Procedure and Checklist

Siting Information	**Client Name:**	Mass. Clean Energy Center (MassCEC)	**Location / GPS Information**	
	Site Name:	WHOI ASIT Tower	**Lat. (DD.ddddd°):**	41.325002
	Form Date:	10 March 2017	**Lon. (DDD.ddddd°):**	-70.566730
	Form Revision Number:	1	**Datum:**	WGS 1984 (position) / EGM96 Global Geod (elevation)
	Deployment Date:	07 October 2016	**Elevation (m MSL):**	12.63 m MSL
	Time Onsite/Offsite:	Approximately 10:00 AM – 3:00 PM	**UTM Easting (m):**	368882.9
	Staff Onsite:	M.V. Filippelli; A. Kirincich; WHOI staff	**UTM Northing (m):**	4576020.3
	Form Author:	M. V. Filippelli	**UTM Zone:**	19 North
	Site Time Zone:	Eastern (GMT –5, during Standard time)	**GPS Type:**	Trimble GeoXH
	Site Mag. Declination:	14.6° W	**GPS Serial Number**	4807419973
	Site Description	Lidar is deployed on the Air Sea Interaction Tower (ASIT) offshore structure owned and operated by Woods Hole Oceanographic Institution (WHOI); Tower is approximately 2 miles south of Martha's Vineyard, MA. Station has a walking platform at approximately 11 m MSL, with a section of lattice mast that extends from the platform to approximately 21 m MSL. The walking platform has a "diving board" extension oriented southwest, on which the lidar is deployed. The lidar sits upon a work bench mounted outboard of the southeast side of the diving board. Figure 1 illustrates the site configuration Aside from the immediate structure, the closest obstruction is Martha's vineyard. Open ocean fetch for the southern half of the compass; Site access controlled by WHOI; additional site details attached separately.		

Lidar Unit Information	**Lidar Model / Version:**	Leosphere Windcube V2	**Serial Number:**	WLS7-436
	Deployment Number:	1	**Computer OS:**	N/A
	Mfg. Validation Date:	August 2016	**System Time Zone:**	UTC
	Mfg. Validation Method:	Reference Windcube s/n WLS7-94	**System Time Server:**	GPS
	Grid / Autonomous Power:	ASIT shore power,	**Motion Cor. (Y/N, ver.):**	No
			Complex Flow Cor.:	No
	Nearest Ref. Station (tower, sodar, lidar):	WHOI ASIT tower (mast-mounted sensors) Buzzards Bay CMAN (BUZM3) Martha's Vineyard Airport (MVY)	**Height**	~24 m
			Distance / Bearing:	Collocated; BUZM3 – 40 km @ 282°; MVY – 8.6 km @ 334°
	Ref. Station Configuration:	- See Metocean sensor commissioning form for ancillary sensor configuration - BUZM3: http://www.ndbc.noaa.gov/station_page.php?station=buzm3 - MVY: https://www.ncdc.noaa.gov/ - Lidar configuration summary presented in Table 1		

Communication Information	**Interface Software & Ver.:**	Windcube Anywhere web interface (link in comments field)	**Pri. Control Method:**	WHOI access via MVCO network connection
	Unit User Name:	Redacted	**Sec. Control Method:**	MassCEC team access via Windweb Internet portal
	Unit Password:	Redacted	**Pri. Data TX Method:**	factory email delivery (*.STA files)
	Unit Local IP address:	Redacted	**Sec. Data TX Method:**	FTP (via WHOI network link)
	Unit External IP address:	Redacted	**Data TX Frequency:**	*.STA files: daily via email; *.RTD: TBD for WHOI
	Cellular Service Provider:		**Sat. Service Provider:**	N/A
	Cell Modem Model:		**Sat. Modem Model:**	N/A
	Cell Modem S/N:		**Sat. Modem S/N:**	N/A
	Cell Phone Number:		**Sat. Modem IMEI:**	N/A
	Cell Modem IP Address:		**Sat. SIM (Dec):**	N/A
	Cell ESN / SIM ICCID (DEC):		**Sat. MSISDN:**	N/A

	Comments:	- Direct access to lidar through WHOI network, or Windweb interface; Back-up cellular internet connection planned - Windweb interface for lidar: http://windcubeanywhere.leosphere.com/windweb - FTP for Stakeholder data: FTP: ftp://ftp.awstruepower.com User: MassCEC_Stakeholder Pass: s74!MC3d

