.
Black Helicopters	Helicopters with search lights are natural enemies of astronomers.	We work with the Border Patrol and have had few issues. None recently	$150,000	1%	$1,500	Several incidents, but no major damage was done. Automatic current switches work.
Subawards	Salary increases at subaward institutions	Budget for the increases	$10,000	5%	$500	
Mirror Reflectivity	Mirrors lose a few percent yearly. If rate doubled we would need to re-coat more often.	Continue coating mirrors with our demonstrated system.	$50,000	1%	$500	We have extensive experience with the 10-meter and VERITAS telescopes.
Vandalism	The basecamp could be vandalized.	We have fences. Shooting out mirrors is possible, but we have had no problems.	$20,000	2%	$400	Alarms are difficult to use with the 24 hour activity. Few problems at basecamp in past 20 years.

Cost of Utilites	The VERITAS project utilites bill is estimated at $136k.	VERITAS building was designed to LEED standards.	$0	0%	$0	SI's commitment is to pay the electric bill, not provide a fixed $ amount.
Site Access 2	Lack of BASECAMP site access due to Forest Service action	Signed new agreement with the Forest Service.			$0	Unlikely under current agreement.
Retirements	Senior staff retirements	Retirements were staggered.		100%		No costs are assigned.
Animal Encounters	Bears, ring tail cats, rattle snakes have all visited the basecamp site.	Use flashlights. Do not feed the animals. Brief staff		0%		Do not know how to assign cost.
Site Access 1	Lack of site access due to demonstrations	Actions by TON or others				During EA process, we were not subject to demonstrations.
Scientific workload	The scientific and engineering VERITAS staff is limited. New TeV projects (CTA) could impact operations.	Most of the work for CTA takes place at the collaborating institutions not the VERITAS site.				This impact should be manageable.
UDAs and others	At night the basecamp area is active with UDAs, drug transporters and government agencies chasing them.	Brief the observers.				We have had only minor issues in the several years FLWO has used the basecamp site.

6.2.2 Safety, Environment, and Health SAO maintains compliance with the Smithsonian Institution's safety requirements. The SAO (i.e., Harvard-Smithsonian CfA) Safety Office performs regular (yearly) safety inspections at the Whipple Observatory including the summit, ridge and basecamp facilities. The VERITAS Project participates in the SAO/SI safety program. VERITAS has adopted a number of task specific safety policies including: no solo work at night or on man-lifts, man-lifts and fork-lifts only to be operated by certified individuals, etc. The VERITAS safety officer coordinates all aspects of the VERITAS Safety program. Anyone planning to carry out on site work or intending to observe must read the FLWO User's Safety Guide before arrival, take part in a safety briefing provided by the Project Office and read a VERITAS-specific safety document on the internal project wiki. Both the User's guide and the VERITAS safety document can be found in Appendix A. Individuals who violate the safety guidelines are asked to leave the site.

6.2.3 Conflict Resolution Most decisions, particularly those of a technical nature and which do not impact the baseline performance requirements, are made at the Sub-project level. If conflicts arise, decisions can be appealed to the Group Leader. If the Group Leader is unable to resolve the issue, or if it involves more than one group, the Project Office becomes involved. If the Project Office is unable to settle the matter, the VEC arbitrates.

6.2.4 Financial & Business Operations Controls The SAO Subcontracts and Procurement Department is responsible for procuring all goods and services required by the VERITAS Project. The authority to make purchases under $3,000 has been delegated to Whipple Observatory.

In general, the Purchasing Section of the Department is responsible for procurements that are under the Simplified Acquisition Threshold (currently $150,000), have a period-of-performance less than one year in length, and use the Terms and Conditions of a Fixed-Price Supply or Service type contract whereas the Subcontracting Section deals with procurements that are over the Simplified

Acquisition Threshold, are of a multi-year duration, or require special Terms and Conditions such as those required for Cost Reimbursement, Research & Development, Time & Materials, or Labor Hour type contracts.

The procurement of supplies, materials, equipment, services, and building construction, alteration and repair with appropriated funds are governed by those provisions of the Federal Acquisition Regulation (FAR) and other federal regulations appropriate to the Smithsonian Institution's role as a trust instrumentality of the United States.

6.3 Advisory Groups

In response to early reviews, an External Science Advisory Committee was formed. The ESAC is a representative panel of distinguished U.S. scientists drawn from the fields of high-energy astrophysics and particle physics. The committee presently has eight members. The ESAC's formal charge is as follows:

> "The External Advisory Committee will be composed of 9 scientists drawn from the high energy astrophysics / high energy physics community. The EAC will typically meet once per year in Tucson, but might be called upon at other times if needed. The purpose of the committee will be to provide high level scientific guidance to the collaboration. Members of the VERITAS collaboration, e.g., project science, engineering, and management teams will give short briefings. The External Advisory Committee will provide a summary to the PI with recommendations, suggested plan of action, and general observations after conclusion of the meeting."

