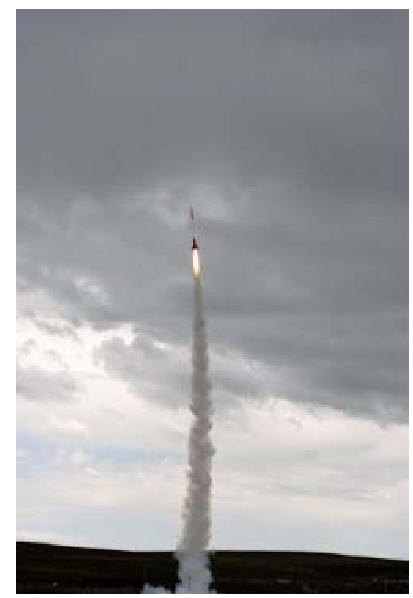
Glenda Project – Executive Summary - 2014

Dedication

On May 31st, 2013, The weather research community lost Tim Samaras, an explorer, pioneer, engineer, and storm chaser. Also lost in the same El Reno OK, F-5 tornado were his son Paul, and research partner Carl Young. Tim's TWISTEX Team was one of the best research groups out there and our continuing work is dedicated to their efforts, and ultimate sacrifice.



Glenda Project – Purpose

The primary mission of the Glenda Project is to provide the capability to rapidly gather previously inaccessible localized microclimate data from altitudes ranging from ground level to over 100,000 feet and to return this data for immediate use.

The Glenda Project is mix of adaptable ground stations combined with a reusable sounding rocket delivery system, and rapidly deployable weather balloons which are designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

Glenda Project – Data Capabilities

The Glenda Project has the capability to collect temperature, humidity, barometric pressure, wind speed and other types of environmental data from ground level to over 100,000 feet.

Glenda payloads are designed to be launched into thunderstorms, tornados, and other volatile weather environments and to return intact with its collected data.

Glenda Project – Engineering / Computing / Remote Sensing

David Davis – Edmonds, WA – Engineering - Brings decades of experience from engineering work in private industry and United States government in rocket research, and aerospace. Extensive background in electronics, mechanics, communications, computing, and storm spotting. Member of the National Association of Rocketry since 1983, and been involved with hobby related rocketry since the 1960’s.

CERTIFIED SKYWARN SPOTTER

Robert Pullman – Ponchatoula, LA - Remote Sensing - Has three decades of experience in communication and the computer industry and his expertise is world renown. His work has enabled governments to formulate policies and legislation in international, national and local forums. He has developed products that are used by universities for seminars, by corporations for internal operations to meet government regulations, by scientists for research work in field and laboratory conditions, by government departments for device operations and maintenance, and by the military for use in battlefield activities.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Media Communications / Public Relations

Tim Quigg in Dayton, WA brings a unique mix of personal background and professional experience to the Glenda Project. Quigg has over two decades of experience in customer service and media relations. He is the former Assistant Editor of Extreme Rocketry Magazine (2000 to 2007), as well as a freelance writer of numerous articles for Sport Rocketry Magazine. He is a current member of the National Association of Rocketry, and is the 2001 recipient of the National Association of Rocketry's President's Award, in recognition of his work with youth in model rocketry on a national level. He has also written a book on the topic of high power rocketry; "A Guide to Level One Certification" currently published by ARA Press. Quigg is a highly decorated 30-year veteran of law enforcement, and is currently the supervisor at a Southeastern Washington State E911 Communications Center.

Glenda Project – Columbia County, WA - Intercept Teams

John Quigg in Dayton, WA, brings to the project a mix of skills ranging from high tech computing, to storm spotting field abilities. As the head of our field operations Intercept Team, John plans the missions, deploys the field assets, and collects the data. A SKYWARN trained storm spotter, and a master behind the camera, John continues to bring back amazing photos, and video from the field on our continuing storm intercept operations.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Typical Flight Vehicles

<u>9875 Booster</u>

- 4” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 20,000 ft altitude envelope

<u>5475 Booster</u>

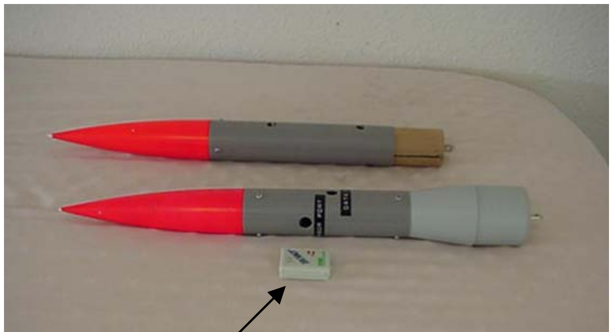
- 2.125” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 15,000 ft altitude envelope

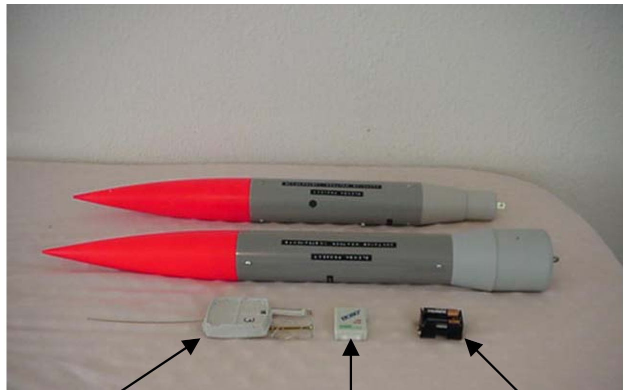
<u>FAR 101 Booster</u>

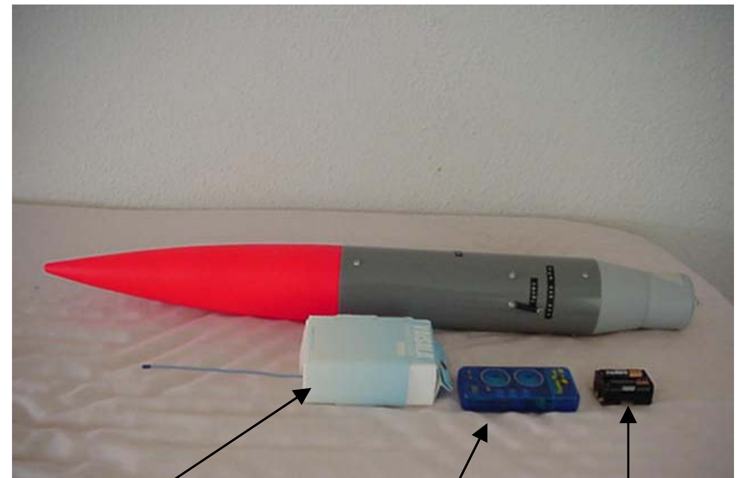
- 3” diameter booster, 2.125” diameter capsule
- GPS, and Temperature dual data logger Payload
- 2,500 foot altitude envelope
- Exempt from FAA Waiver Constraints

Glenda Project – Typical Flight Payloads

The Glenda project uses several different payload capsule configurations carrying a variety of instrumentation in order to gain weather related information, and other micro-climate data







54mm (2.125”) Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- Used by 54mm & 75mm boosters.

75mm (3”) Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- RS92 Digital Radiosondes transmitting temperature, RH, barometric pressure, and GPS coordinates.
- Used by 54mm & 98mm boosters.

98mm (4”) Capsule

- RS80 Analog Radiosonde transmitting temperature, RH, and barometric pressure.
- Audio location beacon
- Used by 75mm boosters.

Glenda Project – Typical Flight Profile

2 – Intercept Phase

3 – Data Collection Phase

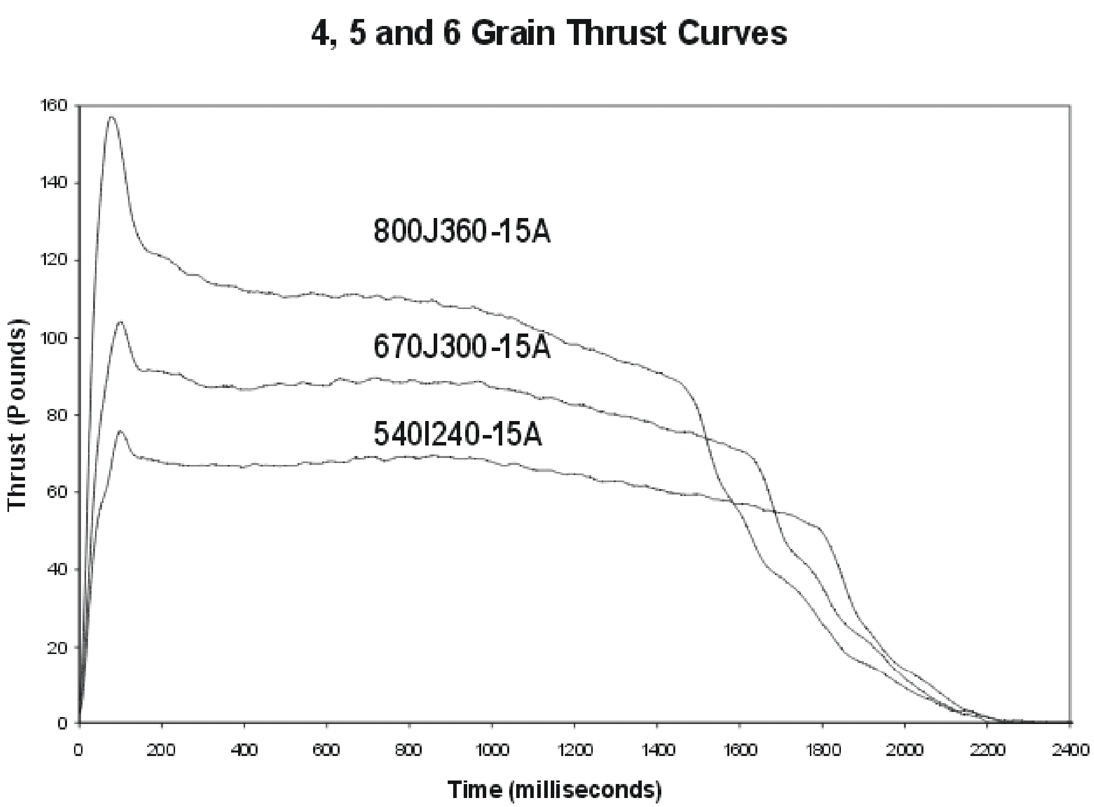
4 – Recovery Phase

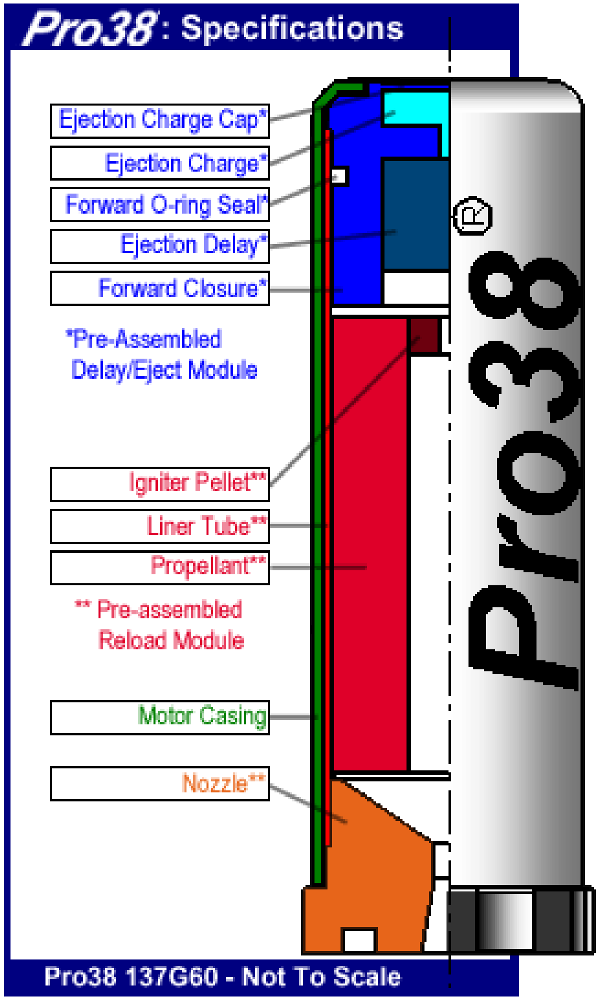
1 – Launch Phase

Note: Propulsion is provided by reloadable /reusable rocket motors giving the capability of rapid turnaround between flights.

Glenda Project – Propulsion

The Pro38 / Pro54 rocket motor propulsion system is the first commercial thermoplastic propellant-based solid rocket motor and is produced by Cesaroni Technology Inc. of Toronto Canada. The Pro38 / Pro 54 is a modular, reloadable Solid propellant rocket motor system designed primarily for use in launching small experimental payloads by universities, colleges, research institutes and sport rocketry enthusiasts.





Glenda Project – Data Collection Methods

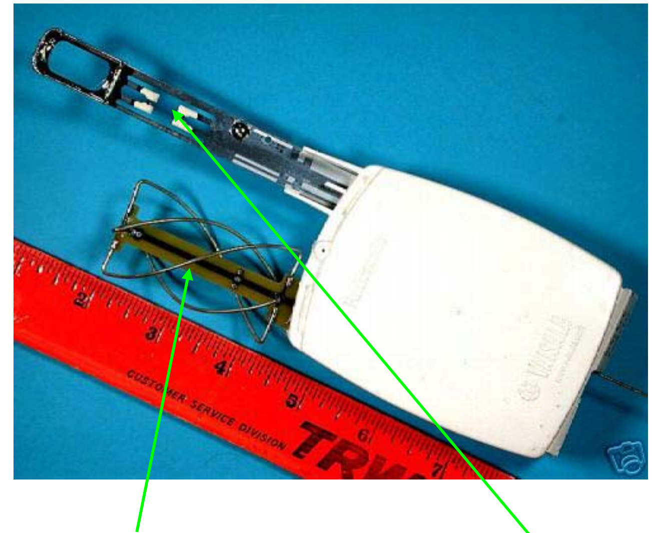
Glenda has several methods for collecting data:

- Rocket Launched - Active Flight Data Collection Systems – Transmitters
- Weather Balloon Launched – Active Flight Data Systems - Radiosondes
- Rocket Launched - Passive Flight Data Collection Systems – Dataloggers
- Ground Stations

Glenda Project – Active Payloads - Transmitters

Converted Radiosonde Payloads

The Glenda Project uses converted radiosondes that are designed primarily for use with weather balloons. The circuitry and sensors function properly under thrust loads of the Glenda boosters and are compatible with NOAA / NWS radiosonde receiver systems.



The radiosonde contains instruments capable of making direct measurements of air temperature, humidity and pressure. These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package.

Vaisala RS92 Radiosonde

<u>Radiosonde Specifications:</u>

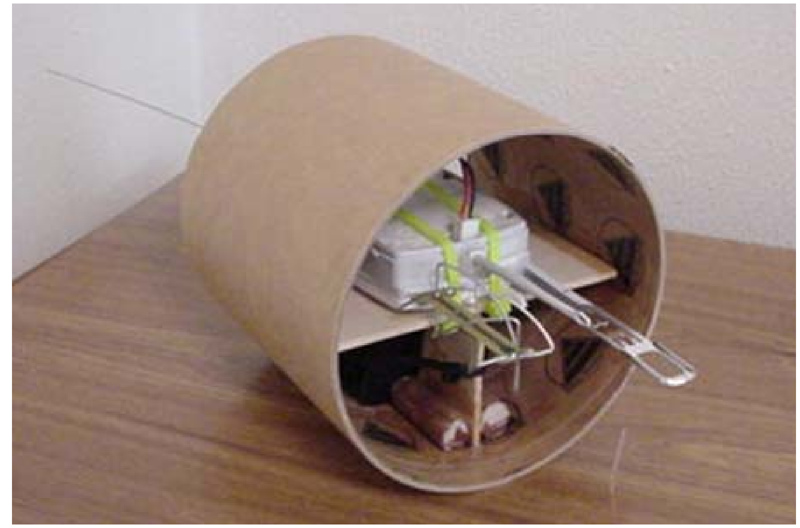
- Pressure range 3mb to 1060mb +/- .1mb
- Operating temperature range of -90°C to +60°C
- Relative Humidity from 0 to 100%
- Sampling Rate of once per second for the sensor suite
- Provides positioning data via GPS for payload location and wind velocity

Glenda Project – Active Payloads - Transmitters

Data Acquisition Flow Diagram

Sensor Data Transmitted from Capsule

- Barometric Pressure Sensor Data
- Temperature Sensor Data
- Relative Humidity Sensor Data
- GPS - Payload Position Data



Active Payload cushioned within the flight capsule

Ground Receiver and Antenna System

Data recorded into Laptop and graphically displayed

GPS – Ground Station / Chase Vehicle Position Data

Glenda Project – Active Payloads - Application

Mobile Ground Station / Intercept Vehicle

Isolated Laptop
Power Supply

Telemetry
Receiver

Cellular Modem
w/ internet connection

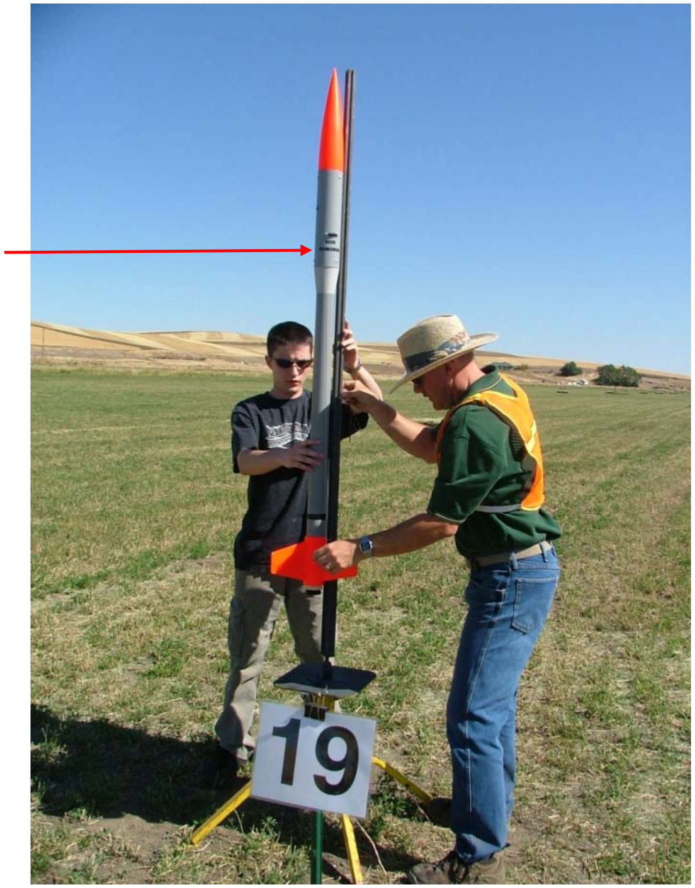
Laptop

Not Shown:

a) External Telemetry Receiver Antenna
b) External GPS Antenna
c) External Cellular Modem Antenna

Flight Vehicle

Payload
Capsule

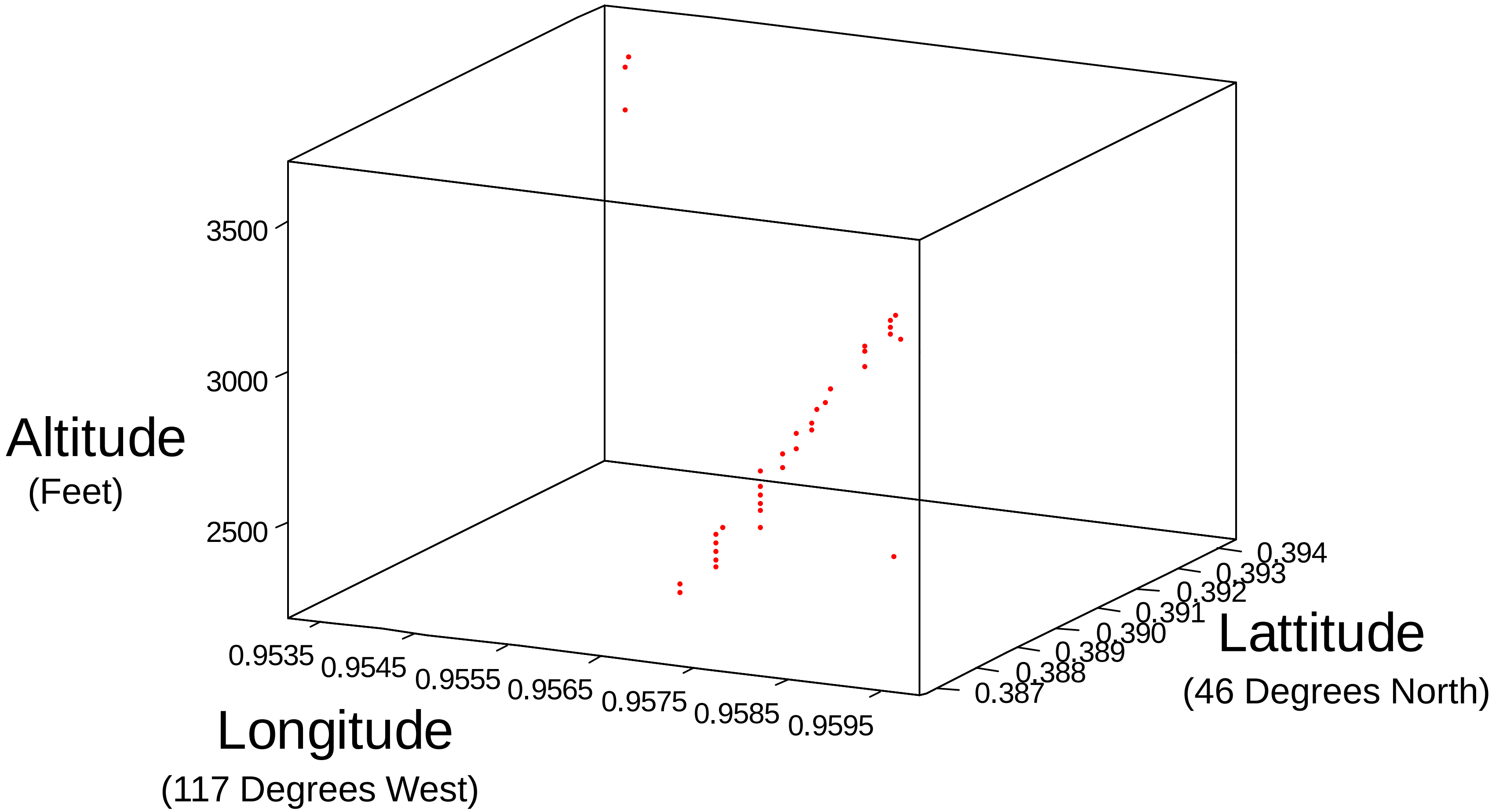


Length: 65”
Diameter: 3”
Dry Weight: 3.5 Pounds
Attainable Altitudes: 2,000 feet
to 20,000 feet

Glenda Project – Active Payloads - Application

“Lone Tree” Launch Site – June 11th, 2011

Lattitude / Longitude / Altitude / Motion

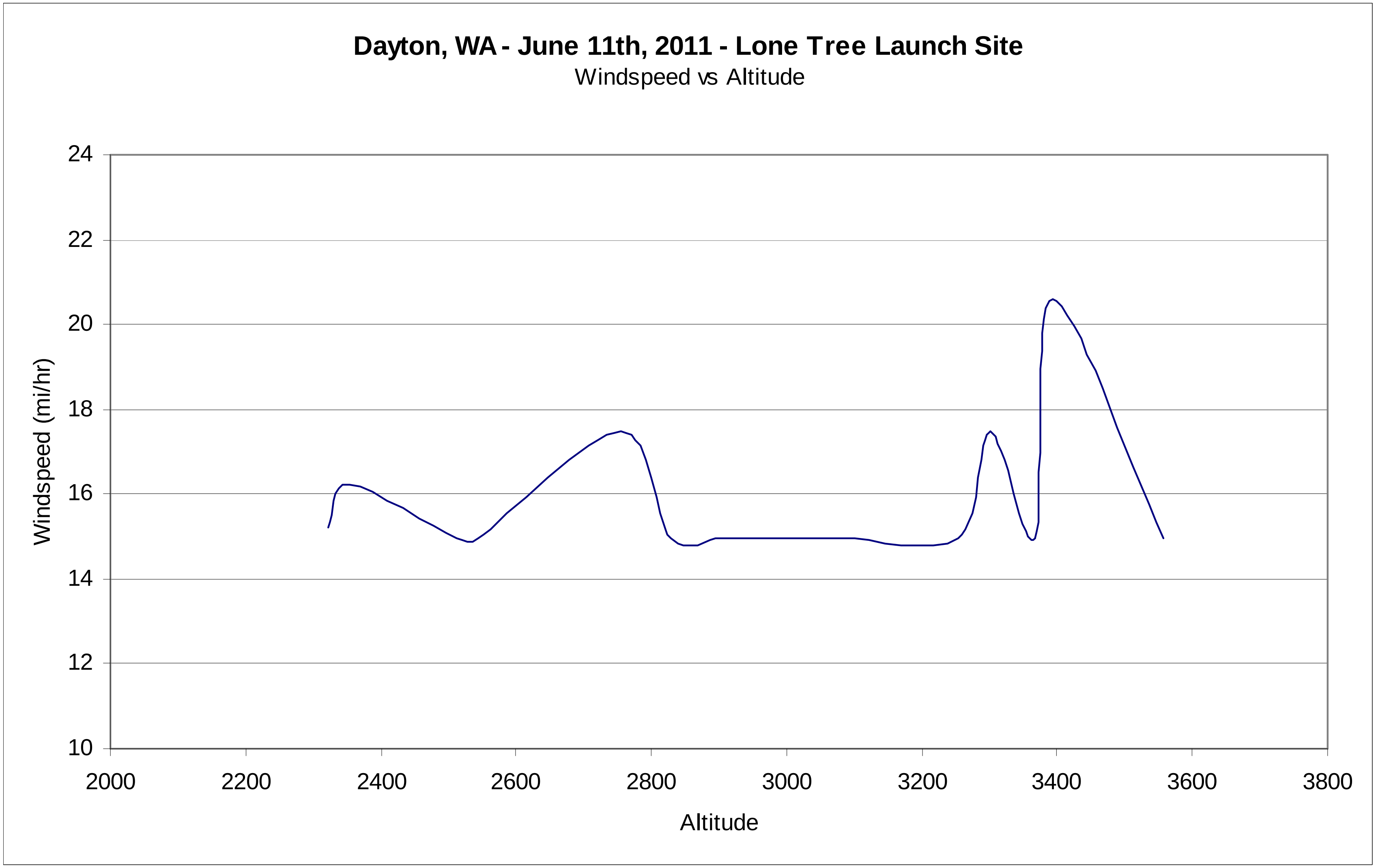


Note: After an initial shift at altitude, due to the winds aloft, recovery was nominal

Glenda Project – Active Payloads - Application

Wind Speed vs. Altitude

“Lone Tree” Launch Site – June 11th, 2011

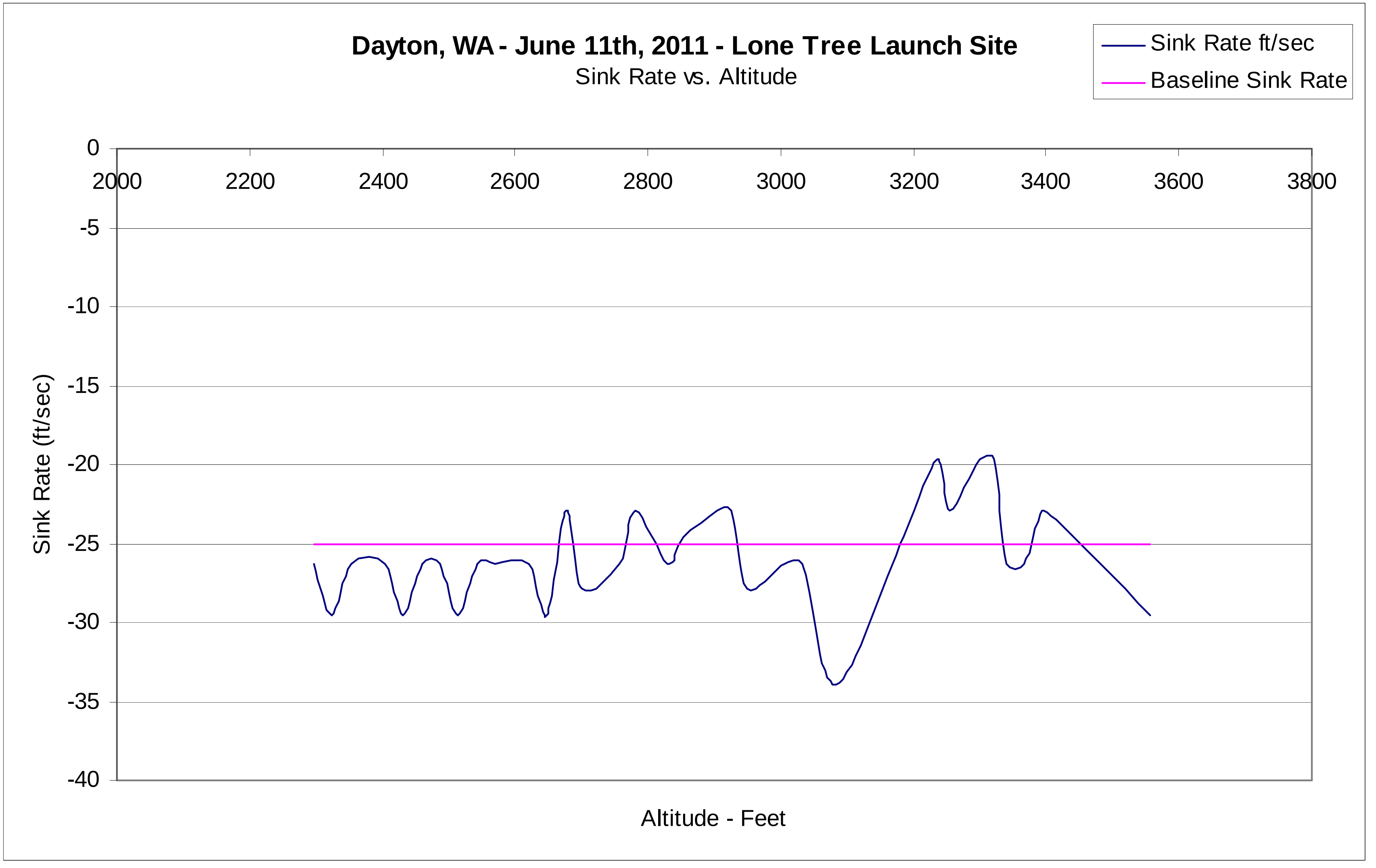


Note: Windspeed values remained relatively consistent during the flight

Glenda Project – Active Payloads - Application

Sink Rate vs Altitude

“Lone Tree” Launch Site – June 11th, 2011



Note: The baseline capsule sink rate was 25 feet per second (-25 fps) and was able to continue to detect updrafts and downdrafts. No consistent pattern was detected.

Glenda Project – Active Payloads - Transmitters

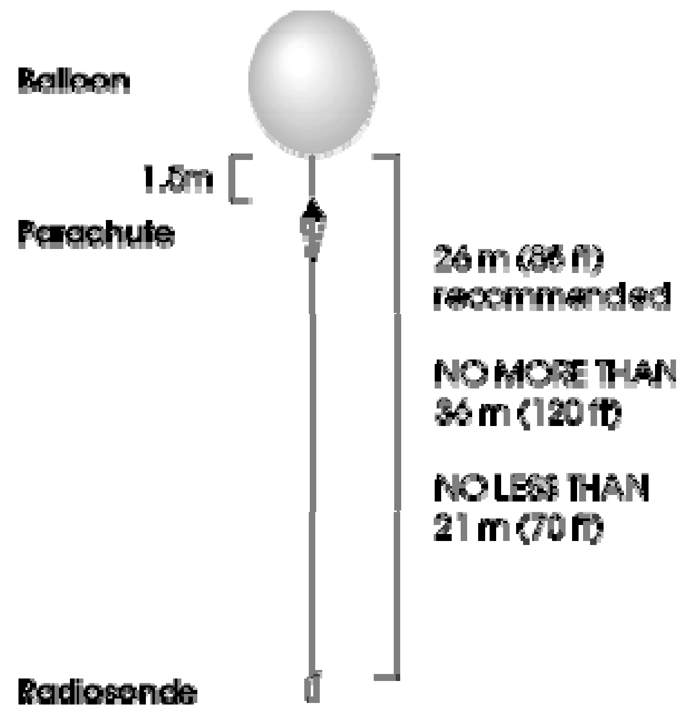
Weather Balloon - Radiosonde Payloads

In 2013, the Glenda Project expanded our flight capability to conduct actual weather balloon launches with the intent to expand our flight envelope to over 100,000 feet. The most significant challenge was the development of the ground support equipment and infrastructure.

The signal / data processing systems were already in place which made the transition to actual balloon launches rather seamless.

100 gram and 150 gram balloons

Parachute and Radiosonde de-reeler



Glenda Project – Weather Balloon Fill System

Ground Support Equipment (GSE) in support of balloon inflation

Pressure Regulator with connector to Helium Tank

15 foot connection hose

Balloon “Stinger” with flow control / shut off valve

Un-inflated weather balloon on “Stinger”.

Radiosonde Launch Platform

Glenda Project – Active Payloads - Application

May 18th , and May 19th – Weather Balloon Launch

On May 18th, and May 19th 2013, the Glenda Project launched its first weather balloons deploying Vaisala RS-92 radiosonde payloads.

The first flight on May 18th was flown using a 150 gram balloon filled with 40 cubic feet of helium. Projected flight altitude was approximately 100,000 feet. The RS-92 payload contained a GPS only telemetry package. Ground wind speed was in excess to 10 miles per hour and the balloon headed rapidly to the Northeast. Data was collected until signal was lost due to altitude and distance at approximately 11,000 feet. While the balloon continued on to its maximum altitude, we lost signal to the payload.

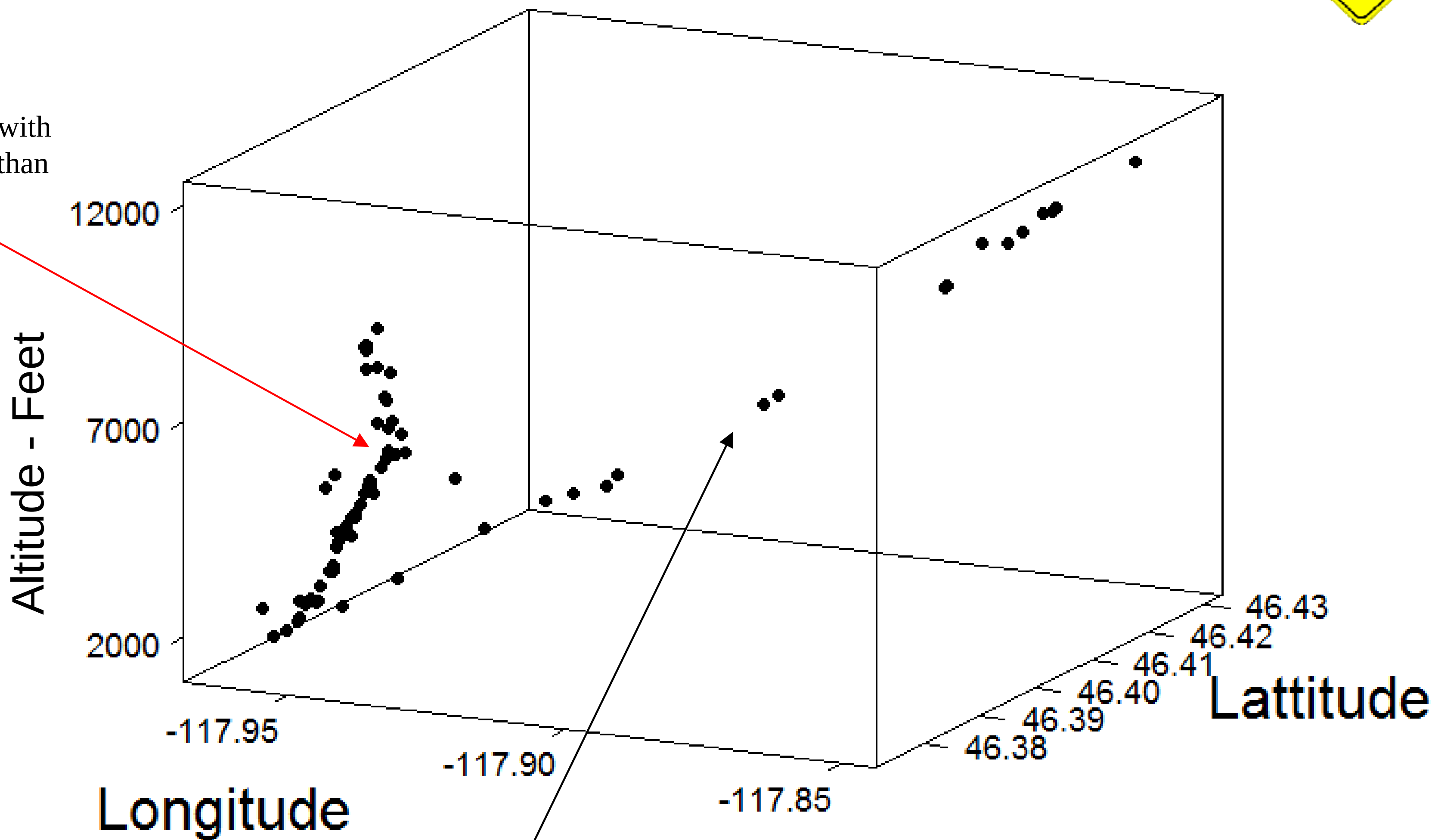
The second flight on May 19th, was made using a 100 gram balloon, again filled with 40 cubic feet of helium with a projected altitude of 80,000 feet. With the flight, the RS-92 contained a full sensor suite of GPS, Temperature, Relative Humidity, and Barometric Pressure sensors. A full data set was collected until signal loss occurred at approximately 9,000 feet. The balloon continued on to its maximum altitude.

