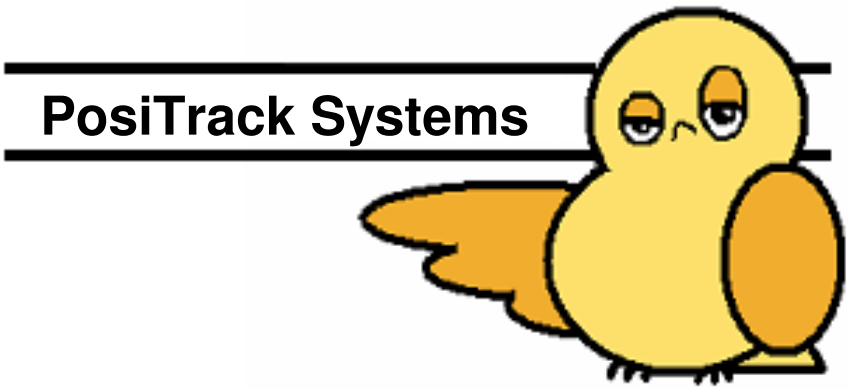


Athlete Performance Tracking

PosiTrack Team:

Andreea Hrehorciuc
Mikey Valdes
Jeff Anderson
Ryan Lynne

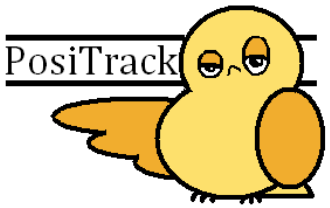
April 14th, 2010

Agenda

- **Overview**
- **PosiTrack Team**
- **System Overview**
  - » Motivation
  - » Design Solution
  - » Design Alternatives
  - » Hardware Design
  - » Software Design
- **Finances**
- **Revised Schedule**
- **Future Work**
- **What We Learned**
- **Conclusion**
- **Acknowledgments / Questions**
- **Tests Results & Algorithms**
- **Live Demo**

PosiTrack Mascot !!

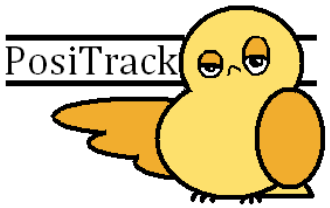
Owls are well know for their tracking ability!



PosiTrack Team

- **Andreea Hrehorciuc:**
  - » 5th year Computer Engineering student
  - » Was responsible for the GUI Development and Documentation
  - » Experienced with Software Design and Digital Processor Design
  - » Worked for 2 years at Glentel as a Systems Administrator

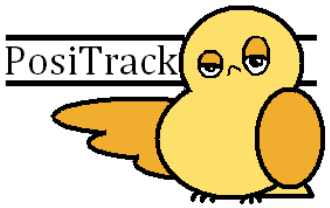
- **Mikey Valdes:**
  - » 4th year Electronics Engineering student
  - » Was responsible for Documentation and the Message Passing between GUI and Gumstix
  - » Experienced with Embedded Programming, and Analog/Digital Design
  - » Worked 8 months at Safeway Inc. as a Software Developer



PosiTrack Team

- **Jeff Anderson:**
  - » 5th year Physics Engineering Student
  - » Was responsible for overall Software Design, Localization Algorithms, and Documentation
  - » Experienced with Software Design and Hardware Design
  - » Worked 8 months at Broadcom as a Software Design Engineer

- **Ryan Lynne:**
  - » 5th year Electronics Engineering Student
  - » Was responsible for Hardware Design, Hardware Driver Development, and Documentation
  - » Experienced with Microelectronics, Analog/Digital Design, and Embedded Systems
  - » Worked 8 months at PMC Sierra as an ASIC Design Engineer



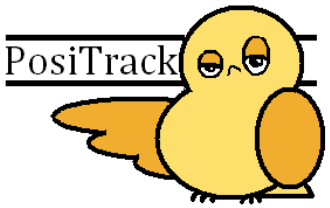
System Overview

The PosiTracker is a small wearable module that can track an athletes location, speed, acceleration and energy output in real time.

This module is worn on the upper back and communicates back to a main computer over a wireless connection.

- **The PosiTracker can be used by sports teams as a Training Tool**
  - » Smart player interchanges (Shift/Line changes)
  - » Objective measure of player exertion and fatigue

- **The PosiTracker can also be used as a Broadcasting Tool**
  - » Bring fans closer to the game through live in-game statistics
  - » Many sports already have live statistics (Nascar, Horse Racing)



Motivation

- **We believe that this is a great idea !!!**
- It is very likely that in the next 10 years many professional sports teams will have adopted a performance tracking device
- Applications in Hockey, Football, Soccer, Baseball, Basketball, Tennis, Speed Skating, Rugby, Lacrosse …
- Currently three companies make a very similar identical product:
  - » www.GPSports.com
  - » www.VXSport.com ($1500 per player + software costs)
  - » www.AliveTEC.com
- However, these companies use a GPS for localization which will not work in indoor arenas
- Our system utilizes wireless signal strength for localization and will work both indoors and outdoors

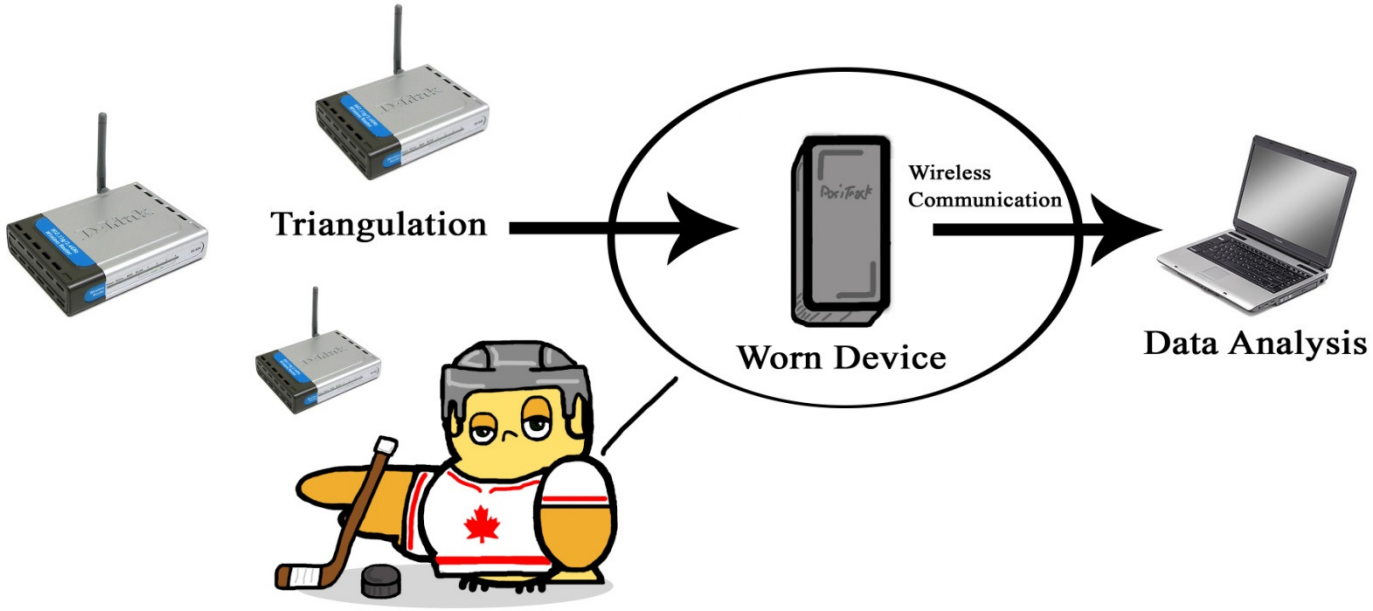
Motivation

Our main target is large sports teams such as the Vancouver Canucks for use as both a broadcasting and a training tool

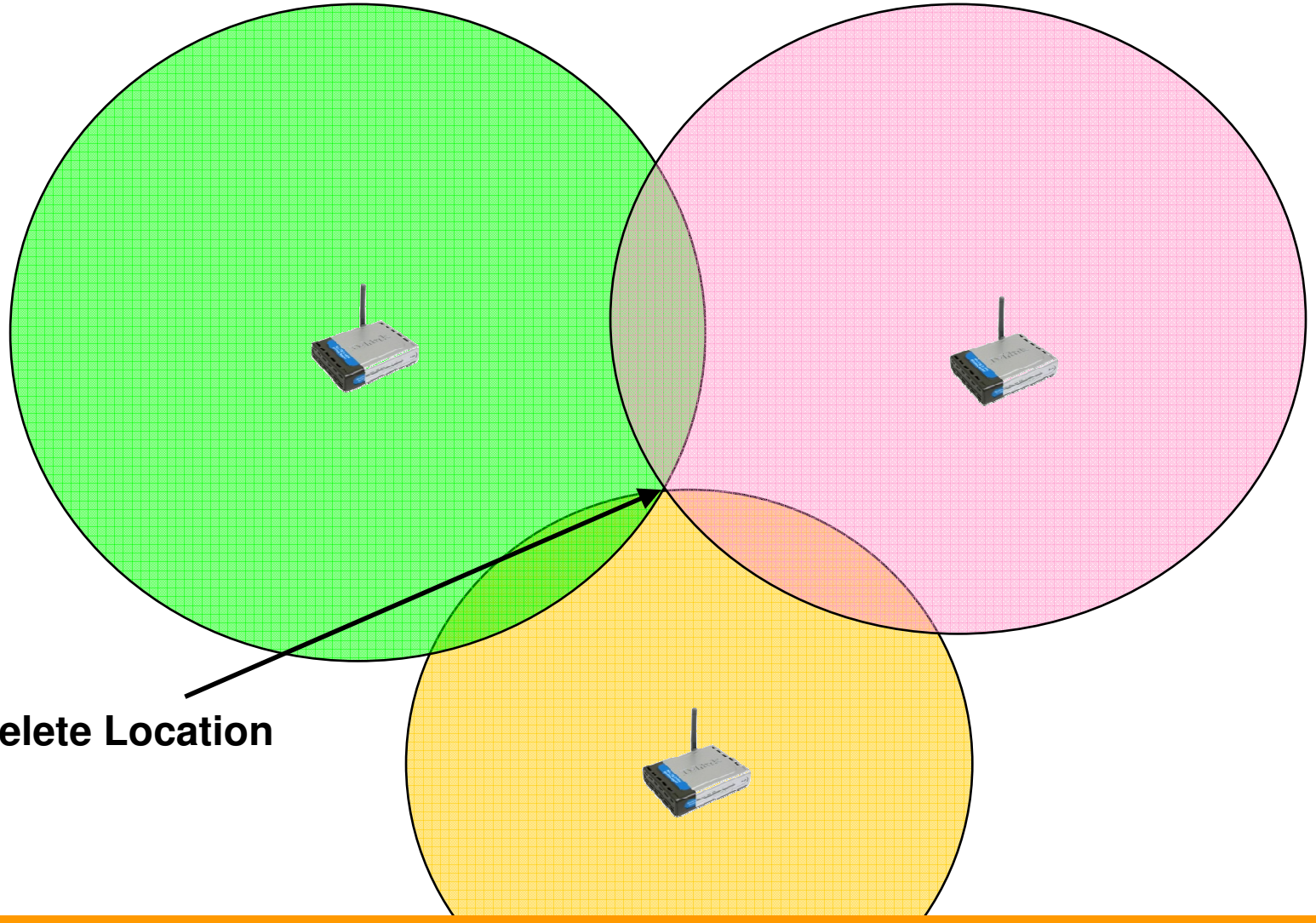
- **The average salary for a player on the Vancouver Canucks is $1.7 million dollars**
  - » This is a huge investment on each player
  - » PosiTracker can protect this investment through better training
  - » PosiTracker can provide an edge over other hockey teams (Winning = $$$)
- **CTV spent $90 million dollars for Olympic Broadcasting rights**
  - » This is a massive investment for just a 2 week period
  - » PosiTracker can provide live statistics giving the viewer incentive to choose CTV over another channel (Viewers = $$$)

Design Solution

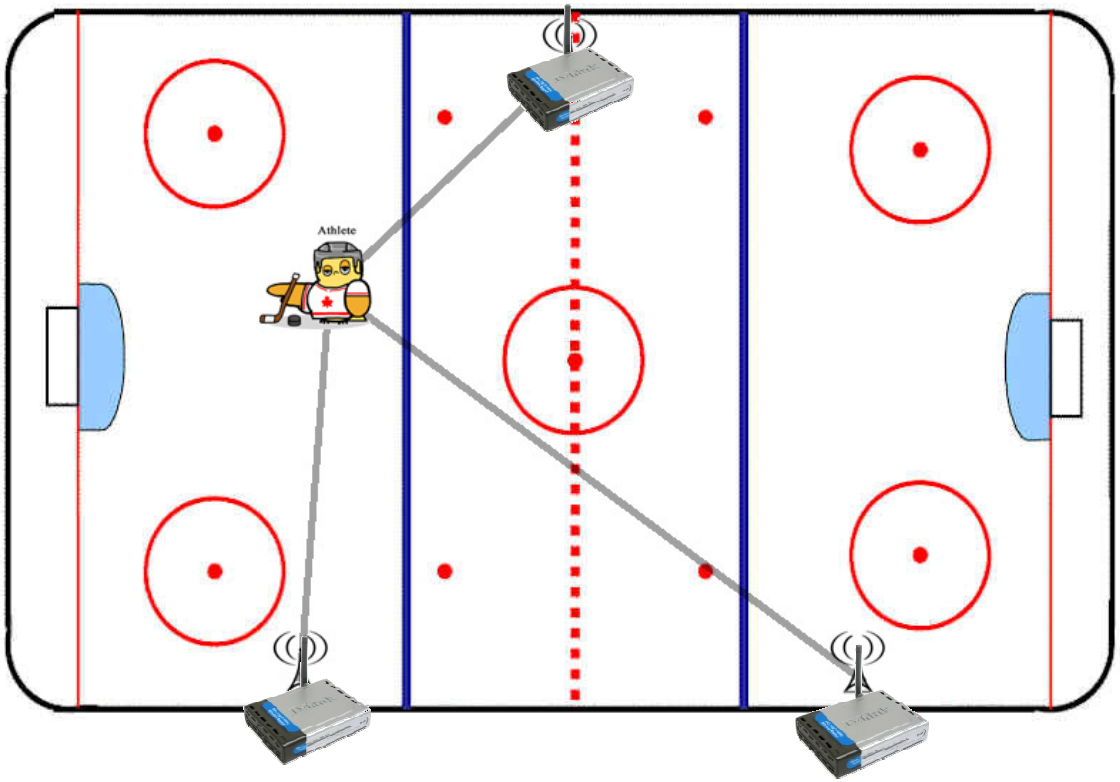
- **PosiTracker uses WiFi signal strength to determine the location, speed, and acceleration of the athlete**
  - » Uses magnitude of signal strength to determine location
  - » System works indoors (unlike GPS and PosiTrack competitors)
  - » Accuracy of localization is increased using a 3-axis accelerometer and gyroscope (dead reckoning)



Design Solution



Design Solution



Standard Wireless Access Points are placed around a hockey rink for signal strength localization and to also create a wireless link to each athletes module

Design Solution

The PosiTracker can potentially be attached to an Athletes under-armour.

Ideal location is on the upper back to prevent damage and to improve device performance

Design Solution

Image Source: www.gpsports.com

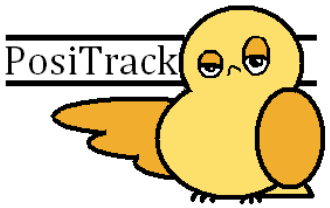
GPSports

Module Harness

Image Source: www.gpsports.com

Alternatively a simple strap worn over the shoulders can attach the PosiTracker to the Athlete.

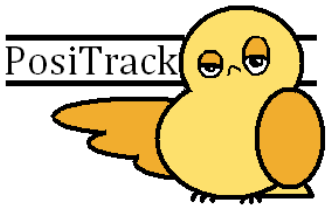
This is the solution that our competitors GPSports have adopted.



Design Alternatives

- **GPS Localization:**
  - » Uses the arrival time of electromagnetic waves from satellites
  - » Works almost everywhere outside
  - » **Doesn't work indoors**
  - » 1 - 3m accuracy
  - » Standard off the shelf hardware

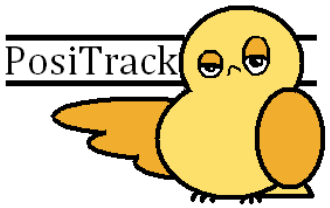
- **Acoustic / Ultrasonic Localization:**
  - » Uses the arrival time of high frequency sound (30-50kHz)
  - » Limited range due to high frequencies
  - » Works both indoors/outdoors
  - » High accuracy 0.1 - 1m
  - » Requires custom hardware for receivers and transmitters



Design Alternatives

- **Signal Strength Localization:**
  - » Uses WiFi signal strength from wireless access points
  - » Limited range due to logarithmic decay of signal strength
  - » Works both indoors/outdoors
  - » 1 - 3m accuracy
  - » Standard off the shelf hardware (WAP's and wireless cards)

- **Ultra Wide Band Localization:**
  - » Uses the arrival time of high frequency EM waves (>5GHz)
  - » Extremely short range due to high frequencies
  - » Works both indoors and outdoors
  - » Expensive custom hardware is required for receivers and transmitters
  - » High accuracy 10 - 15cm



Design Alternatives

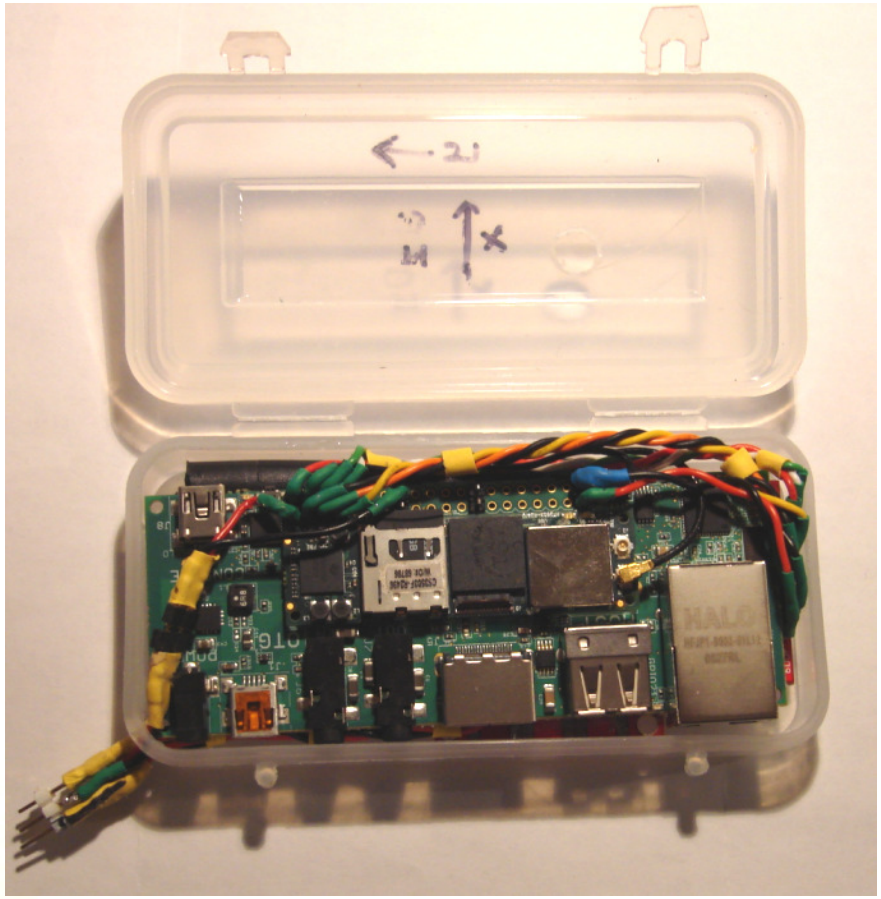
Ultimately we used Signal Strength Localization as it works indoors, has satisfactory accuracy, and doesn't require any custom hardware