The ESAC's first meeting was held in 2004. Subsequent meetings were held in 2005, 2007, 2009, 2011, and 2014 Their reports are made available to the VERITAS Collaboration and to members of the JOG. The most recent report (2011) of the ESAC can be found in Appendix A. The report from the meeting in November 2014 is in preparation.

6.4 Data Management Plan

There are significant quantities of various forms of data produced by VERITAS each year (~45 TB / year; ~311 TB total as of September 2014). The data storage methodology is detailed in a management plan that was presented to, and reviewed by, both the various funding agencies and previous review committees. The VERITAS data management plan has functioned well and without incident for the past 7 years of operation. A document briefly summarizes the VERITAS Data Management Plan for VERITAS, as does a presentation on the VERITAS Data Archive and Distribution principles. Both can be found in Appendix A.

7. RESOURCE PLAN

U.S. site-operation funding is jointly held and managed by the VERITAS Project Office. Foreign contributions are provided in-kind. VERITAS is currently funded for the period 2013-2016. The cost of maintaining and operating VERITAS over this 3-year period is $4.275 million. These operations costs are supported by the DOE, the NSF and the SAO, each with an equal one-third share. The budget was based on six years of experience operating the facility. The annual operations budget is currently about 6.8% of the construction cost of the experiment (summing the 4-year construction, control building and upgrade costs but excluding significant, difficult to quantify R&D expenses and in-kind contributions from SAO). Details of the current budget are given below. In Fall 2015, the Project Office will apply for new research funds to support operations from 2016-2019. For this period, the SAO has committed to its share of operational support at the current level ($475k / yr; $1.425 million total). It is anticipated that the budgetary request to NSF and DOE for this period will be significantly less than the nominal two-thirds share of the current budget ($2.85 million). An exact figure is not possible at this time as it depends on the success of an experimental reduced spending plan implemented in 2014 (15-20% less; >$220k / yr less) and if the next funding cycle coincides with a potential project sunset date.

This site-operations budget does not include the salaries of the PI (Wystan Benbow), nor the Project Manager (Steve Criswell). The site-operations budget also does not support the VERITAS science groups, nor does it provide observers, maintenance of some high-level systems, teams for complex tasks, or data quality monitoring. These activities are all provided scientific base (operations) grants from both the DOE/OHEP and the NSF, to academic personnel at institutions and universities involved in the VERITAS Project. These grants depend on successful review of the proposals and availability of funding.

Operations funds are disbursed by the Project Office as sub-awards to collaborating institutions or via sub-contracts to private vendors. Estimated costs for all sub-awards and sub-contracts are contained in the operations funding request to the Agencies. Sub-contracts to vendors are made through the SAO “Sub-contracts and Procurement Office” in accordance with standard government bidding procedures. Sub-awards to institutions are based upon quotations, prior procurement costs, and detailed labor cost estimates. Before sub-awards are granted these costs are reviewed and revised as appropriate. As with sub-contracts, sub-awards are made through the “Sub-contracts and Procurement Office” via a negotiated contract between SAO and the recipient. The fiscal provisions of sub-awards are monitored both by the VERITAS Project Office and by SAO.

7.1 Salaries

Approximately 54% of the current budget pays for the salaries, benefits and overheads for the 7 VERITAS Project Office employees described earlier. These are the Observatory Manager, the Project Administrator (0.3 FTE), the IT Specialist, the two Electronics Technicians, the Optical Technician and the Maintenance Technician. Due to the unique nature of VERITAS and its peculiar, custom-built systems both the Observatory Manager and the Deputy Observatory Manger / IT Specialist are scientists. All employees are paid following the standard Government Pay Scale.

7.2 Sub-Awards to Collaborating Institutions

Approximately 15% of the budget (including pass-through) funds the annual sub-awards issued by the VERITAS Project Office. Several high-level VERITAS systems require special skills and / or resources for maintenance. Here responsibility is delegated to the appropriate collaboration institution which provided the components for VERITAS, and any significant specific costs for these university groups to maintain these sub-systems are supported via sub-awards from this grant. The sub-awards cover the specific costs of maintaining and repairing the focal plane instrumentation, the electronics readout system, the data acquisition system, the data archive, the electronics and PMT testing systems, the multiple VERITAS trigger systems, and other VERITAS electronics. The only travel allowed with the sub-award funding is to bring technical personnel to the VERITAS site for specific technical work (i.e. observing is not funded).

7.3 Utilities

These are 11% of the budget and are an unavoidable component of operating the instruments. These include the costs of electrical power (primarily), maintenance of the high-speed microwave-communication link, fuel for the back-up generator, and telecommunication expenses.