The following slides display the data collected from the two flights.

Glenda Project – Active Payloads - Application

May 18th , and May 19th – Balloon Launch Flight Comparisons

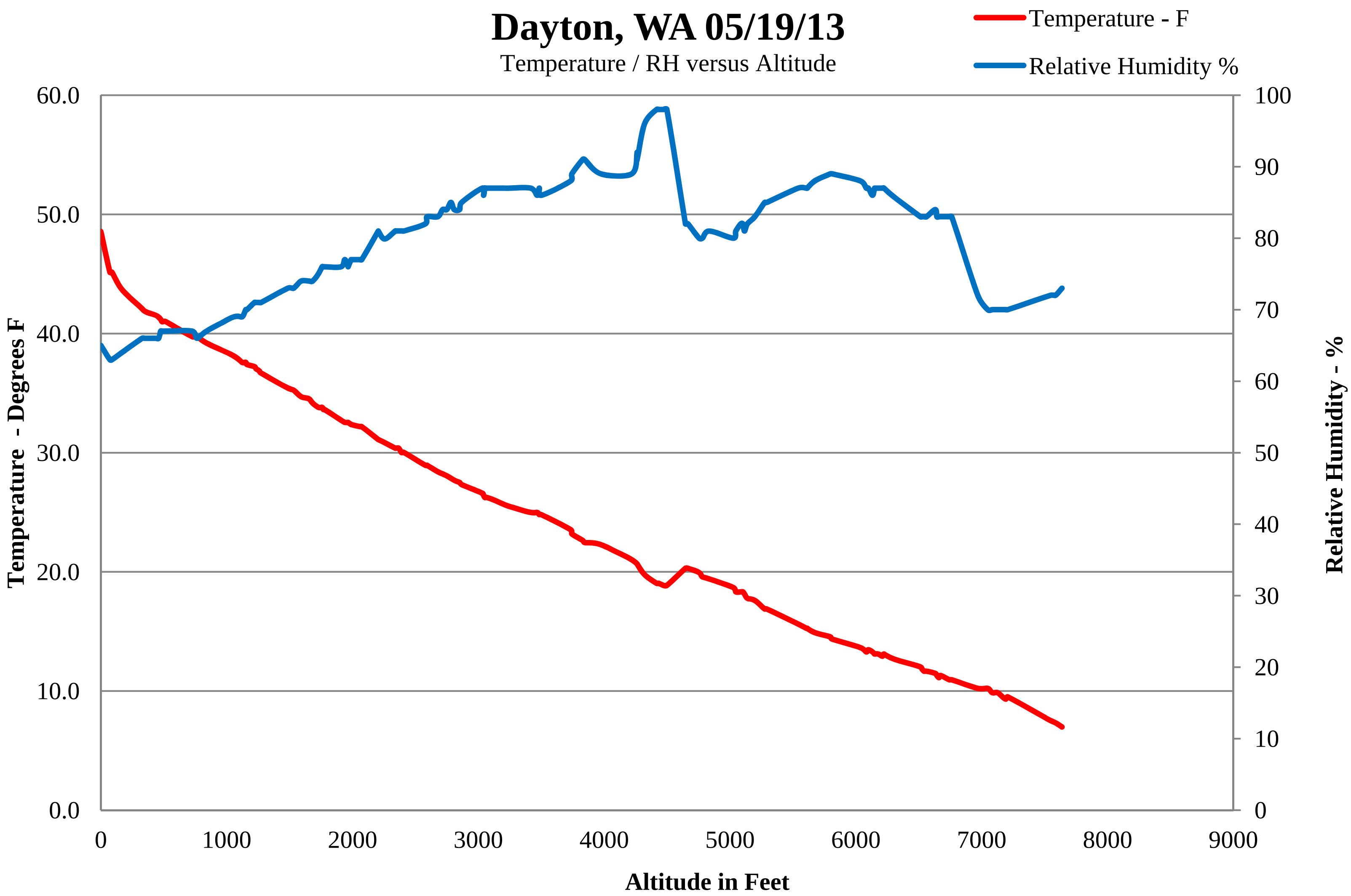
05/19 – Balloon launch with ground wind speed less than 10 miles per hour



05/18 – Balloon launch with ground wind speed greater than 10 miles per hour

Glenda Project – Active Payloads - Application

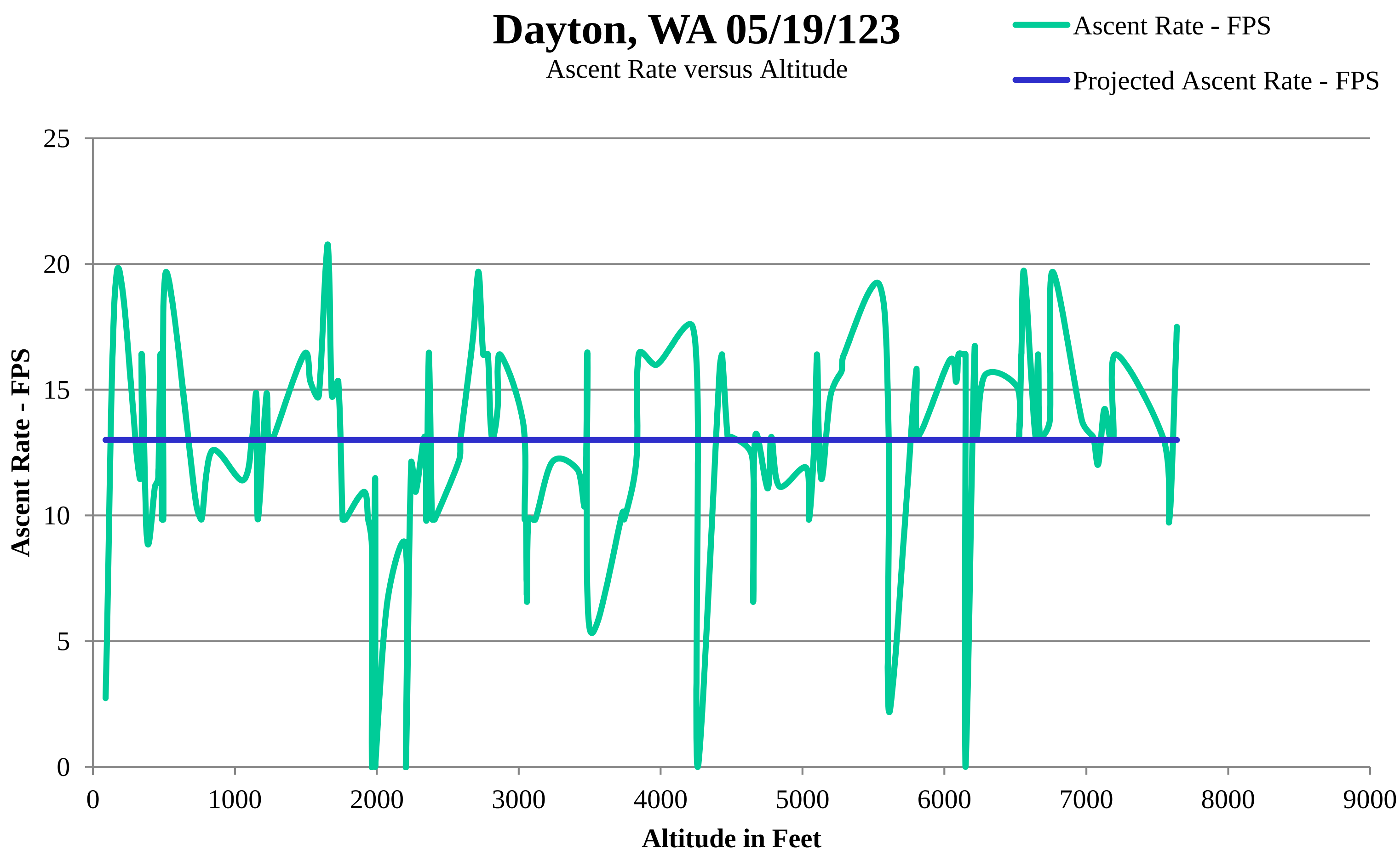
May 19th – Temperature / RH versus Altitude



Note: RH drop at around the 4,500 foot mark while temperature continues to drop along predicted lines. Shifts tend to occur at microclimate boundaries

Glenda Project – Active Payloads - Application

May 19th – Balloon Ascent Rate versus Altitude



Note: Weather balloons are designed to ascend at predictable linear rates. The micro climate at "Lone Tree" continues to exhibit updrafts and downdrafts throughout the entire flight

Glenda Project – Active Payloads - Application

May 18th , May 19th, and June 1st – Weather Balloon Launch

The results of these flights have established the capability of the Glenda Project to launch balloon deployed payloads into thunderstorms, and tornadic systems.

While the flights were a conceptual success, there are still improvements to be made. Primarily, if we're to attain data above 10,000 feet, our existing omni-directional antenna system will need to be upgraded to include a Yagi uni-directional antenna operating in parallel in order to receive the weaker radiosonde transmissions.

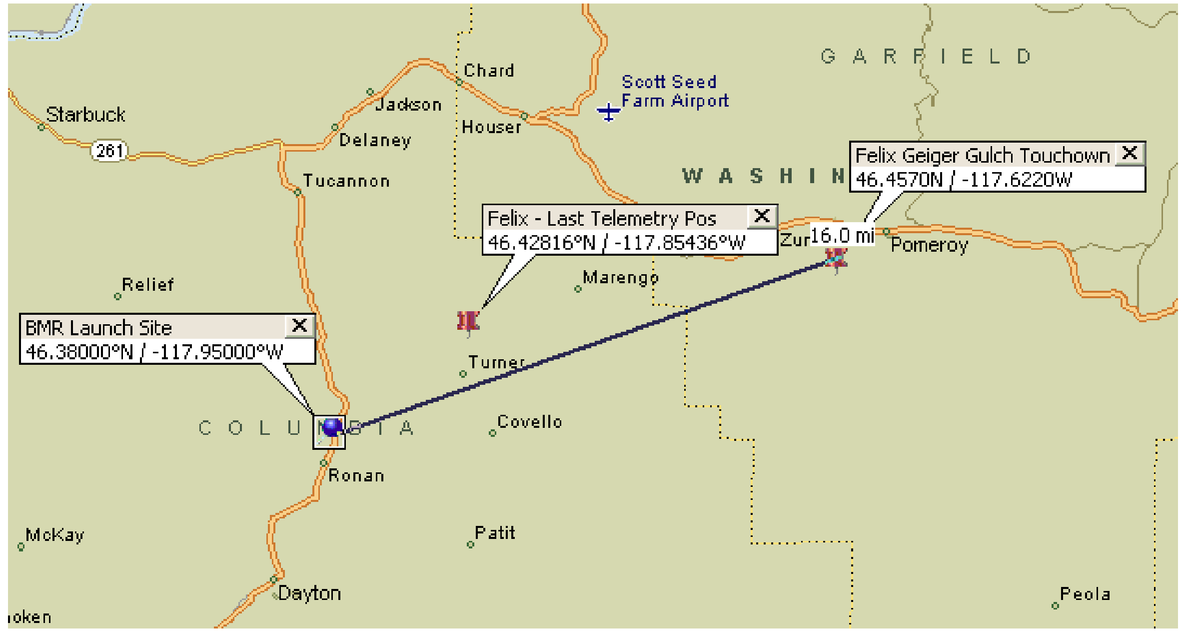
Our June 1st balloon launch at the Pendleton Oregon National Weather Service Open House was an operational success as well. However, our radiosonde frequency of 402.875 MHz was over powered by their 400 Mhz repeater transmissions which resulted in loss of signal post launch. In order to prevent this at future NWS launches, a radiosonde operating at a different frequency will be necessary. There are units available which operate at 1680 MHz and this will require both an antenna and receiver upgrade for them to be successful.

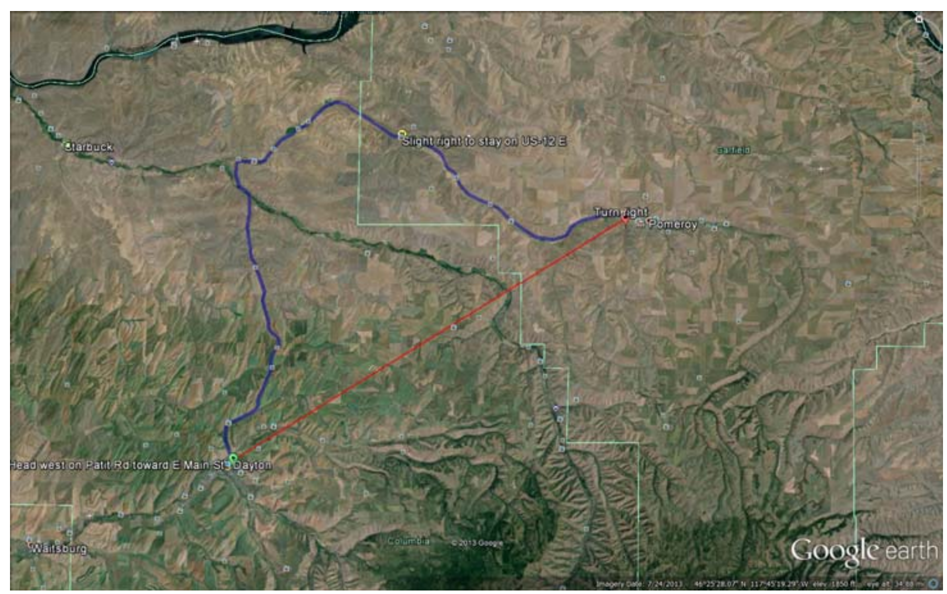
The success of these launches culminates over 15 years of development and operational maturity. Additional launches are planned as our systems continue to grow and evolve.

Glenda Project – Active Payloads - Application

May 18th , Balloon Launch – Payload Recovered – Projected Altitude

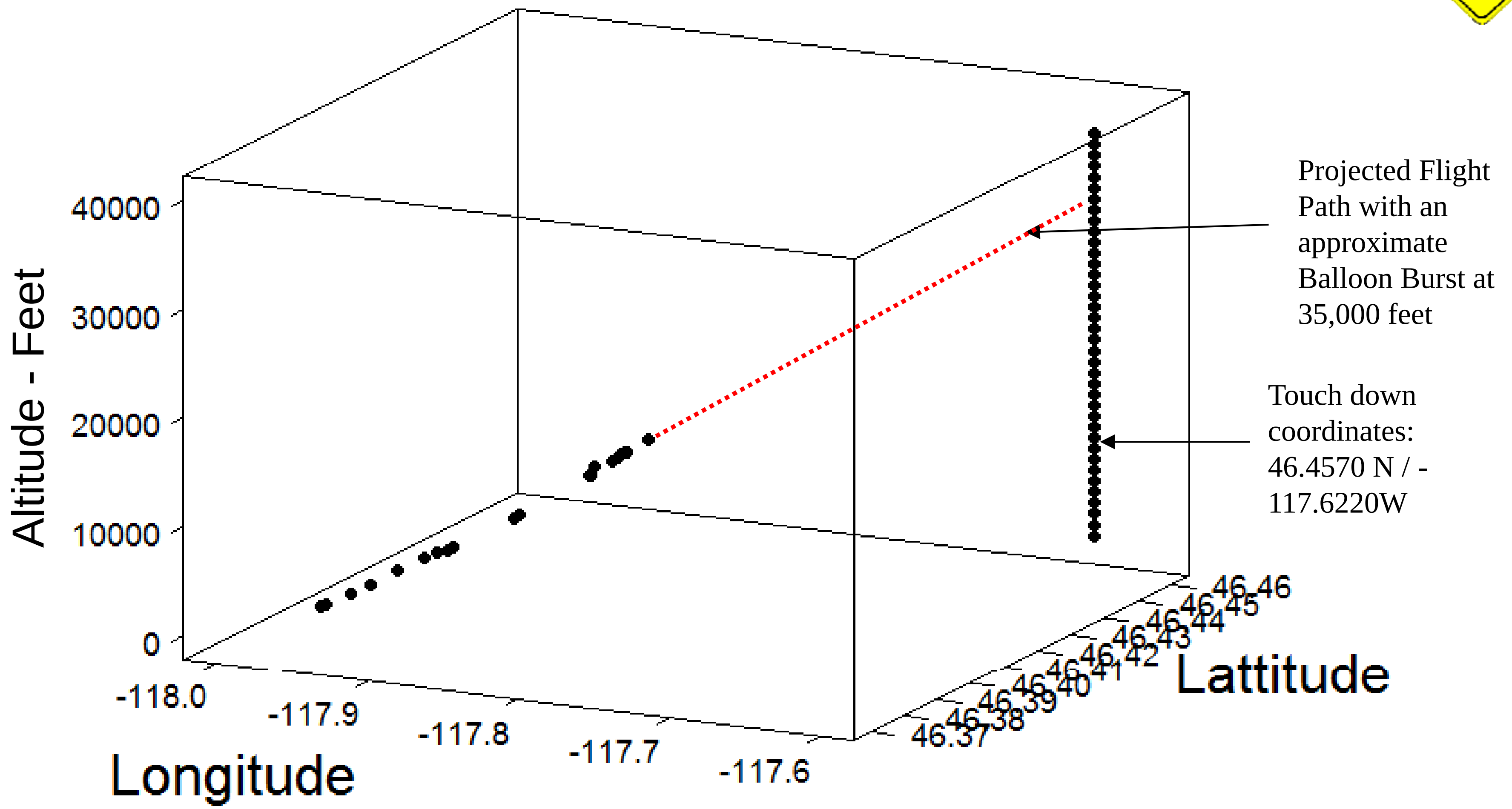
On October 19th, five months after the May 18th launch of the first balloon radiosonde, it was found by a hunter in rough terrain 16 miles from the launch point and 20 miles from the Dayton facility.





Glenda Project – Active Payloads - Application

May 18th , Balloon Launch – Payload Recovered – Projected Altitude



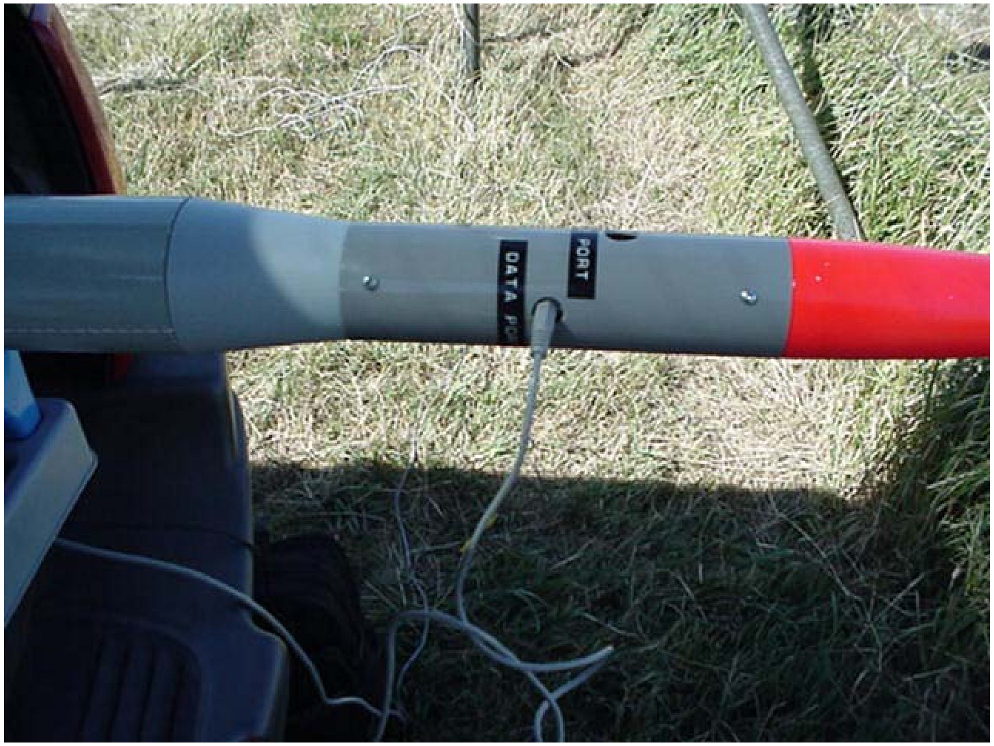
By combining the recovery touchdown point and the projected trajectory using our existing telemetry, we can reasonably determine that we achieved an altitude in excess of 35,000 feet. While this is well under our 100,000 feet prediction, it is a significant accomplishment.

Glenda Project - Passive Payloads – Data Loggers

A data logger is an electronic instrument that records measurements over time. Typically, data loggers are small, battery-powered devices that are equipped with a microprocessor, data storage and sensors. Most data loggers utilize software on a personal computer to initiate the logger and view the collected data.

Prior to a Glenda launch, the data logger is connected to a laptop computer. Then, systems software is used to select logging parameters (sampling intervals, start time, etc.) and initiate the logger. The logger is then disconnected from the laptop and installed inside the Glenda payload capsule. Upon launch, the logger records each measurement and stores it in memory along with the time and date.

Post recovery, the logger is then reconnected to the laptop computer and the software is used again to readout the data and see the measurements as a graph, showing the profile over time. The tabular data can be viewed as well, or exported to a spreadsheet for further manipulation.



Canmore GT-740FL GPS Data Logger

The GT-740FL is a single board GPS receiver / data logger featuring surface mount components and power supply designed to with stand the high flight loads of the Glenda boosters.

Data logger Specifications:

- 48 track verification channels
- SiRF IV low power chipset
- Adjustable sampling rates from 1 second +
- Satellite signal reception sensitivity: -163dbm
- Position: +/- 2.5 meters CEP
- Data compatible with Google Earth
- Size/Weight: .625 x 1.17 x 2.75" (16 x 30 x 70 mm)/approx. 2.5 oz.(71 grams)
- Time to reposition: < 0.1 second average
- Time to boot: <34 seconds (cold), 1 sec (hot)
- Ultra low power consumption; over 17/56 hours continuous use
- Water resistant to IPX6 standard

MicroLite Temperature Datalogger

The MicroLite USB Datalogger is a small electronic device for monitoring and recording temperature. Manufactured to stringent IP68 standards, the MicroLite logger is dustproof and is only 4.3” long and 1” thick. The data logger features a three digit LCD display, direct USB connection, wide temperature range, high accuracy and large sample memory. Data can be displayed on the small numeric screen or downloaded to the MicroLab Lite software via the USB 2.0 connector.

<u>Datalogger Specifications:</u>

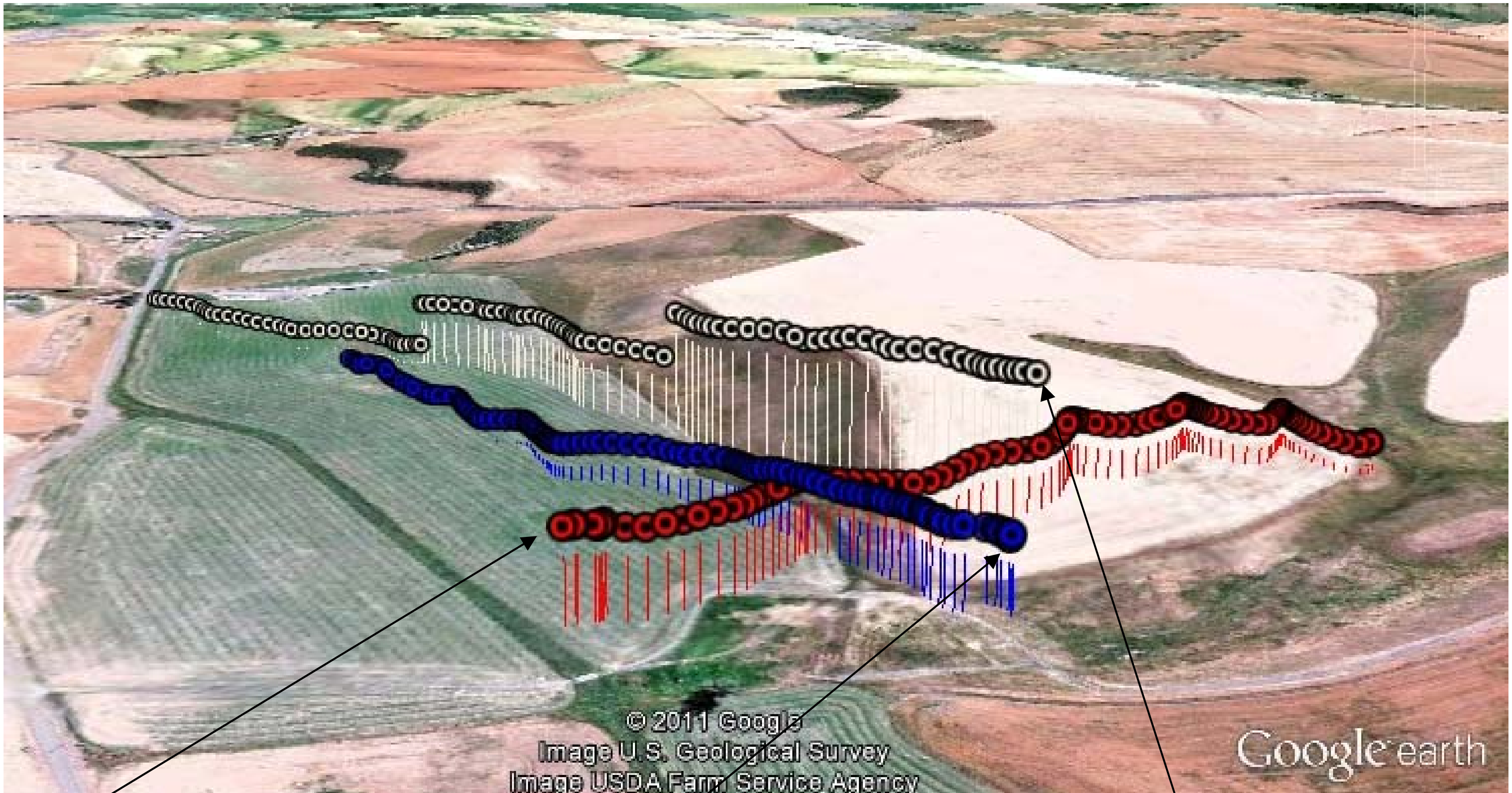
- Internal Temp Sensor: -40°C to 80°C Thermal Conductor enabling a fast sensor response time
- Sampling Resolution A/D Resolution: 16Bit 0.1°C
- Data Storage Capacity: 16,000 Samples
- Sampling Rate: 1 per second to 1 per 2 Hours
- Battery: Replaceable 3V Lithium Battery - CR2032
- Battery Life: 2 Years at 1 second Sampling Rate
- Dimensions: 11cm x 3.9cm x 2.6cm (4.3" x 1.5" x 1.0")
- Weight: 45.5 grams (1.6oz)
- Software: MicroLab Lite for Windows
- Standard Compliance: IP68, NEMA6 (30 Minutes for 0.5 meter Depth) CE, FCC

Glenda Project - Passive Payloads – Application

GPS Data Logging

4D wind current mapping over local terrain.

(4D is latitude, longitude, elevation and velocity)



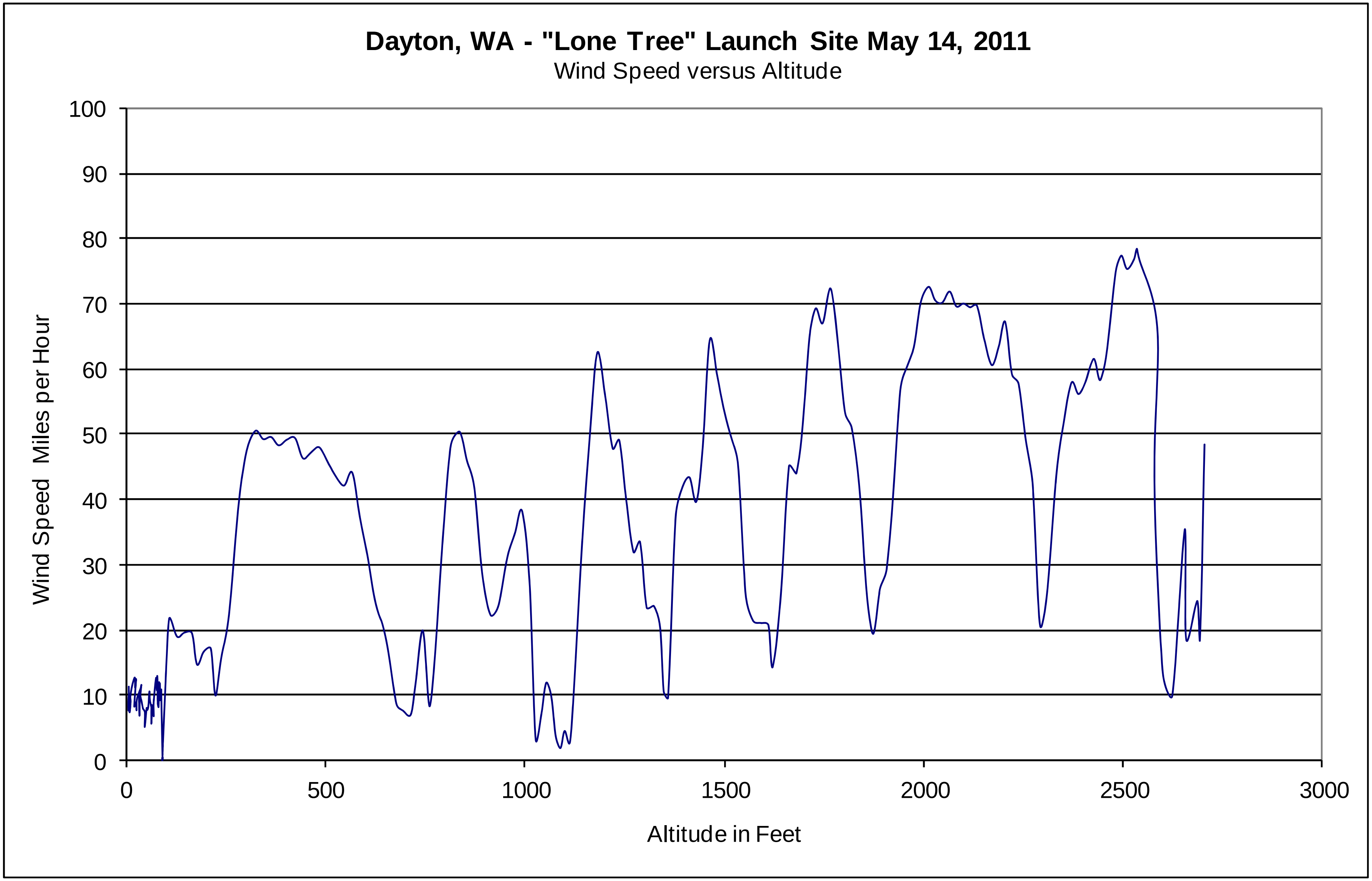
May 14th
7554 Booster – Aerotech I211
"Thunderstorm Intercept"
Apogee: 2,706 Feet
Ground Level Wind Speed: 4.5 mph

June 11th
9875 Booster – CTI I170
Apogee: 2,211 Feet
Ground Level Wind Speed: 10 mph

October 1st
7554 Booster – Aerotech I211
Apogee: 2,354
Ground Level Wind Speed: 14.5 mph

Glenda Project - Passive Payloads – Application

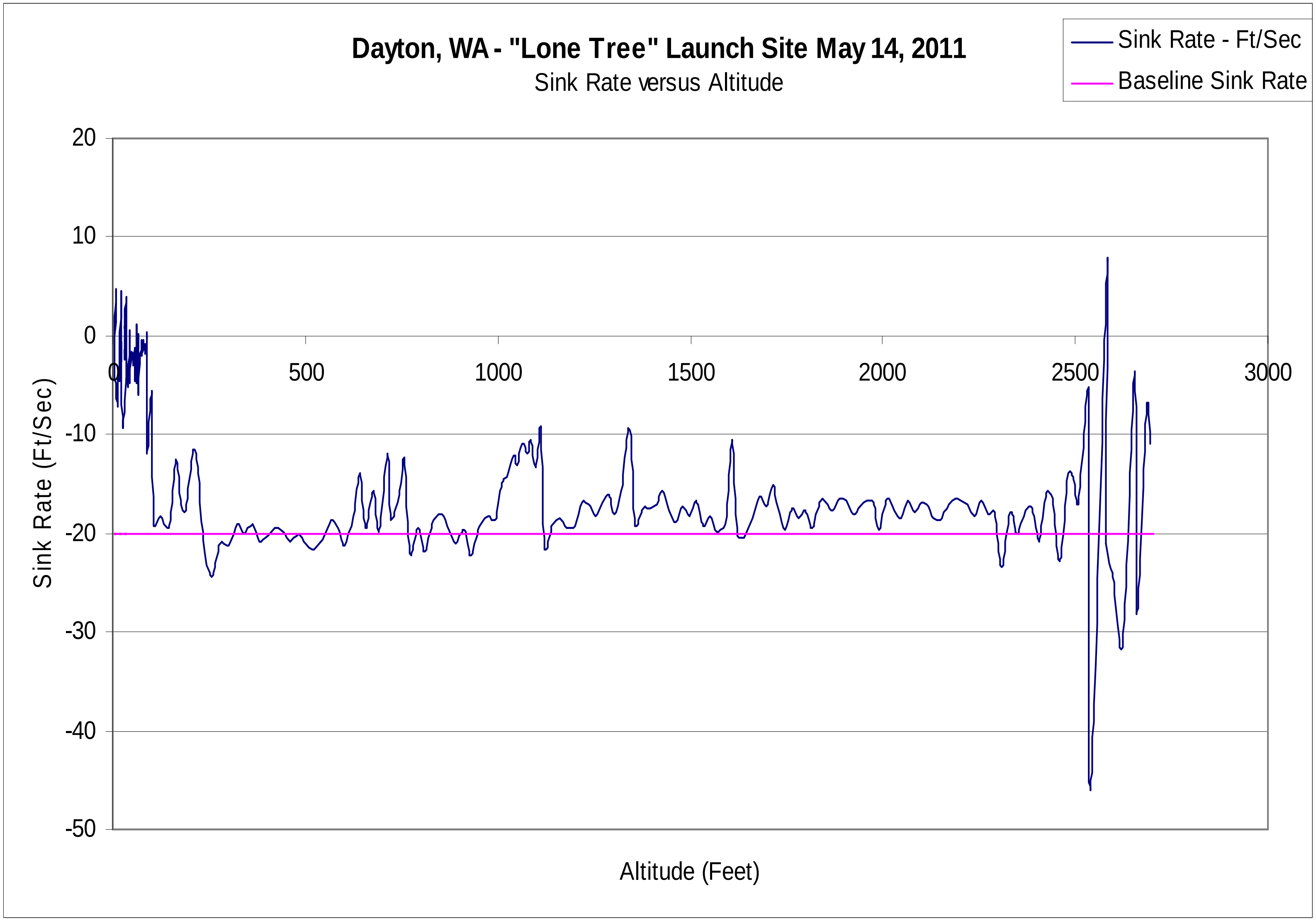
GPS Data Logger – Wind Speed vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Note: Wind Speed is increasing with Altitude

Glenda Project - Passive Payloads – Application

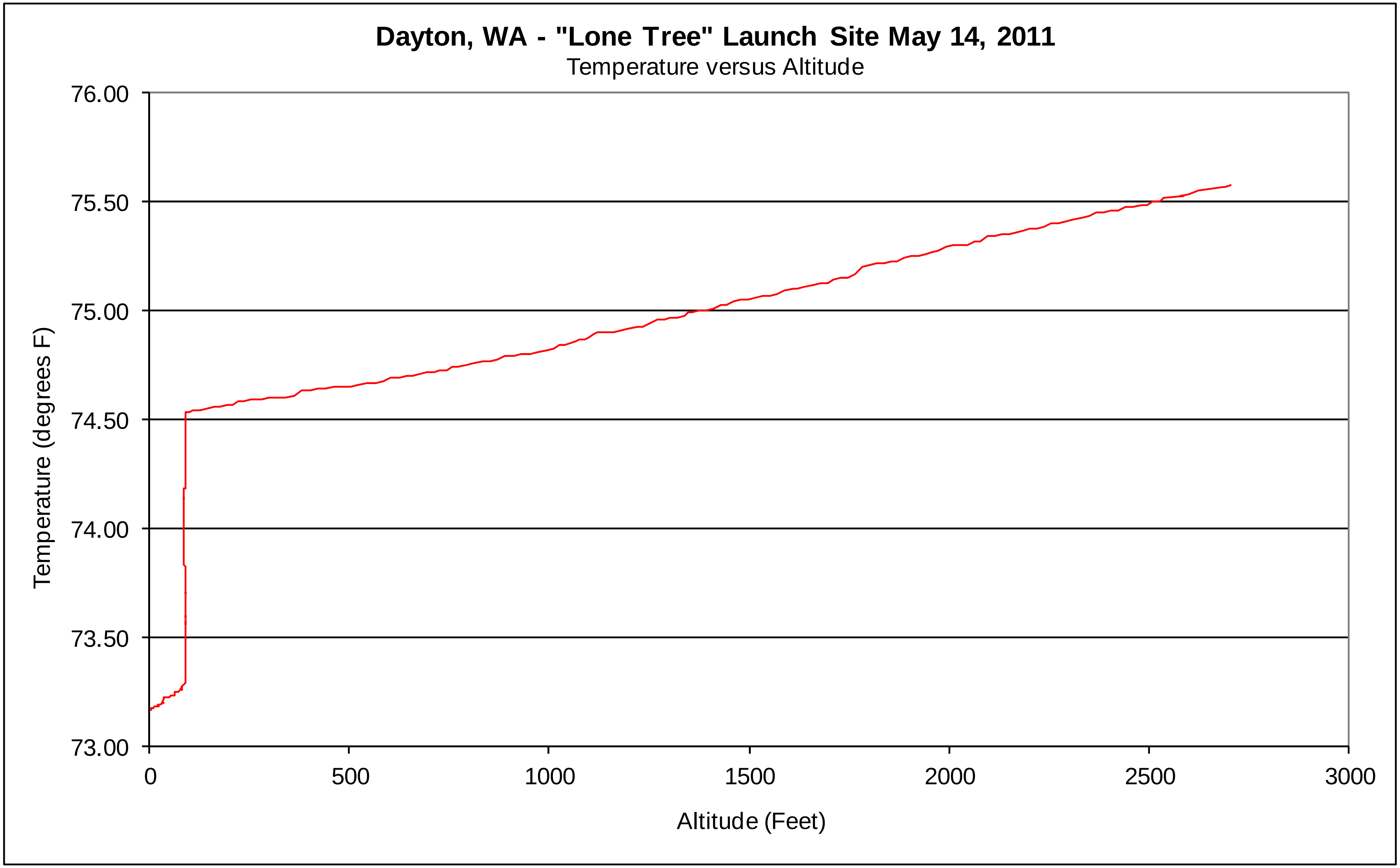
GPS Data Logger – Sink Rate vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Note: The “Baseline” Sink Rate of the capsule is 20 feet per second (-20)
There are significant Updrafts and Downdrafts due to the approaching thunderstorm

Glenda Project - Passive Payloads – Application

Temperature / GPS Data Logger – Temperature vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Glenda Project – Ground Stations

The Glenda Project has found that, over time, without knowing ground level weather conditions, there is no effective baseline to measure from as we launch instrument packages into severe weather systems.