Hardware Design

PosiTracker Prototype

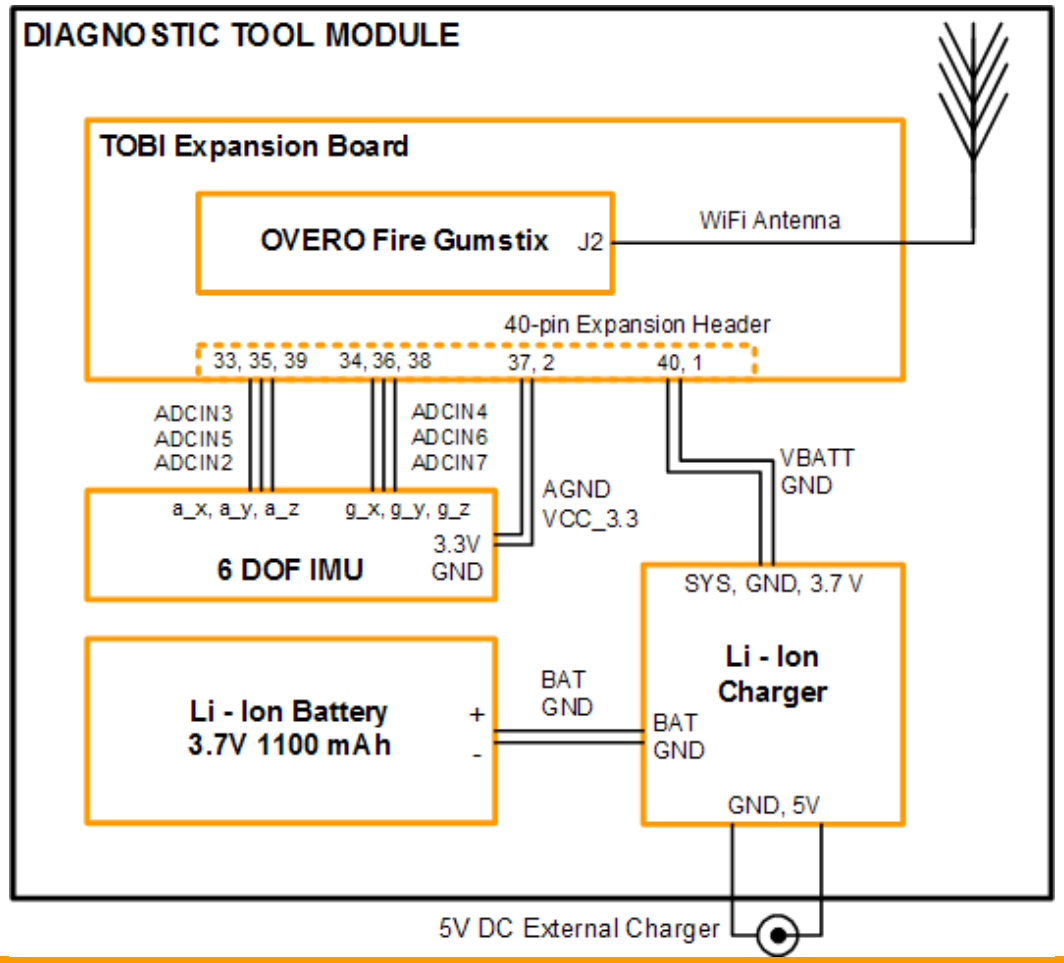
Dimensions: 110 x 51 x 21 mm

Weight: 105 grams



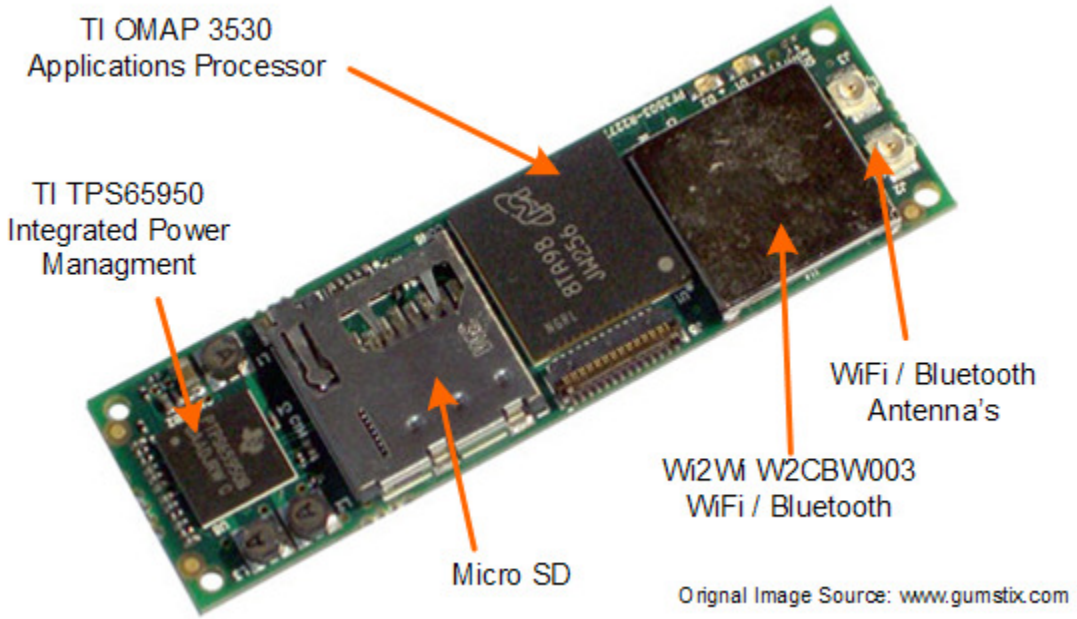
Hardware Design

Schematic for PosiTracker Prototype



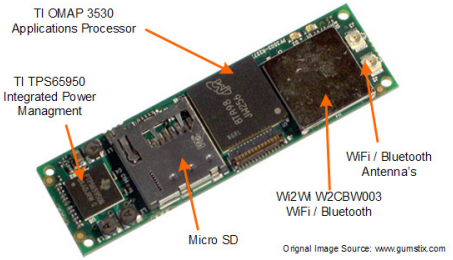
Hardware Design

- **Overo Fire COM Gumstix**



- 600 MHz
- 256 Mb Ram / Flash
- WiFi and BlueTooth
- Runs Linux
- 6 separate 10bit Analog to Digital lines
- Chosen as a powerful rapid development platform
- Heart of the PosiTracker Module

Hardware Design

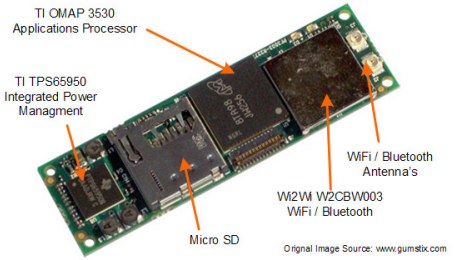


Why the Overo Fire Gumstix?

- **Versatile and Reusable:**
  - » Helped our case for ESSEF funding
  - » Allows for future additions such as a GPS or BlueTooth heart rate monitor

- **Was designed for Embedded Applications:**
  - » Low power, light weight, and has extremely small dimensions
  - » 1.6W, 5g, 58 x 17 x 4.2 mm
  - » Draws 390mA @4V (1.6W) with WiFi transmitting continuously

Hardware Design



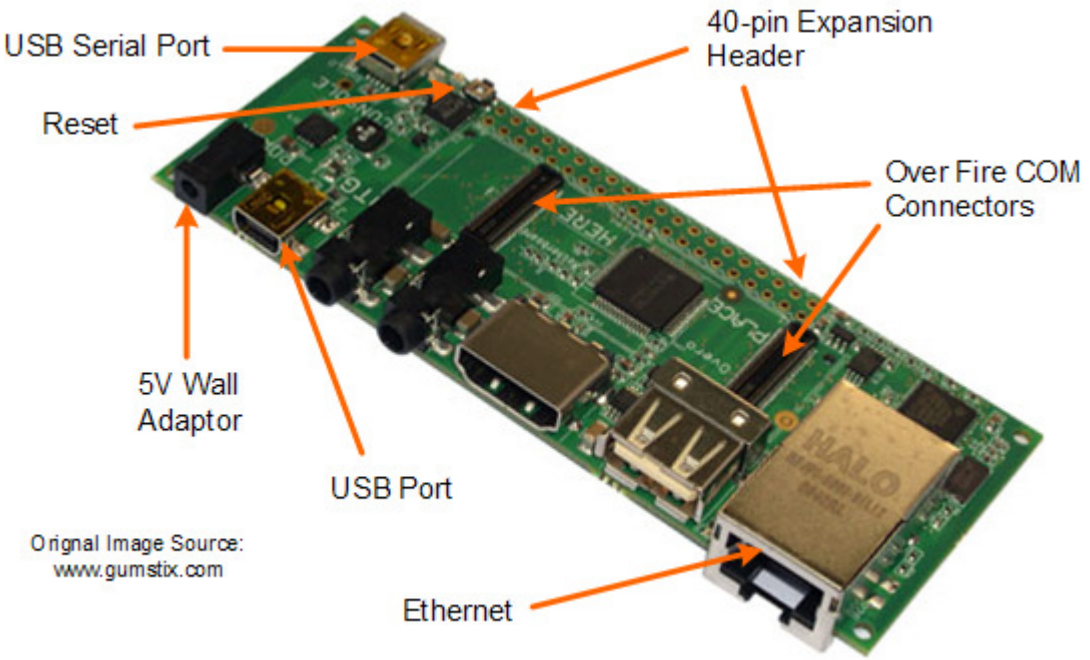
Why the Overo Fire Gumstix?

- **Powerful enough to run Linux:**
  - » Design is not limited by the power of the hardware
  - » Access to almost unlimited open source software and device drivers
  - » Allowed for rapid development of a prototype

- **Built in WiFi BlueTooth and A/D converters:**
  - » Built in WiFi allows us to measure signal strength and to create a wireless link to each player
  - » Built in BlueTooth allow a heart rate monitor to be easily attached
  - » Built in A/D converters allowed us to easily attach an accelerometer and gyroscope

Hardware Design

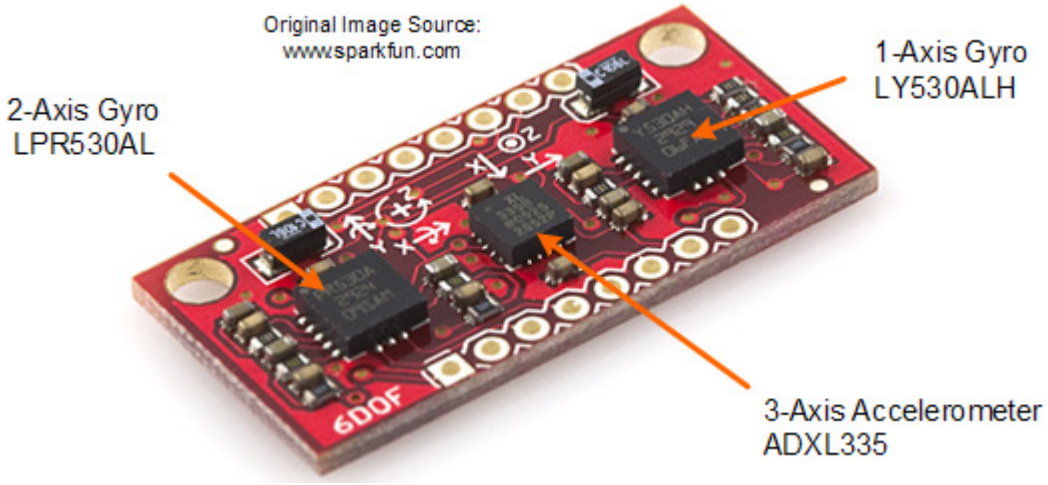
- **Tobi Expansion Board**



- Needed to attach the power and A/D lines to the Overo Fire COM
- Also provides debugging ability through USB and Ethernet

Hardware Design

- **Sparkfun 6-DOF IMU**

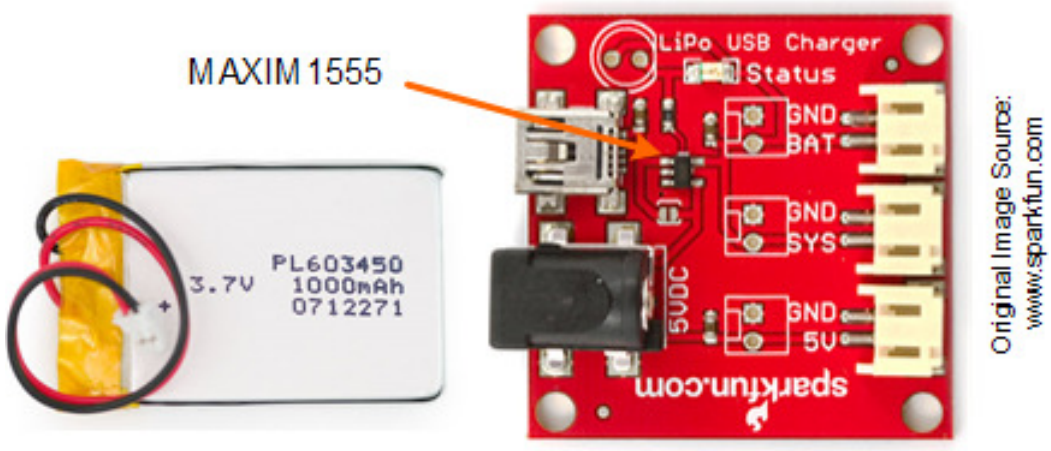


- 3-axis accelerometer
- 2-axis gyroscope
- 1-axis gyroscope
- 6 Degrees of Freedom (DOF)

- Needed to provide inertial data for dead reckoning
- Power provided by the Tobi Boards power management
- The 6 analog lines are connected to the header on the Tobi Board

Hardware Design

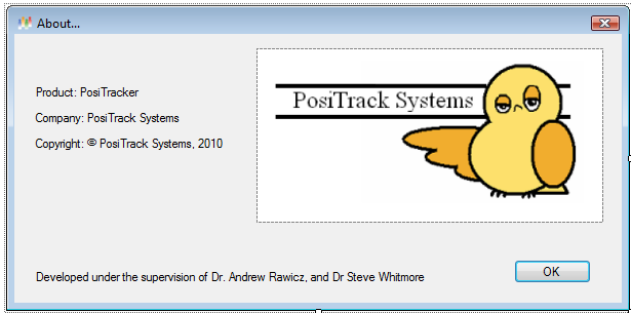
- **Sparkfun Li-Poly Charger**
- **1000 mAh Li-poly Battery**

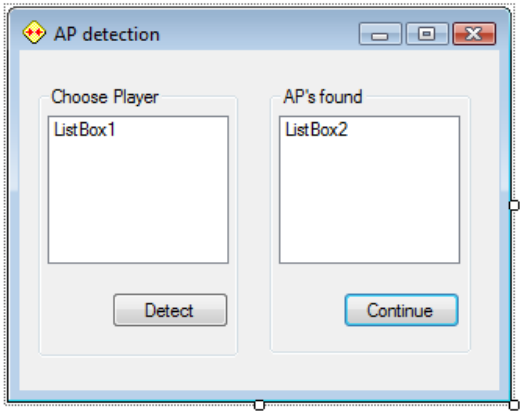


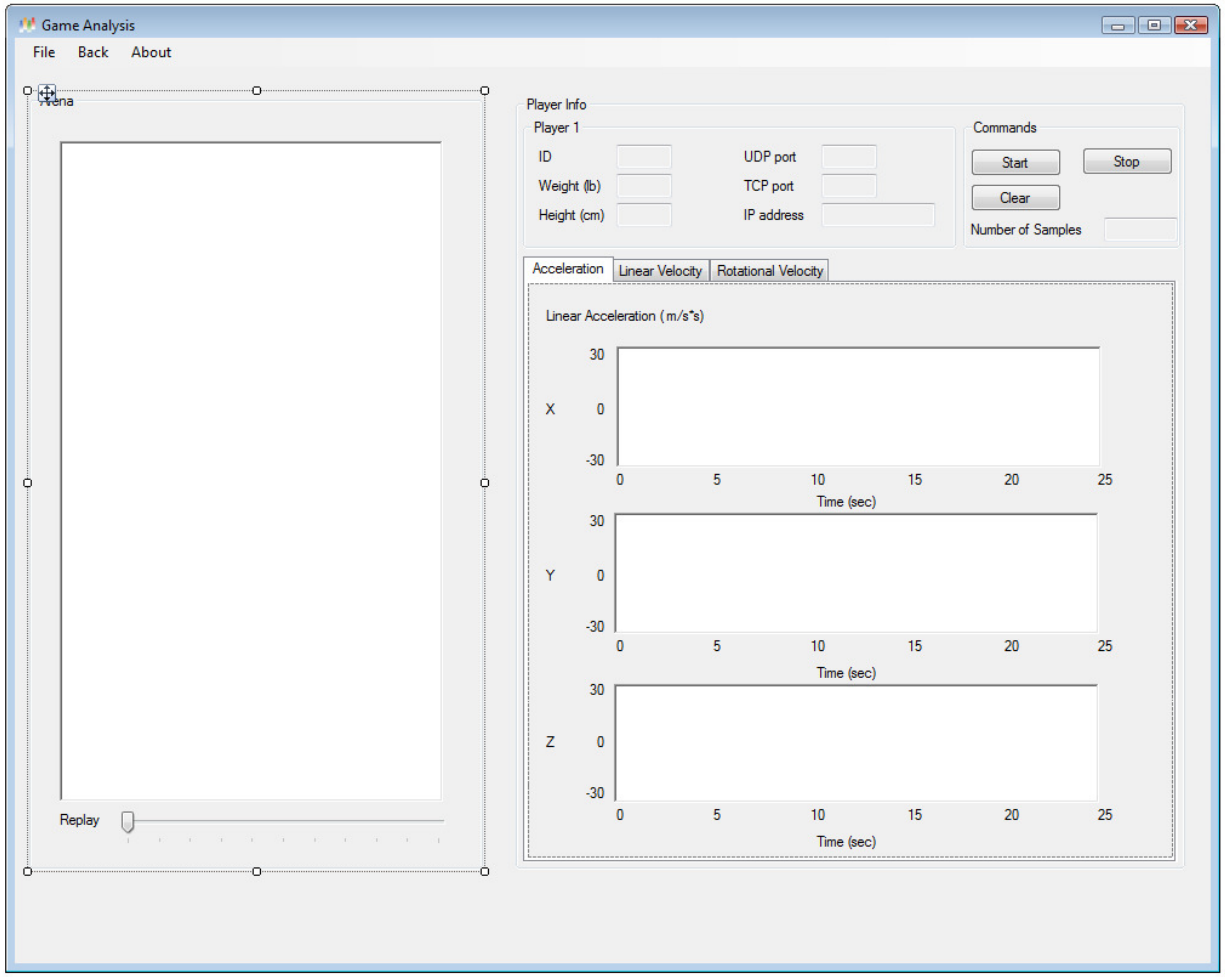
- Li-Poly batteries require special charging circuits
- Charge time is approximately 5 hours
- Run time is approximately 2.5 hours

Software Design

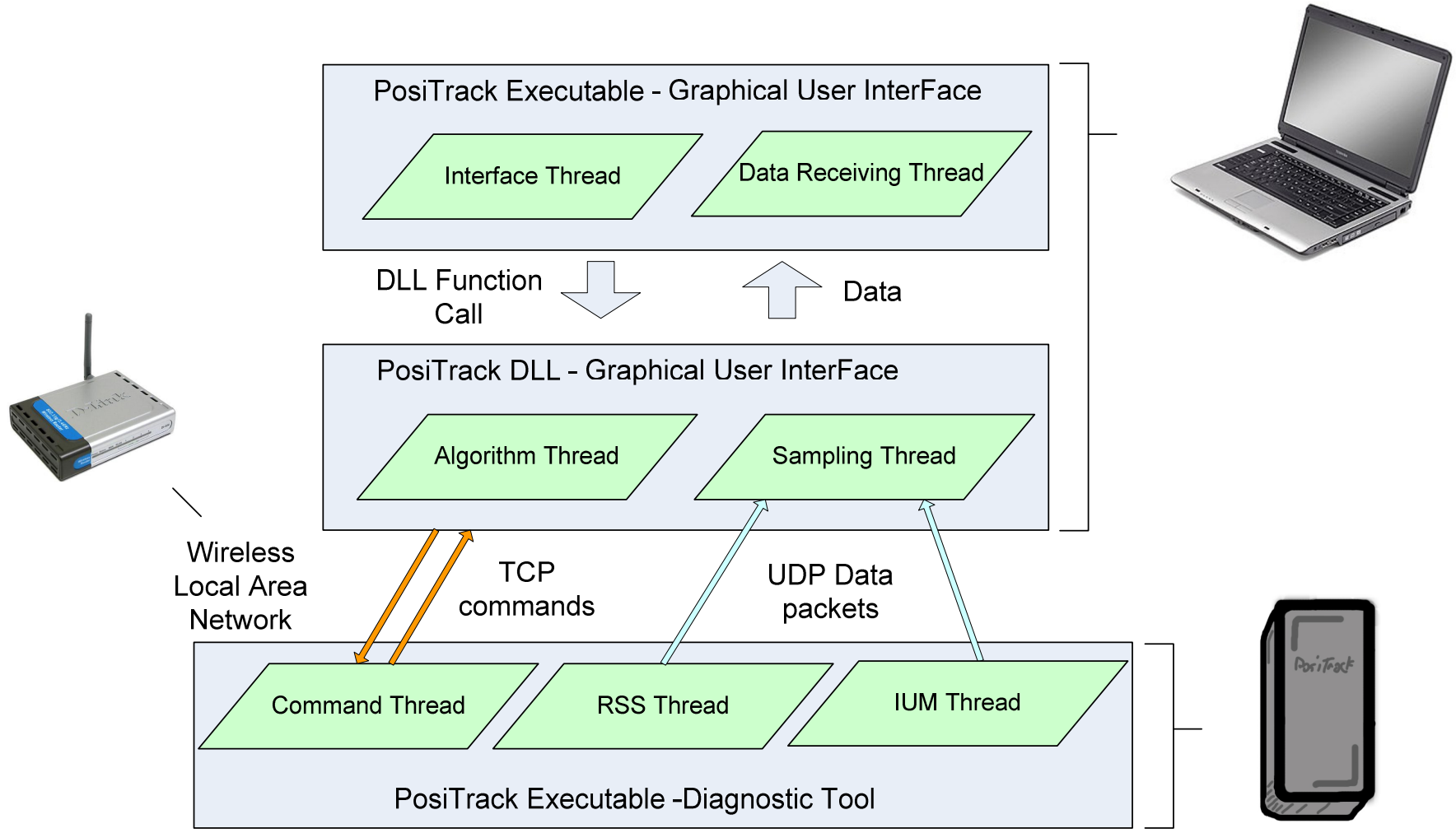
GUI DESIGN







Software Design



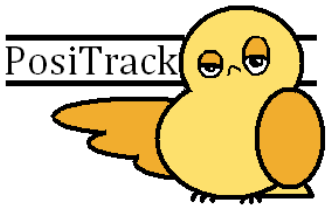
Software Design

UDP Message Passing

Widows
"Client"

