Electronics Development Corporation

Apex Sensing Using COTS Motion Processor Units

NDIA Fuze Conference

July 9, 2015

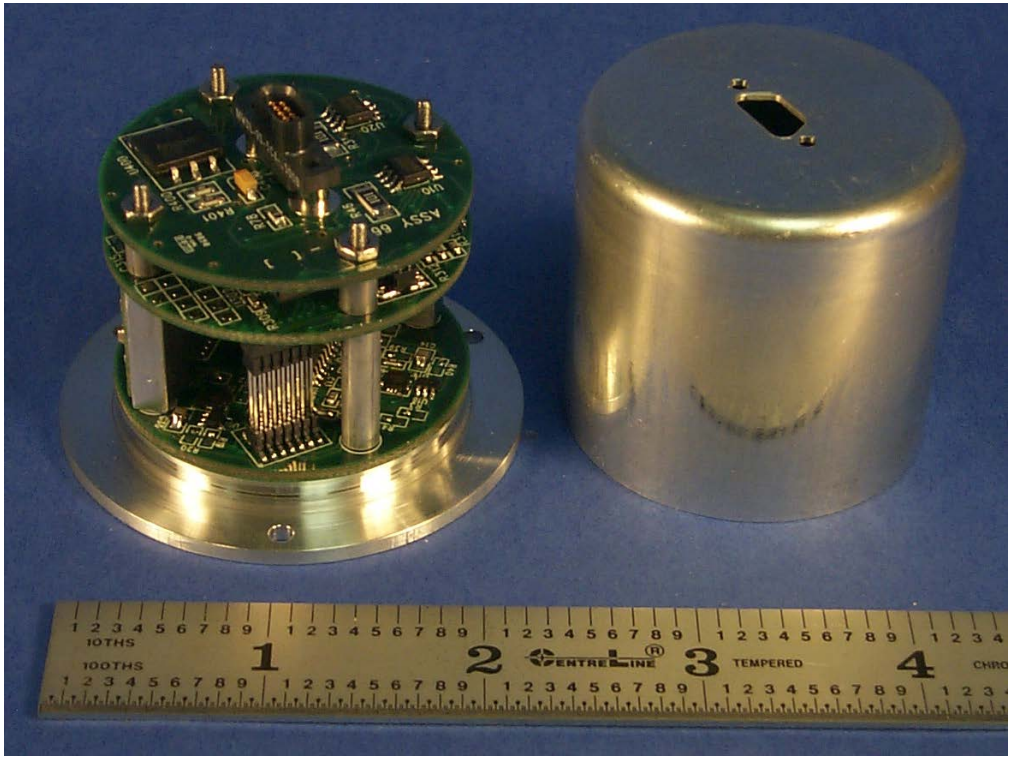
Contact info:
Robert N. Johnson
(410) 312-6651
rnj@elecdev.com

Apex Sensor/Free-Flight Sensor

- Update on in-process investigations
- Leverage mature technology of “motion processors” for smart phones and game controllers
- Smart device that can sense apex:
  - Acceleration only along axis (drag)
  - Roll (spin) okay if present
  - Rotation in another axis (pitch) indicates apex
- Has to be full 6-DoF device
- May be useful for detecting free flight of guided or direct-fire trajectories with different algorithms
- Suitability for munition use under investigation on a CRADA with ARDEC and not covered today

Earlier EDC Free-Flight Sensor

- 2005-2006 timeframe AF SBIR
- “Smart” 6-axis sensor to determine if air-dropped weapons were in free flight and separated from the aircraft
- Worked, but too big and too expensive
- Technology has changed!

