

**Bristol Systems Inc.**

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# **Technologies to Watch in 2008**

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# These are OLD Technologies!

- Rule of thumb: 10 years from lab to market with a HUGE  $\sigma$
- Technology Readiness Levels (AF, NASA)
  - Principles, concept, proof of concept, lab breadboard, environment test, prototype, system test, statistical testing.
- Convergence
- Market readiness (telecom vs. healthcare)
- Competing technologies

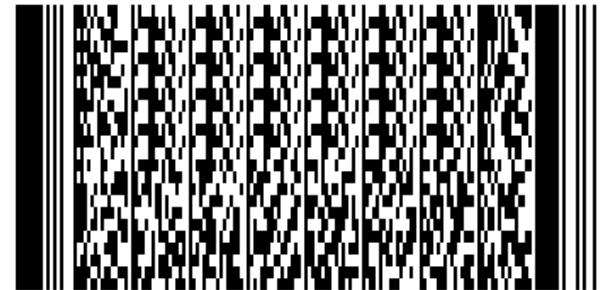
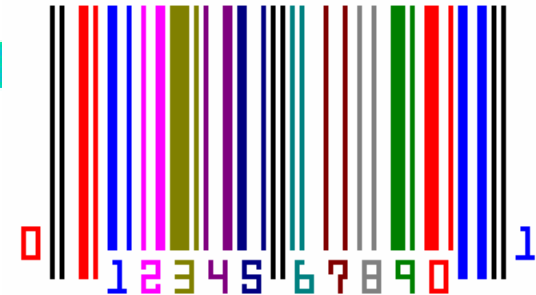
# Key Technologies

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- Wireless: cell, DSRC, RFID, AEI, 4G, ...
- Intelligent antennas & software radio
- Sensors and Nano-technology
- GPS3
- Satellite photo, GIS, and map integration
- Biometrics
- Organic LEDs
- Your favorites???

# 1 & 2D Barcodes

- 1D barcode
  - Invented 1948
  - Capacity a dozen or so characters
  - Usage: failed for RR cars; UPC in 1973, self ID
  - Many variants and codes
- 2D barcode
  - Invented 1990
  - Capacity several K
  - Usage: postage, self ID,...
  - Many variants and codes



# RFID

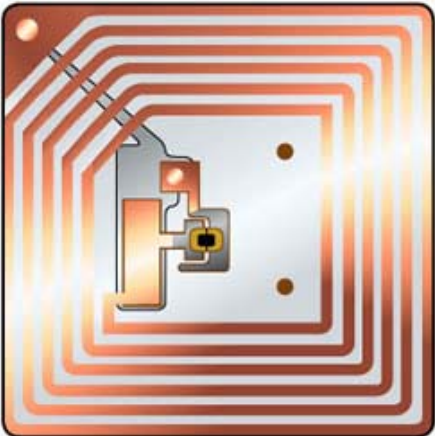
RFID = Radio frequency (self-) identification (device)

- Invented circa 1940's - for tracking and espionage; modern patents in 70's and 80's. Uses active reader energy reflection to return information.
- Attachable, implantable, insertable, and even digestible (Kodak, to monitor drug ingestion)
- Passive (usually), active and semi-active
- Manufacturing races: Hitachi Feb 2007 0.05mm x 0.05mm, paper embeddable, 2-300m range
- PolyIC, Philips: 13.56Mhz polymer tags, roll-printable. Promising but silicon may win.
- 2007: built-in firewalls and anti-spoofing