- **Unregulated send rate**
  - » Better for real time applications, no transmission rate constraints like TCP
- **Small segment header overhead**
  - » 8 bytes of overhead vs 20 bytes for TCP
- **Lower Latency**
  - » Message isn't verified for order or completeness
- **Broadcast functionality**
  - » Can communicate with multiple Servers

Linux
"Server"

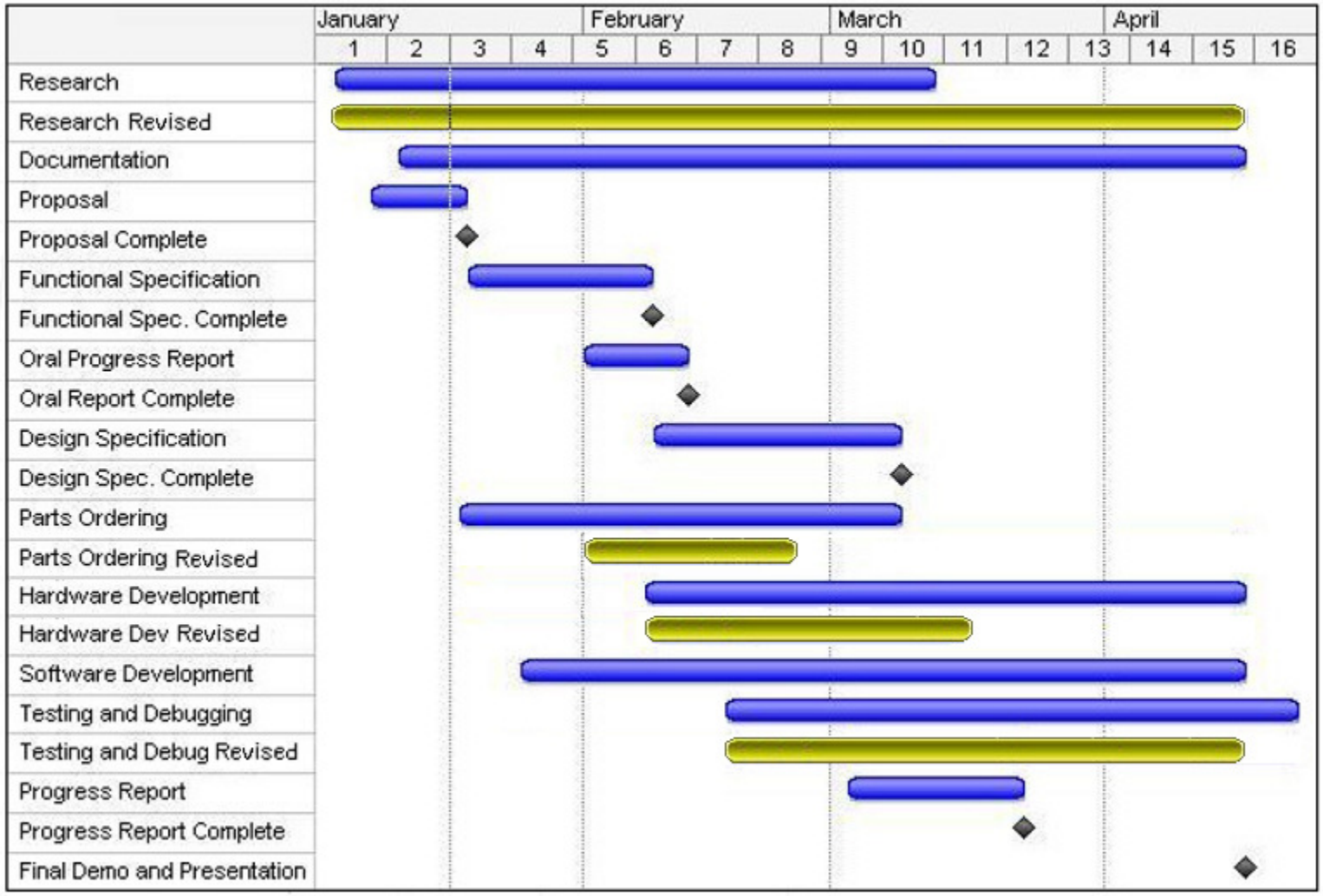


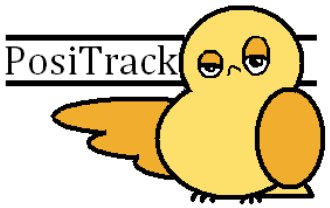
Finances

Expense	Source	Unit Cost
Overo Air Gumstix	www.gumstix.com	$219.00
Tobi Expansion Board	www.gumstix.com	$69.00
WiFi Antenna	www.gumstix.com	$10.00
5V AC Wall Adaptor	www.gumstix.com	$10.00
MicroSD Card 2GB	www.gumstix.com	$20.00
LiPoly Charger	www.sparkfun.com	$16.95
IMU 6DOF Razor	www.sparkfun.com	$89.95
1000mAh Li-Poly Battery (x2)	www.sparkfun.com	$23.90
Misc Parts / Costs		$46.00
Shipping Costs		$61.75
Final Cost:		**$566.55 US $581.90 CAN**

- Under our initial cost estimate of $612.54
- High cost of shipping was offset by borrowing wireless access points
- Funding only covered $450, remainder was split amongst group members

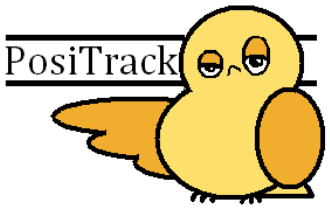
Revised Schedule





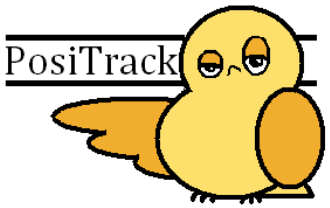
Future Work

- **Use a longer wave length (900MHz instead of 2400MHz)**
  - » These waves travel further which would allow for higher localization accuracy
  - » A new WiFi standard (WRAN) 802.22 will be in this range (analog TV spectrum)
- **Stronger WAP transmitters**
  - » Higher signal strength would allow for higher localization accuracy
  - » Signals with higher power have less relative interference
- **Adding a wireless BlueTooth heart rate monitor**
  - » Was not included in the prototype due to the time constraint (4months)
- **Adding a GPS unit**
  - » Can be added using the I2C, SPI, or GPIO interfaces
  - » Would allow for outdoor localization without wireless access points



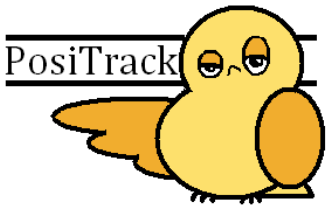
Future Work

- **Custom expansion board for the Overo Fire COM**
  - » Would drastically reduce the size and weight of the PosiTracker Module
  - » Would combined the battery charger and accelerometers/gyroscopes onto a single board
  - » Would eliminate unused peripherals (ethernet, audio jacks etc.)
- **Increase the number of wireless access points**
  - » Each additional WAP would increase accuracy
- **Custom casing and harness**
  - » Create a custom case that could withstand impacts
  - » Create a sports harness to attach the PosiTracker to the athlete
- **Further develop localization algorithms**
  - » More time is needed to improve accuracy
  - » Actual sports testing of algorithms is needed



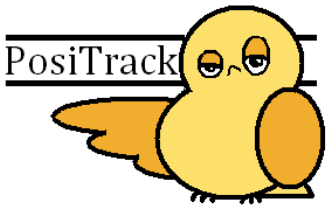
What We Learned

- **Andreea Hrehorciuc:**
  - How to interface different programming languages via DLLs
  - How the Gumstix can be used for a multitude of applications
- **Mikey Valdes:**
  - How to create a wireless link between two operating systems
  - Taking an idea from just a concept to a functional model
- **Ryan Lynne:**
  - How amazing WiFi technology is!
  - The smallest signal the Gumstix can pick up over WiFi is -90dB or 0.000000001 W or ~1 billion times smaller than the original signal
  - How to create an embedded system using Linux
- **Jeff Anderson:**
  - Interesting/complicated Localization methods and algorithms.
  - Increased programming skill



Conclusions

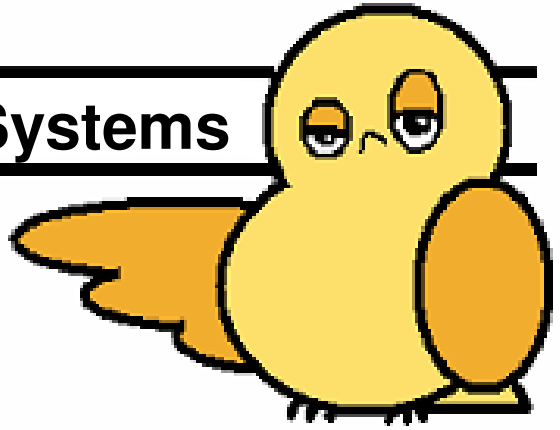
- The PosiTracker fills a market niche for the indoor performance tracking of athletes and can be used for training and broadcasting purposes
- With further development the PosiTracker prototype will be able to track an athletes position, speed, acceleration, and power output
- Current Accuracy of these measurements is
  - RSS
    - Location standard deviation of ~2m
  - Dead Reckoning
    - Acceleration ±0.5m/s^2
    - Linear Velocity ± 2m/s after 30s
    - Distance Travelled ± 2m after 30s
- Further development of the algorithms could increase this accuracy
- In conclusion, we believe that in the future the PosiTracker could a viable and marketable product with real world applications



Acknowledgements

- Engineering Student Society Endowment Fund for their generous financial contribution!
- Stuart Lynne for his help with compiling the Linux kernel and modifying the WiFi device driver!
- The TA's for their feedback!
- Glentel for allowing us to borrow two wireless access points!

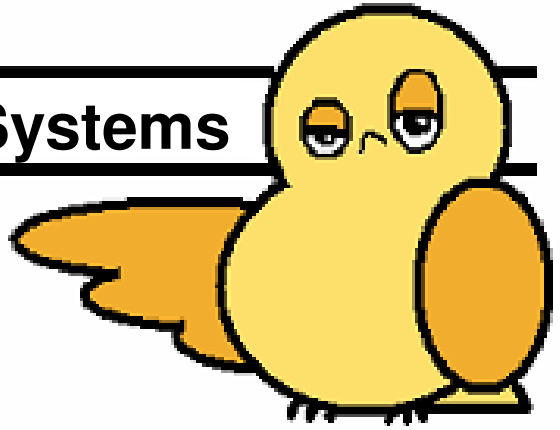
PosiTrack Systems



Questions ?

April 14th 2010

PosiTrack Systems



Demo: Test Results

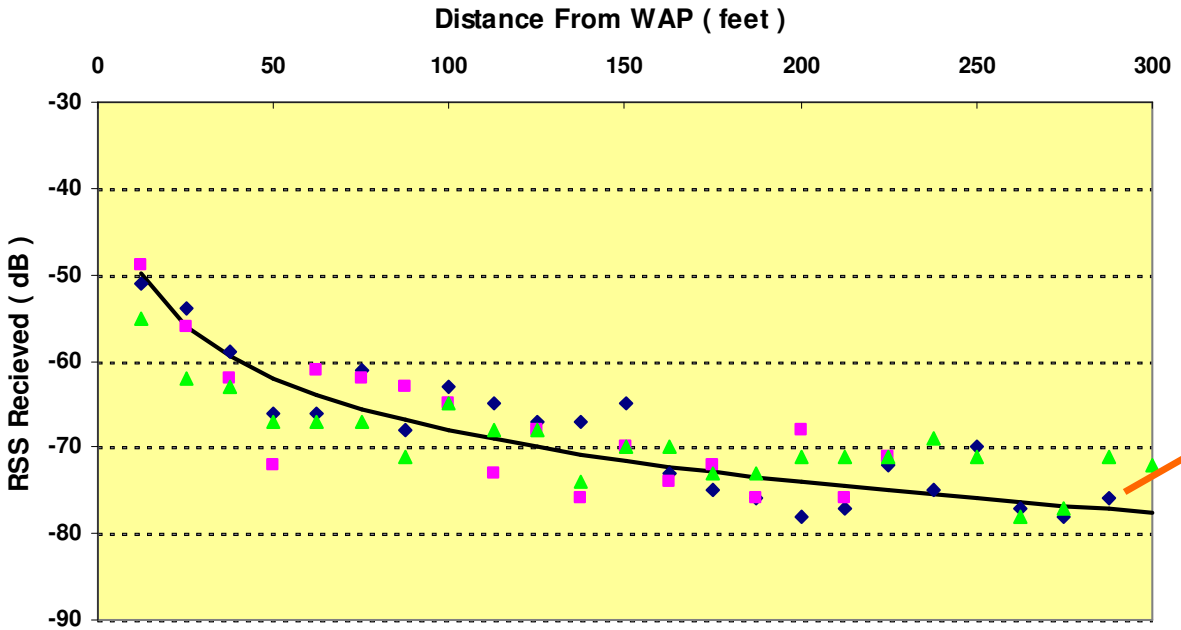
April 14th 2010

Range Test

300 ft Range

Wireless Access Point

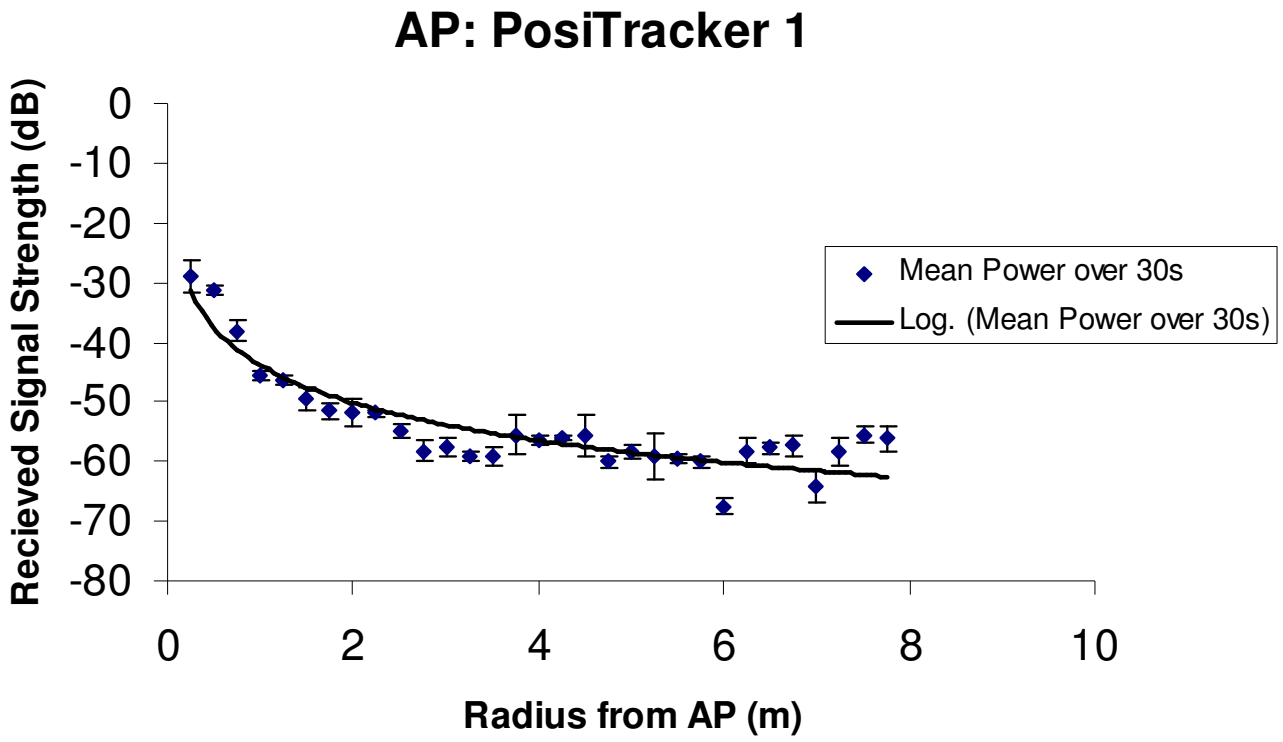
Maximum Range Test



- The maximum range of the wireless link between the WAP and PosiTracker was found to be approximately 300 ft
- This is more than enough range to cover an entire hockey rink

Algorithms & Test Results

- **Propagation Model:**
- **Measured Power at distances 0m to 8m**
- **Also measured line of sight range to be ~300ft.**

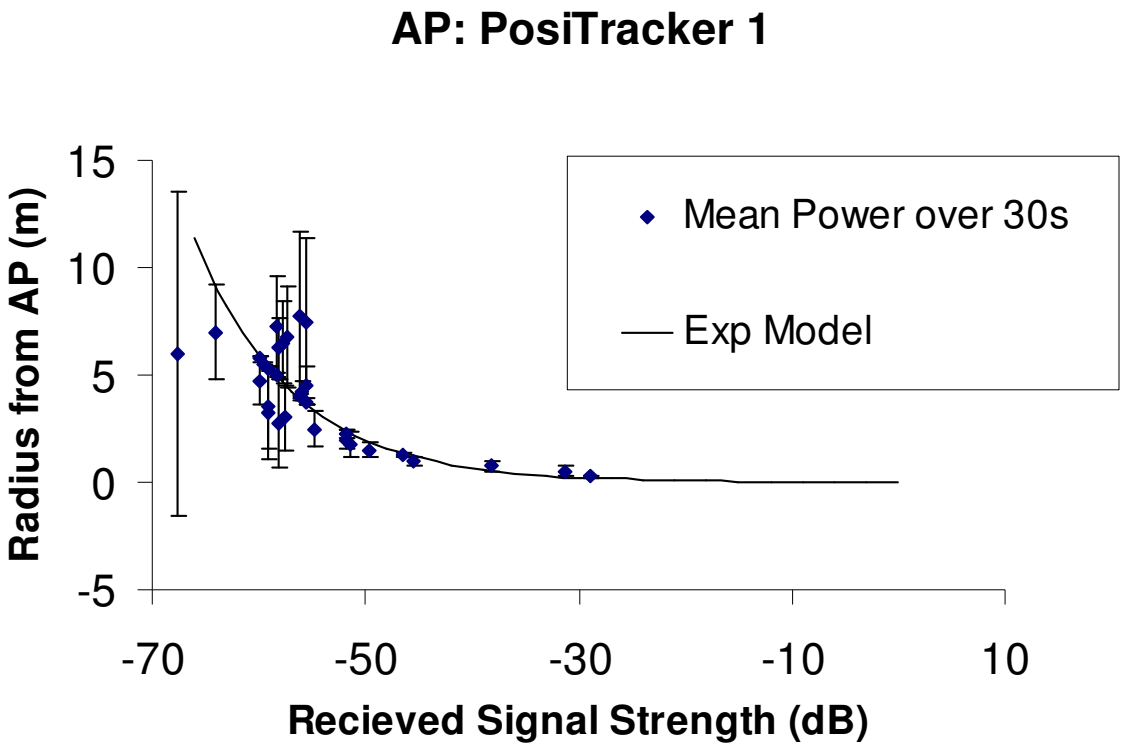


Algorithms & Test Results

- **Propagation Model:**

  - $R = \mathrm{Exp}(P + \varphi)/(\beta)$

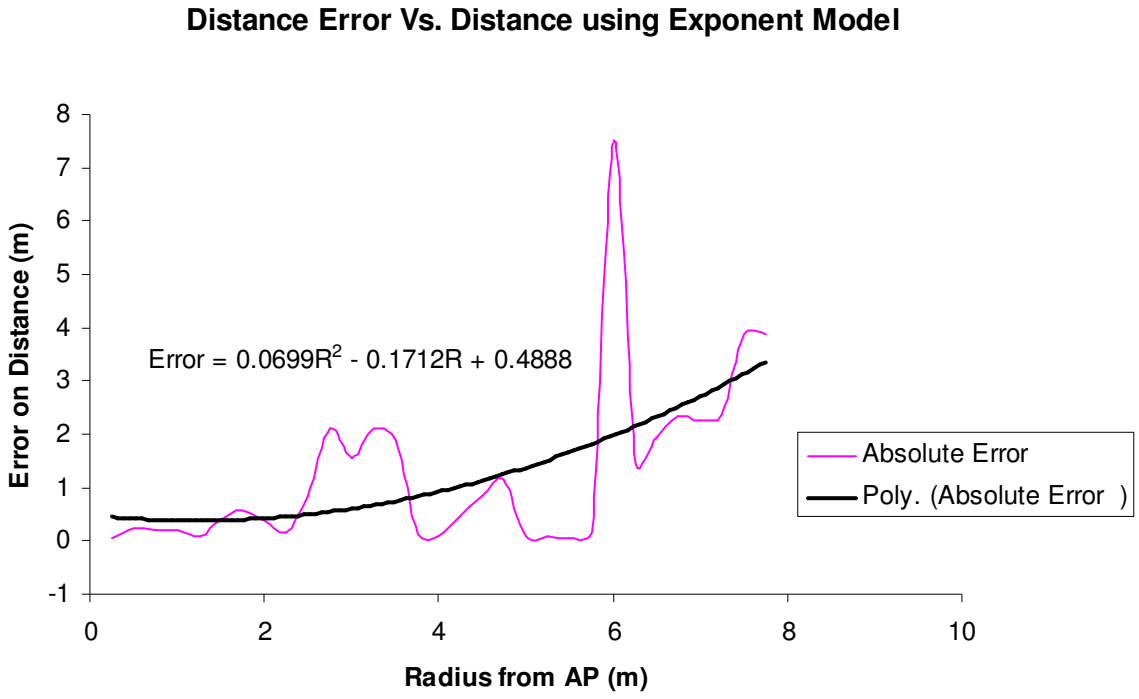
AP	φ	β
PosiTracker0	48.2	9.7
PosiTracker1	44.4	8.3
PosiTracker2	52.1	3.6
PosiTracker3	48.6	5.5