	Item	Note or Value	Comments
Setup Checklist / Verification	Verify that nothing is within the measurement cone; ±15° or ±30˚ from vertical over the center of the system	**OK**	Note (1)
	Physical Orientation of lidar body (°T, or ° Magnetic)	**215.5° True**	Lidar chassis North oriented approximately 215.5°True based upon GPS and Site Measurements – Note (2)
	User-defined Directional offset (°)	**155.3°**	Original offset of 155.4° is incorrect due to magnetic interference from structure, but was retained for the sake of data continuity. Note (2), Note (6)
	Post Processing offset	**60.5°**	Note (2)
	Internal Compass Reading (°)	**166.7°**	Note (3)
	Internal GPS reading (Lat / Lon)	**OK**	GPS Location=Lat:41.325040N, Long:70.566678W
	System leveled? Photograph bubble level on body	**OK**	Photographing bubble caused work deck to distort; verified through pitch/roll
	Internal Level Measurement – Pitch (°)	**±0.1°**	Measurements since deployment vary ±0.3°; re-level during site visits
	Internal Level Measurement – Roll (°)	**±0.1°**	Measurements since deployment vary ±0.3°; re-level during site visits
	Height to lidar laser plane (m AGL or MSL)	**13.1 m MSL**	Work bench elevation ~12.6 m, Windcube lens height approximately 0.5m Note (4)
	Lidar monitoring heights (m above laser plane)		See Table 2 below; Note (5)
	Onsite Power supply functioning?	**OK**	Site uses 110 VAC (grid power) supplied at the tower
	Lidar power converters functioning and connected?	**N/A**	
	Lidar grounded?	**OK**	Lidar grounded through ASIT power supply. Tower structure ground floats, did not connect ground lug.
	Peltier(s) functioning?	**N/A**	
	Additional components?	**OK**	Top cover installed and secured; bird spikes installed ad secured; See Figure 2
	System assembled, secured and locked?	**OK**	
	External connections functional – LAN, USB, Antenna, etc.?	**OK**	
	Wiper fluid reservoir filled and properly connected?	**OK**	
	Wiper and washer functioning?	**OK**	Successful onsite test; reservoir secured
	Desiccant packs in place and functional?	**N/A**	
	Unit physically secured – fence, arrowhead anchor, security cable, etc.?	**OK**	Plastic feet bolted through wooden work bench surface; cover tied on; spikes glued on
	Verify System configuration via Direct Connection (LAN)	**OK**	
	Verify Remote connectivity:	**OK**	Connected through MVCO network & through Windweb remote
	Verify real-time data – do they make sense?	**OK**	
	Notes Continued Below		

Note (1): The WHOI 3D anemometer and Rohn lattice mast are inside the scan cone. Lidar chassis oriented such that all 4 beams are unobstructed; all interference is well below first range gate

Note (2): original offset was determined to be incorrect. In the interest of data continuity, no changes made to the lidar, but a specific alignment analysis was conducted to identify an offset for post-processing (see reference below). Offset estimated to be 60.5°. Diagram of tower and lidar orientations provided below in Figure 4.

Note (3): limited confidence in onboard compass; defer to external measurements. Original offset was 165.1; drift to 166.7 as of March 2017 via Windweb

Note (4): rounded to 13.0 m to set monitoring heights since no decimals allows in reporting elevations

Note (5): Leosphere has no lens height offset input for system configuration, so reporting elevations in data files **DO NOT** reflect actual monitoring heights relative to MSL; Need to have 13 m added to reporting elevation

Note (6): Offset has drifted to 155.3° on Windweb as of March 2017; Change being investigated with NRG Systems; Offset value rounded to 155° for alignment analysis.

Additional Configuration notes:

- Check and set level during site visits; attempt document bubble level better
- Alignment analysis reference – Dubois, L., et al. "Wind Direction Offset Adjustments for the Metocean Initiative", 10 March 2017

Departure Checklist

Item	Value / Comments
Close all system panels and covers.	OK
GPS points taken at unit and Northern reference	OK @ unit; physical access restricted for North GPS reference - Used compass & GPS points of diving board orientation
Pictures of site and system (N, NE, E, SE, S, SW, W, NW) toward and away from system	OK – General site photographs embedded below; Stakeholder Directional photographs & Data here: Web: https://ftp.awstruepower.com FTP: ftp://ftp.awstruepower.com Username: MassCEC_Stakeholder Password: s74!MC3d (sierra-Seven-Four-Exclamation-MIKE-CHARLIE-Three-delta) Additional site photos added to support lidar orientation investigation
Current Temperature on site	
Current Conditions on site	Sunny, light breeze from NE
Current time and date on site	07 October 2016

