

# DARPA Spectrum Challenge

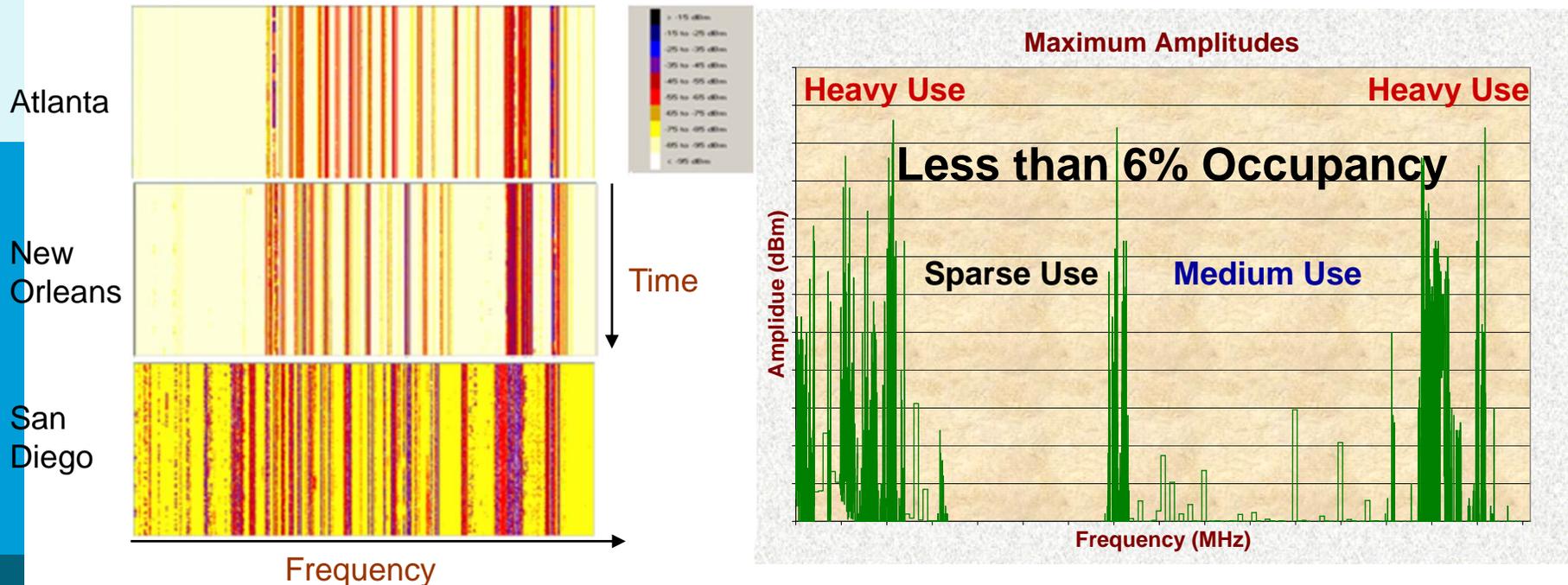


WINLAB 

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# Setting the Stage: Spectral Occupancy.



- FCC measurement shows that occupancy of approximately 700 MHz of spectrum below 1 GHz is less than 6~10%
- ~ 13% spectrum opportunities utilized in New York City during 2004 Political Convention to nominate U.S. Presidential Candidate
- Enter cognitive radios and dynamic spectrum access

# Setting the Stage: What are We to Do?

- 2011 State of the Union address, the President emphasized the objective of improving economic development through a proposed “National Broadband Initiative”
  - Double the amount of wireless spectrum available for mobile broadband
  - Bring high-speed wireless services to roughly 98% of Americans within a few years.
- The FCC has opened up large chunks of spectrum
  - In the 300MHz to 400MHz band for unlicensed use
  - National Broadband Plan: To open up 500 MHz in next 10 years
- Bandwidth + CR Technologies + Coexistence Issues + Economics + ..... = Many unsolved problems that need to be tackled

# DARPA Spectrum Challenge

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Two scenarios:

□ Competitive:

- Radios might often operate in settings where the different parties have drastically different and contradictory objectives
- Yes, could be motivated by “tactical” scenarios
- But could also be motivated by “greed” oriented scenarios

□ Cooperative:

- Radios might often operate in settings where the different parties need to share and coexist
- Commercial applications and the general “spectrum commons” problem
- Theoretical results allow for improved “joint” capacity
  - Challenge, though, theoretical results assume coordination, which typically might not be possible or easy to do...