Algorithms & Test Results

- **Propagation Model:**

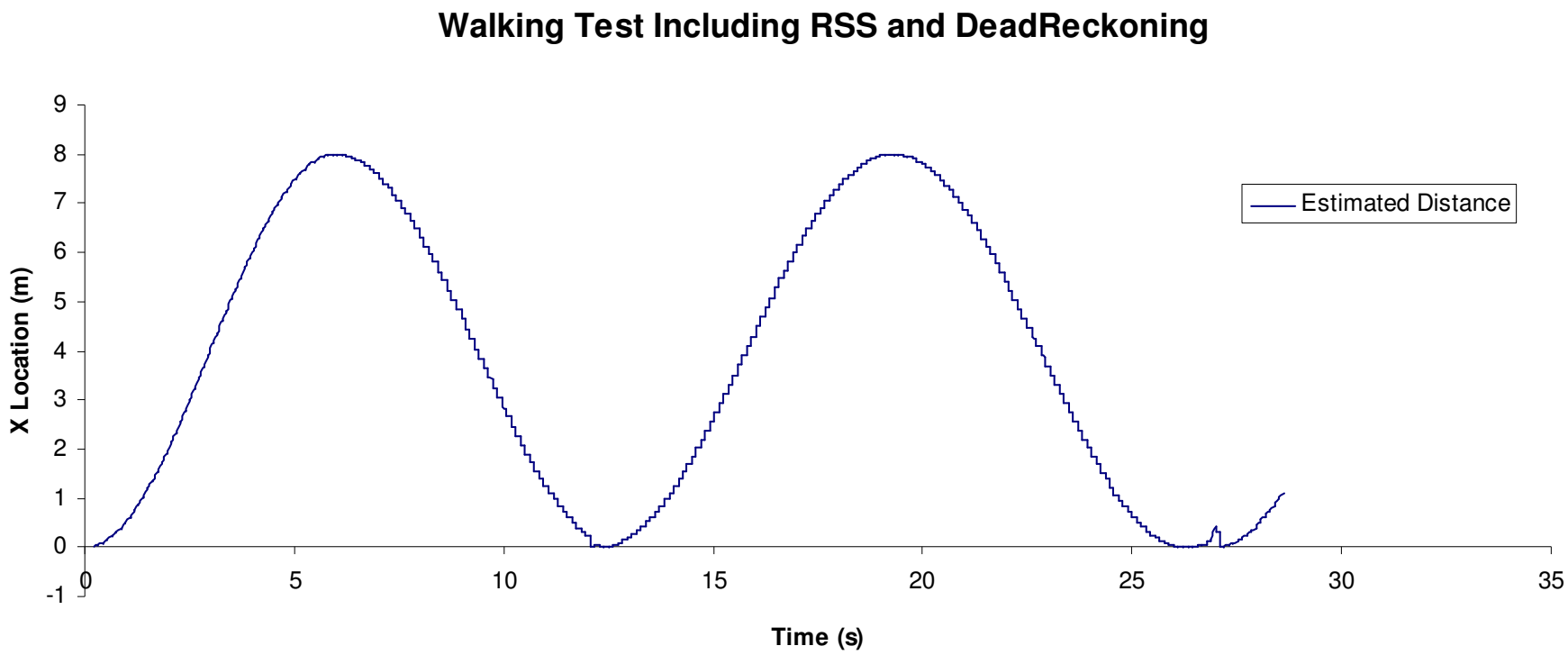
- **Probability Distribution of known location spreads as you increase distance from the AP**