7.4 Materials & Equipment

These expenses comprise 9% of the budget, and cover the replacement costs of miscellaneous electrical and mechanical components for VERITAS, high-voltage equipment and components, cables, and connectors. They also cover tools, office supplies, safety supplies, facility supplies, and new optical/telescope equipment and components. As significant portion of these funds are used to replace networking equipment, site-operation computers and their peripheral devices on a staggered schedule. The project carefully monitors its consumption of the various components, and the budget is based on the historical burn rates. No acceleration of the historical burn rate is assumed.

7.5 Services

These expenses comprise 4% of the budget, and include: janitorial and related facility maintenance, miscellaneous tradesman services, safety-related services, and heavy-equipment (e.g. man lifts) certification. Services for VERITAS specific systems are also included, e.g. for the electronic cooling system (fans, chillers and AC), for the UPS-equipment maintenance, and for repairs of the high-voltage system. Other services include a two-"room" conference calling system for VERITAS Project Office, Working Group and Committee meetings, and the costs of hosting various project-related meetings in Tucson.

7.6 Travel

Travel expenses comprise 6% of the proposed budget, and include the following:

- Project Scientist visits to the VERITAS site;
- Attendance of Project Office personnel at one collaboration meeting; one meeting is historically held in Tucson;
- Attendance of Project Office personnel at an annual VERITAS technical workshop
- Trips for Project Office personnel to attend Smithsonian-mandated training
- Trips for Project Office personnel to meet with agency representatives
- Travel for members of the External Science Advisory Committee to attend a review meeting
- Travel for the Observatory Manager and the IT Specialist to attend a one-week conference per year; both are active scientists.

7.7 Shipping

Minimal expenses are included cover the costs of shipping, sometimes bulky, components offsite for repairs.

8.0 PROJECT BASELINE

The four VERITAS telescopes are permanently installed at the Whipple Observatory Basecamp. Operation of the VERITAS telescopes at the Whipple Observatory Basecamp is possible because the U.S. Forest Service, the Smithsonian's landlord at the Basecamp, has permitted the operation of VERITAS as part of its 20-year Term Special Use Permit which is valid until 2028. The baseline for engineering-operations at the FLWO Basecamp are discussed herein and include:

8.1 Facility Description

The baseline facility includes infrastructure and buildings as follows:

8.1.1 Major Infrastructure VERITAS' major infrastructure components include:

- utility services, specifically power and communications, connecting the site to the existing service infrastructure at the FLWO Basecamp;
- an individual UPS for each telescope;
- trenching and conduit for distribution of utilities on the site; and,
- pads and foundations for the support and servicing of 4 telescope elements and for associated water-chillers and HVAC systems.

8.1.2 Buildings The facility includes the following buildings:

- a central control building housing the control room, offices for the Observatory Manager and the Deputy Observatory Manager / IT Specialist, an electronics workshop with office space for the 2 Electronics Technicians, an open office area with wired cubicles for 5 visitors, an electronics room, a conference room, a kitchen, a restroom, and storage areas.
- Shared use of the FLWO administrative complex, including a machine shop, a mirror coating lab, office space, warehouse storage, a visitor's center and a motor pool.
- Sheds at each telescope for the UPSs; and,
- an electronics trailer at each telescope.

8.2 Technical Scope

The technical scope of the VERITAS Project, i.e. the observational metrics required to achieve the science goals, consists of the following:

- to maintain a 4-telescope array in operation at the FLWO Basecamp; and
- to attain the following observing efficiencies (per year):
  - >900 h of observational (science) data;
  - >90% of observational data with 3 or more telescopes operational;
  - <8% of potential observing time to be used for engineering (excluding calibration);
  - <10% down time, due to electronic, mechanical or electrical failures.

The typical observing time achieved per year is approximately 1000 hours in good weather conditions and low-levels of moonlight These values are obtained from nightly run-logs and a corresponding data base, and are summarized in the quarterly reports to the JOG.

8.3 Performance Scope

The performance characteristics of the VERITAS array are indicated in Table 2 and are sufficient to meet the project's science goals. In Summer 2012, an upgrade to VERITAS was completed, reducing the experiment's energy threshold and increasing its sensitivity (i.e. the time required to detect a 1% Crab Nebula Flux source).

Parameter	Upgraded Array
Peak Energy	~100 GeV
Energy Range	~60 GeV to ~30 TeV
Energy Resolution	~15%
Angular Resolution	~0.1º

Source Location (absolute pointing)	<0.025º
1% Crab Nebula Flux Detection	<24 h

Table 2 VERITAS – Performance Capabilities

9. SCIENCE PROGRAM

VERITAS began routine operation with the full four-telescope array in September 2007. During the initial operations of VERITAS, an ability to observe during periods of partial moonlight (<30% illumination) was developed. This increased the observing yield by about 25% from the initial 800 h / year expected, and we now acquire approximately 1000 hours per year of good-weather observations. The annual VERITAS observation yield is shown in Table 3. Towards the end of the 2011-12 observing season, a new capability to observe during all phases of the moon was developed. VERITAS now acquires another ~30% more data (~300 h). As these bright-moon data are less sensitive, have higher threshold and are subject to larger systematic issues than normal observational data, they are accounted for separately. Although the first scientific publication from this bright-moon program will be published in early 2015, the program's continuation will continue to be evaluated annually for variety of cost-benefit and maintenance reasons.