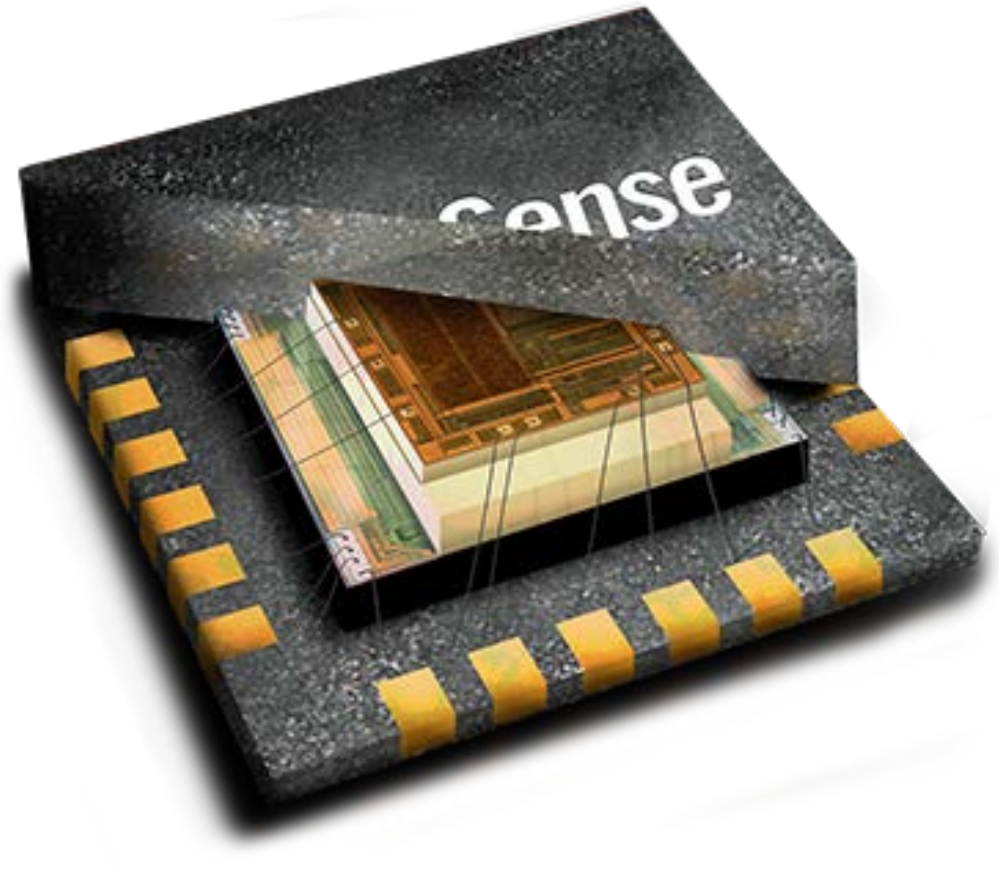


Commercial Motion Processors

- Virtual explosion of use
- Smart phones, fitness bands, game controllers, hobby “drones”, etc.
- 3, 6, 9, even 10 “axes”
- ≈$5 in small quantities, $3 in large quantities
- One major supplier (InvenSense) says they are about to ship their one billionth device
- Active open-source user community

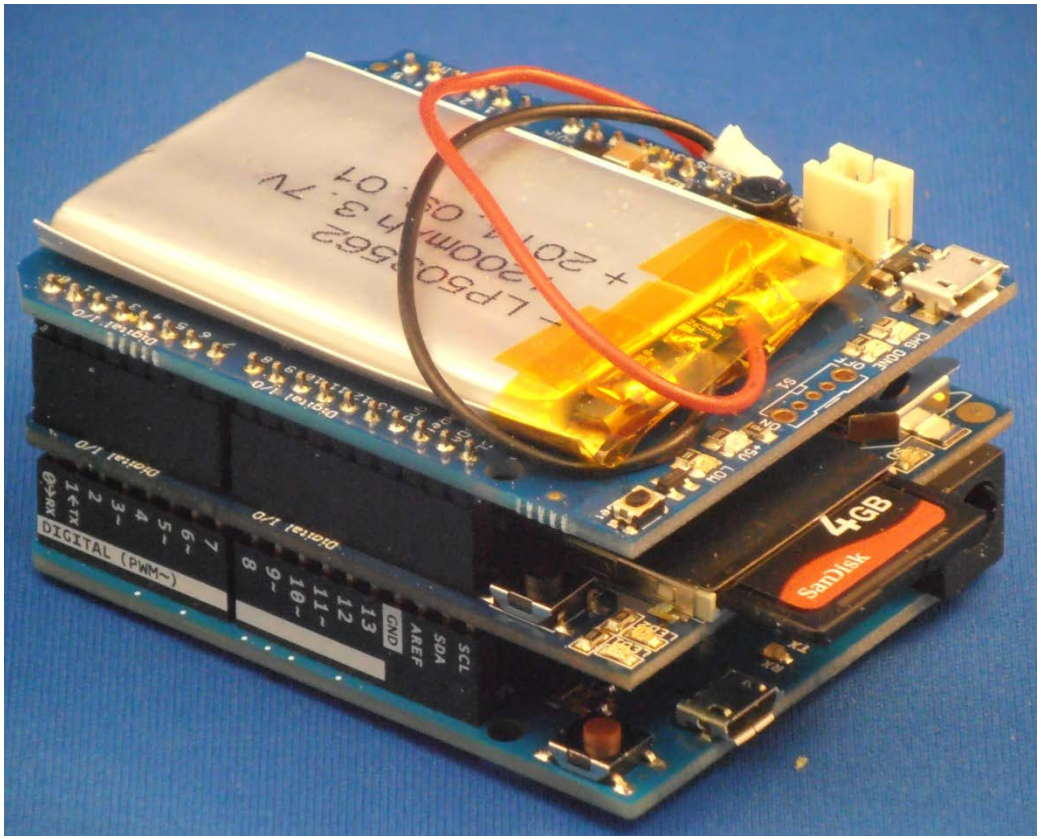
Representative Device

- Multi-chip module with 9 axes in 3 x 3 mm
- Dedicated motion processor (recognize gestures, steps, free fall, etc.)
- On-board 32-bit ARM processor for user applications
- Rated for 10,000 g
- Good test bed for proof of concept

