Monitoring Program for Assessing the Impact of Rosemont Copper Mine Sky Brightness as Seen from the F. L. Whipple Observatory on Mt. Hopkins

25 September 2013

Revision	Description	Date
0	Original Issue Approved by Dr. Charles Alcock, Director SAO	25 Sep 2013

1. Introduction

The purpose of this Rosemont Copper Mine sky brightness monitoring plan is to outline a selected approach to long term monitoring the sky brightness at telescopic sites at or near the summit of Mt. Hopkins. The plan outlines the monitoring that will take place on Mt. Hopkins to establish a baseline observatory sky brightness and how sky brightness changes over time as the result of the new Rosemont Mine site, and other related and unrelated activities. We will refer to this plan as the Rosemont Monitoring Plan (RMP).

Night sky observers are concerned with visibility impairment caused by terrestrial light sources brightening the sky, thus reducing the visibility of the stars. The operation plan for the new mine is to run 24 hours a day, utilizing wide spread ground lighting to improve safety. This lighting will scatter into the atmosphere, thus increase the background illumination.

The RMP outlines the monitoring method, monitoring location, and required maximum light levels. The resulting data will be available for uses by the Rosemont Mine operators to better control their illumination levels, thereby minimizing the impact of their operations on the observing efficiency on Mt. Hopkins.

This document is a supplement to comments submitted to the US Forest Service (USFS) by the Smithsonian Astrophysical Observatory (SAO), a federal cooperating agency in the environmental impact statement for the Rosemont Copper Mine (RCM). The RMP will not only benefit the Observatory, but should also be beneficial to RCM.

The STEM Laboratories monitoring plan (henceforth, the plan) outlined in the Rosemont Copper Project Light Pollution Mitigation Recommendation Report (Monrad Engineering Inc., Rev 1, June 18, 2012) is a novel and potentially powerful approach to monitoring sky brightness and light pollution. However, we find that, by itself, the plan is inadequate to meet the long-term monitoring required to ensure that light from RCM does not excessively impact science observations from Mt, Hopkins. The plan is also very preliminary and many critical issues have not yet been addressed. This is a concern since those very issues are important to the success of any monitoring program.

Concerns:

1. The plan does not include support from Fred Lawrence Whipple Observatory (FLWO). Therefore:

a. Monitoring does not include the most critical measurement for FLWO, i.e. direct measurements of sky brightness from Mt. Hopkins.

b. FLWO personnel may not have access to the data and therefore could not provide an Observatory assessment of the impact.

2. The plan does not provide continuous monitoring. The Observatory operates every night of the year with the exception of an approximately four week maintenance period during the monsoon season. It is critical to ensure that there are not occasional but sustained increases in sky brightness that could be missed by less frequent monitoring.

3. The plan relies heavily on the longevity of a single small private contractor, STEM Laboratory, Inc. Therefore, the plan assumes that STEM Laboratory, Inc. will remain in

operation for the entirety of the mine plan-of-operation, i.e. 20-25 years. Since sky conditions will be a concern for as long as the Observatory exists, the monitoring should, at some level, be tied to the Observatory rather than be solely dependent on a contractor.

4. The plan does not outline criteria for triggering an exceedance or a protocol for reporting and correction of any exceedance.

5. A calibration plan was not provided. Calibration is critical to ensuring that changes in sky brightness can be identified.

2. Roles and Responsibilities

1. US Forest Service

a. Establish and chair a Rosemont Copper Mine Sky Brightness Monitoring Plan oversight committee. The committee will consist of five members one each from USFS (chair), FLWO, RCM, the RCM lighting engineer, and an independent astronomer knowledgeable in photometric/spectroscopic measurements. The committee will ensure that RCM lighting is following the approved Monrad plan and that its contribution to sky brightness is within the mitigation goals. This committee will meet quarterly to review the collected data, determine its quality and whether or not the below action level criteria are exceeded. It may be called to meet earlier if lighting exceeds action levels. A report will be issued to the USFS following each meeting.

b. Provide access to all STEM Laboratory Monitoring Plan Information to the Rosemont Copper Mine Sky Brightness Monitoring Plan Oversight Committee and federal cooperating agencies.

c. Provide oversight and confirmation that the Rosemont Mine Lighting Plan is implemented and maintained in accordance with the approved design.

