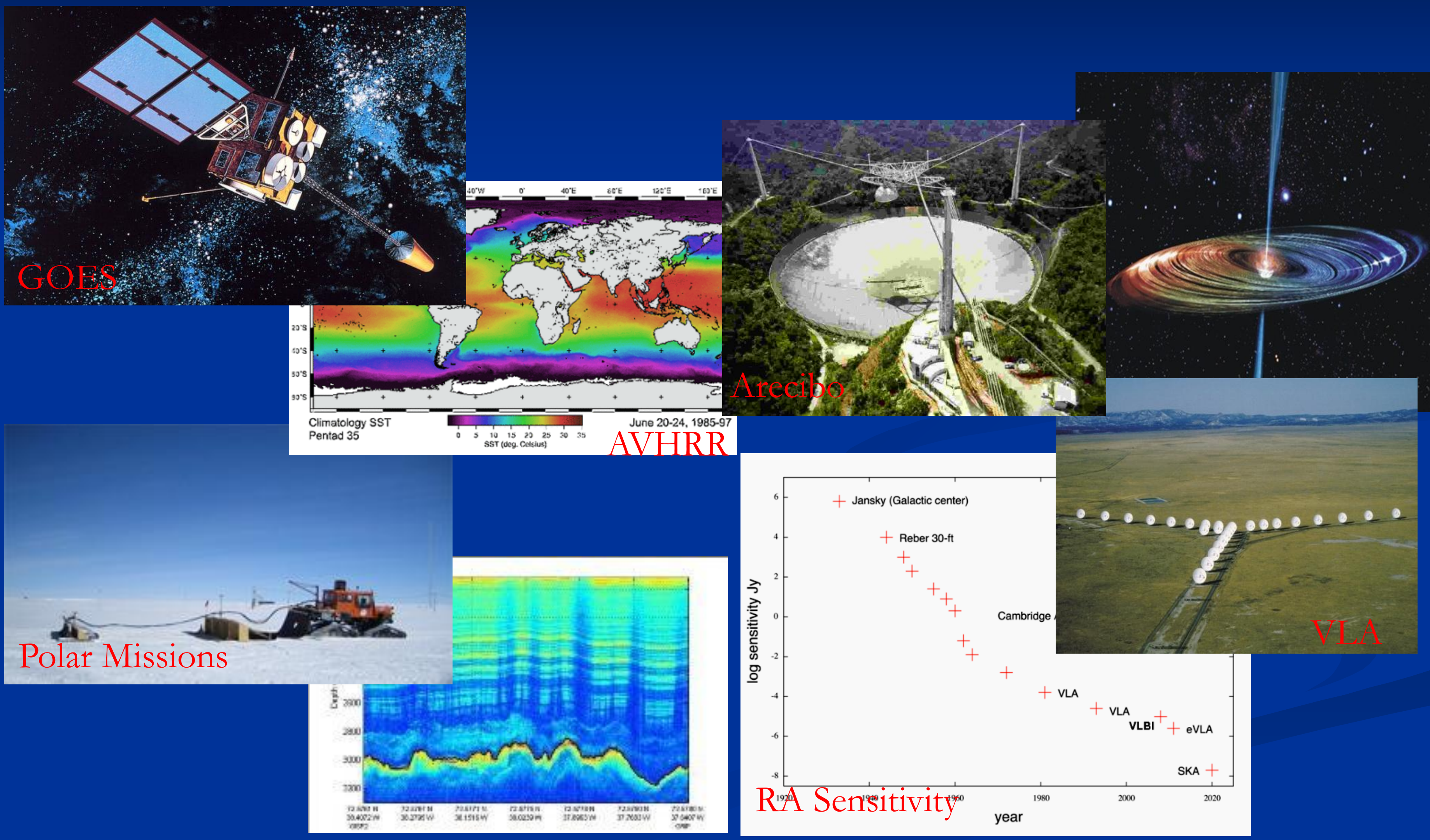
Spectrum: Trillion Dollar Impact

Paul J Kolodzy, PhD
Independent Telecommunications Consultant
Chair FCC Spectrum Policy Task Force

Committee on Radio Frequencies Presentation
Washington D.C.
May 18, 2010

The Spectrum of Uses for the RF Spectrum: Science



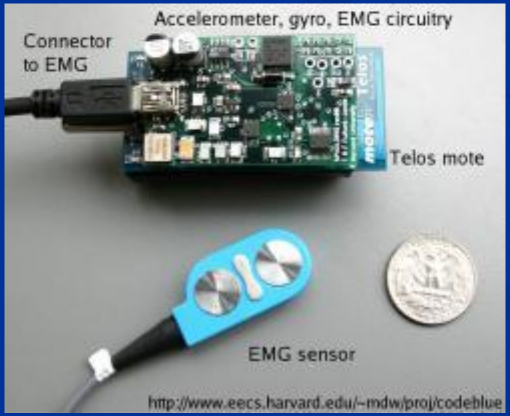
The Spectrum of Uses for the RF Spectrum: Consumer

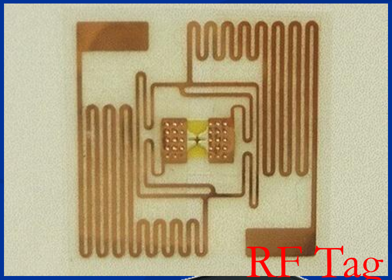
The Spectrum of Uses for the RF Spectrum: Commercial