This acknowledgement has driven the development of several different types of mobile ground station where their usage can be adapted based on our mission and data requirements.

Some typical examples:

a) Digital Chart Recorders

b) Recording Anemometers

c) TMQ-34 Mobile Military system

d) Coastal Environmental WeatherPak 400 Wireless ground station

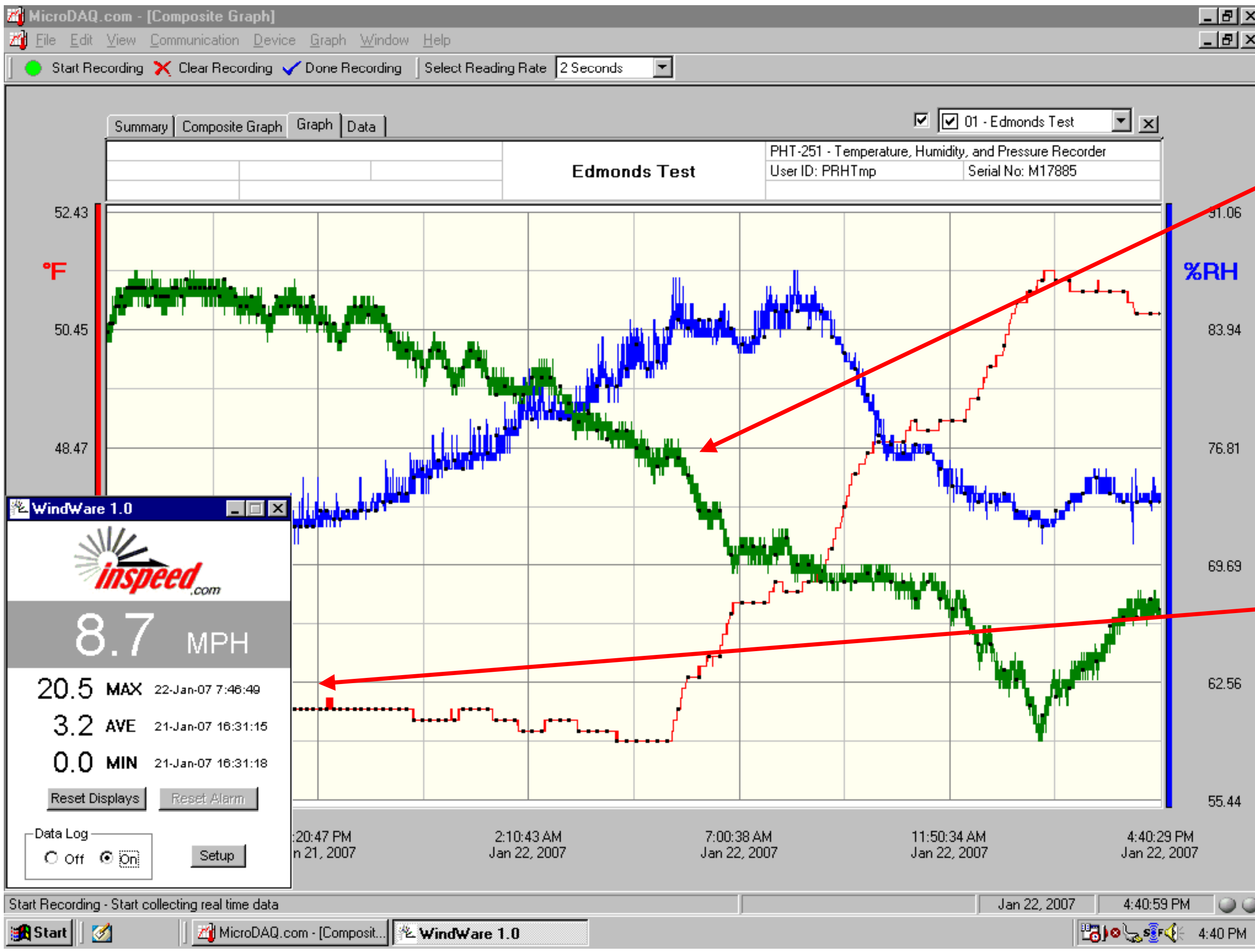
e) Mobile Mesonet ground stations

Glenda Project – Ground Stations

Digital Chart Recorders

Glenda Project utilizes sensors combined with ground based laptops to provide a digital based chart record of ground baseline conditions mapped over time.

The basic example below is a digital chart record of temperature, humidity, barometric pressure and wind speed at a test site.



Pressure, Temperature, & Barometric Pressure data stream using Micro-DAQ software and COM 1 port

Wind Speed data using InSpeed Anemometer and supporting software Using COM 3 port via USB port application adapter

Glenda Project – AN/TMQ-34 Ground Station

Glenda also has an operational portable military weather station. This acquisition further enhances the projects ground condition data collection capabilities.

The TMQ–34 is a military self contained portable weather measuring system that is powered by a rechargeable Ni CAD battery.

The TMQ–34 alphanumerically displays wind speed and direction, peak wind, temperature, dew point, barometric pressure, 3-hour pressure change, and the minimum and maximum temperature.

The entire TMQ–34, including the system case, weighs about 20 pounds. The set contains a computer module with a pressure sensor, and the main sensor module with a red sensor for temperature, a white sensor for humidity, a wind direction compass, and an anemometer to measure wind speed.

The TMQ–34 can operate in temperatures ranging from a low of –59.5°F to 132°F. The TMQ–34 is intended for use in a tactical environment with an operating range of 100 feet below sea level to 10,000 feet above sea level.

Glenda Project – WeatherPak 400 Ground Station

Coastal Environmental Wireless HazMat Weather Station

The Glenda Project has been able to obtain a Coastal Environmental WeatherPak 400 TRx2 mobile wireless weather station.

Some of its numerous features are:

- Wireless radio data Telemetry with a 5 mile range
- Self aligning Fluxgate Compass
- Complete sensor suite to record Temperature, Relative Humidity, Barometric Pressure, Wind Speed, and Wind Direction.
- Weighs less than 10 pounds and is deployable in less than 60 seconds
- Highly portable with its own transit case
- Serial data interface to support data logging and display
- Alternate Power Sources from 120VAC to 12 VDC
- “Stand Alone” capability without requiring a computing interface
- Tested and designed for HazMat and severe environments
- Capability to measure “Sigma Theta” to determine atmospheric instability

Glenda Project – WeatherPak 400 Ground Station

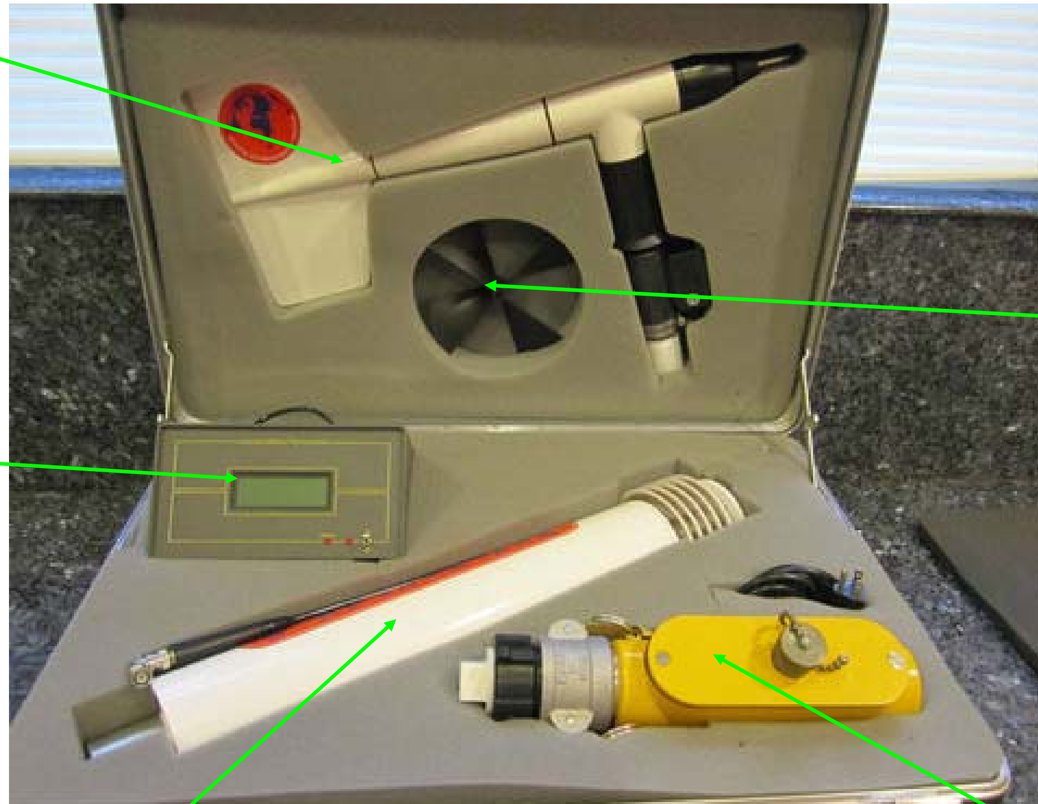
Coastal Environmental Wireless HazMat Weather Station

System Components

Anemometer / Wind Direction Sensor

Anemometer Propeller

Telemetry Receiver Display



Sensor Suite Unit containing Temperature, Relative Humidity, Barometric Pressure and Telemetry Radio transmitter

Power Distribution Junction Box

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

One of the datasets collected by the Weatherpak 400 is called "Sigma Theta" and is a measurement of Atmospheric Stability.

Atmospheric Stability can be defined as the resistance of the atmosphere to vertical motion. Vertical motion is directly correlated to different types of weather systems and their severity. Atmospheric vertical motion can be either ascending, or descending and are commonly called updrafts, or downdrafts.

Often under calm conditions, and especially over flat terrain, heated air parcels do not rise immediately. They have inertia and remain on the surface until some disturbance permits cooler surrounding air to flow in beneath and provide the needed buoyancy. This disturbance is the trigger for atmospheric in-stability.

Thunderstorms with strong updrafts and downdrafts develop when the atmosphere is unstable and contains sufficient heat, and moisture.

As air rises, it cools and serves as an indicator of atmospheric stability. The term for the rate of this cooling is called the "Adiabatic Lapse Rate", and is the traditional method for determining atmospheric stability.

In mountainous terrain, temperature and humidity measurements taken at mountaintop and valley-bottom ground stations provide reasonable estimates of the lapse rate and moisture conditions in the air layer between the two levels.

Adiabatic Lapse Rates (under "baseline" conditions):
Dry: 5.5 degrees F decrease per 1,000 feet elevation increase.
Moist: 3 degrees F decrease per 1,000 feet elevation increase.

A large decrease in temperature with height indicates an unstable condition which promotes up and down wind currents. A small decrease with height indicates a stable condition which inhibits vertical motion. Where the temperature increases with height, through an inversion, the atmosphere is extremely stable. (ie capping)

Lapse rate data is typically collected using balloon carried radiosondes, or rocket launched capsules, as the data is not attainable using conventional ground stations.

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

“Sigma Theta” (ST) is a compound term with its origins coming from both the Statistical / Mathematic community and the Physical Sciences.

The term “Sigma” comes from the Statistical community and is a mathematical term used to define the concept / process called “standard deviation”. Standard Deviation is a process used to explain the amount of variability within a data set with the higher the deviation, the higher the level of variability within the data set.

“Theta” comes from the Physical Sciences / Weather community as the term defining the angle of wind direction.

“Sigma Theta” translated means the amount of variability of the changes in wind direction within a dataset.

Robert Yamartino developed the “standard” ST model back in the 1980’s and it has been adopted by the HazMat / EPA community as their preferred model for measuring atmospheric stability using ground based sensors and is based off of the following equations:

Step 1: Compute the average sine of wind direction, the average cosine, and epsilon

$$S = \frac{1}{N}\sum_{i=1}^{N} \sin\theta_i \qquad C = \frac{1}{N}\sum_{i=1}^{N} \cos\theta_i \qquad \varepsilon = \sqrt{1-(S^2 + C^2)}$$

Step 2: Compute sigma theta as the arcsine of epsilon, and apply a correction factor

$$\sigma_\theta = \text{arcsine}(\varepsilon)\left[1 + \left(\frac{2}{\sqrt{3}} - 1\right)\varepsilon^3\right]$$

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

Frank Pasquill took the next step, and determined levels of Sigma Theta for differing degrees of atmospheric stability. He created a seven tiered system from “A” to “G”, where Class “G” reflects the most stable atmospheric condition, to Class “A” which reflects the highest level of atmospheric in-stability.

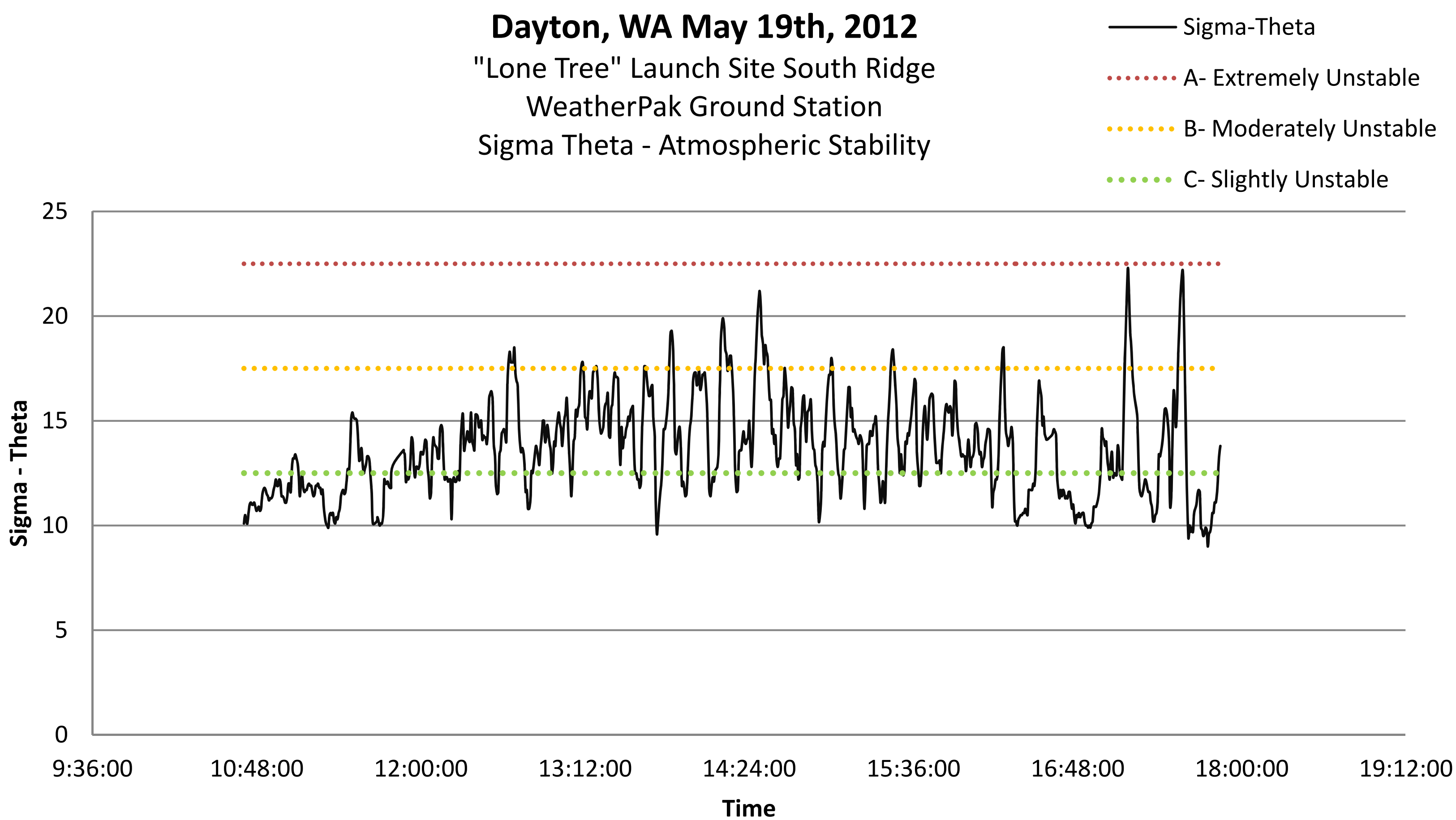
His results are shown in the table below:

Stability Class		Description	Definition
1	A	Extremely Unstable	$22.5 \leq \sigma_\theta$
2	B	Moderately Unstable	$17.5 \leq \sigma_\theta < 22.5$
3	C	Slightly Unstable	$12.5 \leq \sigma_\theta < 17.5$
4	D	Neutral	$7.5 \leq \sigma_\theta < 12.5$
5	E	Slightly Stable	$3.8 \leq \sigma_\theta < 7.5$
6	F	Moderately Stable	$2.1 \leq \sigma_\theta < 3.8$
7	G	Extremely Stable	$\sigma_\theta < 2.1$

Based on this Stability Class table, we can now make determinations of atmospheric stability based on ground station data and not have to rely on balloon launched radiosondes, or rocket launched payloads.

Glenda Project – Ground Station - Application

WeatherPak 400- Sigma Theta



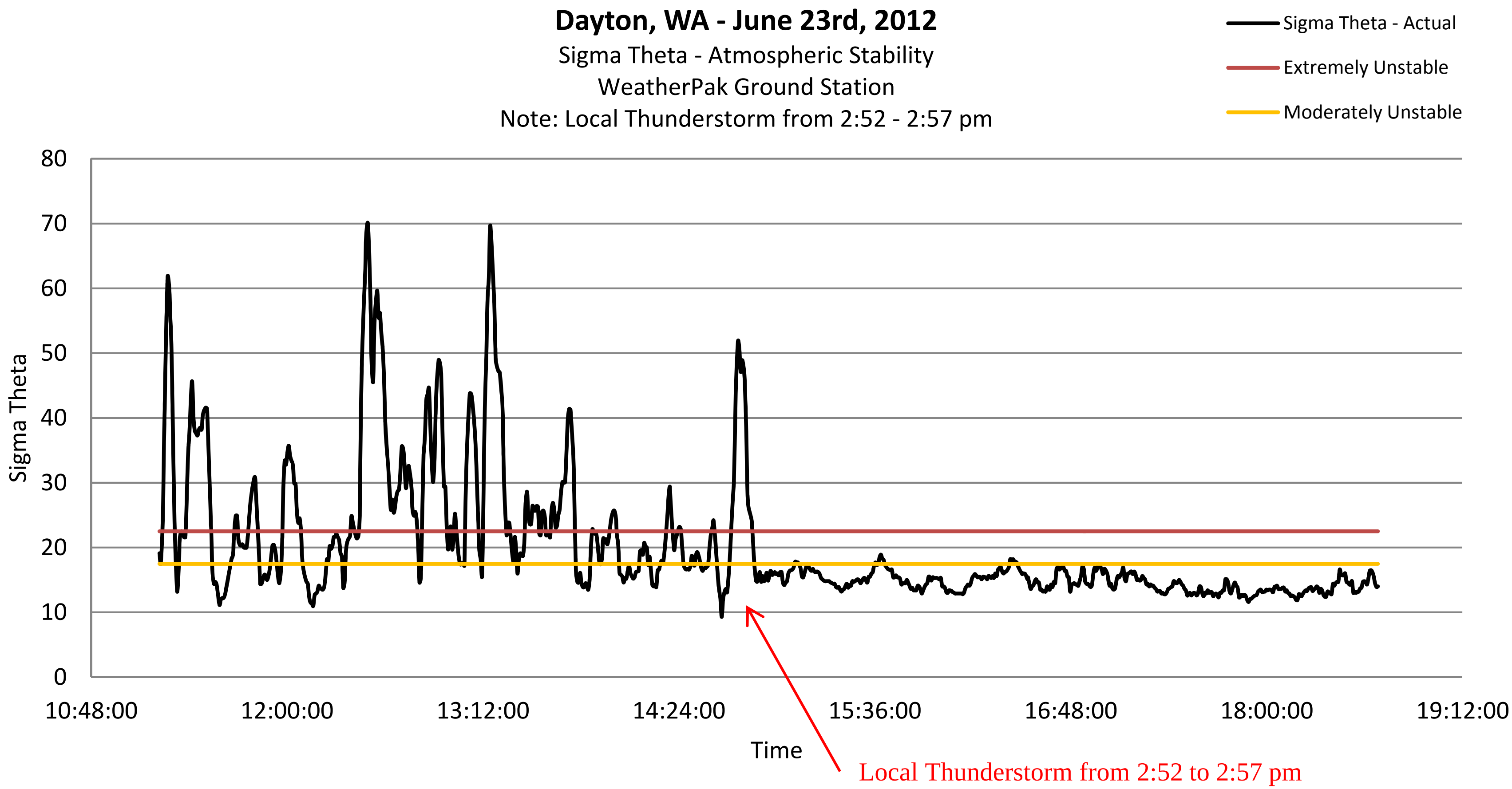
Note that the bulk of the ST data falls in the “Slightly Unstable” range with several points falling into the “Moderately Unstable” band. This implies that atmosphere instability is occurring. However, not severe.

Note also, that atmospheric instability is independent from wind speed as you can have strong winds in a stable atmosphere and calm winds in an unstable atmosphere.

Sigma Theta provides us a tool to measure atmospheric stability using ground based sensors in a mobile environment without the need for lapse rate data and its supporting infrastructure requirements.

Glenda Project – Ground Station - Application

WeatherPak 400- Sigma Theta



On June 23rd, the WeatherPak 400 was deployed on the south ridgeline above the BMR “Lone Tree” launch site.

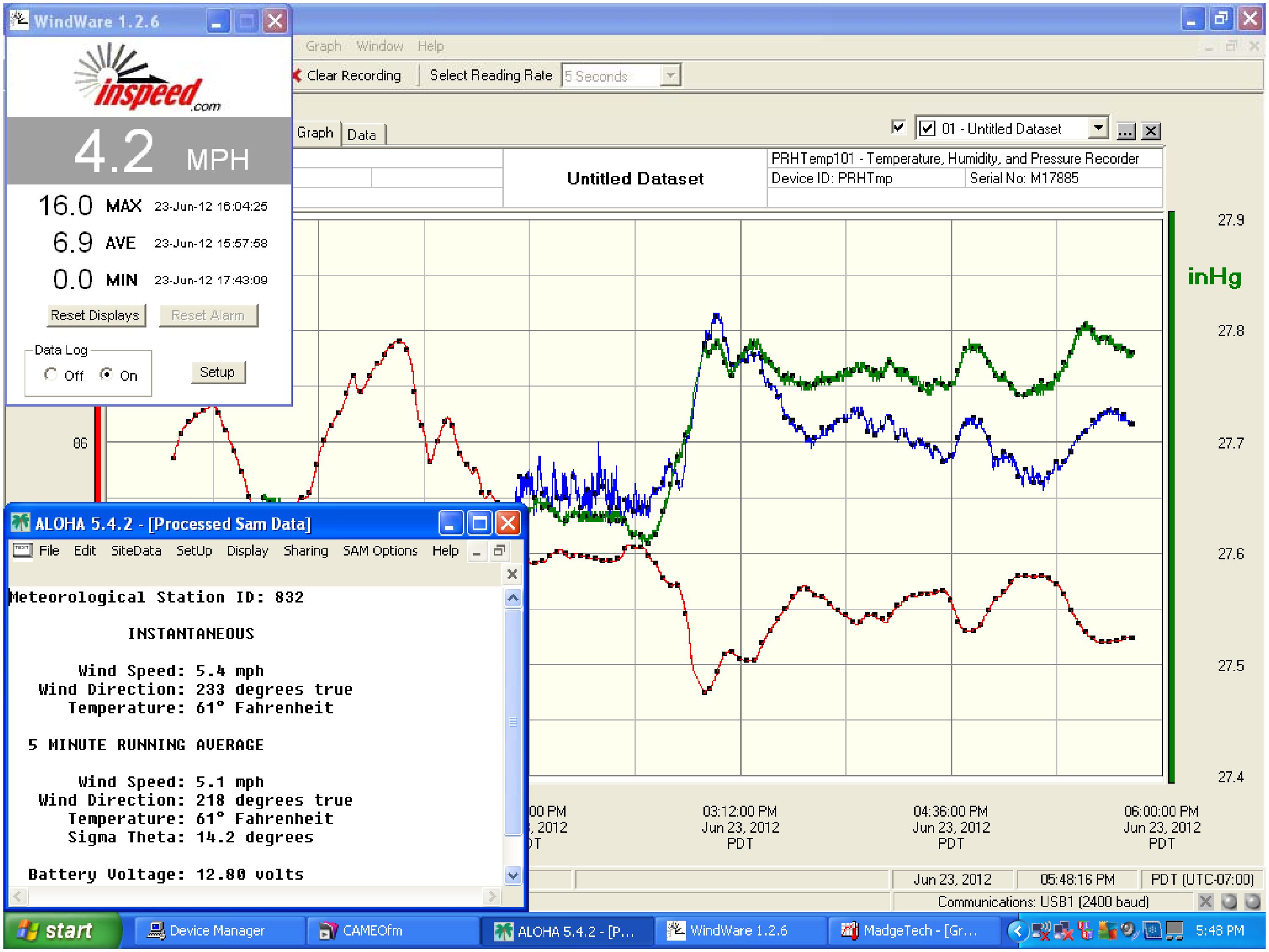
Sigma Theta values reflected “Extremely Unstable” conditions until the passage of a local thunderstorm from 2:52 to 2:57 pm where the Sigma Theta values returned to normal limits.

A case can now be made that Sigma Theta values can be used as a severe weather pre-cursor, and continued deployment opportunities are expected.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment

Dayton, WA – June 23rd, 2012

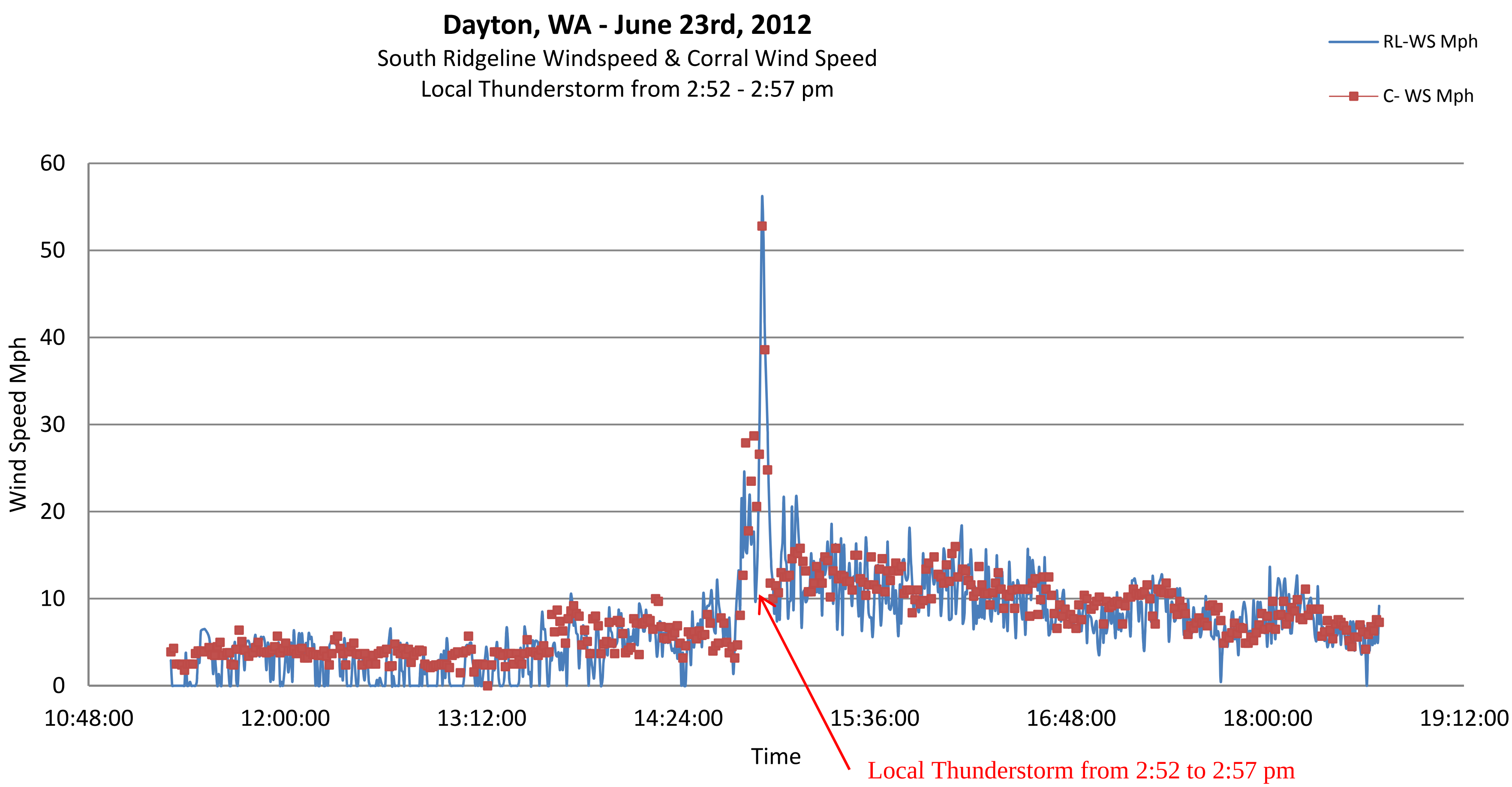


Data from both the wireless and mobile ground stations were displayed side by side on a common interface for seamless integration.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment

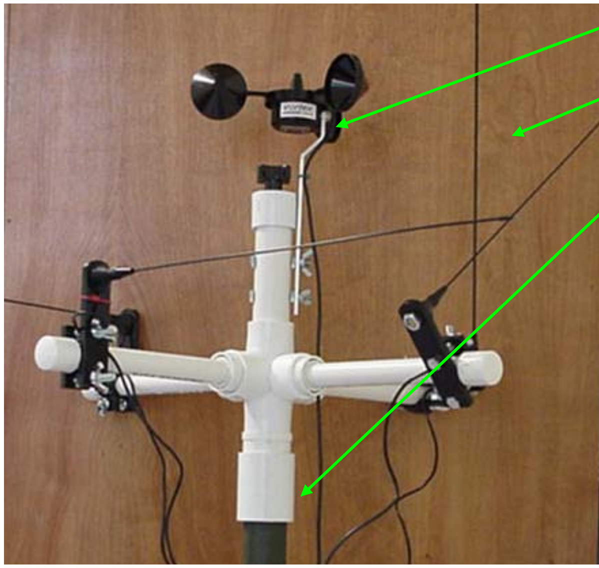
Dayton, WA – June 23rd, 2012



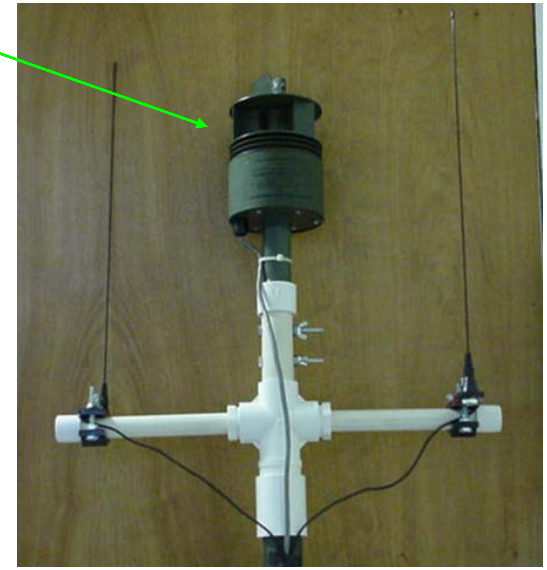
On June 23rd, our first dual deployment accoured as a thunder storm passed over two ground stations simultaneously with one station the wireless WeatherPak and the second, our hard wired mobile station.

Glenda Mobile Ground Station Mast System

<u>Removable / Adaptable Mast Sensor Head</u>



- In-Speed Anemometer / TMQ-34 Sensor
- Two / Four Wide Band Receiver Antennas for Radiosonde telemetry signals.
- Mast System Interface Adapter
- Light weight PVC / Fiberglass construction to reduce potential for lightning strike
- Antennas with 1.2 GHz capability allows multiple frequencies and multiple radiosonde reception
- Mast head integrates with man portable mast system



Glenda Project – Intercept Teams

In order to obtain data from dynamic weather phenomena it is necessary to seek out and intercept storms and to launch sensors into the heart of the disturbance, capture the data, and return the data for immediate processing and analysis. Hence the name, Intercept Team.

The Intercept Teams utilize Jeep Grand Cherokee 4 wheel drive units, and other heavy duty trucks, equipped with specialized tires and suspension to handle road debris situations and evasive maneuvers while on the go. When storm data is required, the teams immediately equip the vehicles with instrument packages and laptop computers inside the vehicle and attach to the roof, weather instrumentation, satellite dishes, sensors and communication gear. Portable rocket launching stands and weather rockets are loaded into the back of the jeep. Transforming from a ordinary vehicle to a fully operational weather pursuit vehicle takes as little as five minutes.

Glenda Project – Intercept Teams

Mobile Mesonet Ground Station Vehicles

Intercept Team vehicles can feed information directly over the web to Acurite and Weather Underground fully automatically. Vehicles are equipped with full weather station sensors and forecasting ability, weather warning radios, a short wave wefax system, wifi connectivity both local and cellular, and 20 meter and 2 meter transmission systems which allows communications between team vehicles and Emergency Management and First responders . Vehicles have the capability of independent operation with either an onboard generator and / or back-up 12 VDC battery systems.