2. Smithsonian Institution, Fred Lawrence Whipple Observatory

a. Establish, operate, and maintain a sky brightness monitoring system at the Fred Lawrence Whipple Observatory on Mt. Hopkins.

b. Provide spectroscopic data from existing telescope resources

c. Participate on the Rosemont Copper Mine Sky Brightness Monitoring Plan Oversight Committee

d. Analyze sky brightness data and Rosemont Copper Mine sky brightness impacts from pre-mine operations throughout the operational lifetime of the mine.

e. Establish and maintain a public access web-based sky brightness data base

f. Report any Rosemont Copper Mine sky brightness exceedances to the Forest Service and the Rosemont Copper Mine Sky Brightness Monitoring Plan Oversight Committee for review and any required action.

3. Rosemont Copper Mine

a. Participate on the Rosemont Copper Mine Sky Brightness Monitoring Plan Oversight Committee

b. Provide $ 218,069 funding for establishing the Smithsonian Institution sky brightness monitoring system at the Fred Lawrence Whipple Observatory on Mt. Hopkins.

c. Provide $100,000 (0.5 full time equivalent) funding per year of the life of monitoring plan (beginning in calendar year 2014) to coordinate operations, data analysis and curation, and maintenance.

3. Sky Brightness Monitoring Plan Purpose and Objectives

The primary purpose of this RMP is to describe the rationale and methodology for long term monitoring of the skies above the Santa Rita Range.

Sky brightness monitoring tasks outlined in this RMP document the method that we will use to determine the sky brightness in the vicinity of Rosemont Copper Mine with respect to levels consistent with world class observation of the universe.

The principal objectives of the plan are as follows:

- Continuously monitor the sky brightness levels in the visible spectrum at the MMT summit and FLWO Ridge facilities using a fixed sky brightness monitoring station. A small portion of the near ultraviolet spectrum is monitored as well, while the near infrared is filtered out.
- Identify notification steps in the event that sky brightness levels exceed predetermined action levels, so that mitigation steps can be initiated.

4. Scope

4.1. Fixed Site Monitoring

The sky brightness level will be monitored at a single fixed site in the location previously occupied by the IOTA instrument. Data will be collected at the same time each evening for a fixed period of time, when the sky is clear enough to observe.

4.2. Regular Spectroscopic Monitoring

Regular spectroscopic monitoring will be conducted with the MMT using the Blue Channel spectrograph, FAST spectrograph at the Tillinghast telescope, or successor instrument. Low resolution spectra (5-10Å per resolution element) of the night sky over a broad wavelength coverage (3000-8000 Å) will be obtained at a range of elevations and azimuths centered in the direction to RCM. The multiple azimuth observations, particularly those in the direction of undeveloped dark skies, will provide a repeatable baseline. These spectrographs are well calibrated and will provide absolute measurements across a wide spectrum to ensure that light sources outside the RCM Monrad plan are not being used. These measurements can then also be used to recalibrate the fixed site sky brightness monitors.

4.3. Data Evaluation

The unreduced data will be available to all by the end of each evening. A monthly report will be issued summarizing observations. Periodically (more often than weekly) the data will be tested

for internal consistency and reduced to usable form. All of the RMP data will be publicly available through a web portal and the datasets will be backed up and archived on a primary server operated by FLWO. No less frequently than once per year, the entire system will be evaluated and the sky brightness monitors calibrated.

5. Sampling Sites

A single site with a seven element sky brightness sampling strategy will be used. Each of the seven simultaneous sampling units shall integrate a 20^{o} cone into a single integrated brightness index. Individual samples will be collected over a discrete length of time, and filtered to remove short-term effects that do not affect the observing efficiency of the site.

In selecting the exact site, factors such as the view of active roads, trees and other sources of transient sky brightness will be considered. The fixed location will be selected to represent areas closely associated with and proximal to key telescope facilities sensitive to sky brightness. The baseline sampling site is listed below in Table 1.