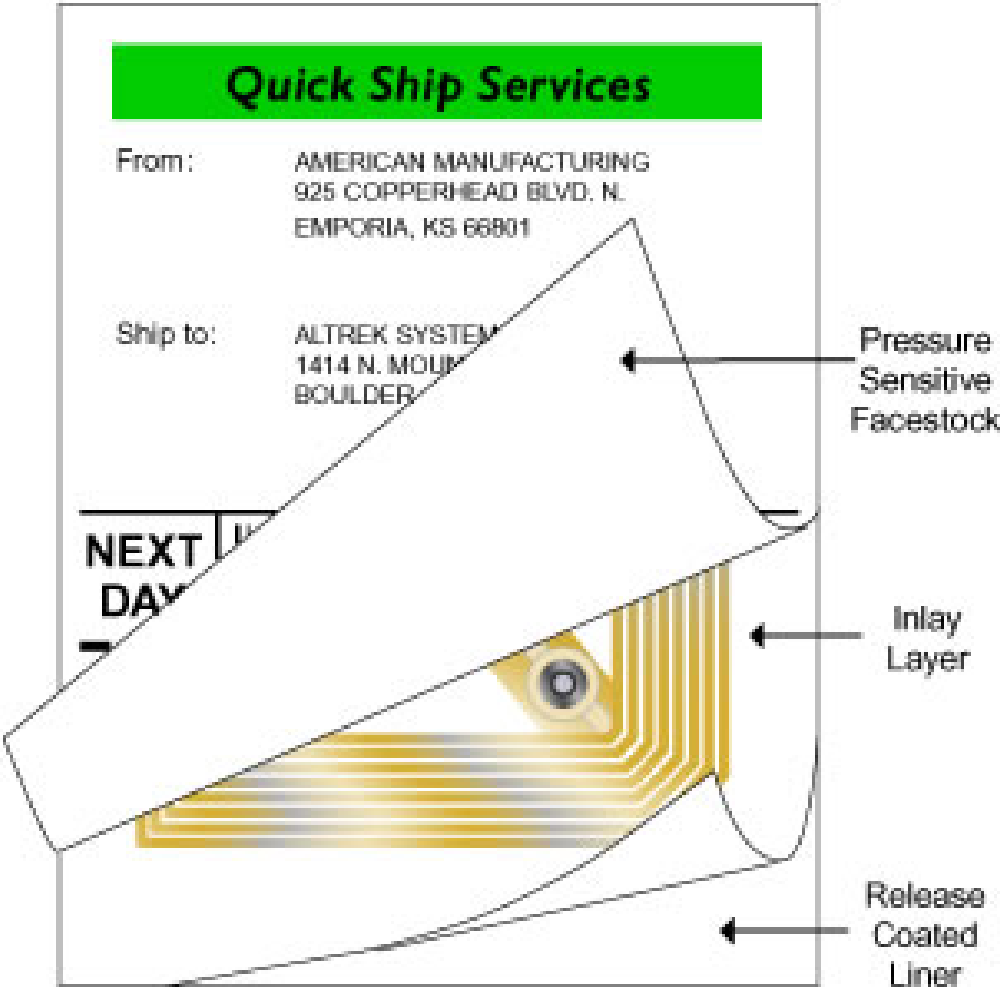
# Small RFIDs



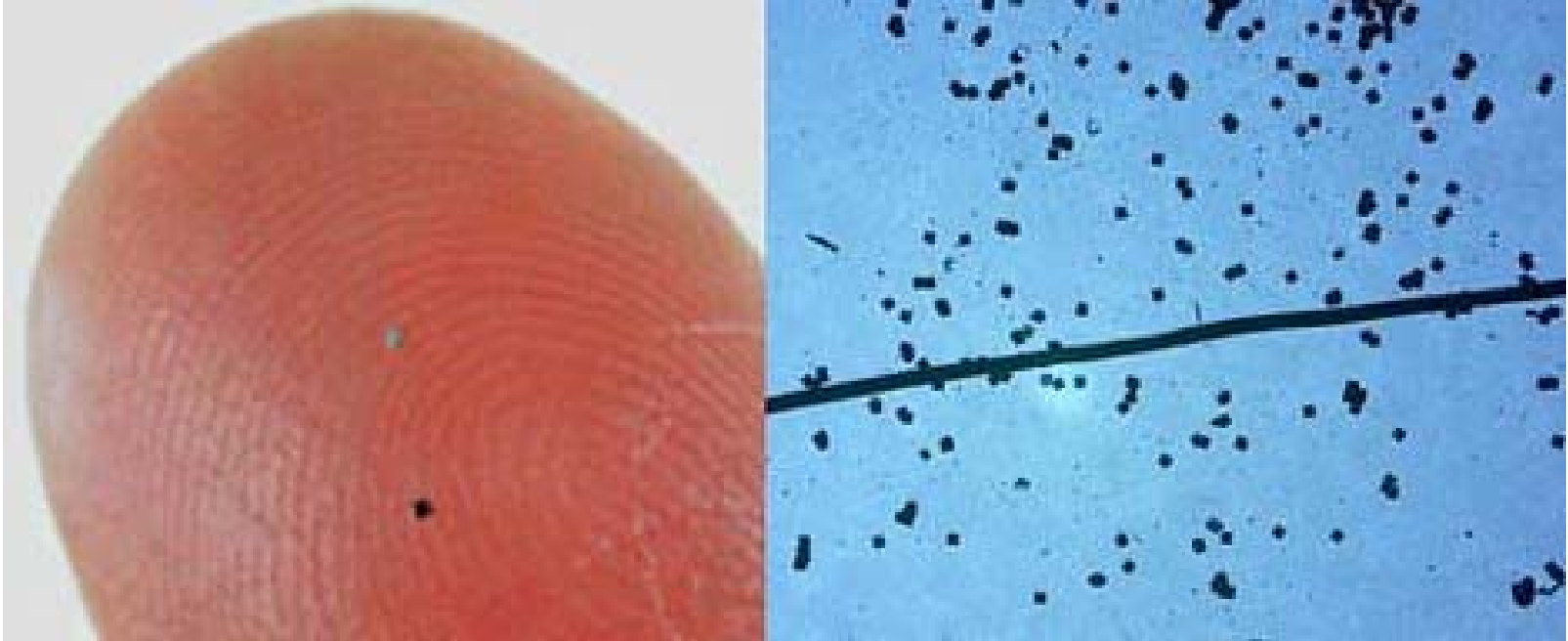
9mm tag



1cm tag



# Tiny RFIDs



Hitachi's "RFID powder" 0.05 mm x 0.05 mm, Announced Feb 2007  
with applications in 2-3 years

# Medium RFIDs

## ➤ Toll Road Sensors



# Automatic Equipment Identification

- Railroad cars
- 1970's attempt to use bar codes failed (dirt)
- 2 Watts
- 902.250-921.500 Mhz
- Passive tags



# RFID vs. 1&2D barcodes

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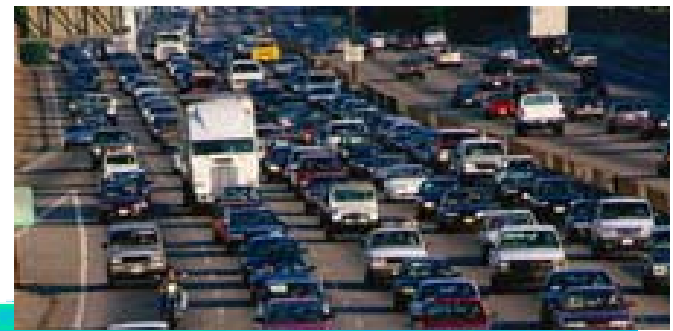
- Reader distance, not line of sight, is limit
- Dynamic information (read and write)
- Can add memory capacity
- Anti-collision (multiple simultaneous reads)
- Works in harsh environments (dust, rain)