Millimeterwave Body Scanners


Monitoring Space Clutter


TeraHertz Imaging




RF Tag


OffShore Telemetry


Amateur Radios

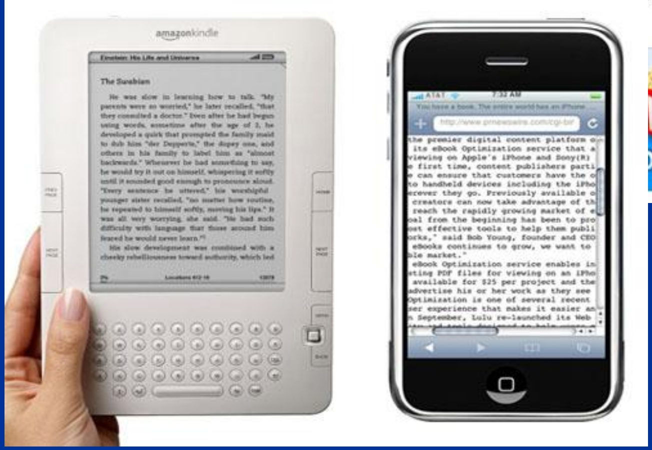
Applications are only Limited by our Imagination

iPhone Apps

Radar

Garage Door Opener

Electronic Books



Wildlife Tracking Tags

Spectrum Technology and NSF

Users / Applications — Technology and Architectures — Marketplace and Viability

Biological Sciences
RF Exposure
Wildlife Tracking
Climate Change Impact
Marine Science
NEON

Engineering
Radio Access Algorithms
Software Defined Radios
Miniaturization of RF Devices
Adaptive Modulations
Real-Time RF Mitigation
Wide BW Digitizers

CISE
Software Defined Radios
Adaptive Modulation
Advanced Wireless Networking
Cognitive Radios

GeoSciences
Upper and Lower Atmospheric Research
Remote Sensing
CubeSats
Meteorology

Mathematical and Physical Sciences
Radio Astronomy Facilities
Radio Access Algorithms,
Miniaturization of RF Devices
Adaptive Antennas,
Real-Time RFI Mitigation

International Science and Engineering

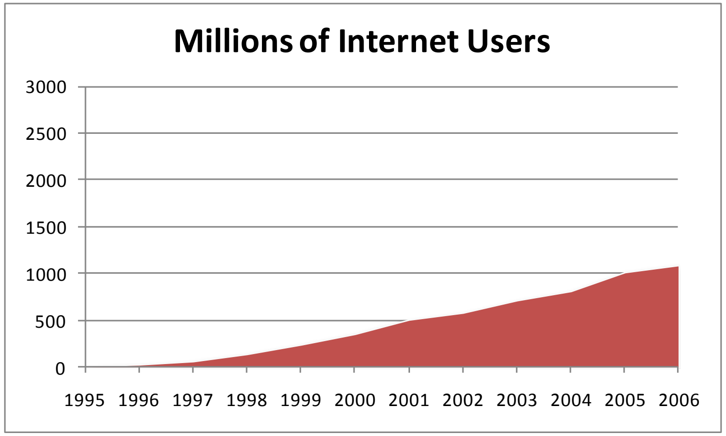
Cyber Infrastructure
Networking
Campus bridging
Climate Prediction
HPWREN

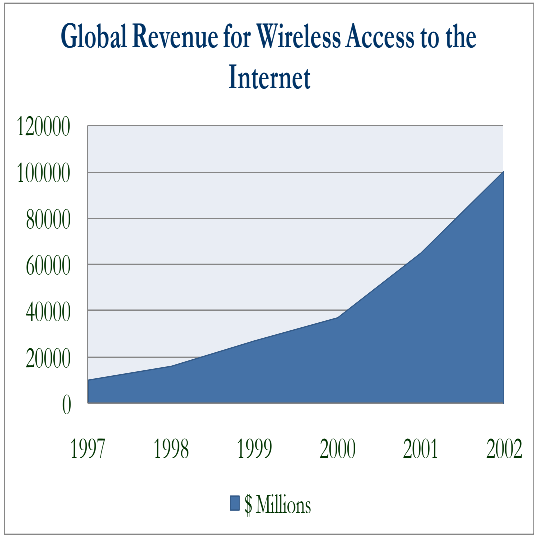
Social Behavioral & Economic Sciences
Economics of Radio
SharingSpectrum auctions
Secondary markets