Season	Time [h]	Dark [h]	Moon [h]	A / B [h]	4 Tel. %	≥3 Tel. %
2007-08	1004	876	128	893	96	100
2008-09*	1151	909	242	1001	81*	99*
2009-10	1133	980	152	962	94	100
2010-11	1192	997	196	1053	93	100
2011-12	1160	907	253	1058	93	100
2012-13	1097	909	189 (276)	937	92	100
2013-14	1124	967	157 (325)	942	94	100
Average	1123	935	188	978	92 (94)	100

Table 3: Each season's observation yield and its break down into dark / moonlight time, good (A/B) weather data and the fraction of these data with all 4 and at ≥3 telescopes operating. In 2012-13 & 2013-14, the moonlight time also shows the additional bright-moon program time in parenthesis. A telescope was taken offline for 1.5 months in May 2009 for its relocation (asterisk), and the average 4-telescope percentage is given with and without this period.

The VERITAS Science Program is managed by the Science Board (VSB), which decides the broad science goals and the make-up of the Science Working Groups (SWGs) and the Time Allocation Committee (TAC). During 2014, the VSB organized the development a long-term observation program for VERITAS assuming operation through at least 2017, with an overall view of operation through 2019. This long-term plan (LTP; see Appendix A) was developed by members of VERITAS, with input from the larger scientific community. It built upon the work of the 2011 LTP that was strongly endorsed (see Appendix A) by the VERITAS External Science Advisory Committee (ESAC). The themes, pillars and "general science drivers" of new LTP are unchanged from the 2011 LTP, but the program now has a strong legacy focus, with particular emphasis on leveraging the unique US assets (e.g. Fermi, Swift, Auger, IceCube) with no near-term successor, or that are about to come online (e.g. HAWC, Advanced LIGO). The VERITAS science program will to follow the guidelines outlined in this LTP, as is successfully did with the prior incarnation from 2011-14. This plan was submitted for endorsement by the VERITAS ESAC in November 2014 and the preliminary feedback was very enthusiastic (the formal report is in preparation).

Seventy percent of VERITAS observation time is pre-allocated in the 2014 VERITAS LTP. For the remaining 30% of dark and dim-moon time, as well as all bright-moon time, the SWGs will organize observation proposals each year, both for VERITAS and for complementary external observatories, to address the themes of the LTP. These SWGs are:

- **Blazar SWG:** The coordinator is Amy Furniss (Stanford) and the deputy coordinator is Matteo Cerruti (SAO).
- **Galactic SWG**: The coordinators are Gernot Maier (DESY) and Brian Humensky (Columbia University)
- **Dark Matter, Astroparticle Physics and Extragalactic Non-blazar Working Group:** The coordinators are Rene Ong (UCLA) and Ben Zitzer (Argonne National Lab).
- **Gamma-ray Burst SWG:** The coordinator is David Williams (U. California, Santa Cruz) and the deputy coordinator is Jeremy Perkins (GSFC/UMBC/CRESST).

All VERITAS observation proposals are evaluated by the TAC in September as part of an annual open competition. There will also continue to be an up ~100 h allocation available for Director's Discretionary Time (DDT) granted by the Spokesperson. This is for observations of targets that recently became particularly interesting and were unable to be considered by the TAC. It also includes time for engineering projects to improve the array. Figure 3 shows the planned break down of observations.

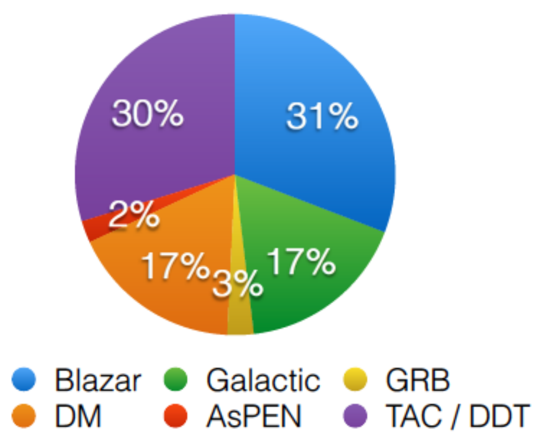

Figure 3: Breakdown of planned VERITAS observing time by topic: Blazars, Galactic objects, Gamma-ray bursts (GRBs), Indirect Dark Matter (DM) detection), AstroParticle-Extragalactic-Non-blazar (AsPEN) objects. Aside from the time granted in the annual TAC competition or via DDT channels, only the pre-planned topical allocations are shown. It is possible that the allocations for any given topic (e.g. Dark Matter) will exceed the pre-planned amount in a single year.