# Self ID Applications



- **Inventory**
- **Supply chain management**
- **Mass transit**
- **Postal and courier services**
- **Perishable tracking (food, flowers, drugs)**
- **Document Management**
- **Healthcare, pharmaceutical industry**
- **Access management**
- **Anti-counterfeiting**
- **Toll collection**
- **Airline baggage handling**
- **Animal identification**
- **ITS (next slide)**

# ITS



- Intelligent Transportation Systems, defined by the US Department of Transportation (DOT) as the integration of intelligent vehicles and intelligent infrastructure.
- Three key problems:
  - **Congestion**
  - **Safety, esp. road traffic accidents**
  - **Security and emergency handling**

# ITS Applications

- **Automatic congestion/accident detection and notification**
- **Event and work-zone scheduling**
- **Signal retiming and dynamic speed limits**
- **Re-routing traffic and closing highway entrances**
- **Defect and warranty Info (has the engine fire hazard been fixed?)**
- **Transit and fleet supply chain information**
- **Curve speed and lane departure warnings**
- **Low bridge warnings**
- **Instability warnings**
- **Road condition (wet, snow, ice, oil) warnings**
- **Instant weather (Clarus)**
- **Dynamic signage information**
- **Approaching emergency vehicle warnings**
- **Roadway hazard detection**
- **Accident prevention (fixed objects, intersections, RR Xing...)**
- **Vehicle to vehicle collision avoidance**
- **Pre- and post- violation warnings (speed, signals, stop signs)**
- **Emergency evacuation routing**
- **Driver authentication and qualification via biometrics**

# Needed Convergence



- Satellite Data
- Digital Maps
- GIS
- GPS
- Road Camera Data
- Sensors
- RFID
- DSRC
- 4G

# Map Vision



- Maps will be delivered to iPod, cell phone, and in-vehicle units real-time and will include weather, construction, traffic, congestion, accident, and event info.
- GPS fully integrated
- Dynamic rerouting of destination directions
- Satellite and GIS overlays
- Teen tracking

# Map Distribution Vendors

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- Apple will extend iTunes
- Google has beta mobile maps now
- Yahoo is investing in cell phone products
- Government (e.g. NOAA, NASA, DOT)
- Large news agencies, e.g. Dow Jones
- Others for local traffic, weather, events...

# Traffic Flow Analysis

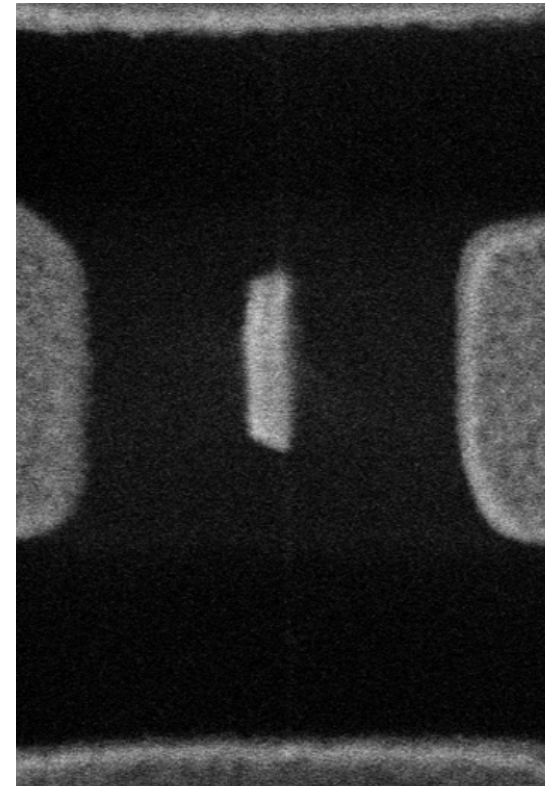
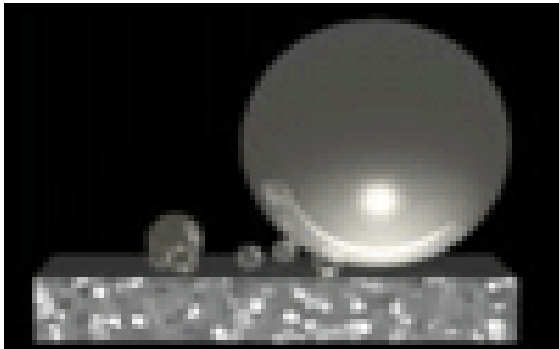
- Sensors: video, embedded loops, toll cards, cell phones, in vehicle GPS and communicators, RFIDs, ... detect flow level
- Flow analysis yields
  - Freeway entrance timing control
  - Variable speed limits
  - Dynamic traffic signs
  - DSRC messages
  - (Soon) 4G cellular messages