Office of Polar Programs
Radio Science Facilities
Voice and Data Connectivity

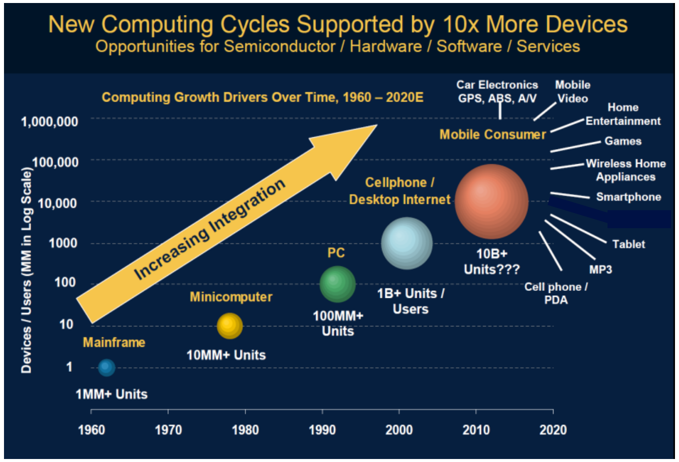
Wireless Impact to the Internet

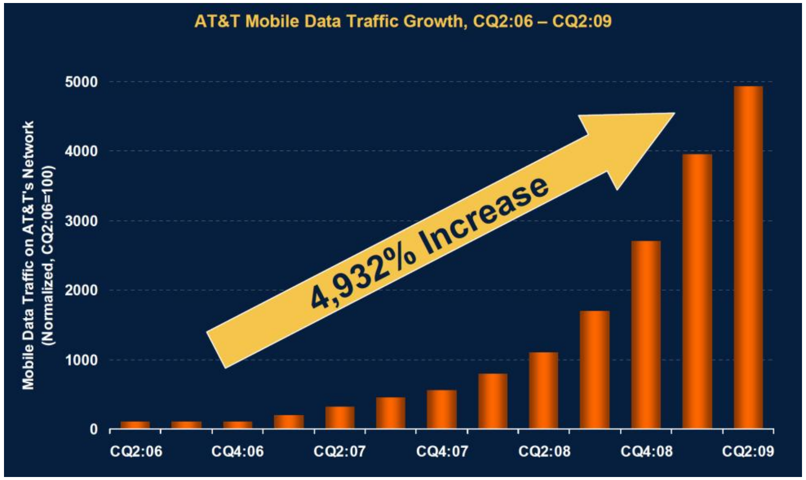
PAST





near FUTURE



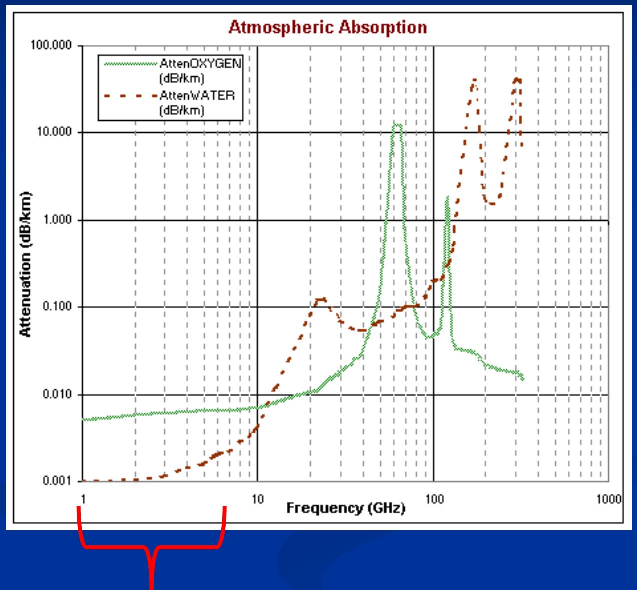


Spectrum Impact on the Economy: Communications Alone

- Total revenues reported to the FCC by communications firms grew from $335 billion in 2000 to more than $430 billion in 2008. (does not include the impact of wireless which is estimated to be 5-10x the raw value of the service)
- Some estimate that the economic impact from all RF spectrum applications is 5-10% of the economy ($700B - $1.4 T)
- GPS devices and systems to generate annual revenues of $240 B by 2013 (April 2010 – ABI Research)

- Raising broadband penetration (predominantly wireless) in developing countries could increase global GDP by US$300-400B and 10-14 million jobs (Feb 2009 McKinsey & Company)

Not All Bands are Created Equal



"BeachFront Spectrum" = Propagation, Bandwidth

- Propagation and Scattering Characteristics versus
- Spatial Reuse versus
- Transmitter and Receiver Efficiencies

Spectrum is Scalable

- Between 100,000 – 250,000 Base stations in US (350,000 Base stations in China)
- If Spectrum Reuse is 3 (typical) and 2,000 MHz can be re-used, and 1 bit per second per Hz (spectral efficiency) then …
- ~1.5 x 10^{14} bps available across the US, or …
- 500 kbps per person is available, 24 hours a day, 365 days per year or 3.5 Mbps IF spectral efficiency could be raised to 7 bits per second per Hz (twice as efficient as HDTV) .

Negroponte Switch: Services that were once wired such as computer networks and telephones are becoming wireless and services that were once wireless like TV broadcasting are becoming wired.

Value of Spectrum

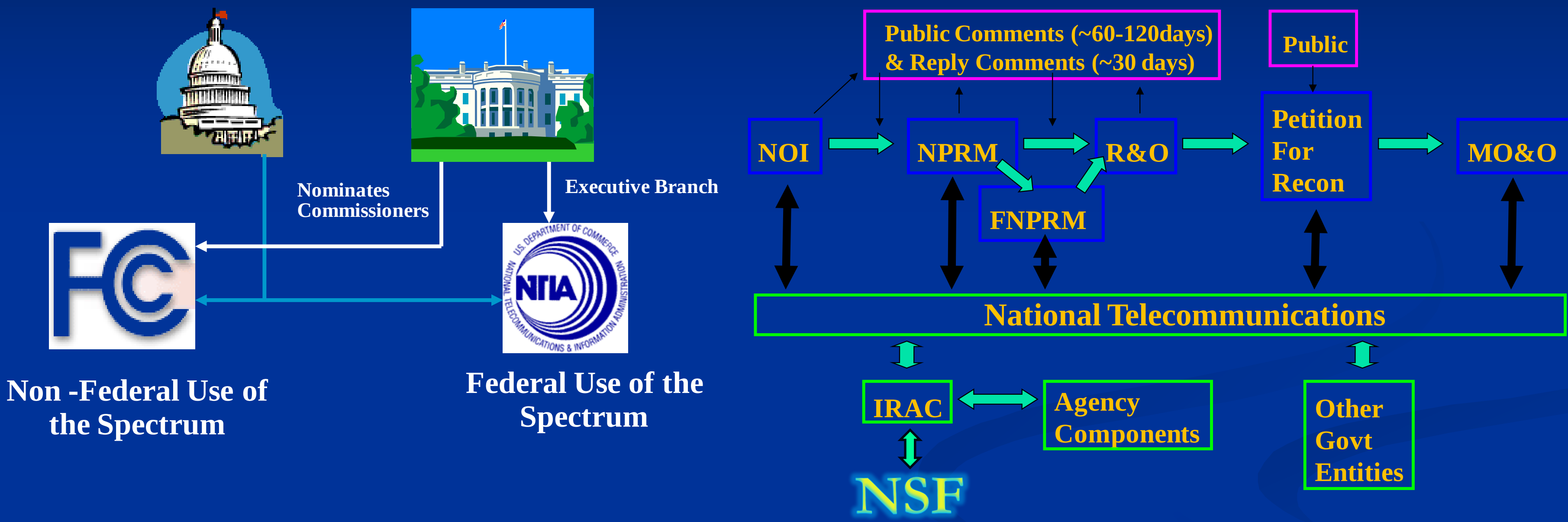
- $0.03 - $1.00 per MHz*POP[1] (US)
- 300 M POPs and ~3,000 MHz
- → $450 B in US (@$0.50)