Contact Information

	Client Contact	Installer / Alternate Contact
Company:	Massachusetts Clean Energy Center (MassCEC)	Woods Hole Oceanographic Institution (WHOI)
Contact Person:	Tyler Studds	Anthony Kirincich
Phone Number:	Office: (617) 315-9378	
Cell Number:		
Email address:	TStudds@MassCEC.com	akirincich@whoi.edu
Physical Address:	63 Franklin Street, 3rd Floor, Boston, MA 02110 http://www.masscec.com/	
Comments	- WHOI has primary campaign operations responsibility; - Site access controlled through WHOI, who provide permission and transport	

Obstruction Verification	DIR	Description	Elevation Angle (°)	Horizontal Distance (m)
	N	N/A		
	NE	ASIT Mast	~70°	~4 m
	E	N/A		
	SE	N/A		
	S	N/A		
	SW	N/A		
	W	N/A		
	NW	N/A		
	Comments	- Tower, boom and sensor configuration and heights to change with installation of new anemometers and met sensors; table to be updated upon equipment commissioning; - while structure may be within laser cone, all beams are unobstructed and equipment is well below first lidar range gate; see Figure 3		

Table 1: Current Lidar Configuration Summary

Data File Header - *.STA
HeaderSize=40
Version=2.1.1
ID System=WLS7-436
ID Client=MassCEC
Location=MVCO ASIT
GPS Location=Lat:41.325040N, Long:70.566678W
Comments=Lense height is 13 m above msl; chassis @ 170deg Mag, offset is 155.4 to address declination of 14.6 deg W
FCR Option=OFF
timezone=UTC+0
****
Windcube Parameters (internal use only)
****
Sampling Frequency (Hz)=250000000.000
Ref Frequency (Hz)=67800000.000
Pulses / Line of Sight=20000
Samples / Pulse=1024
Reflected Pulse Start=59
Reflected Pulse End=133
Ref pulse samples nb=1
Nb High Pass Filter Points=5
FFT Window Width=50
Laser Diode Current (mA)=1900
LOS=
Init Drive Position (°)=V
Pulse Repetition Rate (Hz)=30000.000
Pulse Duration (s)=0.000000175
Trigger Delay Time=0.000000020
Wavelength (nm)=1543.000

ScanAngle (°)=28.000
DirectionOffset (°)=155.400
Declination (°)=165.100
PitchAngle (°)=0.200
RollAngle (°)=-0.200
CNRThreshold=-23.000
VrThreshold (m/s)=1.700
SigmaFreqThreshold (m/s)=0.750
WiperCNRThreshold=-19.000
WiperAltitude (m)=100
WiperDuration (ms)=5000
Altitudes (m)=

Table 2: Altitudes

Measurement Heights Relative to Lens (m)	Measurement Heights Relative to MSL (m)
40	53
47	60
67	80
77	90
87	100
97	110
107	120
127	140
147	160
167	180
187	200

Table 3: Status Verification

Realtime status file
LIDAR WINDCUBE STATUS REPORT
2016_11_09__19_30_01
WLS7-436 - MassCEC
GPS: 41°19'30.14"N 70°34'00.04"W 30.7m
v2.1.1
Alarm origin: None
Warning origin: None
EDFA:

- Loss of Output power?: OK
- Loss of Input power?: OK
- LD current bias?: OK
- Case temperature out of range?: OK
- Laser diode temperature out of range?: OK
- Disabled EDFA?: OK
- Out of range power supply?: OK
LDC=1871
CAT=38
DIODE:
FFT(fMAO) = 13950.353931
SYSTEM:
Optical head: 28.3 °C, Computer rack: 40.0 °C, Optical rack: 38.0 °C
Space disk used(%)=0.61
IP-dhcp:
IP-static: 128.128.205.182
Data saved correctly
Tcpu(°C)=41.0
Tmb(°C)=40.0
SIGNAL:
CNRm =
40.0 -19.0
47.0 -18.8
67.0 -17.5
77.0 -16.8
87.0 -16.5
97.0 -16.6
107.0 -17.0
127.0 -18.1
147.0 -19.4
167.0 -20.6
187.0 -21.6
COMPASS:
Connected
Pitch angle(deg)=0.2
Roll angle(deg)=-0.2
PTH:

Not connected
DATA AVAILABILITY:
AvailableAltitudes(%)=85.7
LAST TIME SYNC:
Wed Nov 9 19:29:30 GMT 2016 offset 0.000793 sec
WINDCUBE POWER PACK M50 (PV):
None
FLOW COMPLEXITY RECOGNITION (FCR):
FCR-disabled

Figure 1: WHOI ASIT Station, View from Northwest – Lidar deployed on the work bench