Table 1

Locations of Fixed-Site Sky Brightness Monitoring

Fixed Site	Location	Location Coordinates
1	IOTA Site, Mt. Hopkins	Lat: 110° 53' W Lon: 31° 41' N

6. Monitoring Equipment

The fixed-site sky-brightness monitoring equipment will be employed to document and track the sky-brightness over time. The measurement instruments will include devices to monitor sky brightness, cloud levels, all-sky image, and a subset of local meteorological conditions. The selected instrumentation was chosen because of their general use and ability to be calibrated.

Table 2

Sky-Brightness Instrumentation Summary

Measurement	Provider	Model
Sky Brightness Monitor	Unihedron	SQM-LE
All Sky Camera	SBIG	AllSky-340
Cloud Monitor	Cyanogen	Boltwood Cloud Sensor II

6.1. Sky Brightness Monitors

The Sky Quality Meter – LE, from Unihedron (http://unihedron.com/index.php) employs the TAOS TSL237 light-to-frequency converter (http://unihedron.com/projects/darksky/TSL237-E32.pdf) and uses a microprocessor and a temperature sensor to derive a corrected and accurate brightness measurement. The unit is Ethernet controlled.

6.2. All Sky Camera

The All-sky camera from SBIG in California (http://www.sbig.com/products/cameras/specialty/the-allsky-340-camera/) is an industry standard.

6.3. Cloud Monitor

The Cloud Sensor is a Boltwood II, which is considered one of the best off-the-shelf products of its type (http://www.cyanogen.com/fix.php). The system is widely used, including in several sites on Mt. Hopkins.

7. Monitoring Schedule

The monitor will operate each night during the period between 10:30PM MST and 2:30AM Mountain Standard Time when it is safe to operate. The system will query the cloud sensor to determine if the conditions will support a valid sky brightness measurement. If so, the movable dome will open, and measurement will proceed. If there is cloud cover, rain, or other meteorological activity inconsistent with telescope observation, the system will remain closed, but continue to query the cloud sensor. If the weather improves before the time window closes, the system will open and complete the measurement. This will ensure that a systematic error is not introduced into the data by measuring at a set time in the evening, while avoiding dawn and dust sky light phenomena such as zodiacal light and human activity.

Measurement may be interrupted by equipment failure for several nights without affecting the ultimate usefulness of the data. In addition, there will be a planned system shutdown set to coincide with the overall observatory shutdown, sometime during the months of July or August. During that period the system will be cleaned, maintained, and calibrated.

8. Performance Evaluation

Measurement will proceed in three stages: establishment of a pre-operational baseline, establishment of a post-operational baseline, and long term monitoring with comparison to the difference between those baselines. Numerous factors can affect an individual sky brightness measurement that are not necessarily indicative of an overall decay in the quality of the observatory site. The initial measurement period will span a long enough time (4-6 months), that when aggregated will tend to filter out these short term effects and yield a determination of the sky brightness at the Mt. Hopkins site prior to the operation of the mine. The second, post-operational baseline, will be conducted after the mine is operational, when the approved lighting design has been installed and operating nominally. The change in the overall measured sky

brightness will act as a calibration of the allowable deviation of the post-operation sky brightness (see below).

During the monitoring stage, long stretches of data will be required to ensure that changes in the sky brightness are significant and not transitory phenomena. Therefore once the baselines have been established, data will be aggregated over month long periods before trends can be reliably identified.

The data will be reduced, filtered, and aggregated as outlined in a SAO provided Sky Brightness Data Handling Procedure.

9. Action Levels

This plan sets the following action level:

A notice is triggered when data indicate measured sky brightness has changed to an unacceptable degree, thus materially affecting the efficiency of the observatories on Mt. Hopkins (10% or greater increase in sky brightness over established mine induced sky brightness. Specifically, this represents a change in sky brightness that is equal to or greater than 10% of the change between the pre- and post- operational baselines)

10. Exceedance Actions/Notification

Type of Exceedance	Action/Notification	Remediation
Notice	**Notice** that the level of sky brightness has exceeded the post-operational baseline will be sent to the responsible parties. The notice shall indicate the measured levels, and the period over which they were measured. The responsible parties shall have seven days to review the data, their records, and reply to the notice with an indication whether any of their activities could have contributed to the higher than nominal sky brightness.	The responsible parties shall meet within two weeks of the initial notice being issued to propose remediation plans to reduce sky brightness as seen from the Mt. Hopkins site.