Algorithms & Test Results

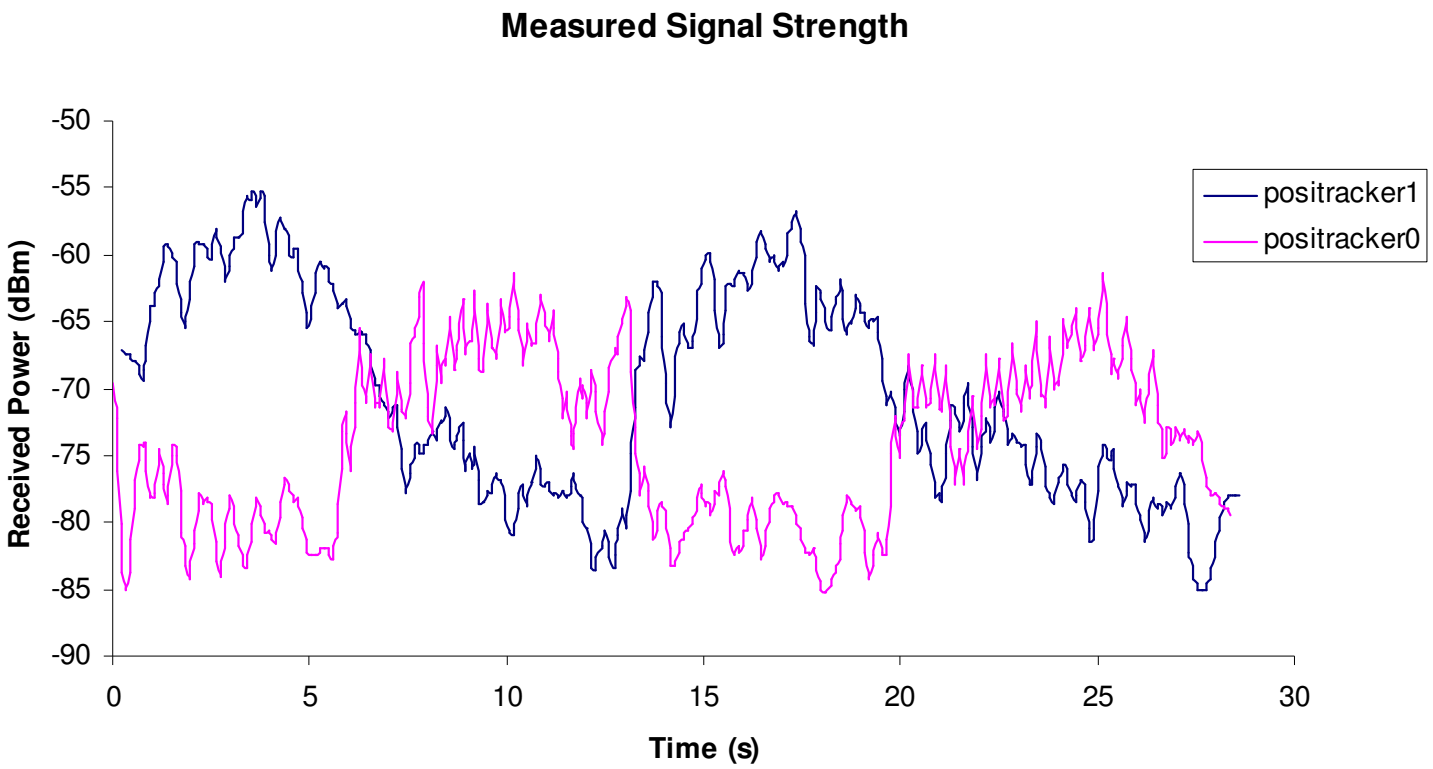
Algorithms & Test Results

- **One Dimensional Test Result**



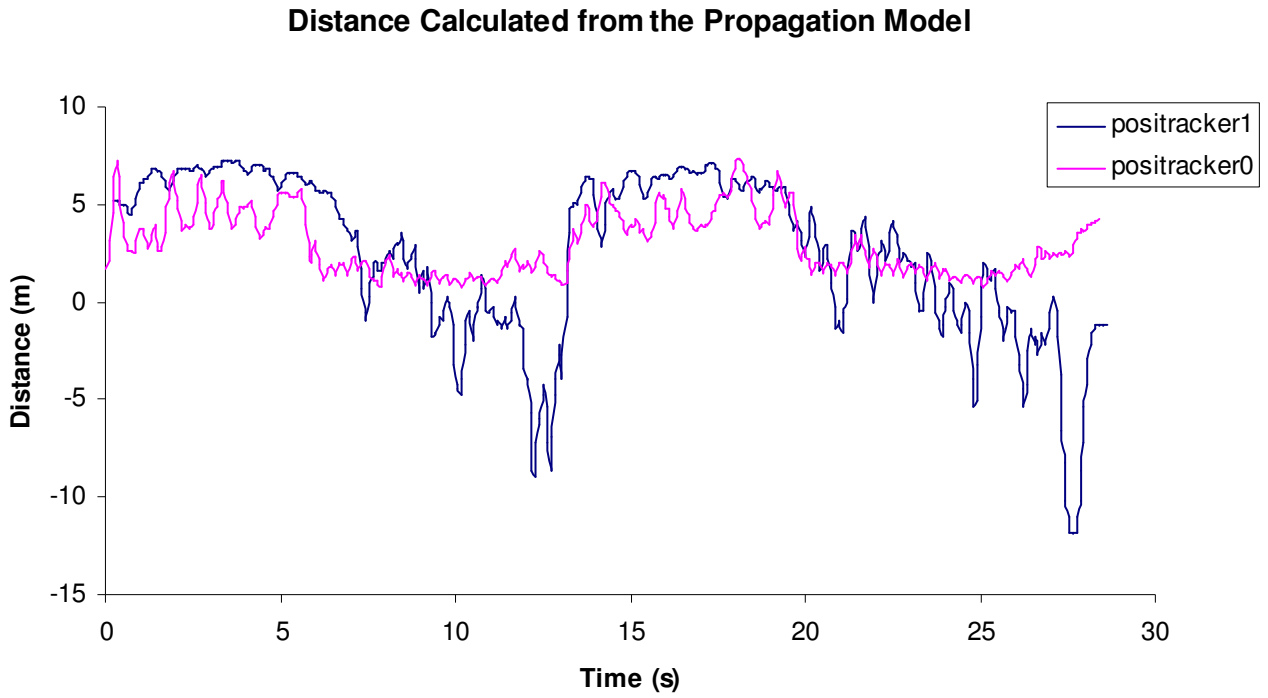
Algorithms & Test Results

- **One Dimensional Test Result**



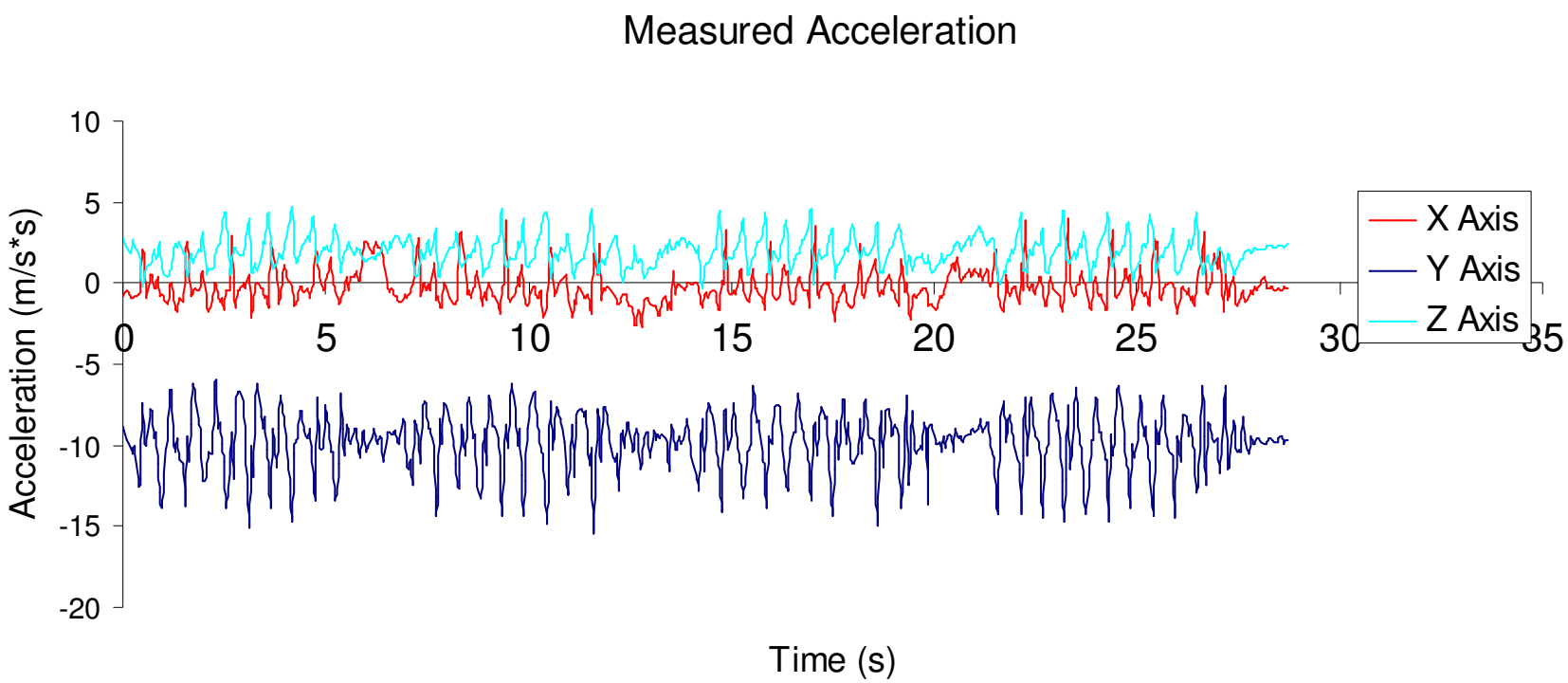
Algorithms & Test Results

- **One Dimensional Test Result**



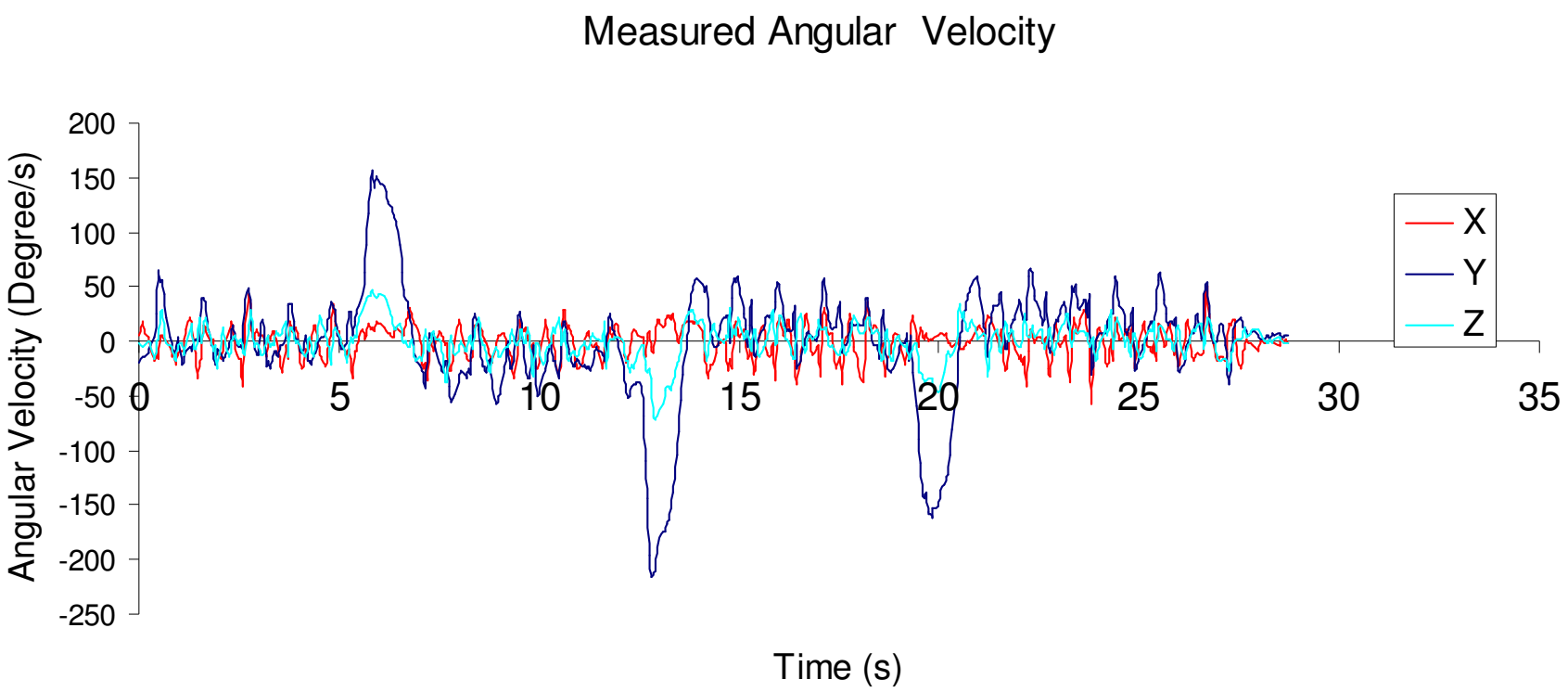
Algorithms & Test Results

- **One Dimensional Test Result**



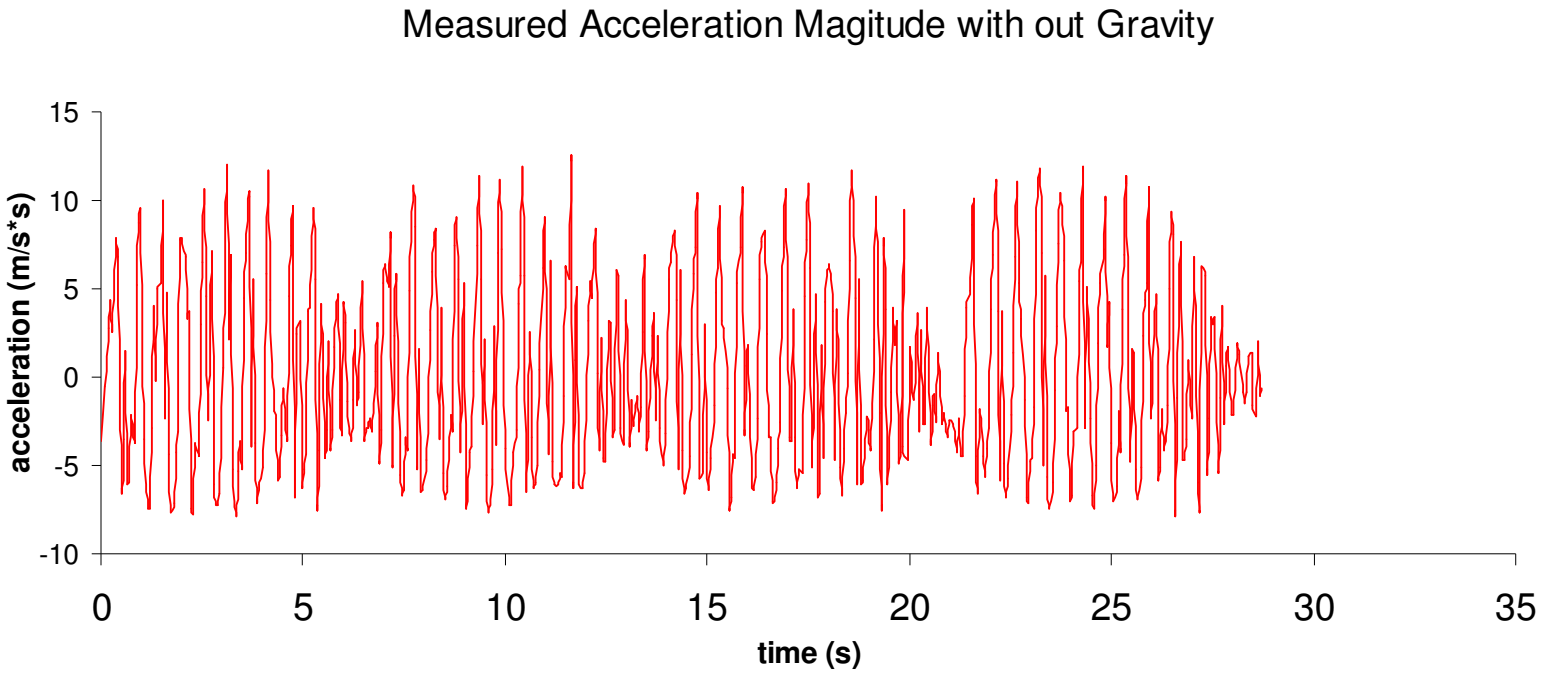
Algorithms & Test Results

- **One Dimensional Test Result**



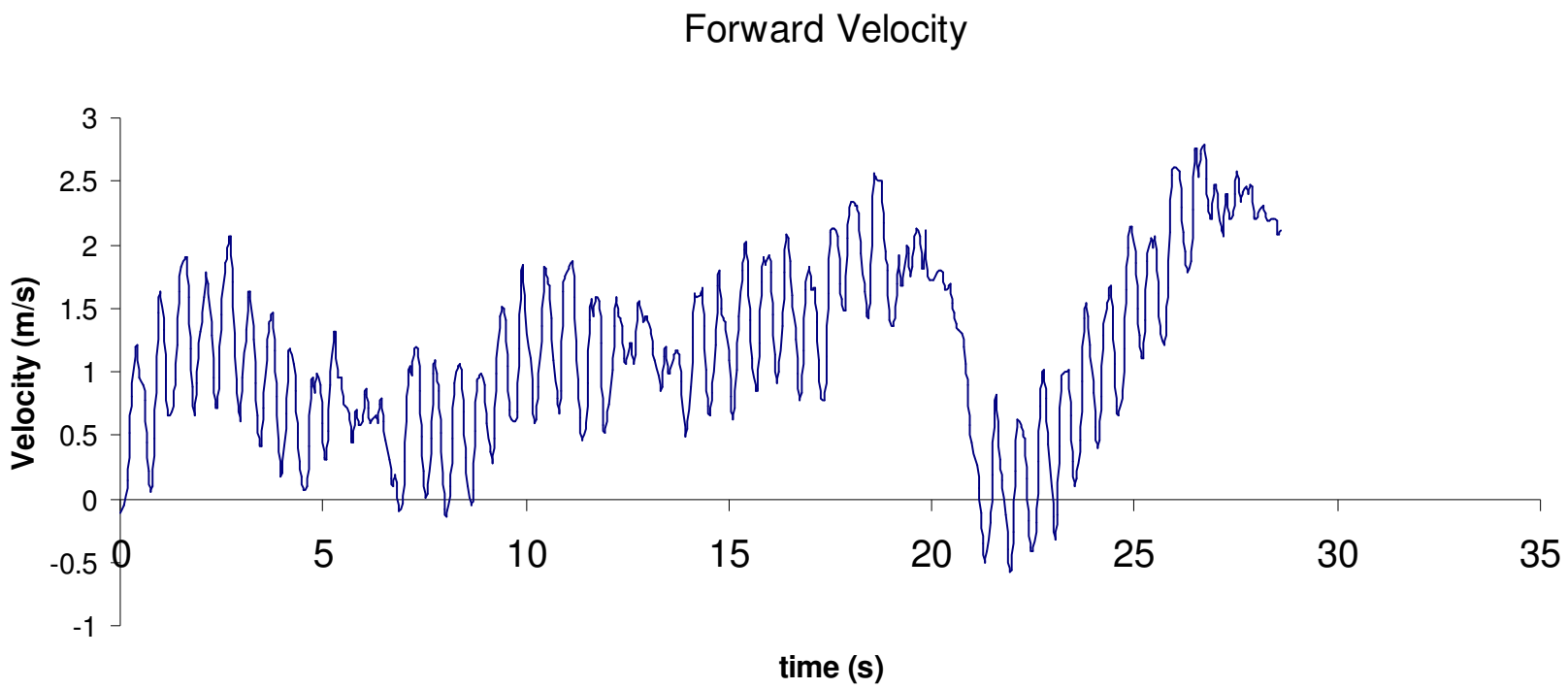
Algorithms & Test Results

- **One Dimensional Test Result**



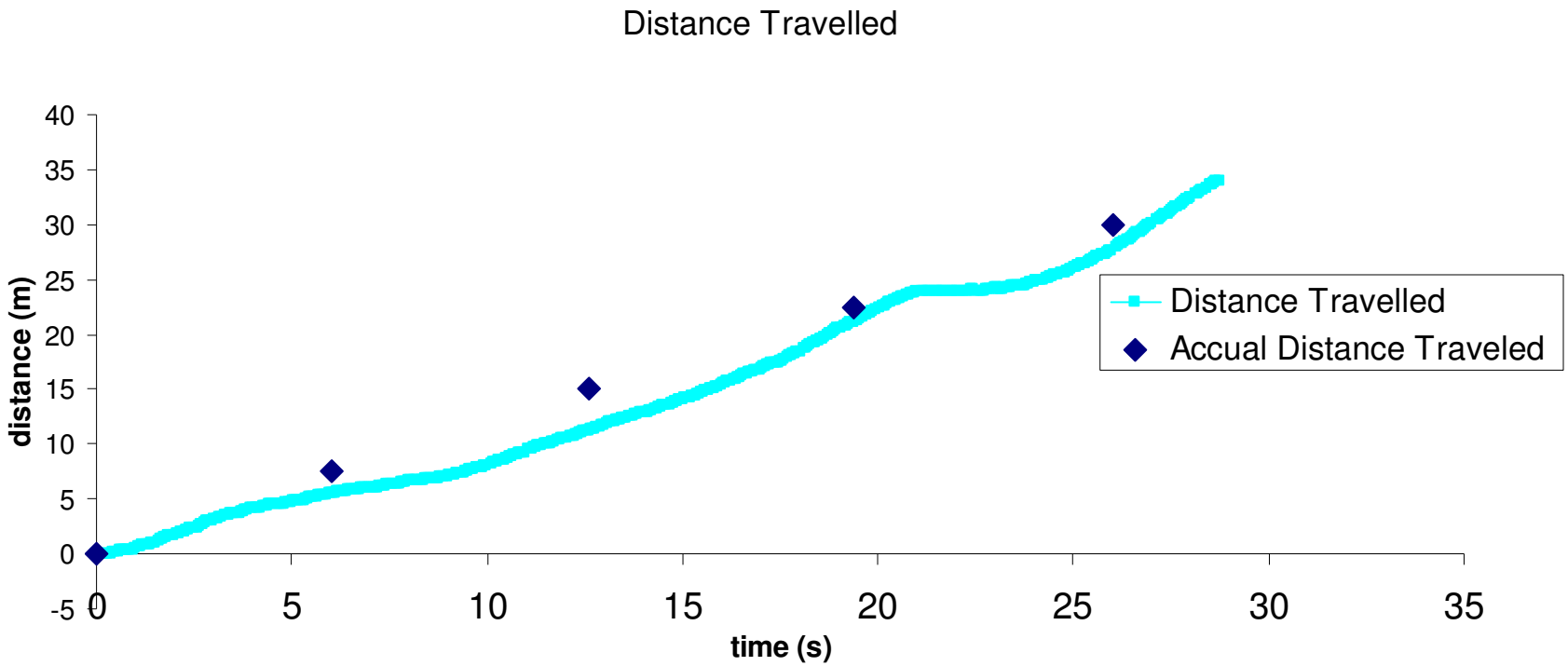
Algorithms & Test Results

- **One Dimensional Test Result**

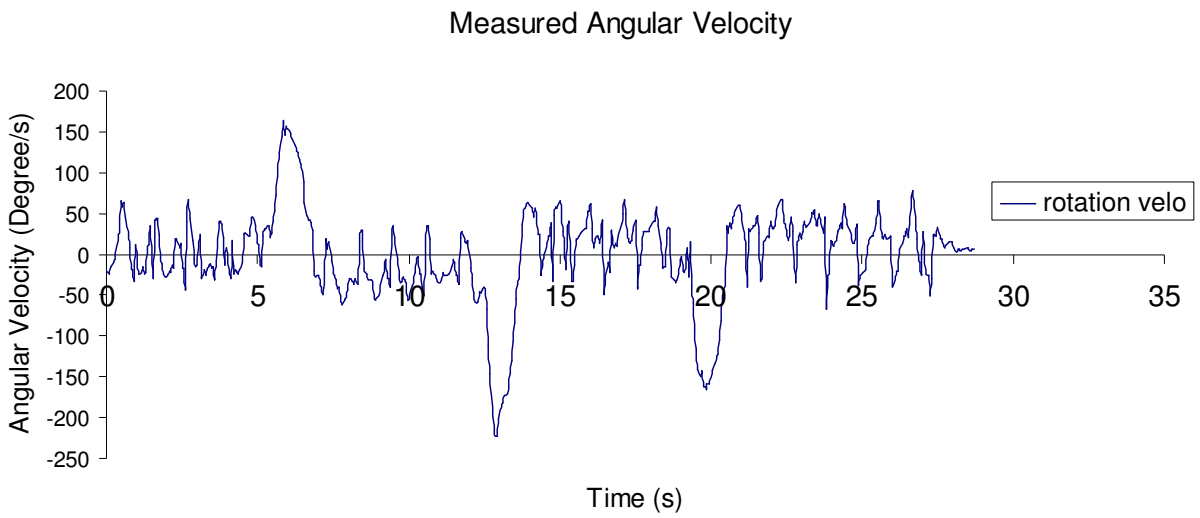


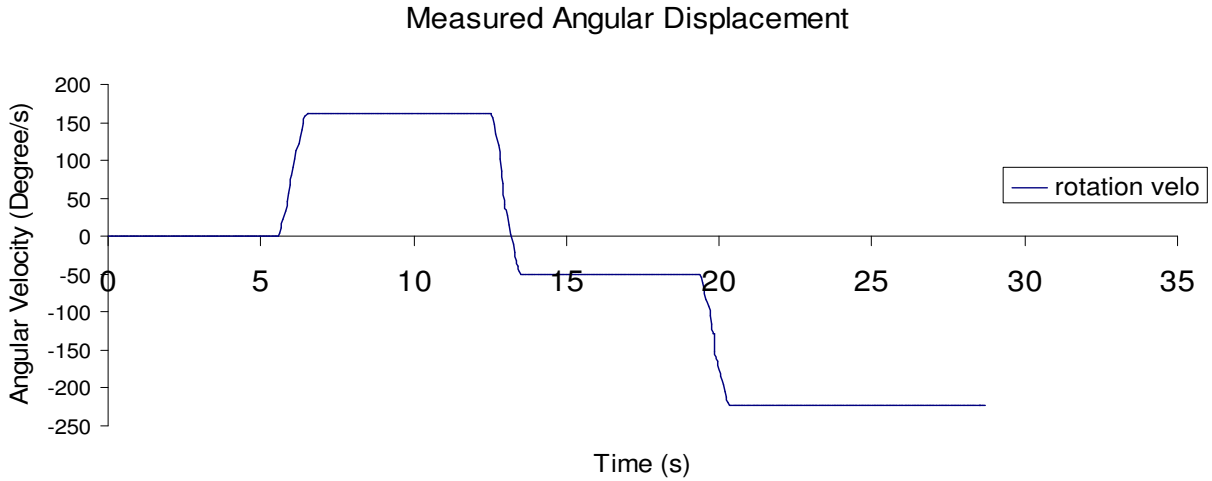
Algorithms & Test Results

- **One Dimensional Test Result**