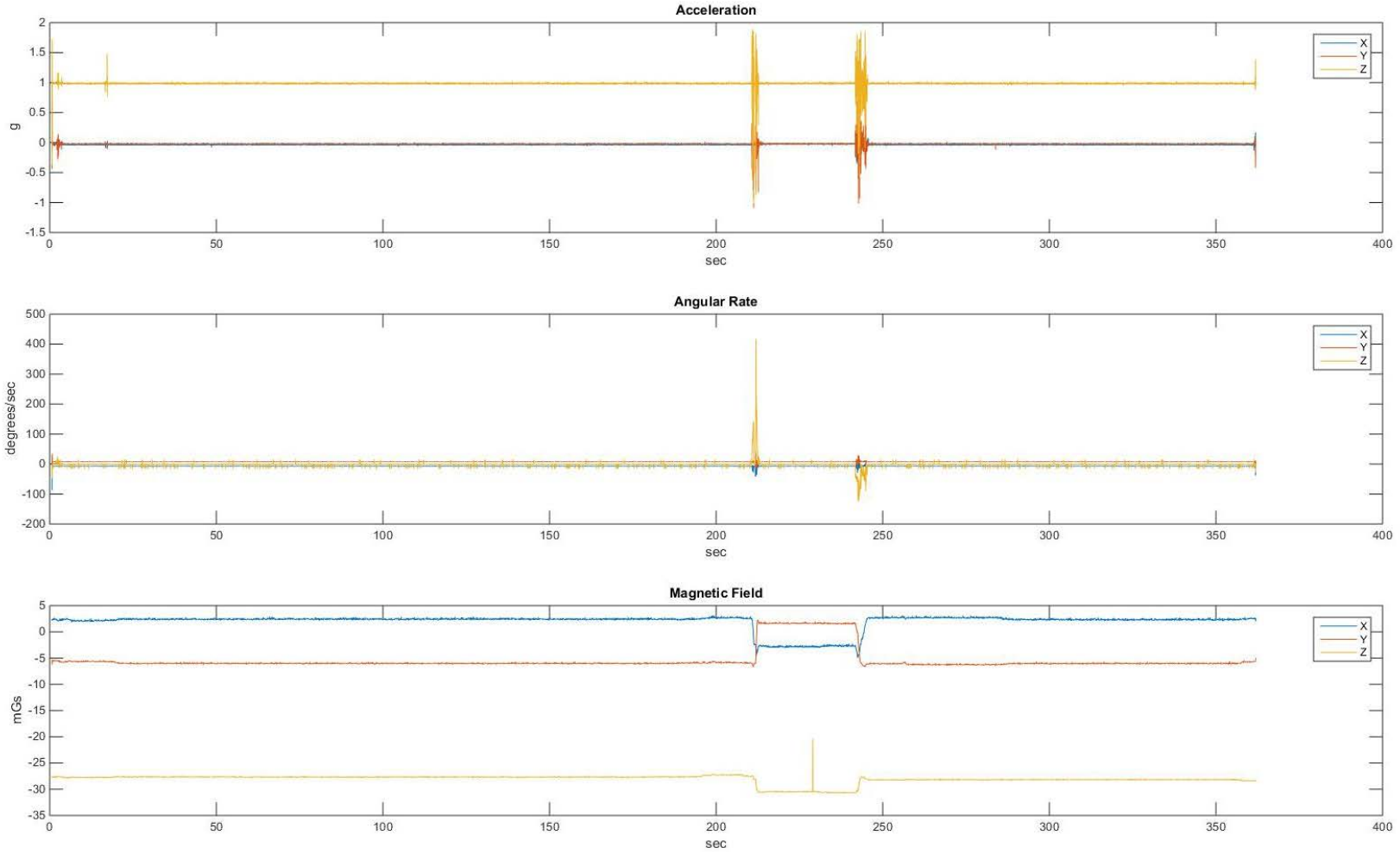


Open Source Motion Recorder

- All COTS
- Arduino-based
- Memory card
- LiPo battery
- Records 9 axes at 100 Sa/s (each) with occasional dropouts
- Big, but used for initial survey testing

