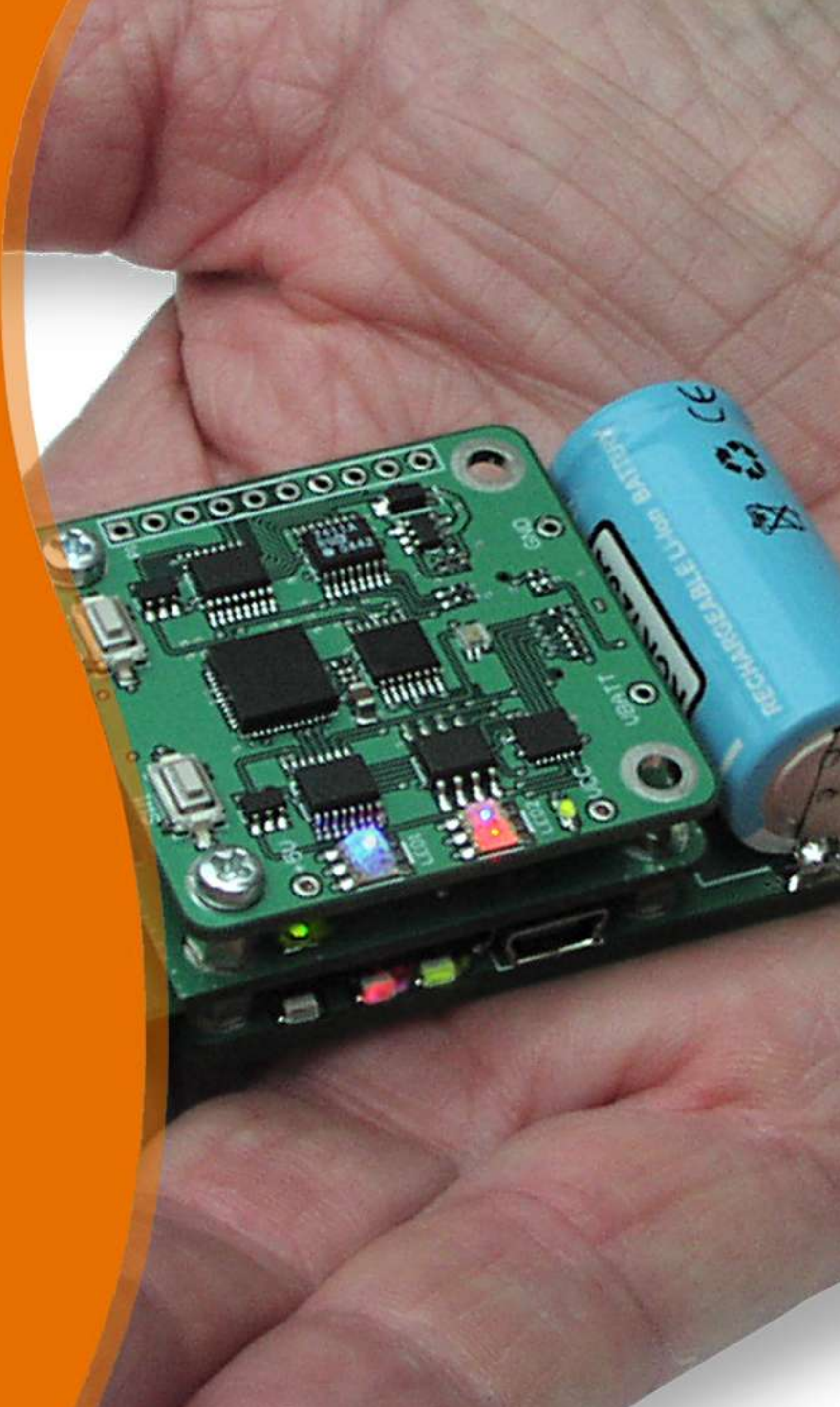