Figure 2: Windcube WLS-436 as Deployed on WHOI ASIT – Cover and Bird Spikes shown, fluid reservoir behind unit

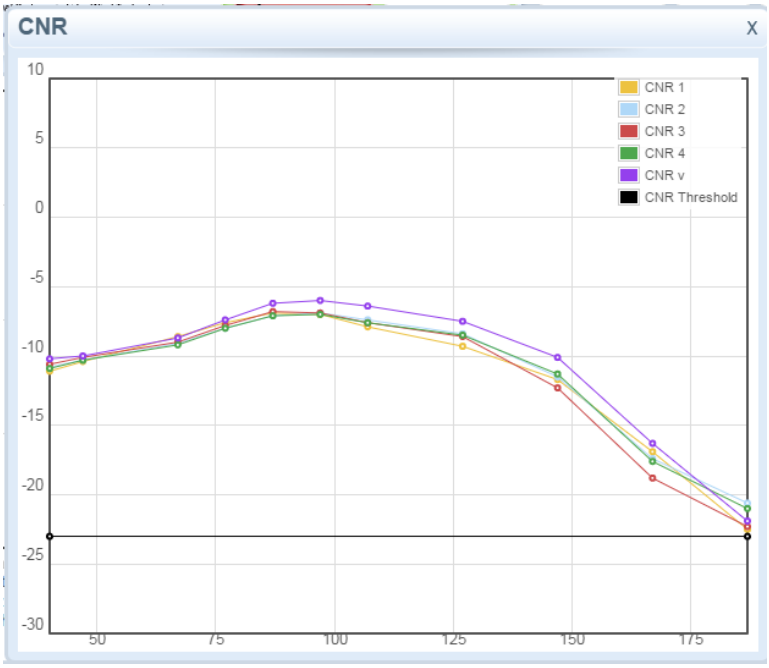

Figure 3: Clear beam path verification:

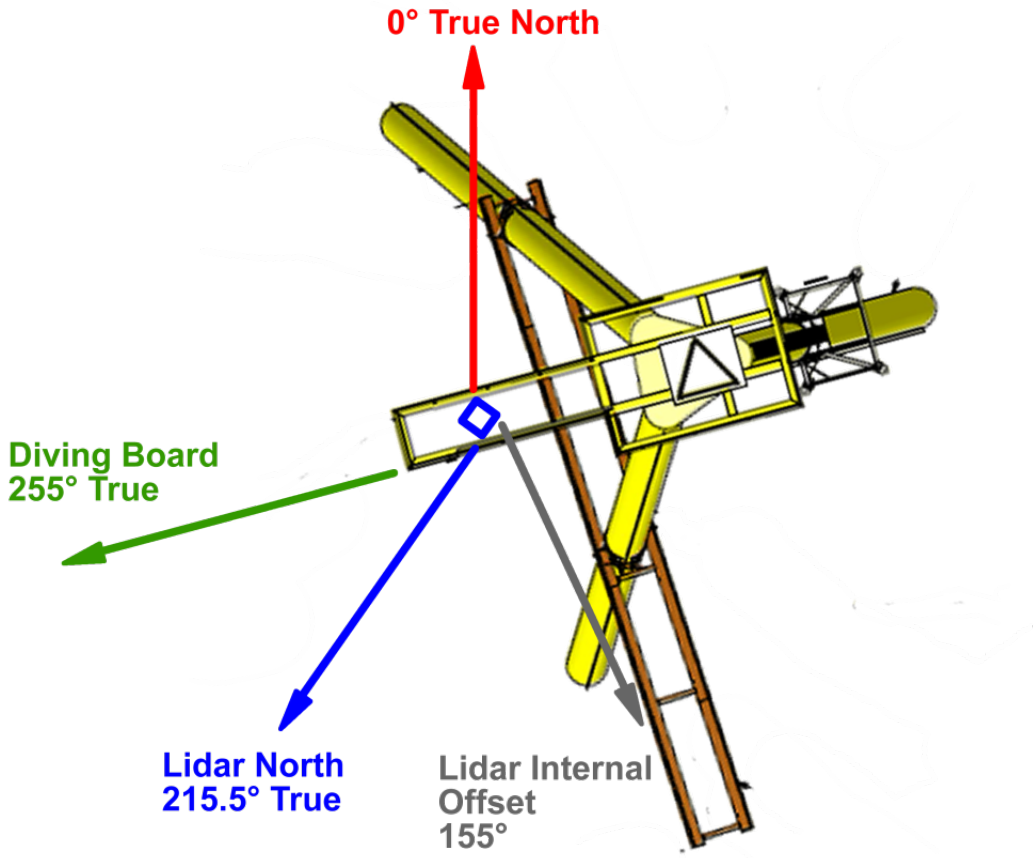

Figure 4: Diagram of Estimated WLS7 436 and ASIT Orientations

Table 4: Document Revision Table

Date	Document Revision Comments and Changes	Author	Version
2016-11-09	Initial DRAFT	MVF	Rev 0
2017-03-10	Finalized primary station information; updated sensor direction offset; updated site history and activity; changes highlighted in red text.	MVF	Rev 1