11. Meteorological and Ambient Light Level Monitoring

Meteorology monitoring will be conducted at the fixed site. Cloud cover, wind speed, direction, temperature, perspiration state, and relative humidity will be measured.

12. Quality Assurance / Quality Control

The utility of the sky brightness data, when measured over long periods of time, is dependent on the quality of the instruments' calibration. The sky brightness monitors shall have periodic (at least once per year) calibration with a National Institute of Standards traceable standard light source. The results of the calibrations, and well as the traceability information for the light source, shall be available on the same site that the data is available.

The monitoring system shall log housekeeping information, such as: temperature, dome opening power, etc., to the same site that the sky brightness data is logged. This data shall be reviewed over time to determine if system is functioning nominally, and whether intervention is warranted.

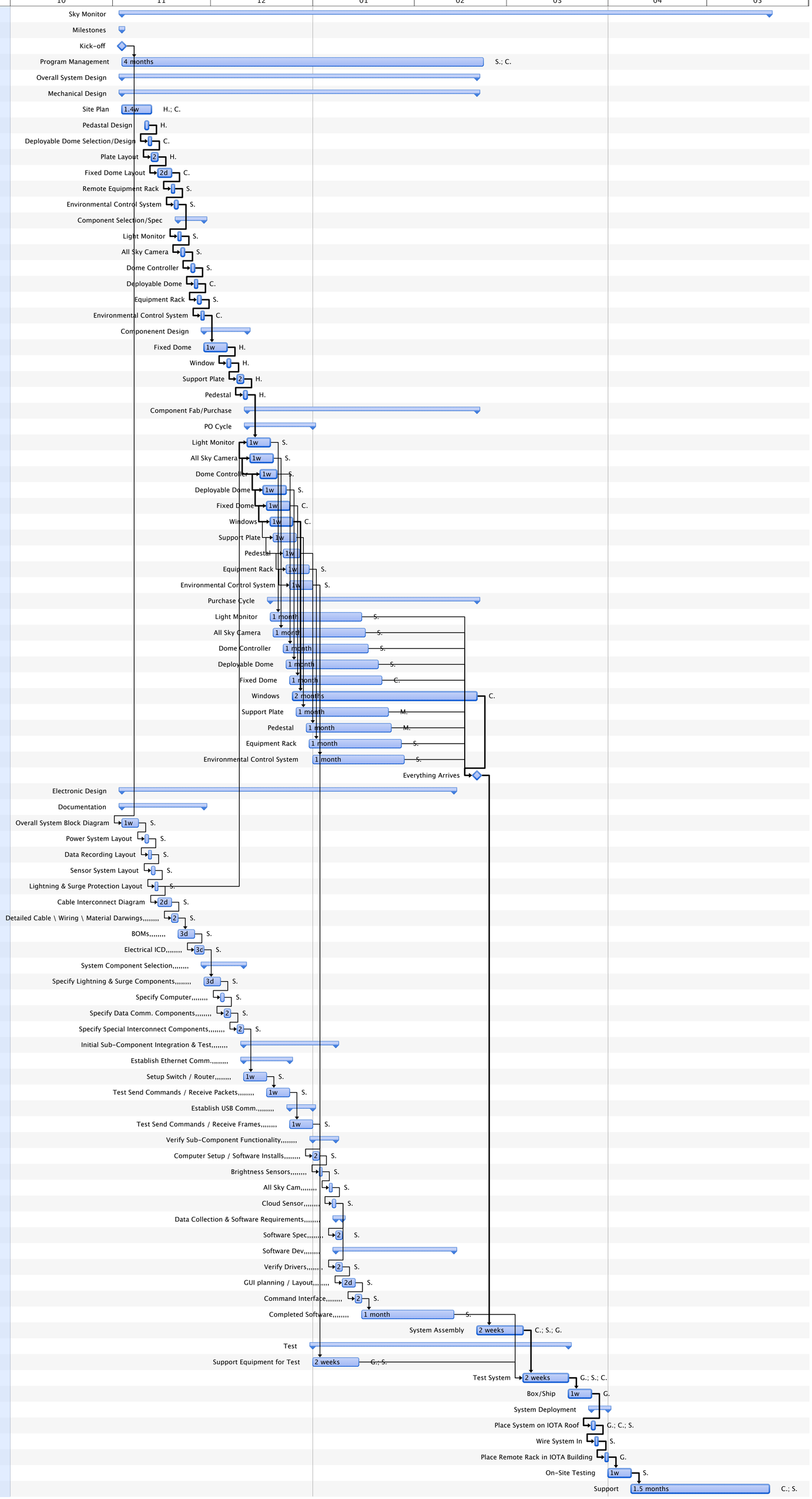
13. Electronic Data Management and Reporting