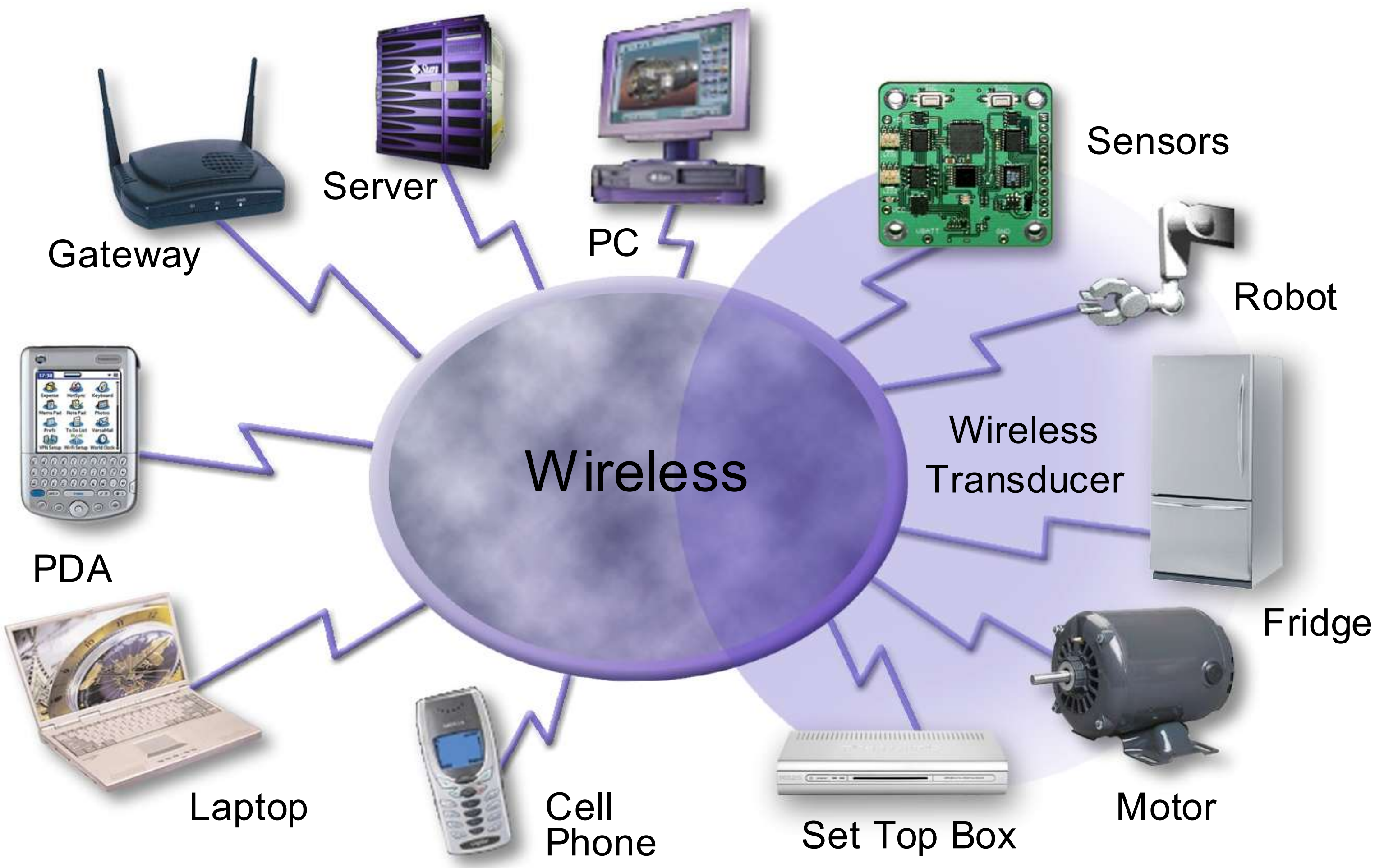
JAVA™ ON SENSORS