# The Arena: The ORBIT testbed

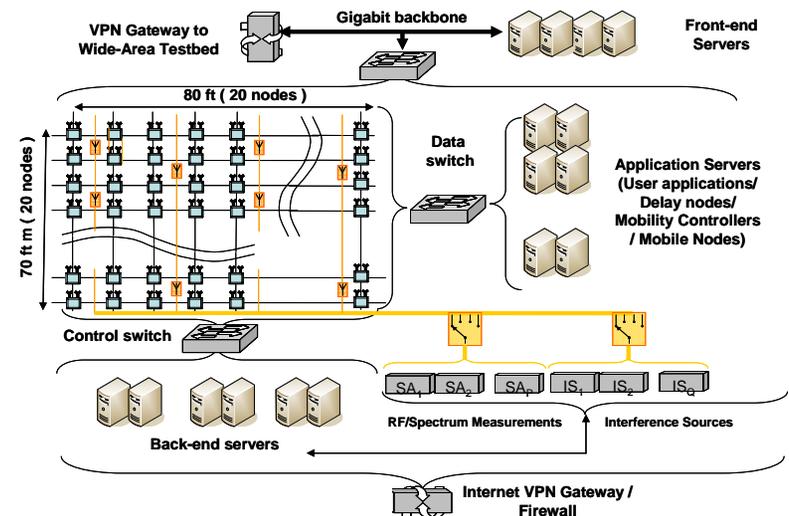
Two-dimensional grid of 400 nodes

- Nodes can be dynamically interconnected into specified topologies
- Reproducible wireless channel models
- Broad array of wireless technologies allows experimentation for many application scenarios



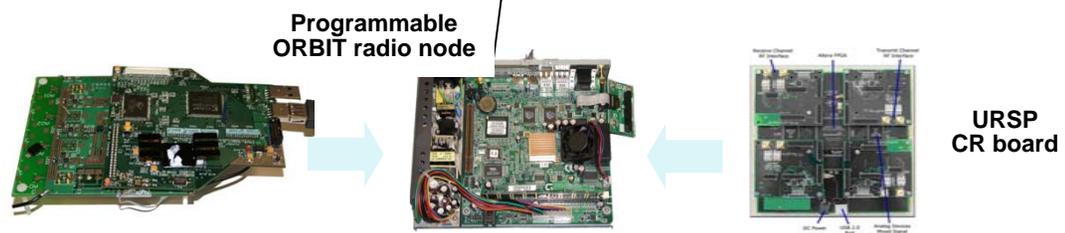
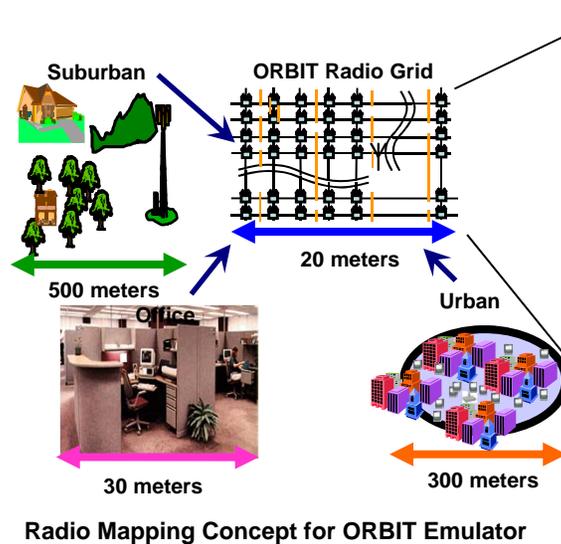
ORBIT is open-access:

- WINLAB developed for NSF, >450 user groups world-wide
- Used by several companies and DoD organizations



# The Arena: The ORBIT testbed (con't)

- ORBIT radio grid testbed currently supports ~10 USRP and ~30 USRP2 (GNU) radios, 100 low-cost spectrum sensors, WARP, Zynq+AD+Parallela and GENI CR-Kit platforms