- $0.03 - $0.50 per MHz*POP (World)
- 5,000 M POPs and ~3,000 MHz
- → $3,000 B Worldwide (@$0.20)

Artificial or Actual Scarcity has produced a 3-4 x increase in valuation over the past 4 years

[1] POP = Population

National Spectrum Regulation and Policy



Spectrum Management has a National component (FCC and NTIA) and International Component (ITU). It requires interaction between the Technical and Legal Communities as well as among Government Agencies

Applications Continue to Increase the Needs

- Average mobile broadband subscriber is expected to consume (per month) 55 MB email, 2.7 GB Internet Radio, 9 GB video, and 27 GB HD movies → 2008 Rysavy Research

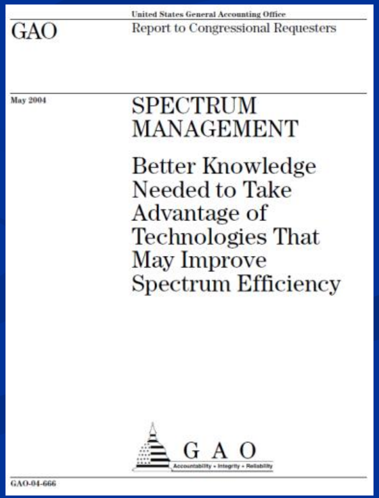
- If laptops are included monthly mobile traffic escalates (per user) from 1GB per month in 2009 to 14 GB per month in 2015 (Cisco)

YouTube

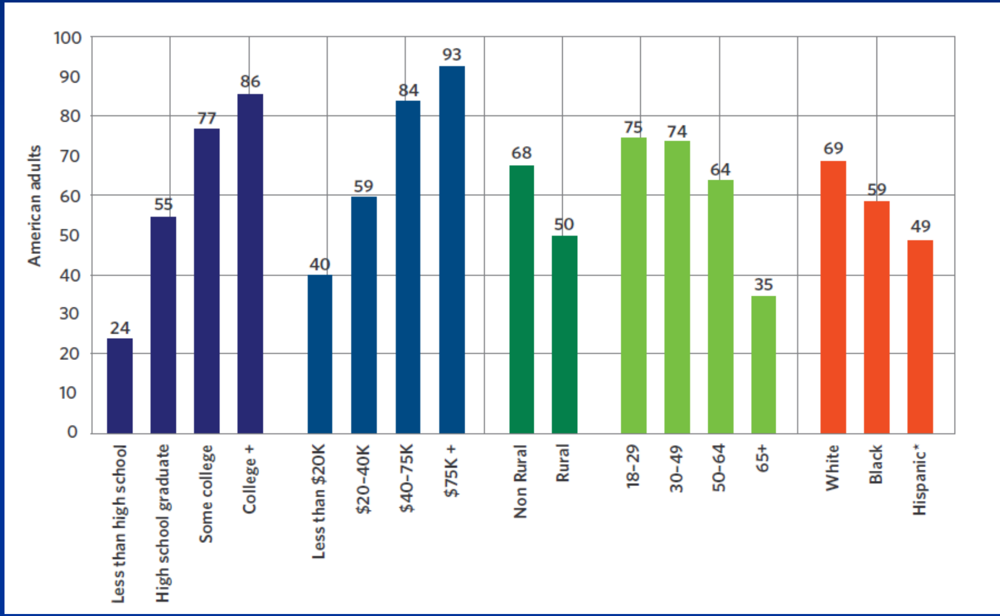
InformationWeek
BUSINESS INNOVATION POWERED BY TECHNOLOGY

FCC Chair Cites 'Spectrum Crisis'

UPDATE -- Verizon CEO: What spectrum crisis?


GAO
United States General Accounting Office
Report to Congressional Requesters
May 2004
SPECTRUM MANAGEMENT
Better Knowledge Needed to Take Advantage of Technologies That May Improve Spectrum Efficiency
GAO
Accountability * Integrity * Reliability
GAO-04-666

The Race is On!
Technology, Policy, and Applications



Broadband Adoption by American Adults (2010 FCC National Broadband Plan)

- ITU estimates additional spectrum for Broadband is 760 MHz in 2010, 1280-1720 MHz by 2020
  - Valuation of $230 – 520 B in US alone)
- Option to encourage customers to use femtocells to decrease spectral loads
- Network operators optimally balance the expense (scarcity) of additional spectrum against the expense of additional cell sites, more advanced networks, and other inputs.