9.1 VERITAS Long-term Science Program:

The LTP is based on the projected "ultimate" accomplishments of VERITAS given a typical annual observation yield of 970 hours (A/B weather). During the planning, strong consideration was given to creating a balanced program in fundamental physics and astrophysics. The plan is based on 4 major themes of scientific exploration: Particle Physics and Fundamental Laws, Cosmology, Black Holes, and Galactic Tevatrons / Pevatrons.

9.2 Particle Physics and Fundamental Laws:

The origin of dark matter (DM) is one of the most compelling mysteries facing 21st century physics and astronomy. In the standard scenario, where DM is comprised of weakly interacting massive particles (WIMPs), DM annihilation in astrophysical regions with a large concentration of DM would produce a clearly recognizable signal of VHE γ-rays. This indirect detection technique provides an important complement to direct-detection experiments underground and to searches for new particle physics at the LHC. Even if the LHC detects evidence for super-symmetry, only astrophysical VHE γ-ray measurements can reveal the distribution of dark matter in haloes. In addition, the characteristic shape of the VHE spectrum provides crucial information on the particle mass and branching ratios beyond the capabilities of direct-detection experiments and the LHC. As the world's premier VHE detector, VERITAS will make the most-sensitive searches for dark matter in the mass region above 200 GeV. Since the predicted signal for DM sources outside the Galactic Center are predicted to be very weak, long, dedicated exposures on the most promising dark matter targets are required.

In addition to dark matter searches, VERITAS has significant sensitivity to other aspects of particle physics, including searches for axion-like particles and primordial black holes that could be created in the early universe. The detection of fast VHE γ-ray flares from a GRB or a blazar will allow VERITAS to make the most sensitive tests to date of Lorentz-invariance violation, especially for quadratic ($\sim E^2$) and higher-order terms in the electromagnetic dispersion relation.

9.3 Cosmology

VERITAS observations of distant blazars, and possibly GRBs, are used to make significant cosmological measurements. The γ-ray spectra of blazars/GRBs are modified by interactions with intergalactic radiation fields through pair-production (γ γ to e^+ e^-) and subsequent cascade processes. As a result, these spectra contain an imprint of the extragalactic background light (EBL) and the intergalactic magnetic field (IGMF).

The EBL is the combined flux of all extragalactic sources integrated over the entire history of the universe, and its calorimetric information carries unique information regarding the epochs of galaxy formation and the history of galaxy evolution. Detailed measurements by VERITAS of a number of blazars at different redshifts will enable the first reliable determination of the density and spectrum of the EBL in the optical-IR band, which is also sensitive to the dark matter content of the universe and its evolution. Since VERITAS has a catalog of 29 blazars extending out to redshifts of >0.6, a multi-year observing program makes an EBL-*measurement* possible.

Currently there are only weak constraints on the IGMF and no direct measurements. The γ-ray beams from AGN / GRBs provide a measurement of the IGMF strength not accessible to other techniques. A measurement of the IGMF would have profound cosmological implications because it implies a primordial field produced in the early universe. Even a good constraint on the IGMF has high value, and recent work combining Fermi-LAT and VHE blazar measurements already provide the first reliable *lower bounds* on the IGMF. Using multi-year blazar studies, VERITAS will use three different observables to constrain or determine the IGMF.

9.4 Black Holes:

Active galactic nuclei (AGN) are believed to be powered by the accretion of matter onto a super-massive (10^{6-9} solar mass) black hole (SMBH). About 10% of all AGN have collimated, relativistic outflows of particles (jets), and blazars (the most numerous, identified source of VHE γ-rays) are a class of AGN where one jet is pointed directly towards Earth. The VHE γ-rays are believed to be created by these jets in a compact region near the SMBH event horizon. Thus VERITAS studies of AGN probe the innermost regions of these powerful particle accelerators, where the bulk of their luminosity is emitted, and are critical to understanding the process of astrophysical jet formation and evolution, the effect of the jet on the surrounding environment, as well as the process of matter accretion and magneto-hydrodynamics in the strong-gravity region near the central SMBH. Blazars are among the most variable objects in the universe, and the brightest and fastest variability is observed in the VHE band. During flaring episodes, it is possible for VERITAS to rapidly generate unprecedented statistics, particularly at >TeV energies, which when combined with multi-wavelength data (radio, optical, X-ray and Fermi) will conclusively address issues in source modeling, the EBL, the IGMF, and the origin of ultra-high-energy cosmic rays (UHECRs). Observing VHE flares is key for the program, but most of our goals will be accomplished without them, using deep exposures. Large flares are rare, so multiple years are needed to catch future events, and to acquire these deep data sets. In addition to detailed studies of a few sources for targeted scientific programs, we are amassing enough AGN detections that, for the first time, we will also be able perform population studies using these deep exposures. Black holes may also power jets in GRBs and micro-quasars, and their study will constrain jet-physics and black-hole accretion in different environments.