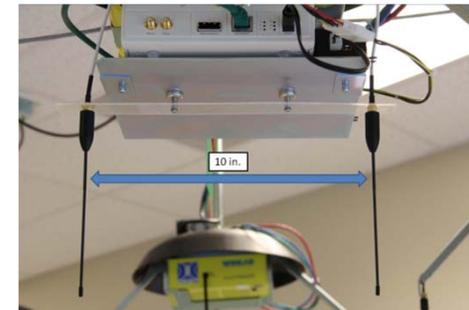
# The Arena: Platform



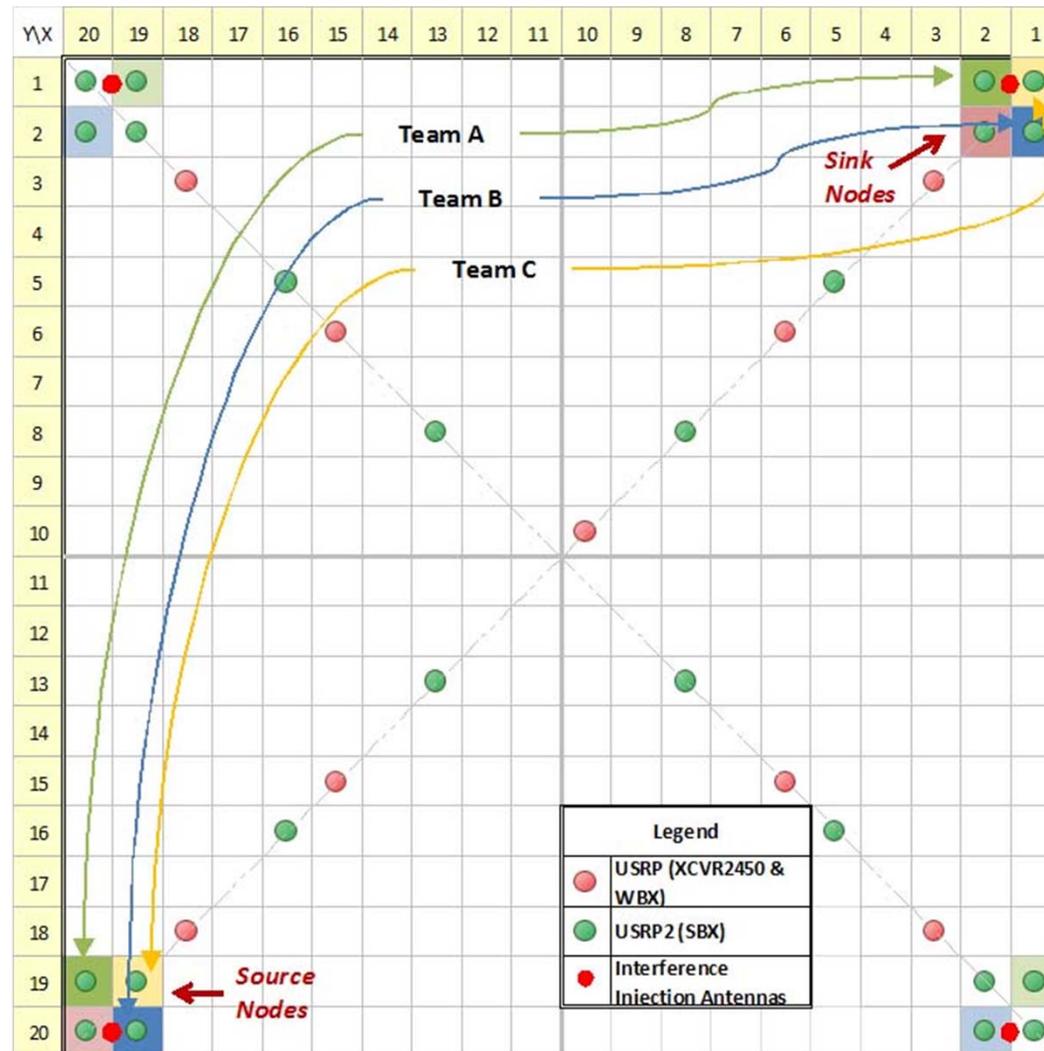
- 2<sup>nd</sup> gen Quad Core i7 with Q67 Express
- 16 GB DDR2
- 3 x Gigabit Ethernet
- PCI-Express X16
- Mini-PCI - Express
- Mini-PCI
- 8 x USB 2.0
- 2 x COM