Glenda Project – Intercept Teams

Columbia County – Dayton, WA

In 2012, the Columbia County / Dayton, WA Intercept Team became the "eyes" for Emergency Management and First Responders in severe weather situations.

SKYWARN

Approaching Storms for Intercepts

Glenda Project – Intercept Teams
Columbia County – Dayton, WA

The Dayton storm team made significant advances in 2012 in the areas of micro-climate research and coordination with regional emergency management resources.

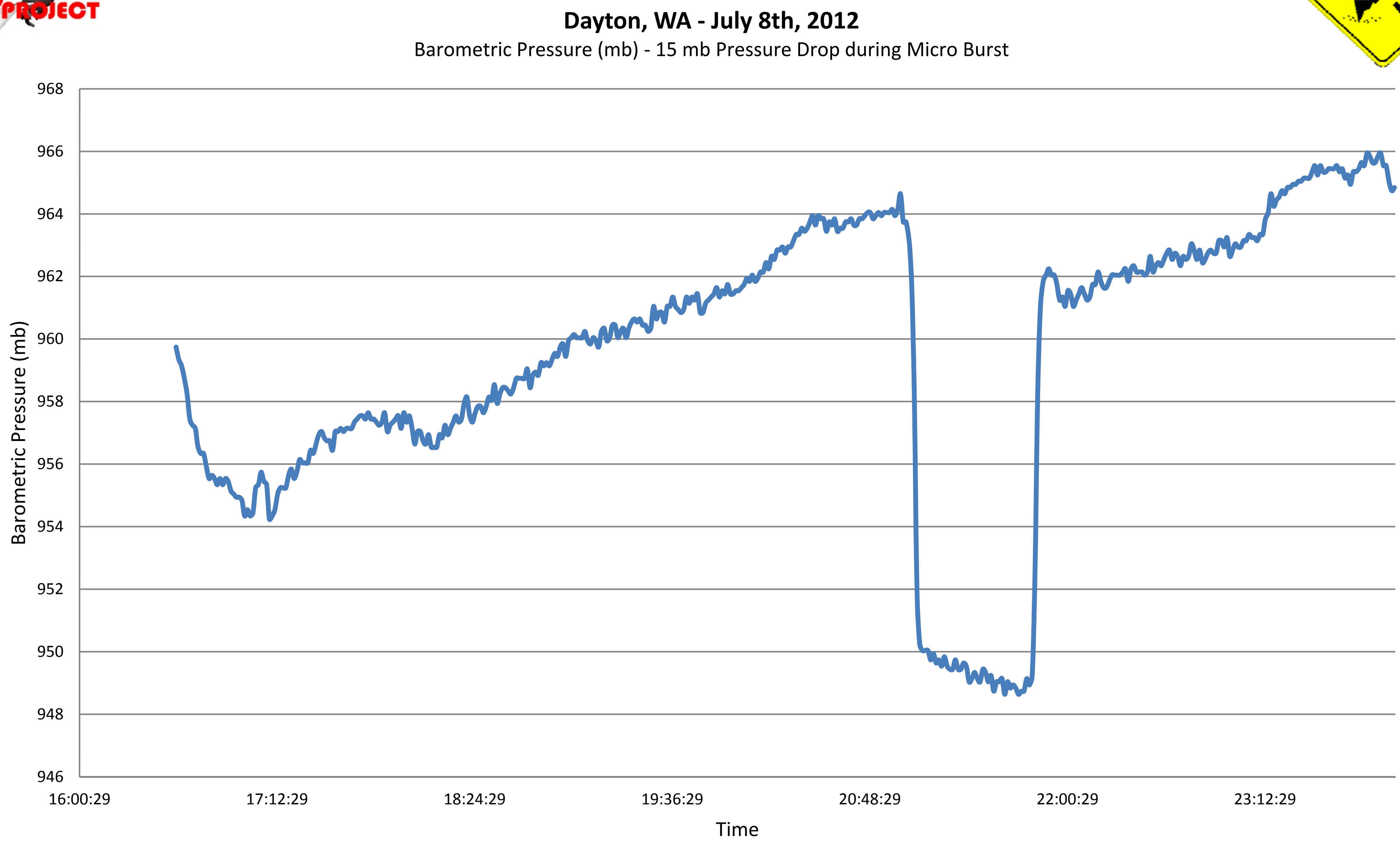
The year started out with significant upgrades to data collection and analysis hardware. Extech RHT50 data loggers were deployed this year. These compact data loggers record barometric pressure, temperature and humidity at rates of up to one minute intervals, recording over 10,000 data points for later download and analysis. Two such data loggers are now in operation; one that records at the team's base of operations in Dayton, while the other travels with the team recording the team's movements in relation to the micro-climate they are in. Team member safety has been enhanced through the use of StrikeAlert II lightning detectors, which monitor electromagnetic field densities and can detect approaching lightning strikes up to 40 miles away. In addition to a hand-held Kestral wind meter, a vehicle-mounted Vortex anemometer has also been deployed this year.

Real-time Doppler radar has been incorporated into the storm team's expanded list of tools this year as well. Using the Doppler radar coupled with the on-board Holux GPS navigation system, the team can pinpoint their exact location in relation to storm systems, providing them the best possible opportunity to position themselves in relation to storm system movements to obtain the best possible data. Unlike other storm "chase" teams, this capability allows the Dayton Intercept Team to concentrate less on chasing storms, and more on positioning themselves to intercept storms.

Glenda Project – Intercept Teams - Applications

Between the months of April and August of 2012, the Dayton storm team intercepted five major storm fronts that traveled through southeastern Washington State. One storm on July 8th, 2012 created a micro-burst over the north residential area of the town of Dayton, which was recorded on the team's on-board data loggers. Responding to the affected area, the team was able to assist with and coordinate emergency services response. They coordinated storm debris removal to assist with the response of fire, ambulance and law enforcement units, the evacuation of an elderly person trapped in their residence by storm debris, and assisted with crowd control until power was restored by the power company hours later. All information and storm observations were relayed by the Dayton storm team in real time to the Pendleton National Weather Service and to the local Emergency Management office which resulted in local and regional severe weather alerts being issued.

Glenda Project – Intercept Teams - Applications



The Columbia County / Dayton, WA Intercept Team achieved a successful intercept of a microburst thunderstorm and recorded a 16 mb pressure drop during the event.

Glenda Project – Intercept Teams - Applications

As a result of the team's response to the July 8th, 2012 storm emergency, subsequent meetings were held with local emergency services. The Dayton storm team has been requested to assist regional emergency services in future storm events. The team has now been equipped with a BK digital radio system that operates over narrow band microwave in the 155 mhz range. This system allows them direct radio communications to regional law, fire, ambulance and emergency management field units as well as the regional 9-1-1 public safety communications center. The team's integrated real time Doppler and GPS capabilities have allowed them the opportunity to coordinate with local and regional fire departments during lightning storms to aid in the staging of fire assets to suppress lightning strike fires.

Additionally, the team has also been asked to provide storm preparedness presentations to the public through local 9-1-1 Public Education Programs and through venues such as National Night Out. The team was also the recipient of an equipment grant from the United States National Forest Service in the form of a complete Olympus OM-2S 35mm camera set complete with multiple lenses to be used for the purpose of documenting storm structures and lightning.

Glenda Project – Intercept Teams – Payload Tracking

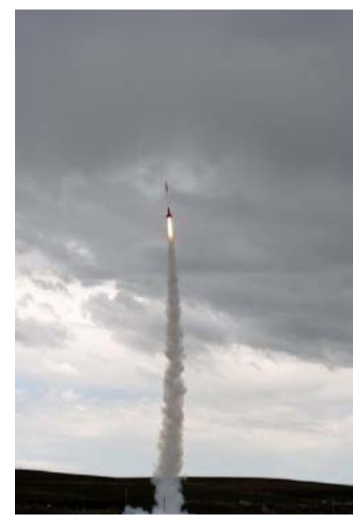
GPS – Payload Tracking System Operational

When payloads are launched into severe weather systems, one of the primary challenges, is their return.

Glenda now has the capability to track payload positions using GPS in real time combined with real time display of the "intercept" vehicles position using "non-internet / non-cellular" driven GPS positioning.

The payload transmits its GPS position to the intercept vehicle, while that vehicle integrates its own position in relation to the moving capsule in real time.

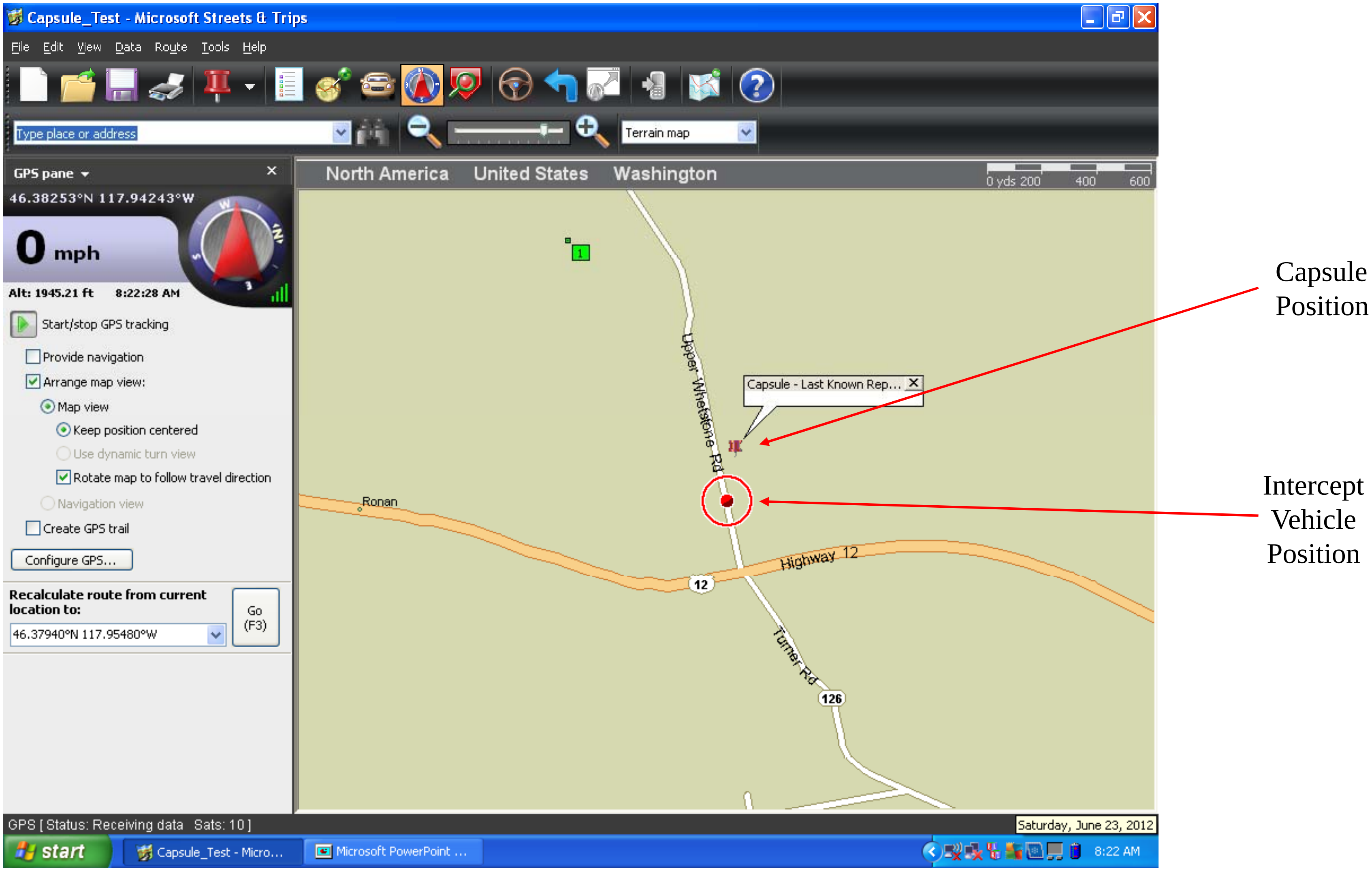
This capability allows real time deployment capture and rapid return to flight for multiple intercepts with the same storm system.



Glenda Project – Intercept Teams - Applications

GPS – Payload Tracking System Operational

Dayton, WA – June 23rd, 2012

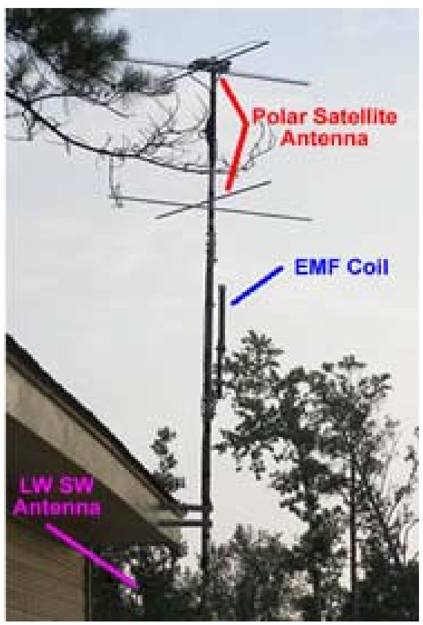


GPS positioning data from both the payload capsule and the intercept vehicle can now be displayed on a common screen in real time allowing for rapid intercepts and near real time return to flight.

Glenda Project – Remote Sensing
Bayou Canada Research Facility

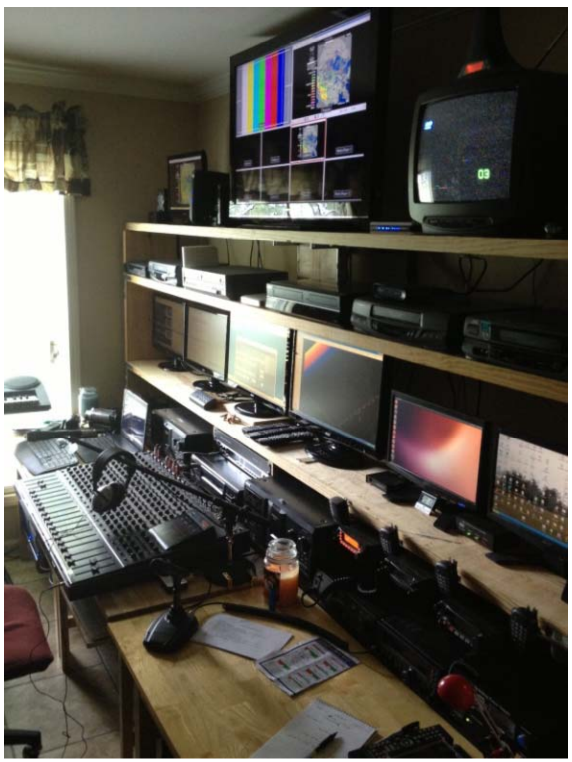
The Bayou Canada Weather Research Facility is located in Ponchatoula, Louisiana, roughly 60 miles north of the Gulf of Mexico.

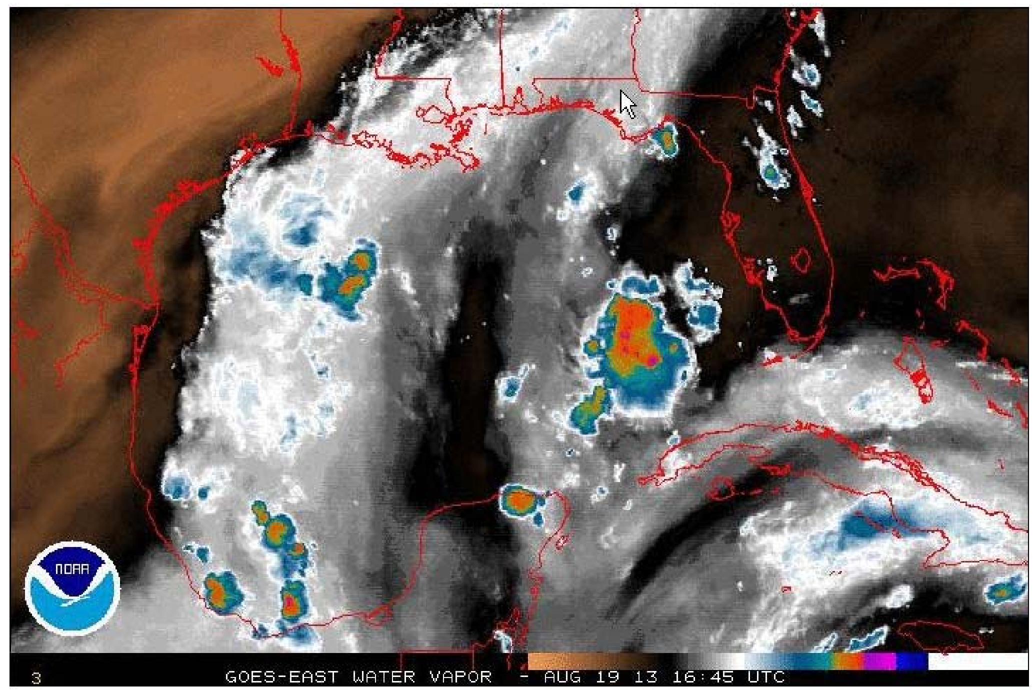
Bayou Canada feeds out weather data in regular intervals as quickly as every two seconds depending on the need for data and weather conditions. We post real time data including radiation and EMF on our website, as well using both web and over the air radio transmissions. We feed directly to: NOAA and the National Weather Service, APRS via ham radio station KE5JJC both over the web and over 2 meter ham frequencies, Citizens Weather Observation Program, Hamweather, PRSWeather, WeatherBUG, and Weather Underground / The Weather Channel.



Glenda Project – Remote Sensing
Bayou Canada Research Facility

Weather information is fed automatically into various computer processing centers as well as the National Weather Services. Because our information is sent at much shorter intervals than most typical airport weather stations, the analysis of our data is quicker and affects the decisions and warning announcements issued by the National Weather Service. Because we can provide both mobile and base visuals, additional information can be sent to the National Weather Service via cell phone or ham radio transmissions. The NWS monitors particular ham radio frequencies for reports in major weather situations. The National Weather Service will issue watches and warnings both over the air (weather stations and public networks) and over the web based on the information that we and additional stations send them. The NWS is of course the official source for Emergency Management Centers.

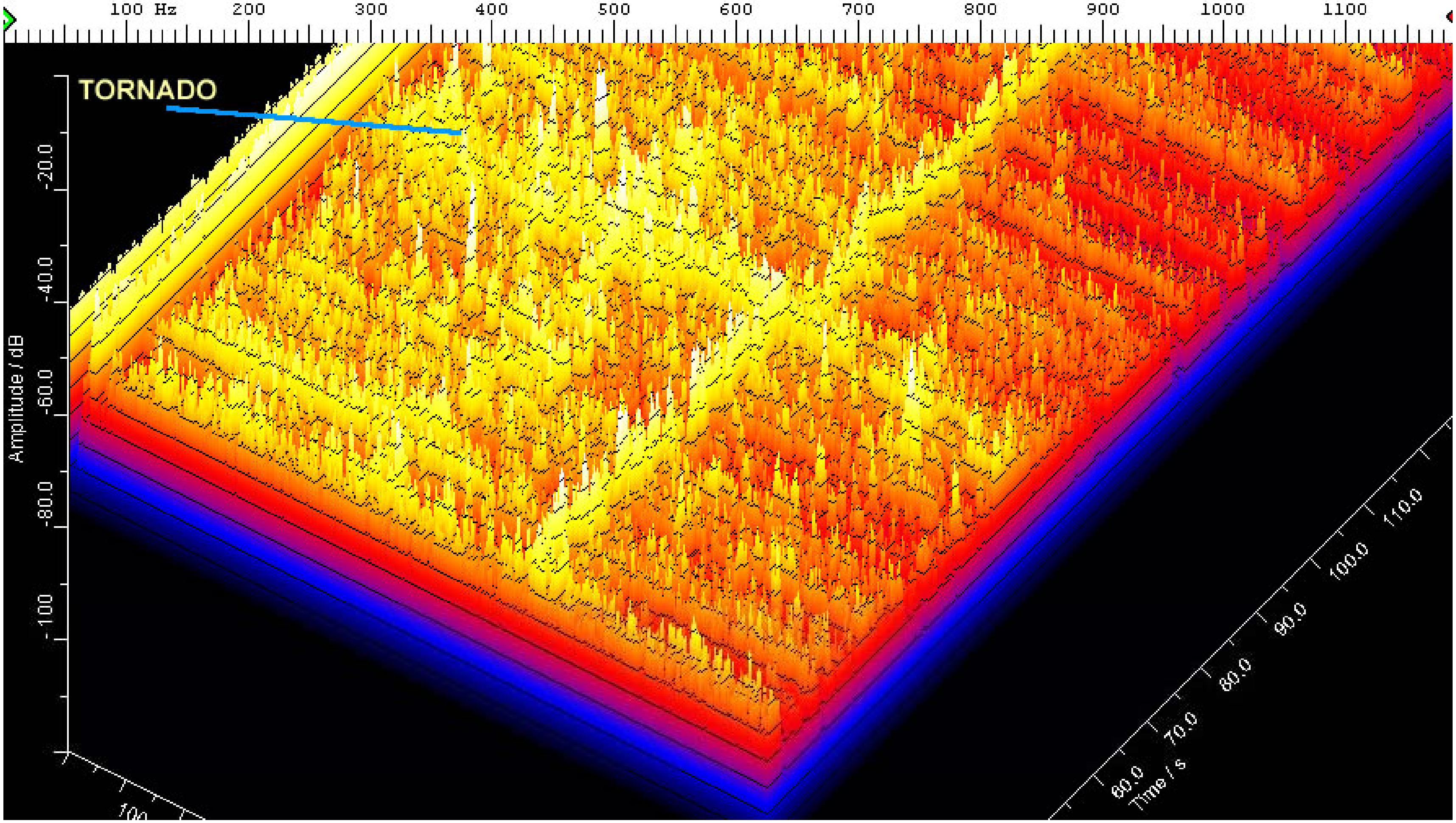




Glenda Project – Remote Sensing – Application

EM Field Mapping

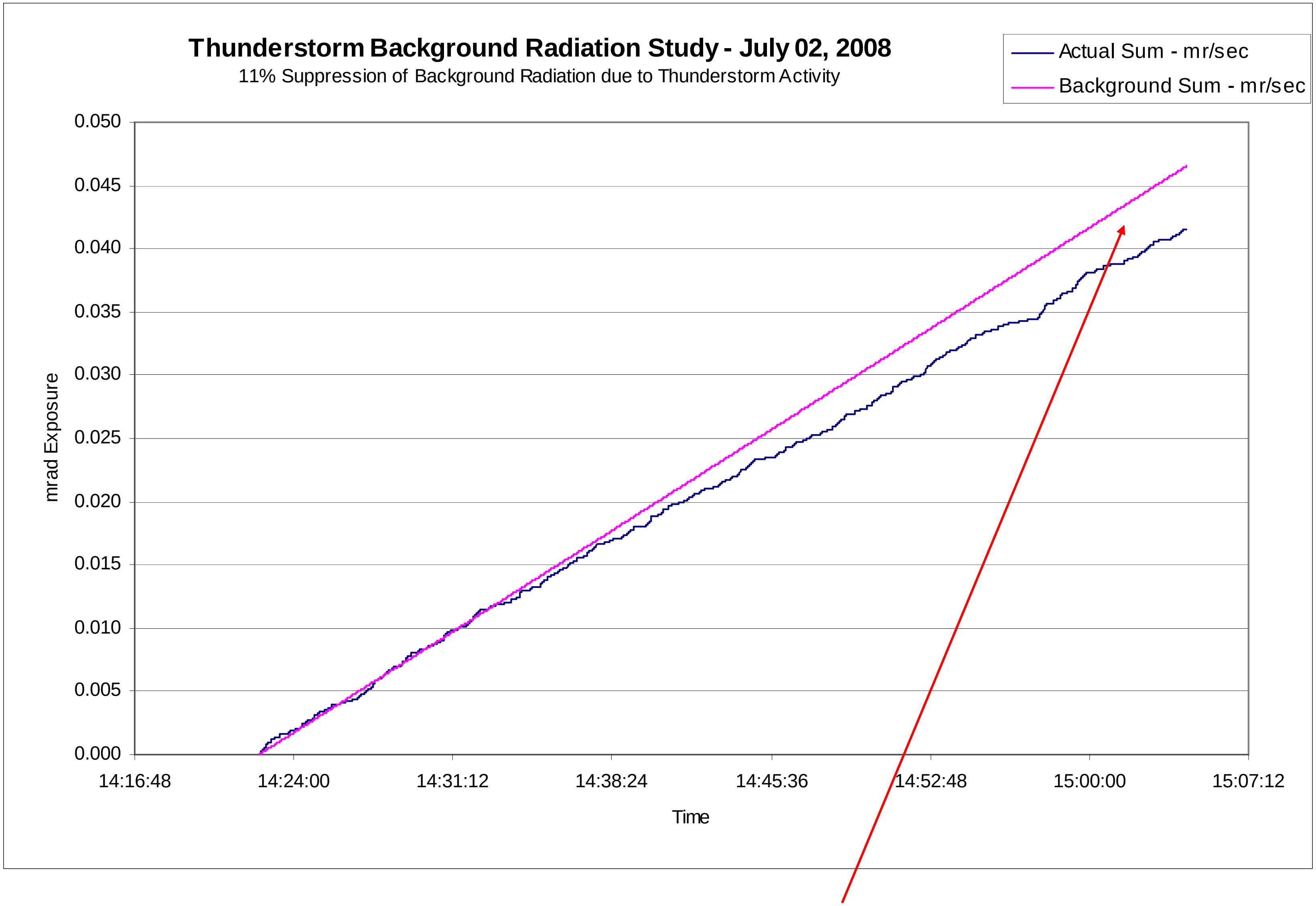
Combining Glenda computing and sensors allows the capability for advanced analysis and detection. Shown below is a 3D Electromagnetic Field (EMF) analysis of a tornado based off of a three second data capture. The circular effects of the funnel are easily visible and provide a snap shot of the electrical activity around a tornado.



Glenda Project – Remote Sensing – Application

Gamma Radiation Studies

Data collection capability of Gamma Ray Radiation during Thunderstorms



During this extensive Thunderstorm, lightning suppressed the “background” gamma radiation count by 11 percent

In Conclusion

The Glenda Project is a highly mobile data collection system designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

The operational Glenda Project shows the differences between Hollywood “fiction”, “Reality Television” publicity stunts, and engineering “fact”, from mapping local environments to a full tornadic funnel with a suite of sensors.

In 2012, we achieved multiple storm intercepts, deployed a wireless long range ground station with Sigma Theta capability and built on sustaining relationships with emergency managers and first responders.

For 2013, we developed a balloon deployment capability for applications where booster launches are not feasible and continue to expand the flight envelop of our sensors and ground stations. The Glenda Project is up to the task.

Glenda Project – Executive Summary - 2015

Glenda Project – Purpose

The primary mission of the Glenda Project is to provide the capability to rapidly gather previously inaccessible localized microclimate data from altitudes ranging from ground level to over 100,000 feet and to return this data for immediate use.

The Glenda Project is mix of adaptable ground stations combined with a reusable sounding rocket delivery system, and rapidly deployable weather balloons which are designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

Glenda Project – Data Capabilities

The Glenda Project has the capability to collect temperature, humidity, barometric pressure, wind speed and other types of environmental data from ground level to over 100,000 feet.

Glenda payloads are designed to be launched into thunderstorms, tornados, and other volatile weather environments and to return intact with its collected data.

Glenda Project – Engineering / Computing / Remote Sensing

David Davis – Edmonds, WA – Engineering - Brings decades of experience from engineering work in private industry and United States government in rocket research, and aerospace. Extensive background in electronics, mechanics, communications, computing, and storm spotting. Member of the National Association of Rocketry since 1983, and been involved with hobby related rocketry since the 1960’s.

CERTIFIED SKYWARN SPOTTER

Robert Pullman – Ponchatoula, LA - Remote Sensing - Has three decades of experience in video / media communication and the computer industry and his expertise is world renown. His work has enabled governments to formulate policies and legislation in international, national and local forums. He has developed products that are used by universities for seminars, by corporations for internal operations to meet government regulations, by scientists for research work in field and laboratory conditions, by government departments for device operations and maintenance, and by the military for use in battlefield activities.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Media Communications / Public Relations

Tim Quigg in Dayton, WA brings a unique mix of personal background and professional experience to the Glenda Project. Quigg has over two decades of experience in customer service and media relations. He is the former Assistant Editor of Extreme Rocketry Magazine (2000 to 2007), as well as a freelance writer of numerous articles for Sport Rocketry Magazine. He is a current member of the National Association of Rocketry, and is the 2001 recipient of the National Association of Rocketry's President's Award, in recognition of his work with youth in model rocketry on a national level. He has also written a book on the topic of high power rocketry; "A Guide to Level One Certification" currently published by ARA Press. With over 33 years in law enforcement, he's currently the Civil Deputy for the Columbia County Sheriff's Office.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Columbia County, WA - Intercept Teams

John Quigg in Dayton, WA, brings to the project a mix of skills ranging from high tech computing, to storm spotting field abilities. As the head of our field operations Intercept Team, John plans the missions, deploys the field assets, and collects the data. A SKYWARN trained storm spotter, and a master behind the camera, John continues to bring back amazing photos, and video from the field on our continuing storm intercept operations.

CERTIFIED SKYWARN SPOTTER

Glenda Project – Typical Flight Vehicles

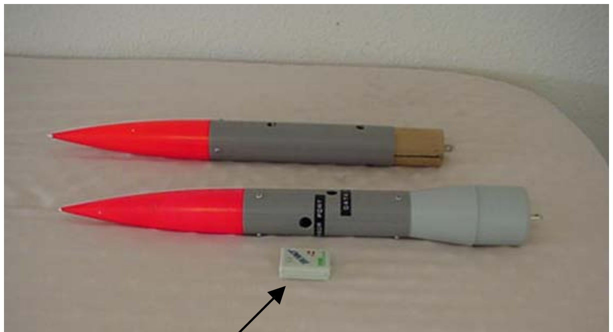
9875 Booster
- 4” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 20,000 ft altitude envelope

5475 Booster
- 2.125” diameter booster, 3” diameter capsule
- RS92 Digital Radiosonde Active Payload with GPS
- GPS, and Temperature dual data logger payload
- 2,000 to 15,000 ft altitude envelope

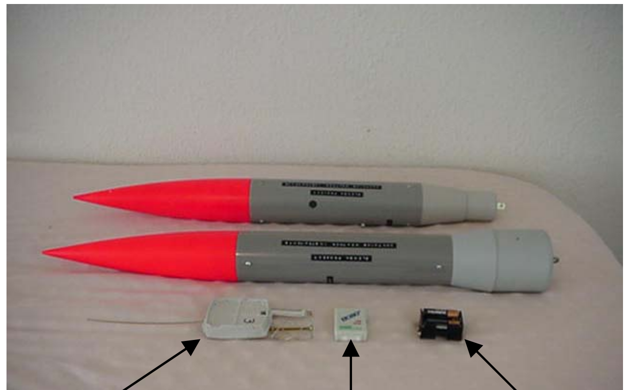
FAR 101 Booster
- 3” diameter booster, 2.125” diameter capsule
- GPS, and Temperature dual data logger Payload
- 2,500 foot altitude envelope
- Exempt from FAA Waiver Constraints

Glenda Project – Typical Flight Payloads

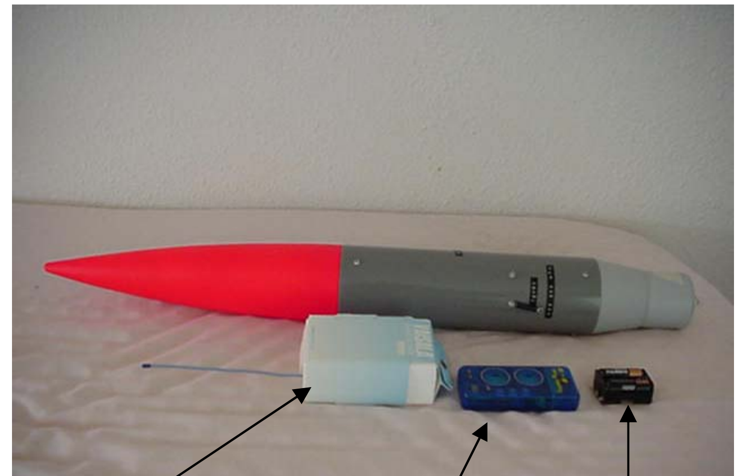
The Glenda project uses several different payload capsule configurations carrying a variety of instrumentation in order to gain weather related information, and other micro-climate data



Datalogger



RS92 Digital Radiosonde   Datalogger   Battery Pack



RS80 Analog Radiosonde   Locator Beacon   Battery Pack

54mm (2.125") Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- Used by 54mm & 75mm boosters.

75mm (3") Capsules

- Datalogger Payloads
- Measures Temperature & RH values at 1 second intervals.
- RS92 Digital Radiosondes transmitting temperature, RH, barometric pressure, and GPS coordinates.
- Used by 54mm & 98mm boosters.

98mm (4") Capsule

- RS80 Analog Radiosonde transmitting temperature, RH, and barometric pressure.
- Audio location beacon
- Used by 75mm boosters.

Glenda Project – Typical Flight Profile

2 – Intercept Phase

3 – Data Collection Phase

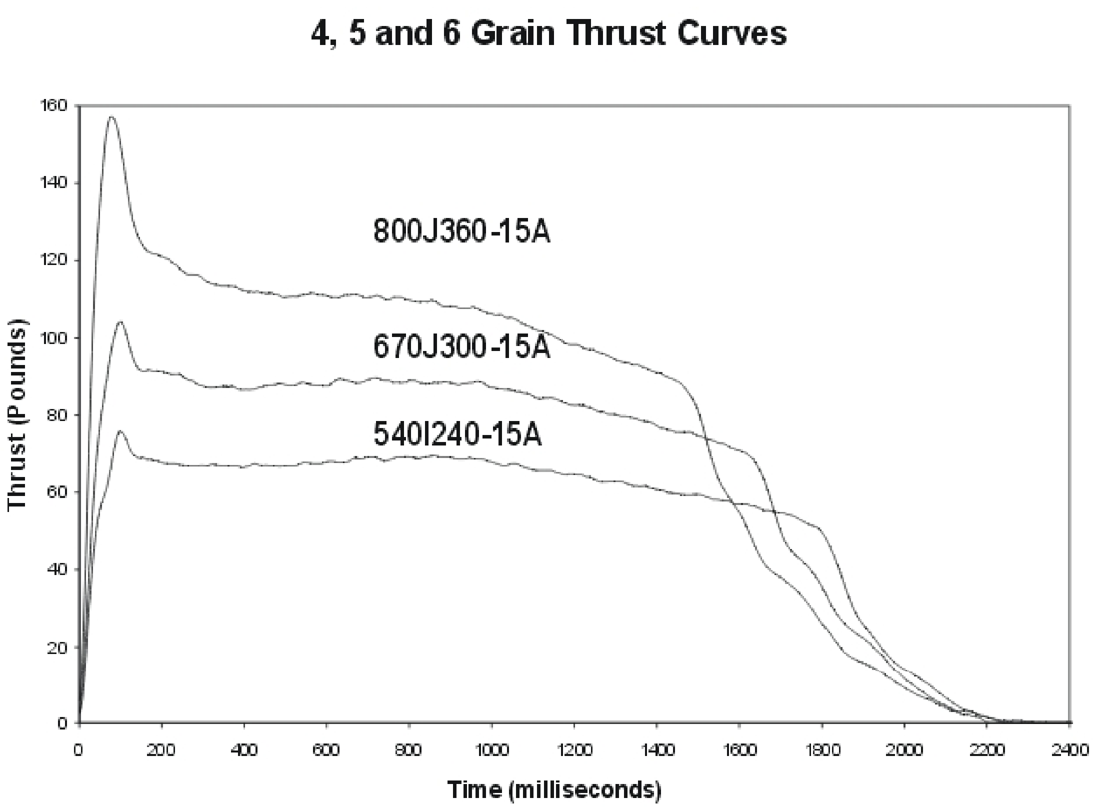
4 – Recovery Phase

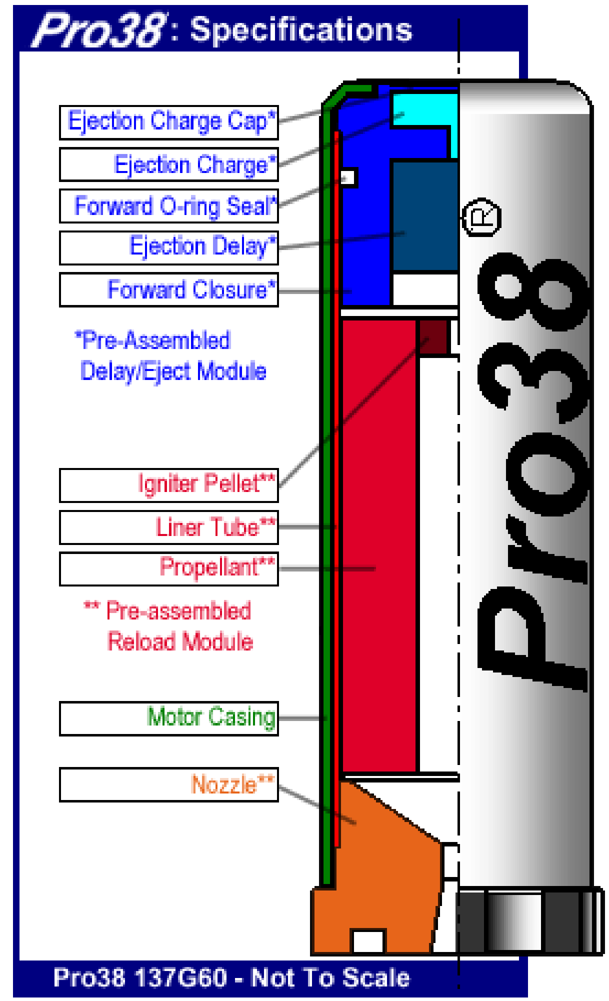
1 – Launch Phase

Note: Propulsion is provided by reloadable /reusable rocket motors giving the capability of rapid turnaround between flights.