9.5 Galactic Tevatrons / Pevatrons:

The galaxy appears to be full of cosmic Tevatrons. These sources include SNRs, that are powered by the Fermi acceleration of particles in the blast shock created by the original supernova explosion; pulsar wind nebulae, that are powered by spinning, highly magnetized neutron stars; binary systems whose acceleration mechanisms are not yet well understood; and "dark accelerators", mysterious sources who produce radiate strongly in the γ-ray band, but not at lower energies. The primary goals of studying these Tevatrons are to constrain their magnetic fields (strength and geometry), the power spectrum of magnetic turbulence, and other parameters governing the acceleration process; to pin down mechanisms of particle acceleration up to PeV energies, and to determine their contribution to the cosmic-ray make-up.

9.6 Outline of the Pre-planned Observation Program

The following section describes the breakdown of the 70% of VERITAS observing time that will be pre-planned. While we expect the following detailed plans to evolve, the time allocations for each topic will be roughly preserved. However, the time should be considered the minimum taken, since 30% of VERITAS time will be awarded by the TAC and may supplement these programs. In addition to these specific programs, numerous VERITAS programs (e.g., measuring the cosmic-ray electron spectrum, which has implications for dark-matter searches) are symbiotic to direct source observations, since they use the exposures to all sources. The pre-allocated program is organized following the SWG structure and described in the following subsections.

9.6.1 Indirect Dark Matter Detection Program (166 h / yr): We will probe the dark-matter (DM) particle mass and constrain the DM annihilation cross section within an order of magnitude of generic predictions, and strongly constrain DM scenarios with Sommerfeld or astrophysical boosts. Only a modest astrophysical boost is needed for detection. This program has two main components:

- **Dwarf galaxies (146 h / yr):** Dwarf galaxies have extremely high concentrations of DM and no astrophysical backgrounds that may confuse the origin of a VHE signal. They are the best VHE targets and we will acquire ~110 h / yr on the 5 most promising dwarf galaxies. In addition, we will acquire 4 h / yr on each of the 9 remaining Northern dwarf spheroidal galaxies that VERITAS has yet to observe (36 h / yr total) to perform a comprehensive DM survey.
- **Galactic Center (20 h / yr):** We will observe the Galactic Center, which has the highest local concentration of dark matter, at large zenith angles (LZA). Due to the large effective area at LZA, these observations are very sensitive at more than a few TeV and improve on the deep HESS result focused on lower energies. We will obtain unprecedented limits on generic DM models at high mass (>few TeV) to complement the LHC.

9.6.2 Blazar Observation Program (278 h / yr): While our understanding these objects is very important and will be dramatically improved, much of this program is focused on our goals in fundamental physics (i.e. Lorentz-invariance constraints, EBL/IGMF measurements, searches of axion-like particles). VERITAS has already observed nearly all 42 Northern VHE blazars. However, we have not yet detected 13 of these objects and some of our results are plagued by low statistics, as the objects' fluxes were near the sensitivity limit of the detector. Identifying "common" blazar flares (brightening by at least a factor of five) is thus of great importance, and one major flaring event could change our understanding of the Universe. Correspondingly we will spend 198 h / yr monitoring the flux from all known VHE blazars, with a cadence / exposure-depth selected based on the importance of detecting flares from the object, as well as the potential impact of deepening the exposure on their low state (i.e. the minimum result). Contemporaneous radio, optical/UV, X-ray and GeV monitoring will be organized to enable source modeling, and Target of Opportunity (ToO) proposals in these wavebands will be submitted yearly to ensure coverage of flaring events. An pre-approved allocation of ToO observations (80 h / yr) exists to enable immediate follow-up to flares from the monitoring program, to deepen exposures on new VHE discoveries, and to respond to high-value discovery opportunities indicated by flaring at lower energy. To aid this effort, optical and Swift X-ray monitoring of all VHE blazars and high-value candidates has already been set up, in addition to several automatic LAT analysis/alert pipelines.

9.6.3 Galactic Source Observation Program (218 h / yr): This program comprises many different source classes, but collectively these objects are the most powerful Tevatrons / Pevatrons in the Galaxy. The objects of interest include binary systems, pulsar wind nebulae, supernova remnants, and pulsars. In addition we will survey select regions of the sky to identify new sources and source-classes of VHE emission. We note that Fermi-LAT and Milagro have detected, and HAWC eventually will detect, a number of γ-ray sources unidentified at other energies. VERITAS observations of these objects with significantly better angular resolution (and energy resolution in the case of HAWC / Milagro) are key to understanding the origin of the emission. Follow-up observations of these important targets will be proposed via the TAC process.

- **Binary Systems (53 h / yr):** These natural particle accelerators operate under varying, but regularly repeating, environmental conditions. As such, they provide a uniquely constraining laboratory for models of particle acceleration, and γ-ray production, emission and absorption processes. We will make deep annual observations of the two Northern VHE binaries and discovery efforts on a variety of candidates (ToO based for many).