SAO will provide a data recording system.

Acronyms and Abbreviations

FLWO	Fred Lawrence Whipple Observatory
MMT	Multi Mirror Telescope
RCM	Rosemont Copper Mine
RMP	Rosemont Monitoring Plan
SAO	Smithsonian Astrophysical Observatory
USFS	US Forest Service

#	Title	Given Planned Duration	Given Planned Work	Expected Start	# Predecessors
0	**Sky Monitor**			**Nov 4, 2013 8:00 AM**	
1	**Milestones**			**Nov 4, 2013 8:00 AM**	
2	Kick-off			Nov 4, 2013 8:00 AM	
3	Program Management	4 months	4 months	Nov 4, 2013 8:00 AM	2
6	**Overall System Design**			**Nov 4, 2013 8:00 AM**	
7	**Mechanical Design**			**Nov 4, 2013 8:00 AM**	
8	**Site Plan**			**Nov 4, 2013 8:00 AM**	
15	Pedastal Design	1 day	1 day	Nov 11, 2013 8:00 AM	9
17	Deployable Dome Selection/Design	1 day	4 hours	Nov 12, 2013 8:00 AM	15
19	Plate Layout	2 days	2 days	Nov 13, 2013 8:00 AM	17
21	Fixed Dome Layout	2 days	2 days	Nov 15, 2013 8:00 AM	19
23	Remote Equipment Rack	1 day	4 hours	Nov 19, 2013 8:00 AM	21
25	Environmental Control System	1 day	1 day	Nov 20, 2013 8:00 AM	23
27	**Component Selection/Spec**			**Nov 21, 2013 8:00 AM**	
28	Light Monitor	1 day	4 hours	Nov 21, 2013 8:00 AM	25
30	All Sky Camera	1 day	1 day	Nov 22, 2013 8:00 AM	28
32	Dome Controller	1 day	4 hours	Nov 25, 2013 8:00 AM	30
34	Deployable Dome	1 day	1 day	Nov 26, 2013 8:00 AM	32
36	Equipment Rack	1 day	100 %	Nov 27, 2013 8:00 AM	34
38	Environmental Control System	1 day	1 day	Nov 28, 2013 8:00 AM	36
40	**Componenent Design**			**Nov 29, 2013 8:00 AM**	
41	Fixed Dome	5 days	5 days	Nov 29, 2013 8:00 AM	38
43	Window	1 day	4 hours	Dec 6, 2013 8:00 AM	41
45	Support Plate	2 days	2 days	Dec 9, 2013 8:00 AM	43
47	Pedestal	1 day	1 day	Dec 11, 2013 8:00 AM	45
49	**Component Fab/Purchase**			**Dec 12, 2013 8:00 AM**	
50	**PO Cycle**			**Dec 12, 2013 8:00 AM**	
51	Light Monitor	1 week	4 hours	Dec 12, 2013 8:00 AM	47; 101
53	All Sky Camera	1 week	4 hours	Dec 13, 2013 8:00 AM	51SS+1 day
55	Dome Controller	1 week	4 hours	Dec 16, 2013 8:00 AM	53SS+1 day
57	Deployable Dome	1 week	4 hours	Dec 17, 2013 8:00 AM	55SS+1 day
59	Fixed Dome	1 week	4 hours	Dec 18, 2013 8:00 AM	57SS+1 day
61	Windows	1 week	4 hours	Dec 19, 2013 8:00 AM	59SS+1 day
63	Support Plate	1 week	1 day ?	Dec 20, 2013 8:00 AM	61SS+1 day
64	Pedestal	1 week	1 day ?	Dec 23, 2013 8:00 AM	63SS+1 day
65	Equipment Rack	1 week	4 hours	Dec 24, 2013 8:00 AM	64SS+1 day
67	Environmental Control System	1 week	4 hours	Dec 25, 2013 8:00 AM	65SS+1 day
69	**Purchase Cycle**			**Dec 19, 2013 8:00 AM**	
70	Light Monitor	1 month	4 hours	Dec 19, 2013 8:00 AM	51
72	All Sky Camera	1 month	4 hours	Dec 20, 2013 8:00 AM	53
74	Dome Controller	1 month	4 hours	Dec 23, 2013 8:00 AM	55
76	Deployable Dome	1 month	4 hours	Dec 24, 2013 8:00 AM	57
78	Fixed Dome	1 month	4 hours	Dec 25, 2013 8:00 AM	59
80	Windows	2 months	4 hours	Dec 26, 2013 8:00 AM	61
82	Support Plate	1 month	5 days	Dec 27, 2013 8:00 AM	63
84	Pedestal	1 month	4 days	Dec 30, 2013 8:00 AM	64
86	Equipment Rack	1 month	4 hours	Dec 31, 2013 8:00 AM	65
88	Environmental Control System	1 month	1 day	Jan 1, 2014 8:00 AM	67
90	Everything Arrives			Feb 19, 2014 5:00 PM	70; 72; 74...