Glenda Project – Propulsion

The Pro38 / Pro54 rocket motor propulsion system is the first commercial thermoplastic propellant-based solid rocket motor and is produced by Cesaroni Technology Inc. of Toronto Canada. The Pro38 / Pro 54 is a modular, reloadable Solid propellant rocket motor system designed primarily for use in launching small experimental payloads by universities, colleges, research institutes and sport rocketry enthusiasts.





Glenda Project – Data Collection Methods

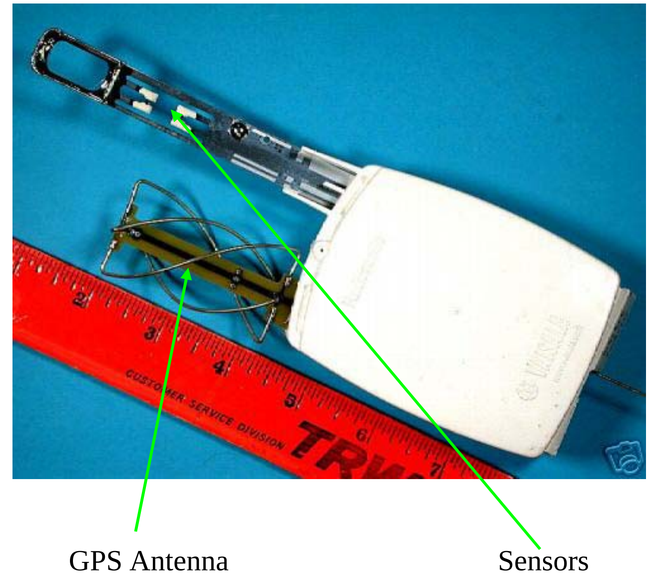
Glenda has several methods for collecting data:

- Rocket Launched - Active Flight Data Collection Systems – Transmitters
- Weather Balloon Launched – Active Flight Data Systems - Radiosondes
- Rocket Launched - Passive Flight Data Collection Systems – Dataloggers
- Ground Stations

Glenda Project – Active Payloads - Transmitters

Converted Radiosonde Payloads

The Glenda Project uses converted radiosondes that are designed primarily for use with weather balloons. The circuitry and sensors function properly under thrust loads of the Glenda boosters and are compatible with NOAA / NWS radiosonde receiver systems.



The radiosonde contains instruments capable of making direct measurements of air temperature, humidity and pressure. These observed data are transmitted immediately to the ground station by a radio transmitter located within the instrument package.

Vaisala RS92 Radiosonde

<u>Radiosonde Specifications:</u>

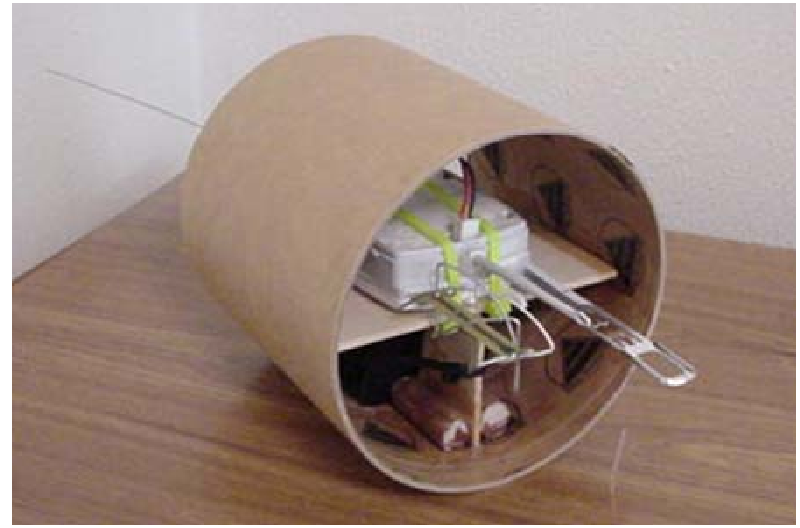
- Pressure range 3mb to 1060mb +/- .1mb
- Operating temperature range of -90°C to +60°C
- Relative Humidity from 0 to 100%
- Sampling Rate of once per second for the sensor suite
- Provides positioning data via GPS for payload location and wind velocity

Glenda Project – Active Payloads - Transmitters

Data Acquisition Flow Diagram

Sensor Data Transmitted from Capsule

- Barometric Pressure Sensor Data
- Temperature Sensor Data
- Relative Humidity Sensor Data
- GPS - Payload Position Data



Active Payload cushioned within the flight capsule

Ground Receiver and Antenna System

Data recorded into Laptop and graphically displayed

GPS – Ground Station / Chase Vehicle Position Data

Glenda Project – Active Payloads - Application

Mobile Ground Station / Intercept Vehicle

Isolated Laptop Power Supply

Telemetry Receiver

Cellular Modem w/ internet connection

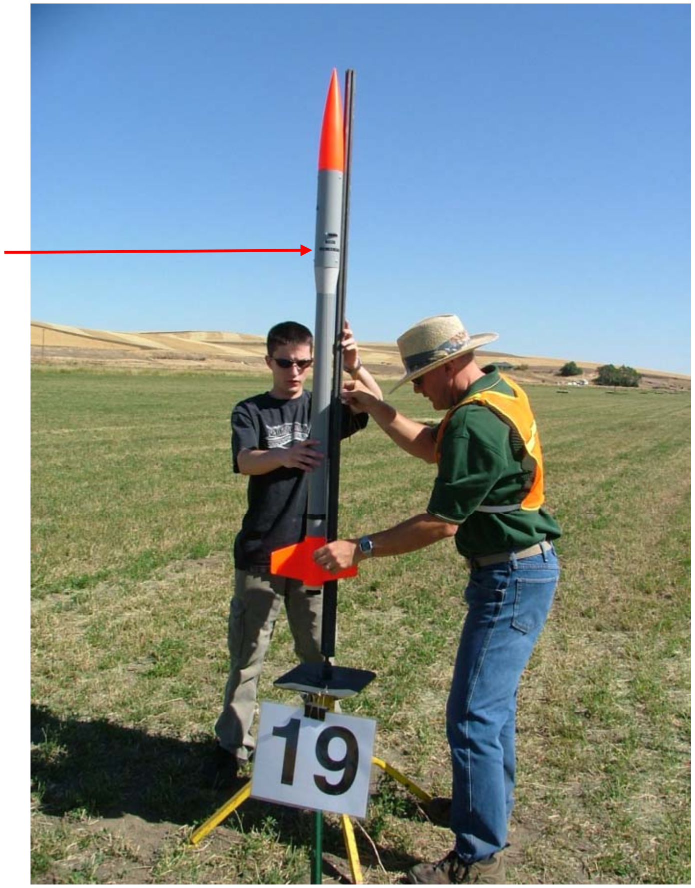
Laptop

Not Shown:

a) External Telemetry Receiver Antenna
b) External GPS Antenna
c) External Cellular Modem Antenna

Flight Vehicle

Payload Capsule

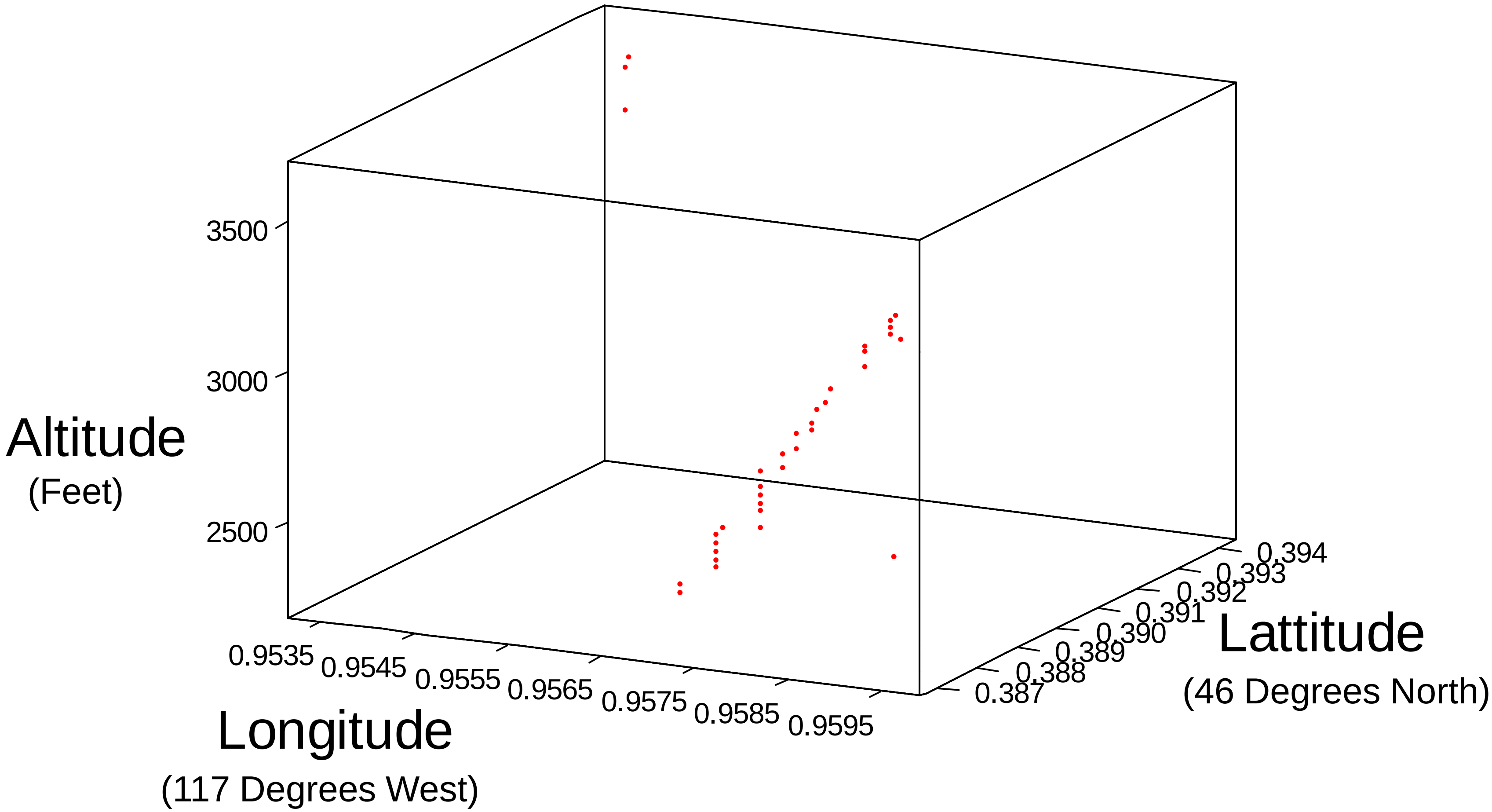


Length: 65”
Diameter: 3”
Dry Weight: 3.5 Pounds
Attainable Altitudes: 2,000 feet to 20,000 feet

Glenda Project – Active Payloads - Application

"Lone Tree" Launch Site – June 11th, 2011

Lattitude / Longitude / Altitude / Motion

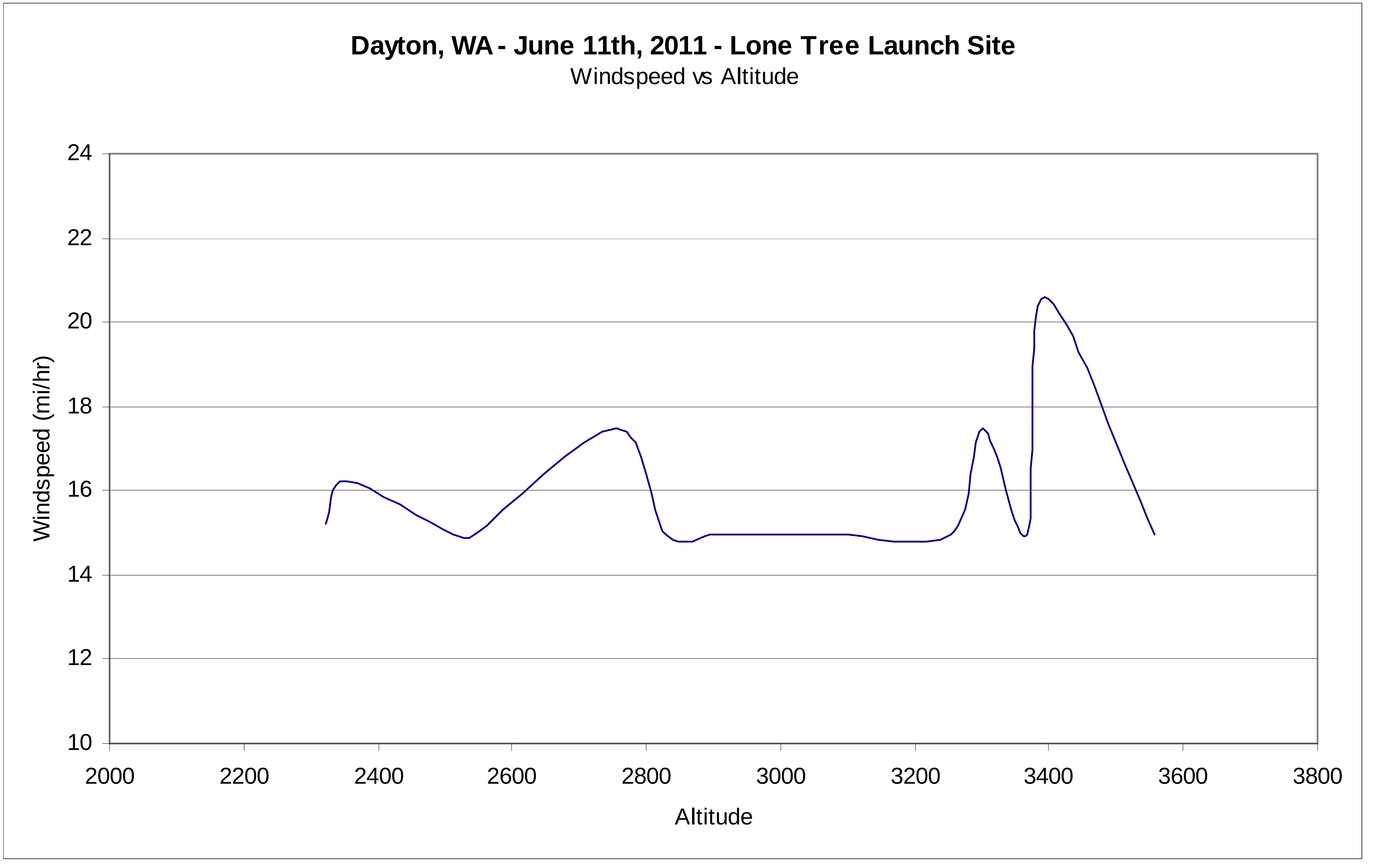


Note: After an initial shift at altitude, due to the winds aloft, recovery was nominal

Glenda Project – Active Payloads - Application

Wind Speed vs. Altitude

“Lone Tree” Launch Site – June 11th, 2011

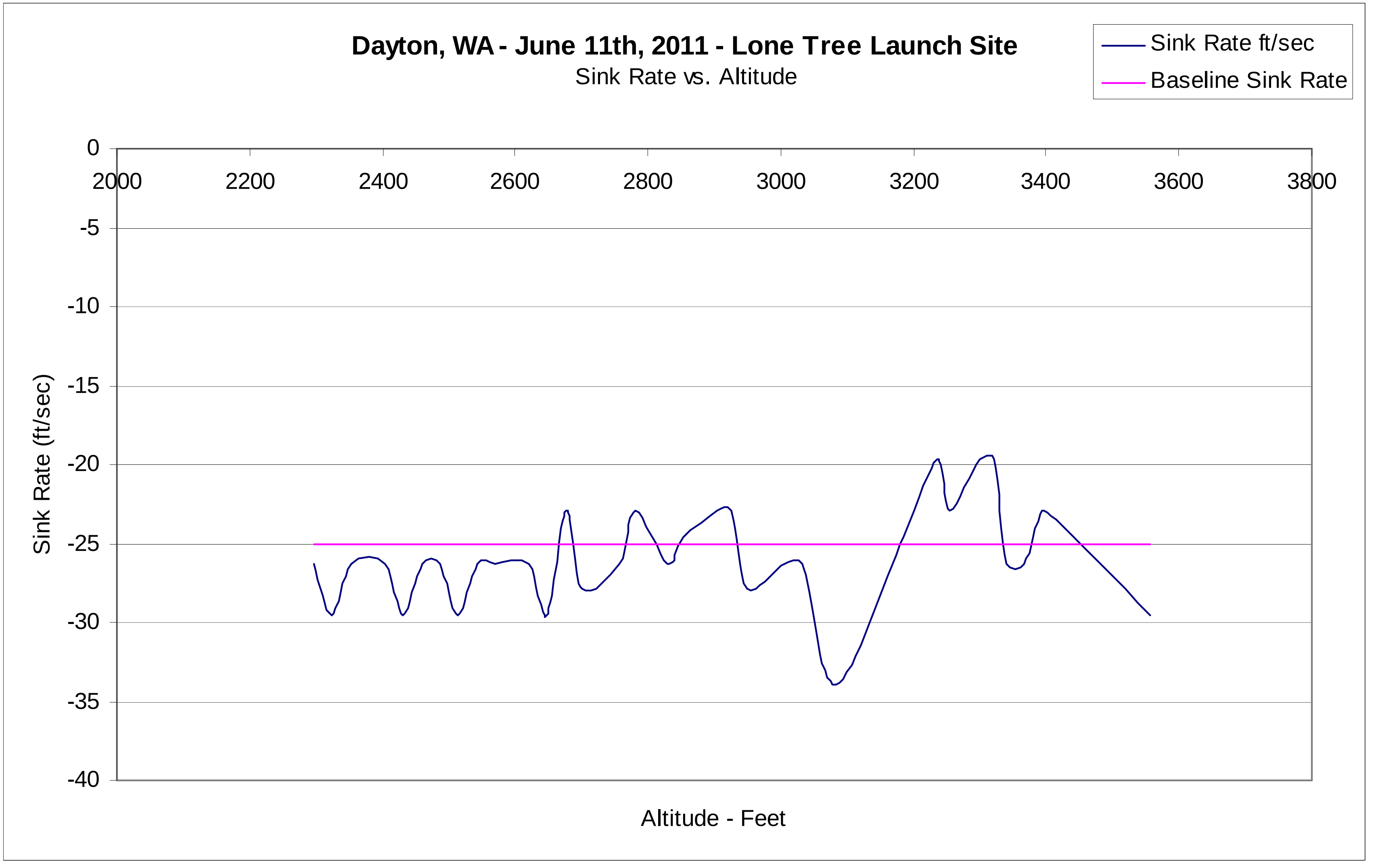


Note: Windspeed values remained relatively consistent during the flight

Glenda Project – Active Payloads - Application

Sink Rate vs Altitude

“Lone Tree” Launch Site – June 11th, 2011



Note: The baseline capsule sink rate was 25 feet per second (-25 fps) and was able to continue to detect updrafts and downdrafts. No consistent pattern was detected.

Glenda Project – Active Payloads - Transmitters

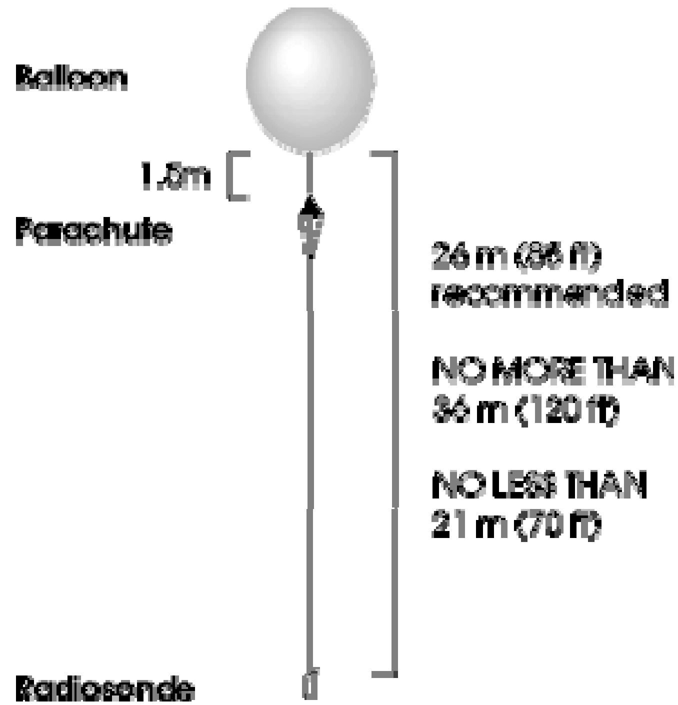
Weather Balloon - Radiosonde Payloads

In 2013, the Glenda Project expanded our flight capability to conduct actual weather balloon launches with the intent to expand our flight envelope to over 100,000 feet. The most significant challenge was the development of the ground support equipment and infrastructure.

The signal / data processing systems were already in place which made the transition to actual balloon launches rather seamless.

100 gram and 150 gram balloons

Parachute and Radiosonde de-reeler

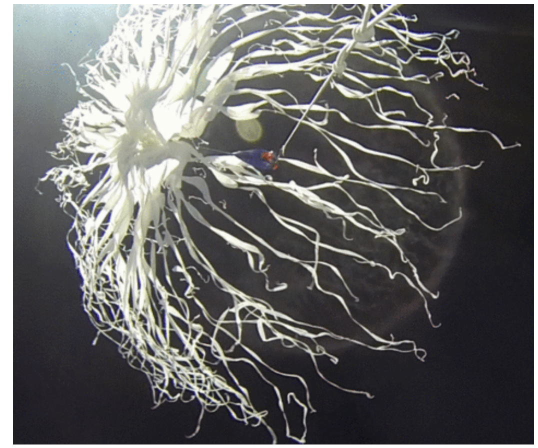


Balloon Launched Payloads – Typical Flight Profile

2 – Data Collection Phase

At 100,000 feet, the temperature is around -40 degrees F with air pressure close to a vacuum

3 – Balloon Burst



1 – Launch Phase

4 – Recovery Phase

Glenda Project – Weather Balloon Fill System

Ground Support Equipment (GSE) in support of balloon inflation

Pressure Regulator with connector to Helium Tank

15 foot connection hose

Balloon “Stinger” with flow control / shut off valve

Un-inflated weather balloon on “Stinger”.

Radiosonde Launch Platform

Glenda Project – Active Payloads - Application

May 18th , and May 19th, 2013 – Weather Balloon Launch

On May 18th, and May 19th 2013, the Glenda Project launched its first weather balloons deploying Vaisala RS-92 radiosonde payloads.

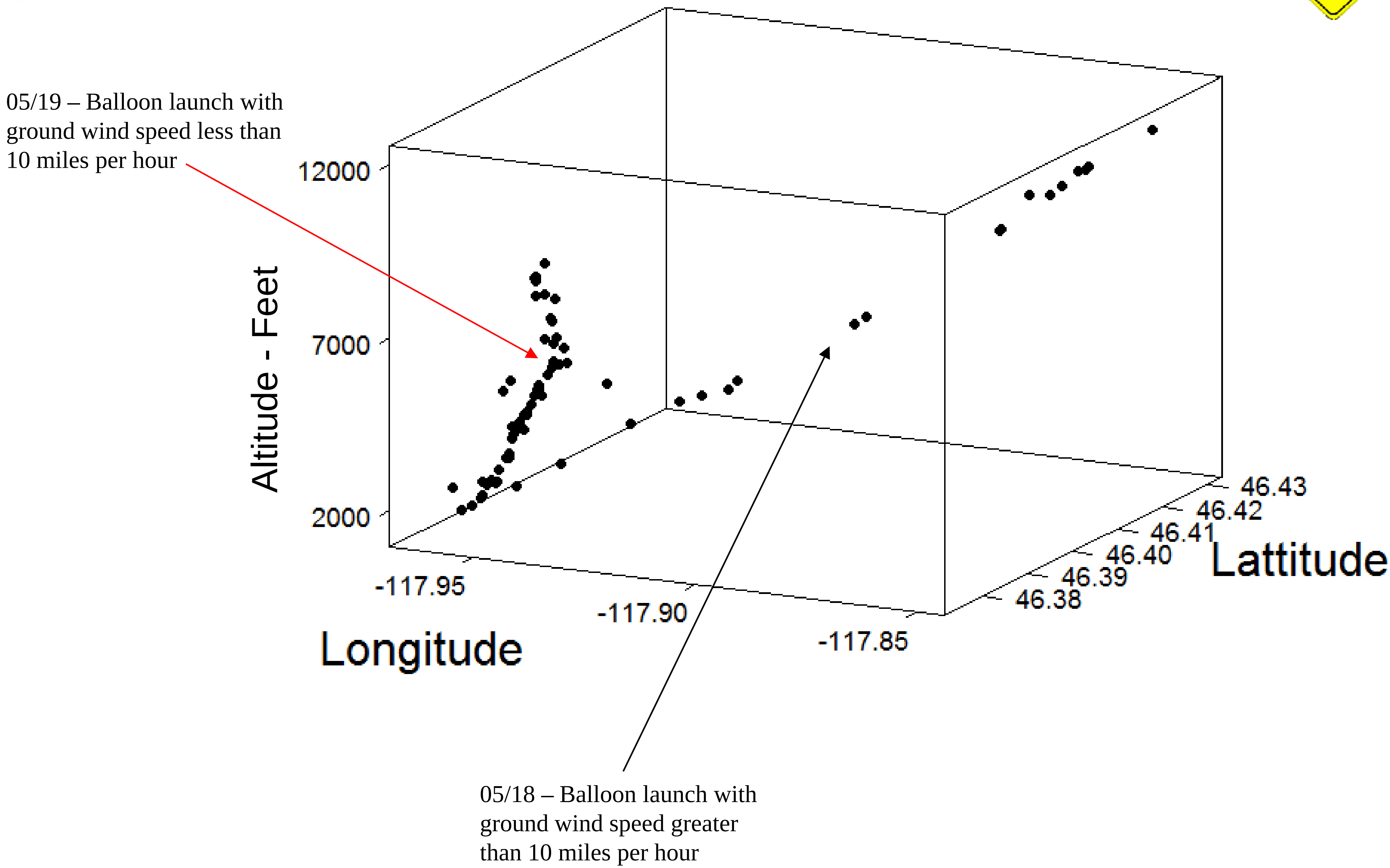
The first flight on May 18th was flown using a 150 gram balloon filled with 40 cubic feet of helium. Projected flight altitude was approximately 100,000 feet. The RS-92 payload contained a GPS only telemetry package. Ground wind speed was in excess to 10 miles per hour and the balloon headed rapidly to the Northeast. Data was collected until signal was lost due to altitude and distance at approximately 11,000 feet. While the balloon continued on to its maximum altitude, we lost signal to the payload.

The second flight on May 19th, was made using a 100 gram balloon, again filled with 40 cubic feet of helium with a projected altitude of 80,000 feet. With the flight, the RS-92 contained a full sensor suite of GPS, Temperature, Relative Humidity, and Barometric Pressure sensors. A full data set was collected until signal loss occurred at approximately 9,000 feet. The balloon continued on to its maximum altitude.

The following slides display the data collected from the two flights.

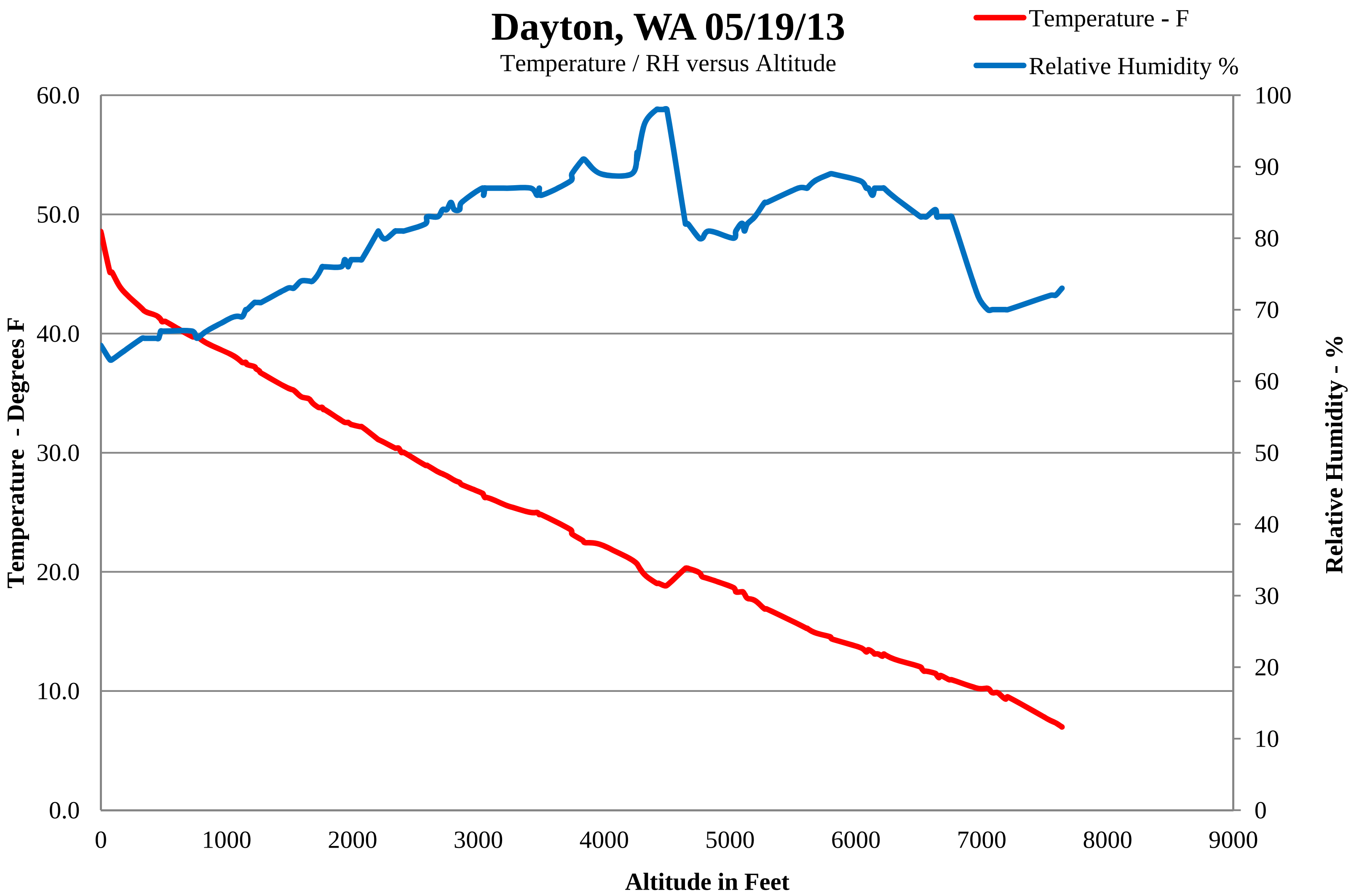
Glenda Project – Active Payloads - Application

May 18th , and May 19th, 2013 – Balloon Launch Flight Comparisons



Glenda Project – Active Payloads - Application

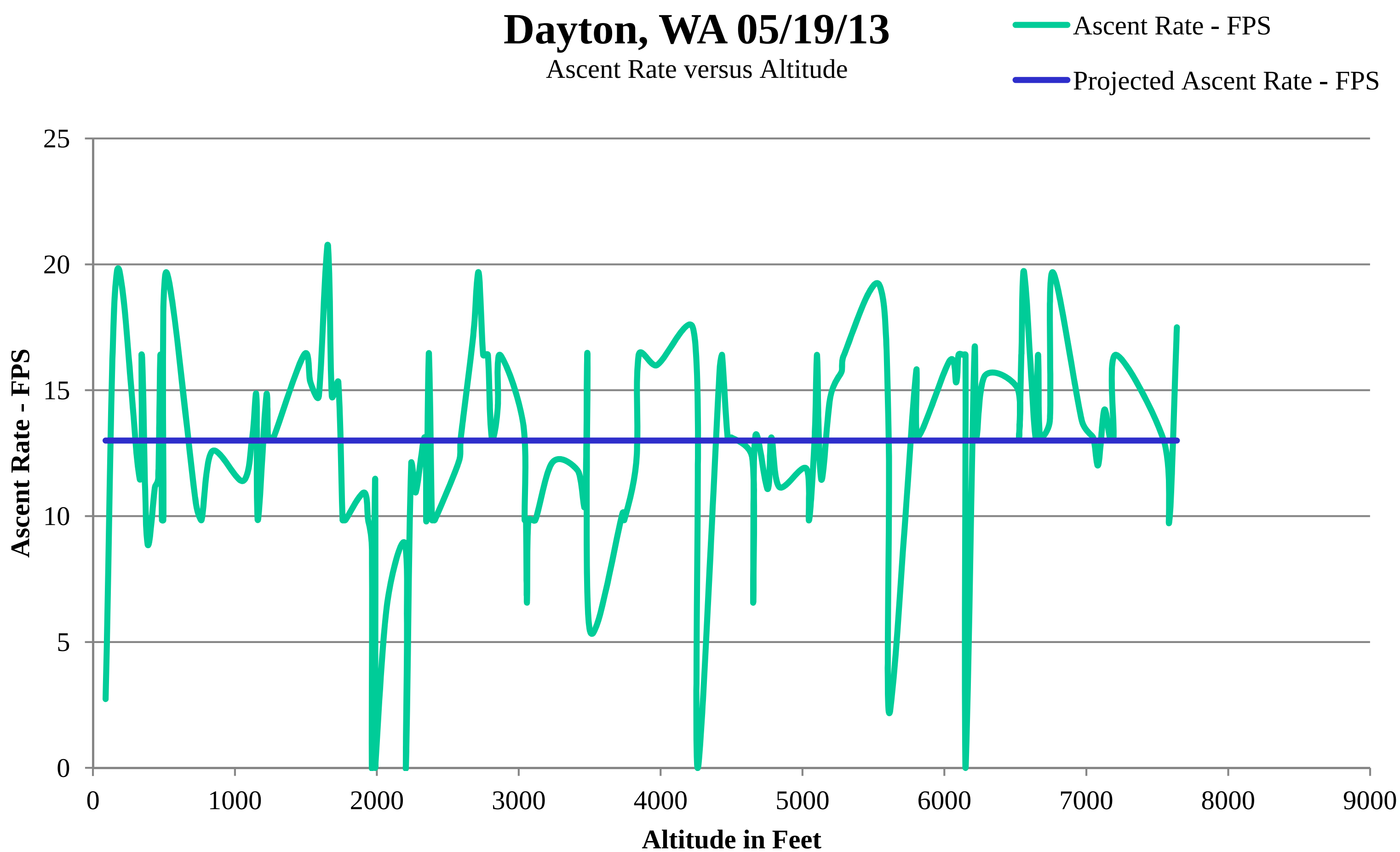
May 19th, 2013 – Temperature / RH versus Altitude



Note: RH drop at around the 4,500 foot mark while temperature continues to drop along predicted lines. Shifts tend to occur at microclimate boundaries

Glenda Project – Active Payloads - Application

May 19th, 2013 – Balloon Ascent Rate versus Altitude



Note: Weather balloons are designed to ascend at predictable linear rates. The micro climate at “Lone Tree” continues to exhibit updrafts and downdrafts throughout the entire flight

Glenda Project – Active Payloads - Application

September 13th, 2014 – Weather Balloon Launch

The results of the 2013 flights established the capability of the Glenda Project to launch balloon deployed payloads into thunderstorms, and tornadic systems.