- **Pulsar Wind Nebulae (32 h / yr):** TeV-detected PWN are numerous enough to allow population studies, and, unlike at GeV energies, TeV observations are not contaminated by non-nebular emission. PWN can reveal energy dependent morphology, allowing the study of particle transport within, and the evolution of, the PWN. We will take deep exposures of a few key systems.
- **Shell-type SNR (57 h / yr):** We will make deeper studies of the Tycho and IC 443 SNR. The shells are interacting with dense material, enabling the study pionic emission and cosmic-ray escape and SNR diffusion. The Tycho SNR studies have profound importance for the origin of hadronic cosmic rays and are the major component of this program
- **Sky Surveys (20 h / yr):** VERITAS will survey the Cygnus and Galactic center regions to search for new sources and source-classes of VHE emission. In the past these surveys have resulted in several objects of unknown classification.
- **Pulsars (56 h / yr):** The Crab Pulsar was recently and surprisingly detected at TeV energies by VERITAS (published in *Science*). These observations challenge nearly all models for particle acceleration in the regions surrounding pulsars, and may extend to even higher energies. VERITAS will make an unprecedented measurement of the Crab Pulsar and survey other selected millisecond pulsars for TeV emission. These studies can also be used to probe potential Lorentz invariance violation.

9.6.4 Gamma-ray Burst Observation Program (24 h / yr): Our goal is to detect the first GRB at VHE and to use the signal for both astrophysical modeling, as well as to take advantage of the unprecedented opportunity it presents to constrain the EBL, the IGMF and potential Lorentz invariance violation. Whenever a timely, visible, well-defined GRB position is received, VERITAS will immediately observe it to detect either prompt or afterglow emission; typically within 1-3 minutes of the initial detection by a satellite experiment (Fermi LAT/BAT & Swift).

9.6.5 Extragalactic Non-Blazar Program (20 h / yr): These rare VHE emitters rank amongst the most interesting sources detected by VERITAS, yielding papers in both *Nature* and *Science*. The radio galaxy M87 will be monitored (20 h / yr) to build up the deepest-ever exposure and to identify flaring states. These will trigger intense high-spatial-resolution Chandra X-ray and radio observations, to correlate any morphological changes with the VHE flux to indicate the acceleration region of TeV photons in AGN. A pre-approved ToO program also exists in case of the Fermi-LAT identification of a flare from the radio galaxy NGC 1275, with similar follow-up protocols. Time will also proposed via the TAC process for risky, often-LAT-guided discovery observations of radio galaxies, globular clusters and galaxy clusters. The latter two classes can contain up to 85% dark matter; M87 and NGC 1275 are at the heart of the famous Virgo and Perseus galaxy clusters, respectively.

10. Decommissioning and Disposition Plans

VERITAS is an active experiment with plans to operate until at least 2019. The site is secure until at least 2028 and plausibly much longer, it is likely that the VERITAS hardware may find scientific use at the VERITAS site beyond the lifetime of the VERITAS collaboration (e.g. to search for trans-Jovian objects, or as an AGN monitor for the Cherenkov Telescope Array, or as a teaching instrument), and there is no competition for the space the VERITAS telescopes occupy. Therefore there is no pressure from the host organization (SAO) to remove the instrument from the site and no decommissioning plan has been developed, or even discussed with the funding agencies. However, when it becomes apparent that VERITAS operations will cease to be funded, the general decommissioning strategy will proceed as follows. First the title to the VERITAS property would be sought by SAO from NSF and DOE. While this lengthy process proceeds, alternate uses for the instrumentation will be explored. If no immediate post-VERITAS use were found, but an option seemed plausible, the mirrors would be removed from the telescopes and placed into storage to prevent weathering. All other components can withstand considerable time in the elements, so no further steps would be needed. The mirror removal would take the three VERITAS technicians ~1 month (later re-installation would have a similar time scale). If the VERITAS hardware needed to be removed entirely, we estimate it would take the VERITAS technicians ~6 months to remove the mirrors, telescope-mounted hardware and cabling from the optical support structures, to use a crane to lift off the metal structures, and to pull out the VERITAS cabling from the ground. Outdated equipment would be placed on government excess, while telescope mirrors, photon detectors (PMTs), and various electronics would be kept for use in future experiments. Depending on the level of clean-up and/ or care-in property disposition required, the time scale could stretch longer. The VERITAS utilities and building would remain in place on any foreseeable timescale (i.e. the lifetime of the observatory). In terms of final data analyses, we will keep the VERITAS data accessible online for at least 5 years after the completion of data taking. We anticipate most publications from these data would be completed within about one year, with some more difficult legacy publications (e.g. source catalogs), multi-observatory collaborative efforts and student theses taking approximately two years.

Appendix A

The following internet links are provided for each of the documents referenced in the text. In general, all the files can be found in the following web directory: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/

If there are any issues downloading a file, please contact the Project Scientist (Wystan Benbow; wbenbow@cfa.harvard.edu).