RF Spectrum is a Key Resource for enabling economic engine, scientific exploration, educational advances, and defensive capabilities

The 3 P's of Using RF Spectrum

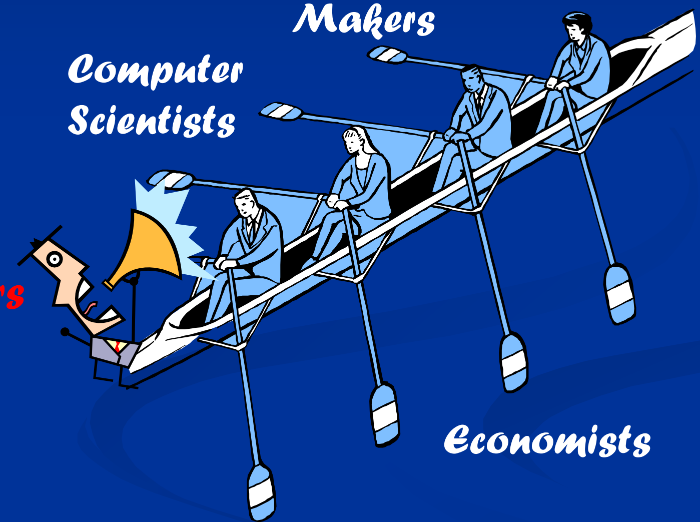
- **Possible** – technology for components, radios, intelligence, networking, applications, sensing and new applications (NSF is involved)

- **Permissible** – regulatory: impact to current systems including interference analysis techniques, new methods for managing rules … e.g. NAS studies (NSF is involved)

- **Prudent** - Economically viable (includes interference mitigation), technical, economic and security robustness (NSF could be involved)

Multi-Disciplinary

Not just in Words



Electrical Engineers, Computer Scientists, Communications Engineers, Lawyers, Policy Makers, Economists, Physicists, Material Scientists, Pontificators

Spectrum Technology and NSF

Users / Applications   Technology and Architectures   Marketplace and Viability

Biological Sciences	Engineering	Computer & Information Science and Engineering
GeoSciences	Mathematical and Physical Sciences	International Science and Engineering
Cyber Infrastructure	Social Behavioral & Economic Sciences	Office of Polar Programs

Possible (Technology)   Permissible (Policy)   Prudent (Security/Economics)

Areas of NSF Research

To be refined by the upcoming EARS Workshop

Quantitative Interference

- Analytical Methodology for Interference Analysis
- Statistical Analysis Techniques
- Interference Mitigation Technologies

Networking

- Scalability, Mobility, Reliability
- Wireless vs Wired Networking
- Impacts of Multi-Network including In-building Wireless/Femtocells

Spectrum Efficiency

- Device, Component, and System Technologies
- Spectral Flexibility
- Economic versus Technical Efficiencies
- Impact of Applications (QoS, etc)

Spectrum Management and Policy

- Mixed Economic Models
- Enabling Better Spectrum Access
- Enabling Dynamic Policies on Devices and for Policy Makers
- Multi-Network, Multi-Modal Architectures