91	**Electronic Design**			**Nov 4, 2013 8:00 AM**	
92	**Documentation**			**Nov 4, 2013 8:00 AM**	
93	Overall System Block Diagram	5 days	40 hours	Nov 4, 2013 8:00 AM	2
95	Power System Layout	1 day	4 hours	Nov 11, 2013 8:00 AM	93
97	Data Recording Layout	1 day	4 hours	Nov 12, 2013 8:00 AM	95
99	Sensor System Layout	1 day	4 hours	Nov 13, 2013 8:00 AM	97
101	Lightning & Surge Protection Layout	1 day	4 hours	Nov 14, 2013 8:00 AM	13SS; 99
103	Cable Interconnect Diagram	2 days	1 day	Nov 15, 2013 8:00 AM	101
105	Detailed Cable \ Wiring \ Material Darwings,,,,,,,,	2 days	1 day	Nov 19, 2013 8:00 AM	103
107	BOMs,,,,,,,,	3 days	1 day	Nov 21, 2013 8:00 AM	105
109	Electrical ICD,,,,,,,,	3 days	1 day	Nov 26, 2013 8:00 AM	107
111	**System Component Selection,,,,,,,,**			**Nov 29, 2013 8:00 AM**	
112	Specify Lightning & Surge Components,,,,,,,,	3 days	1 day	Nov 29, 2013 8:00 AM	109
114	Specify Computer,,,,,,,,	1 day	1 day	Dec 4, 2013 8:00 AM	112
116	Specify Data Comm. Components,,,,,,,,	2 days	1 day	Dec 5, 2013 8:00 AM	114
118	Specify Special Interconnect Components,,,,,,,,	2 days	1 day	Dec 9, 2013 8:00 AM	116
120	**Initial Sub-Component Integration & Test,,,,,,,,**			**Dec 11, 2013 8:00 AM**	
121	**Establish Ethernet Comm.,,,,,,,,**			**Dec 11, 2013 8:00 AM**	
122	Setup Switch / Router,,,,,,,,	5 days	5 days	Dec 11, 2013 8:00 AM	118
124	Test Send Commands / Receive Packets,,,,,,,,	5 days	5 days	Dec 18, 2013 8:00 AM	122
126	**Establish USB Comm.,,,,,,,,**			**Dec 25, 2013 8:00 AM**	
127	Test Send Commands / Receive Frames,,,,,,,,	5 days	5 days	Dec 25, 2013 8:00 AM	124
129	**Verify Sub-Component Functionality,,,,,,,,**			**Jan 1, 2014 8:00 AM**	
130	Computer Setup / Software Installs,,,,,,,,	2 days	2 days	Jan 1, 2014 8:00 AM	127
132	Brightness Sensors,,,,,,,,	1 day	1 day	Jan 3, 2014 8:00 AM	130
134	All Sky Cam,,,,,,,,	1 day	1 day	Jan 6, 2014 8:00 AM	132
136	Cloud Sensor,,,,,,,,	1 day	1 day	Jan 7, 2014 8:00 AM	134
138	**Data Collection & Software Requirements,,,,,,,,**			**Jan 8, 2014 8:00 AM**	
139	Software Spec,,,,,,,,	2 days	2 days	Jan 8, 2014 8:00 AM	136
141	**Software Dev,,,,,,,,**			**Jan 8, 2014 8:00 AM**	
142	Verify Drivers,,,,,,,,	2 days	2 days	Jan 8, 2014 8:00 AM	136
144	GUI planning / Layout,,,,,,,,	2 days	2 days	Jan 10, 2014 8:00 AM	142
146	Command Interface,,,,,,,,	2 days	2 days	Jan 14, 2014 8:00 AM	144
148	Completed Software,,,,,,,,	1 month	20 days	Jan 16, 2014 8:00 AM	146
150	System Assembly	10 days	30 days	Feb 20, 2014 8:00 AM	90
154	**Test**			**Jan 1, 2014 8:00 AM**	
155	Support Equipment for Test	10 days	10 days	Jan 1, 2014 8:00 AM	67
158	Test System	10 days	12 days	Mar 6, 2014 8:00 AM	148; 150;...
162	Box/Ship	5 days	4 hours	Mar 20, 2014 8:00 AM	158
164	**System Deployment**			**Mar 27, 2014 8:00 AM**	
165	Place System on IOTA Roof	1 day	3 days	Mar 27, 2014 8:00 AM	162
169	Wire System In	1 day	4 hours	Mar 28, 2014 8:00 AM	165
171	Place Remote Rack in IOTA Building	1 day	4 days	Mar 31, 2014 8:00 AM	169
173	On-Site Testing	5 days	5 days	Apr 1, 2014 8:00 AM	171
175	Support	30 days	2 days	Apr 8, 2014 8:00 AM	173