John S. Nolan, Cristina Cifuentes
Sun Labs



Wireless Networks



The State of the Art

- Ideas of “Smart Dust”
- Berkeley motes, TinyOS, IEEE 802.15.4
- Sun Labs Anteater project
  - > Research into impact and meaning of such systems to Sun Microsystems
  - > Major customer advantage seen as economics and flexibility
- Most of the work is aimed at infrastructure issues
  - > Size, power, and networking (mesh networking)

Applications: Chicken and Egg

- Not a lot of convincing applications out there based on Wireless Transducer Networks – why?
- Our conclusion: partly due to pain of developing applications using current technologies
  - > Low-level C like languages
  - > Unproductive development tools
  - > Too many low-level concerns in current systems
    - Most high-level software developers do not know how hardware works, or even have an appreciation any more
  - > Not accessible to majority of software developers

What Is Our Solution?

- Provide an opportunity for developers to create applications using Java to run on Wireless Transducer Devices
  - > Java is 4x more productive than C-like languages
  - > VM architecture allows good abstraction of low-level details
  - > VM architecture can protect vital areas of devices from accidental or purposeful corruption
  - > Take advantage of Java's dynamic capabilities for developer productivity

What Is Our Solution? (2)

- Provide a more powerful mid-level device which can be battery powered
  - > Give space to allow exploratory programming
    - Avoid premature optimization issues
  - > Provide a device which will allow more processing closer to the transducer to reduce network traffic
    - Network accounts for majority of power drain
    - Be smart about what to send – requires processing
  - > Enable over-the-air reprogramming
    - Greater developer productivity
    - Leverages dynamic nature of devices and Java

Demonstration

- Demonstration of programming and deploying
- Demonstration of hardware devices

How Can We Provide Java on Next Generation Sensor Devices?

- Squawk VM
  - Small J2ME VM written mainly in Java
  - Able to run on-the-metal, without an underlying OS
  - Simple port to different platform
- Build new wireless sensor device using off-the-shelf hardware components

6 months later ...

The SunSpots System

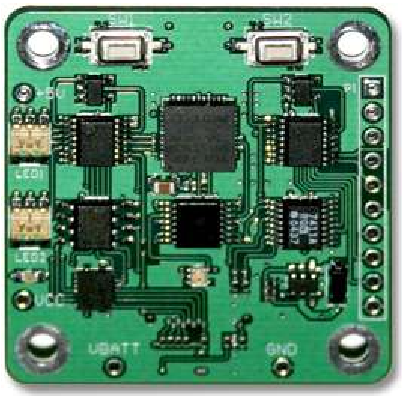
- Hardware
  - > 32-bit ARM core
  - > Chipcon CC2420 based wireless platform
  - > SPI based peripherals
  - > Simple sensor board
- Software
  - > Squawk: Java VM
  - > Desktop build and deploy scripts
  - > Libraries for
    - Driving hardware: radio, sensor boards, ...
    - Basic 802.15.4 network functionality
  - > SpotWorld: graphical desktop interface

SunSpot Hardware

- ARM7 core
  - 256K RAM/2M ROM
- CC2420 radio
  - Strip antenna
- Single LED
- Double sided connector for stackable boards
- Can be powered from single 1.5V battery
  - Requires 25-90mA depending on operation
- 35x25 mm in size
- Supporting testboard with USB connection to desktop

SunSpot Sensor Board

- All-singing sensor board
  > 3D accelerometer
  > 9 I/O Pins (PWM capable)
  > Temperature sensor
  > Light sensor
  > IRDA serial connection



- Mainly for demonstration purposes
  > All SPI driven peripherals
- Users can build own transducer boards
  > Experimental board available