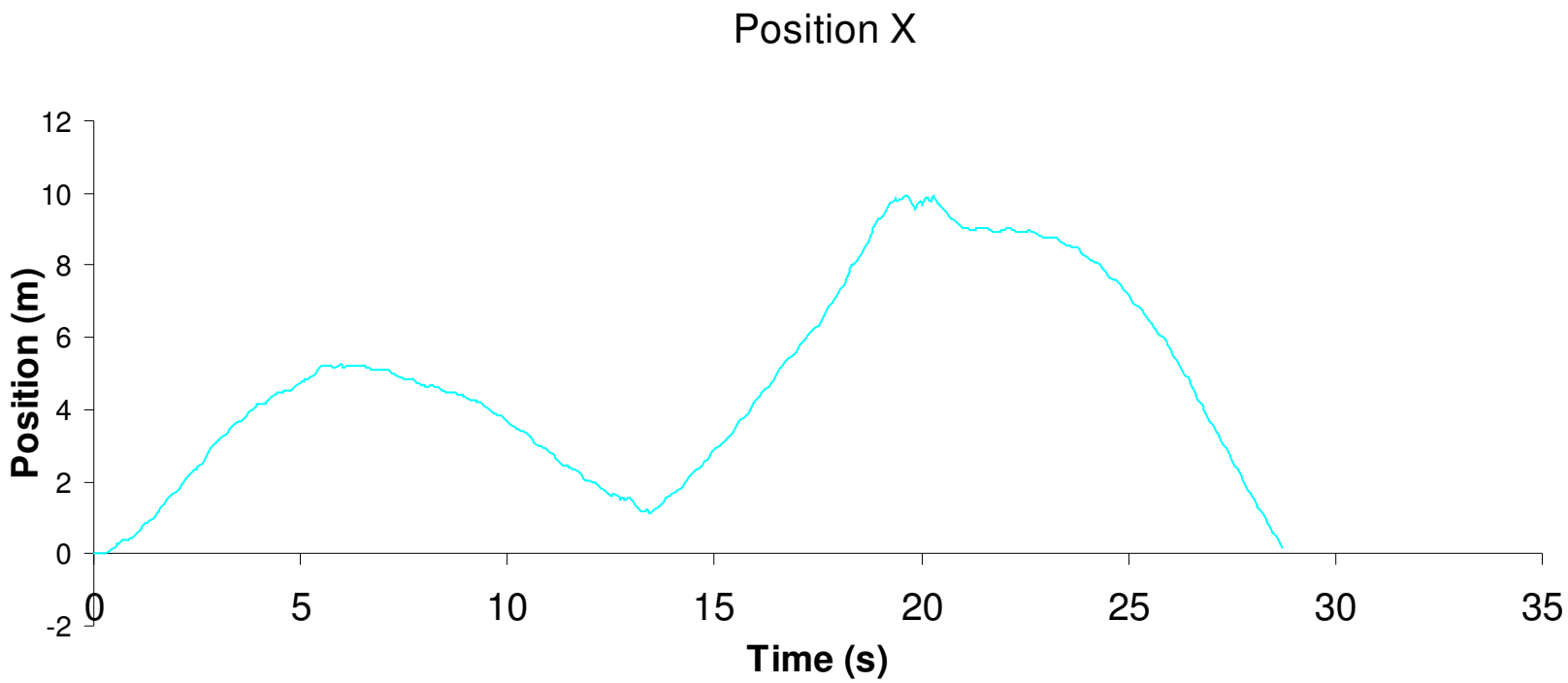
Algorithms & Test Results





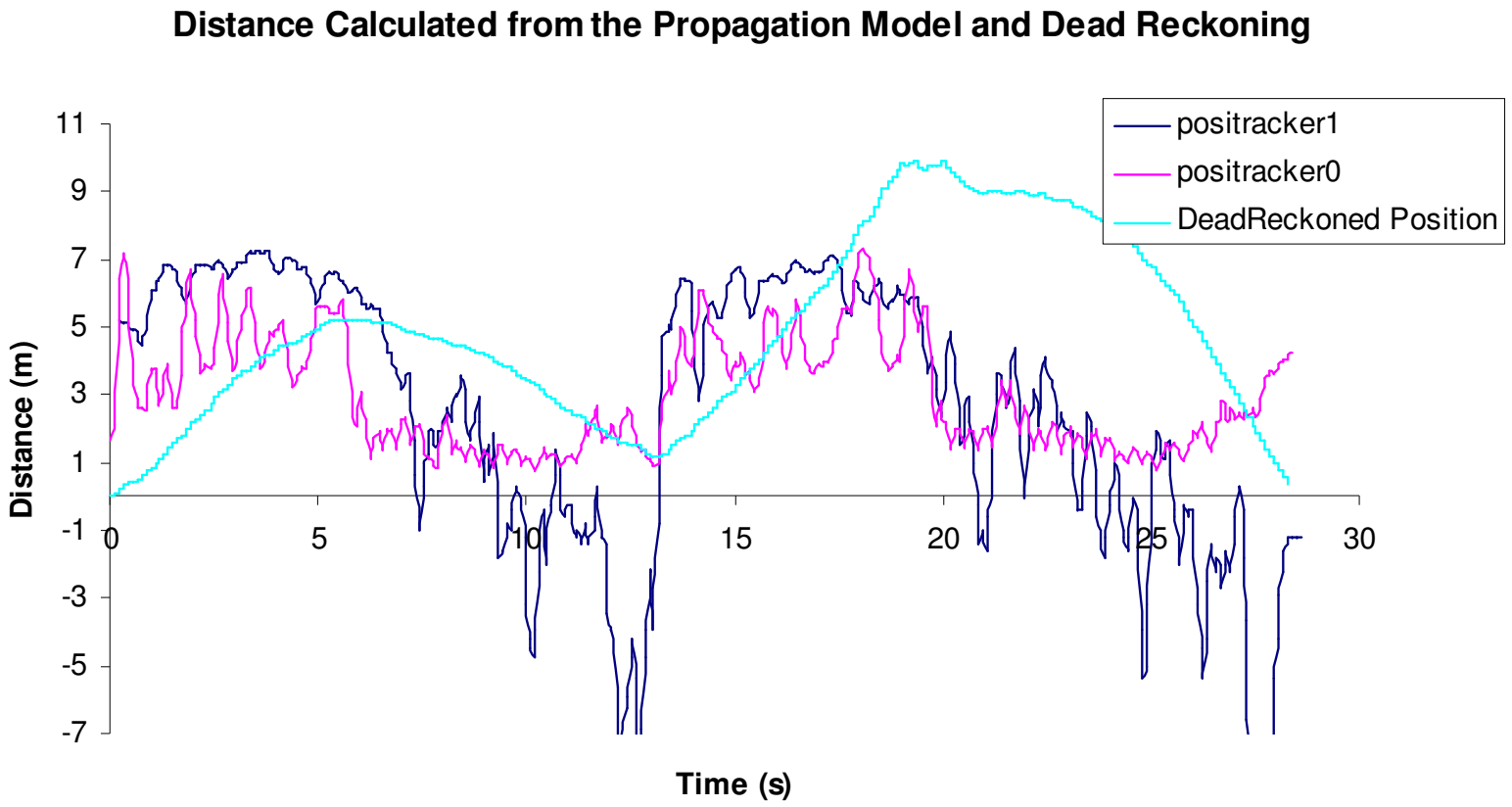
Algorithms & Test Results

- **One Dimensional Test Result**



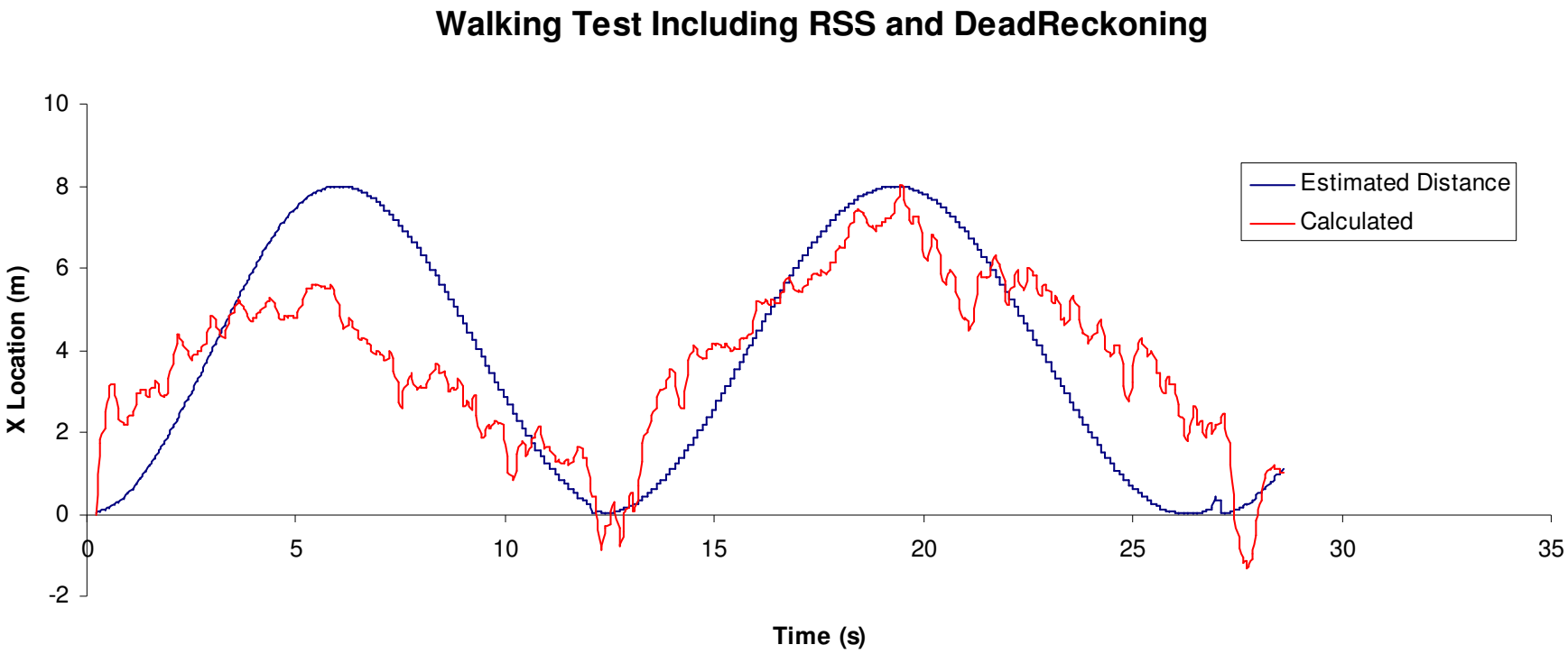
Algorithms & Test Results

- **One Dimensional Test Result**



Algorithms & Test Results

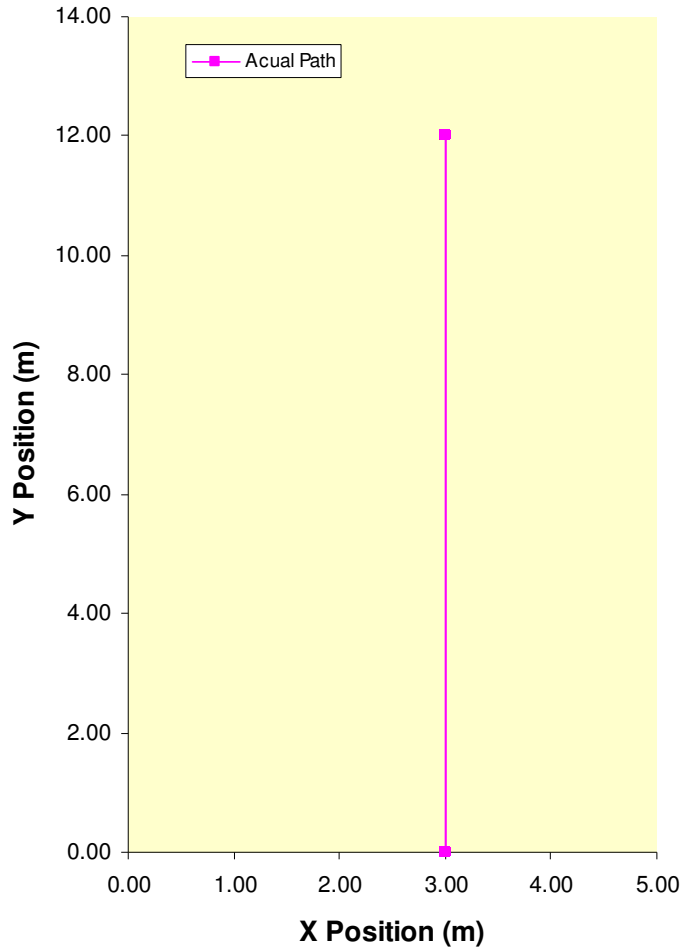
- **One Dimensional Test Result**



2D localization

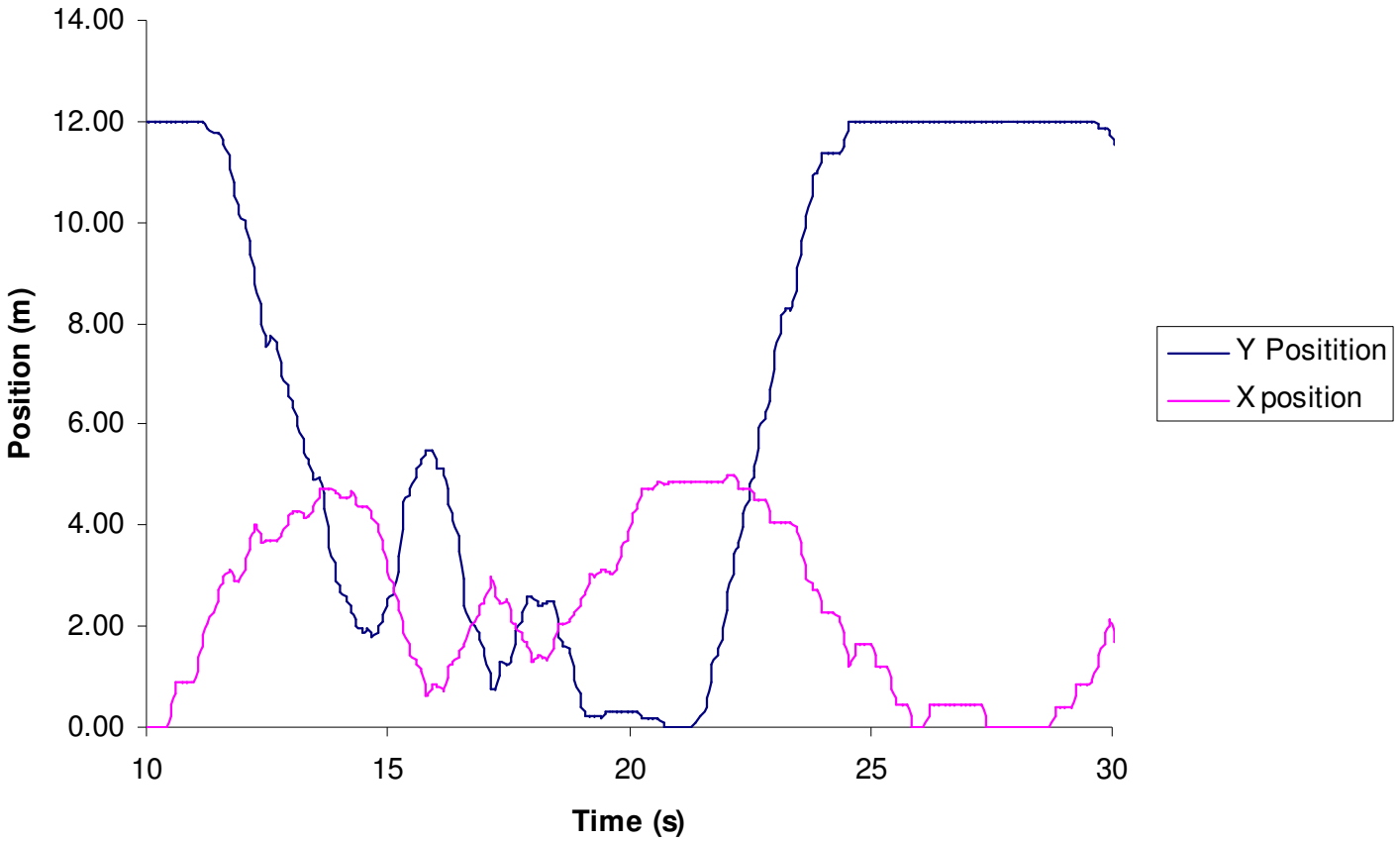
Algorithms & Test Results

- **Two Dimensional Test Result**
- **Test Case**
- **Geometric Algorithm**
- **Probability Distribution Algorithm**
- **Map Algorithm**



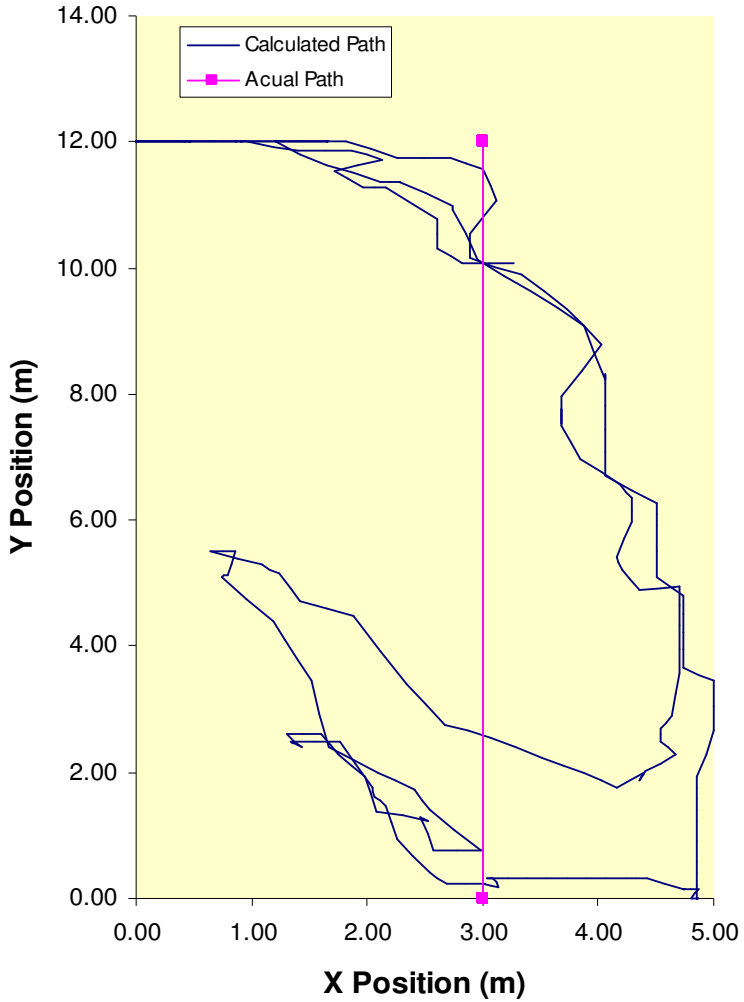
Algorithms & Test Results

- **Two Dimensional Test Result : Geometric Algorithm**



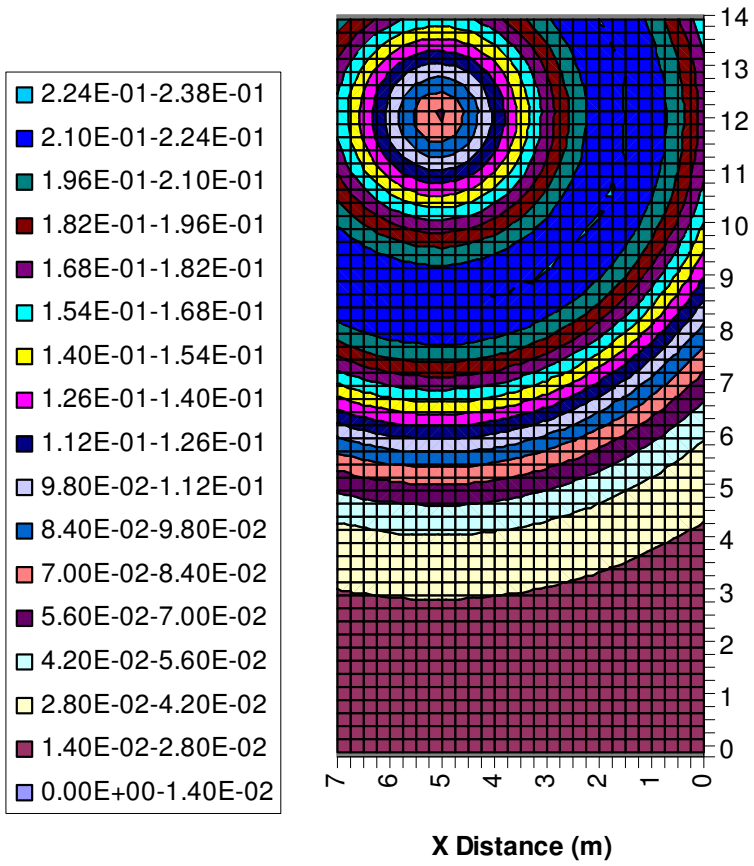
Algorithms & Test Results

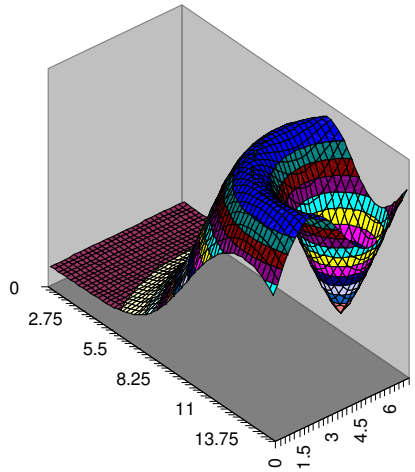
- **Two Dimensional Test :**
  - **Geometric Result**