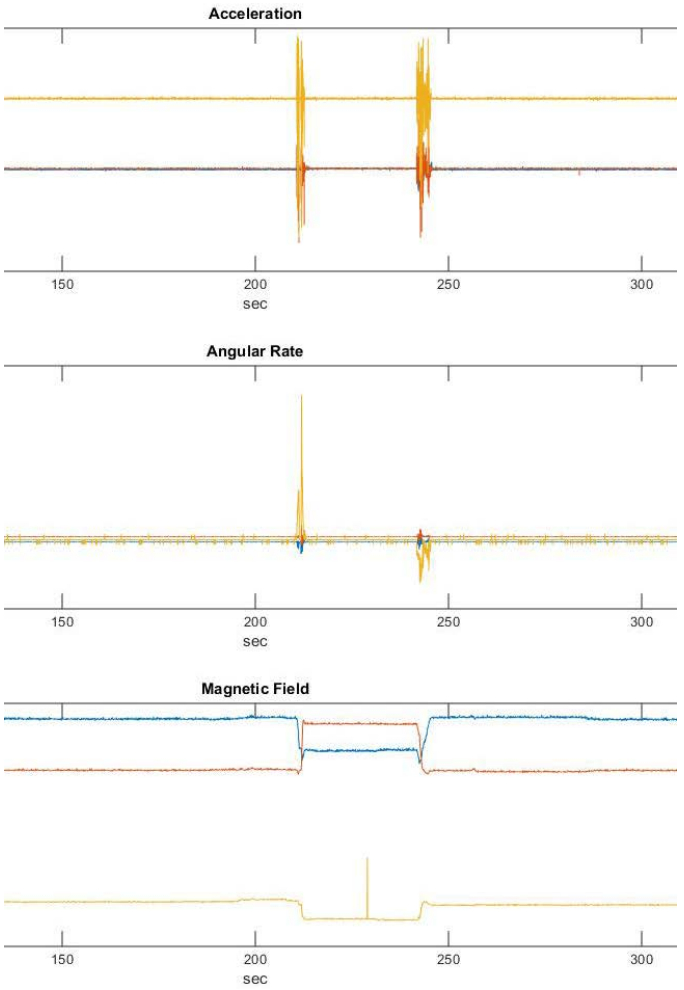


Stability Test – w/180° Rotation



Regarding all those axes…

- Commercial motion processors, and virtually all hobby applications, are attitude sensors
- Rate gyros are “special” – they all suffer from offsets and drift
- Triaxial accelerometers can stabilize roll and pitch, but not yaw
- Magnetometers can stabilize yaw



EDC 6-DoF Test Fixture

- From free flight SBIR
- Can calibrate 6 axes, but can't simulate apex:
  - Free fall, but possibly with drag
  - Random roll orientation
  - May be spinning
- Testing an apex sensor is hard!

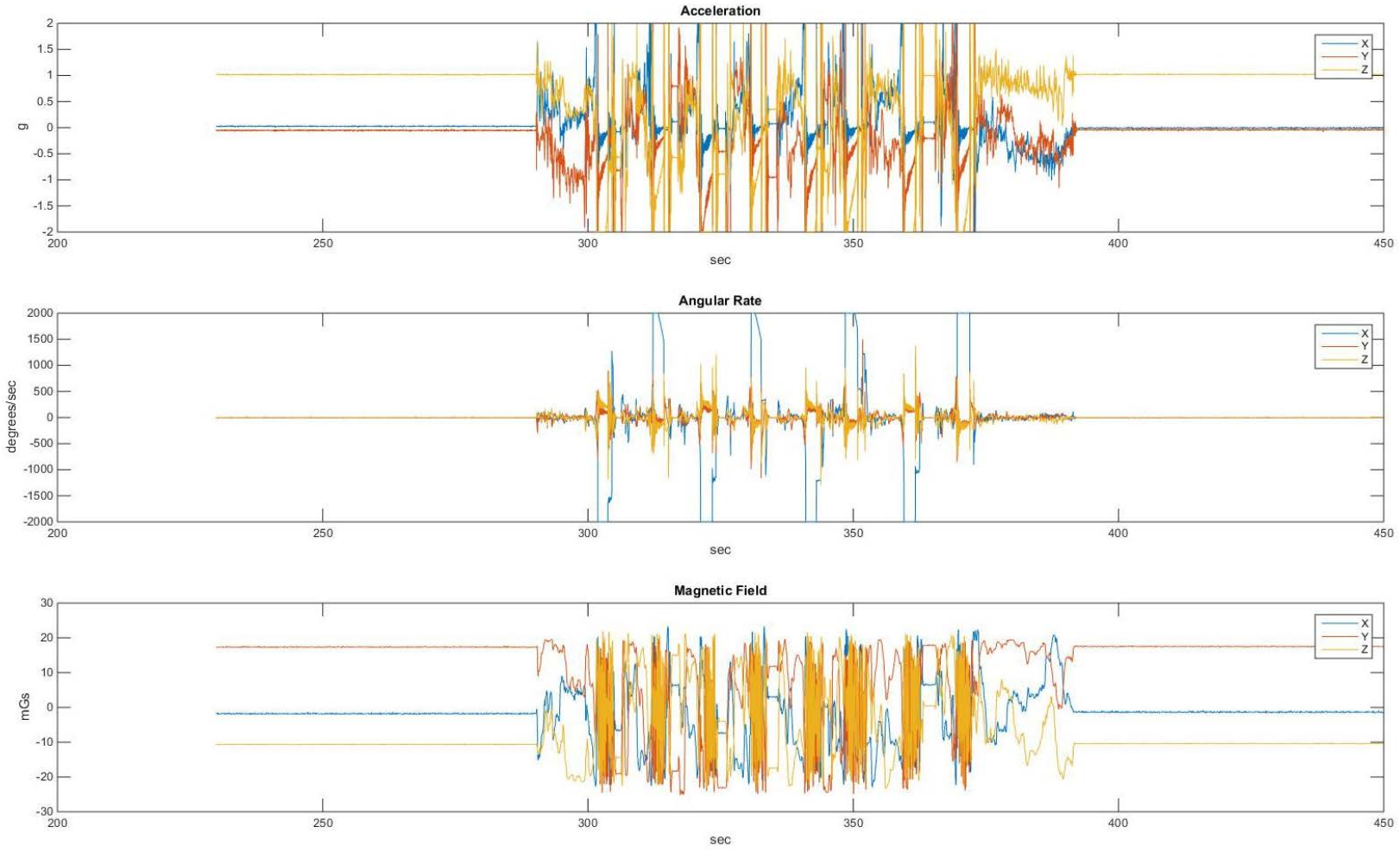
So how do you make an apex?