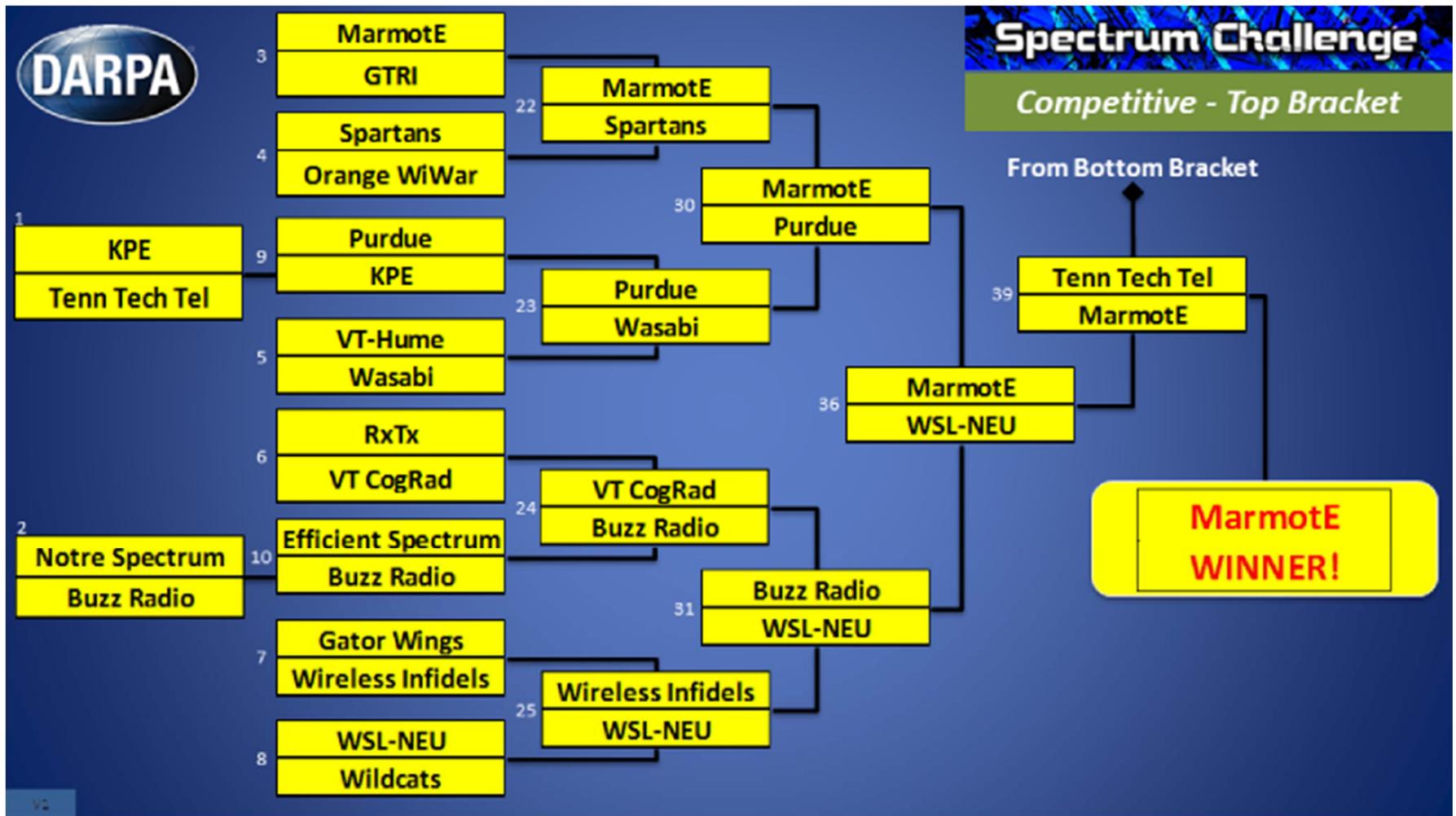
- USRP N210
- SBX



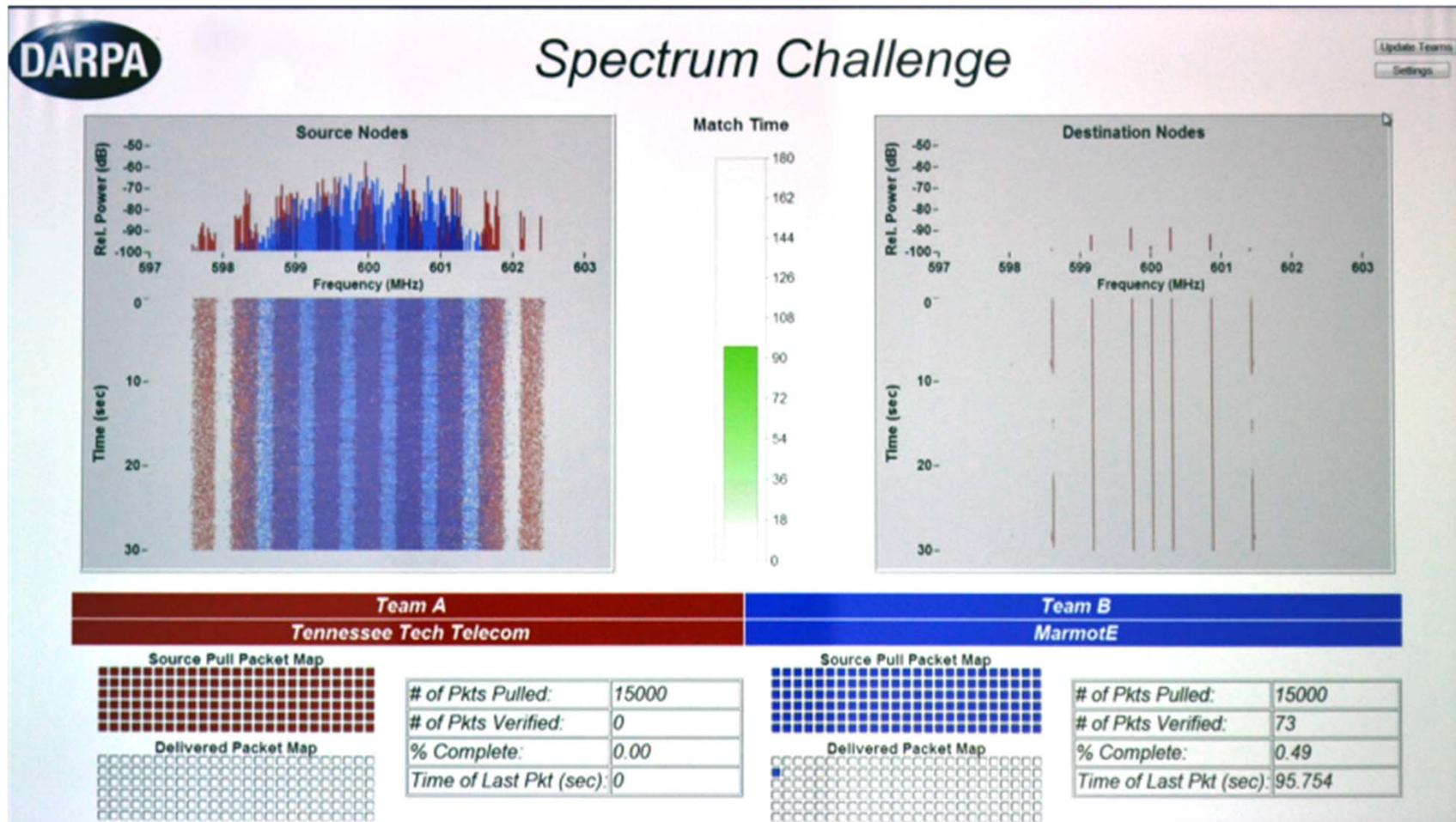
# The Arena: Playground



# Preliminary Tournament - Competitive



# Preliminary Tournament – Competitive (contd.)