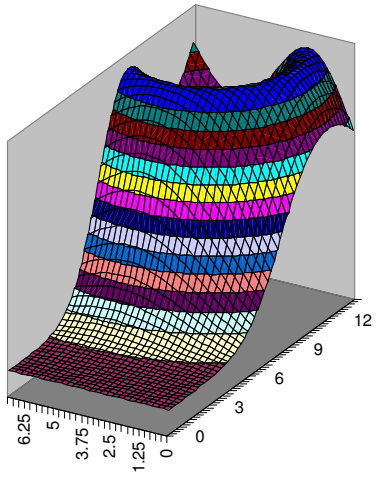


Algorithms & Test Results

- **Two Dimensional Test:**
- AP PosiTracker1 Radius Distribution

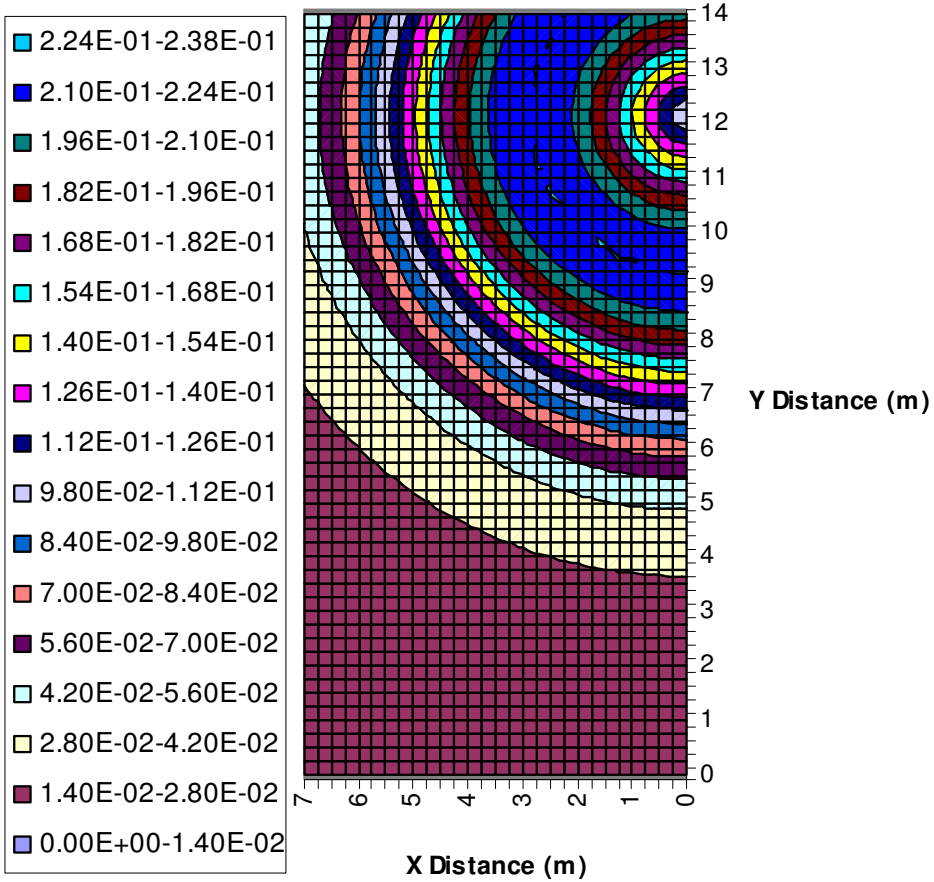


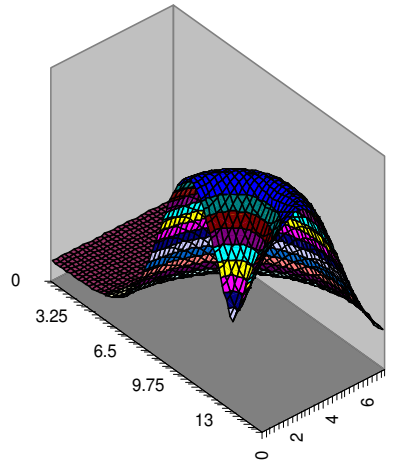


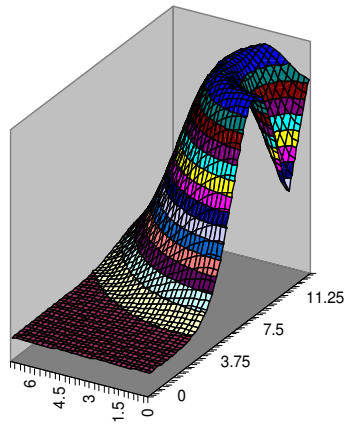


Algorithms & Test Results

- **Two Dimensional Test:**
- AP PosiTracker0 Radius Distribution

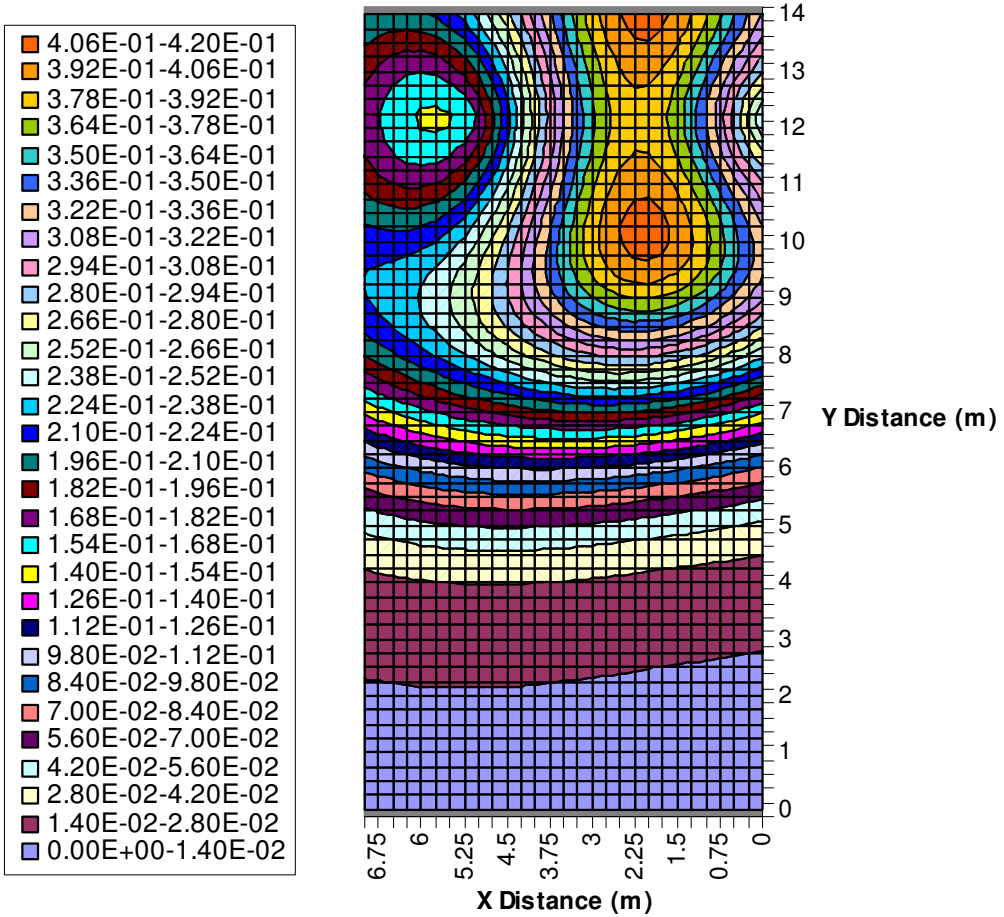


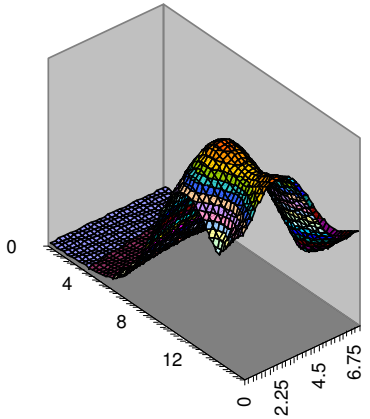


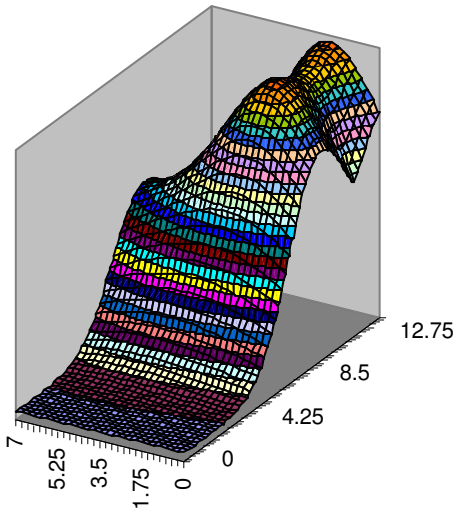


Algorithms & Test Results

- **Two Dimensional Test:**
- AP PosiTracker1 Radius Distribution

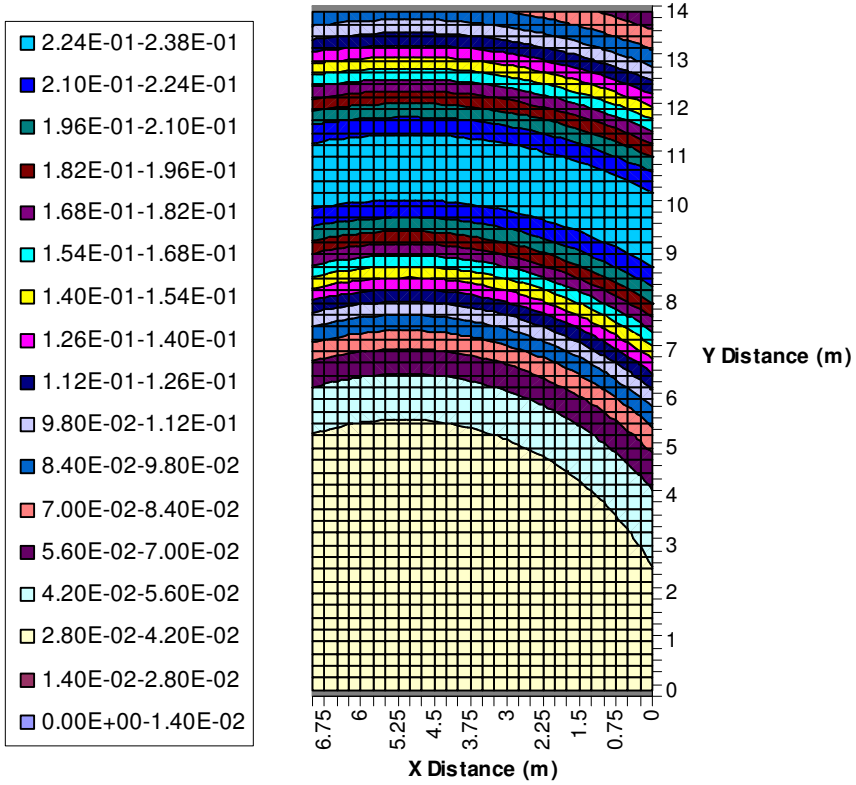


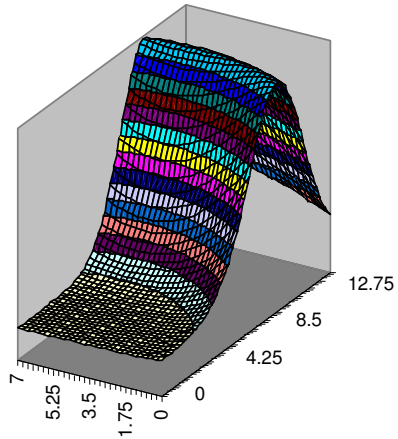


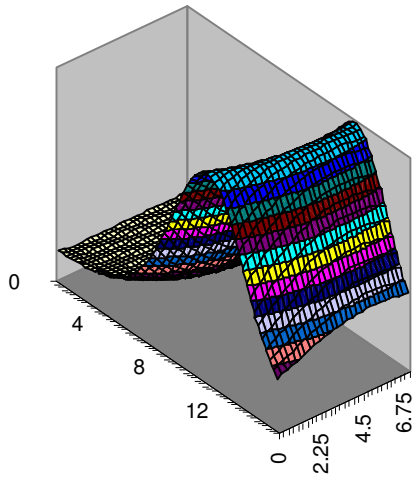


Algorithms & Test Results

- **Two Dimensional Test:**
- AP PosiTracker3 Radius Distribution

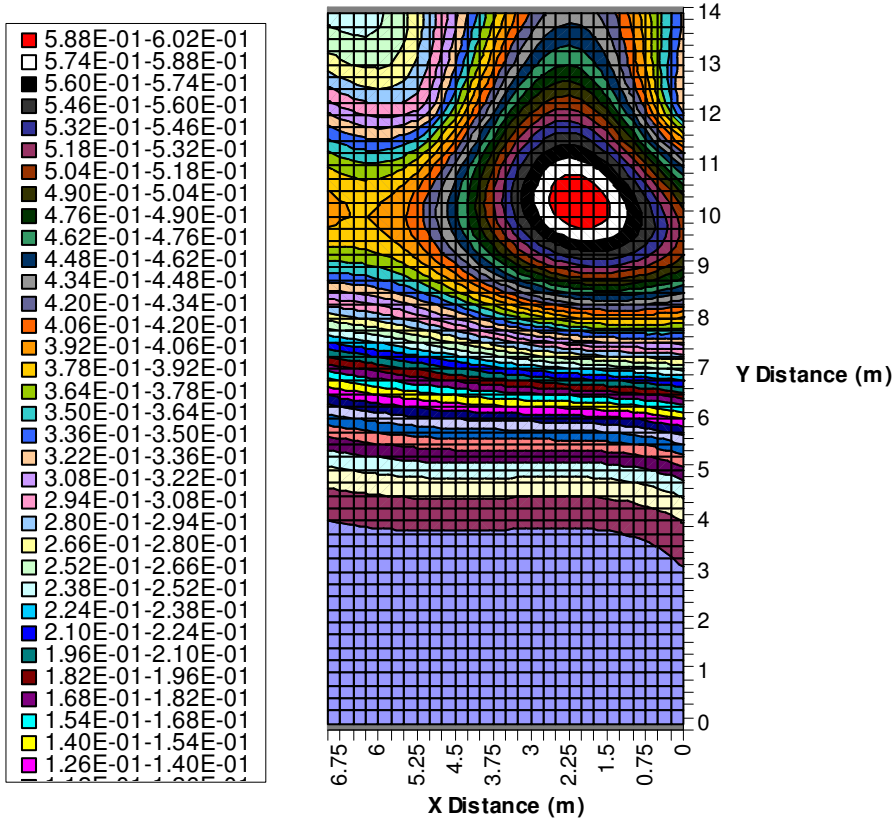


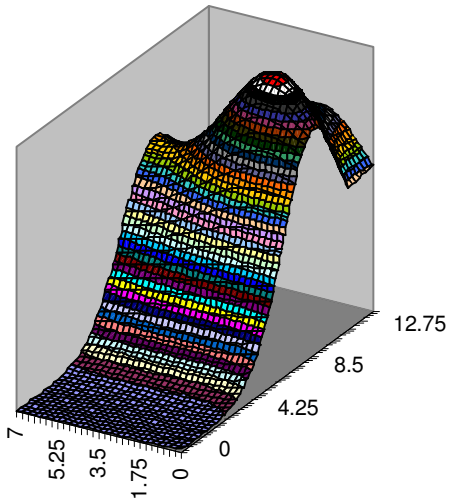


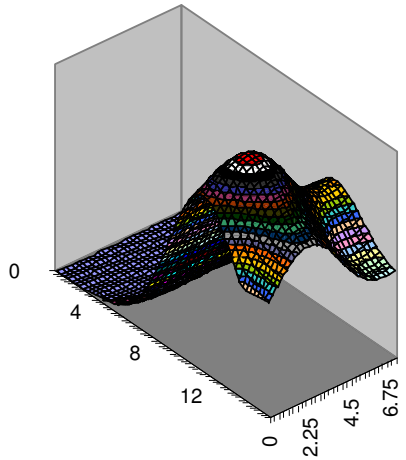


Algorithms & Test Results

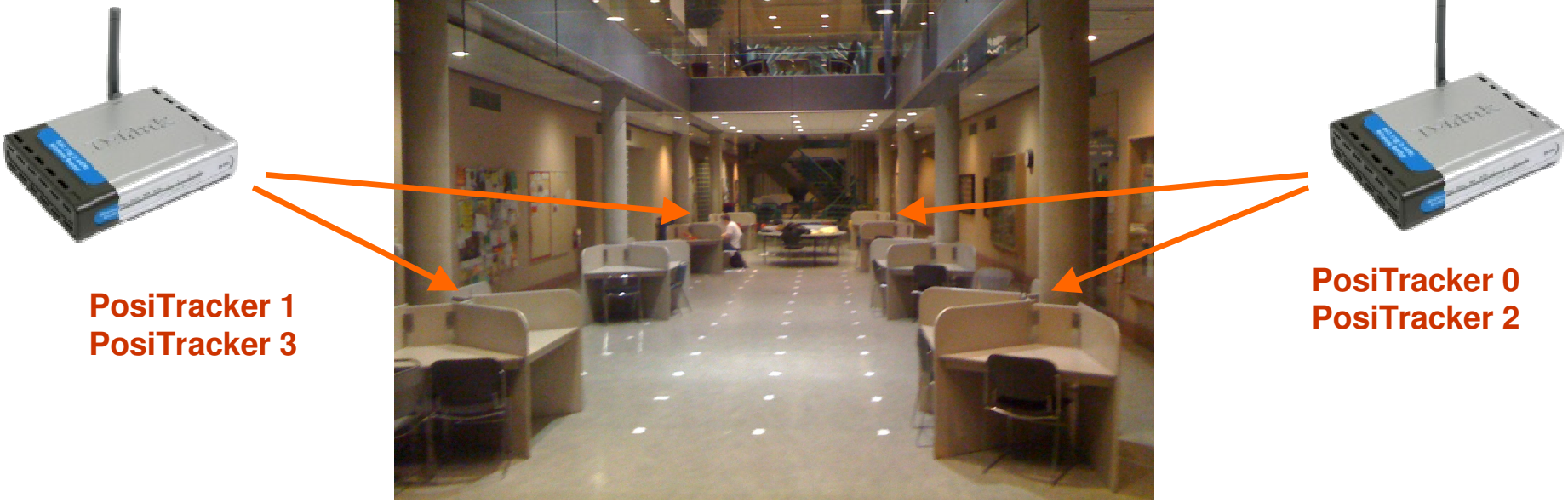
- **Two Dimensional Test:**
- AP PosiTracker3 Radius Distribution





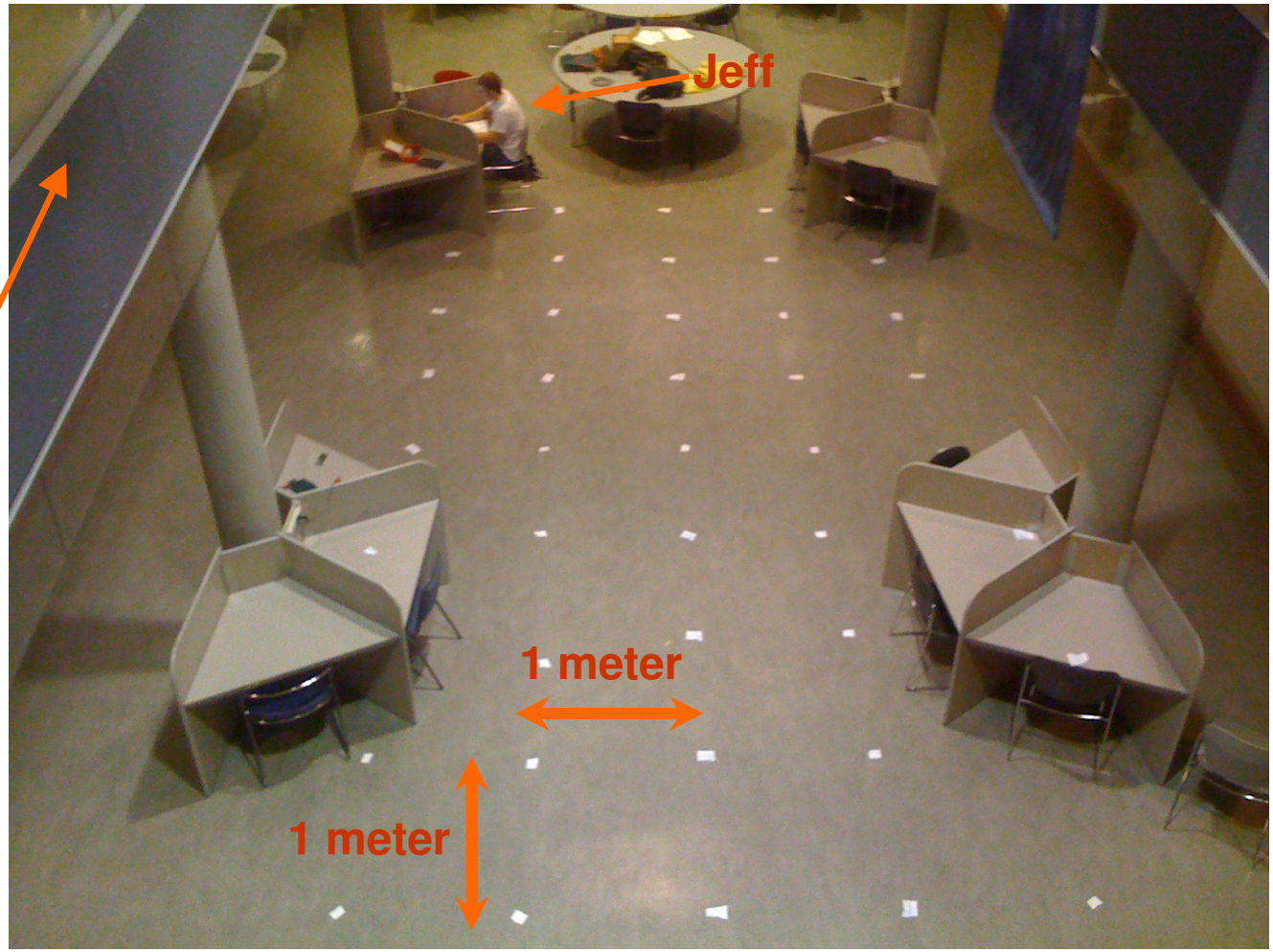


WAP Power Mapping



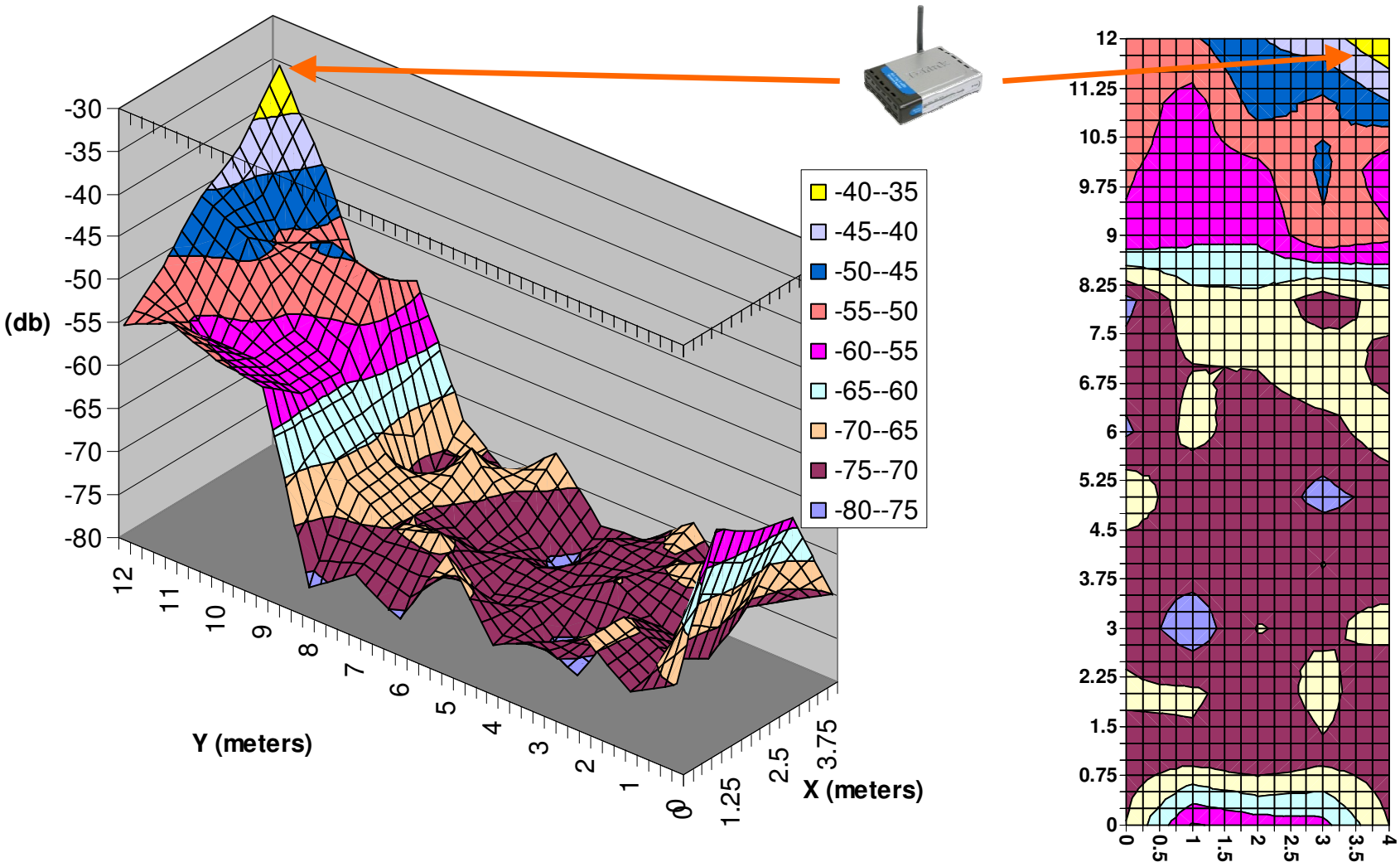
- 4 Wireless Access Points were placed in the ASB Atrium below IRMACS
- Markers were placed in a 1x1 meter grid pattern
- Signal strength from each AP was measured for 5s at each location
- Over 21,000 samples taken (at 4 am)