SunSpot Squawk VM

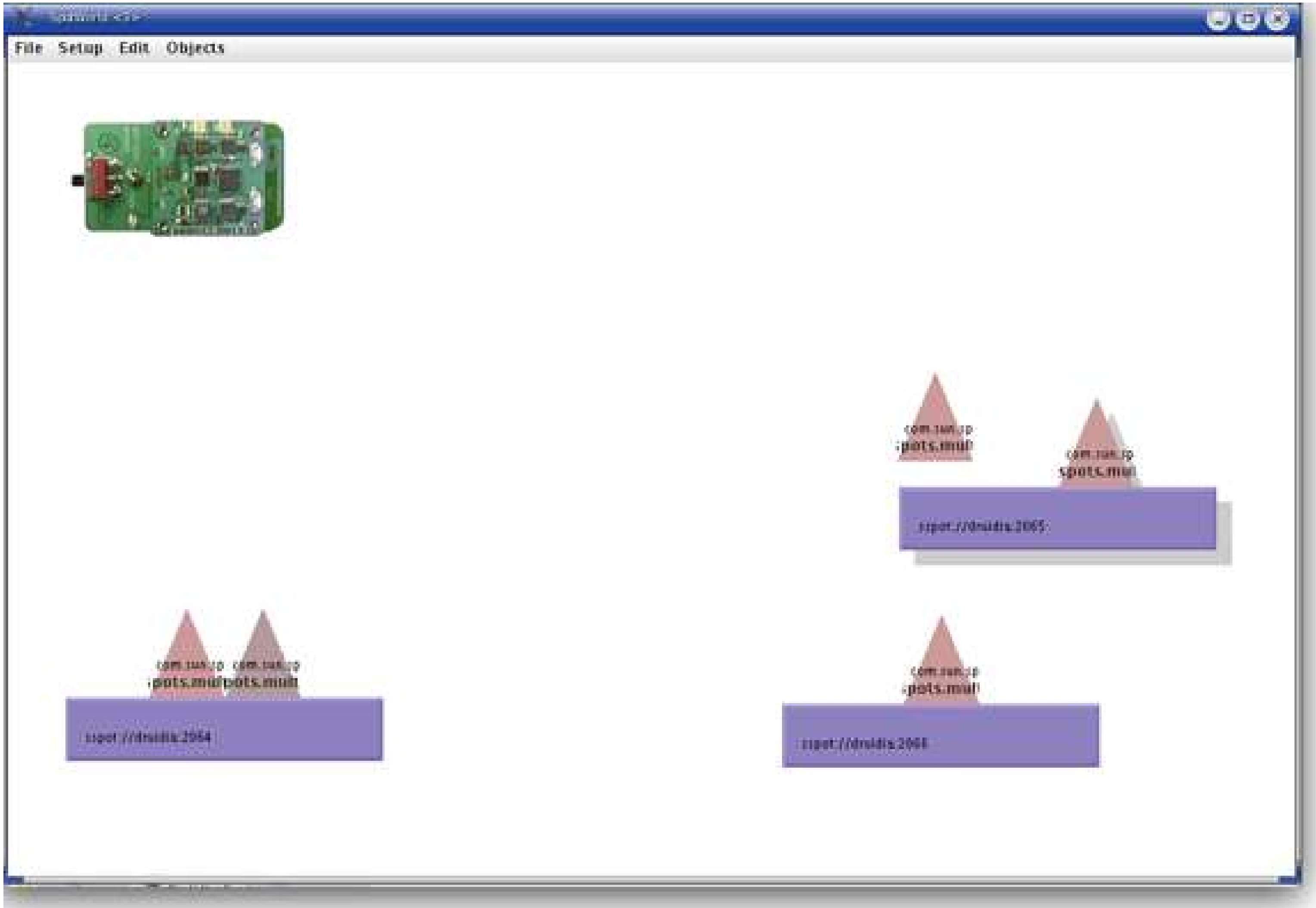
- Fully capable CLDC 1.0 Java VM
  - > GC, threads, etc.
  - > Extra features: isolates, suites, direct interrupts, etc.
  - > Tiny amount of C, mainly written in Java
  - > Currently 80K RAM for VM
    - Can reduce overhead by using some parts from flash memory
  - > Libraries 380K flash
    - Most of the Java components of the VM
    - Full CLDC 1.0

SunSpot Build and Deploy Scripts

- Full range of developer tools
  - > Use standard IDEs to create Java code
  - > Build and deploy scripted to make as simple as possible
    - Ant based
  - > Simple debugger available
    - Working on compliant JDWP debugger

- USB connection to testboard
  - > Testboard provide port for SunSpots
  - > Can program devices on testboard
    - Working on over-the-air programming of SunSpots

SunSpot SpotWorld



SunSpots: Enabling Developers To ...

- Build wireless transducer applications in Java
  - Use simple sensor board for IO
  - Use simple radio connections to communicate
- Integrate new hardware
  - Utilize libraries to integrate own hardware devices
- Build new network layers
  - Access to all levels of hardware via Java
  - Can implement own protocols
  - Can implement own MAC if desired

Future

- Collaborate with qualifying partners, July 2005
- Use within Sun Labs
  - > Gesture based interfaces, building instrumentation, self-organising systems, etc.
- Iterate hardware design
  - > Smaller chips, lower power, cheaper, etc.
- Iterate VM
  - > Smaller footprint, faster, smarter interrupts, power management, etc.
- Open schematics and VM to the community?

Conclusions

- Java on “wireless sensor networks” is here
  - > Small Java-based VM
    - Java runs on the bare metal, no underlying OS needed
  - > Better developer experience than the state-of-the-art
    - Standard Java development and debugging tools
    - Simple out-of-the-box experience (SpotWorld)
  - > Mid-level sensor device that can be battery powered
    - Enable exploratory programming
    - Enable more on device computation and reduce network traffic
    - Enable over-the-air programming