A. Teaming Agreement: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS-TeamingAgreement_10-17-08.pdf
B. Science Board Document: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS-Science-Board-V5.3.pdf
C. Time Allocation Document (update in progress; pending ESAC review of 2014 LTP): http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS_Time_Allocation_v2.pdf
D. Speaker's Bureau Charge: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS-Bureau-Charge.pdf
E. Simulations Working Group Charge and Implementation Strategy: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/SimulationsWG_Charge_V4.pdf
F. Data Calibration / Data Quality (DCDQ) Working Group Charge and Implementation Strategy: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/DataCalibration-WG-V2.pdf
G. FLWO User's Safety Guide: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/FLWO_Users_Safety_Info_Training.pdf
H. Gamma-wiki Safety Page: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/Safety-GammaWiki.pdf
I. 2011 ESAC Report: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/ESAC-2011-Report.pdf
J. Data Management Plan: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/Data_Management_Plan.pdf
K. VERITAS Data Archive and Distribution Policy: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS-DataArchive-Distribution.pdf
L. 2014 Long-Term (5-year) Science Plan: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS_2014_SciencePlan.pdf
M. 2011 Long-term (5-year) Science Plan: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS_2011_SciencePlan.pdf
N. 2011 Long-term (5-year) Science Plan Supporting Figures: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS_2011_SciencePlan_Appendix.pdf
O. VERITAS Organization Charts (Figures 1 & 2): http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/VERITAS_Org_Charts.pdf

The most recent VERITAS Site Operations Proposal to DOE, and Related Documents can be found at: http://veritas.sao.arizona.edu/~benbow/VERITAS_EOP/DOE_Prop_2013_2016

Appendix B – Sub-Project Descriptions

Optics/Mechanics Group

SP 1 Mirrors: SAO
SP 2 Telescopes: SAO
SP 3 Peripherals: UCD, NUI-Galway, Institutes of Technology: Galway and Cork

Camera Group

SP 4 Photomultiplier Tubes: Purdue University
SP 5 High Voltage: The University of Chicago
SP 6 Focal Plane Instrument: Iowa State University
SP 7 Flash ADCs: Washington University in St. Louis
SP 8 Trigger Level 1 – CFDs: UCLA
SP 9 Trigger Level 2 – Pattern: Argonne National Lab, Iowa State University
SP 10 Trigger Level 3 – Array: UCLA
SP 12 Cables and Connectors: University of Utah
SP 13 VME Data Acquisition: The University of Chicago
SP 14 Integration: The University of Chicago
SP 15 Calibration: University of Utah

Software Group

SP 16 Data Acquisition Software: UCD, McGill University
SP 17 Data Reduction: Purdue University
SP 18 Data Archiving: UCLA
SP 19 Outreach: Adler
SP 21 Simulations: UCLA, Iowa State University, Purdue University
SP 23 Array Control: Washington University in St. Louis
SP 24 Offline Analysis: Minnesota

Management Group

SP 19 Facility: SAO
SP 20 Project Office: SAO

Appendix C: Acronym List

ADC – Analog to Digital Converter
AST – NSF Division of Astronomy
AURA – Associated Universities for Research in Astronomy
CfA – Center for Astrophysics (Harvard-Smithsonian CfA)
CFD – Constant Fraction Discriminator
CDR – Critical Design Review
DAQ – Data AcQuisition system
DOE – Department of Energy
DOE-PM – DOE Program Manager
EA – Environmental Assessment
EI – Enterprise Ireland
EMAC – External Management Advisory Committee
EOP – Project Execution Plan and Project Management Plan
ESAC – External Science Advisory Committee
FADC – Flash ADC
FLWO – Fred Lawrence Whipple Observatory
FONSI – Finding of No Significant Impact
FTE – Full Time Equivalent
GeV – Giga electron Volts
GLAST – Gamma ray Large Area Space Telescope
IACT – Imaging Atmospheric Cherenkov Technique
ICD – Interface Control Document
JOG – Joint Oversight Group
KPNO – Kitt Peak National Observatory
MIE – Major Item of Equipment
NSERC – Natural Sciences and Engineering Research Council
NSF – National Science Foundation
OHEP – Office of High Energy Physics
PI – Principle Investigator
PHY – NSF Division of Physics
PMT – Photo Multiplier Tube
R&D – Research and Development
SAGENAP – Scientific Assessment Group for Experiments in Non-Accelerator Physics
SAO – Smithsonian Astrophysical Observatory
SI – Smithsonian Institution
SP – Sub-project
TeV – Tera electron Volts
UCLA – University of California at Los Angeles
VEC – VERITAS Executive Committee
VERITAS – Very Energetic Radiation Imaging Telescope Array System
VHE – Very High Energy
VME - VERSAmodule Eurocard
WBS – Work Breakdown Structure
WU – Washington University