# Preliminary Tournament - Cooperative



**Spectrum Challenge**

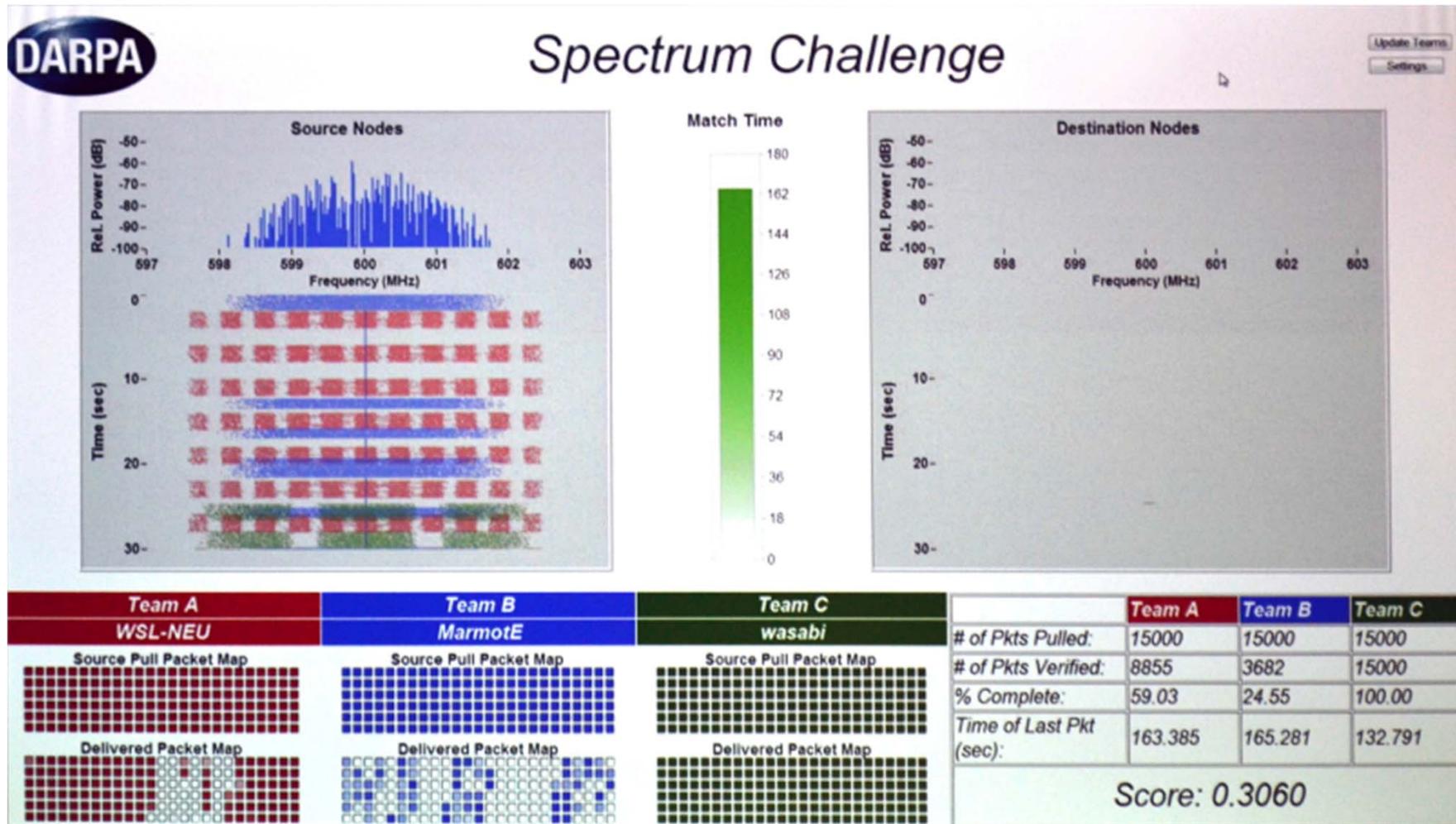
*Cooperative Finals*

Finalists:		Cumm Score
A1	WSL-NEU	0.7631
A2	Wasabi	0.7549
B1	Efficient Spectrum	0.6681
B2	MarmotE	0.7422