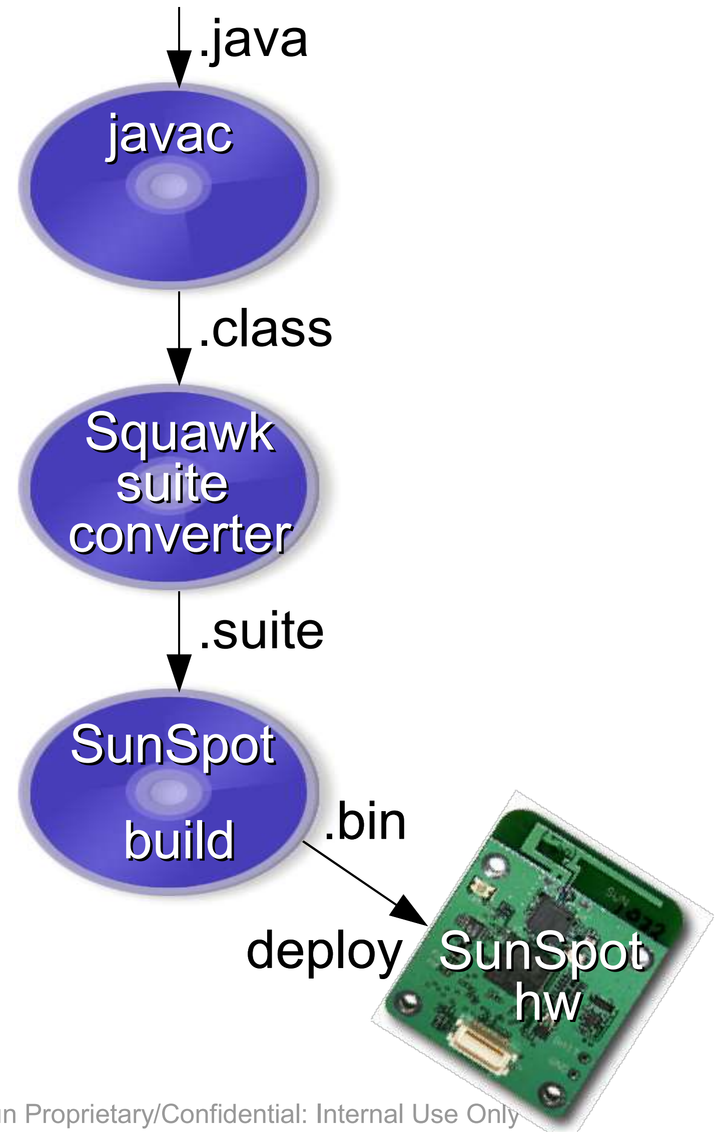
The Team

Questions

Appendices

- Following slides are additional material which can be used in support of questions, or purely just FYI

SunSpot Build and Deploy Process



SunSpot Software Libraries

- Standard J2ME Java libraries
  - > CLDC 1.0
- Hardware libraries
  - > SPI, AIC, TC, PIO drivers all in Java
  - > Sensor board hardware driven by Java (no C)
    - ADCs, GPIO, IRDA, etc.
- Radio libraries
  - > Drive Chipcon CC2420 hardware from Java (no C)

Software Libraries (2)

- Network libraries
  - > 802.15.4 MAC layer in Java (no C)
  - > Simple GCF implementations of connections
- Desktop libraries
  - > Create connections from standard J2SE VMs to wireless devices
  - > Utilize Spot in testboard as a gateway

Example: Application

```java
//Open a stream over the radio

StreamConnection conn = (StreamConnection) Connector.open
                                           ("radio://"+otherSpotAddress+":100");

DataOutputStream output = conn.openDataOutputStream();


//Read pin 4 of the ADC on the Sensor board (ADT7411 is the type of ADC)

RangeInput input = new ADT7411RangeInput(Sensorboard.getADC(),4);


//Loop and send the data

while(true) {

    try {

        output.writeInt(input.getValue());

        output.flush();

        Thread.yield();

    } catch (Exception e) {

        System.err.println("SENDER problem "+e);

    }

}
```

Example: Sensor

```
public synchronized static Accelerometer3D getAccelerometer() throws IOException {
        if (accelerometer == null) {
            //get the ADC inputs
            RangeInput xInput = new ADT7411RangeInput(getADC(),4);
            RangeInput yInput = new ADT7411RangeInput(getADC(),5);
            RangeInput zInput = new ADT7411RangeInput(getADC(),6);

            //get the contol pins
            SingleBitOutput selfTest = new MAX6966SingleBitOutput(getIOPort1(),7);
            SingleBitOutput powerDown = new MAX6966SingleBitOutput(getIOPort1(),8);
            SingleBitOutput fullScale = new MAX6966SingleBitOutput(getIOPort1(),9);
            accelerometer = new LIS3L02AQAccelerometer
                                   (xInput,yInput,zInput,selfTest,powerDown,fullScale);
        }
        return accelerometer;
    }
```