Table 5: Site History and O&M Log

Date	Site Actions, Changes and Comments
2016-10-07	Initial system installation and commissioning
2016-11-27	Initial set of collocated ancillary sensors installed – see associated commissioning form.
2016-12-14	• Offshore station power shut down due to underwater work; • Lidar does not come back up upon restoration of shore power - Likely due to excessive current draw on the 100 W ASIT power node. • Final components of Ancillary sensor suite installed – see associated commissioning form; • lidar physical orientation measurements and GPS coordinates collected on Site by AWST; • Lidar Data outage begins.
2016-12-23	• Lidar Data record resumes with restoration of lidar power; • New power configuration has the lidar share power across two 100 W power modules – expected to accommodate cold power-up. • Communications not restored to normal; temporary WHOI collection and distribution of *.STDSTA files via FTP
2017-01-28	• Normal lidar communications and Connection to Windweb server restored; • standard email data file transfer restored; • Earlier *.STA files backfilled

Scans of Verification Documentation

Performance Verification Certificate - WINDCUBE® v2

System	*WLS7-436*
Test date	*08-2016*

Reference system

Renewable NRG Systems reference Lidar: **WLS7-94**

The Reference Lidar was certified by Danish Technical University (DTU) in February 2015 at the Høvsøre Test Site.

The reference Lidar measurement has been compared to a 116m reference mast with a test process approved by DANAK.

Data analysis

Data used for comparison are averaged 10 minutes data.

Wind speed and direction data are compared using regression curves applying the model ***y=ax+b*** . Where ***y*** is the Lidar wind speed, ***x*** the reference wind speed, ***a*** the regression gain and ***b*** the regression offset. ***R²*** is the coefficient of determination.

Wind speed mean deviation presented in this report is the mean of wind speed difference between the reference and the tested Lidar during the validation period. The mean deviation and its standard deviation are given in m/s.

Results

Horizontal Wind speed regression:

Altitude	*Criteria*	*Value*	*Passed*
40m	Wind speed regression gain is 1±0.02	1.018	yes
	Wind speed regression offset is 0±0.2 m/s	-0.006	yes
	Coefficient of determination R^2 is greater than 0.99	0.998	yes
80m	Wind speed regression gain is 1±0.015	1.007	yes
	Wind speed regression offset is 0±0.2 m/s	-0.008	yes
	Coefficient of determination R^2 is greater than 0.99	0.999	yes
120m	Wind speed regression gain is 1±0.015	1.007	yes
	Wind speed regression offset is 0±0.2 m/s	0.001	yes
	Coefficient of determination R^2 is greater than 0.99	0.999	yes
160m	Wind speed regression gain is 1±0.015	1.010	yes
	Wind speed regression offset is 0±0.2 m/s	0.033	yes
	Coefficient of determination R^2 is greater than 0.99	0.999	yes

Wind direction regression:

Altitude	*Criteria*	*Value*	*Passed*
100m	Wind direction regression gain is 1±0.01	1.002	yes
	Wind direction regression offset is 0±2°	-1.416	yes
	Coefficient of determination R^2 is greater than 0.99	1.000	yes

Horizontal Wind speed Deviation and Standard deviation of deviation:

Altitude	*Criteria*	*Value*	*Passed*
40m	Wind speed deviation is 0±0.1m/s	0.043	yes
	Wind speed std deviation of deviation is 0±0.2 m/s	0.073	yes
80m	Wind speed deviation is 0±0.1m/s	0.022	yes
	Wind speed std deviation of deviation is 0±0.2 m/s	0.057	yes
120m	Wind speed deviation is 0±0.1m/s	0.038	yes
	Wind speed std deviation of deviation is 0±0.2 m/s	0.072	yes
160m	Wind speed deviation is 0±0.1m/s	0.095	yes
	Wind speed std deviation of deviation is 0±0.2 m/s	0.106	yes

Validation Service agreement

System **WLS7-436** has passed Renewable NRG Systems, Inc. acceptance tests.

Llewellyn Cobden