- With an air cannon and a Nerf football, of course
- Recently upgraded EDC air cannon from 40 mm to 75 mm (to fire baseballs) – even larger in process
- Prototype apex sensor and on-board recorder
- Cannon capable of hundreds of ft/s, but may need higher ballistic density projectile

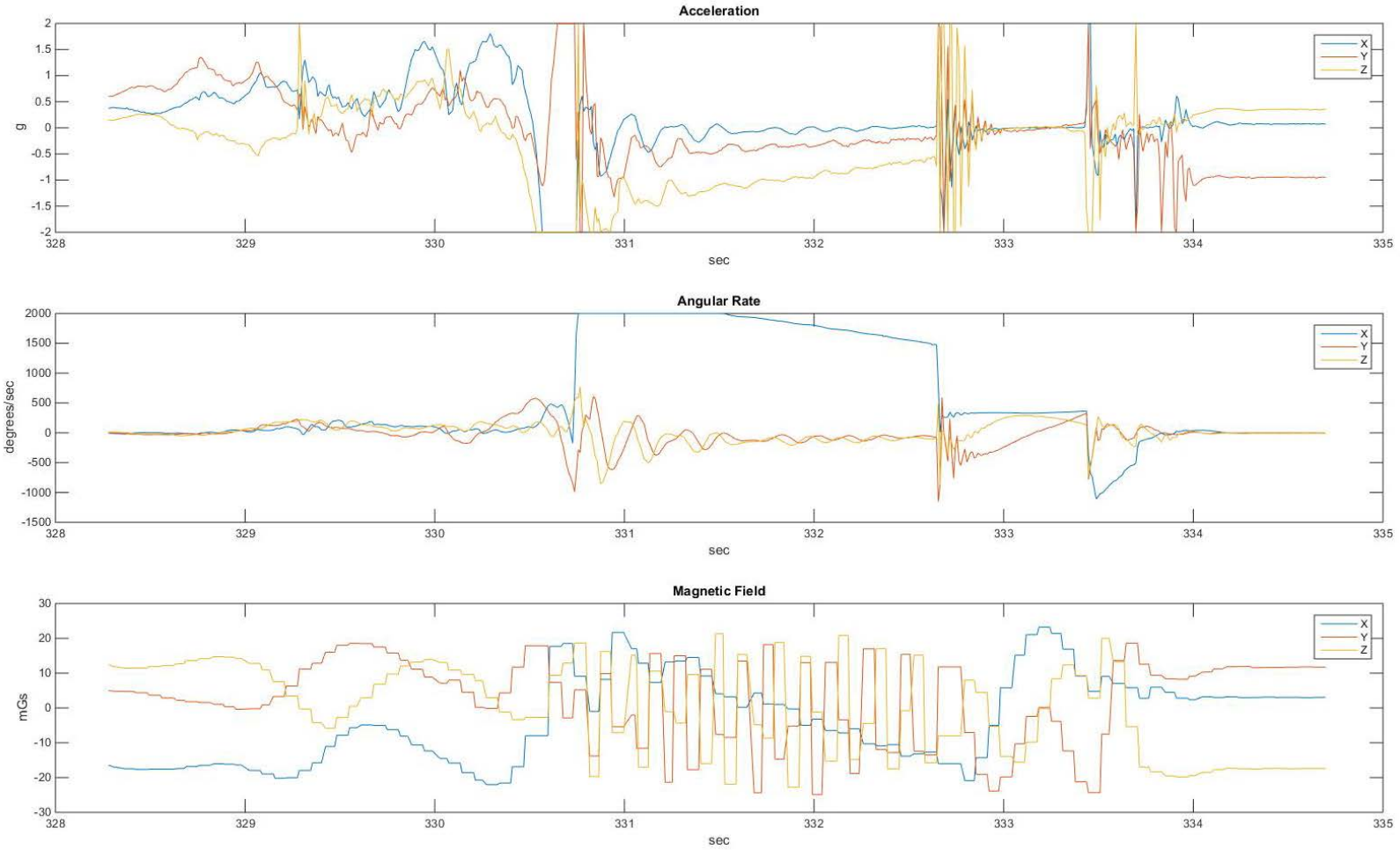
Instrumented Nerf Football

- Arduino recorder described earlier
- This version hand-tossed only, not suitable for air cannon
- Convenient for quick-response survey tests
- Following slides show typical test results