While the flights were a conceptual success, there were still improvements to be made. Primarily, the ability to attain data above 10,000 feet required a re-design of our existing omni-directional antenna system to include a Yagi uni-directional antenna operating in parallel in order to receive the weaker radiosonde transmissions.

Our September 13th, 2014 balloon launch featured the deployment of our new Yagi antenna and we achieved successful data capture to 38,000 feet until we lost signal due to battery failure driven by the colder temperatures at altitude. Our 2015 balloon launches will feature lithium cells which will eliminate this problem.

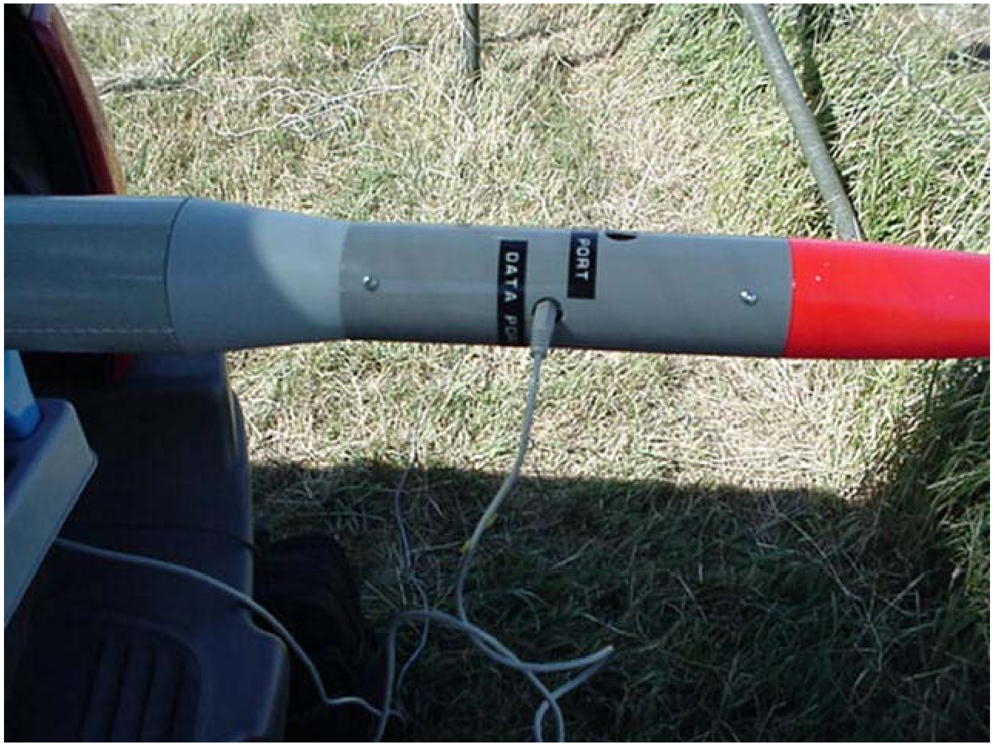
The success of these launches culminates over 15 years of development and operational maturity. Additional launches are planned as our systems continue to grow and evolve.

Glenda Project - Passive Payloads – Data Loggers

A data logger is an electronic instrument that records measurements over time. Typically, data loggers are small, battery-powered devices that are equipped with a microprocessor, data storage and sensors. Most data loggers utilize software on a personal computer to initiate the logger and view the collected data.

Prior to a Glenda launch, the data logger is connected to a laptop computer. Then, systems software is used to select logging parameters (sampling intervals, start time, etc.) and initiate the logger. The logger is then disconnected from the laptop and installed inside the Glenda payload capsule. Upon launch, the logger records each measurement and stores it in memory along with the time and date.

Post recovery, the logger is then reconnected to the laptop computer and the software is used again to readout the data and see the measurements as a graph, showing the profile over time. The tabular data can be viewed as well, or exported to a spreadsheet for further manipulation.



Canmore GT-740FL GPS Data Logger

The GT-740FL is a single board GPS receiver / data logger featuring surface mount components and power supply designed to with stand the high flight loads of the Glenda boosters.

Data logger Specifications:

- 48 track verification channels
- SiRF IV low power chipset
- Adjustable sampling rates from 1 second +
- Satellite signal reception sensitivity: -163dbm
- Position: +/- 2.5 meters CEP
- Data compatible with Google Earth
- Size/Weight: .625 x 1.17 x 2.75" (16 x 30 x 70 mm)/approx. 2.5 oz.(71 grams)
- Time to reposition: < 0.1 second average
- Time to boot: <34 seconds (cold), 1 sec (hot)
- Ultra low power consumption; over 17/56 hours continuous use
- Water resistant to IPX6 standard

MicroLite Temperature Datalogger

The MicroLite USB Datalogger is a small electronic device for monitoring and recording temperature. Manufactured to stringent IP68 standards, the MicroLite logger is dustproof and is only 4.3” long and 1” thick. The data logger features a three digit LCD display, direct USB connection, wide temperature range, high accuracy and large sample memory. Data can be displayed on the small numeric screen or downloaded to the MicroLab Lite software via the USB 2.0 connector.

Datalogger Specifications:

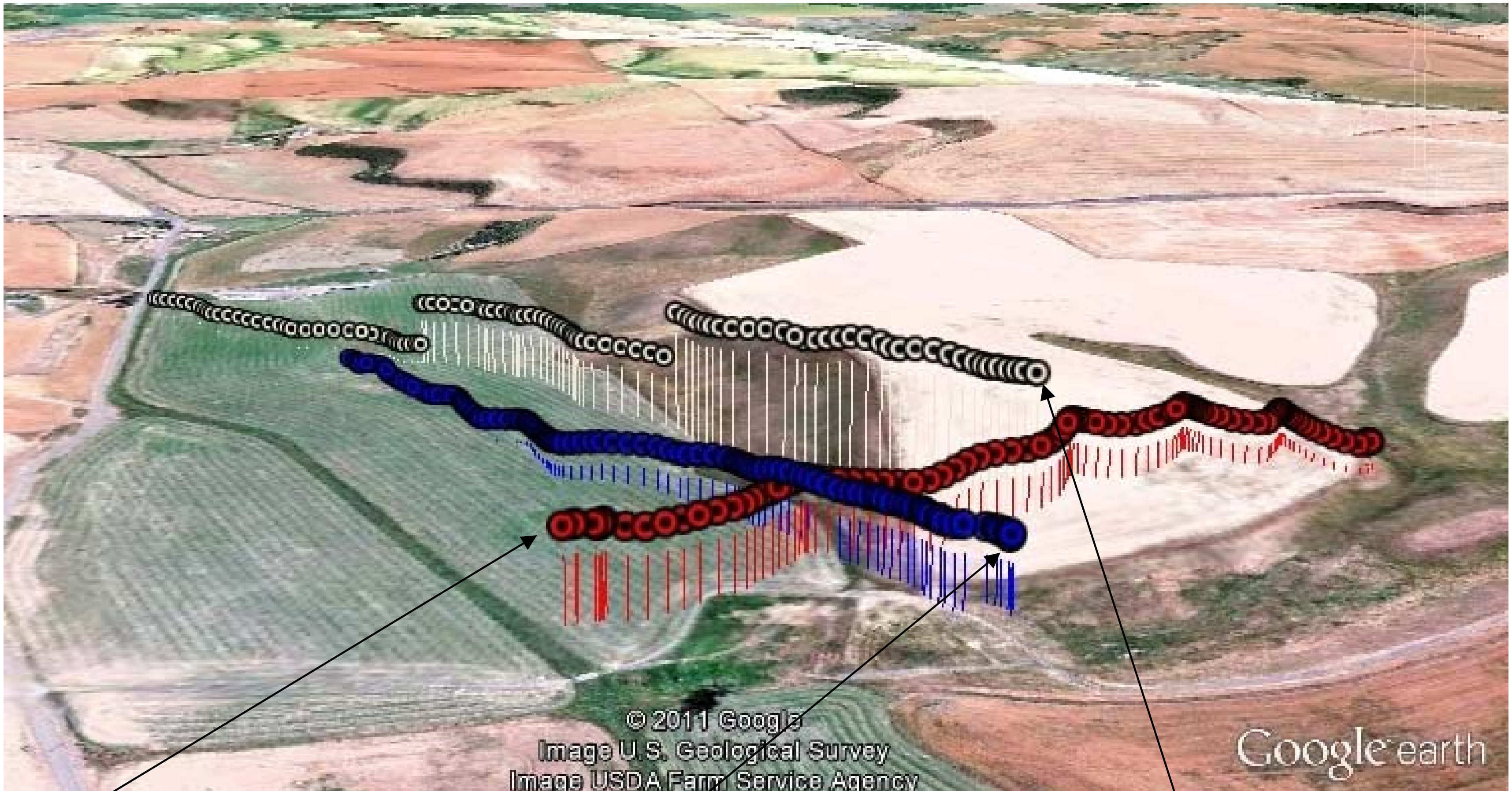
- Internal Temp Sensor: -40°C to 80°C Thermal Conductor enabling a fast sensor response time
- Sampling Resolution A/D Resolution: 16Bit 0.1°C
- Data Storage Capacity: 16,000 Samples
- Sampling Rate: 1 per second to 1 per 2 Hours
- Battery: Replaceable 3V Lithium Battery - CR2032
- Battery Life: 2 Years at 1 second Sampling Rate
- Dimensions: 11cm x 3.9cm x 2.6cm (4.3" x 1.5" x 1.0")
- Weight: 45.5 grams (1.6oz)
- Software: MicroLab Lite for Windows
- Standard Compliance: IP68, NEMA6 (30 Minutes for 0.5 meter Depth) CE, FCC

Glenda Project - Passive Payloads – Application

GPS Data Logging

4D wind current mapping over local terrain.

(4D is latitude, longitude, elevation and velocity)



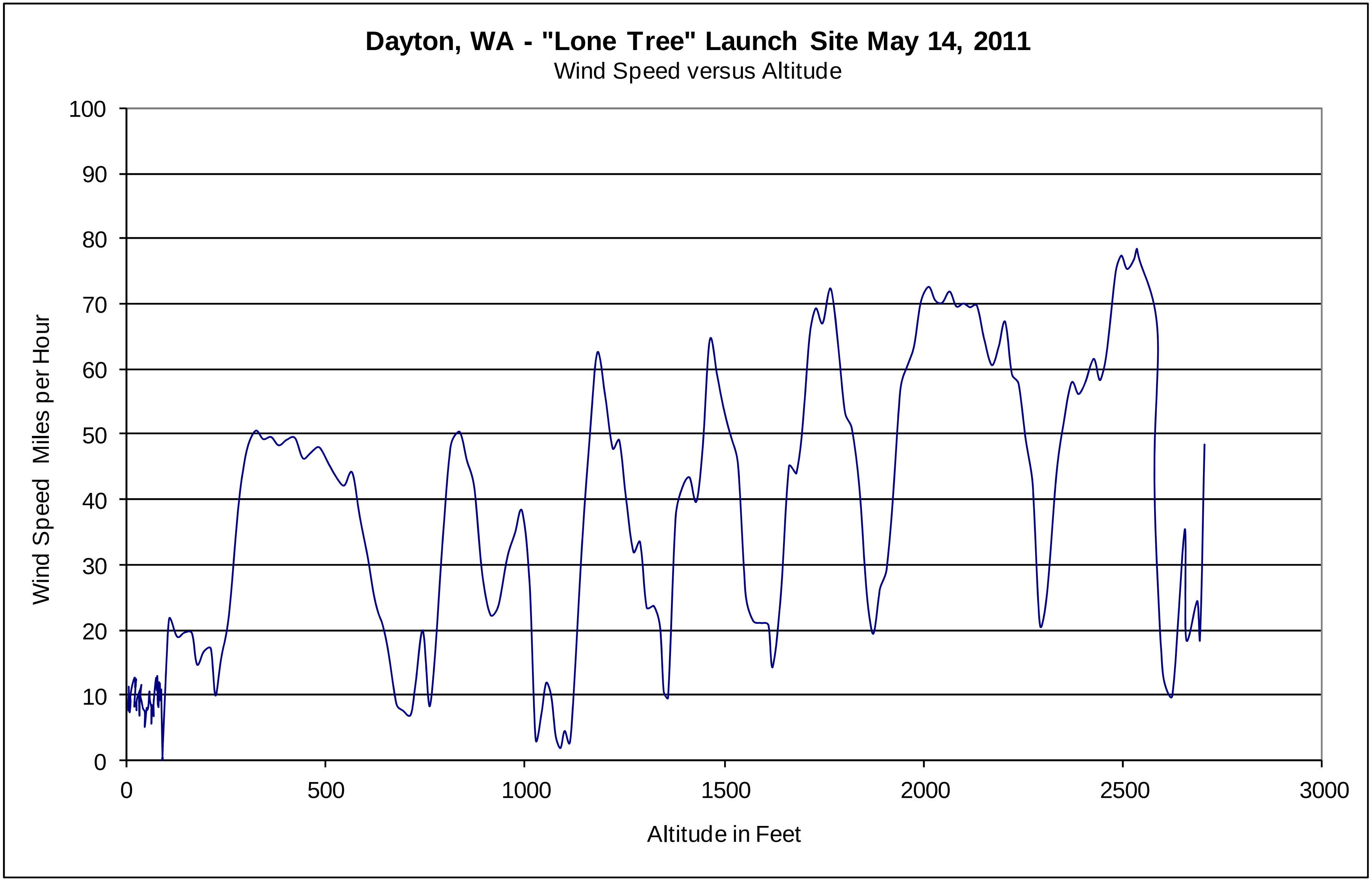
May 14th
7554 Booster – Aerotech I211
"Thunderstorm Intercept"
Apogee: 2,706 Feet
Ground Level Wind Speed: 4.5 mph

June 11th
9875 Booster – CTI I170
Apogee: 2,211 Feet
Ground Level Wind Speed: 10 mph

October 1st
7554 Booster – Aerotech I211
Apogee: 2,354
Ground Level Wind Speed: 14.5 mph

Glenda Project - Passive Payloads – Application

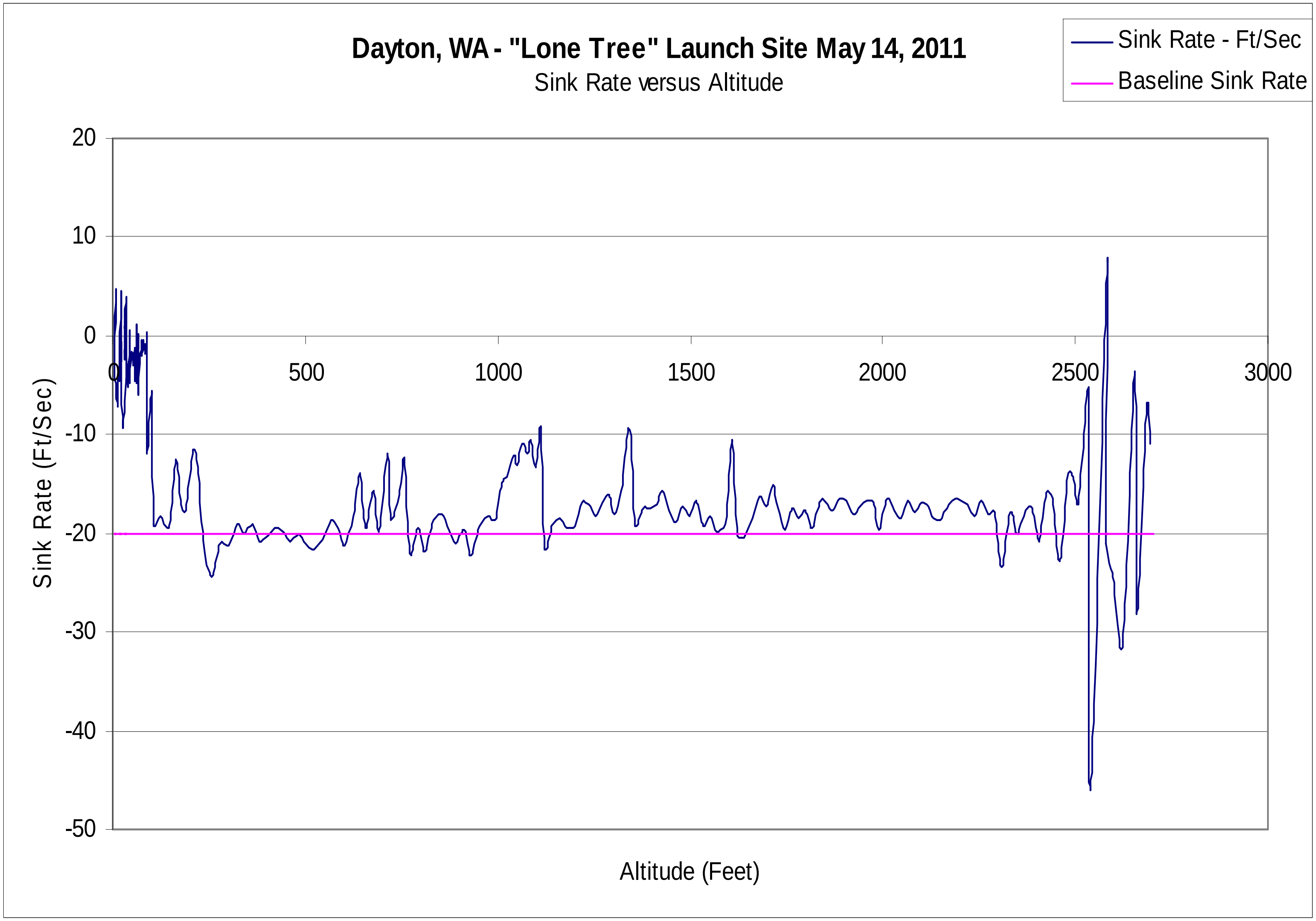
GPS Data Logger – Wind Speed vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Note: Wind Speed is increasing with Altitude

Glenda Project - Passive Payloads – Application

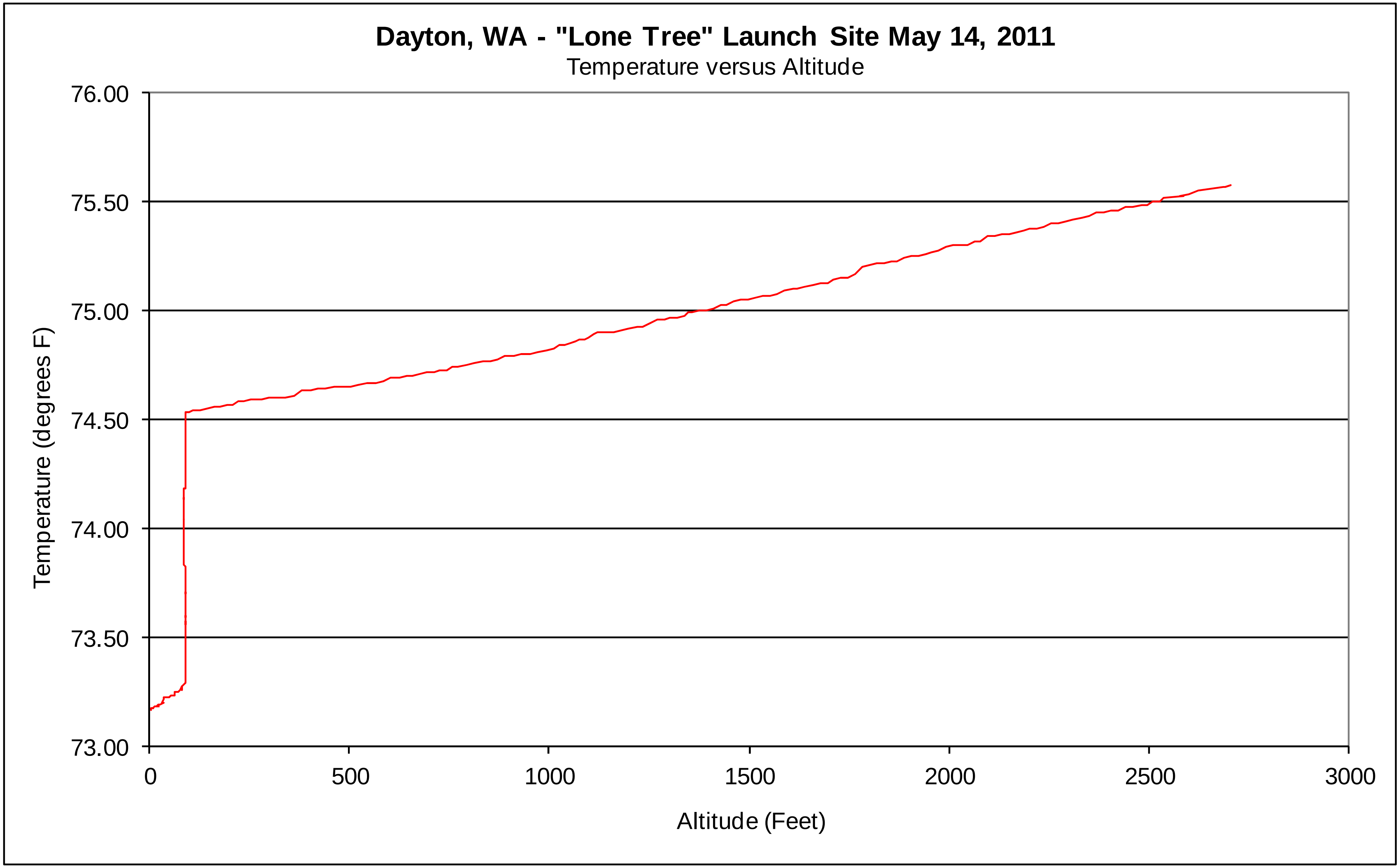
GPS Data Logger – Sink Rate vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Note: The “Baseline” Sink Rate of the capsule is 20 feet per second (-20)
There are significant Updrafts and Downdrafts due to the approaching thunderstorm

Glenda Project - Passive Payloads – Application

Temperature / GPS Data Logger – Temperature vs Altitude
“Lone Tree” Launch Site – May 14th, 2011



Glenda Project – Video Payloads

In May 2007, the Glenda Project deployed its "First Generation" camera probe called "Ranger Intercept" named from the lunar photographic missions from the 1960's.

While successful, the payload did not gather the high resolution images required for viable analysis.

Since 2007, cameras and optics have matured to the point where high definition / high resolution images are now possible from compact / light weight payloads.

In September 2014, Glenda successfully deployed a High Definition digital movie camera as an auxillary camera "pod" into our existing payload capsule. This increased resolution now provides a visual record of the environment captured by the on-board sensor suite.

May 2007 – "First Generation" Camera Flight

September 2014 – "Second Generation" Camera Pod

Glenda Project - Video Payloads – Application

September 13th, 2014 – Deployment of the Second Generation “Ranger Intercept” Video Payload

2. Mid - Boost

Photo Courtesy of Jon Preston

3. Apogee

4. Descent

5. Final Approach

1. Launch

Photo Courtesy of Jon Preston

6. Landing

Glenda Project – Ground Stations

The Glenda Project has found that, over time, without knowing ground level weather conditions, there is no effective baseline to measure from as we launch instrument packages into severe weather systems.

This acknowledgement has driven the development of several different types of mobile ground station where their usage can be adapted based on our mission and data requirements.

Some typical examples:

a) Digital Chart Recorders

b) Recording Anemometers

c) TMQ-34 Mobile Military system

d) Coastal Environmental WeatherPak 400 Wireless ground station

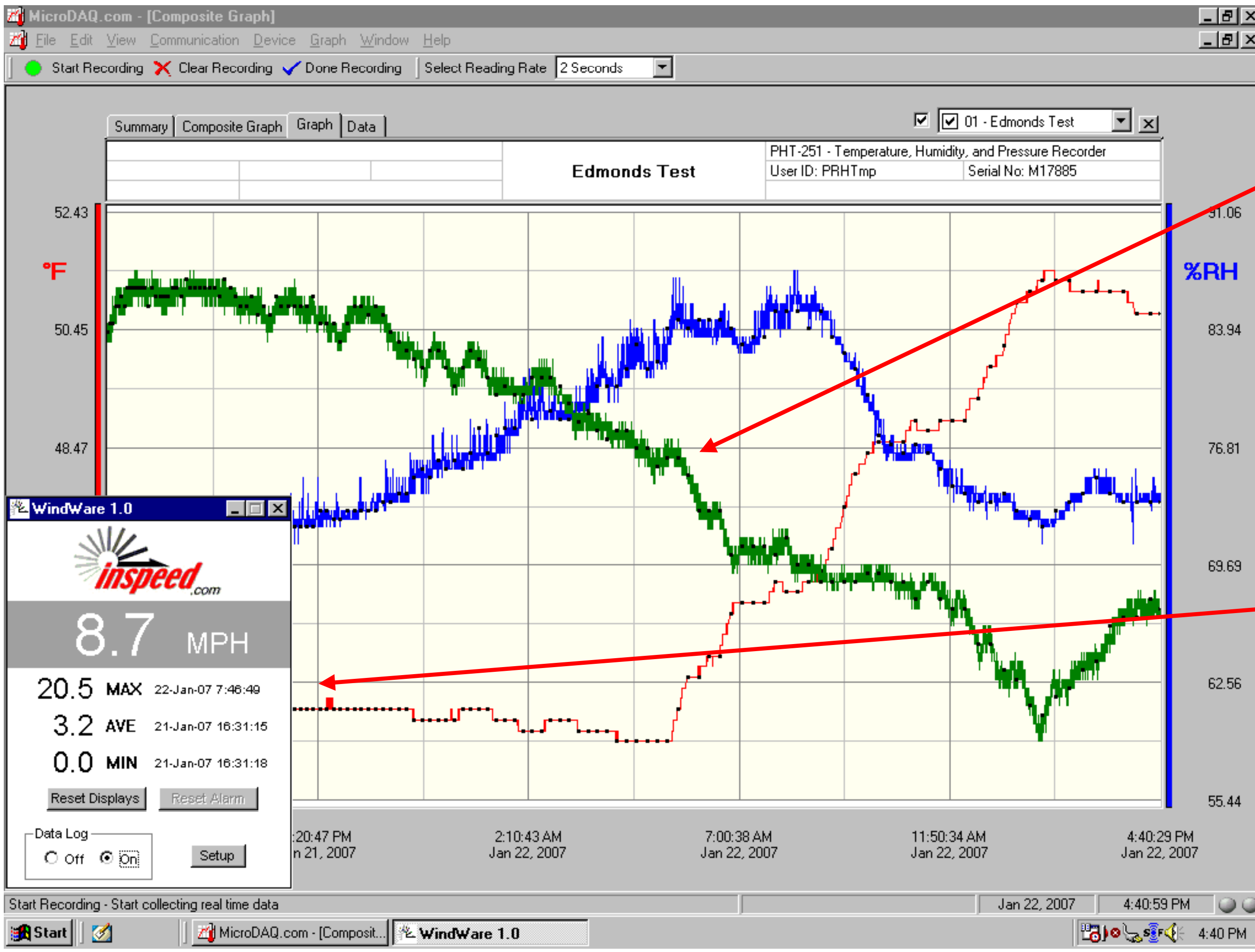
e) Mobile Mesonet ground stations

Glenda Project – Ground Stations

Digital Chart Recorders

Glenda Project utilizes sensors combined with ground based laptops to provide a digital based chart record of ground baseline conditions mapped over time.

The basic example below is a digital chart record of temperature, humidity, barometric pressure and wind speed at a test site.



Pressure, Temperature, & Barometric Pressure data stream using Micro-DAQ software and COM 1 port

Wind Speed data using InSpeed Anemometer and supporting software Using COM 3 port via USB port application adapter

Glenda Project – AN/TMQ-34 Ground Station

Glenda also has an operational portable military weather station. This acquisition further enhances the projects ground condition data collection capabilities.

The TMQ–34 is a military self contained portable weather measuring system that is powered by a rechargeable Ni CAD battery.

The TMQ–34 alphanumerically displays wind speed and direction, peak wind, temperature, dew point, barometric pressure, 3-hour pressure change, and the minimum and maximum temperature.

The entire TMQ–34, including the system case, weighs about 20 pounds. The set contains a computer module with a pressure sensor, and the main sensor module with a red sensor for temperature, a white sensor for humidity, a wind direction compass, and an anemometer to measure wind speed.

The TMQ–34 can operate in temperatures ranging from a low of –59.5°F to 132°F. The TMQ–34 is intended for use in a tactical environment with an operating range of 100 feet below sea level to 10,000 feet above sea level.

Glenda Project – WeatherPak 400 Ground Station

Coastal Environmental HazMat Weather Station

The Glenda Project now has several Coastal Environmental WeatherPak 400 TRx2 mobile vehicle mounted and wireless weather stations.

Some of its numerous features are:

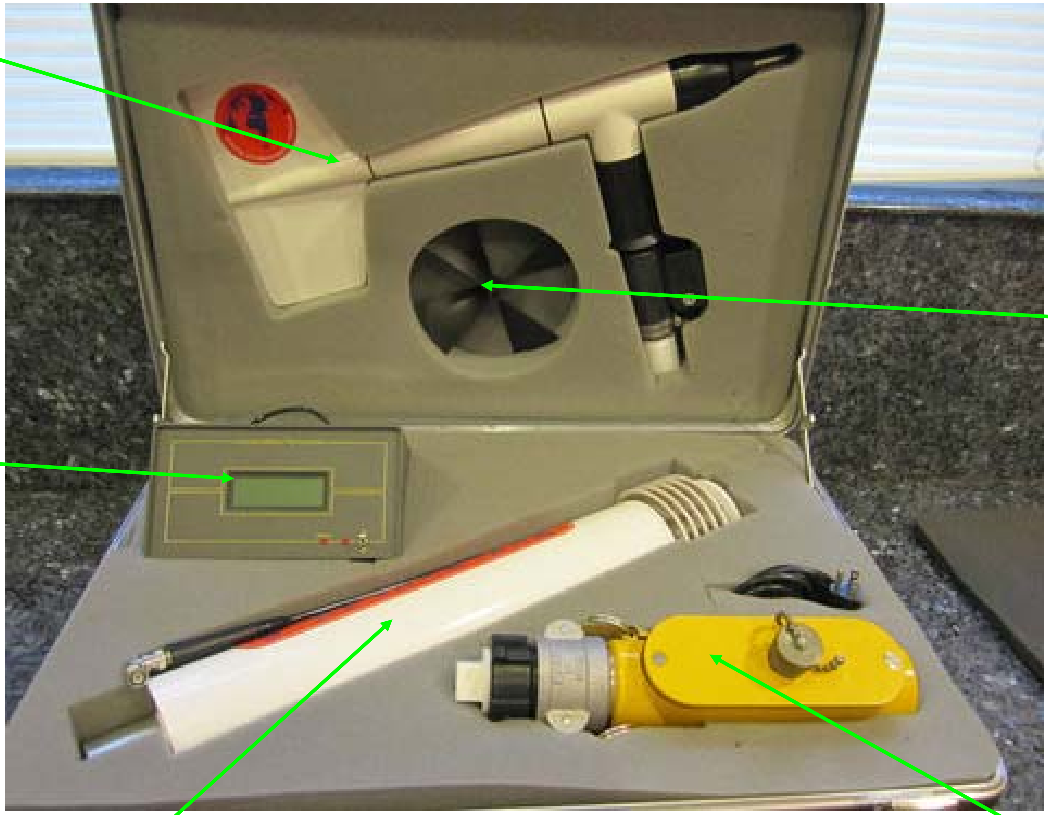
- Wireless radio data Telemetry with a 5 mile range
- Self aligning Fluxgate Compass
- Complete sensor suite to record Temperature, Relative Humidity, Barometric Pressure, Wind Speed, and Wind Direction.
- Weighs less than 10 pounds and is deployable in less than 60 seconds
- Highly portable with its own transit case
- Serial data interface to support data logging and display
- Alternate Power Sources from 120VAC to 12 VDC
- "Stand Alone" capability without requiring a computing interface
- Tested and designed for HazMat and severe environments
- Capability to measure "Sigma Theta" to determine atmospheric instability

Glenda Project – WeatherPak 400 Ground Station

Coastal Environmental Wireless HazMat Weather Station

System Components

Anemometer / Wind Direction Sensor



Anemometer Propeller

Telemetry Receiver Display

Sensor Suite Unit containing Temperature, Relative Humidity, Barometric Pressure and Telemetry Radio transmitter

Power Distribution Junction Box

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

One of the datasets collected by the Weatherpak 400 is called “Sigma Theta” and is a measurement of Atmospheric Stability.

Atmospheric Stability can be defined as the resistance of the atmosphere to vertical motion. Vertical motion is directly correlated to different types of weather systems and their severity. Atmospheric vertical motion can be either ascending, or descending and are commonly called updrafts, or downdrafts.

Often under calm conditions, and especially over flat terrain, heated air parcels do not rise immediately. They have inertia and remain on the surface until some disturbance permits cooler surrounding air to flow in beneath and provide the needed buoyancy. This disturbance is the trigger for atmospheric in-stability.

Thunderstorms with strong updrafts and downdrafts develop when the atmosphere is unstable and contains sufficient heat, and moisture.

As air rises, it cools and serves as an indicator of atmospheric stability. The term for the rate of this cooling is called the “Adiabatic Lapse Rate”, and is the traditional method for determining atmospheric stability.

In mountainous terrain, temperature and humidity measurements taken at mountaintop and valley-bottom ground stations provide reasonable estimates of the lapse rate and moisture conditions in the air layer between the two levels.

Adiabatic Lapse Rates (under “baseline” conditions):
Dry: 5.5 degrees F decrease per 1,000 feet elevation increase.
Moist: 3 degrees F decrease per 1,000 feet elevation increase.

A large decrease in temperature with height indicates an unstable condition which promotes up and down wind currents. A small decrease with height indicates a stable condition which inhibits vertical motion. Where the temperature increases with height, through an inversion, the atmosphere is extremely stable. (ie capping)

Lapse rate data is typically collected using balloon carried radiosondes, or rocket launched capsules, as the data is typically not attainable using conventional ground stations.

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

"Sigma Theta" (ST) is a compound term with its origins coming from both the Statistical / Mathematic community and the Physical Sciences.

The term "Sigma" comes from the Statistical community and is a mathematical term used to define the concept / process called "standard deviation". Standard Deviation is a process used to explain the amount of variability within a data set with the higher the deviation, the higher the level of variability within the data set.

"Theta" comes from the Physical Sciences / Weather community as the term defining the angle of wind direction.

"Sigma Theta" translated means the amount of variability of the changes in wind direction within a dataset.

Robert Yamartino developed the "standard" ST model back in the 1980's and it has been adopted by the HazMat / EPA community as their preferred model for measuring atmospheric stability using ground based sensors and is based off of the following equations:

Step 1: Compute the average sine of wind direction, the average cosine, and epsilon

$$S = \frac{1}{N}\sum_{i=1}^{N} \sin\theta_i \qquad C = \frac{1}{N}\sum_{i=1}^{N} \cos\theta_i \qquad \varepsilon = \sqrt{1-(S^2 + C^2)}$$

Step 2: Compute sigma theta as the arcsine of epsilon, and apply a correction factor

$$\sigma_\theta = \text{arcsine}(\varepsilon)\left[1 + \left(\frac{2}{\sqrt{3}} - 1\right)\varepsilon^3\right]$$

Glenda Project – WeatherPak 400 Ground Station

Sigma Theta Overview

Frank Pasquill took the next step, and determined levels of Sigma Theta for differing degrees of atmospheric stability. He created a seven tiered system from “A” to “G”, where Class “G” reflects the most stable atmospheric condition, to Class “A” which reflects the highest level of atmospheric in-stability.