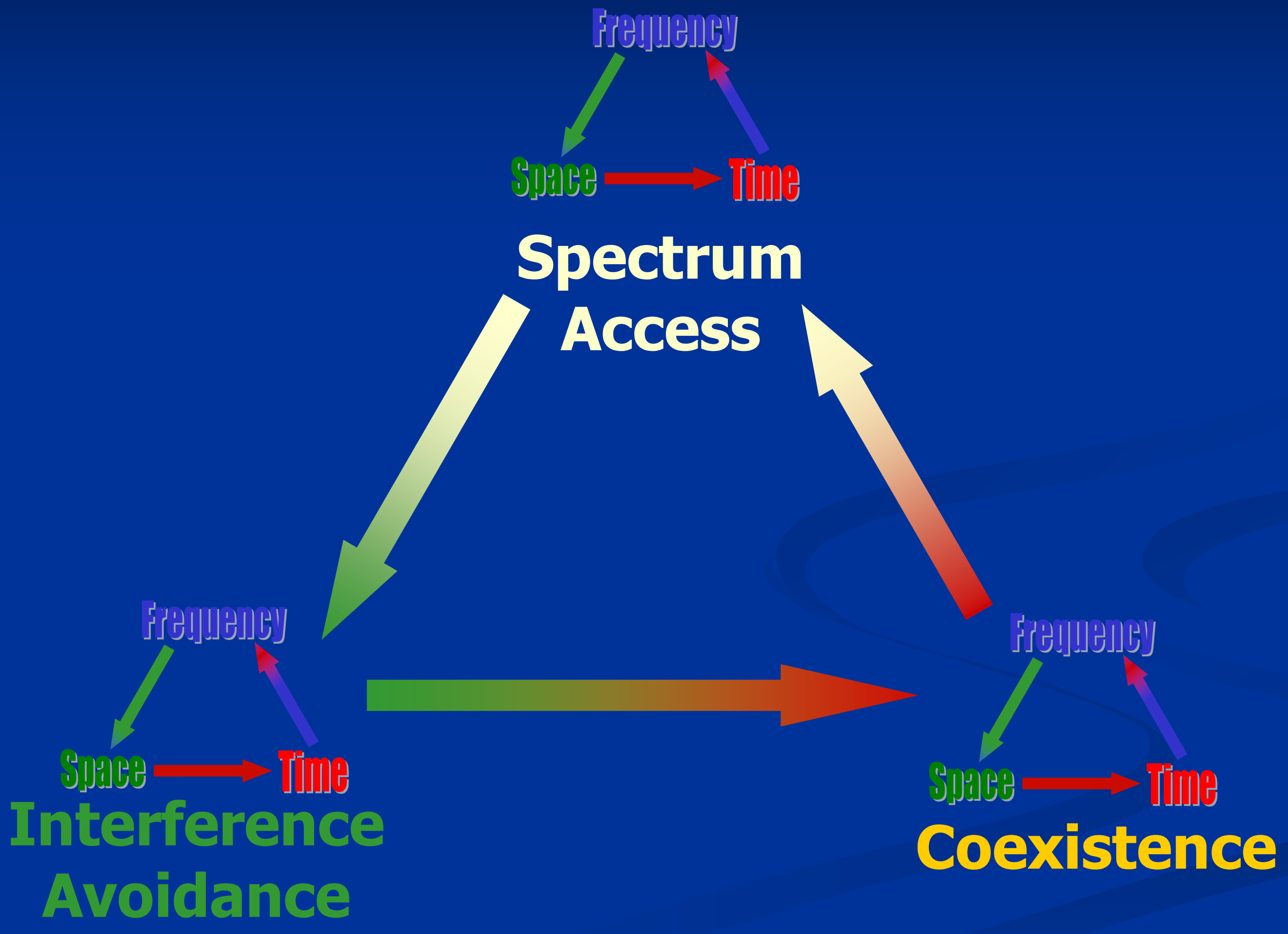
The Spectrum Development Conundrum

- Developers of Technology, Product, and Policy are Disconnected

  - Technology concepts are created more rapidly than policy;
  - Industry won't invest in promising concepts if policy is uncertain; and
  - Policy won't change without evidence that promising concepts are viable;

Disruptive Technology needs to be developed by an unbiased research organization such as the National Science Foundation

How does DSA Impact these Telecommunications Needs?

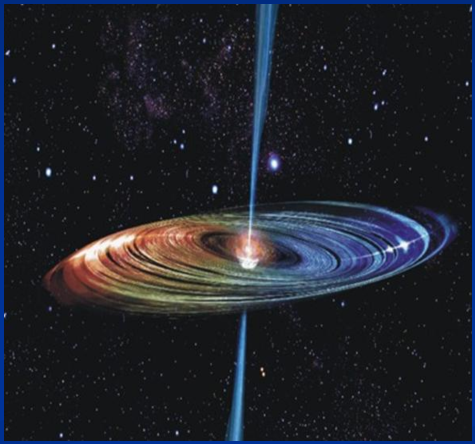


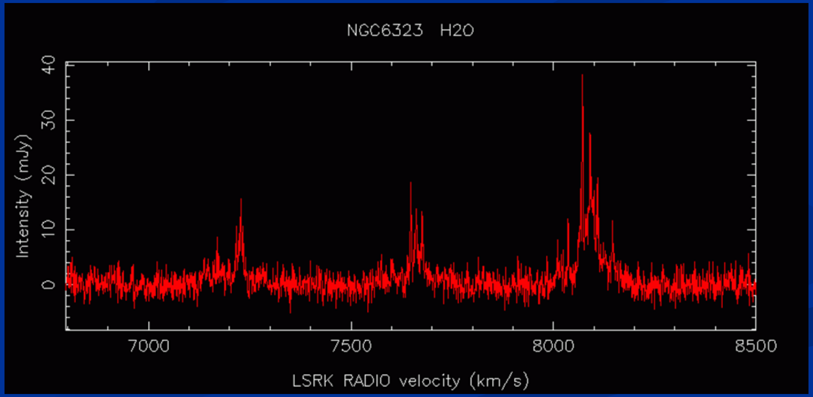
Spectrum Access

Passive – Radio Astronomy Sensing (RAS)

- Extreme Sensitivity – Noise Limited
- Limited Locations
- Billions Invested
- International Community
- Some Bands Protected, but many are not
  - **Spatial Isolation**
  - **Temporal Isolation**

- Space-Time DSA?????



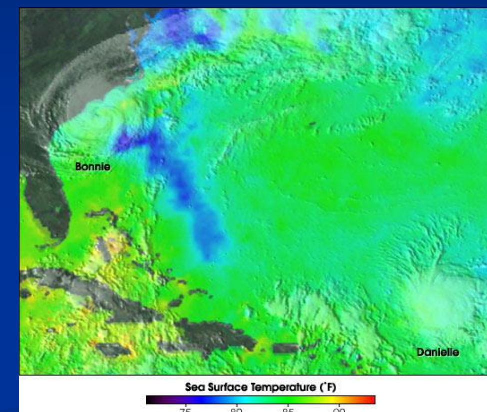


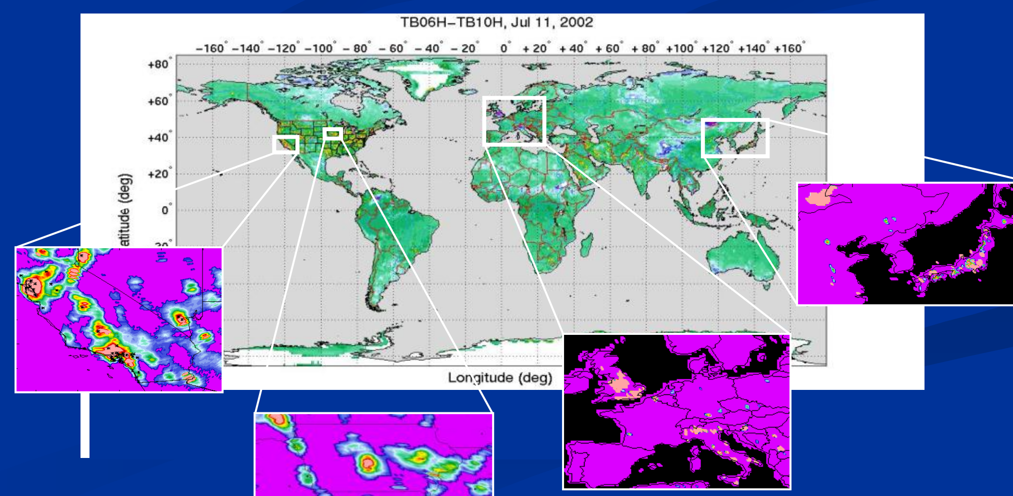
mJy = -260 dBm/m^2 Hz

Spectrum Access

Passive – Earth Exploration Satellite Service (EESS)

- Extreme Sensitivity
- Limited Numbers, follows Keplarian Physics
- Billions Invested
- International Community
- Some Bands Protected, but many are not
  - **Spatial-Time Coordination**
- Space-Time DSA?????