# GPS3

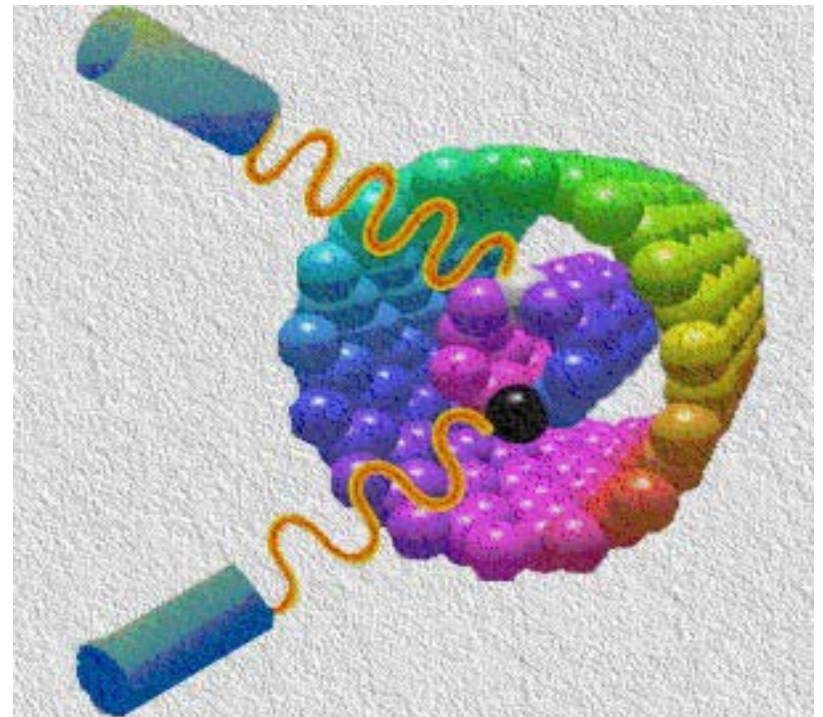
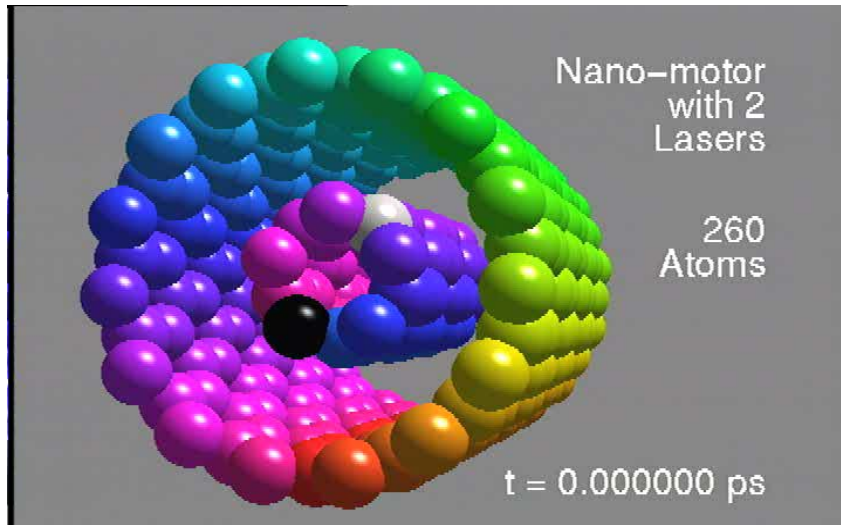
- Driven by US Govt to enhance GPS with more signals, L1C, L2C and L5: new civilian signals, military codes to replace SA, anti-jamming, fast acquisition, higher availability
- Satellites ready 2013 or so, receiver development now!
- More accurate, smaller, 12 and 24 channels, ruggedized with high G resistance (can be added to munitions).
- High volume munitions → high volume GPS → very low costs → high non-military volumes → cell phones, wrist watches, vehicles, containers... → ITS vision
- International: augmentation (DGPS, uplinks), standards

# Nanotechnology

- R. Feynman "There's Plenty of Room at the Bottom" 1959



# Nano-motor driven by 2 lasers



# Nano-applications

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- Endoscopic surgery
- Fall detectors (geriatrics)
- Crash detectors and predictors
- Inertial Guidance Systems (small, cheap)

# Organic LED Monitors



- OLED = LED whose electroluminescent layer is organic (usually a polymer)
- Advantage over LCDs is no need for backlighting
- Thinner, draw less power, more rugged
- Organic electroluminescence dates back to 50's
- 2000 Chemistry Nobel Prize for OE in polymers (Heeger, MacDiarmid & Shirakawa work 1970s-90s)
- Better color, contrast, life ... → Many applications!
- OLED TV's – Sony 27" for \$2500, BUT 1,000,000:1 contrast ratio, >100% NTSC color.
- Don't confuse: LCD monitors that have LED backlights.

# IPv6

- Multiple proposals converged in 1994 and by 1996, RFC 2460 defined its essence.
- 128 bit address space structured for:
  - Ease of routing
  - Deprecating NAT
  - IPv4 interoperability
  - Nomadic computing (e.g. all cell phones)
  - Unknown extensions

# IPv6 Implementations

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- Most OS support dual stack v4 and v6
- ICANN root DNS servers are dual stack
- US govt mandates all backbones of all agencies be v6 by 2008
- China's Next Generation Internet uses v6 and will showcase it for 2008 Olympics
- US military has vast v6 plans (every soldier, weapon, listening device, radio...)

# UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

## RADIO SERVICES COLOR LEGEND

- |                               |                           |  |
|-------------------------------|---------------------------|--|
| AERONAUTICAL MOBILE           | INTER-SATELLITE           | RADIO ASTRONOMY                              |
| AERONAUTICAL MOBILE SATELLITE | LAND MOBILE               | RADIO DETERMINATION SATELLITE                |
| AERONAUTICAL RADIOLOCATION    | LAND MOBILE SATELLITE     | RADIOLOCATION                                |
| AMATEUR                       | MARITIME MOBILE           | RADIOLOCATION SATELLITE                      |
| AMATEUR SATELLITE             | MARITIME MOBILE SATELLITE | RADAR NAVIGATION                             |
| BROADCASTING                  | MARITIME RADIOLOCATION    | RADAR NAVIGATION SATELLITE                   |
| BROADCASTING SATELLITE        | METEOROLOGICAL AIDS       | SPACE OPERATION                              |
| EARTH EXPLORATION SATELLITE   | METEOROLOGICAL SATELLITE  | SPACE RESEARCH                               |
| FIXED                         | MOBILE                    | STANDARD FREQUENCY AND TIME SIGNAL           |
| FIXED SATELLITE               | MOBILE SATELLITE          | STANDARD FREQUENCY AND TIME SIGNAL SATELLITE |

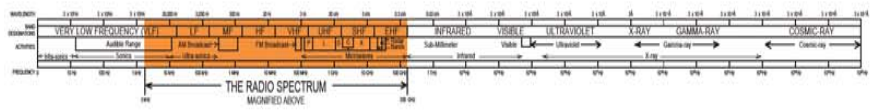
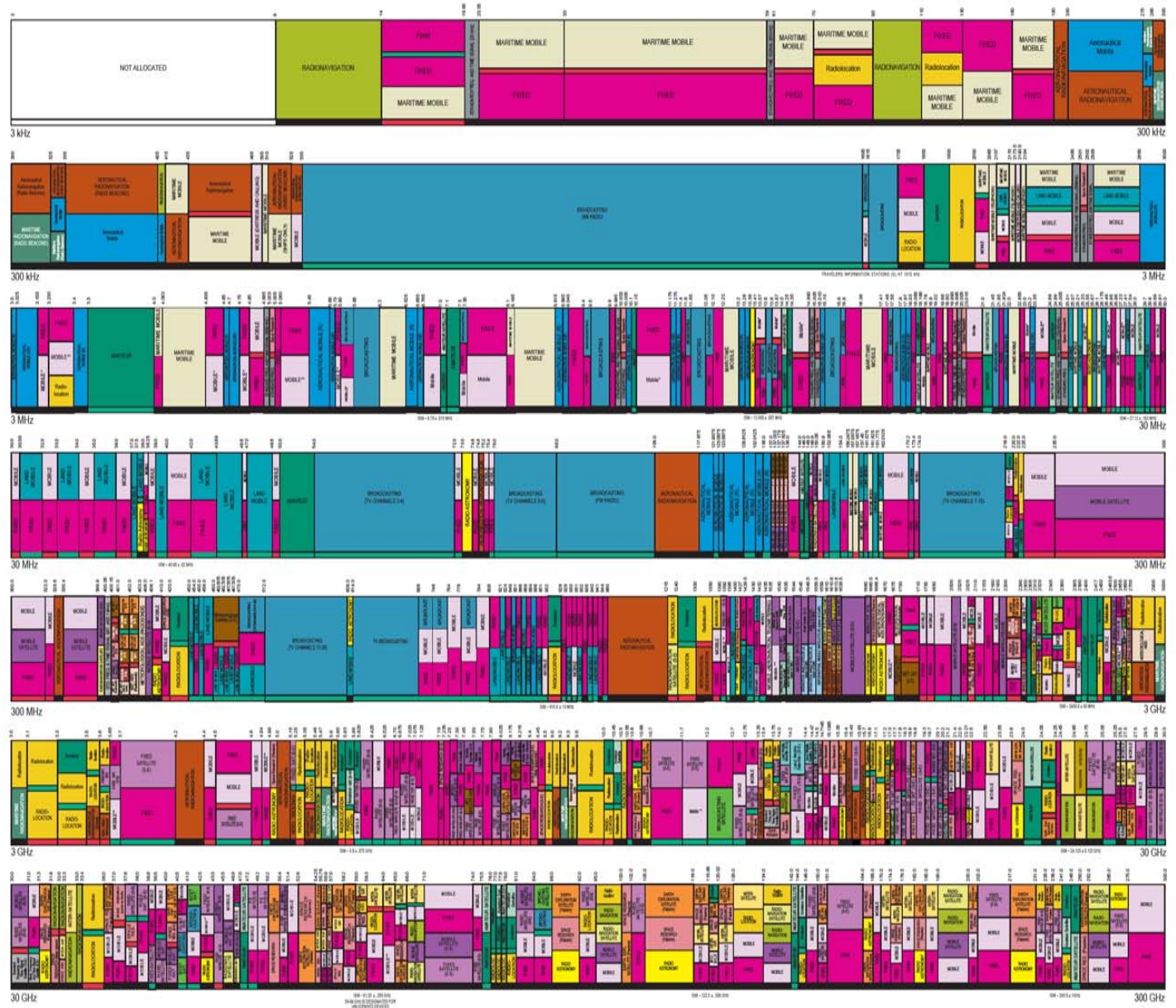
## ACTIVITY CODE

- |                          |                                  |
|--------------------------|----------------------------------|
| GOVERNMENT EXCLUSIVE     | GOVERNMENT/NON-GOVERNMENT SHARED |
| NON-GOVERNMENT EXCLUSIVE |                                  |