Game #	Team A	Team B	Team C	Group Score
25	WSL-NEU	Wasabi	Efficient Spectrum	0.2339
26	Wasabi	WSL-NEU	MarmotE	0.308
27	Efficient Spectrum	MarmotE	WSL-NEU	0.2212
28	MarmotE	Efficient Spectrum	Wasabi	0.213

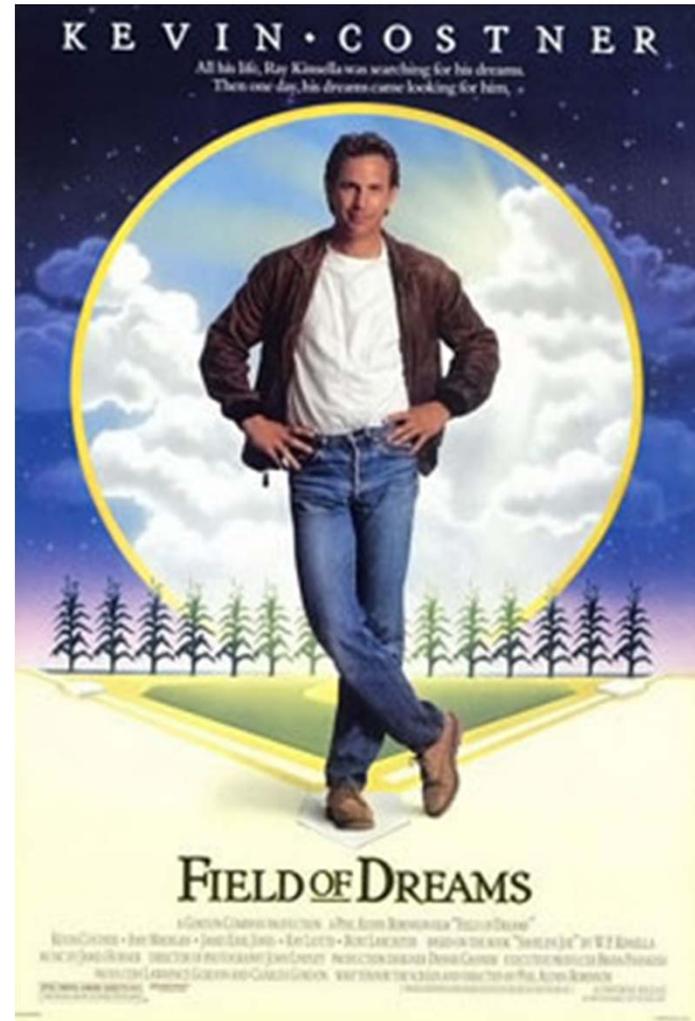
**WSL-NEU  
WINNER!**

# Preliminary Tournament – Cooperative (contd)



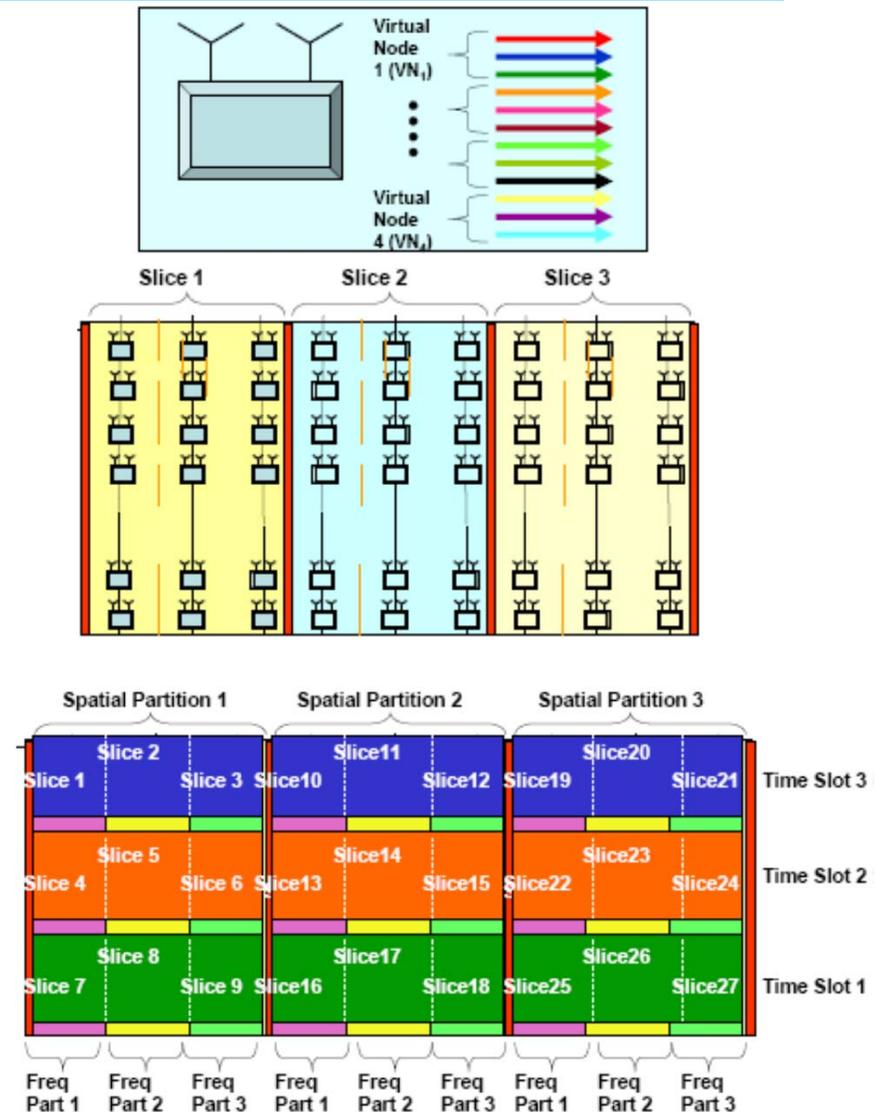
# If you build it, they will come... en masse!