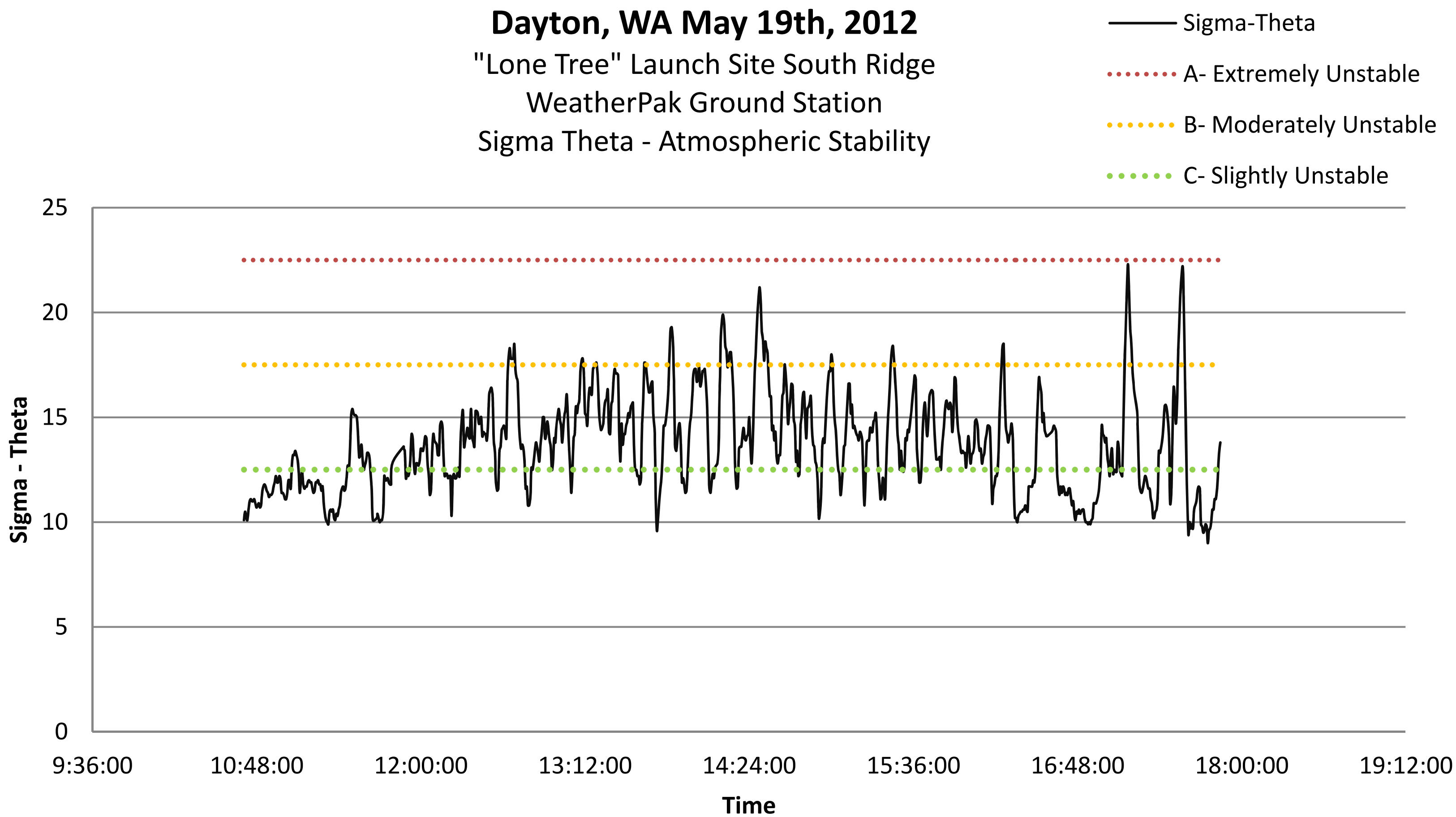
His results are shown in the table below:

Stability Class		Description	Definition
1	A	Extremely Unstable	$22.5 \leq \sigma_\theta$
2	B	Moderately Unstable	$17.5 \leq \sigma_\theta < 22.5$
3	C	Slightly Unstable	$12.5 \leq \sigma_\theta < 17.5$
4	D	Neutral	$7.5 \leq \sigma_\theta < 12.5$
5	E	Slightly Stable	$3.8 \leq \sigma_\theta < 7.5$
6	F	Moderately Stable	$2.1 \leq \sigma_\theta < 3.8$
7	G	Extremely Stable	$\sigma_\theta < 2.1$

Based on this Stability Class table, we can now make determinations of atmospheric stability based on ground station data and not have to rely on balloon launched radiosondes, or rocket launched payloads.

Glenda Project – Ground Station - Application

WeatherPak 400- Sigma Theta



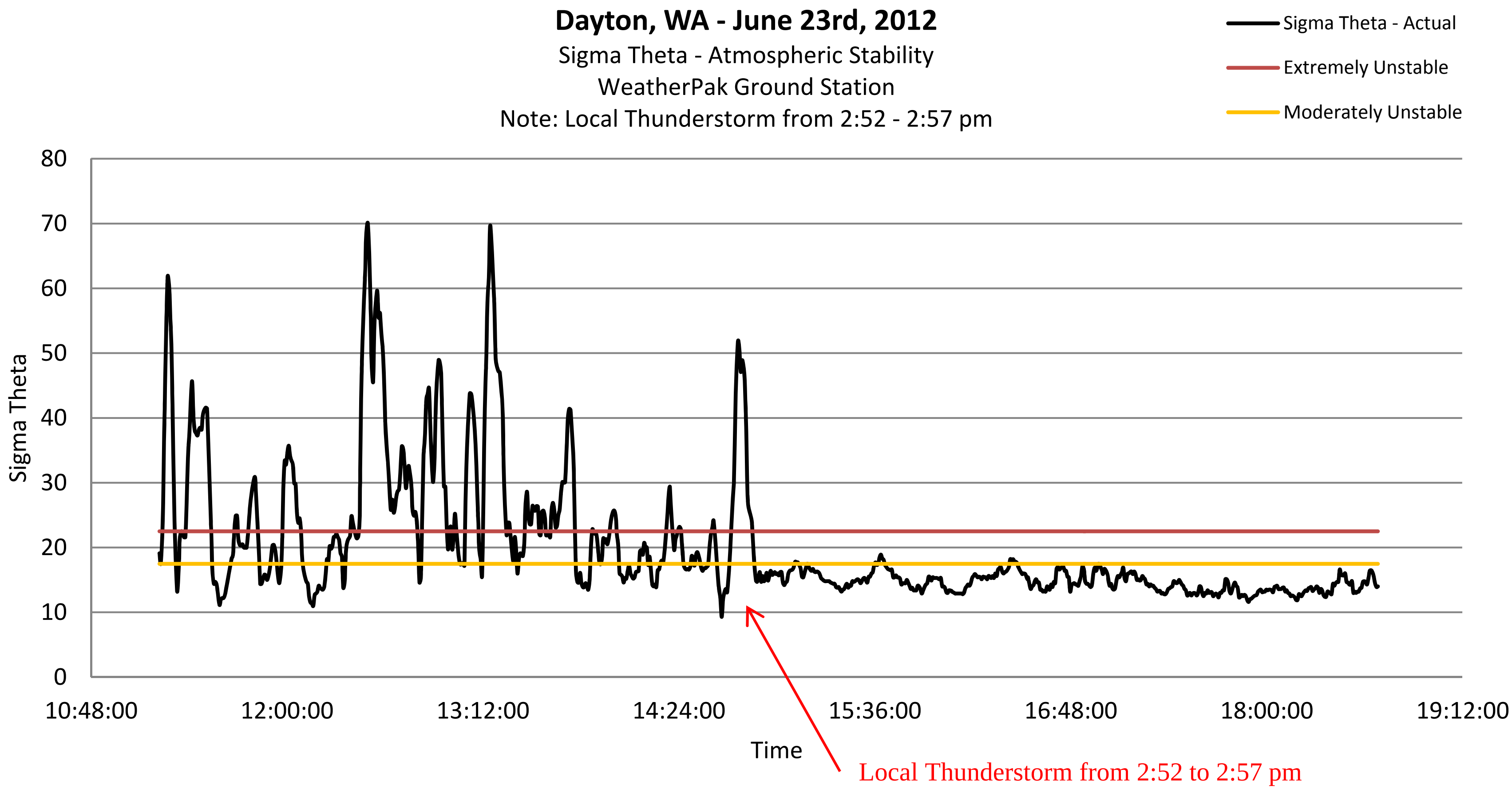
Note that the bulk of the ST data falls in the “Slightly Unstable” range with several points falling into the “Moderately Unstable” band. This implies that atmosphere instability is occurring. However, not severe.

Note also, that atmospheric instability is independent from wind speed as you can have strong winds in a stable atmosphere and calm winds in an unstable atmosphere.

Sigma Theta provides us a tool to measure atmospheric stability using ground based sensors in a mobile environment without the need for lapse rate data and its supporting infrastructure requirements.

Glenda Project – Ground Station - Application

WeatherPak 400- Sigma Theta



On June 23rd, the WeatherPak 400 was deployed on the south ridgeline above the BMR "Lone Tree" launch site.

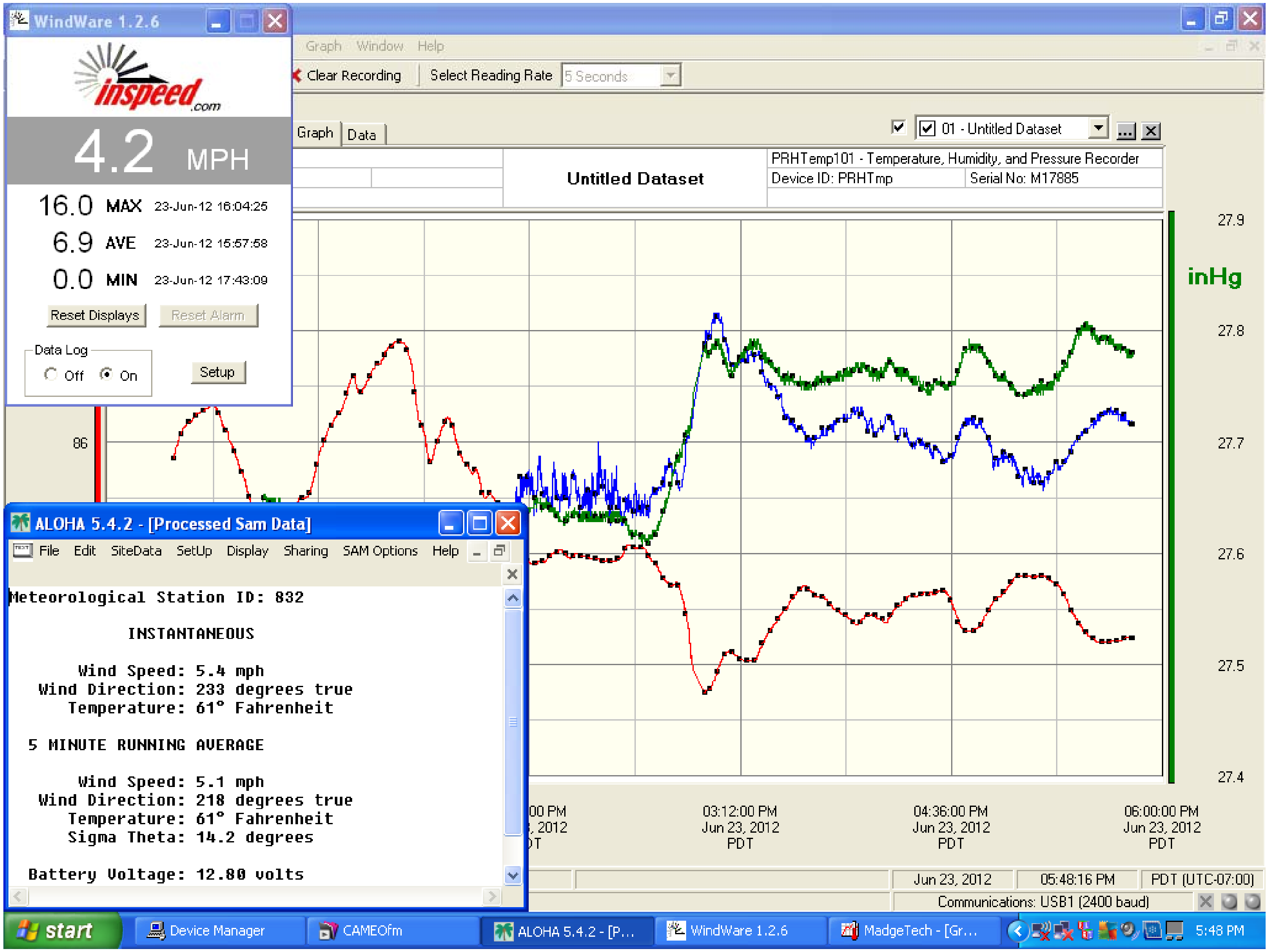
Sigma Theta values reflected "Extremely Unstable" conditions until the passage of a local thunderstorm from 2:52 to 2:57 pm where the Sigma Theta values returned to normal limits.

A case can now be made that Sigma Theta values can be used as a severe weather pre-cursor, and continued deployment opportunities are expected.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment

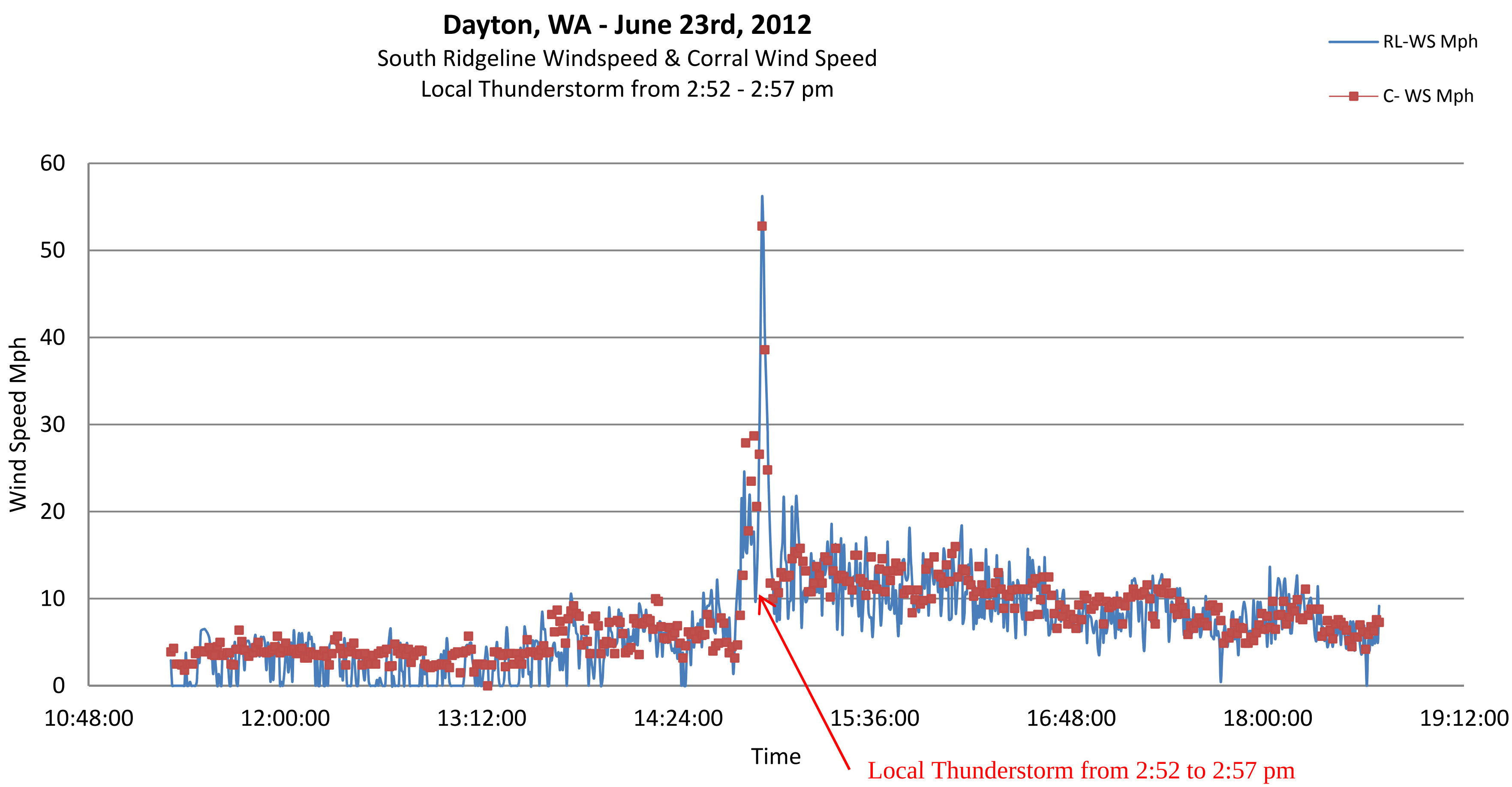
Dayton, WA – June 23rd, 2012



Data from both the wireless and mobile ground stations were displayed side by side on a common interface for seamless integration.

Glenda Project – Ground Station - Application

Dual Ground Station Deployment
Dayton, WA – June 23rd, 2012

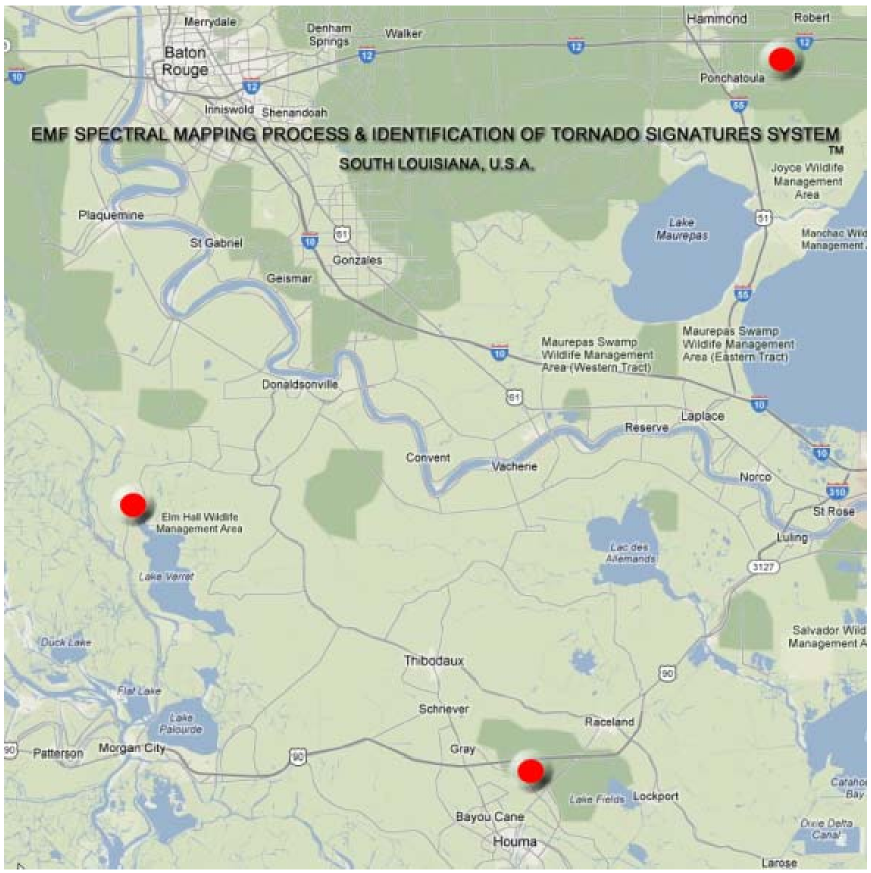


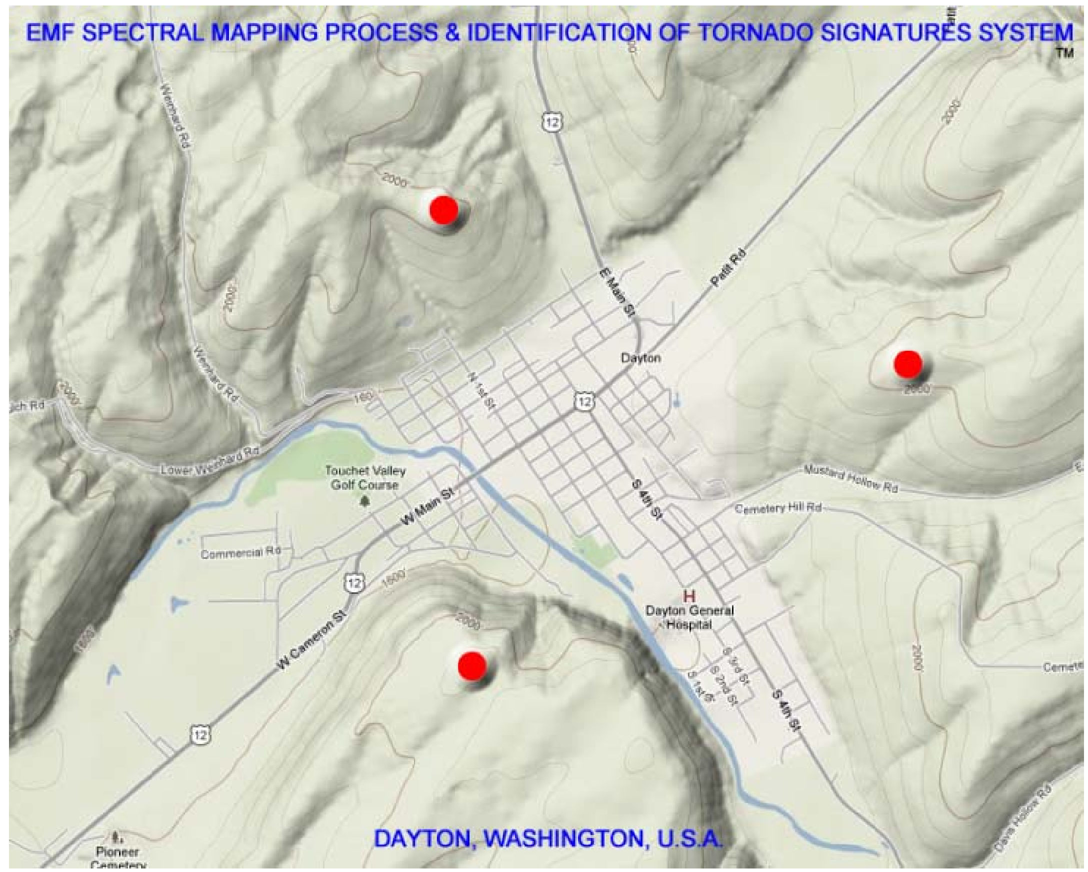
On June 23rd, our first dual deployment accoured as a thunder storm passed over two ground stations simultaneously with one station the wireless WeatherPak and the second, our hard wired mobile station.

Glenda Project – Remote Sensing

Electro Magnetic Field Mapping and Identification of Tornadic Signatures

The Glenda Project is developing an Electro Magnetic Field Spectral Mapping Process and Identification of Tornado Signatures System. The system uses an integrated network of ground stations that automatically and continuously displays the bearings of both "conventional", and energetic disturbances in the atmosphere. Using a standard triangulation methodology, combined with an advanced interlinked computer network for data analysis, 3D models of the atmosphere can be built reproducing the real time conditions.

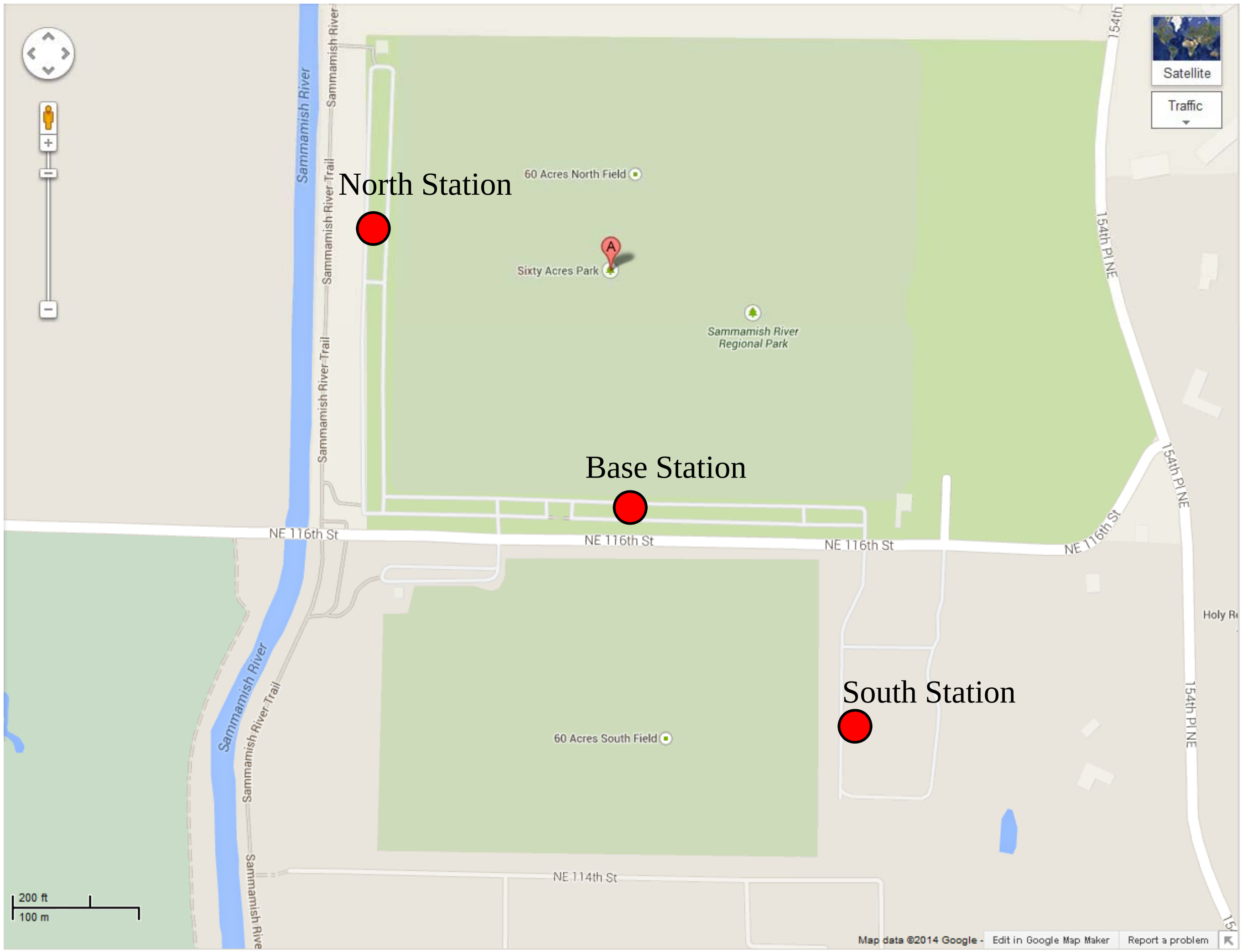




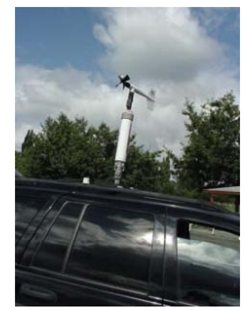
Glenda Project – Remote Sensing – Application

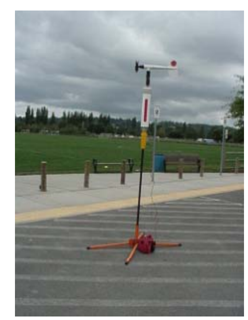
Electro Magnetic Field Mapping and Identification of Tornadic Signatures

On September 3rd, 2014, the Glenda Project took the first of a series of steps by deploying the GlendaNet, a set of three WeatherPak weather stations monitoring "conventional" weather variables. Two of the WeatherPaks were wireless, with the third, hard wired to an intercept vehicle.




North Station


Base Station


South Station

Glenda Project – Remote Sensing – Application

Electro Magnetic Field Mapping and Identification of Tornadic Signatures

The GlendaNet monitored, and recorded multiple variables such as wind speed, wind direction, temperature, relative humidity, barometric pressure, and Sigma Theta (Atmospheric Stability). Multiple laptops were deployed in support of each weather station. In the future, a single integrated recording station will be deployed, reducing system set up time while increasing system reliability.

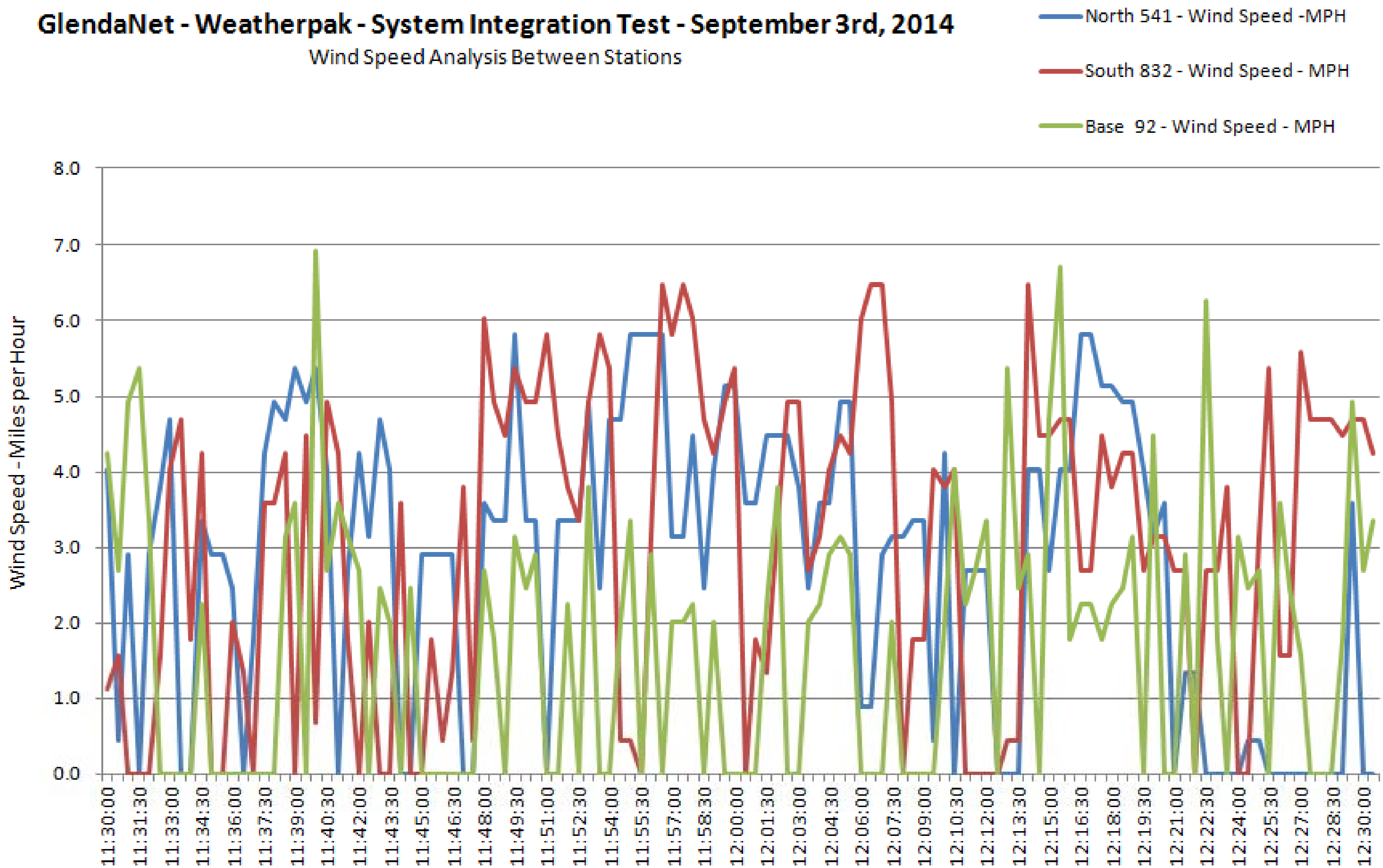
WeatherPak Receivers

Laptop Data Recorders

Multiple Weather Stations – Multiple Receivers – Multiple Data Recorders – All in a Mobile Environment

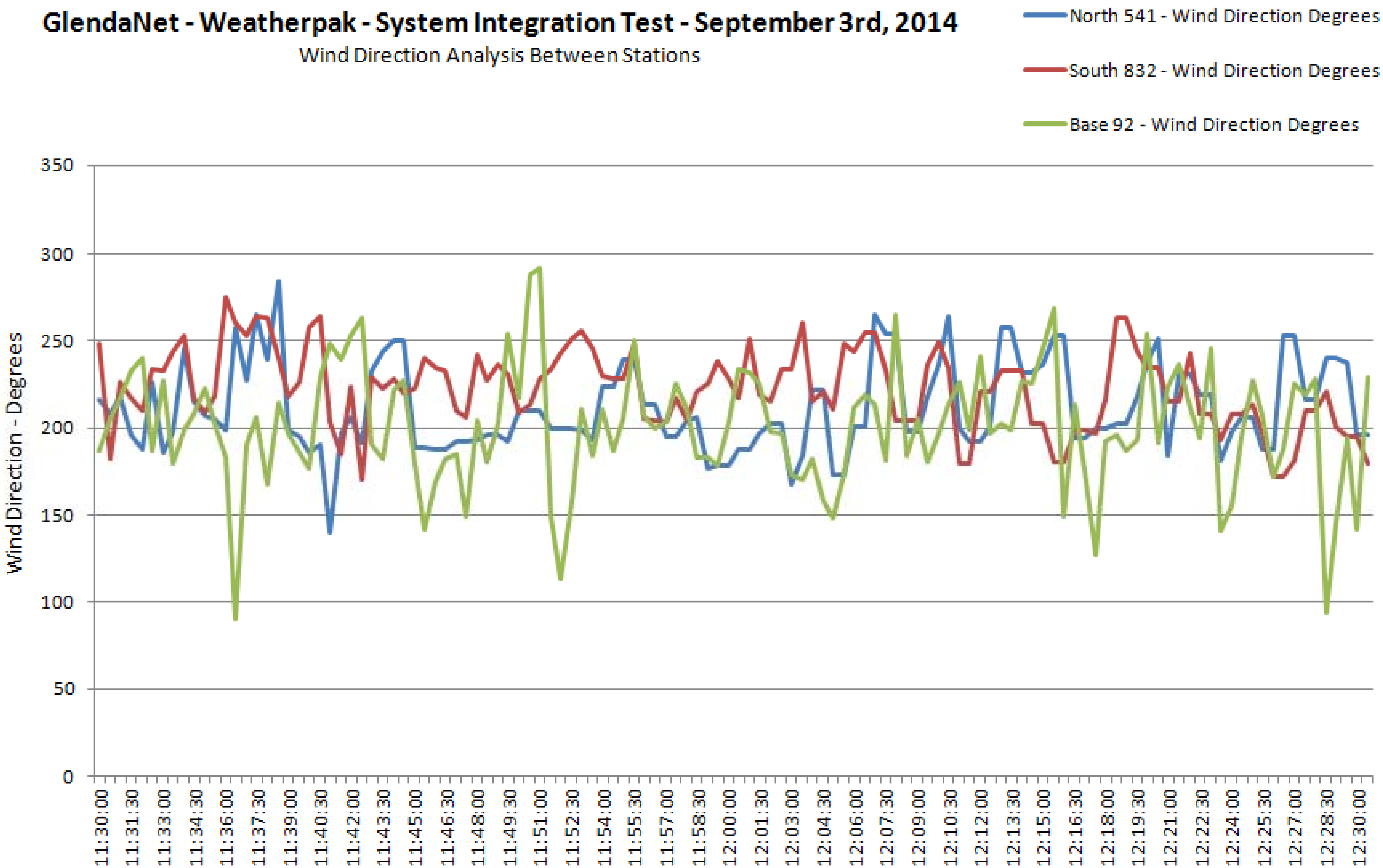
Glenda Project – Remote Sensing – Application

Electro Magnetic Field Mapping and Identification of Tornadic Signatures



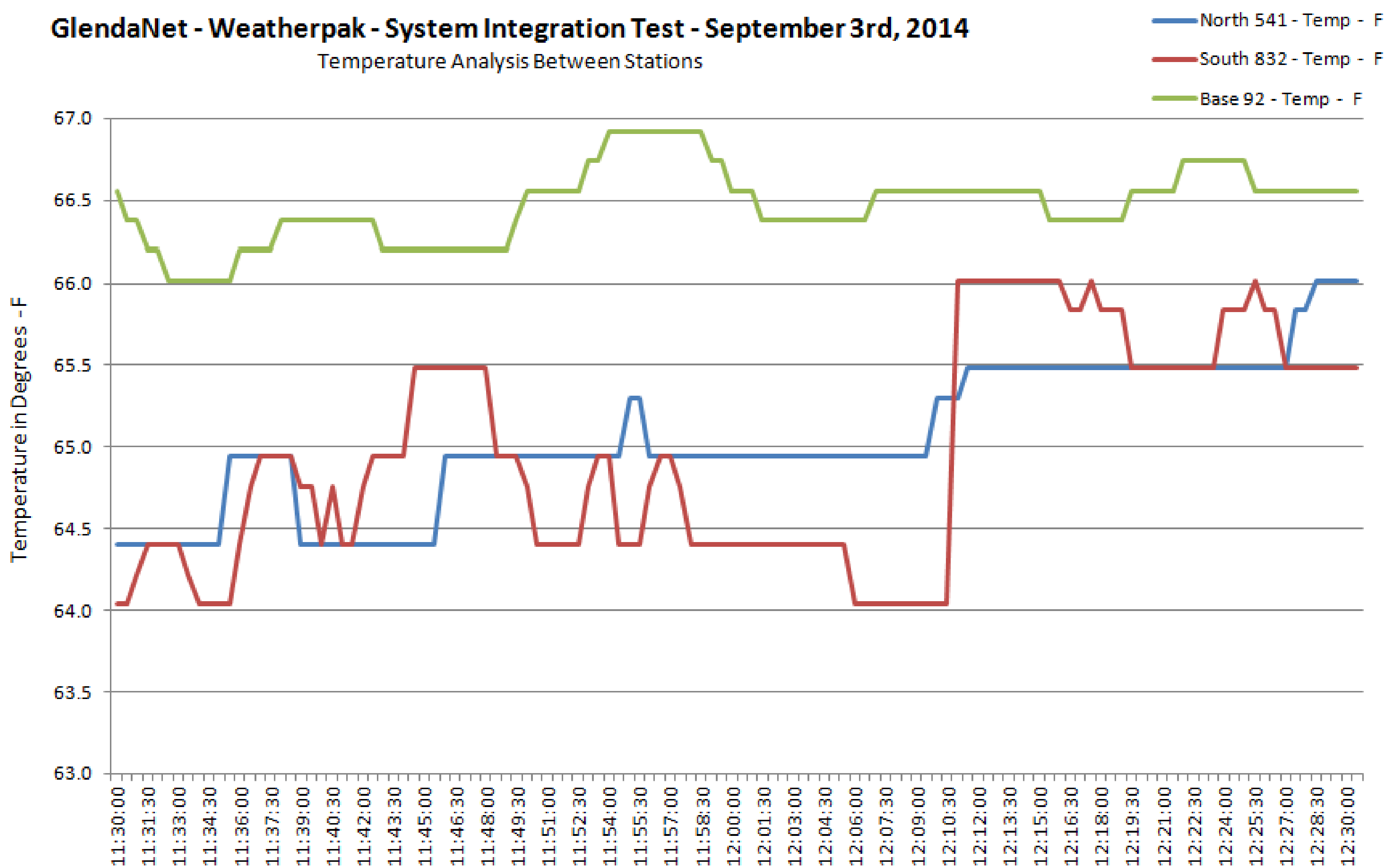
Glenda Project – Remote Sensing – Application