## ALLOCATION USAGE DESIGNATION

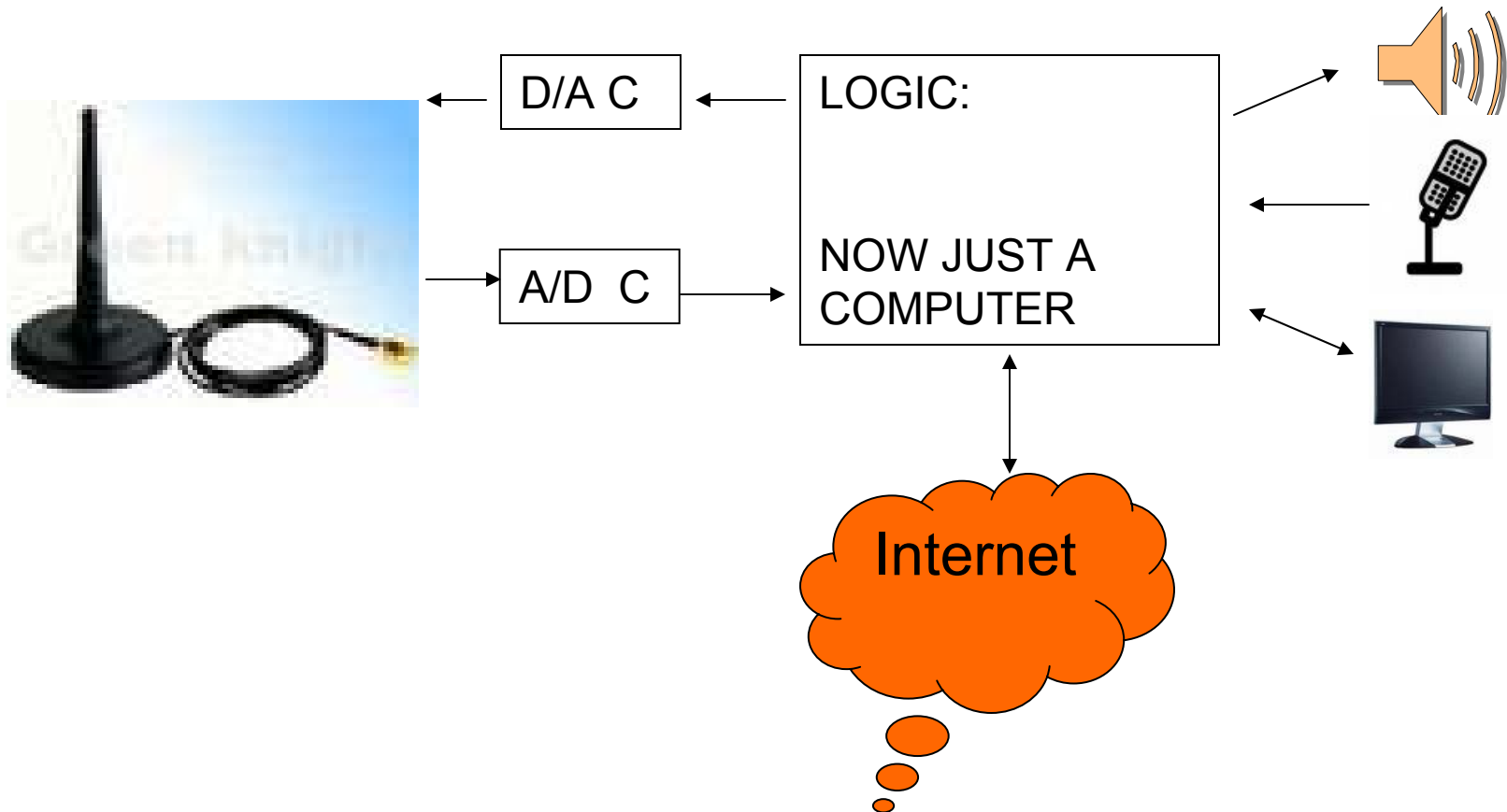
SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

This chart is a graphic design printout of the Table of Frequency Allocations used by the FCC and ITU. As such, it does not constitute an offer of service, is illustrative and subject to change under the Table of Frequency Allocations. Therefore, for complete information, users should consult the Table as approved by the Federal Bureau of Investigation.



PLEASE NOTE: THE SPACING OF THE SERVICES IN THIS CHART IS PROPORTIONAL TO THEIR ACTUAL RANGE OF FREQUENCIES OCCUPIED.