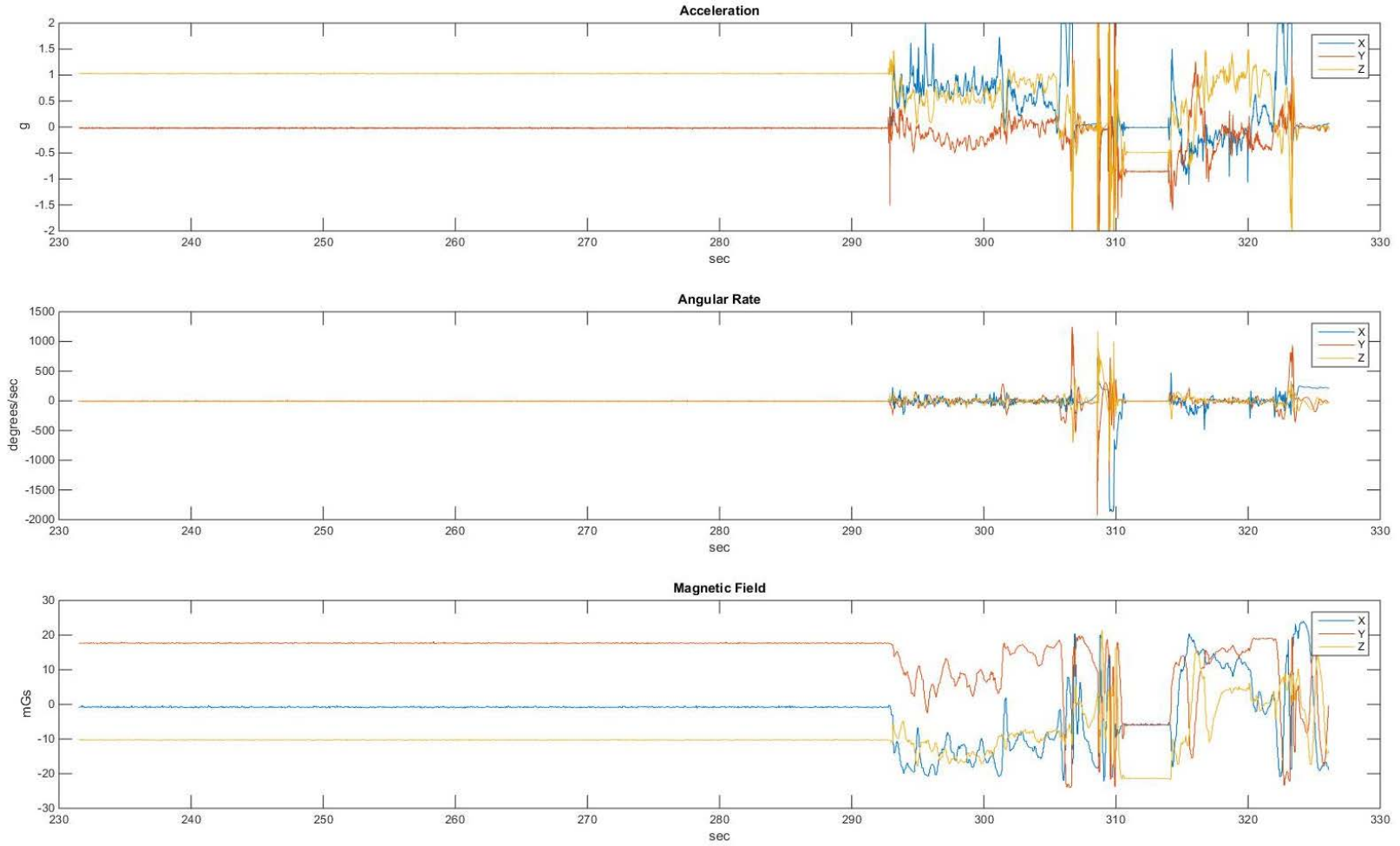
Overhand Throw Series



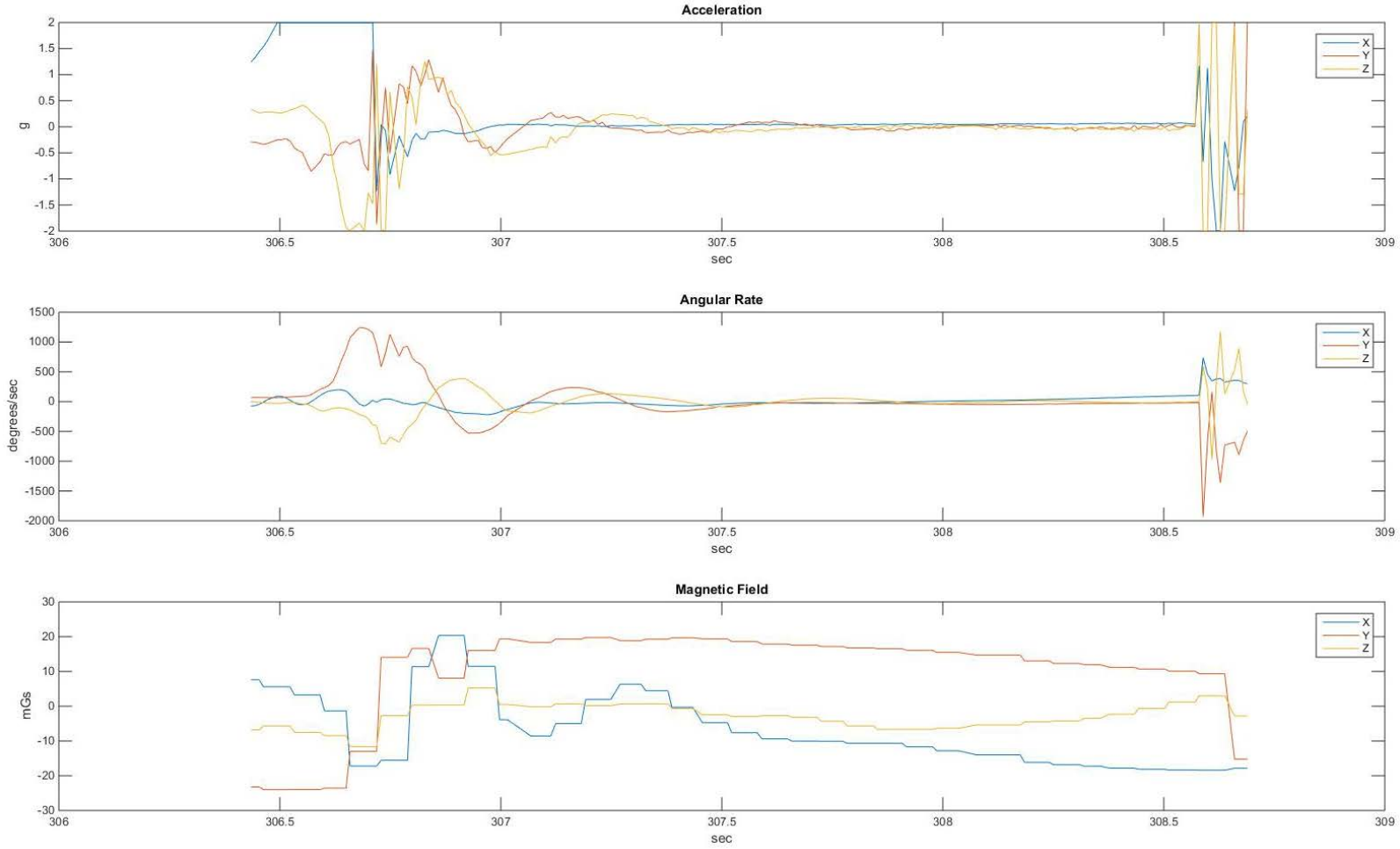
Overhand Throw



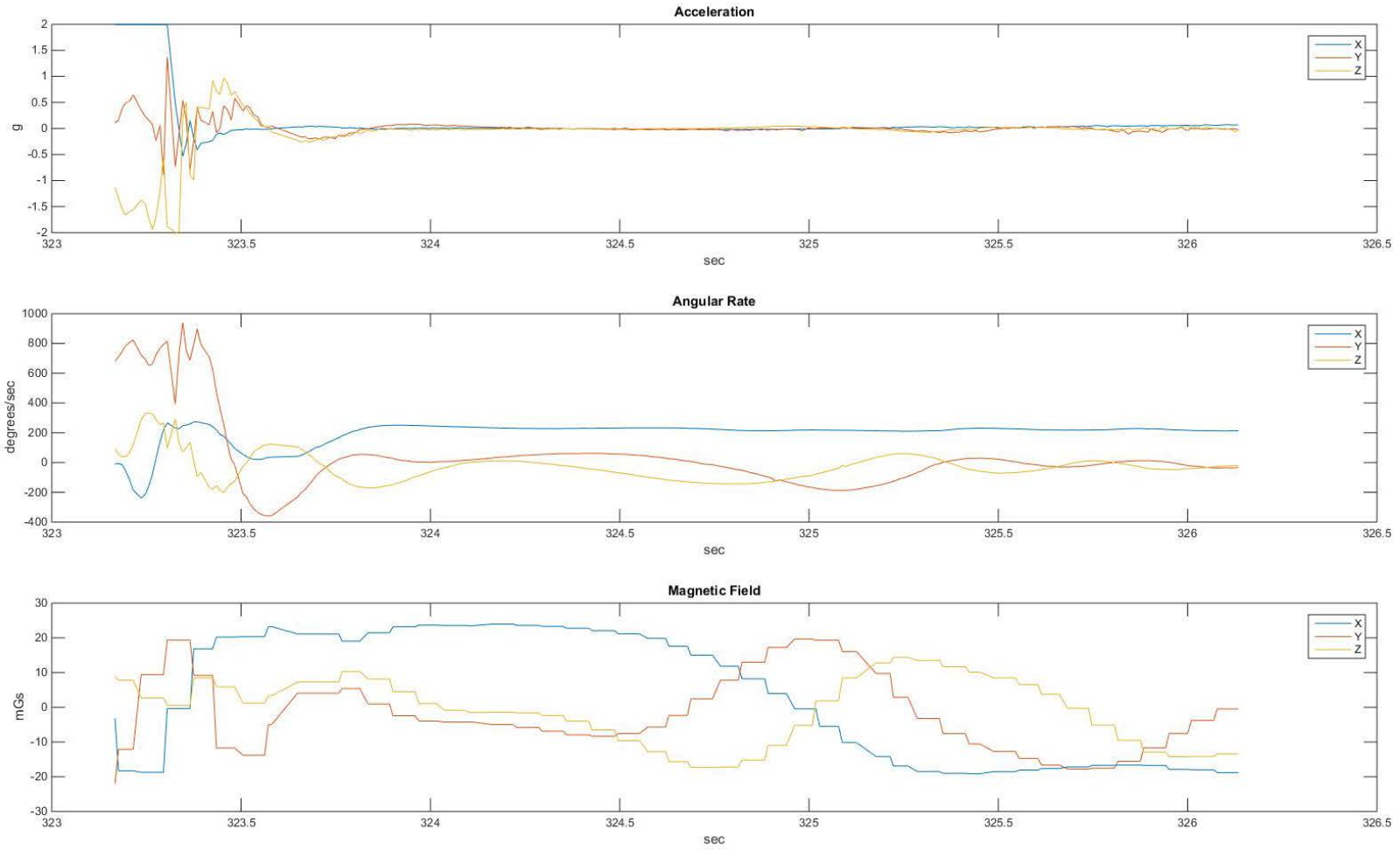
Underhand Throw Series



Underhand Throw -- Flat

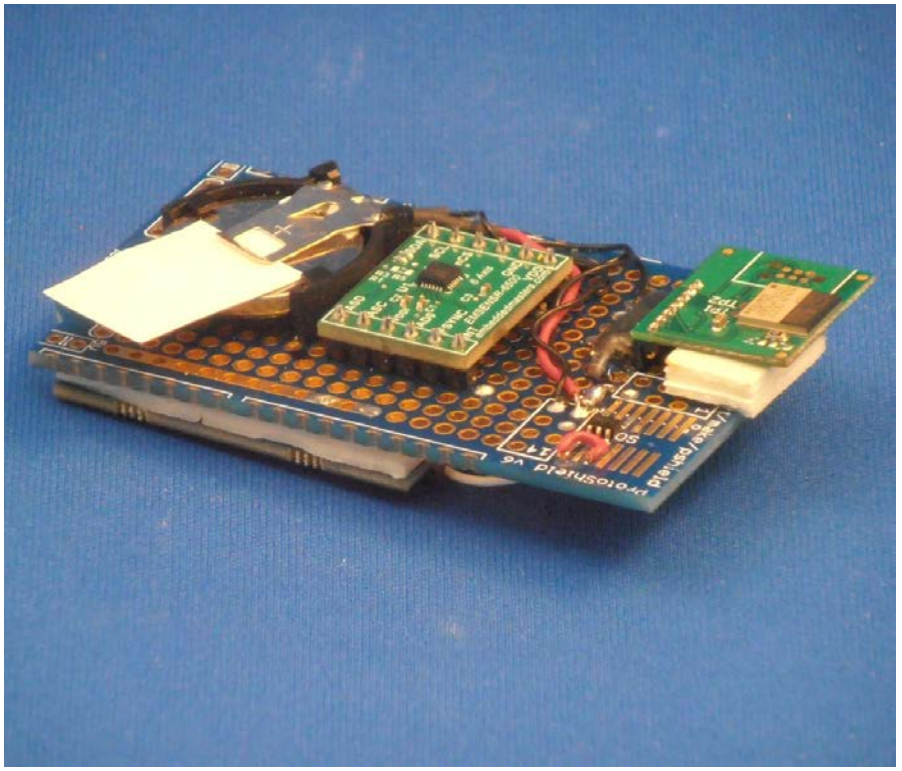


Underhand Throw -- Lofted



Prototype telemetry version

- 3 x 3 mm motion processor on breakout board
- 7 x 7 mm Bluetooth Low Energy module used in streaming data mode
- 100+ m range
- Should be much more rugged
- Also looking at adapting one of our existing gun-rugged recorders



Improved Instrumented Nerf

- Should be rugged enough for air cannon

Apex Sensor Next Steps

- Complete the “ruggedized” Nerf football
- Test using the EDC 6-axis test fixture
- Integrate with telemetry system and test in free flight (hand tossed)
- Test in air cannon
- Start design of higher ballistic density version
- Continue to develop math model of sensor performance for more realistic applications – is this really useful and a valid flight sensor?