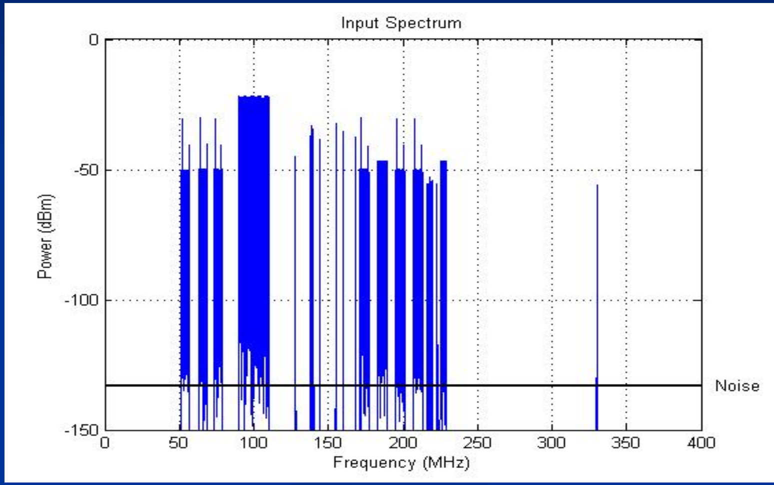


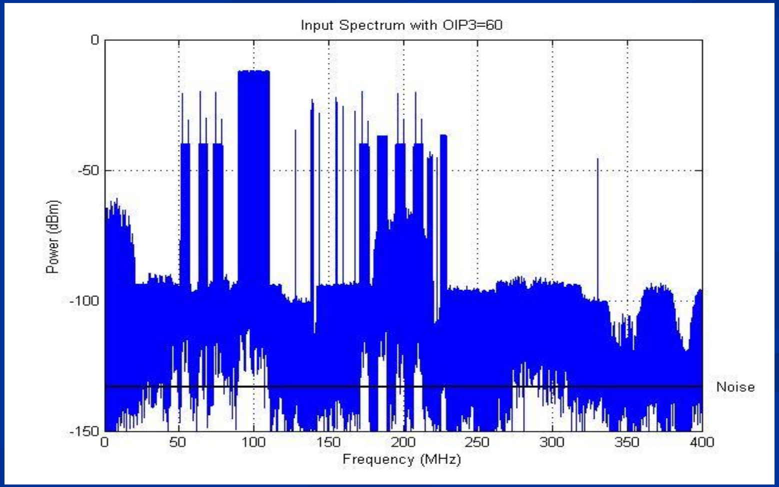


Interference Avoidance

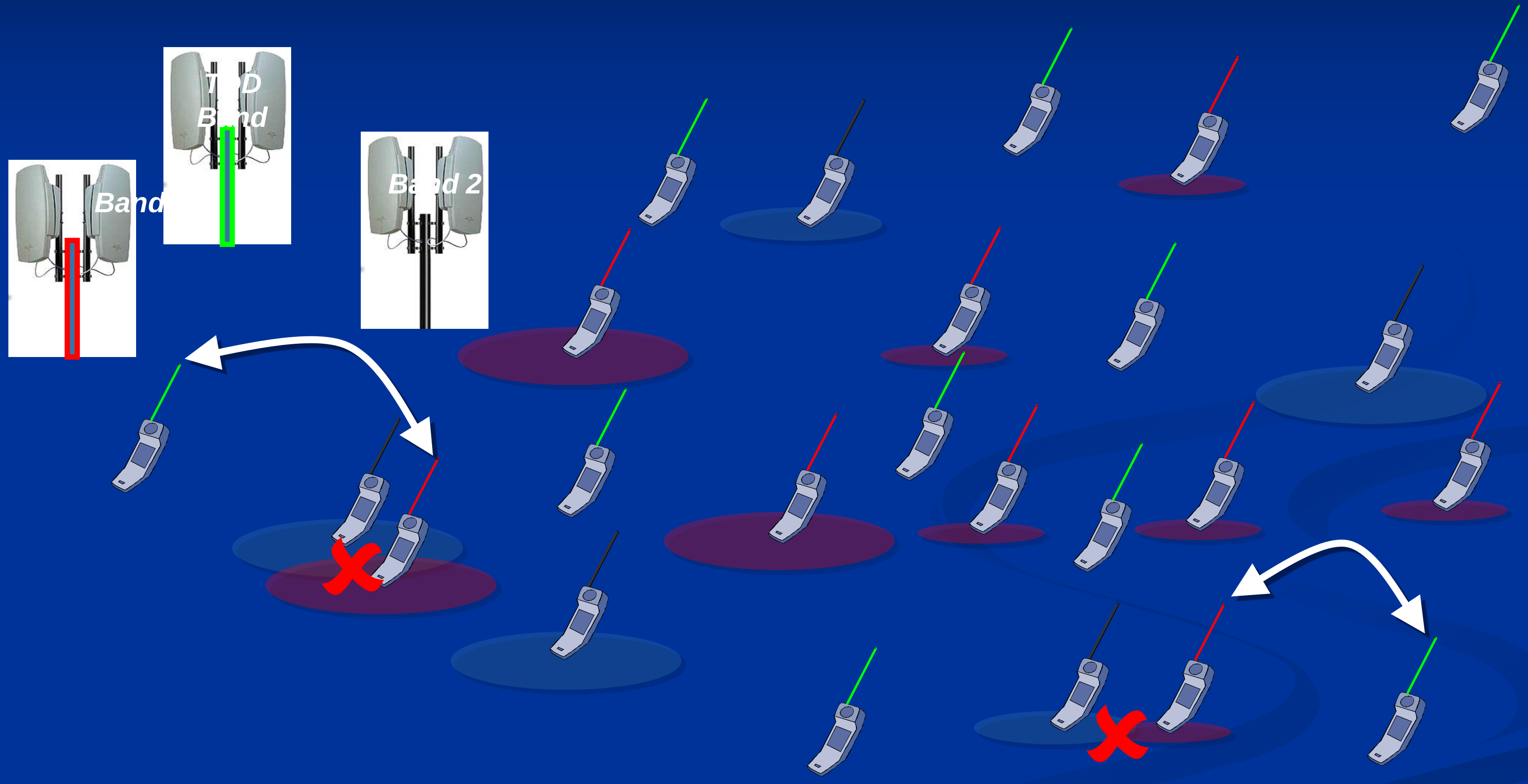
Overcome Device Limitations, Environmental Sensing, etc