# Software Defined Radio



# Intelligent Antennas

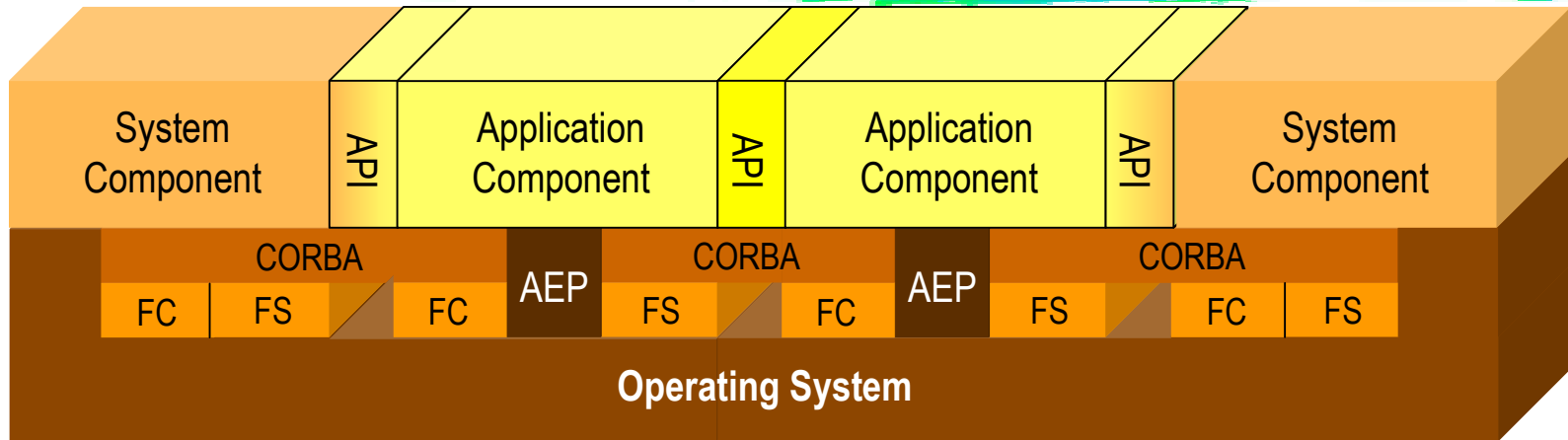
- MIMO versus Phased/Adaptive Arrays
  - $d > \text{wavelength}$  versus  $d < \text{wavelength}$
- Redundant transmission: STBC=space time block coding ( $s_{ij}$ ) = (symbol transmitted on antenna  $j$  in time slot  $i$ ).
- DOA, TOF estimation
- Beam forming (pulses, cancellation)
- Dirty Paper Coding = pre-cancel interference (1983)
- Used in GPS for narrow-band anti-jamming
- Multi-user and distributed MIMOs
- IEEE 802.11n (2x2 and 4x4)
  - csiro.au patent, class action suit, draft n HW



# JTRS

- DoD's ("Jitters") Joint Tactical Radio System
  - Reduce dozens of radio families to one
  - Upgradeable modules, software, firmware, OS
  - Reusable software applications ("waveforms")
  - Multiprocessing
  - Open architecture ("Software Communications Architecture" = SCA version 2.2.2)
  - Mandated compliance for procurement
  - Funded 4 radios (base, ..., mobile war-fighter)
  - Program simplified and restarted for 2007

# SCA



**Legend**

- Application Component..... [Yellow Box]
- System Component..... [Orange Box]
- Framework Control (FC) and Framework Services (FS)..... [Light Orange Box]
- Common Object Request Broker (CORBA)..... [Dark Orange Box]
- SCA Application Environment Profile (AEP)..... [Dark Brown Box]

# Waveforms

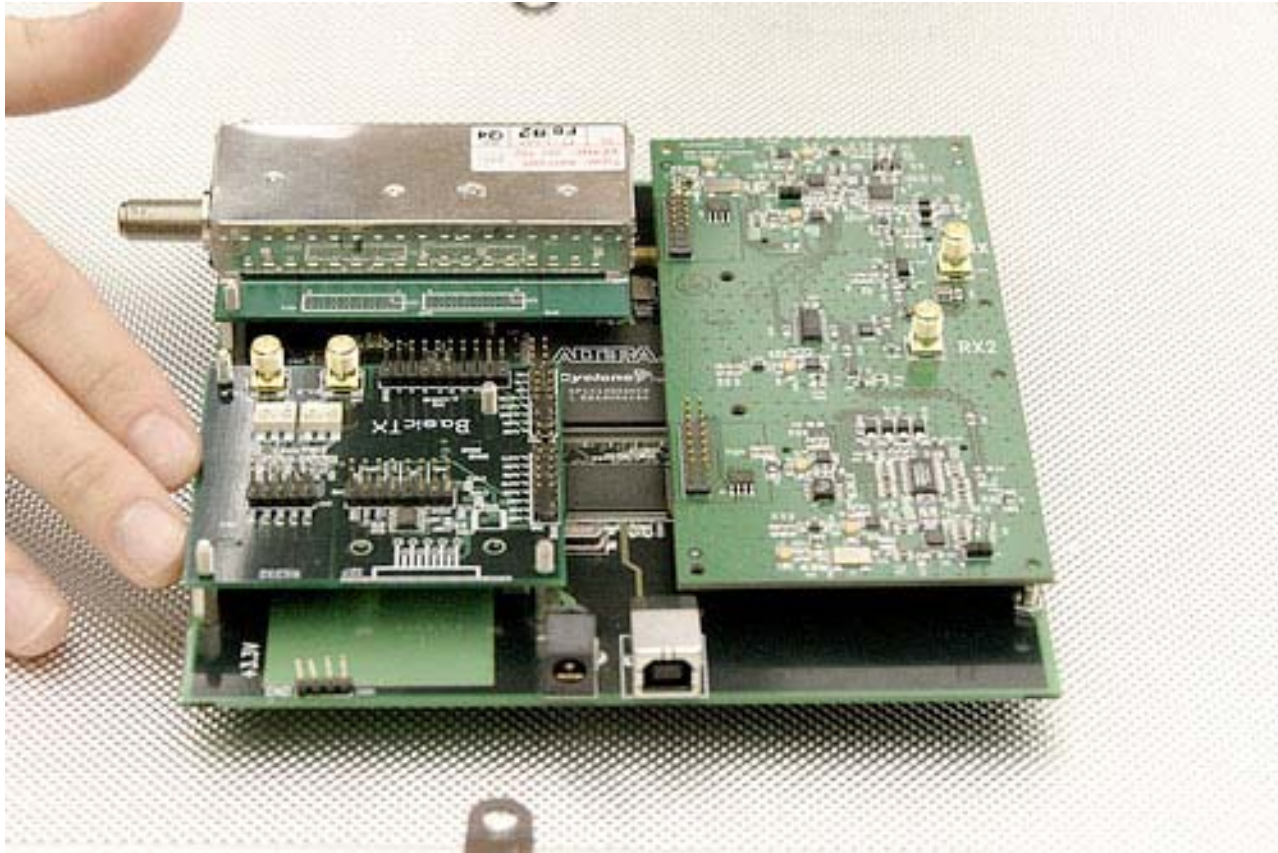
- A waveform is the entire set of radio and/or communications functions that occur from the user input to the radio frequency output and vice versa.
- Originally 32, now 9, DoD waveforms
  - Wideband networking, soldier radio, airborne networking, mobile user, single channel ground/airborne, Link-16, enhanced position locating reporting system, HF, UHF SATCOM
- Others: AM, FM, TV, GPS, DSRS, ...