PROPOSAL BUDGET WORKSHEETS

SUMMARY

Period of Performance: November 1, 2013 through June 30, 2014

	Nov 1, 2013 THRU Jun 30, 2014					
	Est. Hrly			TOTAL		
Productive Labor:	Rate	Hrs	Dollars	Hrs	Dollars	
#1- Astrophysicist	$38.45	115	$4,422	115	$4,422	
Total Productive Labor		115	4,422	115	4,422	
Leave @ 19.7%			871		871	
Total Direct Labor			5,293		5,293	
Fringe Benefits @ 27.9%			1,477		1,477	
Direct Operating Overhead Base			6,770		6,770	6,770
Direct Operating Overhead @ 32.1%			2,173		2,173	
Travel - (see schedule)			14,198		14,198	
Transportation - (see schedule)			500		500	
Engineering Services - (see schedule)			122,885		122,885	
Materials Overhead @ 4.8% of Material Base Below			2,142		2,142	
G & A Base			148,668		148,668	148,668
G & A @ 12.4%			18,435		18,435	
Materials - (see schedule)		36,815		36,815		
Equipment - (see schedule)		7,800		7,800		
Materials Base			44,615		44,615	
ESTIMATED COST			$211,718		$211,718	$211,718
Management Fee (3%)			$ 6,352		$ 6,352	
GRAND TOTAL			$218,070		**$218,070**	

Note - Estimate does not include $109,263 funding per year (constant FY 2014 $) required for operations coordination, data analysis, curation and maintenance.