WAP Power Mapping

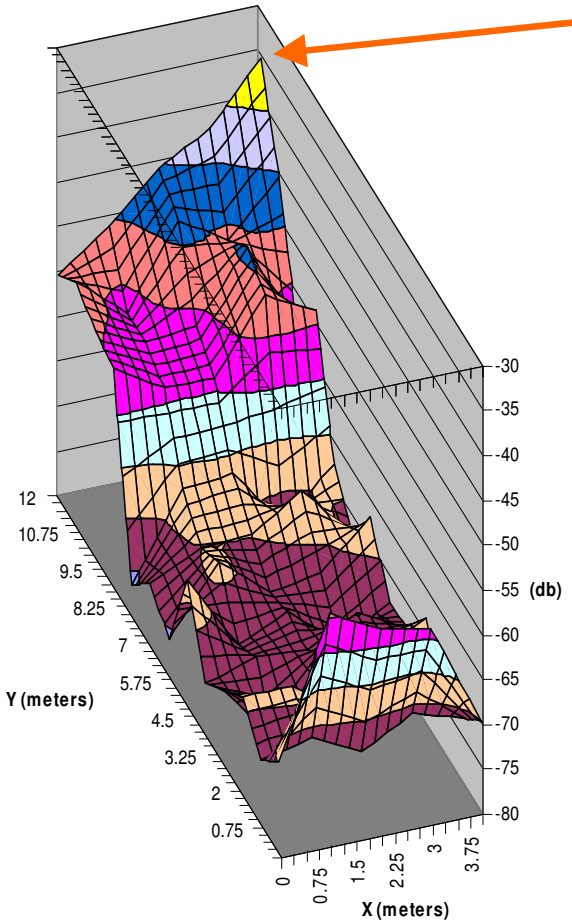


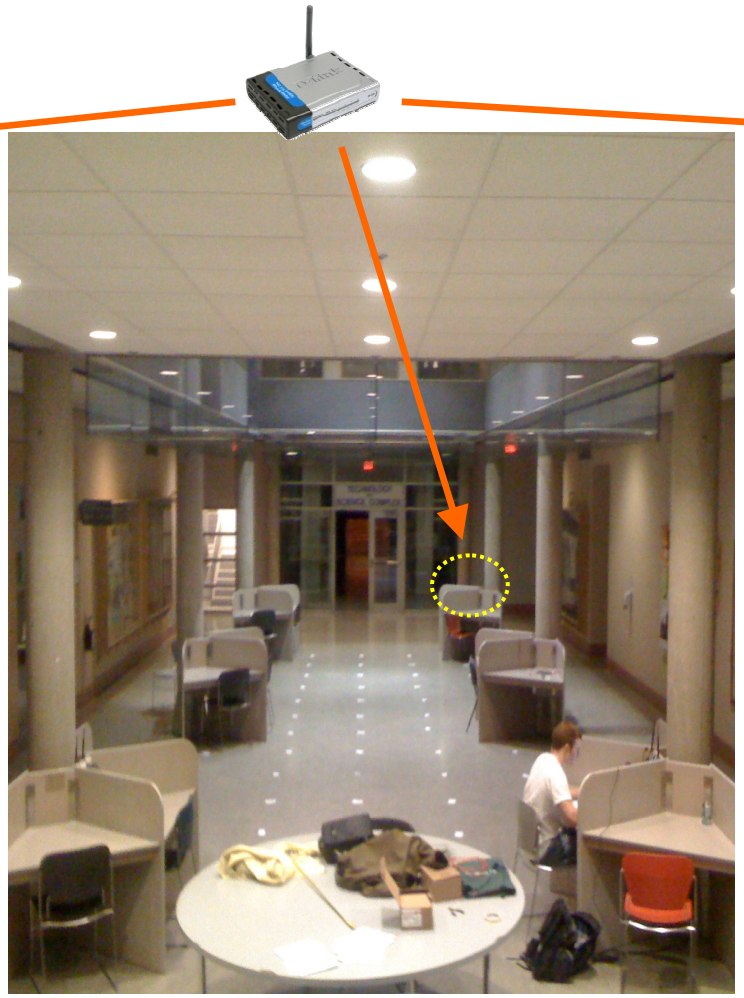
WAP Power Mapping

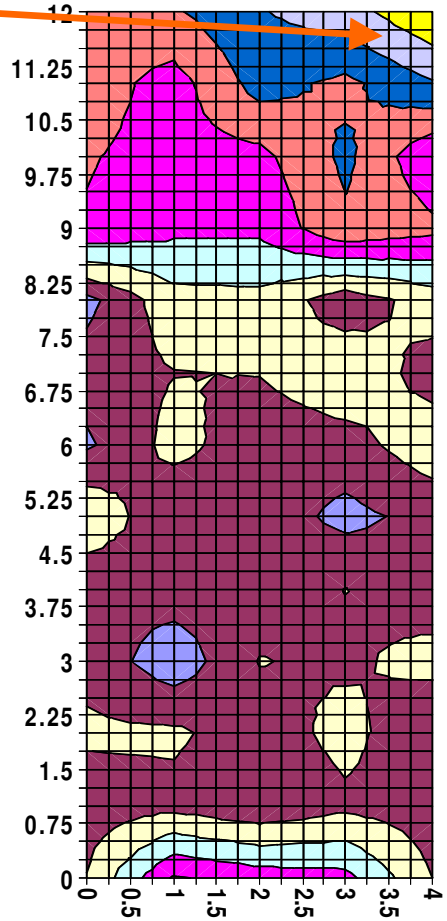
WAP Power Mapping



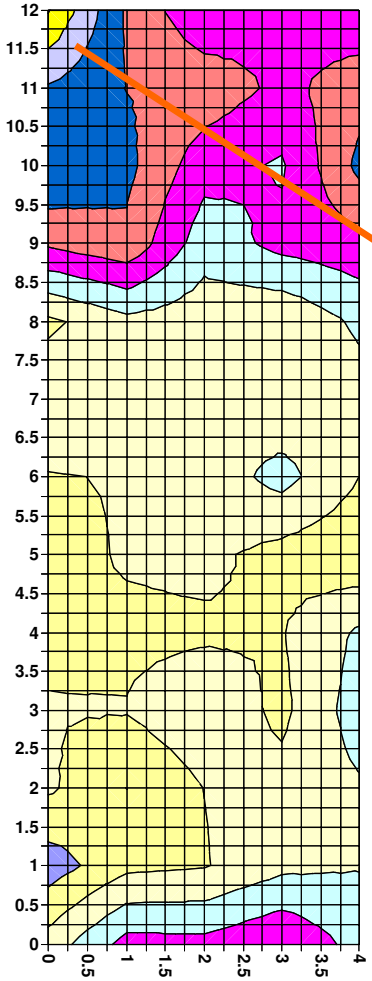
WAP Power Mapping

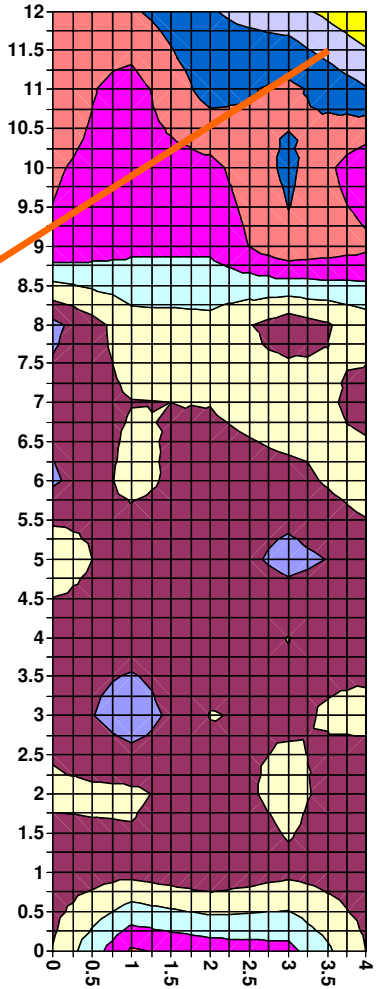




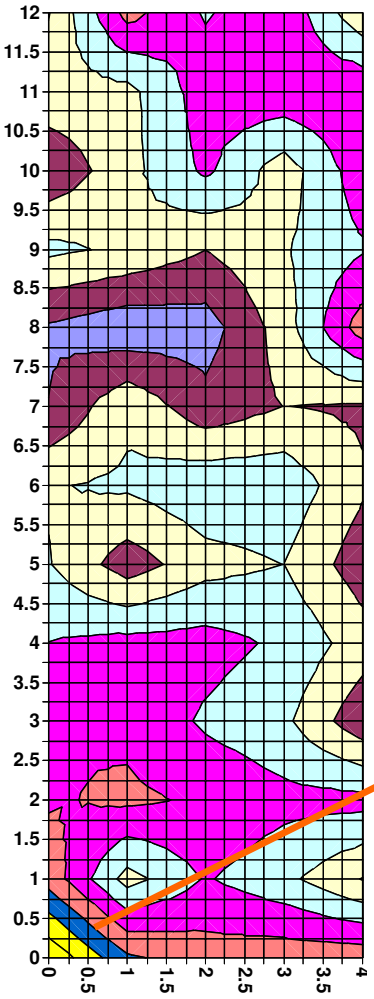


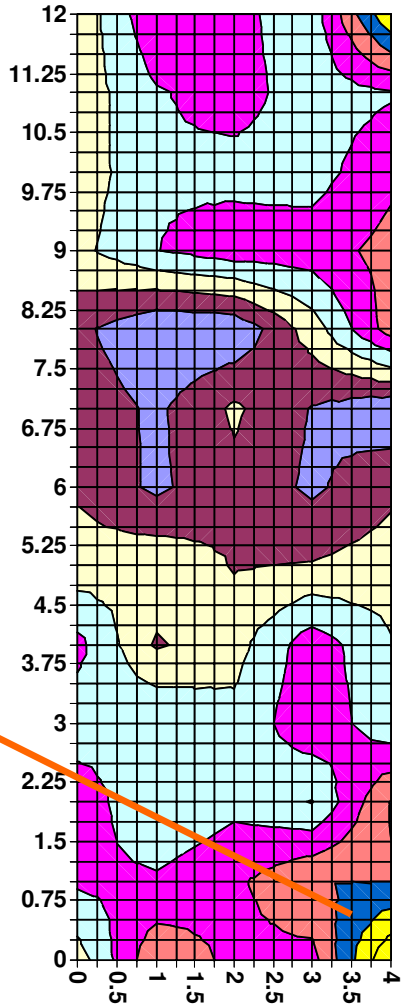
WAP Power Mapping



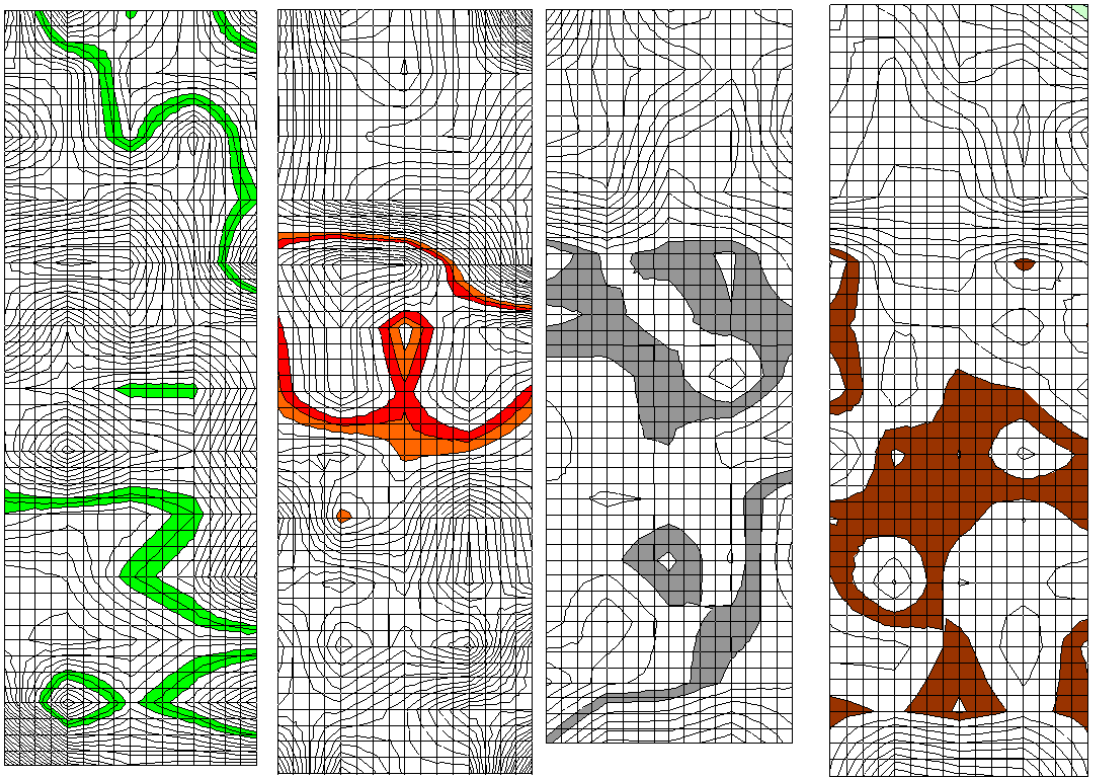


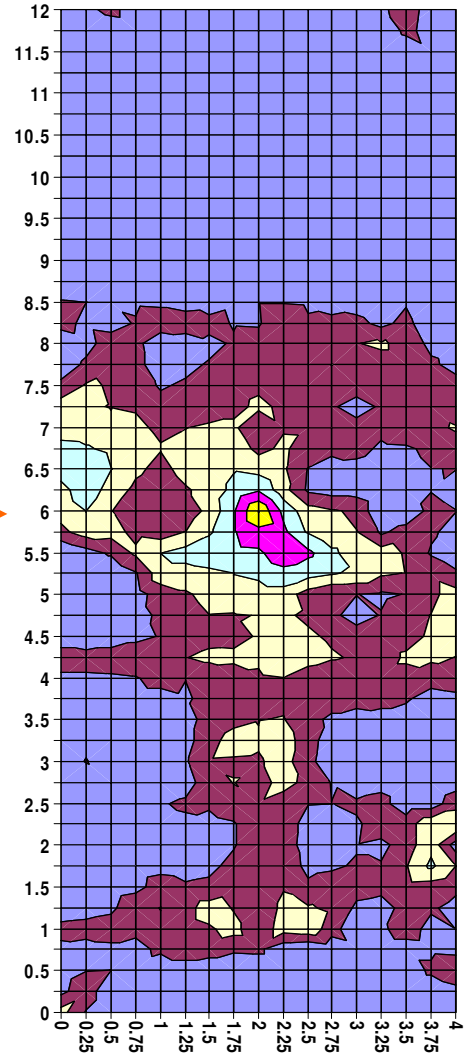
WAP Power Mapping





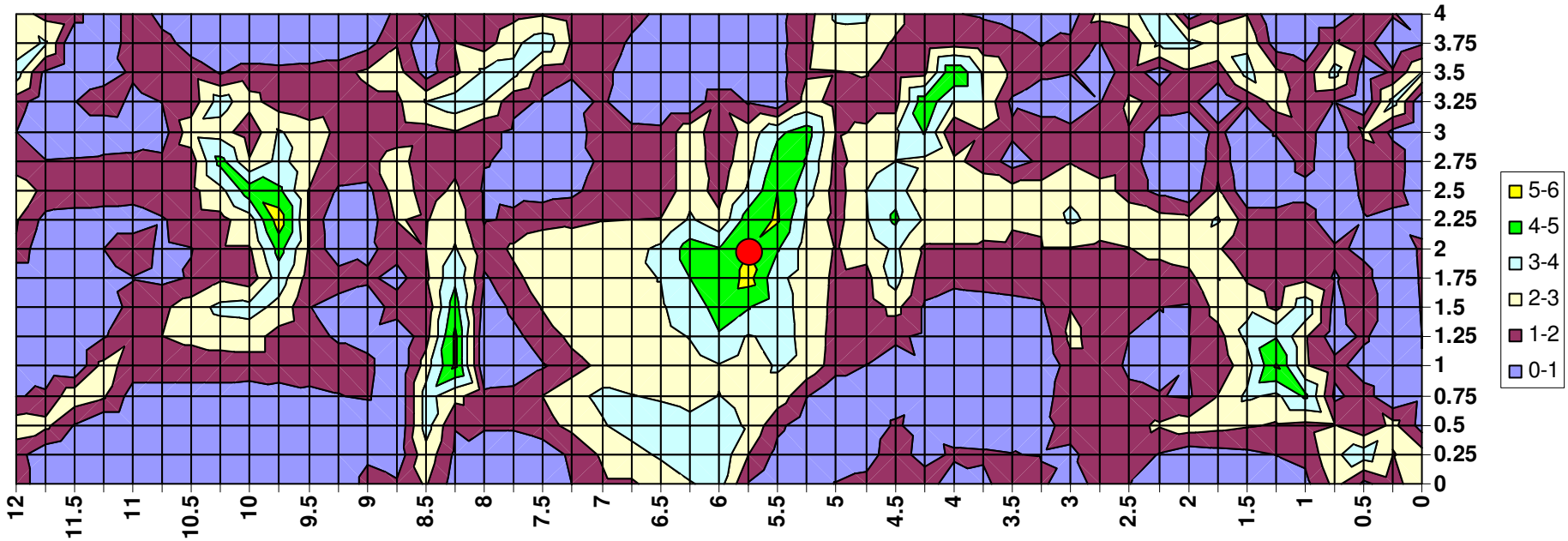
WAP Power Mapping





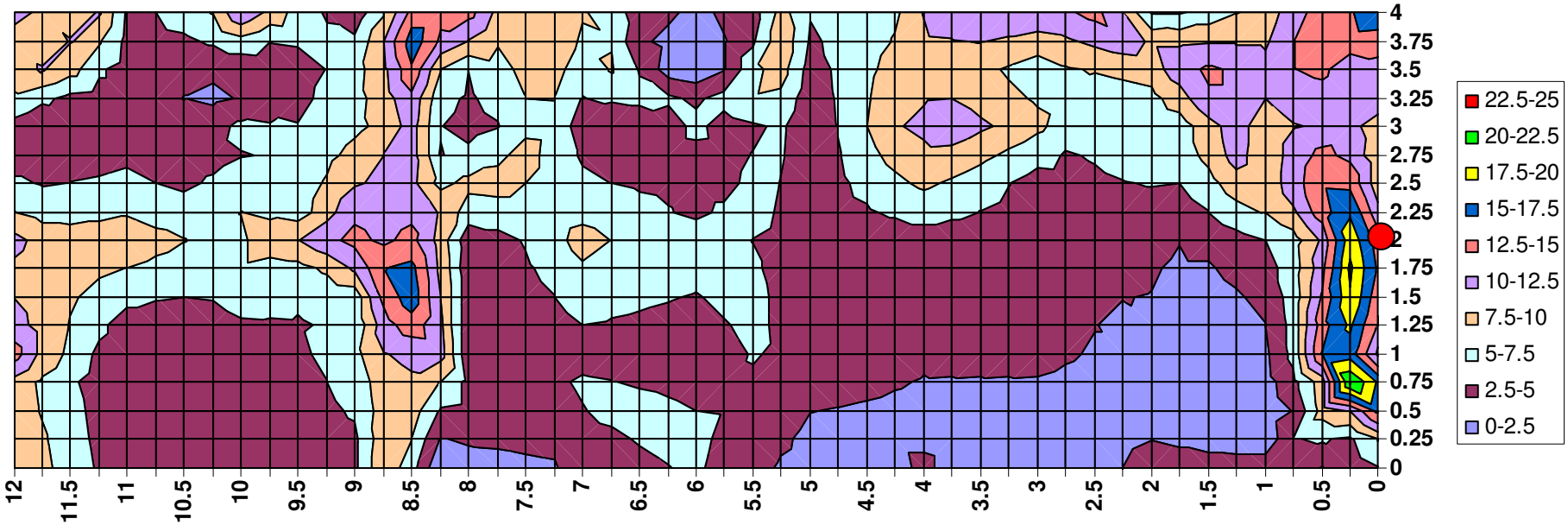
- By adding up the possible locations for the individual WAPS we can find the most probable location
- In this case it is the middle of the test area (ideal case)

WAP Power Mapping



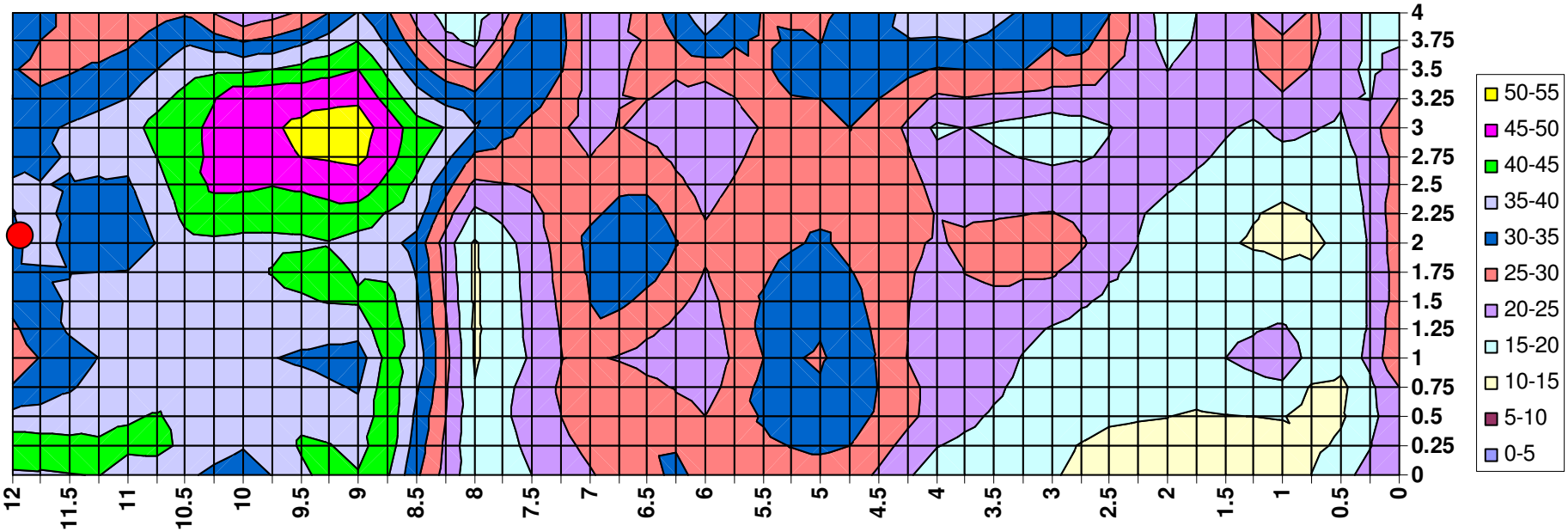
- This is the results of this using real test data
- Person stood in the middle of the test area for 5s (2.5m / 6m)
- Actual location is indicated with red dot
- Error of probable location less than 0.5m

WAP Power Mapping



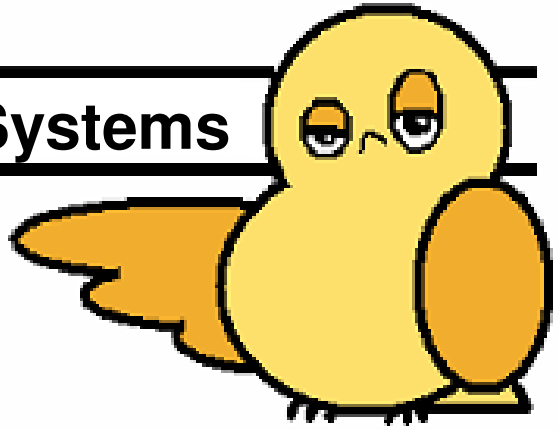
- This is the result uses real test data
- Person stood middle far right of the test area for 5s (2.5m / 0m)
- Actual location is indicated with red dot
- Error of probable location less than 1m

WAP Power Mapping



- This is the result uses real test data
- Person stood middle far left of the test area for 5s (2.5m / 12m)
- Actual location is indicated with red dot
- Error of probable location less than 3m

PosiTrack Systems



Live Demo

April 14th 2010