- When the DSC was first envisioned, we expected between 10 and 20 teams would be interested
- But... after announcing the DSC on various public forums, 90 teams showed up
  - Quite a diverse group
  - Testament to advancements in radio research in academia, small business, hacker groups, and motivated individuals
- Lions and tigers and bears!



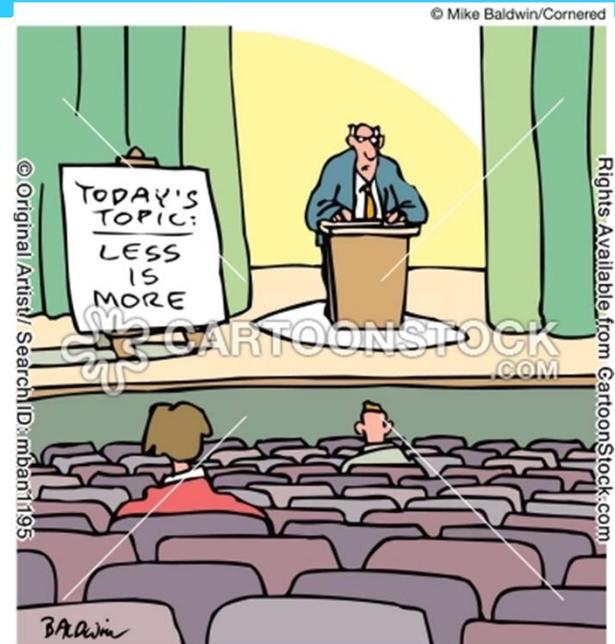
# Bizarre world of “wireless testbed virtualization”

- The testbed was primarily meant to support one user at a time per domain (sandbox, grid, outdoor, etc)
- 90 teams and a short time frame, what could we do?
  - Time to virtualize the testbed
  - We are wireless people, virtualization of wireless is hard
  - Securing virtualization is a research area!
- Time, frequency, spatial issues
- At one point, 46 teams were on the grid at once!
  - Call Guinness!
  - Conflicts happen
  - ORBIT services had a workout

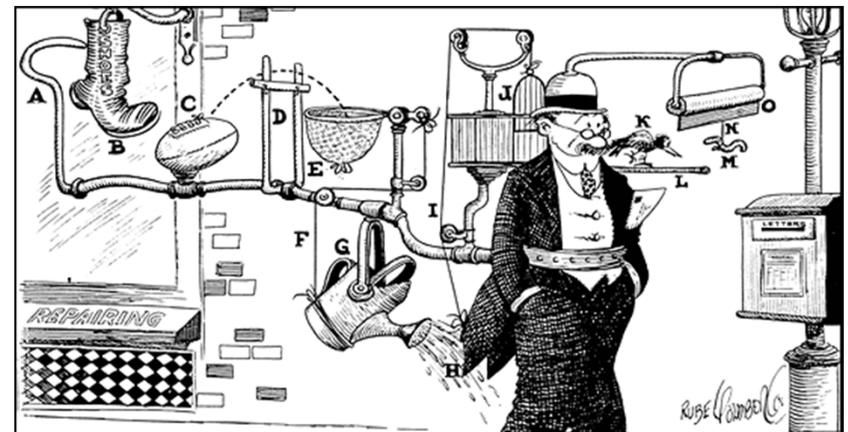


# Lessons Learned: KISS

- During the hurdles, we saw and heard many, many things...
- 1. Complicated solutions look good on paper but if not implemented then what good are they?
- 2. Simple strategies survived Hurdle 3 better than complicated strategies
- Several teams told us they underestimated how much work was really needed
- Advanced techniques were often “brittle”
  - The curse of feedback
- Many clever ideas had poor ROI
  - DNS lookup savings...
- The benchmark radio with QAM64 could do very well in Hurdle 3!