TRAVEL SCHEDULE

YEAR 1

DESTINATION	NO TRIPS	NO TRAVELERS	DAYS/ TRIP	RATE PER DIEM	TOT PER DIEM	AIR FARE	TOT AIR FARE	AUTO RATE	TOT AUTO	MISC	TOTAL COST
Tucson, AZ	2	4	2	$146	$2,336	$317	$2,536	$65	$260	$2,000	$7,132
Tucson, AZ	1	4	7	$146	$4,088	$317	$1,268	$65	$910	$800	$7,066
TOTAL TRAVEL YEAR 1					$6,424		$3,804		$1,170	$2,800	$14,198

Transportation Schedule

Cost Basis	Vendor	Item	Cost	
Estimate	FedEx	shipping units	$	500
TOTAL			**$**	**500**

Materials Schedule

Cost Basis	Vendor	Item	Total Cost
Price List	Cyanogen	Cloud sensor	$ 1,700
Price List	Unihedron	sky brightness monitors (14, 7 spares)	$ 4,900
Price List	SBIG	all sky camera	$ 3,000
Price List	TBD	USB DirectShow Digitizer (for all sky camera--2)	$ 150
Estimate	TBD	laptop with Windows 7 (3)	$ 6,000
Price List	TBD	CAT6 cabling, 50 to 100 feet (2)	$ 20
Price List	TBD	weather-tight USB feed through connector (2)	$ 60
Price List	TBD	USB cabling, 6, 15 & 25 feet (6)	$ 60
Price List	TBD	USB hub (2)	$ 80
Price List	TBD	8 port 10/100/1000 Ethernet Switch (2)	$ 200
Price List	TBD	Broadband Ethernet Router (2)	$ 300
Price List	TBD	USB DAQ (2)	$ 700
Estimate	TBD	J Thermocouples (10)	$ 850
Estimate	TBD	Hybrid SPD power line	$ 200
Estimate	TBD	Hybrid SPD data lines	$ 100
Estimate	TBD	Lightning Rod System plus installation	$ 2,500
Price List	Edmunds	Fused Silica Windows (10)	$ 2,000
Estimate	TBD	Aluminum Plate	$ 250
Estimate	TBD	Various O-rings (multiple)	$ 500
Estimate	TBD	Support for Testing	$ 1,000
Estimate	TBD	Boxing and shipping	$ 1,250
Estimate	TBD	Rack	$ 500
Quote	HATNet	Removable Dome	$ 7,800
Price List	EXTECH	Light Meter	$ 200
Price List	Stellarnet	Integrating Sphere	$ 1,745
Price List	Stellarnet	Light Source	$ 750
TOTAL			**$ 36,815**

Equipment Schedule

Cost Basis	Vendor	Item	Cost
estimate	TBD	HAT dome	$7,800
Total			$7,800

ENGINEERING SERVICES SCHEDULE

YEAR 1

TITLE	Grade/Step	HRS	PRODUCTIVE LABOR DOLLARS	LEAVE @ 19.70%	TOTAL DIRECT LABOR	FRINGE BENEFITS @ 27.90%	SUB TOTAL	ENG. O/H @ 30.50%	TOTAL ENG DOLLARS
Project Engineer	15/10	136	$10,133	$1,996	$12,129	$3,384	$15,513	$4,732	$20,245
Mechanical Engineer	13/09	94	$5,204	$1,025	$6,229	$1,738	$7,967	$2,430	$10,397
Mechanical Designer	12/10	100	$4,686	$923	$5,609	$1,565	$7,174	$2,188	$9,362
Machinist	11/10	72	$2,814	$554	$3,368	$940	$4,308	$1,314	$5,622
Electrical Engineer	13/10	694	$38,670	$7,618	$46,288	$12,914	$59,202	$18,057	$77,259
TOTAL ENGINEERING YEAR 1		1,096	$61,507	$12,116	$73,623	$20,541	$94,164	$28,721	$122,885