# GNUradio

- Origin: MIT's SpectrumWare (mid '90s)
- Excellent papers and talks - Eric Blossom
- Identical concepts as SCA, radically different architectures. GNUradio is a data flow abstraction with input and output streams.
- GNUlibrary is a library with lots of examples.
- Many hardware devices supported, one flagship device, USRP = Universal Software Radio Peripheral. Low cost, open, interchangeable RF modules, configurable FPGA, USB2, high speed DA/AD converters, ...

<http://www.ettus.com/>

# USRP



# GNUradio Users

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- Industry, academic, govt research
  - Cognitive Radio (next slide)
- Hackers, who download ??? over the air
- HAMS [My call sign KI6 IMO]
- Radio Astronomers
- Many waveforms
- SAR = synthetic aperture radar.

# Cognitive Radio

- Mitola, McGuire 1999: radio adjusts to every possible observable parameter – the ultimate software radio dream
- Some ideas now commercial, e.g. smart antennas
- Most radio spectrum unused; hence, adjust and use (OFDM usually)
  - Licensed band – IEEE 802.15
  - Unlicensed band – IEEE 802.19
- Ultra Wide Band – time modulation
  - IEEE 802.15.4a

# Wireless Generations

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- 1G: analog cellular
- 2G: digital voice, SMS
- 2.5G: a little faster
- 3G: serious bandwidth, still cellular, power requirements force smaller cells, many single points of failure
- 4G: uses IPv6, peer to peer, part of the Internet, under construction (Sprint et al)

# 4G Vision

- First, every mobile device, phones, pda's, laptops, wrist watches, ... will be 4G nodes.
- Huge volumes will drop costs
- Street lights, traffic lights, utility poles, etc. will all be 4G infrastructure routers
- Public vehicles, truck fleets, taxi fleets, and eventually all vehicles will be 4G equipped as pervasively as car radios (deprecating DSRC)
- Low cost sensors and cameras will attach to 4G from public vehicles, infrastructure routers, etc.
- Bandwidth now at 100mbps moving, 1Gbps stationary
- Usage costs will be so low "you're always connected"
- New "killer applications", e.g. TV, movies, social nets, ITS

# Many Other Topics

- RADAR
- Phased array antennas The Cobra Judy operates in the 2900-3100 MHz band. The octagonal S-band array, composed of 12,288 antenna elements, forms a large octagonal structure approximately 7 m in diameter. and is integrated into a mechanically rotated steel turret. The system weighs about 250 tons.
- Radio Astronomy
- Open Source in Healthcare
- Social networks and computing
- Biometrics
- Air to Ground Internet and IFE



# Discussion Time!!!

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# How GPS Works

- The GPS receiver locks onto a satellite and listens for a known code or bit pattern being broadcasted by the satellite at a known time.
- The receiver computes the time it received the first bit of the code using its local clock. Sphere radius = transmission time /  $c$ .
- Since local “cheap” clock differs by  $\delta t$  from the satellites’ atomic clocks, need a 4th satellite to eliminate  $\delta t$  from the sphere equations.

# GPS Anti-jamming 1/2

- Use “dirty paper” to null any signal over ambient noise in the GPS frequency bands
  - Run out of antennas with lots of jammers
  - Antenna array too large (35cm) for some appls
- Space Time (or Frequency) Adaptive Processing
  - Time output of each antenna to weight and process
- Adaptive narrow band filtering
  - Effective for structured jamming signals, but not broadband random signals

# GPS Anti-Jamming 2/2

- Beam steering
  - Use knowledge of satellite position
- Narrow signal band to improve gain
  - Not good in high acceleration, e.g. missiles
- Use micro/nano-technology to embed inertial guidance system in the GPS antenna. Gives satellite position and allows signal band narrowing.
- Use stronger signals from newer satellites, better codes and transmission shaping

# Investment Criteria

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- ROI and cash flow
- Competition
- Projected market size (systems, parts)
- Internal talent & opportunity cost
- Possible partnerships/acquisitions

# Credits and References

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- Kerner, Physics of Traffic, 2004 (distinguishes free flow, congested flow, moving jams)
- [www.fas.org](http://www.fas.org)