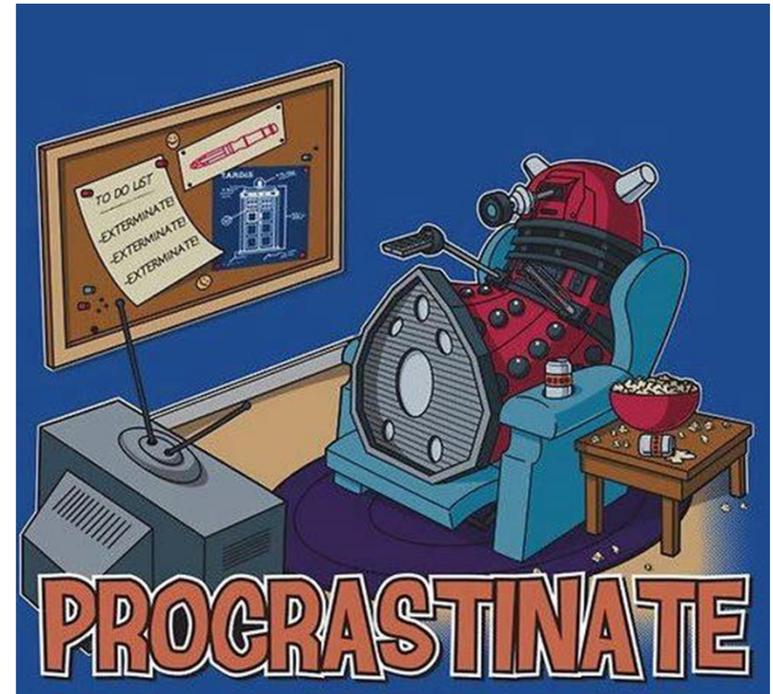


“Wow, excellent turnout.”

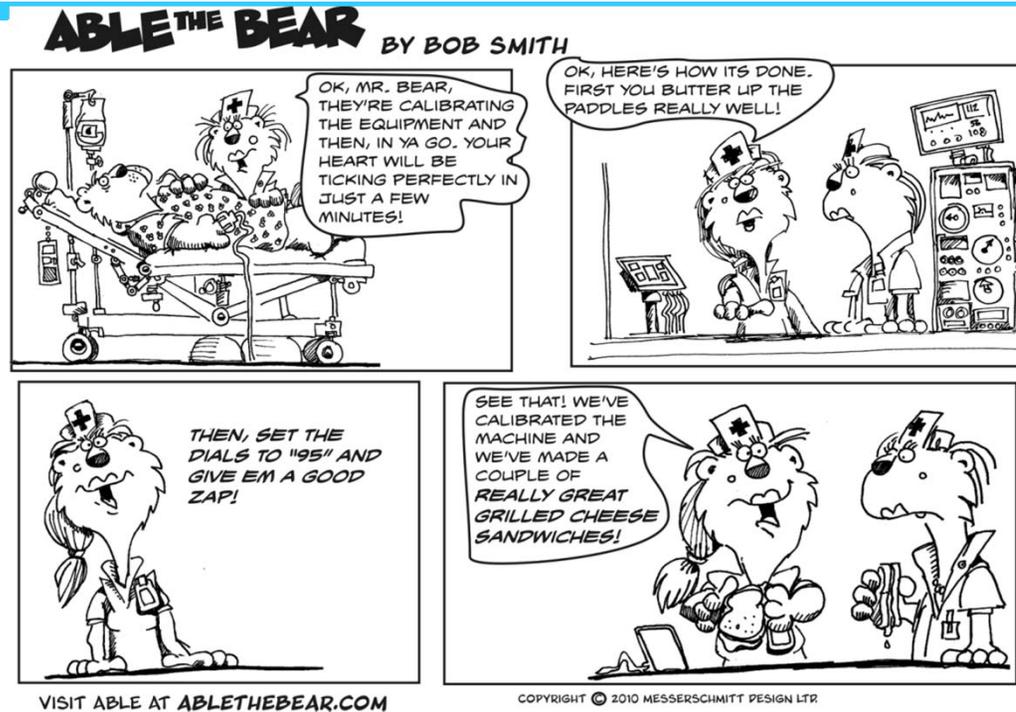


# Lessons Learned: people will wait and wait...

- In all events so far, we have seen a mad dash to the finish
  - 46 teams on ORBIT occurred at the end of Hurdle 3
  - Most validation for the Preliminary Event took place in the last week
- Hooray for the early submitters...
- We gave up tournament development time to give teams “extra time”



# Lessons Learned: Calibration



- We have made a very concerted effort to calibrate things as much as possible
  - Geometry, radios and sensitivities
- Design space for the teams is extremely vast

# More Information

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<http://dtsn.darpa.mil/spectrumchallenge/>  
<http://www.orbit-lab.org/DC>