- Device Characteristics are well known
  - OOBE
  - IP3 – PA/LNA
- Trade-Space between better devices and using more spectrum
- Focus of Marshall Presentations





DSA to enable Coexistence?



The Policy Issues

- What is the protection level provided to a licensee?
  - Noise-limited versus interference-limited operations?
  - What are the Spectrum Rights and Responsibilities?
  - How does DSA impact those rights?
- How to compute the impacts?
  - Static, worst case analysis versus statistical analysis

?????

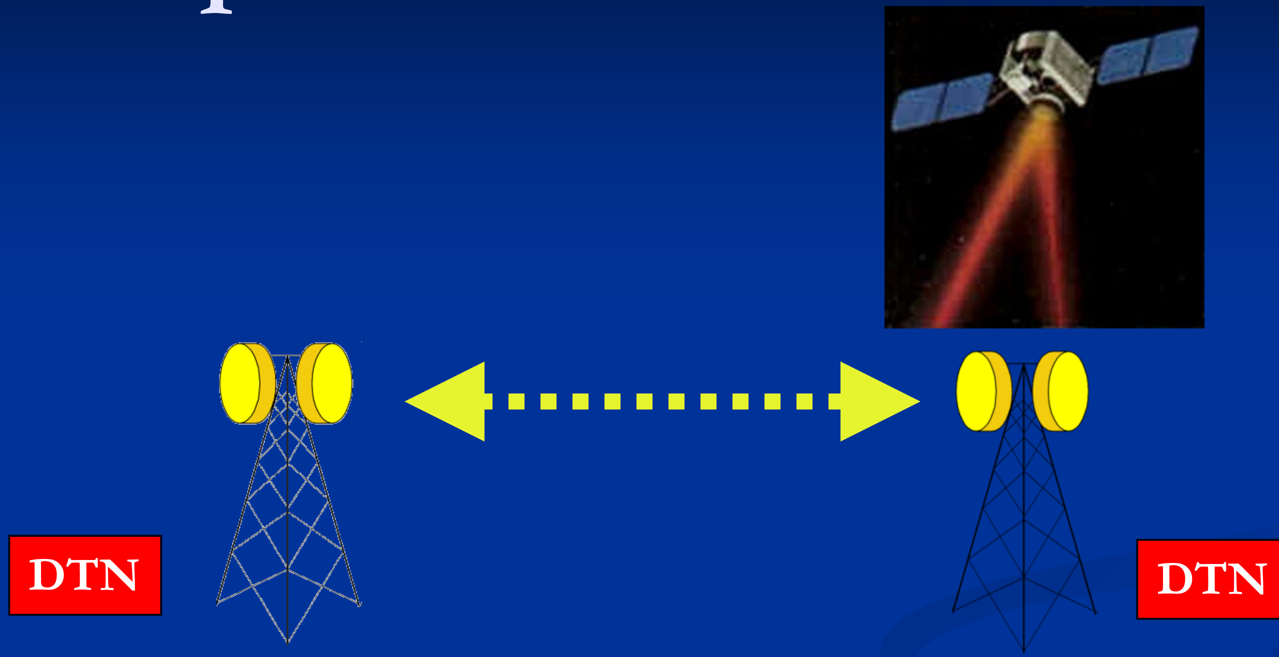
% Capacity Loss

Interference Floor

Practical Noise Floor

KTB (aka noise floor)

Disruption Tolerant Networking



- Experiment: Use Disruption Tolerant Networking to demonstration viability of temporal sharing of 6-7 GHz bands

Summary

- Impact of RF Spectrum Technologies (Device, Systems, Services, and Capabilities Enabled) in US is greater than $1T annually;
  - This growth is possible through impartial scientific development to enable the possible, permissible, and prudent use of the RF Spectrum → interference management
- The NRC Study addressed a great deal but need to more quickly focus away from defining issues and more toward addressing "win-win" scenarios and the impact of policy to technology issues; and
- There is a great opportunity for technical and policy leadership in devising new techniques and methodologies for opening up access to the spectrum for INTENSIVE use