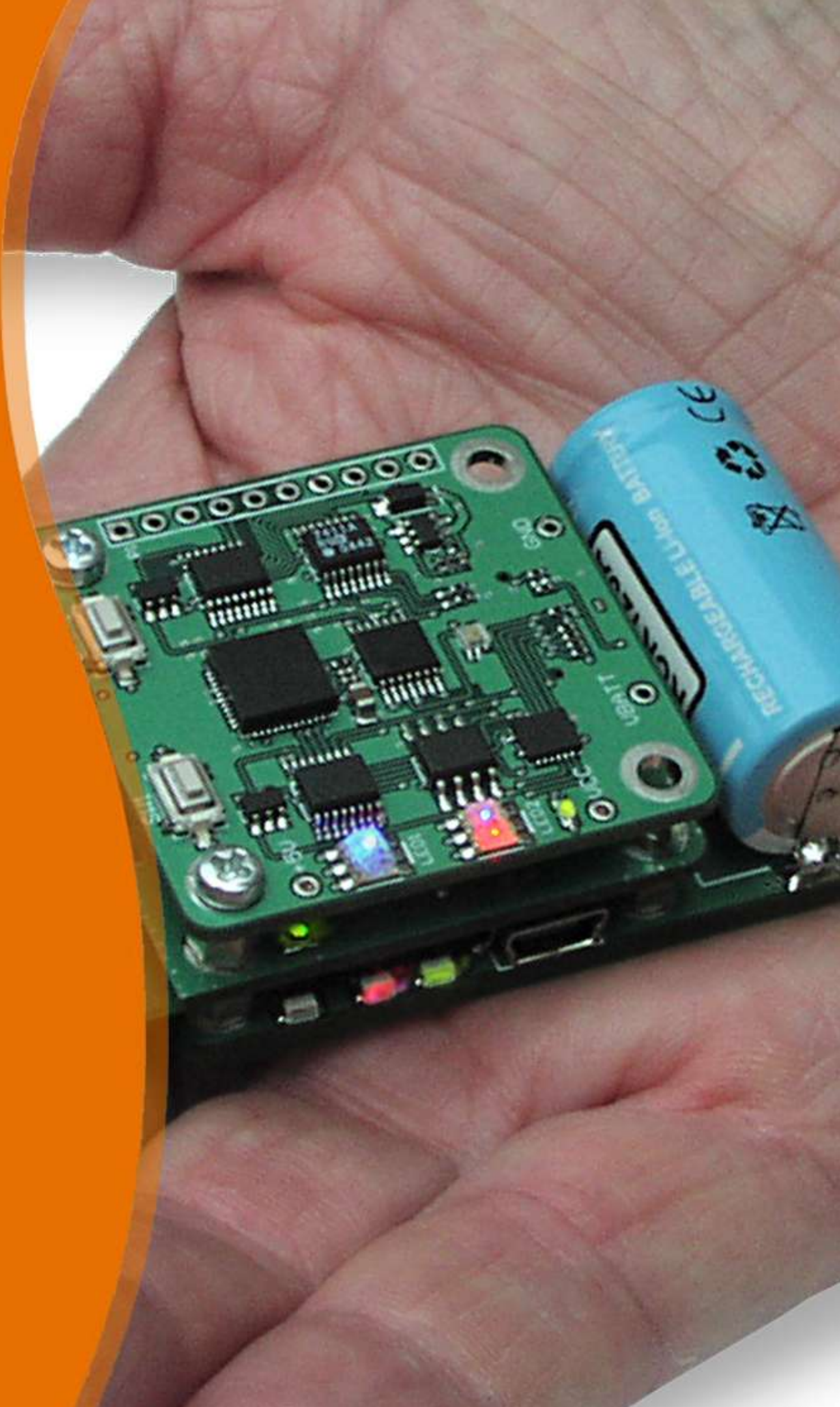
Experimental Results (April 15, 2005)

Benchmark	.class	.suite
Richards (Gibbons)	11,770	4,584
Richards (Deutsch)	19,655	6,788
DeltaBlue	27,520	9,724
Game of Life	7,390	3,396

Sampling (samples/sec)	
ARM PIO lines	11,760
Sensor board input lines	300-800

Radio range:	90 mts

Benchmark	LOC	ms on ARM7 EB40 board
Richards (Gibbons)	410	5,277
Richards (Deutsch)	456	8,382
DeltaBlue	984	4,766
Game of Life	354	4,032



john.nolan@sun.com
cristina.cifuentes@sun.com