Electro Magnetic Field Mapping and Identification of Tornadic Signatures



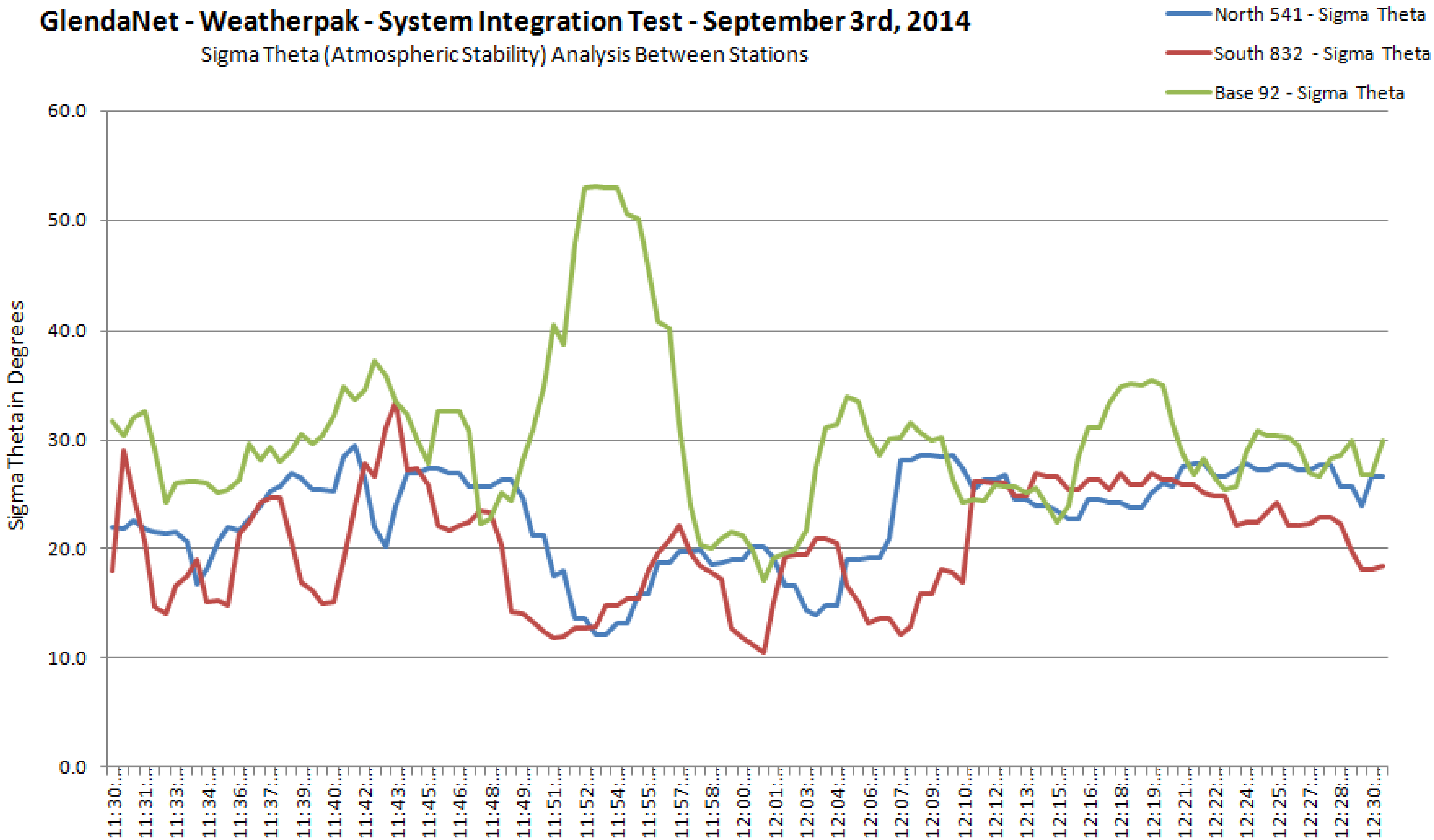
Glenda Project – Remote Sensing – Application

Electro Magnetic Field Mapping and Identification of Tornadic Signatures



Glenda Project – Remote Sensing – Application

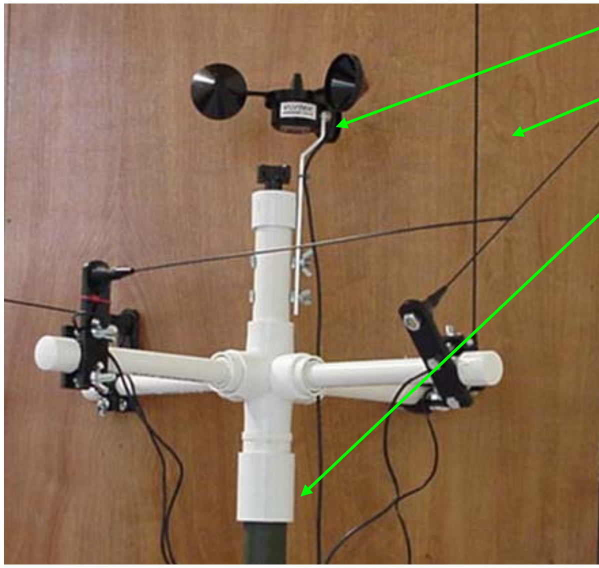
Electro Magnetic Field Mapping and Identification of Tornadic Signatures



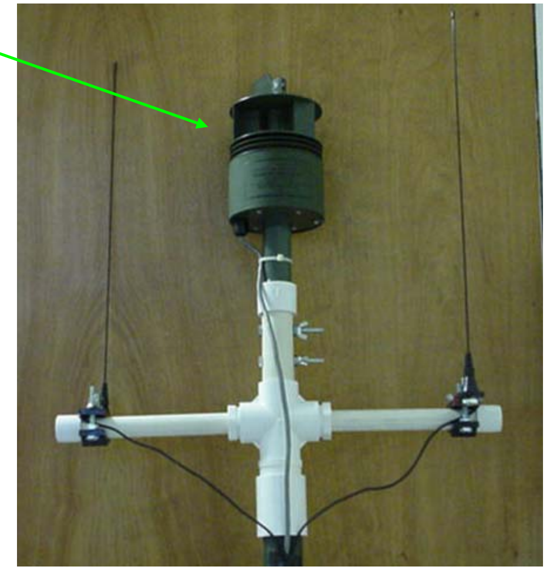
Note – The shift in Wind Direction at 11:52 impacts the Sigma Theta (Stability) Values

Glenda Mobile Ground Station Mast System

Removable / Adaptable Mast Sensor Head



- In-Speed Anemometer / TMQ-34 Sensor
- Two / Four Wide Band Receiver Antennas for Radiosonde telemetry signals.
- Mast System Interface Adapter
- Light weight PVC / Fiberglass construction to reduce potential for lightning strike
- Antennas with 1.2 GHz capability allows multiple frequencies and multiple radiosonde reception
- Mast head integrates with man portable mast system



Glenda Project – Intercept Teams

In order to obtain data from dynamic weather phenomena it is necessary to seek out and intercept storms and to launch sensors into the heart of the disturbance, capture the data, and return the data for immediate processing and analysis. Hence the name, Intercept Team.

The Intercept Teams utilize Jeep Grand Cherokee 4 wheel drive units, and other heavy duty trucks, equipped with specialized tires and suspension to handle road debris situations and evasive maneuvers while on the go. When storm data is required, the teams immediately equip the vehicles with instrument packages and laptop computers inside the vehicle and attach to the roof, weather instrumentation, satellite dishes, sensors and communication gear. Portable rocket launching stands and weather rockets are loaded into the back of the jeep. Transforming from a ordinary vehicle to a fully operational weather pursuit vehicle takes as little as five minutes.

Glenda Project – Intercept Teams

Mobile Mesonet Ground Station Vehicles

Intercept Team vehicles can feed information directly over the web to Acurite and Weather Underground fully automatically. Vehicles are equipped with full weather station sensors and forecasting ability, weather warning radios, a short wave wefax system, wifi connectivity both local and cellular, and 20 meter and 2 meter transmission systems which allows communications between team vehicles and Emergency Management and First responders . Vehicles have the capability of independent operation with either an onboard generator and / or back-up 12 VDC battery systems.

Glenda Project – Intercept Teams

Columbia County – Dayton, WA

The Glenda Project principle Intercept Team is based in Columbia County Washington and is equipped with an extensive sensor suite from lightning detectors, GPS positioning data loggers, anemometers, to real time internet Doppler radar.

Using the Doppler radar coupled with its on-board GPS navigation system, the team can pinpoint their exact location in relation to storm systems, providing them the best possible opportunity to position themselves in relation to storm system movements. Unlike other storm "chase" teams, this capability allows the Dayton Intercept Team to concentrate less on chasing storms, and more on positioning themselves to intercept storms.

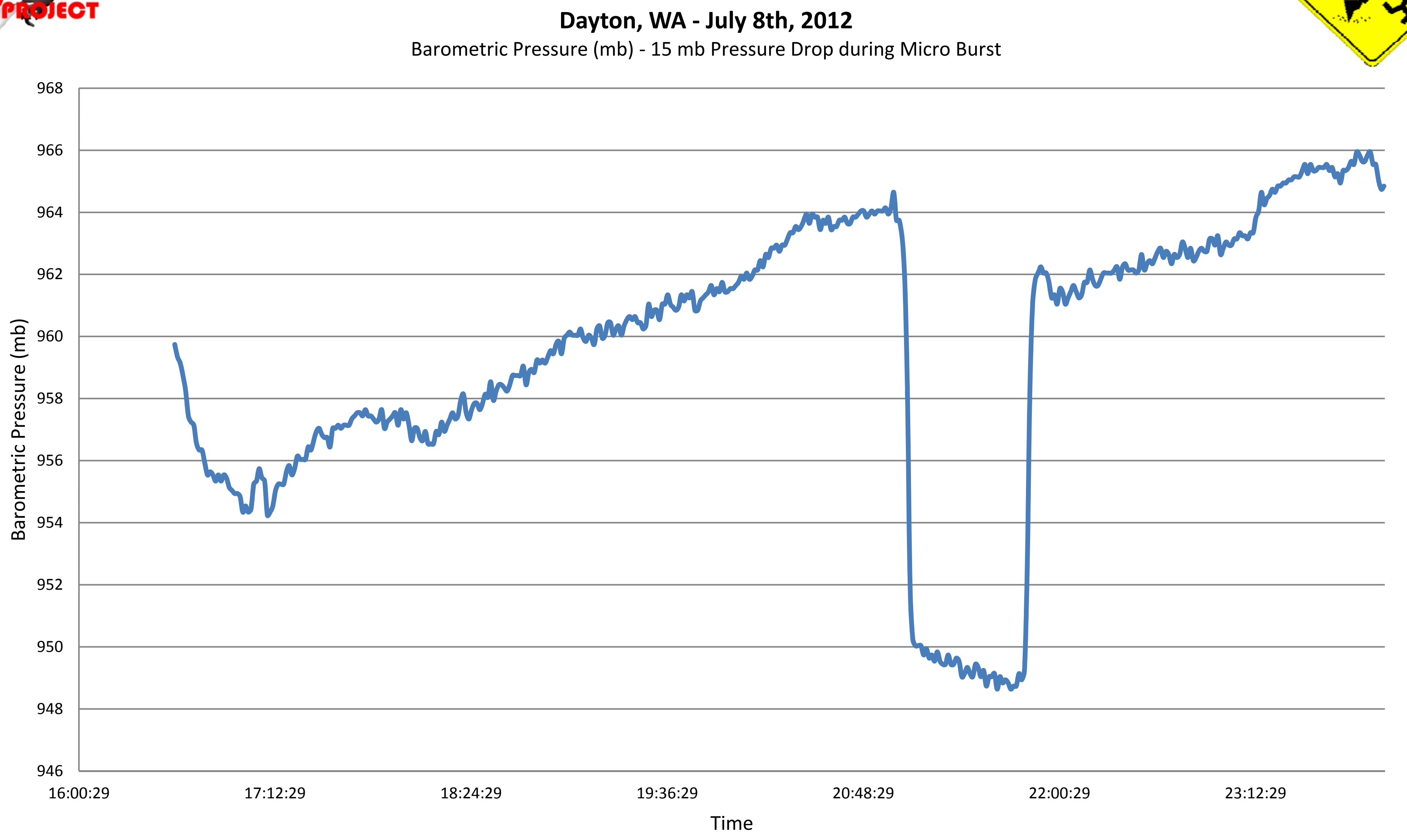
This intercept capability now allows the team to best support local first responders in order for them to pre-deploy assets into the field mitigating severe weather impacts when they occur.

On July 8th, 2012 a severe weather incident created a micro-burst over the north residential area of the town of Dayton, Washington which was detected and recorded on the team's on-board data loggers. Responding to the affected area, the team was able to assist with, and coordinate emergency services response. They coordinated storm debris removal to assist with the response of fire, ambulance and law enforcement units, the evacuation of an elderly person trapped in their residence by storm debris, and assisted with crowd control until power was restored by the power company hours later. All information and storm observations were relayed by the intercept team in real time to the Pendleton National Weather Service and to the local Emergency Management office which resulted in local and regional severe weather alerts being issued.

Glenda Project – Intercept Teams - Applications

As a result of the team's response to the July 8th, 2012 storm emergency, subsequent meetings were held with local emergency services. The Dayton intercept team has been requested to assist regional emergency services in future storm events. The team has now been equipped with a BK digital radio system that operates over narrow band microwave in the 155 mhz range. This system allows them direct radio communications to regional law, fire, ambulance and emergency management field units as well as the regional 9-1-1 public safety communications center. The team's integrated real time Doppler and GPS capabilities have allowed them the opportunity to coordinate with local and regional fire departments during lightning storms to aid in the staging of fire assets to suppress lightning strike fires.

Glenda Project – Intercept Teams - Applications



The Columbia County / Dayton, WA Intercept Team achieved a successful intercept of a microburst thunderstorm and recorded a 16 mb pressure drop during the event.

Glenda Project – Intercept Teams - Application

Columbia County – Dayton, WA

In 2012, the Columbia County / Dayton, WA Intercept Team became the "eyes" for Emergency Management and First Responders in severe weather situations.

SKYWARN

Approaching Storms for Intercepts

Glenda Project – Intercept Teams – Payload Tracking

GPS – Payload Tracking System Operational

When payloads are launched into severe weather systems, one of the primary challenges, is their return.

Glenda now has the capability to track payload positions using GPS in real time combined with real time display of the "intercept" vehicles position using "non-internet / non-cellular" driven GPS positioning.

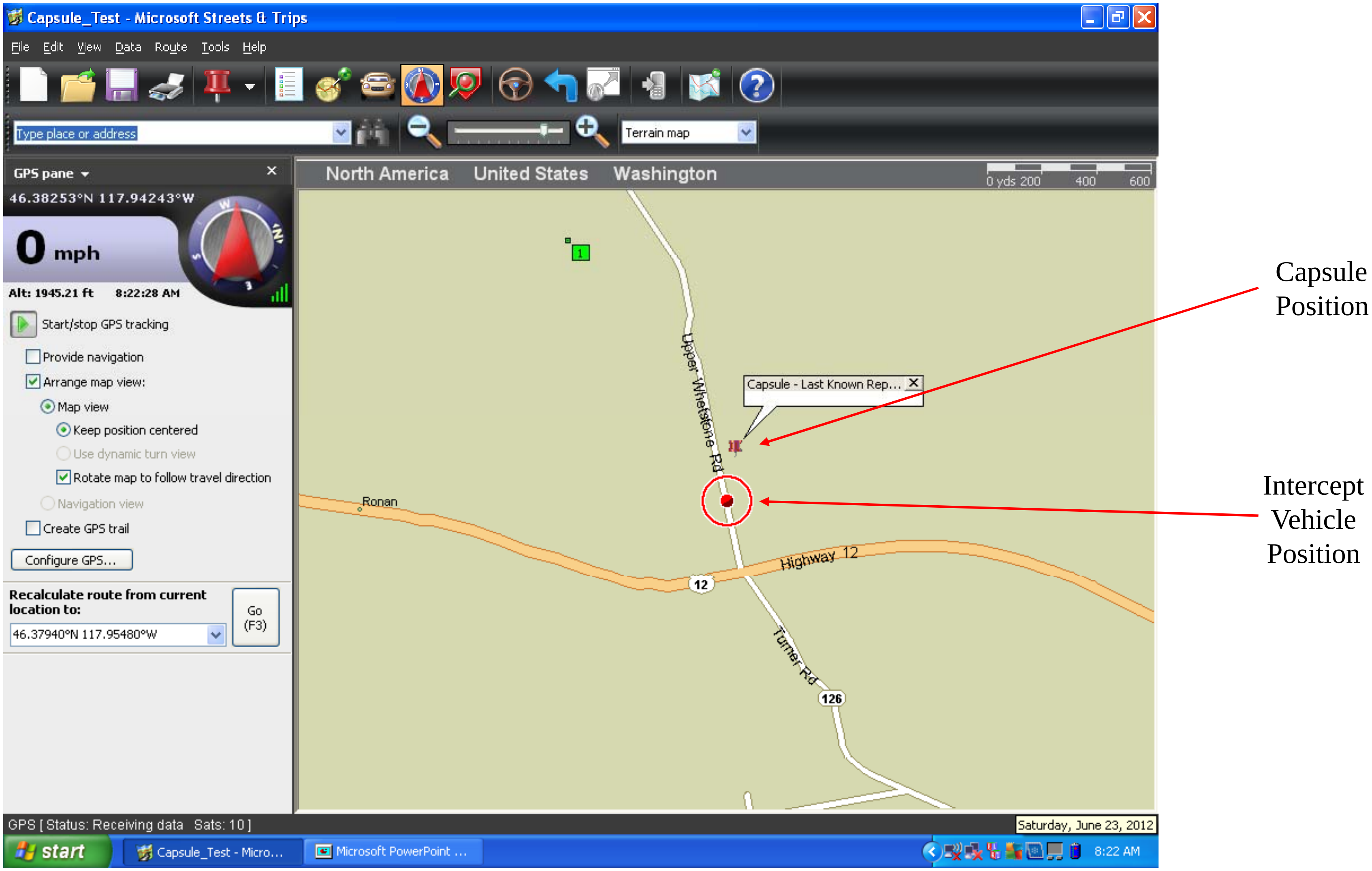
The payload transmits its GPS position to the intercept vehicle, while that vehicle integrates its own position in relation to the moving capsule in real time.

This capability allows real time deployment capture and rapid return to flight for multiple intercepts with the same storm system.

Glenda Project – Intercept Teams - Applications

GPS – Payload Tracking System Operational

Dayton, WA – June 23rd, 2012

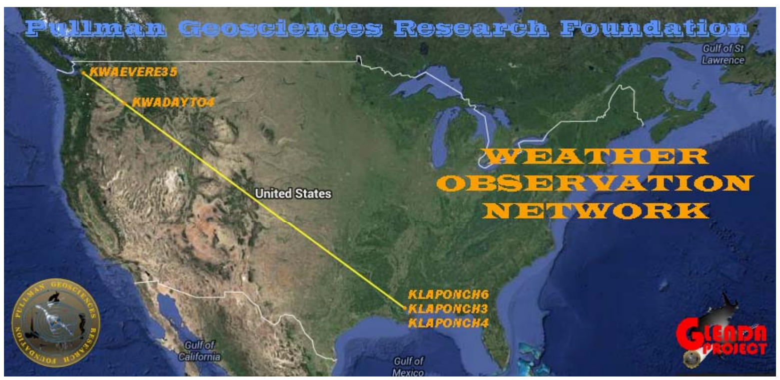


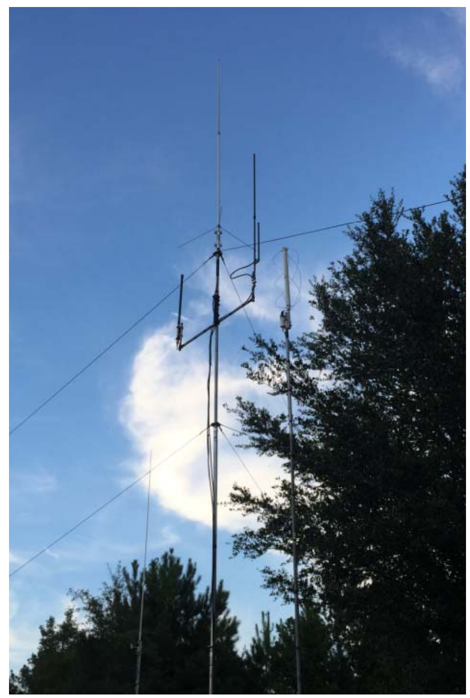
GPS positioning data from both the payload capsule and the intercept vehicle can now be displayed on a common screen in real time allowing for rapid intercepts and near real time return to flight.

Glenda Project – Remote Sensing
Bayou Canada Research Facility

The Bayou Canada Weather Research Facility is located in Ponchatoula, Louisiana, roughly 60 miles north of the Gulf of Mexico.

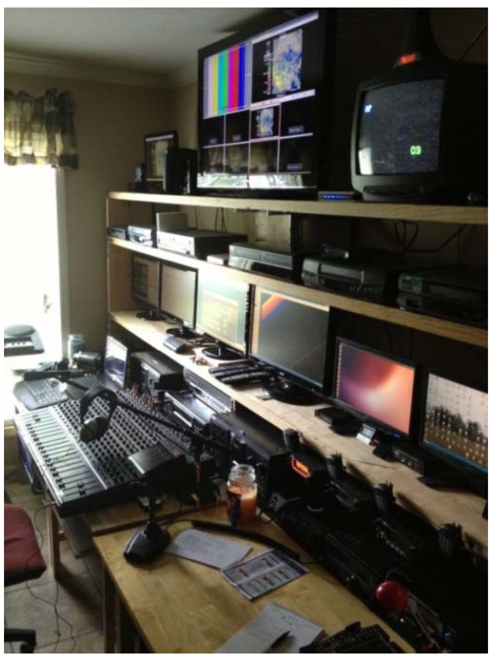
Bayou Canada feeds out weather data in regular intervals as quickly as every two seconds depending on the need for data and weather conditions. We post real time data including radiation and EMF on our website, as well using both web and over the air radio transmissions. We feed directly to: NOAA and the National Weather Service, APRS via ham radio station KE5JJC both over the web and over 2 meter ham frequencies, Citizens Weather Observation Program, Hamweather, PRSWeather, WeatherBUG, and Weather Underground / The Weather Channel.

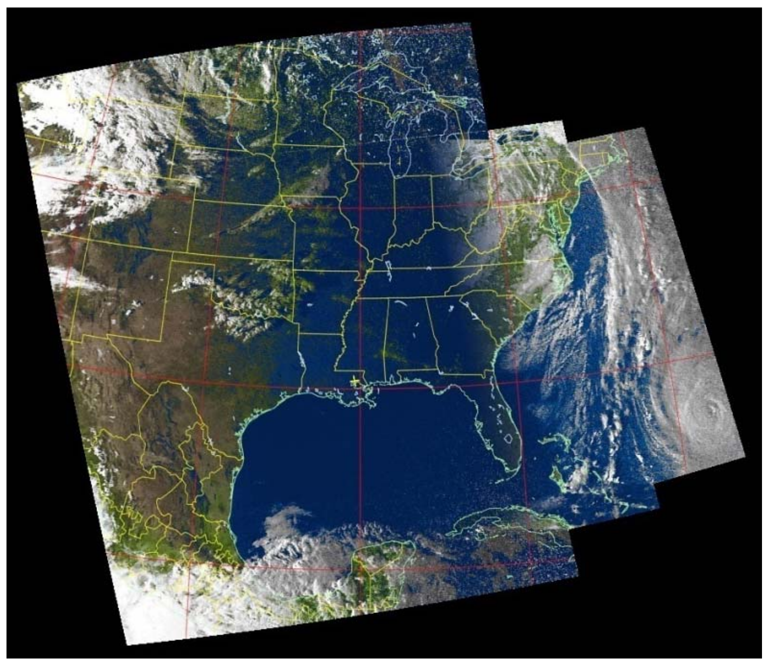


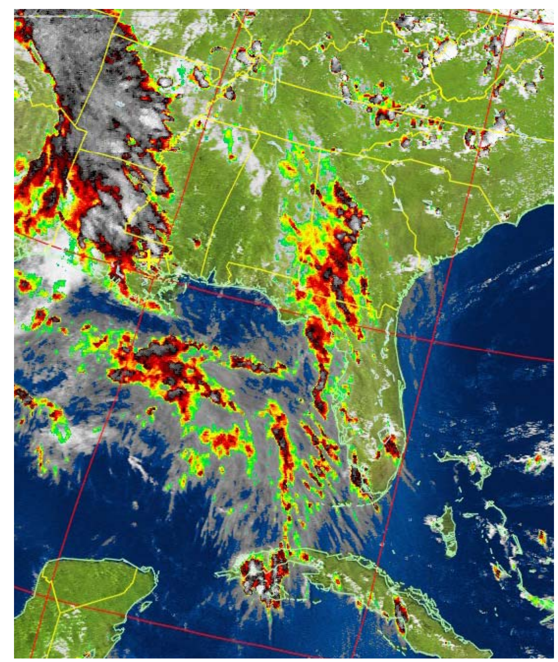


Glenda Project – Remote Sensing
Bayou Canada Research Facility

Weather information is fed automatically into various computer processing centers as well as the National Weather Services. Because our information is sent at much shorter intervals than most typical airport weather stations, the analysis of our data is quicker and affects the decisions and warning announcements issued by the National Weather Service. Because we can provide both mobile and base visuals, additional information can be sent to the National Weather Service via cell phone or ham radio transmissions. The NWS monitors particular ham radio frequencies for reports in major weather situations. The National Weather Service will issue watches and warnings both over the air (weather stations and public networks) and over the web based on the information that we and additional stations send them. The NWS is of course the official source for Emergency Management Centers.



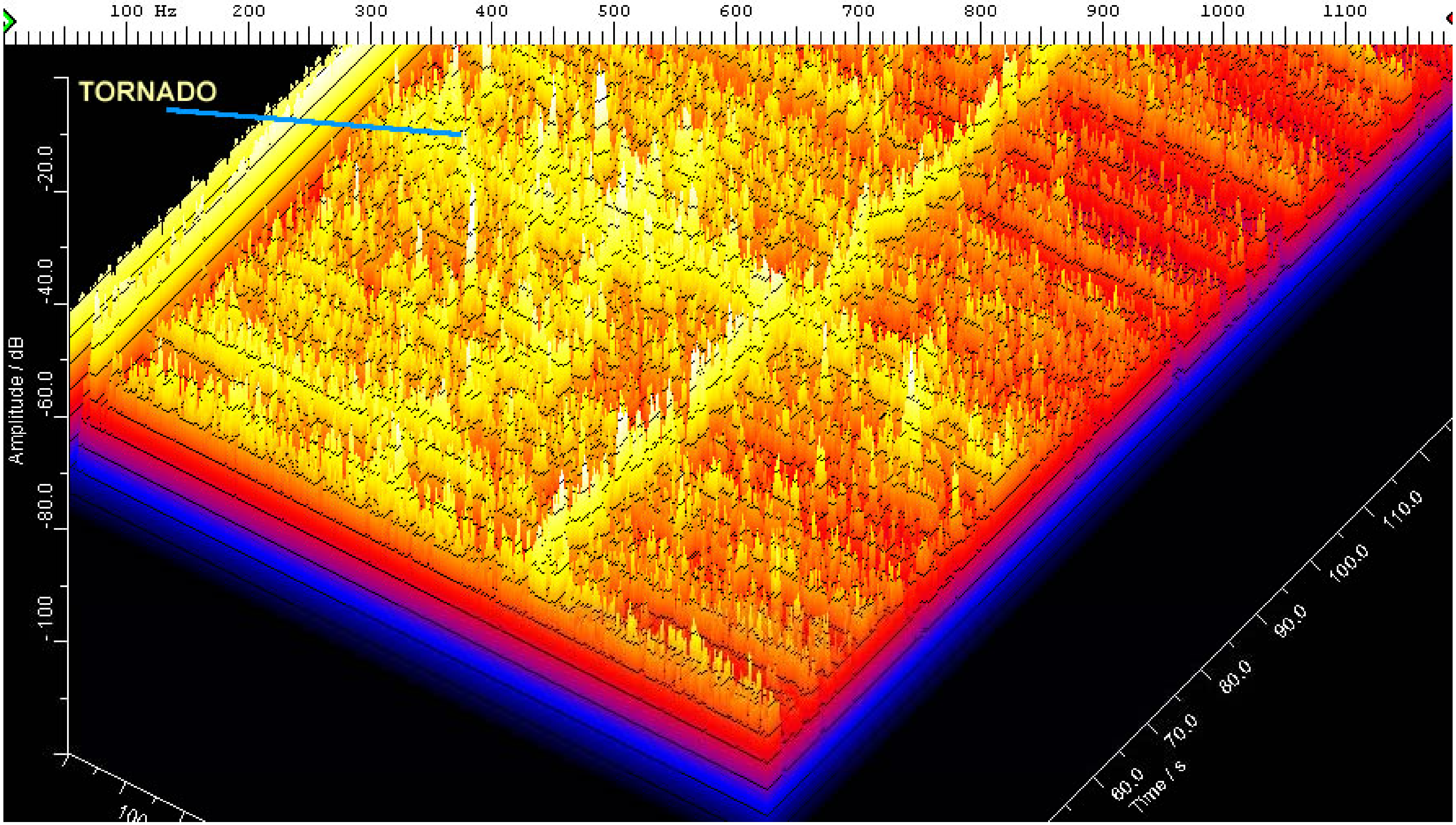




Glenda Project – Remote Sensing – Application

EM Field Mapping

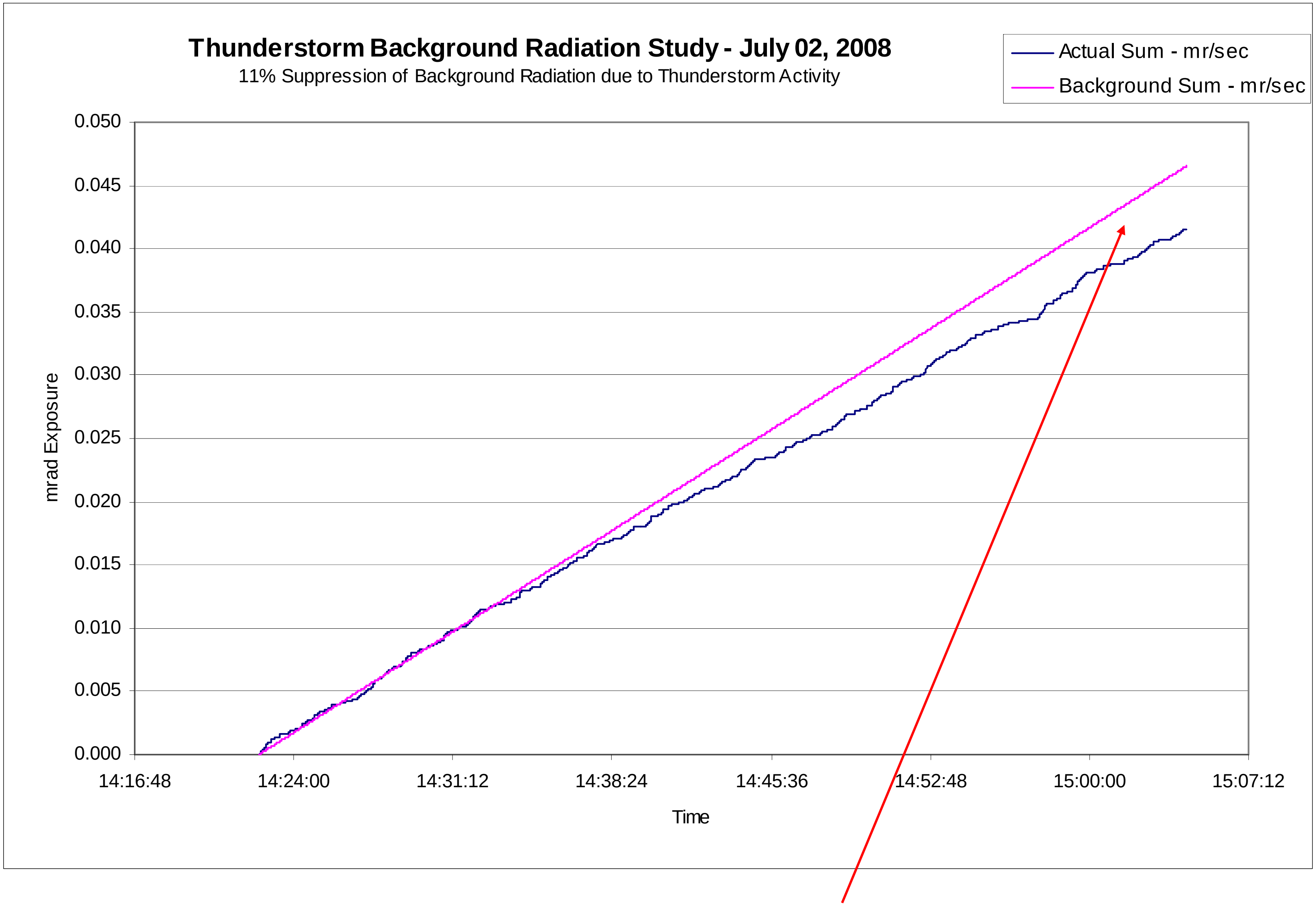
Combining Glenda computing and sensors allows the capability for advanced analysis and detection. Shown below is a 3D Electromagnetic Field (EMF) analysis of a tornado based off of a three second data capture. The circular effects of the funnel are easily visible and provide a snap shot of the electrical activity around a tornado.



Glenda Project – Remote Sensing – Application

Gamma Radiation Studies

Data collection capability of Gamma Ray Radiation during Thunderstorms



During this extensive Thunderstorm, lightning suppressed the “background” gamma radiation count by 11 percent

Glenda Project – Educational Outreach

Over many years, the Glenda Project has developed strong local community ties with educational and governmental groups ranging from the National Weather Service, museums, to local schools.

The Glenda Project provides mentorship support to the National Associate of Rocketry "Team America Rocketry Challenge " (TARC), and the NASA Student Launch Initiative (SLI) involving high school, and college student designed and launched payloads.

Glenda is also involved with the Science, Technology, Engineering, and Mathematics (STEM) programs at several local schools providing a ready built application.

Glenda Project – Educational Outreach

April 2014 – Museum of Flight, Seattle, WA – “Climate Day”

August 2014 – Museum of Flight, Seattle, WA – STEM “Science Fest”

June 2013 – NWS Pendleton, Oregon Open House

February 2014 – Edmonds, WA –
Westgate Elementary School “Science Night”

In Conclusion

The Glenda Project is a highly mobile data collection system designed to place instrument packages into areas previously considered to be to hazardous or inaccessible using traditional platforms such as aircraft, helicopters, kites, etc.

The operational Glenda Project shows the differences between Hollywood “fiction”, “Reality Television” publicity stunts, and engineering “fact”, from mapping local environments to a tornadic funnel with a full mission suite of sensors and cameras.

We have achieved multiple storm intercepts, deployed a wireless long range ground station network with Sigma Theta capability and built on sustaining relationships with emergency managers and first responders.

An operational balloon deployment capability for applications where booster launches are not feasible is now in place and we continue to expand the flight envelop of our sensors and ground stations.

The Glenda Project is up to the task.